Guide for the Planning, Design, and Operation of Pedestrian Facilities

American Association of State Highway and Transportation Officials

July 2004

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Chapter 1

Introduction

Walking is the oldest and most basic mode of travel and is a fundamental part of the United States transportation system. The American Association of State Highway and Transportation Officials' (AASHTO's) *Policy on Geometric Design of Highways and Streets* (1), known commonly as the AASHTO Green Book, encourages roadway designers to provide for pedestrians:

"Interactions of pedestrians with traffic are a major consideration in highway planning and design."(1)

Improving conditions for pedestrians requires cooperation among many different interests, and must include changes not only in how we design streets and highways, but also in how we manage future growth and re-shape existing urban areas. In many parts of the country, communities have already begun to change land use planning and urban design practices to accommodate and encourage walking, bicycling, and higher levels of transit.

Safety is a key consideration in the planning, design, and operation of pedestrian facilities. Because pedestrians are the most vulnerable of all transportation facility users, particular attention to pedestrian safety is needed. Accessibility and usability are also key considerations for pedestrian facilities, which should accommodate pedestrians of all abilities.

1.1 Purpose

The purpose of this guide is to provide guidance on the planning, design, and operation of pedestrian facilities along streets and highways. Specifically, the guide focuses on identifying effective measures for accommodating pedestrians on public rights-of-way. Appropriate methods for accommodating pedestrians, which vary among roadway and facility types, are described in this guide. The primary audiences for this manual are planners, roadway designers, and transportation engineers, whether at the state or local level, the majority of whom make decisions on a daily basis that affect pedestrians. This guide also recognizes the profound effect that land use planning and site design have on pedestrian mobility and addresses these topics as well.

The *Manual on Uniform Traffic Control Devices* (MUTCD) (8) defines a pedestrian as a person afoot, in a wheelchair, on skates, or on a skateboard. Persons afoot may use walkers or canes, be pushing a stroller or delivery hand truck, or be assisting a youngster on a tricycle. A pedestrian may also have a vision or cognitive disability, be preoccupied or lost, or be disadvantaged by weather or conditions underfoot. Everyone is a pedestrian at one time or another, so the concept of the "design pedestrian" should include children, older persons, and people with disabilities for whom walking and mass transit are often the primary mode chosen for independent travel.

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The design and construction of streets and highways in public rights-of-way must consider pedestrians. The AASHTO Green Book (1) states, "Pedestrians are a part of every roadway environment and attention should be paid to their presence in rural as well as urban areas."

Accessibility laws, implementing regulations, and standards require that, where pedestrian facilities are newly provided or altered, they be accessible to and usable by people with disabilities. Furthermore, Title II of the Americans with Disabilities Act (ADA) (5) specifically requires the construction of curb ramps along existing pedestrian routes. In addition, if pedestrian use is understood, such as a neighborhood walk-to-school requirement or a bus stop along a roadway, accessible facilities should be available. Residents may also seek usability improvements in existing facilities in order to travel locally.

The Federal Highway Administration (FHWA) has issued program guidance to help states and localities interpret the ADA and provisions in the Transportation Equity Act for the 21st Century (TEA-21) legislation relating to pedestrians and bicyclists. This program guidance calls upon every transportation agency to make accommodation for bicycling and walking a routine part of their planning, design, construction, operations, and maintenance activities. Pedestrians of all abilities should be accommodated on pedestrian facilities, and sidewalks and pedestrian crossing features should be considered from the beginning of project planning.

In 2000, FHWA issued design guidance mandated by TEA-21 which states that walking facilities will be incorporated into all transportation projects unless "exceptional circumstances" exist (7). Exceptional circumstances that might warrant the omission of pedestrian facilities in a new or reconstruction project include the following:

- Pedestrians are prohibited by law from using the roadway. In this instance, an effort may be necessary to accommodate pedestrians elsewhere within the right-of-way or within the same transportation corridor.
- The cost of establishing walkways would be excessively disproportionate to the need or probable use. Excessively disproportionate is defined as exceeding 20 percent of the cost of the larger transportation project.
- Where scarcity of population or other specific factors indicates an absence of need.

The needs of pedestrians, motor vehicles, and bicycles may conflict, as may the needs of pedestrians of differing abilities. This guide provides guidance on how these conflicting needs can be resolved so that all modes of travel are accommodated safely and efficiently. In instances where conflicting issues cannot be resolved, practitioners should exercise their best judgment to reconcile the competing needs.

1.2 Scope

The scope of this guide includes planning, design, and operation of both existing and new pedestrian facilities. Although these guidelines can be applied to existing pedestrian facilities, it is usually most practical to implement these guidelines when a new facility is constructed or an existing facility is being reconstructed. This guide is not intended to set forth strict standards, but to present sound guidelines that provide for the needs of pedestrians and other roadway users. However, in some areas of the guide, design criteria have

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been provided to indicate suggested minimums. Where deviations from these suggested minimums or from an agency's guidelines are needed, the deviations should be considered on the basis of an engineering study and the rationale for not conforming to this guide or an agency's guidelines should be documented.

The construction of a highway or street project, including any associated pedestrian improvements, is the culmination of a planning and design process that is often lengthy and complex, and involves many agencies and individuals. During each step of the process, important decisions are made that affect subsequent steps and the overall design outcome. This project development process has four distinct phases. State departments of transportation (DOTs) and other transportation agencies use a range of terminology to describe the process. For the purposes of discussion, the following outlines the process and terminology:

- *Concept Definition*—The identification of a project, including its need, geographic limits, community context, and other specifics to enable feasibility studies to begin.
- *Planning and Alternatives Development*—The broad range of activities that balances competing interests, resulting in the selection of a preferred plan that meets regulatory requirements and is sufficiently detailed to proceed with final design and construction.
- *Preliminary Design*—The initial phase in the final design process.
- *Final Design*—Completion of construction documents and specifications for the construction of a project.

1.3 Design Regulations and Guidelines

The most recent editions of the following manuals and guides include pertinent information on pedestrian design and should, therefore, be used in conjunction with this guide.

1.3.1 AASHTO's *Policy on Geometric Design of Highways and Streets* (Green Book) (1)

The current edition of this highway design guide, commonly known as the "Green Book," was published in 2001 and included significant changes in stopping and intersection sight distance calculations. The purpose of the Green Book is to provide direction to the engineering and planning community on appropriate design measures for roadways. The Green Book also provides general direction on pedestrian facility design elements such as sidewalk separation from the roadway, sidewalk widths, curbs, medians, and islands.

1.3.2 *Manual on Uniform Traffic Control Devices* (MUTCD) (8)

The FHWA, with the active assistance from the National Committee on Uniform Traffic Control Devices (NCUTCD), adopted a new manual in 2003. Pedestrian provisions in the MUTCD are located in all 10 parts of the manual. In general, the manual provides directives for traffic control devices that are to be used as standards, including warrants and design of pedestrian signs and signals.

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1.3.3 *Highway Capacity Manual* (HCM) (12)

The Transportation Research Board (TRB) published the most recent edition of the HCM in 2000. The HCM provides direction on calculating the levels of service for pedestrians on various widths of sidewalks and crosswalks, and outlines the effect of pedestrians on traffic delay at intersections.

1.3.4 *Uniform Vehicle Code* (UVC) (10)

The National Committee on Uniform Traffic Laws and Ordinances (NCUTLO) developed the UVC as a guide for use by state legislatures. The purpose of the Code is to establish a uniform set of motor vehicle and traffic laws for application nationwide to ensure the safety of all highway users across the country. Article V of the Code is titled "Pedestrians' Rights and Duties," and contains the vast majority of information in the Code related to pedestrians. In addition, Article II of the Code contains a discussion on pedestrian control signals.

1.3.5 Accessibility Laws, Regulations, and Standards (2–5)

Federal accessibility legislation also influences the provision, design, and operation of pedestrian facilities. The Rehabilitation Act of 1973 (often referred to as Section 504) requires that facilities designed and constructed with Federal funding, such as Federal-aid highway monies or Community Development Block Grants, be accessible to and usable by people with disabilities when newly constructed or altered. Since 1984, the standard for such work has been the Uniform Federal Accessibility Standards (UFAS) (3). Section 504 also implements the concept of *program accessibility* for existing facilities, requiring jurisdictions to ensure that people with disabilities are not excluded from the programs, services, and benefits of a state or local government because existing facilities may be inaccessible. A variety of remedies, from offering services elsewhere to altering existing facilities, are possible.

In 1990, Congress passed the Americans with Disabilities Act, which is civil rights legislation that prohibits discrimination on the basis of disability. Title II of the ADA covers state and local government programs and facilities (5). It includes standards for new construction and alteration of state and local government facilities and extends the concept of program accessibility to all state and local government programs, not just those funded with Federal dollars. Implementing regulations were promulgated in 1991 by the U.S. Department of Justice (U.S. DOJ) and (for transit) the U.S. Department of Transportation (U.S. DOT). Title II entities are permitted to use either UFAS or the ADA Accessibility Guidelines (ADAAG) (4) developed by the U.S. Architectural and Transportation Barriers Compliance Board (Access Board) for new facility design and alterations. Program accessibility for existing facilities is governed by the U.S. DOJ implementing regulations. It should be noted that the online version of the ADAAG, available on the U.S. Access Board web site, includes guidance that has not yet been enacted into U.S. DOJ or U.S. DOT regulations and, therefore, is not yet legally required. The portions of the ADAAG that are legal requirements can be found in the *Code of Federal Regulations* at 28 CFR Part 36.

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In general, Title II regulations provide that when new pedestrian facilities (or projects that alter existing facilities) are planned, those facilities must be designed and constructed to be accessible to and usable by people with disabilities. Compliance with UFAS or ADAAG is deemed to provide the required accessibility. Other equivalent standards may also be followed, but accessibility is required even in the absence of relevant technical provisions. The U.S. DOJ implementing regulations specifically require that new and altered sidewalks and streets include curb ramps.

Methods of achieving program access in existing facilities and programs vary. Title II entities with more than 50 employees must develop a *transition plan* to prioritize and install curb ramps in existing facilities. State and local agencies may also be asked to provide individual accommodations in an existing facility to make it usable by a person with a specific disability. Technical guidance provided by U.S. DOJ notes that program accessibility considerations may also require the construction of a sidewalk under certain conditions, for example, where a neighborhood walk-to-school mandate or the locations of bus/transit stops along a roadway indicate the existence of an *accessible pedestrian route*.

Because Section 504 and ADA standards in the UFAS and ADAAG were largely developed for buildings and facilities on sites, a separate rulemaking has been undertaken to adapt current guidelines to the differing conditions of use in the public right-of-way. Until guidelines more specific to public rights-of-way can be finalized, however, designers must continue to apply current standards. Draft guidelines for public rights-of-way, published in 2002 by the U.S. Access Board for public comment, proposed the term "*pedestrian access route*" as the public right-of-way counterpart to the "*accessible pedestrian route*" currently required in UFAS and ADAAG. The pedestrian access route within a sidewalk would be permitted to take the grade of an adjacent roadway or underlying terrain in lieu of the current maximum grade of 8.33 percent (1V:12H) in the UFAS and ADAAG. A width of 1.2 m [4 ft] was proposed for the new pedestrian access route, while the ADAAG and UFAS require 0.9 m [3 ft] for an accessible pedestrian route. Other criteria are similar to those currently included in the ADAAG. In 1999, the U.S. Access Board published *Accessible Rights-of-Way: A Design Guide* (2) that provides guidance on the design of public rights-of-way pending the completion of the ongoing rulemaking. Also, FHWA's *Designing Sidewalks and Trails for Access, Parts I and II* (6, 9), offer extensive guidance on developing accessible pedestrian rights-of-way.

Both the Rehabilitation Act and the ADA require new construction to fully meet accessible design standards. However, when it is *technically infeasible* to fully comply in *alterations*—a change that affects facility usability—the designer must meet new construction standards to the *maximum extent feasible*. Designers should review the discussion of these terms in the ADA Title II implementing regulations since they have specific meanings.

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1.4 Introduction Resources

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Chapter 2

Planning for Pedestrians

The transportation system should provide a safe network of facilities to accommodate pedestrians. The development of such a network begins in the planning stage at the state, regional, and local levels. The challenge that transportation planners and engineers face is to balance the competing interests of each mode of travel in a limited amount of right-of-way. In many cases, pedestrian planning comes down to ensuring that sidewalks and safe crossing opportunities are provided with new roads or during the reconstruction of existing roads. Additionally, a broader plan should be conceived that ensures non-roadway-related pedestrian facilities (e.g., paths along greenways, walkways along rivers, rail–trails, separate paths across major barriers, underpasses/overpasses, and path or walkway connections between neighborhoods) are recommended for implementation as well.

This chapter is organized as follows:

- Section 2.1 presents background material on pedestrian activity in America.
- Section 2.2 provides information on pedestrian characteristics.
- Section 2.3 discusses incorporating pedestrians within various planning strategies.
- Section 2.4 presents strategies for better accommodating pedestrians during site development.
- Section 2.5 discusses accommodating pedestrians within school zones.
- Section 2.6 presents several traffic management and traffic calming techniques that may benefit pedestrians.
- Section 2.7 discusses other programs that may be implemented to increase pedestrian safety.

2.1 Pedestrian Activity in America

2.1.1 Walking as a Basic Transportation Mode

Walking is a fundamental form of transportation that is an integral part of the health and livability of our communities. All travelers are pedestrians at some point during their trip. Some travelers make their entire trip on foot, while others walk to catch the bus, or walk between their parking spaces and the front doors of their destinations. Many people also walk for recreation and exercise. According to a 1990 survey, nearly 100 million Americans age 12 and older (45 percent of the U.S. population) walk for pleasure (16). On average Americans walk, run, or jog about 13 days a month, and on these days pedestrians spend an average of 53 minutes on these activities (4).

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Determining the number of pedestrian trips in the United States without further research is somewhat difficult because current travel surveys ask respondents to report their predominant mode of transportation for each trip. As a result, many pedestrian trips that are combined with auto and transit trips go uncounted. Notwithstanding these limitations, there are at least 56 million pedestrian trips in the United States each day—a number that equals or exceeds 5.4 percent of total transportation trips (40).

Pedestrian activity varies based on age and income. Children, the elderly, and people with vision impairments traditionally walk more than other segments of the population. For these populations, walking is often the only transportation choice available. However, the levels of walking and bicycling have been steadily declining for children. Over the past 30 years, the level of walking and bicycling trips among children has fallen from nearly 50 percent of all trips by children in 1970 to only 10 percent in 1995 (40).

2.1.2 Walk Decision Factors

The current level of walking in the United States is low when compared to the number of people who say they would walk if safe facilities were available. A 1995 poll conducted by Rodale Press found that for Americans whose primary means of transportation is driving, 31 percent would prefer to commute and run errands using some other form of transportation. Additionally, 72 percent of respondents wanted more planning for walking and bicycling in their communities and 59 percent were in favor of more government funding for bicycle and pedestrian transportation.

The decision of whether or not to walk usually takes into account the distance of the trip, perceived safety of the route, and the comfort and convenience of walking versus an alternative mode. However, for many Americans, walking is the only available option. According to the 1995 National Personal Transportation Survey (NPTS), eight million households in the United States do not own a car (23). This represents approximately eight percent of U.S. households and is often higher in urban areas. Furthermore, approximately 30 percent of our population does not drive (15). For these people, access around their communities by foot is particularly vital, whether their trips are to school, the store, or a nearby transit stop (23).

Distance and Densities

Distance is the primary factor in the initial decision to walk. The majority of pedestrian trips are 0.4 km [0.25 mi] or less, with 1.6 km [1 mi] generally being the limit that most people are willing to travel on foot. Most people are willing to walk 5 to 10 minutes at a comfortable pace to reach a destination. With approximately 25 percent of all transportation trips 1.6 km [1 mi] or less in distance, walking has the potential to serve a significant portion of trips (23).

Land-use patterns, community design, and population density have a big impact on trip distance. Higher density communities and/or compact communities with mixed land-use patterns have higher levels of walking because destinations are more likely to be located within walking distance of homes and businesses (23).

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Personal Safety and Security

Personal safety and security are also very important to the decision to walk, and walkway design can make a difference. Sidewalks that are too narrow and/or adjacent to moving lanes of traffic, and pedestrian crossings that are intimidating because of confusing signal indications, excessive crossing distances, or fast-turning vehicles, directly impact the perceived and actual safety of the pedestrian.

A dark street with places where a potential attacker could hide will discourage walking, while a street with pedestrian-scale lighting, open spaces, and other people out walking will tend to encourage walking. The presence of other people on the street has the most positive impact on the feeling of security on a street. Good design tends to attract more walkers, thereby increasing a sense of safety. Diversity of land uses, including residential uses, can also extend the period per day in which pedestrian activity is high. While a downtown with mostly office and office support uses may have an active pedestrian environment during work hours, it may become empty during evenings and weekends. Activity generators on building ground floors add to the sense of security and activity on the street.

Personal Comfort and Attractiveness

A decision to walk is also influenced by the comfort, convenience, visual interest, and other potential destinations along the route. Unlike motorists, pedestrians' slower speeds mean that they prefer more, rather than less, detail in their environment. Does the route have shade and is it separated from traffic? Do the street and the adjacent buildings or landscape provide a pleasant visual environment? Are there benches or other places to sit and rest? Since pedestrians travel more slowly and are not surrounded by the protective environment of a motor vehicle, their immediate physical environment has a profound effect on their level of comfort.

Many factors combine to create an environment that makes walking an easy and natural choice. Generally, areas with high levels of walking have:

- A good mix of land uses
- Continuous and connected pedestrian facilities that are adequately separated from fast-moving vehicular traffic
- Safe and convenient street crossings
- Pedestrian-scale lighting
- A pleasant visual environment

Pedestrians are most likely to walk on routes where the need to cross major streets is minimized. Pedestrian facilities should also be properly maintained to enable pedestrians to utilize the facilities.

Beyond simply providing sidewalks, designing good accessible pedestrian environments requires attention to subtle design features that encourage pedestrian activity. In conventional design practice, different entities are responsible for various parts of the pedestrian

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Age	Characteristics
0–4	• Learning to walk • Requires constant adult supervision • Developing peripheral vision, depth perception
5–8	• Increasing independence, but still requiring supervision • Poor depth perception
9–13	• Susceptible to “dart out” intersection dash • Poor judgment • Sense of invulnerability
14–18	• Improved awareness of traffic environment • Poor judgment
19–40	• Active, fully aware of traffic environment
41–65	• Slowing of reflexes
65+	• Difficulty crossing street • Vision loss • Difficulty hearing vehicles approaching from behind • High fatality rate if hit

Exhibit 2-1. Common Pedestrian Characteristics by Age Group. (40)

environment. For example, city planners lay out the overall roadway network and influence land uses, roadway engineers design the street, landscape architects enhance the visual character of the roadway, and architects and site engineers design the properties along the streets. A central factor in creating good pedestrian conditions is a basic harmony between the roadway and adjacent spaces, which requires coordination between developers, public agencies, and a variety of design professionals.

2.2 Characteristics of Pedestrians

Designers should understand that there is no single “design pedestrian” and that the transportation network should accommodate a variety of pedestrians. For example, children perceive their environment differently from adults and need adult supervision until they learn to navigate the transportation system independently. Children sometimes walk more slowly and they have a lower eye height. On the opposite end of the spectrum, older adults require more time to cross streets, desire more predictable surfaces, benefit from handrails in steep areas, and need places to rest along their route. Older pedestrians are also more likely to be killed or seriously injured in a crash.

Exhibit 2-1 lists some of the common characteristics of pedestrians of various ages. Because we live in an aging population, the needs of older pedestrians will continue to increase. Therefore, much of the discussion in the remainder of this chapter applies to older adults. It is important to remember, however, that pedestrians exhibit a wide range of physical, cognitive, and sensory abilities, and all pedestrians are part of the transportation mix and should be anticipated in the design of pedestrian facilities.

2.2.1 Walking Speeds

Pedestrian walking speeds range from approximately 0.8 to 1.8 m/sec [2.5 to 6.0 ft/sec] (1). The MUTCD (14) recommends a normal walking speed of 1.2 m/sec [4 ft/sec] for calculating pedestrian clearance intervals for traffic signals. Pedestrian age has the greatest impact on walking speed (1). Older pedestrians and pedestrians with physical impairments will generally walk at speeds in the lower end of the speed range. In areas where there is an older population and/or a large number of pedestrians with physical impairments, a slower walking speed such as 0.9 m/sec [3.0 ft/sec] may be considered for design if substantiated by an engineering study. Other factors that affect walking speed include air temperature, precipitation (rain, snow, and ice), time of day, and trip purpose. Walking speeds are also typically faster at midblock locations than at intersections. At locations where it is apparent that pedestrians are having difficulty crossing during the allocated time, the signal timing should be adjusted to account for slower walking speeds. Audible pedestrian signals have been shown to increase crossing speed and decrease the time needed to cross a street.

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2.2.2 Spatial Needs

Two people walking side-by-side or passing one another generally require 1.4 m [4.67 ft] of space, while two people in wheelchairs need a minimum of 1.5 m [5 ft] to pass one another.

When pedestrian volumes increase within a given amount of space, walking rates become slower due to the decreased square footage available per person (40). A means of conveying this principle is the spatial bubble, which is the preferred distance of unobstructed forward vision while walking under various circumstances. Exhibit 2-2 illustrates the spatial bubbles that are comfortable for pedestrians attending a public event, shopping, walking under normal conditions, and walking for pleasure.

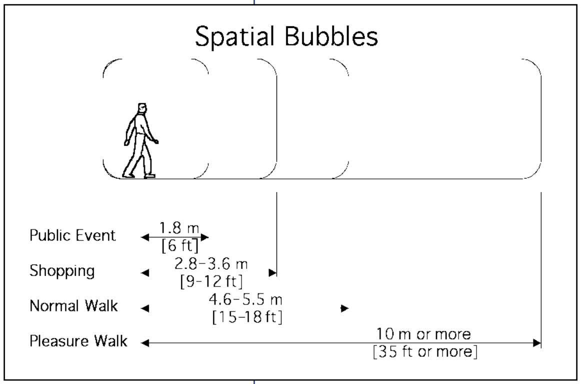

Exhibit 2-2. Preferred Distance of Unobstructed Forward Vision Based on Different Types of Walking (40).

2.2.3 Mobility Issues

In 1994, an estimated 7.4 million persons in the United States used assistive technology devices for mobility impairments, 4.6 million for orthopedic impairments, 4.5 million for hearing impairments, and 0.5 million for vision impairments (38). These numbers are expected to increase because there is a positive correlation between an increase in age and an increase in the prevalence rate of device usage. For example, persons who are 65 years and over use mobility, hearing, and vision assistive devices at a rate four times greater than the total population (38). Pedestrian facilities should safely accommodate those people who rely upon assistive devices to negotiate the transportation network.

Pedestrians with Ambulatory Impairments

Pedestrians with ambulatory impairments may use devices such as wheelchairs, crutches, canes, walkers, and/or prosthetic limbs to enhance their mobility. When using such assistive devices, they require sufficient space to maneuver around barriers and hard, smooth, level surfaces to allow for easier maneuverability.

Wheelchair and Scooter Users

In 1994, 1.7 million Americans identified themselves as wheelchair or scooter users (38). Because wheelchairs and scooters are often difficult to propel over uneven or soft surfaces, users need firm, stable surfaces and structures such as ramps or beveled edges at changes in level. Curb ramps that provide access to street crossings are required wherever a pedestrian route crosses a curb or other barrier. In addition, rough decorative surfaces, such as stamped concrete, can be very uncomfortable for some wheelchair and scooter users.

The stability and controllability of wheelchairs and scooters are also affected by cross slopes and grades of facilities. Cross slopes that are steeper than two percent may cause difficulties because they can cause wheelchairs to veer downhill, and manual wheelchair users must perform additional work to continue traveling in a straight line (9).

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Wheelchair and scooter users require a wider path of travel than most pedestrians. Passing space sufficient for traveling together, passing, and turning around should be provided. Powered wheelchairs and scooters are generally longer than manual chairs and require more maneuvering space. Both manual and powered wheelchairs should be anticipated in walkway design.

Walking-Aid Users

Walking aids include canes, crutches, and walkers. According to the 1994 *National Health Interview Survey on Disabilities*, 7.1 million Americans use walking-aid devices (38). The limitations of pedestrians using walking aids might include:

- Difficulty negotiating steep grades
- Difficulty negotiating steep cross slopes
- Decreased stability
- Slower walking speed
- Reduced endurance
- Reduced ability to react quickly to dangerous situations

Surface quality significantly affects ease of travel for people who use walking aids. Grates and cracks wide enough to catch the tip of a cane or the front casters of a wheelchair can limit facility usefulness. Slippery or uneven surfaces can be hazardous to all pedestrians, and can further reduce the already precarious stability of walking-aid users. Additionally, pedestrians who use walking aids tend to travel more slowly than other people. As a result, they benefit from longer pedestrian signal cycles at intersections and the presence of sufficient widths on the sidewalks to better enable other pedestrians to travel around them (9).

Prosthesis Users

According to the 1994 *National Health Interview Survey on Disabilities,* 173,000 people in the United States have an artificial leg or foot (38). Comfortable walking speeds of prosthesis users may be slower than individuals without disabilities. In general, prosthesis users benefit from extended signal timing at wide intersections. In addition, some people with lower limb prostheses will have greater difficulty than other pedestrians maintaining balance on grades or cross slopes (9).

Pedestrians with Hearing Impairments

Hearing loss limits a pedestrian's ability to use cues such as the increasing noise of an approaching vehicle to detect impending dangers. This puts pedestrians with hearing impairments at a disadvantage when walking in conditions where being able to hear traffic is often the best or first warning of its presence, such as at locations with limited sight lines at driveways, limited sight lines at intersections, right-turn slip lanes, and complex intersections where pedestrians must track potential vehicle conflicts from multiple directions. As many as 40 percent of older adults have hearing impairments. The combination of

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hearing loss and vision loss among older adults can make pedestrian travel particularly challenging. Longer crossing times at intersections, clear sight distances, accessible pedestrian signals (APS), and highly visible signals and markings are some conditions that help to make trips safer (9).

Pedestrians with Vision Impairments

Individuals who are blind or vision impaired often travel independently. Most are not totally blind, nor do all individuals with vision impairments use a white cane, dog guide, or other mobility aid. Pedestrians with vision disabilities may be characterized as (9):

- Having limited perception of the path ahead (preview);
- Navigating with limited information about surroundings, which provides less protection against obstacles and other dangers;
- Relying on memory and unchanging conditions in familiar terrain; or
- Relying on non-visual sources such as sound and texture for information.

White Cane Users

People who are blind often use long white canes to navigate. In the sidewalk environment, cane users typically use a technique by which the cane is swung in an arc in front of the body to detect objects or changes in grade along the walking environment. Cane users benefit from warning surfaces with contrasting texture and resilience that can be detected underfoot and by cane. Detectable warnings installed at the sidewalk-street boundary convey a “stop” message to people with vision impairments. Once the user has stopped and identified the hazard, he or she can determine if it is safe to proceed. Detectable warning installations should be designed in accordance with ADAAG (8) specifications.

Dog Guide Users

People who are blind may use dog guides to travel. A common misconception about dog guides is that the dogs are capable of making decisions for their owners. Dogs guide in response to a specific set of commands given by voice and hand signals. The dog guide stops to indicate stairs, curbs, and other significant changes in elevation and waits for a command from the dog guide user before proceeding. Dog guides do not respond to traffic signals and may not be able to distinguish where the sidewalk ends and the street begins at a curb ramp. Intersections that require pedestrians to deviate from a straight path to take refuge on an island or median may not provide adequate cues for dog guide users since dogs are not trained to follow marked crosswalks and may view medians as obstacles. Intersections are easiest for dog guide users to negotiate when the line of travel from the edge of the sidewalk to the opposite curb is straight rather than skewed.

Providing Information for People with Visual Impairments

While individuals who are visually impaired may use a white cane or dog guide to avoid obstacles in their path, auditory, vibratory, and other cues are used to maintain directional orientation to a destination. These cues can include the sound of traffic

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movement, the slope of curb ramps and the street, sounds and movements of other pedestrians, alignment of the sidewalks, and contrasting color and surface textures. It is recommended that accessible information be available where intersection geometry is nonstandard, wherever a pedestrian detour is required, wherever a pedestrian actuated signal is present, wherever pedestrian traffic is not permitted (whether permanently or temporarily), and in other situations where adequate clues are not provided. Information that is useful to provide for pedestrians with visual impairments includes the following:

- Accessible text messages (larger print and raised text)
- Accessible pedestrian signals (APS)
- Guide strips to assist in way-finding
- Detectable warning surfaces at sidewalk–street boundaries
- Physical barriers to prevent hazards such as missing sidewalk sections or construction-related work
- Contrast used in a consistent manner
- Adequate lighting at pedestrian level

The most effective information will be provided by more than one sense. Auditory, tactile, and kinesthetic information can be combined to provide more reliable inputs that support each other and confirm the information available from another sense. For example, an intersection that provides a raised tactile surface warning, a clearly marked crosswalk, and an APS provides more opportunities for all users to identify the operation of the crossing than an intersection that provides only a pedestrian signal. Redundancy and a multiplicity of formats increase the likelihood that individuals will be able to make safe and informed crossing decisions.

Consistency of information is necessary as well. Strips of varying colors and textures in the sidewalk, often used as a decorative element, can be very confusing to individuals with low vision who may perceive a color change as a change in level or slope. Those who are blind may be confused by a texture change and may not be able to determine if it is decorative or informational. Information needs to be presented in a consistent manner, particularly when using contrasting colors and/or textures, so pedestrians with vision impairments may interpret the intended messages correctly.

Crossing Intersections

Crossing intersections may be particularly difficult for pedestrians with vision impairments. Pedestrians with vision impairments use multiple cues to accomplish the tasks involved in crossing streets and typically take the following steps to cross a signalized intersection:

1. Detect arrival at an intersection by using a combination of cues such as a raised curb, the slope of a curb ramp, the absence of a building front, a detectable warning, remembered landmarks, traffic sounds, and any other available way-finding cues.

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2. Orient themselves toward the crosswalk by using cues such as traffic noise, audible signals, and physical features of the environment, such as the boundary between a sidewalk and an adjacent planting strip that are known to be parallel to the crosswalk, or curb lines that are known to be perpendicular to the crosswalk.

3. Determine whether a pedestrian signal must be actuated to get the walk signal, actuate it if necessary, and return to the edge of street and realign.

4. Determine when it is safe to walk by using traffic or pedestrian surge noise cues or accessible traffic signal indications.

5. Navigate to the opposite curb through any medians, islands, crosswalk angles, or other obstacles. Where pedestrian signals are not audible, people with vision impairments might start to cross an intersection later than other pedestrians because they might wait for the sound of parallel traffic and/or other crossing pedestrians to identify the crossing interval. People with vision impairments might have difficulty identifying and maintaining a correct alignment across the intersection. In combination, these factors increase the time that people with vision impairments might need to cross the street.

At an unsignalized location, a pedestrian who is vision impaired may have difficulty determining a gap in traffic. To discern a gap by hearing alone requires sufficient periods of all quiet to be sure that the sound of a receding car is not masking the sound of an approaching car. Larger gaps and "all-quiet" periods are necessary to determine a safe crossing time.

Crossing independently and safely at some roundabout locations or channelized right-turn lanes may be difficult due to the sound of other traffic.

Pedestrians with Cognitive Impairments

Cognition is the ability to perceive, recognize, understand, interpret, and respond to information. It relies on complex processes such as thinking, knowing, memory, learning, and recognition. Cognitive disabilities can hinder the ability to think, learn, respond, and perform coordinated motor skills.

The skills of people with cognitive disabilities vary tremendously, and they are often hampered by a lack of opportunity to learn and practice navigating in pedestrian environments. People with cognitive disabilities sometimes have difficulty navigating through intersections with complex signals, signs, and configurations.

Designs that accommodate people with cognitive impairments may also benefit children and the more than 20 percent of American adults who do not read English. Signs that use pictures, universal symbols, and colors convey meaning to a broad range of people. For example, pedestrian crossing signals that display a picture of a person walking may be more universally understood than signs reading WALK (9). In fact, the MUTCD (14) states that all new pedestrian signal indications shall consist of symbolized messages rather than the lettered messages of WALK and DON'T WALK, but that existing lettered messages may be retained for the remainder of their useful service life.

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2.2.4 Conclusion

Pedestrian facilities should be designed to safely accommodate all types of pedestrians including children, adults, the elderly, and those with disabilities. At times it is difficult to balance the needs of pedestrians with those of other modes of travel. While the information in this section should give the designer a basic understanding of the breadth of travel needs of pedestrians, refer to the sources listed at the end of this chapter for more specific information on pedestrians with disabilities, pedestrian trip characteristics, and other similar topics.

2.3 Pedestrian Planning Strategies

Pedestrian travel is an essential component of the transportation mix, and pedestrian travel needs should be a component in a wide variety of transportation studies. This includes site-specific transportation studies such as corridor plans, transit access studies, and development-related transportation impact studies as well as broad planning studies that address transportation networks, such as statewide transportation plans, long-range transportation plans, and area plans. There should also be opportunities to initiate independent studies that focus on pedestrian needs.

For more detailed information about pedestrian planning techniques, see the resource list at the end of this chapter. Some common characteristics of pedestrian-friendly urban communities are listed as follows:

Inclusion of Pedestrians in All Planning Activities

Integration of pedestrian accommodations in all municipal work, including close coordination between jurisdictions and seamless connections between communities.

Continuous Systems/Connectivity

Pedestrian circulation and access is provided to shopping malls, transit, downtown, schools, parks, offices, mixed-use developments, and other community origins and destinations as well as other communities in the region. Provision of shortcuts, where available, through buildings or parking lots may provide a time and distance advantage to walking over other modes. Safe and frequent crossing opportunities are provided across freeways and arterials so as not to become barriers for pedestrians.

Pedestrian-Oriented Land Uses

There are things to do or go to, such as shopping, dining, theaters, and other destination activities.

Pedestrian-Supportive Land-Use Patterns

Land-use patterns such as grid street layouts, shorter blocks in business districts, and compact "village-oriented" mixed-use development enhance pedestrian mobility.

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Multimodal Consideration

Streets are designed for all modes of transportation. Parking is hidden or screened and parking supply is reduced or managed to encourage walking. Streets discourage high-speed travel, either by original design, or because they have been retrofitted with traffic-calming measures.

Accessible and Appropriately Located Transit

Locating transit facilities adjacent to work, residential areas, shopping, and recreational facilities encourages pedestrian trips. Enhanced pedestrian access to transit stops makes
taking the bus, train, or trolley more appealing.

Element of Pedestrian Plan	Statewide Pedestrian Plan	Regional Pedestrian Plan	Local Pedestrian Plan
Policies, goals, and actions	✓	✓	✓
Pedestrian design criteria	✓		
Funding for state routes and high-crash locations	✓		
Education and safety issues	✓		
Collection and analysis of pedestrian crash data	✓		
Training element for staff/local governments	✓		
Public involvement	✓	✓	✓
Funding programs for pedestrian facilities and education	✓	✓	
Coordination between jurisdictions/agencies	✓	✓	
ADA compliance	✓	✓	✓

Exhibit 2-3. Elements Found in Pedestrian Plans at Different Levels.

Lively Public Spaces/Character

Secure, attractive, and active public spaces are provided in the community so that pedestrians can observe others or gather and interact. Preservation of important cultural, historic, and architectural resources strengthens community identity.

Pedestrian Furnishings

Furnishings such as benches, public restrooms, drinking fountains, and artwork create a more attractive and inviting atmosphere for walking trips.

Street Trees

Street trees are an essential element in the street environment. Trees provide shade and shelter for pedestrians and give a sense of separation from traffic.

Security and Visibility

A secure environment for pedestrians is provided. Walking areas have adequate pedestrian-scale lighting, open sight lines, and access to emergency services, such as phones and/or call boxes. The best security is provided by pedestrian activity during all hours of the day.

Proper Maintenance

Frequent cleanup and repair of pedestrian facilities on a regular basis, including provisions for timely snow clearance, is essential.

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2.3.1 Integrating Pedestrian Issues into Transportation Planning Studies

This section provides a brief overview of issues that should be considered when integrating pedestrians in a variety of types of transportation planning studies. Pedestrian issues should be incorporated into the scope of transportation planning projects from the outset and should be given an appropriate level of attention throughout the life of the planning study.

Long-Range Transportation Planning

Federal transportation legislation requires that the long-range transportation planning process at the state and metropolitan planning organization (MPO) level include both a pedestrian and bicycle element. Many states and regional governments have developed stand-alone statewide pedestrian and bicycle plans that address a range of issues, provide planning guidance to regional and local governments, identify capital projects for implementation, and may also include design criteria among other topics (see Exhibit 2-3). The eventual long-range transportation plan (LRTP) is prepared with appropriate references to the stand-alone plan. In cases where the state or MPO does not initiate a stand-alone pedestrian plan, pedestrian needs must be addressed directly within the LRTP. Potential advantages of addressing pedestrian needs within the LRTP rather than addressing them within a stand-alone pedestrian plan include integration with the rest of the planning process and the need for fewer planning documents.

Several elements of pedestrian plans that are worthy of note are not included in Exhibit 2-3 either because (1) most agencies currently do not have the capabilities to accommodate them or (2) the techniques and procedures are still relatively new. However, agencies should look to incorporate these elements in future plans. First, agencies should begin developing an inventory of all pedestrian facilities, possibly accessible through a geographic information system (GIS). This type of inventory would facilitate prioritization of pedestrian improvement projects. Second, modern-day regional travel demand models help transportation planners predict future trends and needs for motor vehicle travel. While the pedestrian mode has not been a feature in the most widely used models, transportation planners are working to change this. An overview of several methods for forecasting travel demand of pedestrians is presented in a recent FHWA publication (11). Third, techniques have been developed for calculating pedestrian levels of service (3) and multimodal levels of service (17) for particular facility types. These techniques are similar to the types of analyses that have been conducted to evaluate the quality of service of highways for automobile traffic.

County/Local Comprehensive Planning

Counties and municipalities should include a pedestrian circulation element within their comprehensive plans. At a minimum, the analysis should include a network inventory (including existing walkways and the identification of gaps in the network) and a listing of capital projects. Local plans should be specific on locations needing pedestrian improvements and identifying and prioritizing sidewalk needs and crossing treatments. These plans should also include a policy element that is coordinated with the local land use plan, and revisions as necessary to subdivision regulations that require developers to accommodate pedestrians. As with state and MPO plans, this pedestrian circulation element can be accomplished as a stand-alone plan to be adopted and incorporated into the overall transportation plan or as a component within the overall plan.

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Both Title II of the ADA and U.S. DOT Section 504 regulations require jurisdictions to develop self-evaluations that assess program and facility accessibility and transition plans to identify needed remediation. These documents should be consulted and incorporated into the planning process.

Transit Planning Studies

Pedestrian access is an essential component in the success of transit networks; therefore, transit planning studies should also address pedestrian issues. Both the ADAAG (8) and the UFAS (7) require accessible connections from sites to public transportation stops. Usable routes to and from bus and other transit stops can substantially reduce a jurisdiction's paratransit costs. Transit access studies should include a circulation plan for a specific zone immediately adjacent to (and surrounding) transit stations and transit stops as well as on-site pedestrian and bicycle accommodations. This should include an analysis of the service area, specifically identifying areas that already convey pedestrians towards the transit stop as well as areas that would have a high potential to attract more transit riders if improvements were made. Street-crossing accessibility should be included as a key element in transit planning.

School Route Safety Plans

Getting children to school safely is a concern in communities throughout the United States. Where children are expected to walk to school, an accessible travel route should be provided. *Safe Routes to School* programs concentrate on a zone that has been defined around a school. These studies often involve a planning committee composed of school administrators, professional transportation planners, teachers, students, and parents. The planning process should include an inventory and analysis of existing conditions along the key corridors that surround a school and connect to nearby neighborhoods, as well as an analysis of circulation patterns on the school site itself. The final result is a comprehensive, prioritized list of improvements and an implementation plan. More information on school-related pedestrian issues is provided in Section 2.5.

Corridor Plans

These studies focus on a specific roadway corridor or revitalization area and may address a wider variety of transportation and community planning issues along with pedestrian improvements. These plans can be used to direct future growth along the corridor or may focus more on physical planning issues such as traffic calming, streetscape improvements, improvements to motor vehicle flow, removal of barriers to improve accessibility, improvements to the transit network, or other types of improvements. Even the larger multimodal corridor or investment analyses should include a pedestrian component.

In many communities, the corridor planning process has been amended to include more site-specific studies that address pedestrian opportunities. Examples include a streetscape project along a main street that focuses on pedestrian improvements, or a study of pedestrian crossing treatments for an arterial roadway that has been a barrier to pedestrians.

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Freight Mobility Studies

Freight mobility studies focus on ways to improve the efficiency of freight movement. Deficiencies in infrastructure that may cause delays to trucks, rail, and other modes of freight movement are identified, and alternative design solutions are proposed to improve the operational efficiency of the respective mode. For example, trucks may experience delay at an intersection located near a warehouse due to inadequate turning radii and narrow lanes. By increasing the turning radii and widening the lanes, trucks delivering to the warehouse will experience less delay, improving their overall operational efficiency. This type of solution, however, could also negatively impact the pedestrian traffic through the intersection by increasing crossing distances for pedestrians. Therefore, as part of freight mobility studies, pedestrians should be considered because what may be best for freight movement (i.e., truck traffic) may not be accommodating to pedestrian traffic. There is definitely a need to develop a freight mobility plan that strikes a balance between improving the operational efficiency of freight movement and the needs of pedestrians.

Project-Level Planning

Project-level planning for roadways should include pedestrians as a critical element in "context-sensitive design." This term applies to an emerging trend in the United States to ensure that road design considers the environmental, scenic, aesthetic, historic, and land use impacts of a road project and provides access for other modes of transportation such as bicycles, pedestrians, and mass transit. Specific issues that should be addressed during project-level planning include:

- The need to keep motor vehicle speeds at or below the preferred maximum speed through design measures and traffic calming techniques.
- Pedestrian access along the length of the corridor, providing sidewalks on one or both sides per the recommendations in this guide.
- Measures to buffer pedestrians from high-speed or high-volume motor vehicle traffic, such as additional width between the sidewalk and the roadway and/or appropriate landscaping placed within the buffer.
- Crossing measures needed to ensure frequent and safe opportunities to cross the corridor. Crossing distances should be kept to a minimum. New construction or altered walkways and street crossings shall be accessible to the maximum extent feasible.
- The visual quality of the roadway and aesthetic treatments that encourage walking, such as pedestrian-scale lighting, street trees, landscaping, and other measures.

Pedestrian access should also be a consideration during planning projects for limited access freeways because freeways intersect with streets that serve pedestrians. Interchanges, bridges, and underpasses should be designed to facilitate pedestrian movement. (See Chapter 3 on Design for more specific recommendations.)

Air Quality Conformity Studies/TDM Measures

Pedestrian facilities should be included in air quality conformity studies as a recommendation that can help to reduce automobile dependence. The process of determining the air

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quality benefits of pedestrian projects (e.g., the mode shift), however, is an emerging science. (See *Methods to Estimate Non-Motorized Transportation Demand* (11)).

Transportation Demand Management (TDM) measures are required in urban areas that do not meet the provisions of the Federal Clean Air Act, but they are a good idea everywhere. Employer incentives for walking should be a key strategy. A fair amount of home-based work trips are within a 1.6 km [1 mi] trip distance, which represents a potential market for shifting auto trips to walking trips. Quantifying the actual effect of TDM measures is also an emerging area of study, not only for the pedestrian mode but for other modes as well.

2.3.2 Prioritizing Pedestrian Improvement Projects

In most communities, there are many needs for pedestrian access. In some cases, entire transportation networks have been built with no provisions for pedestrians systems that will take many years and much investment to retrofit. Pedestrian provisions should be considered in all non-limited access roadway projects and roadway reconstruction/rehabilitation projects. However, it is important that local agencies establish criteria for prioritizing improvements. An example is provided below for establishing priorities for an independent sidewalk retrofit and intersection improvement program. Similar criteria and processes can be developed to establish priorities for other types of programs.

Example Criteria for Establishing Priorities in Retrofitting Streets

Establishing priorities for installing sidewalks involves three steps:

- Developing an agreed upon list of criteria
- Developing a methodology for using the criteria to evaluate potential sites
- Creating a prioritized list of sites for sidewalk improvements

It is usually necessary to select several criteria (three or more) rather than relying on just one. Selected criteria should be based on the needs identified for a particular community. Public input is a useful and necessary component of the process. The following are suggested criteria for establishing priorities (12):

- *Existing Pedestrian Volumes*—Locations where existing pedestrian movements are significant, as evidenced by visible worn paths or pedestrian volume counts, or as estimated from travel demand models, are good candidates for sidewalk retrofits. Likewise, locations where existing pedestrian movements are lower than expected, such as near a neighborhood school where no one walks, could be studied for potential sidewalk improvements.

- *Major Pedestrian Generators*—Hospitals, schools, community centers, malls and shopping centers, transit centers, senior citizen housing and centers, libraries, post offices, parks, sports arenas, and other public places are natural pedestrian generators where sidewalks and pedestrian crossings should be given priority.

- *Speed*—Because there is a direct relationship between motor vehicle speed and severity of vehicle–pedestrian crashes, speed should be a criterion in ranking sidewalk

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retrofits. Faster speeds increase the likelihood of a pedestrian being hit because at higher speeds, motorists are less likely to see a pedestrian and even less likely to stop in time to avoid hitting one (7).

- *Street Classification*—Arterial streets should take precedence because they are the main links in the community and generally have higher potential for transit and pedestrian use. In addition, there is a greater need to separate pedestrians from motor vehicles due to higher traffic volumes and speeds.
- *Crash Data*—Vehicle–pedestrian crashes seldom occur with high frequencies at single locations, making crash data difficult to use to target sidewalks. Crash data of all severity levels (fatalities and injuries), however, may reveal a pattern of pedestrian crashes up and down a corridor, indicating a need to provide sidewalks, midblock crossings, and intersection improvements throughout a corridor, not just at crash locations.
- *School Walking Zones*—School walking zones typically extend 0.8–1.6 km [0.5–1.0 mi] from an elementary school. Children are especially vulnerable, making streets (especially arterials) in these zones prime candidates for sidewalk retrofits and crossing improvements.
- *Transit Routes*—Transit riders need sidewalks to access transit stops. Arterials and collectors served by transit are prime candidates for sidewalk retrofits and crossing improvements.
- *Urban Centers/Neighborhood Commercial Areas*—Areas with higher densities and a mix of commercial activity and residential land uses generate higher pedestrian use, even if they are primarily motorists who park their cars nearby. Pedestrian improvements are needed to improve safety and enhance the economic viability of these areas.
- *Disadvantaged Neighborhoods*—Vehicle–pedestrian crash rates are often higher in low and moderate-income neighborhoods with lots of children. In addition, car ownership is often lower. Pedestrian improvements can help reduce crashes and provide access and mobility to people without cars.
- *Missing Links*—Installing sidewalks and improving pedestrian crossings to connect pedestrian areas to each other creates continuous walking systems. These can include connecting cul-de-sacs and creating pedestrian accessways to malls and employment centers.
- *Neighborhood Priorities*—Local residents often know where pedestrian improvements are most needed. Neighborhood residents can help identify locations where they see a need for sidewalks and intersection improvements.
- *Activity Type*—Different types of activities that take place on sidewalks include walking, running, rollerblading, and scootering. Controlled interaction and/or separation of these different types of pedestrian activities should be considered.
- *Transition Plan Improvements*—Accessibility regulations require jurisdictions to prepare transition plans identifying program and facility improvements needed to existing facilities.

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- *Citizen Requests*—Individual residents with disabilities may request sidewalk and street-crossing improvements to make existing routes usable.
- *Street Resurfacing Programs*—Resurfacing programs may require the addition of new curb ramps to existing sidewalks and thus should be coordinated with other pedestrian planning efforts.

Selecting Locations for Improvements

Two simple methods exist for selecting locations for improvements: (1) the overlapping priorities method, and (2) the points method. Establishing priorities should consume only a small percentage of a program budget; the level of effort put into prioritization should be proportionate to the size of the capital budget.

There is no single right way to select which criteria to use when developing priorities. The criteria and methodology should balance safety measures, such as vehicle speeds and pedestrian crash data, and pedestrian usage measures, such as proximity to schools or commercial areas (12).

Overlapping Priorities Method

The easiest way to identify overlapping priorities is through graphical representation. The intent is to identify locations that meet multiple criteria. This methodology is especially useful in cases where there is not a lot of staff time or funding for detailed analysis. It can be accomplished using GIS, or it can be done by hand.

The best way to describe this methodology is by example. Assume that priorities are going to be developed based on transit routes, proximity to schools, and neighborhood commercial areas. Start with a map of the study area. Identify those arterials that have high transit use; draw a 0.8-km [0.5-mi] circle around schools and locations that attract the elderly and/or people with disabilities; and identify the neighborhood commercial areas. This visual approach will make areas of overlapping priorities become immediately clear. The streets without sidewalks within the overlapping areas are the highest priority for constructing sidewalks (12).

Points Method

A weighted points system can be used where staff time and funding are available for more detailed analysis, or if there is a large amount of capital available for sidewalk construction. If there are a lot of competing projects, a more sophisticated point system can be used to explain to the public why certain projects were funded and others were not.

A point system can be developed in many ways; the system should be simple and produce desired outcomes. Any or all of the criteria listed previously can be assigned a range of numbers and then be used to analyze the need for improvements at given locations. For example, a corridor could be assigned points based on the number of "walking along roadway" crashes over a five-year period, the number of buses that travel the corridor during peak times, and the proximity to schools. This method is time-consuming because it will be necessary to analyze multiple locations with sidewalk needs to create a list of priority projects.

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Prioritized List

Both the overlapping priorities and the points methods will produce an initial list of prioritized projects. The next step is to refine the list so that it works, using common sense. Are priority locations ones that might be expected? Are there many surprises? Are priority locations in line with community priorities and expectations? Are some priorities at locations with very low pedestrian need? If the answers to these questions do not reflect community expectations and desires, then the criteria or the methodology may need to be revised. The methodologies should be used to prioritize recognized needs, not to create new priorities that do not make sense.

The final step is to create packages of fundable projects. The prioritization process should result in reasonable packages that decision makers can embrace and support. For example, it may be possible to install sidewalks on one side of every arterial within 0.8 km [0.5 mi] of every elementary school over a period of five years. Or, it may be possible to replace sidewalks in neighborhood commercial areas over a period of three years. The objective is to take what may appear to be an unsolvable problem (endless need for more funds) and to package it in such a way that it begins to address some of the most critical pedestrian needs in a community (12).

2.3.3 Rural Considerations

While pedestrian activity in rural areas tends to be limited because of longer travel distances, occasional pedestrian activity will occur and should be accommodated. Even on roadways in completely undeveloped areas that are not intended as pedestrian routes, it is desirable to provide space for walking adjacent to the traveled way for occasional or emergency pedestrian use. The minimum roadway and shoulder widths as recommended in the Green Book (1) for rural local, collector, and arterial roadways can accommodate occasional pedestrian travel.

In areas where a pedestrian route is needed along a roadway to provide access between public buildings or facilities, shoulders are not usually appropriate as pedestrian facilities, particularly where vehicular traffic travels at higher speeds. In such cases, a full sidewalk or paved path, raised and/or separated from the street, should be considered.

Where rural highways enter small towns and crossroad villages where pedestrian routes are needed, sidewalks should be provided. (See Section 3.2 on Sidewalk Design in Chapter 3.) For rural areas where there are small pockets in which the population, including tourist and seasonal population and/or employment, exceeds approximately 400 persons per square kilometer (1,000 persons per square mile), consideration should be given to using the same design criteria as for urban areas.

There is a desire in some residential developments to retain a "rural" atmosphere, usually defined by very low density (large lots), no streetlights, and streets without curbs and sidewalks. This may be acceptable if traffic volumes and speeds are low enough so that pedestrians, including children, can comfortably use the street. For example, sidewalks may not be needed on local streets with traffic volumes less than 400 vehicles per day. However, it is not a good practice to have an entire neighborhood without sidewalks. If a pedestrian route is located within a street, the pedestrian route must be accessible.

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Wherever there is developed frontage along a road or street, there will be people walking for exercise, visiting neighbors, accessing bus stops, or walking for pure enjoyment. Sidewalks or pathways are needed to safely accommodate these activities (12).

2.3.4 Phased Development of Sidewalks

It is particularly important to plan early for sidewalks in areas that are experiencing development. Retrofitting these areas with sidewalks at a later date is usually more difficult and expensive than installing sidewalks early in the process. In some cases, it may be appropriate to start with shoulders and unpaved paths and then phase in sidewalks as development accelerates. Criteria for installing sidewalks along with new development should be developed with the following in mind:

- *Space for Future Sidewalks*—Space for future sidewalks should be secured and/or reserved when a new right-of-way is being created or an existing one is being developed, and when future developments are indicated in land-use plans.
- *"Triggers" for Future Sidewalks*—In rural settings, if sidewalks are not installed at the time of initial development due to lack of density, guidelines are needed to determine when sidewalks will be needed and how they will be funded. For example, sidewalks could be provided on residential streets once a certain density of dwelling units per acre is reached and, on arterial streets, once they are within a school walking zone or have transit service. A good rule of thumb would be to install sidewalks whenever the level of development results in the roadway changing from open ditches to curb- and gutter-enclosed drainage. This would not apply in those communities where open drainage is retained in built-up areas for ecological or aesthetic reasons. (See Section 3.2 on Sidewalk Design.)
- *Funding for Future Sidewalks*—If sidewalks are not installed at the time of initial development, there should be clear regulations as to who (developer, property owners, or governmental agency) will pay for future sidewalks. It is virtually impossible to have developers pay for sidewalks years after development occurs. One alternative is to have developers pay contributions at the time of development and set the money aside in an account for future sidewalk installation (12).

Opportunities to upgrade sidewalks and other pedestrian facilities should also be considered during routine maintenance and rehabilitation of existing roadways. In some cases, it will be more cost effective to improve pedestrian facilities during routine maintenance of the roadways. Case law surrounding the Americans with Disabilities Act (ADA) has found that resurfacing an existing roadway constitutes an alteration, which requires the addition of curb ramps at intersections where they do not exist. The removal or relocation of sidewalk obstacles should be coordinated with other pedestrian improvements in order to maintain the appropriate sidewalk clear width.

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2.4 Pedestrian-Friendly Site Development

The viability of walking is greatly affected by land-use patterns. Segregated land uses increase the distance between origin and destination points while mixed-use development generally shortens distances and encourages walking. Similarly, the planning and design of large and small developments can either encourage walking by providing good pedestrian circulation and minimizing conflicts between pedestrians and motor vehicles, or send the message that cars are the preferred mode of access to the site by creating large areas for parking and not connecting the development to existing pedestrian facilities.

Land-use planning and site plan review are typically the responsibility of local jurisdictions. This section on pedestrian-friendly site development discusses how land use and site design can impact pedestrians and provides examples of policies and procedures that create more pedestrian-friendly designs.

2.4.1 Development Practices

Land-use planning is usually a local responsibility; therefore, municipal and county-level regulations are an important way for communities to use their authority to guide development. Zoning and land development/subdivision regulations-two of the primary land-use planning tools-can have a significant impact on a community's development pattern and general appearance, and consequently, the quality of the pedestrian environment. The topics addressed by these two types of regulations vary by community, and there is often some overlap between them. In general, zoning can be thought of as regulating land use, while land development/subdivision regulations control the division of land into building lots and the provision and design of infrastructure. The content of these development controls dictate not only the design and construction of basic urban and suburban infrastructure, but also the distances between destinations.

In many communities developed after World War II, zoning ordinances favored single-use zoning, which separated developing areas into large blocks of land that could only be developed with one type of land use. Industrial, commercial, residential, and agricultural lands were isolated from one another. Typically, limits were placed on the allowable densities and/or intensities in each zoning district. As a result, trip distances became longer and automobiles were generally the only convenient mode of transportation. Communities with higher levels of walking contained areas with mixed-land uses, which created shorter distances between various types of land uses and made walking a more viable transportation option. Many communities have recognized this benefit and have made modifications to their zoning ordinances to either encourage or require mixed-use developments.

Street design is a function of the subdivision ordinance in many parts of the country, particularly in developing areas. Planners (who write the ordinances), local elected officials (who vote on the ordinances), and developers (who interpret the ordinances) play a large role in the accommodation of pedestrians. A typical subdivision ordinance covers many issues that affect pedestrian mobility, including:

- Street design and layout
- Block length
- Allowable grades

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- Lot design
- Sidewalk design
- Commercial development design and densities/intensities
- Parking requirements and design
- Landscaping
- Residential design practices

Access management policies also impact site development. These policies are usually established at local, regional, and/or state levels. The basic principles of access management are to facilitate motor vehicle throughput on the major roadway by separating through and turning vehicles, providing adequate spacing between intersections, and limiting direct access to the major roadway.

2.4.2 Strategies in Pedestrian-Friendly Ordinances

Many strategies have been incorporated into zoning ordinances in recent years to promote more pedestrian-friendly communities. Some communities have completely restructured their zoning ordinances to permit mixed-use developments with higher densities, increased densities in proximity to major destination points and transit lines, and traditional neighborhood developments.

Communities across the country are also upgrading their land development/subdivision regulations to encourage pedestrian travel. New land development/subdivision regulations typically provide more detail on specific design principles, such as:

- Requirements that developers include pedestrian accommodations early in the site planning process so that local planners can coordinate with other planned transportation improvements.
- Pedestrian-friendly street design principles, including reduced curve radii, reduced street width, accessible street crossings, limitations on the use of cul-de-sacs, alley design principles, traffic calming design measures, accessible sidewalk standards, street lighting standards, and requirements for street trees in specified districts.
- Requirements for street and sidewalk design that include enhanced connectivity between adjacent residential, commercial, and institutional developments.
- Requirements for commercial developments that place parking to the rear or side of the lot, set maximum limits on amount of parking, encourage shared parking, and direct access to the front of the building from sidewalks and nearby transit connections.
- Requirements for commercial developments to provide pedestrian connections between buildings on-site and to adjacent properties.

When considering how to provide for pedestrians within local jurisdictions, it is important for planners, engineers, and policy makers to understand the effect of local regulations

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on the process of providing and improving pedestrian facilities and to account for this effect when considering changes to local ordinances and policies.

2.4.3 Pedestrian-Oriented Site Development

A first step in creating a pedestrian-friendly site is to ensure that the pedestrian's needs are considered throughout the site planning and design process. Designing a site to meet the needs of the wide range of pedestrian users does not have to be complicated. Site designers and planners should consider the pedestrian point of view when reviewing the site for the first time, and the final design should not just accommodate walking but should encourage it. The following list identifies some key elements of pedestrian-friendly designs:

- Common walkways through parking lots delineated with visible and tactile methods
- Connections to neighborhoods and surrounding areas
- Easily identified building entrances and building frontages located along the street rather than across parking lots
- Convenient and safe access to transit and adjacent sidewalks
- Alignment of walkways for convenient and efficient pedestrian travel
- Accessible public routes of travel to and from the site, as well as throughout the site
- Unimpeded pedestrian travel (no walls, ditches, landscaping, or roads without safe crossings)
- Pedestrian signage and information in accessible formats
- Street trees that provide shade and give a sense of separation from traffic
- Proper illumination

2.4.4 Driveways and Access

Access to commercial property from the adjoining street can be provided through conventional flared driveways or by designs that resemble street intersections with turning radii. (See Section 3.3 on Intersection Design.) For pedestrian safety and comfort, the conventional driveway type is preferred because this type of design encourages motorists to drive more slowly when entering the property.

Where an intersection-style driveway is used (such as to implement a "right-in and right-out only" policy), the following techniques may be used to ensure slow turning speeds and pedestrian right-of-way:

- Continue the sidewalk material across the driveway, preferably at sidewalk height, so motorists know they are entering a pedestrian area.
- Construct sidewalks with cross slopes of two percent or less and provide a pedestrian access route away from inaccessible driveway ramp flares.

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- Keep the radius of the curb as small as practical.
- Use minimum driveway widths for entering and exiting vehicles.
- Provide right-turn channelization for entering vehicles to remove them from the traffic flow, allowing them to stop for pedestrians (29).

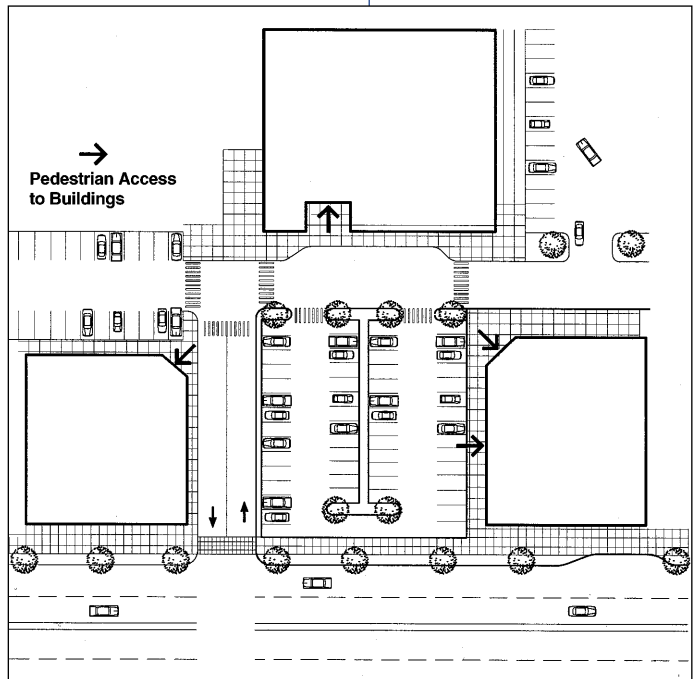

Exhibit 2-4.
Shared Parking Lot (40).

2.4.5 Commercial Parking Lots

Parking lots can have a significant impact on the design and quality of the built environment and the ability of pedestrians to access commercial properties. Conflicts with motor vehicles are a big concern for pedestrians. The following design strategies can help minimize these conflicts.

Location of Parking Spaces

Parking spaces should be located to the side and rear of buildings to allow easy access for pedestrians from adjacent sidewalks.

On-Site Circulation

On-site circulation systems should be designed to reduce conflicts between pedestrians and motor vehicles by clearly defining pedestrian access ways. Striped walkways, raised crosswalks, and walkways within raised parking aisle separator islands are examples of clearly defined pedestrian ways.

Newly constructed pedestrian facilities must be accessible. Using raised crosswalks, speed tables, or other similar traffic calming devices in parking areas can reduce vehicle speeds and give priority to pedestrian crossings.

Shared Parking Lots

Shared parking lots can reduce vehicular travel by allowing easy pedestrian access to more than one commercial development or area. With shared parking, motorists do not have to drive from one site to another to shop at different stores (see Exhibit 2-4). Retailers, however, may oppose shared parking lots for various reasons including marketing, liability, maintenance cost equity, etc. Thus, there may be a need to educate retailers on the potential benefits of shared parking lots.

Parking Structures

Parking structures often appear simple, but without proper planning, parking structures may inhibit pedestrian circulation and accessibility and could be a security concern. Significantly more information is now available as compared to years past on pedestrian issues related to parking structures (5). Of particular importance is the requirement that parking structures meet ADA regulations.

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2.4.6 Pedestrian-Only Site Design

Many cities across the country have created pedestrian-only or auto-free spaces in efforts to improve pedestrian safety and encourage walking. While pedestrian-only areas can take many forms, the most common type in this country is the pedestrian mall. Pedestrian malls are usually several blocks long with retail and commercial developments fronting streets that are reserved for the exclusive use of pedestrians. Exceptions to this pedestrian-only zone are made for deliveries, trash collection, and emergency vehicles. In an interrupted mall, the cross streets are left open to vehicular traffic, while exclusive pedestrian malls extend the length of the shopping or commercial area without intersecting streets. For pedestrian malls to be successful, they must provide a viable and attractive alternative to regional shopping malls. The following are some important planning considerations for pedestrian malls.

- *Proximity of the Mall to Other Developed Areas*—If a pedestrian mall is going to be successful, the mall must draw patrons at various times of the day. Malls located with easy access to commercial, residential, and mixed-use areas are the most successful.
- *Good Pedestrian Access*—The pedestrian mall should have accessible pedestrian connections to other developed areas from which pedestrians will be drawn to the mall.
- *Cooperation and Support from Public and Private Interests*—Successful malls are those that have strong support from both the public and private sectors. Public participation is needed to ensure that a quality project is designed, constructed, and maintained. Strong support from merchants and the general public is vital to the success of a pedestrian mall.
- *Existing Vehicle Traffic Patterns and Adequate Parking Supply*—Outside dense urban areas, providing good vehicle access and adequate parking is important to the success of a pedestrian mall. Good vehicle access creates a larger pool of patrons for the mall by inviting people to drive to the area and then walk around.
- *Good Public Transit Service*—Good public transit service allows another means of access to the pedestrian mall area. Good public transit can also reduce the amount of parking needed for the mall.
- *Good Bicycle Access*—Good bicycle access and adequate bicycle parking allows another means of access to the mall area. Good bicycle access can also reduce the amount of automobile parking needed for the mall, possibly reducing the walking distance across the parking area to access the mall.
- *Accommodation for the Delivery of Goods*—For businesses to be viable in a pedestrian mall, accommodation of the delivery of goods is vital. Creation of the pedestrian mall often eliminates front door delivery access. Alternatives such as the creation of alleys or allowing delivery vehicles on the pedestrian mall during certain hours are strategies that many communities have used to address this issue (29).

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2.4.7 Conclusion

The key to building a pedestrian-friendly development is to create a planning and design process at the local level whereby the needs of pedestrians are incorporated into projects from beginning to end. It is also important to review state planning and design processes to ensure the full consideration of pedestrian needs. By making pedestrian-oriented amendments to local ordinances, policies, and procedures, communities can ensure that new developments and redevelopment projects will improve conditions for pedestrians.

2.5 School Site Planning and Design

Walking to school and back home again has been a part of growing up for many Americans. Even today, a significant number of children walk to school each day in the United States. In many school districts, bus service is not provided for students living within walking distance of schools, often defined as a 0.8 to 1.6 km [0.5 to 1.0 mi] radius around each school. These children have the option either of walking, bicycling, riding with their parents, driving themselves if they are old enough, or carpooling.

In many communities, school officials, teachers, parents, enforcement personnel, elected officials, transportation agencies, and concerned citizens are developing comprehensive programs to improve pedestrian facilities near schools to provide safer routes for children who walk or bicycle back and forth to school (see Exhibit 2-5). However, school districts often face financial constraints, therefore they must balance financial resources between improving pedestrian facilities and other competing programs. In the school site planning and development process, school districts should be sensitive to the needs of students at the various school levels-elementary, middle, and high school. For example, it may be appropriate for an elementary school to be located at an intersection of two lower-volume collector roads, whereas a high school may be located along a minor or major arterial street. The street crossing issues near the high school will likely be more complex than near the elementary school, but the older high school students have different capabilities and characteristics from students in an elementary school. Similar issues should be considered in the school site planning and development process. The remainder of this section focuses primarily on policies and designs for elementary schools and covers basic concepts rather than in-depth material. Additional information related to school site planning and design is available from various sources (13, 19, 26, 28, 36).

2.5.1 Special Considerations Related to Children

The National Highway Traffic Safety Administration (NHTSA) reports that in 1998 over 20,000 pedestrians under 15 years of age were injured in vehicle-related crashes, representing approximately 30 percent of the total pedestrians injured in motor vehicle crashes that year (24). As pedestrians, younger children are involved in a disproportionately high number of crashes for a variety of reasons:

- Young children are shorter than adults; their typical eye height is 1 m [3 ft] above the ground; and their field of vision is different.

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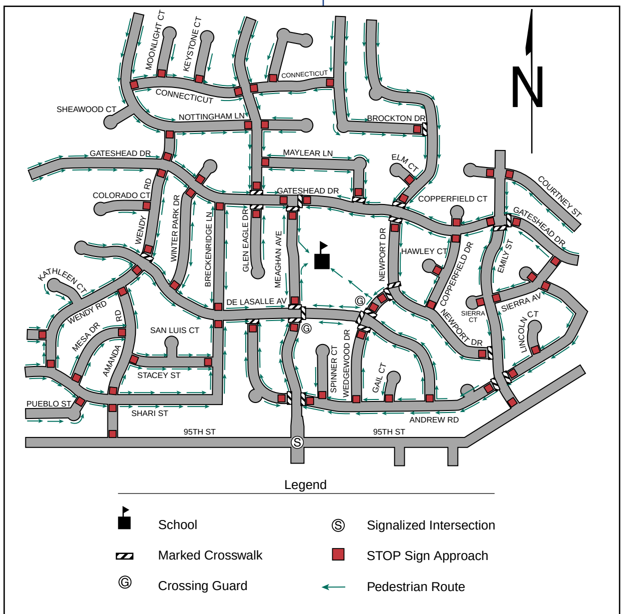

Exhibit 2-5.
Sample Safe Routes to School Map (14).

- Children have one-third narrower peripheral vision than adults and are less able to determine the direction of sounds.
- Children have trouble judging the speed and distance of moving cars as well as the adequacy of gaps in the flow of traffic.
- Children are sometimes too small to be seen.
- The movements of children are less predictable than adults.
- Children have shorter attention spans and may grow impatient at crossings.
- Children have less experience and limited knowledge of traffic laws and driving patterns.
- Since children do not drive, they lack the understanding of what a driver's intentions might be at an intersection or crossing point (40).

2.5.2 Community Response to School Safety

Pedestrian safety is a concern of many citizens and professionals, including parents, teachers, school officials, transportation planners and engineers, law enforcement personnel, and elected officials. Many communities have responded to this concern by creating programs to identify safe walking routes to schools and to identify problems along potential routes or at the school itself, along with solutions to the problems. Increased enforcement, constructing missing sidewalk links, improving crosswalks, installing traffic calming measures, and installing or upgrading traffic signals are the most effective types of improvements that can be made. These physical improvements should be supplemented by programs that educate children, parents, and the driving public about pedestrian safety and the special concerns in and around schools.

2.5.3 School-Related Pedestrian Improvements

Three key components of a school-based pedestrian improvement program include:

1. Providing physical facilities along school walking routes and adjacent to the school, including traffic control devices and traffic-calming tools, to manage speed and provide positive control at crossing locations.
2. Developing effective operations plans and safety programs consisting of supervisory control elements and student/adult education for school trip safety (40).
3. Effectively locating new schools to encourage safe pedestrian access.

Design recommendations for physical facilities leading to and adjacent to schools, along with information about crossing guards and safety programs, are provided in the following sections. Additional detail about programmatic improvements for student pedestrian safety may be found in comprehensive guides prepared by many state and local governments.

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School Location

Schools often serve as a community focal point, providing neighborhood playgrounds and ball fields, serving as polling places, and providing meeting space. Choosing the site where a new school will be located is critical to successfully serving these needs/purposes and should consider pedestrian accessibility as well as vehicular access. Schools should be located centrally in a community, with easy pedestrian access from all directions. In addition, wherever possible, schools should be sited to minimize the need for crossing major highways or rail corridors. Streets leading to schools should include sidewalks and other elements that contribute to pedestrian safety and comfort, such as street trees and additional buffer width between the sidewalk and the roadway. Intersections and crossings within the vicinity of schools should be designed with a focus on the needs of student pedestrians. Often, pedestrian facilities designed to meet the needs of students will also benefit the elderly and disabled during civic events like voting and public meetings. Important elements of a school within the community include (40):

- The school site is centrally located in the community; most children live within 1.6 km (1 mi).
- Pedestrian and bicycle access is available from all directions.
- Bicycle parking is secure and in close proximity to entrances.
- Sidewalks, bike lanes, and trails on adjacent streets or through neighborhoods connect to the school property.
- Linkages between surrounding neighborhoods, such as access between cul-de-sacs, provide enhanced pedestrian connections to the school.
- Effective traffic control devices are provided within the vicinity.
- A school walk route and safety program exists and safety patrols are provided within the vicinity.
- School facilities, including the playground, fields, and meeting rooms, are available for community use.
- Because of the level of pedestrian improvements in the area and the design of the school site, children and adults feel comfortable walking to the school.
- Elementary schools are built on collector streets in the middle of a neighborhood.

School Site Design

There are seven major components of a school site that are interrelated (26). These components are:

- Buildings and landscaping
- Bus and van traffic
- Private vehicle traffic

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- Service vehicle traffic
- Pedestrian and bicycle traffic
- Utilities, stormwater pollution prevention and control, and stormwater drainage
- Playgrounds, athletic fields, and recreation areas

A school site design should be developed that establishes a basic order or process to the site by following principles that establish immediate and long-term uses of the site. The design should give paramount emphasis to the safety of pedestrians and bicyclists near motor vehicle traffic.

Each specific school site has unique conditions that require careful planning and design. Whenever possible, school bus loading and unloading should take place on school property, off the surrounding street system. In addition, consideration needs to be given to finding space for the increasing number of private vehicles being used to drop off and pick up children. Basic concepts for pedestrian-sensitive school design include (40):

- Surrounding streets are equipped with sidewalks and bike lanes.
- Parking is minimized; people are encouraged to walk to school.
- The building is accessible to pedestrians from all sides (or at least, from all sides with entries/exits).
- Trails and pathways provide direct links between the school site and the surrounding neighborhoods.
- Secure bicycle parking is situated close to entrances.
- Bus drop-off zones are separated from auto drop-off zones to minimize confusion and conflicts and are located on the same side of the street as the school.
- Buses, cars, bicycles, and pedestrians are accommodated and provided with designated areas for traveling.
- Pedestrian travel zones (sidewalks, etc.) are clearly delineated from other modes of traffic (through the use of striping, colored and/or lightly textured pavement, signing, and other methods).
- Pedestrians are clearly directed to crossing points and pedestrian access ways by directional signing, fencing, bollards, or other elements.
- Strategically located, well-delineated crossing opportunities are provided, including marked crosswalks at controlled intersections and midblock crossings (signalized if warranted).
- Traffic-calming devices (raised crossings, refuge islands, bulb-outs at crossings, neighborhood traffic circles, landscaping, etc.) are installed in the vicinity to slow vehicles.
- View obstructions are avoided so there is clear visibility of pedestrians throughout the area.

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Pedestrian-Access Routes to the School

Sidewalks and walkways that clearly define access routes to and from schools should be provided in all areas surrounding the school, as well as on the school site. Vertical separation (with curbs) and horizontal separation (planting buffers, ditches, or swales) from motor vehicle traffic are strongly encouraged to improve the safety of pedestrians walking along streets.

On roads without sidewalks, which often occur in rural areas surrounding schools, shoulders may be used to accommodate pedestrians as an interim solution until it is feasible to install a separated pathway (40).

School Bus Stop Design

School bus stops should be designed to provide a sufficient waiting area away from the roadway for students using the stop. Section 10 of the ADAAG (8) includes accessibility provisions for bus stops and loading areas. School bus stops can be integrated into the design of new developments or retrofitted to existing conditions. Typically bus stops are adjacent to sidewalks in urban areas and along shoulders in rural locations. In areas with curb and gutter, curb ramps should be provided (40). When bus stops are located near intersections with high right-turn volumes, signing prohibiting right turns on red during school hours should be considered.

Visibility at Crossings and Along School Walk Routes

Because children are smaller than adults, motorists may have difficulty seeing them at street crossings. Extra care is necessary in the vicinity of schools to ensure that utility poles, traffic control devices, mailboxes, landscaping, and other street furniture do not inhibit motorists' ability to see children. Parked vehicles can also block visibility. Minimum parking setbacks are described in Chapter 3 of this guide. Parking restrictions and sight line issues should be applied to both intersections and midblock crossings near schools. Constructing curb extensions and crossing islands are additional crossing enhancement tools that may be implemented (40).

2.5.4 Traffic Control and Crossings Near Schools

Traffic control in the vicinity of schools is often an extremely important subject. The Institute of Transportation Engineers' (ITE) *School Trip Safety Program Guidelines* (19) include a number of elements that should be considered when conducting a traffic control study for school zones. These elements include, but are not limited to:

- Existing and potential traffic volumes and speeds
- Inventory of existing traffic control devices and roadway facilities
- Adequacy of gaps in the traffic stream
- Number and ages of children who use the crossing

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- Adequacy of lines of sight between motorists and pedestrians (considering the height of children)
- Crash statistics
- Location of the school and the relationship to surrounding land uses (both existing and planned)

Several types of crossing treatments and traffic control devices are available and appropriate for school zones and along school walking routes. The MUTCD (14) contains a number of school-related signs and markings and should be consulted whenever traffic control issues are addressed around school sites. Potential types of crossing devices and traffic control for school areas include:

- Reduced speed zones
- Traffic-calming techniques
- Marked crosswalks where appropriate at intersections and midblock locations
- Curb extensions or expanded parking controls
- Adult crossing guards
- Stop-controlled crosswalks
- Signalized crossings (with pedestrian activators)
- Full accessibility for all pedestrians
- Crossing islands at intersections
- Grade-separated crossings, only where appropriate and where they will be used

Reduced Speed Zones

Many states require reduced speed limits for school zones during school hours. In addition to identifying a standard or statutory speed limit for school zones, the regulations often define the requirements for delineating school zones. In some instances, a local jurisdiction may determine (after a study by traffic engineers) that specific circumstances justify a speed limit that is less than the standard or statutory speed limit for school zones. Fines for speeding within school zones sometimes are doubled or otherwise increased to encourage driver compliance.

Traffic Calming

Traffic calming measures are intended to reduce vehicle travel speeds or reduce the volume of traffic on a street. This has become more important with recent increases in parents driving their children to school. Traffic calming measures that can benefit children who walk to school include raised crosswalks and speed humps on local residential streets, and measures that narrow the travel way in order to reduce speeds and crossing distance. Examples of the latter include curb extensions, crossing islands, and street width

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reductions. More detail regarding traffic calming can be found in Section 2.6 on Neighborhood Traffic Management and Traffic Calming later in this chapter.

Flashing Beacons

Flashing beacons are traffic control devices used to alert drivers to unusual or hazardous situations. There are two types of flashing beacons: (1) those that are warning beacons (always flash) and (2) those that are used to indicate when a sign is active. Flashing beacons are often attached to school zone speed limit signs and are only activated during school hours. Flashing beacons that are activated only during school hours are probably more effective at drawing the attention of drivers compared to beacons that flash throughout the entire day because studies have shown that drivers tend to disregard continually flashing beacons once they become accustomed to them (40). Decisions regarding the appropriate use of flashing beacons and other traffic control devices, including traffic cones and tubular markers, in school areas should be made by persons with traffic and safety expertise.

Exhibit 2-6.
Adult Crossing Guards May Be Needed When Special Crossing Problems Exist (30).
Photo courtesy of Dan Burden.

Crossing Guards and Student-Patrolled Crosswalks

The supervision of children crossing roads in the vicinity of schools during school hours should be carried out by adult crossing guards and may be supplemented by school safety patrols (see Exhibit 2-6). The primary functions of crossing guards are:

- To instruct, direct, and control students crossing the streets and highways at or near schools
- To assist teachers and parents in the instruction of school children in safe crossing practices

Adult crossing guards usually operate under the jurisdiction of the local school district, police department, or traffic engineering department. Whether crossing guards are paid or are volunteers, they should receive adequate training to effectively execute their duties. The school principal, the school transportation director, and a local traffic engineer should work together to determine where to place crossing guards.

To Reduce	By What Means	Examples
Traffic volumes diverters	Physical	Street closures, traffic
Vehicle noise	Legislative	Speed limits, truck/bus restrictions
Visual impacts	Visual	Landscaping to block through views
Traffic speeds	Social; physical	Neighborhood "Speed Watch" program, speed limits, speed humps/tables, street narrowing, landscaping
Collisions/ speeding/ severity of crashes	Legal; physical	Neighborhood traffic circles, speed limits, strict speed enforcement; spot safety improvements

Exhibit 2-7.
Common Residential Traffic Management Program Actions (40).

2.5.5 Safe Routes to School

Creating a safe and comfortable environment for children is a complex but critically important endeavor. It requires coordination and cooperation from parents, school administrators, and local governmental agencies. One method that some local and state governments have used to encourage schools to address pedestrian safety is to develop a *Safe Routes to School* program. This type of program covers many of the elements described in this chapter, and typically provides technical assistance and funding for physical improvements to school walking routes. *Safe Routes* programs may also include an

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educational element that teaches children and parents about pedestrian safety. Procedures for developing safer school walking routes include:

- Form Safety Advisory Committee
- Prepare base maps
- Inventory existing walking conditions
- Inventory traffic characteristics
- Survey children and parents for their concerns
- Design the walk routes
- Identify improvement areas
- Get approval of route maps from all necessary parties
- Implement improvements
- Distribute maps and educate students and parents
- Evaluate the effectiveness of the program

An increasingly important aspect of a *Safe Routes to School* program is the adoption of a *Walk to School Day* program. This program stresses the health benefits for both parents and children of increased exercise and has an associated benefit of decreasing the traffic congestion around the school itself (40).

Many successful *Safe Routes to School*, *Walk to School Day*, and International W*alk to School Day* programs have been implemented. Additional information related to these programs is available from various sources (18, 21, 25, 32, 39).

2.6 Neighborhood Traffic Management and Traffic Calming

Traffic management and traffic-calming programs can have a beneficial effect for pedestrians. Neighborhood traffic-management programs are commonly designed to reduce traffic speeds, vehicle noise, visual impacts, and through volumes in residential neighborhoods by physical, psychological, visual, social, and legal means. Neighborhood traffic-calming programs are intended to lower vehicle speeds and, to a lesser extent, traffic volumes, usually through physical changes to the streets themselves and through laws on parking and speeds. Traffic-calming techniques are often one component of an overall neighborhood traffic-management program (40). The traffic-management and traffic-calming techniques discussed in this section are applicable for residential neighborhoods and urban areas but are generally not applied to arterial streets.

Traffic speed is a critical aspect of pedestrian safety. Research has shown that, with the exception of children and older adults, pedestrians do not normally sustain serious injuries when struck by a vehicle moving at a speed of less than 30 km/h [20 mph] at the time of impact; however, when impact speeds are above 30 km/h [20 mph], injuries to pedestrians are usually serious if not fatal (20). By reducing speeds in a neighborhood through the

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implementation of traffic-management and traffic-calming programs, pedestrians have a greater likelihood of surviving vehicle-pedestrian-related crashes, if the crashes are not avoided altogether.

There are certain overall considerations that are applicable to both traffic management and traffic calming:

- Speed is more critical than volume and should be addressed first.
- Neighborhood involvement is important to successful implementation.
- Traffic-management and traffic-calming measures should fit into and enhance the street environment.
- Traffic-calming designs should be predictable rather than random, and should be easy to understand by drivers and other users.
- Devices need to be well designed and based on current available information on their applications and effects. Information on U.S. experiences with various traffic-calming measures can be found in *Traffic Calming: State of the Practice* (10).
- Traffic-calming areas or devices should be adequately signed, marked, and lit to be visible to motorists, bicyclists, and pedestrians.
- Devices need to be spaced appropriately to have the desired effect on speed—too far apart and they will have limited effect, too close and they will be an unnecessary cost and annoyance. Devices usually need to be spaced about 100 to 150 m [300 to 500 ft] apart.
- Devices should not be under-designed, or they face the possibility of failing to meet objectives. Keeping the slopes too gentle for a speed table or curves too gentle for a chicane will not solve the problem and may appear as a waste of public funds.
- If a measure is likely to divert traffic, the area-wide street system should be considered so as not to shift the problem from one place to another.
- Devices should be adequately maintained to serve their intended purpose.
- The aesthetic appeal of devices should be considered so as not to create an eyesore in a community and disgruntle citizens against its intended purpose.
- Devices should not be hazardous to bicyclists.
- Techniques should allow access for emergency (police, ambulance, fire, etc.) vehicles and equipment.

There are a wide variety of traffic management and calming methods available today. By some estimates, there are over 80 individual techniques. The reported levels of success and application feasibility of these devices vary greatly. A number of excellent manuals and resources are available that address the design and application of traffic management and traffic-calming techniques (10, 33–35, 40). Rather than list the entire catalogue of devices, this section describes some of the more common methods currently used. Readers are directed to the sources at the end of this chapter for more detailed information on when and how to implement these techniques.

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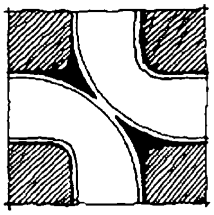
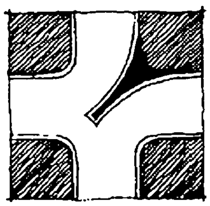
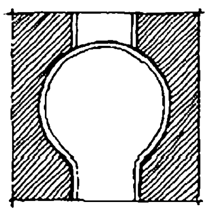
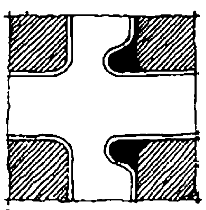
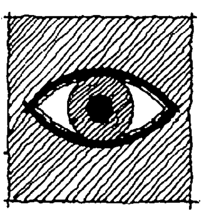
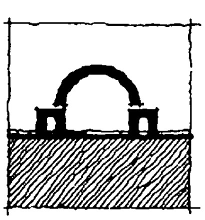
Drawing	Technique	Description
	Diagonal Diverters	Eliminates through traffic while providing partial access in opposite directions; island can become a positive aesthetic amenity and provide refuge for pedestrians.
	Forced Turns and Partial Diverters	Truncated diagonal diverters (one end remains open) and other types of partial diverters discourage commuter traffic by forcing turns, but provides local access opportunities.
	Cul-de-sac/Street Closures	Street is closed and turned into a cul-de-sac; end of street becomes a neighborhood amenity and focal point (landscaped mini park); the ongoing provision of pedestrian and bicycle access is important.
	One-Way Entry and Exit	Curb bulb-outs/extensions are used to close one lane of traffic at intersections; stops through traffic but allows ingress or egress depending on the direction and location of the closure.
	Speed Watch Programs	Citizens and organizations can utilize a radar device and electronic sign board to measure speeds of passing vehicles in their neighborhoods. Letters of warning can be sent to the registered owners of offending vehicles. These programs promote neighborhood awareness of speeding andor to aid police in targeted enforcement.
	Signs and Neighborhood Gateways	Signs such as "Residential Street," and "Local Access Only," or monuments that identify neighborhood districts can be used to supplement the above techniques.

Exhibit 2-8.
Traffic Management Techniques (40).

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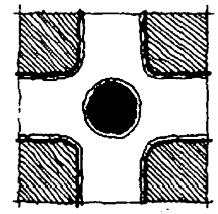
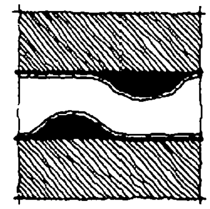
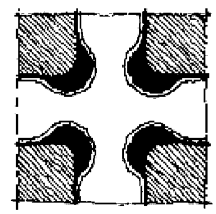
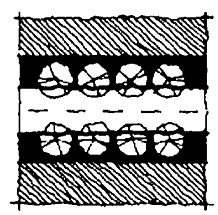
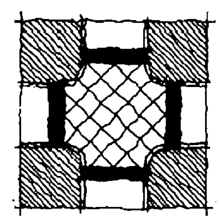
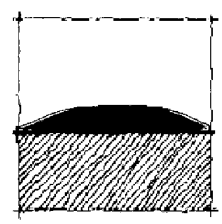
Technique	Description	Drawing
Neighborhood Traffic Circles	Small circular raised islands centered within intersections. Circles can be landscaped or surfaced with special paving. Landscaping can be maintained by the local jurisdiction or by neighborhood volunteers.	
Chicanes	Alternately placed curb extensions into the street that force motorists to drive in a serpentine pattern. Chicanes are offset from each other in mid-block locations to reduce traffic speeds and can be used to keep through-trucks versus local delivery off residential streets.	
Curb Extensions (Curb Bulb-Outs/ Chokers/Neckdowns)	Curb extensions placed at mid-block locations or intersections which narrow the street to provide visual distinction and reduce pedestrian crossing distances. These extensions help to provide a clear visual signal to drivers that a crossing is approaching, and makes waiting pedestrians more visible, and can help to define parallel street parking areas. They narrow the appearance of the street and can be attractive when landscaped.	
Narrower Streets	Narrower streets limit the expanse of pavement visible to the driver and can be effective in slowing traffic, especially when lined with trees or on-street parking. Marked bike lanes can also be used to create a narrowed effect.	
Special Paving	Alternative road surfaces, such as colored concrete or special pavers, can be used along the sides of the street or at intersections to break up the visual expanse of pavement.	
Speed Humps/Tables	A speed hump is wider and smoother than the discredited speed bump. They are effective in slowing cars as they approach pedestrian zones. They are most appropriately used on neighborhood streets.	

Exhibit 2-9.
Traffic Calming Techniques (40).

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Exhibit 2-10.
Diagonal Diverter (30).

Exhibit 2-11.
Neighborhood Gateway (30).
Photo courtesy of Dan Burden.

2.6.1 Traffic Management Techniques

Each of the techniques described below has the potential to improve conditions for pedestrians. Exhibit 2-7 indicates some common residential traffic management program actions, and Exhibits 2-8 and 2-9 illustrate some of the most often used traffic-management and traffic-calming techniques.

Diverters and Street Closures

Diagonal diverters partially close roads and eliminate through traffic while providing access to the surrounding neighborhood. Diverter islands may provide an area for landscaping and aesthetic enhancement. Islands may also provide a crossing refuge area for pedestrians. Full street closures eliminate all through traffic, improving the safety of the street by significantly reducing traffic volumes and speeds near the closure. A disadvantage of full street closures and diagonal diverters is that they cut off emergency vehicle access unless removable or breakaway bollards are used or another route can be provided. They also limit access opportunities for the affected residents. Through traffic may transfer to other local streets in the area if not managed. Another concern is that the closure of streets may contradict other transportation and land use planning goals that encourage an open grid system of streets. Partial street closures reduce through traffic in one direction but not the other. Traffic is diverted while allowing for emergency vehicle and local resident access. When streets are either fully or partially closed, it is always important to continue to provide pedestrian and bicycle access through the closed area (40). Exhibit 2-10 shows a diagonal diverter which closes the road to through traffic.

Gateways

Gateway treatments generally encompass a wide variety of techniques that provide neighborhood identification, such as signs, monuments, landscaping, special paving, narrowed entrances, and other elements (see Exhibit 2-11). These enhancements provide an indication to motorists that they are entering a neighborhood area from an arterial road or other type of street where traffic was moving at higher speeds (40).

Roundabouts

Roundabouts are circular intersections which feature yield control of all entering traffic, channelized approaches, and geometric curvature to reduce speeds. For more information, see Section 3.3 and the FHWA publication *Roundabouts: An Informational Guide* (31).

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2.6.2 Traffic-Calming Methods

Neighborhood Traffic Circles

Neighborhood traffic circles are built in the middle of the intersection of local streets, and the approaches to the intersection may be uncontrolled or stop-controlled. Neighborhood traffic circles can be used for traffic-calming purposes, but may negatively impact pedestrian access for children, older pedestrians, and people with vision and cognitive impairments (22). Neighborhood traffic circles are effective in reducing vehicle speeds. They create a condition where vehicles are forced to significantly reduce their speed at the intersection, which allows better opportunities for pedestrians to cross. Neighborhood traffic circles should be designed with sufficient space provided for the turning movements so that vehicles do not need to swing wide at the intersection to avoid the center barrier and thus intrude into the pedestrian crossing area. Exhibit 2-12 shows an example of a neighborhood traffic circle.

Exhibit 2-12. Neighborhood Traffic Circle.

Most drivers tend to take the shortest path through the neighborhood traffic circle and, when turning left, will turn before the circle rather than going all the way around it. This creates an unexpected movement to crossing pedestrians and other motorists. For this reason, it is best not to locate neighborhood traffic circles at intersections where there are high volumes of left-turning movements.

Neighborhood traffic circles are often landscaped and can provide a nice amenity to the neighborhood. Care must be taken to select landscaping that will not block views between motorists and pedestrians. Trees with high canopies are suggested, along with shrubs (as well as annuals and perennials) that do not exceed a height of 0.6 to 0.9 m [2 to 3 ft]. Sloping curbs at the perimeter of the circle are recommended to allow large vehicles, including emergency vehicles, to drive over the edge of the circle if they cannot turn around the island (40).

Chicanes

Chicanes are curb extensions or other features (such as landscape islands and on-street parking) that alternate from one side of the street to the other and serve to modify the straight line, wide-open look of long residential streets. Studies have shown that chicanes can be very effective in decreasing traffic volumes and vehicular speeds. Chicanes do not block emergency vehicle access and allow local access opportunities. They can be made more visible with signs, painted curbs, landscaping, reflectors, and street lights. Exhibit 2-13 provides an example of chicanes used along a neighborhood street. Note that on-street parking is not permitted near the intersections (40).

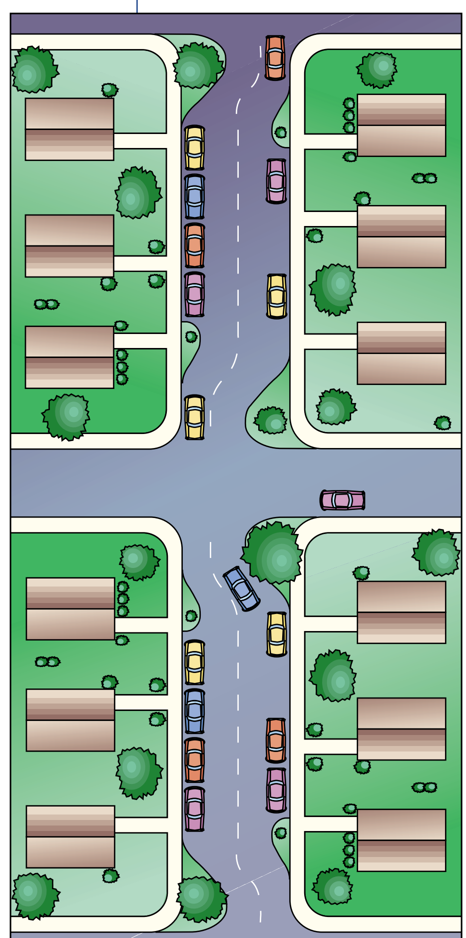

Exhibit 2-13. Chicanes.

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Exhibit 2-14.
Curb Extension (6).

Curb Extensions

Curb extensions (bulb-outs) can be designed in a variety of ways. However, curb extensions should be used only where they can be designed such that larger vehicles can turn without encroaching onto the curb and placing pedestrians in the path of the turning vehicles. Curb extensions can reduce the crossing width for pedestrians at both intersections and midblock crossings, and they can also provide the motorists better views of waiting pedestrians. Curb extensions are often used in conjunction with landscape treatments to enhance the street and buffer adjacent parking, and they are a good way to add sidewalk space for curb ramps. They also help to more clearly identify midblock crossing locations to both pedestrians and motorists; however, care should be taken not to restrict bicycle space or movement. In some cases, a curb extension or "choker" is used at intersections to create a one-way entry or exit point for that specific street segment. Autos are allowed to exit the street, but entrances occur at side streets. Pedestrians and bicyclists are allowed to travel in both directions. Exhibit 2-14 illustrates a typical curb extension at an intersection.

Exhibit 2-15.
Rubber Speed Hump (6).

Narrow Streets

Streets that are either physically narrowed or that create the perception that they are narrower are effective at calming traffic. Reduced street widths in residential and suburban areas are more commonly allowed by local jurisdictions. Narrow streets not only provide the benefit of traffic calming but also help to create a more attractive and pedestrian-friendly character along the street. In addition, narrow streets may also reduce construction and maintenance costs. Trees planted along the sides of a street provide a sense of spatial enclosure and may promote lower operating speeds. On-street parking, curb extensions, separated walkways with planting strips, and bike lanes (i.e., when installed on an existing street so that travel lanes are narrowed) can also make the street appear narrow (40).

Speed Humps (Not Speed Bumps)

Speed humps are raised areas in the roadway that do not function as crossing areas. Speed humps are typically located on local or neighborhood collector streets with volumes greater than 300 vehicles per day but less than 3,000 vehicles per day. Well-designed speed humps allow vehicles to proceed over the hump at the intended speed, usually 30 km/h [20 mph] with minimal discomfort, but driving over the hump at higher speeds may cause discomfort to the vehicle occupants. For low-speed collector roads, speed humps can be designed to accommodate speeds as high as 40 km/h [25 mph]. As a cautionary note, many people with spinal cord injuries, neck injuries, and diseases such as arthritis are raising concerns about the use of some vertical calming devices. Often people with these injuries are passengers and are not in control of the speed of the vehicle. Many designs have been developed for speed humps (6, 35, 40). Exhibit 2-15 illustrates a speed hump built using a rubber material. Inflatable speed humps have been used in the United Kingdom. Speed humps should be designed so that they do not impede low-floor vehicles.

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Speed humps are not speed bumps, which are smaller raised areas 0.3 to 0.9 m [1 to 3 ft] wide. Speed bumps are not suitable for public roads. Occasionally, speed humps are marked on the street as "Speed Bumps" by local jurisdictions in the belief that the term "bump" is more widely understood than "hump."

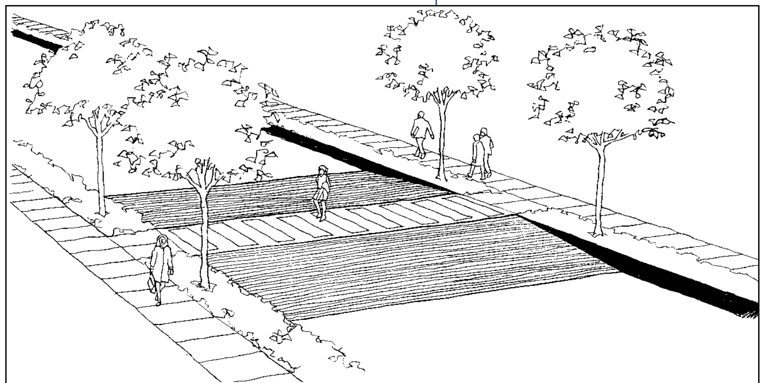

Exhibit 2-16. Raised Crosswalk (40).

Raised Crosswalks/Speed Tables

Raised crosswalks are wider than typical speed humps. Raised crosswalks or speed tables are appropriate at midblock locations on local streets, collector roads, and in other locations such as airport drop-off and pick-up zones, shopping centers, and campuses. Raised crosswalks can make sidewalks accessible without adding curb ramps. They are typically marked with highly visible materials and may have marked or textured approaches (see Raised Intersections). Raised crosswalks require detectable warning strips at the curb lines. Exhibit 2-16 illustrates a typical raised crosswalk (40).

Raised Intersections

Raised (or table top) intersections provide the advantage of slowing vehicles at one of the most critical locations for pedestrian crossing activity. Raised intersections are often paved with contrasting material (scored or colored concrete or unit pavers) to make the roadway stand out visually to approaching motorists. The use of special paving also helps to delineate the pedestrian crossing area. Raised intersections create an area clearly designated for pedestrians. Approaching motorists can see that the intersection is not a location designed for rapid, through movement, which causes them to slow down and yield the right-of-way to pedestrians. Raised intersections are typically installed within urban areas but are not appropriate for high-speed thoroughfares and major arterials. Raised intersections make it easier to meet the ADA requirements because the crosswalk is a natural extension of the sidewalk, with no change in grade; however, they require detectable warnings at the curb line to make them detectable to persons who are vision impaired. Placement of drainage inlets can be simplified at raised intersections where surface water can drain away from the center of the intersection.

2.7 Other Programs to Increase Pedestrian Safety

The physical infrastructure improvements recommended in this guide should be complemented with a combination of education and enforcement programs to further enhance pedestrian safety. This can include:

- *Education Programs*—Education programs targeted both toward motorists and pedestrians are an important part of a comprehensive pedestrian strategy. Education and public awareness programs for motorists should include improvements to driver education courses at schools, and driver education programs should emphasize appropriate driving behavior (using caution in pedestrian zones, anticipating pedestrian movements, etc.) as well as regulations that apply to pedestrian crossings.

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Education programs for motorists should also provide an understanding of the effect of motor vehicles on pedestrians (especially the impact of speeding). Motorists, particularly parents who drive their children to school, should also learn about the limitations of children as pedestrians.

Pedestrians of all ages should be reminded to practice safe behavior. Young pedestrians, in particular, need extra instruction on how to cross the street safely, on laws and regulations that apply to pedestrians, and on how to interact with motorists in the roadway environment. Several excellent pedestrian education curricula have been developed for school-age children.

- *Enforcement Programs*—Law enforcement departments can take a leading role in improving public awareness of existing traffic laws and ordinances for motorists (e.g., obeying speed limits, yielding to pedestrians when turning, traffic signal compliance, and obeying drunk-driving laws) and pedestrians (e.g., crossing the street at legal crossings and obeying pedestrian signals). Many local law enforcement agencies have instituted annual pedestrian awareness weeks when they issue tickets to motorists who disregard pedestrian laws and warn pedestrians to follow the laws as well.

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Chapter 3

Pedestrian Facility Design

3.1 Designing Roadways to Accommodate Pedestrians

Designing a roadway that successfully meets the needs of both vehicular traffic and pedestrians can be a challenging task. The attributes of good roadway design that should be considered in accommodating pedestrians include:

- *Circulation*—The roadway environment should serve the circulation needs of all users, including pedestrians, bicyclists, private vehicles, public transit, and emergency vehicles. Pedestrians should have frequent opportunities to cross streets at well-designed intersection and midblock crossings.
- *Balance*—All features of the roadway environment should work in concert, equitably balancing the needs of all users, including pedestrians.
- *Connectivity*—The roadway system should provide overall connectivity. Walking routes should be obvious and should not require pedestrians to travel out of their way. Every destination should be served by an accessible path of travel.
- *Safety*—Sidewalk users should not feel threatened by adjacent traffic. Measures such as limiting design speeds, providing traffic-calming devices, and selecting appropriate speed limits may be used to encourage lower travel speeds. Additionally, a buffer area separating the sidewalk from the roadway is desirable for safety.
- *Accessibility*—Sidewalks and crossings should be fully accessible to all users.
- *Traffic Engineering Elements*—Elements, such as crosswalk treatments, signal location, and signal timing, should account for pedestrians and other roadway users.
- *Landscaping*—Plantings and street trees in the sidewalk area should contribute to the overall psychological and visual comfort of sidewalk users.

The design of intersections to accommodate pedestrians is addressed later in this chapter.

This section complements the AASHTO *Policy on Geometric Design of Highways and Streets* (3), commonly known as the Green Book, and is intended to explain, in greater detail than the AASHTO guide, how basic roadway design parameters can affect the ability of that roadway to accommodate pedestrians.

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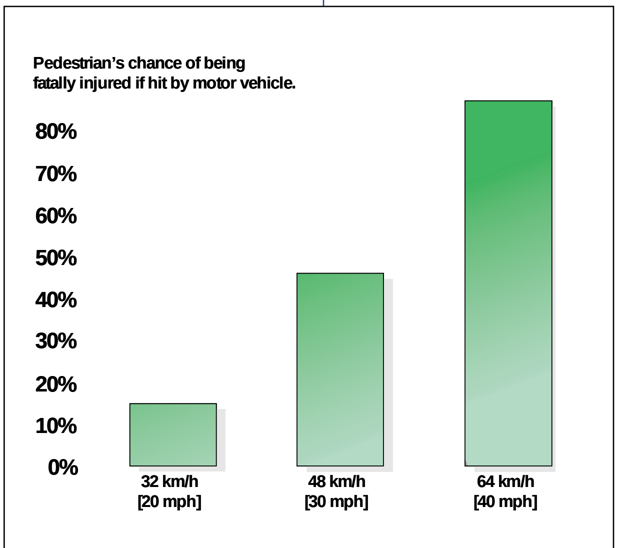

Exhibit 3-1. Probability of Pedestrian Fatality Based on Speed of Vehicle (29).

3.1.1 Speed Management

Selection of an appropriate design speed is one of the most important steps in roadway design. Studies have indicated that in a vehicle-pedestrian crash, the faster a motorist is traveling, the higher the risk that injuries to a pedestrian will result in death (see Exhibit 3-1). Reduced speeds provide more opportunity for pedestrians and motorists to see and react to one another in a timely manner. The AASHTO Green Book (3) presents the factors considered in selecting an appropriate design speed for a particular roadway.

The selected design speed should be appropriate for the specific street being designed, including consideration of the anticipated vehicle operating speeds and the anticipated level of pedestrian activity within an area. In most cases, urban arterial streets with developed frontage should be designed, and traffic control devices employed, to encourage running speeds no greater than 50 to 75 km/h [30 to 45 mph]. When arterial street improvements are being planned, the selection of a design speed should consider factors such as physical and economic constraints and the anticipated vehicle running speeds during off-peak periods. Local residential streets should be designed to encourage vehicle speeds that do not exceed 30 to 40 km/h [20 to 25 mph]. Consistent design speeds are important for maintaining smooth traffic flow; thus, any change in design speed should be accomplished over a sufficient distance to permit drivers to change speed before reaching areas where increased pedestrian activity can be expected (3).

The design speed of a roadway should be a logical one with respect to topography, adjacent land uses, the level of pedestrian activity, and the functional classification of the roadway. Motorists will tend to drive at the speeds they feel comfortable, and these speeds will often be a reflection of the engineered design speed, regardless of the posted speed limit. Where there is no legislatively-mandated speed limit, the posted speed limit for arterial streets should be determined by an engineering study, considering the 85th percentile speed of vehicular traffic and other factors, using the methods presented in the Institute of Transportation Engineers' *Traffic Engineering Handbook* (19). Lowering the posted speed limit below the 85th percentile speed of vehicular traffic will only increase the number of speed limit violations, with little or no effect on the actual prevailing speeds of traffic. Some authorities try to reduce prevailing traffic speeds with consistent enforcement of the posted speed limits, but absent constant 24-hour enforcement, such efforts usually have only a temporary effect. In addition, such enforcement may actually increase the variance of speeds and, thus, create more conflicts between vehicles. If the anticipated 85th percentile speed of vehicular traffic is inconsistent with the anticipated level of pedestrian activity or other factors in the roadway environment, then an effective method to reduce prevailing speeds may be to reduce the roadway design speed and modify the roadway geometrics accordingly. This may be accomplished with reduced lane widths, signal progression to match the desired vehicle running speed, and traffic-calming techniques. The geometric design and traffic-control devices should be consistent with lower speeds. Research is currently underway in National Cooperative Highway Research Program (NCHRP) Project 3-72, *Lane Widths, Channelized Right Turns, and Right-Turn Deceleration Lanes in Urban and Suburban Areas*, to help determine appropriate uses of narrower lane widths on urban and suburban arterials.

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3.1.2 Roadway Widths

The number of lanes on a roadway is selected primarily to serve the demands of vehicular traffic at a desired level of service. However, designers should also consider the effects of roadway width on pedestrians. The wider the roadway, the more difficult it is for pedestrians to cross, and the greater the barrier effect the roadway may represent for the communities through which it passes. In most cases, undivided six-lane arterials, with or without parking, are not pedestrian-friendly, while eight- and ten-lane arterials create an even more formidable barrier to pedestrians.

Using lane reductions is one method of reducing the total number of lanes on a commercial street that may be considered where roadway level of service requirements permits. For example, some four-lane undivided roads may be re-striped as three-lane roads, with one lane for through traffic in each direction of travel and a center left-turn lane. This may also provide space for the addition of sidewalks and/or bicycle lanes on both sides of the road. More detailed information on road narrowing techniques is presented in Section 3.3.2 on crossing distance considerations. Another alternative to wide streets is the use of two or more parallel streets, either as two-way streets or as one-way couplets, instead of funneling all traffic onto one community-splitting arterial.

Other effective techniques of reducing pedestrian crossing distances include using narrower lanes and introducing raised medians, both as pedestrian refuges and to provide space for aesthetic plantings. The selection of lane widths for roadways in developed areas involves reaching a balance among the competing needs of motor vehicles, bicycles, and pedestrians. The considerations in reaching such a balance include safety, traffic operational efficiency, and mobility. Site-specific considerations strongly influence this balance, so the choice of lane width should address site-specific conditions. Wider lanes are desirable to effectively accommodate larger vehicles, such as trucks and buses, and to increase the level of service for vehicular traffic. Narrower lanes make shorter crossings for pedestrians, may provide space to accommodate bicycle lanes, and may reduce waiting times for motorists during pedestrian signal phases. The AASHTO Green Book (3) generally permits lane widths on urban streets in the range from 3.0 to 3.6 m [10 to 12 ft], chosen based on consideration of the factors discussed above. On multilane arterials, the use of wider curb lanes and narrower median lanes may constitute the most efficient use of available roadway width. On rural roadways, pedestrians are not generally a major consideration in the selection of lane width. For further information on the selection of appropriate lane widths, see the AASHTO Green Book (3).

3.1.3 Curbs

The use of curbs along a roadway can improve the comfort, safety, and usability of adjacent pedestrian facilities. The presence of a curb clearly defines and distinguishes between the areas intended for motor vehicle operation and the areas intended for pedestrian usage. Two general types of curb designs are used: vertical curbs and sloping curbs. Vertical curbs are intended to discourage drivers from leaving the roadway. Sloping curbs are designed so that drivers may traverse them easily when the need arises (3).

Vertical curbs are generally preferred to sloping curbs where sidewalks or other pedestrian facilities are immediately adjacent to the roadway or separated by a narrow planted buffer strip, because drivers are more reluctant to cross a vertical curb than a sloping curb.

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Exhibit 3-2.
Vehicles Parked Over Sloping Curb.
Photo courtesy of John LaPlante.

Exhibit 3-2 illustrates how drivers may drive over a sloping curb onto the adjacent sidewalk. Parking on the sidewalk blocks the pedestrian route and involves potential risk for pedestrians. However, vertical curbs are not recommended along roadways with design speeds over 70 km/h [45 mph].

Further guidance on the use, placement, and design details of shoulders and curbs is presented in the AASHTO Green Book (3).

3.1.4 Sight Distance and Sight Lines

Sight distance is a principal design element in roadway design and can refer to several different calculations: stopping sight distance, decision sight distance, and passing sight distance. However, the designer must also keep in mind that, as important as it is for the motorist to see everything on or adjacent to the roadway, it is of equal importance for the pedestrian, particularly children and wheelchair users, to be able to view and react to potential conflicts (18).

Adequate sight distance and clear sight lines are key considerations at crosswalk locations. Features such as landscaping, parked cars, utility poles, traffic control devices, and street furniture can create sight obstructions to the pedestrian. When these features cannot be relocated, curb extensions or parking restrictions are desirable so that pedestrian paths or sight lines are not blocked. Also, because amenities that may also be sight obstructions are often provided after an intersection has been constructed or reconstructed, sight distance and sight line issues need to be addressed both during the initial design phase as well as throughout the operational life of the intersection.

The AASHTO Green Book (3) recommends that roads should intersect at an angle as close to 90 degrees as practical and should not intersect at an angle less than 60 degrees. A 90-degree intersection angle represents the most desirable design for both pedestrian and vehicular traffic. With a 90-degree intersection angle, sight lines are optimal, conflict space limited, and crossing distances (and hence exposure times) are reduced. The profile of intersection approaches is another complicating factor. The sight lines and sight distance of traffic approaching an intersection on a significant upgrade are compromised, which limits the opportunities for both the pedestrian and the motorist to assess the situation (18).

Vehicles parked near crosswalks can create sight line restrictions, since the ability of the motorist and pedestrian to see each other may be limited by the presence of the parked vehicles. On urban streets with 30 to 50 km/h [20 to 30 mph] speed limits, a minimum no-parking zone of 6 m [20 ft] from the crosswalk on both the near and far side of the intersection is recommended on all intersection legs. A no-parking zone of 9 m [30 ft] in advance of each signal, stop sign, and yield sign should also be provided. Where practical, longer no-parking zones on intersection approaches are desirable. For example, where the posted speed limit is in the range from 55 to 70 km/h [35 to 45 mph], it is desirable to provide a no-parking zone 15 m [50 ft] from crosswalks on each intersection approach. In areas where the speed limit exceeds 70 km/h [45 mph], on-street parking should be prohibited.

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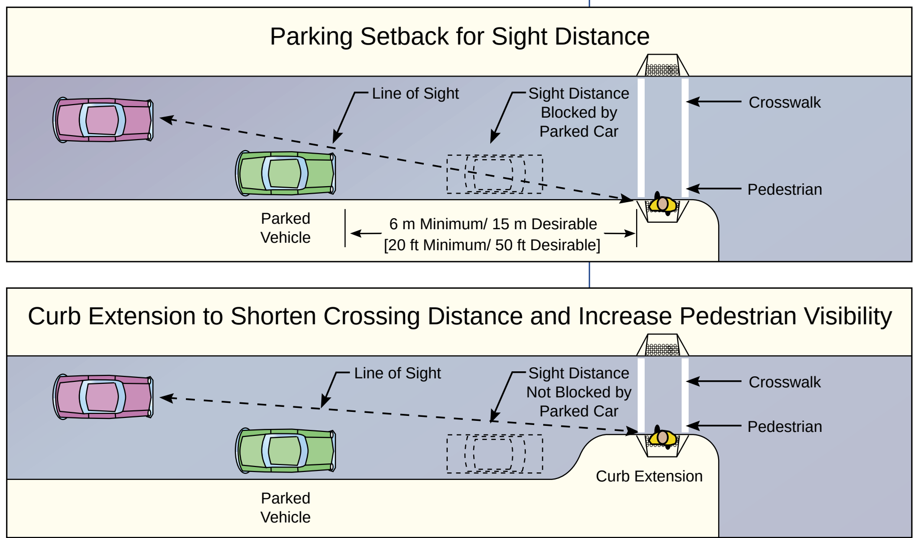

Exhibit 3-3. Recommended Parking Setback and/or Curb Extension Installation (18).

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The position of a waiting pedestrian in relation to parked cars is important for pedestrian visibility. For example, if a vehicle is parked 6 m [20 ft] away from the crosswalk, an adult standing on the curb can only see or be seen 18 m [60 ft] without looking over or through a vehicle. Children and people in wheelchairs cannot see or be seen over a parked car, and if the parked vehicle is a van or sport-utility vehicle, no pedestrians can see or be seen. For this reason, the use of curb extensions, as illustrated in Exhibit 3-3, is desirable. Without curb extensions, pedestrians may need to step into the parking lane to see around parked vehicles in order to make a safe crossing. However, the use of curb extensions may not be practical at all locations where parking is permitted. The use of curb extensions is discussed further in Section 3.3 on Intersection Design.

3.1.5 Lighting Overview

Low-light conditions can reduce the conspicuity of pedestrians. Two-thirds of pedestrian fatalities occurred during low-light conditions (dusk, dawn, or dark). Among pedestrians 21 to 44 years old, 81 percent of fatalities occur in low-light conditions (10).

Along wide arterials where continuous lighting is provided, streetlights are desirable on both sides of the roadway. In most cases, street lighting along the roadway can be designed to illuminate the sidewalk area as well. Lighting should be adequately spaced to provide a uniform level of light. The visibility needs of both the pedestrian and motorist should be considered.

In urbanized areas, lighting is desirable at intersections and other potential pedestrian crossing areas. This is particularly important where a higher volume of pedestrians is expected (e.g., near schools, community centers, and places of worship). The selection of luminaire locations is important to lighting effectiveness. An offset location of the luminaries may provide for better visibility or contrast.

In shopping districts or downtown areas with high pedestrian volumes, pedestrian-scale lighting should be considered in addition to streetlights to improve pedestrian comfort and security. Pedestrian-scale lighting may also be installed in selected areas of activity to create a sense of intimacy and place (14).

Pedestrian-scale lighting is particularly useful to pedestrians with vision impairments. Pedestrian-scale lighting may use high-pressure sodium vapor, mercury vapor, metal halide, or incandescent lighting.

For further information and guidance on roadway lighting levels, refer to the *Informational Guide for Roadway Lighting* by AASHTO (1).

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3.2 Sidewalk Design

All roadways along which pedestrians are not prohibited should include an area where occasional pedestrians can safely walk, whether on unpaved walkways, on shoulders in rural or less developed areas, or on sidewalks in more urban areas. On an access route that is intended for pedestrian use, a walkway that meets the applicable ADA requirements must be provided (8). Newly constructed or improved pedestrian walkways must meet ADA requirements.

Just as vehicles need roads, pedestrians need walkways, and roadways and walkways should be designed in concert with one another. Sidewalks benefit both pedestrians and motorists by creating separation between pedestrian and vehicular travel paths. In an area where sidewalks are not provided, there is a substantially increased risk of vehicle–pedestrian conflicts. A 1996 study that analyzed vehicle–pedestrian collisions and exposure under various roadway situations found that locations with no sidewalks are more than two times more likely to have vehicle–pedestrian crashes than sites with sidewalks (21).

When continuous sidewalks, walkways, crossings, and other pedestrian-related facilities are provided in an area, pedestrian numbers will increase (28). Even in areas where there may not be an initial demand for pedestrian facilities, walking can almost always be expected to increase when adequate facilities are provided.

People with disabilities make up nearly one-fifth of the U.S. population, so it is important that sidewalks meet their needs. Additionally, many Americans are aging into sensory or cognitive disabilities. Older people, children, and people who are blind or have low vision are disproportionately represented among pedestrians and in pedestrian crash data. It is important that sidewalks be usable by pedestrians for whom they may represent the only mode of independent travel.

Providing adequate and accessible facilities should lead to increased numbers of people walking, improved safety, and the creation of social space. Attributes of well-designed sidewalks, include the following:

- *Accessibility*—A network of sidewalks should be accessible to all users and meet ADA requirements.
- *Adequate Width*—Two people should be able to walk side-by-side and pass a third person comfortably and different walking speeds should be possible. In areas of intense pedestrian use, sidewalks should be wider to accommodate the greater volume of walkers.
- *Safety*—Design features of the sidewalk should allow pedestrians to have a sense of security and predictability. Sidewalk users should not feel they are at risk due to the presence of adjacent traffic.
- *Continuity*—Walking routes should be obvious and should not require pedestrians to travel out of their way unnecessarily.
- *Landscaping*—Plantings and street trees within the roadside area should contribute to the overall psychological and visual comfort of sidewalk users, without providing hiding places for attackers.

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- *Social Space*—Sidewalks should be more than areas to travel, they should provide places for people to interact. There should be places for standing, visiting, and sitting. The sidewalk area should be a place where adults and children can safely participate in public life.

- *Quality of Place*—Sidewalks should contribute to the character of neighborhoods and business districts and strengthen their identity.

3.2.1 Types of Pedestrian Facilities

There are several ways in which pedestrians can be accommodated in the public right-of-way:

- *Sidewalks*—Sidewalks, provided on both sides of a street, are the preferred pedestrian facility. Where one side of the street is undeveloped, sidewalks may be provided only on the developed side of the street. Sidewalks provide the greatest degree of comfort and safety for pedestrians. *The Uniform Vehicle Code* (23) defines a sidewalk as that portion of a street between the curb lines, or the lateral lines of a roadway, and the adjacent property lines, intended for use by pedestrians. Sidewalks may also, in some cases, be built on easements. Sidewalks usually have a hard surface, but can also be constructed of compacted aggregate. To comply with ADA guidelines, newly constructed, reconstructed, or altered sidewalks must be accessible to persons with disabilities.

- *Off-Road Paths*—An off-road path, paved or unpaved, can be an appropriate facility in rural or low-density suburban areas. Paths are generally set back from the road and separated by a green area, ditch, swale, or trees. Paths can be flexible in that they can deviate from the exact route of a road in order to provide more direct access for key destinations. Paths that generally follow the roadway alignment are sometimes known as "side paths."

- *Shared-Use Paths*—Where off-road paths are developed for use by both pedestrians and bicyclists, they are referred to as shared-use paths. The design of shared-use paths is addressed in the AASHTO *Guide for the Development of Bicycle Facilities* (2). Design guidance for shared-use paths is also provided by trail design criteria in the U.S. Access Board draft *Guidelines for Outdoor Developed Areas* (6).

- *Shared Streets*—In some circumstances, it may be possible to allow shared use of a street for people walking and driving. These are usually specially designed spaces, such as pedestrian streets or "woonerfs," which are used on local urban streets with extremely low vehicle speeds. Guidelines for developing these kinds of facilities can be found elsewhere (e.g., *Pedestrian Facilities User Guide* (29)).

Most highway shoulders are not pedestrian facilities, because they are not intended for use by pedestrians, although they can accommodate occasional pedestrian usage. Policies concerning shoulder cross slope and width for specific highway functional classes (local, collector, and arterial roads) are presented in the AASHTO Green Book (3). Where a shoulder serves as part of a pedestrian access route, it must meet ADA requirements for pedestrian walkways to the maximum extent possible.

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3.2.2 Sidewalk Installation

Sidewalks are constructed under four conditions: (1) new construction in areas with existing or anticipated pedestrian use, (2) new construction with no initial pedestrian presence, (3) reconstruction of existing sidewalks that do not presently accommodate the needs of all users, and (4) addition of sidewalks in reconstruction projects in areas of increasing pedestrian activity and where pedestrian needs are not being met.

Although the specific details of sidewalk installation can vary from urban to suburban to rural areas, all new and reconstructed sidewalks must be accessible to and usable by persons with disabilities.

The guidelines presented below for rural roadways, local urban and suburban streets, and urban collectors and arterials provide the best advice on when and where to install sidewalks. A useful rule-of-thumb for existing roadways is that sidewalk installation should be considered when the roadway drainage is changed from shoulders and open ditches to a curb-and-gutter section with drainage grates and sewers. This usually occurs when the level of roadside development increases to the point where open drainage ditches are no longer considered appropriate, except in those areas where natural drainage is retained for ecological and/or aesthetic reasons. The needs and desires of local communities should be considered in deciding where sidewalks should be provided.

Where provided, sidewalks should be built within the public right-of-way or in a sidewalk easement along the right-of-way. This will provide access to the sidewalk for maintenance activities.

Rural Roadways

Pedestrian activity along rural roadways can reasonably be expected to be fairly low. While sidewalks are not specifically recommended for rural roadways, sidewalks may be desirable (or necessary for accessibility) to serve schools, shops, and transit stops. Where it is impractical to provide a sidewalk or walkway along a paved rural road, a paved or unpaved shoulder can accommodate occasional pedestrian usage. Policies concerning shoulder width and cross slope for rural roadways in various functional classes are presented in the AASHTO Green Book (3).

Where a shoulder serves as part of a pedestrian access route, it must meet ADA requirements to the maximum extent feasible. There are many locations where it may not be technically feasible to provide a shoulder with the cross slope of two percent or less that is required for pedestrian access routes. On superelevated sections (i.e., at horizontal curves), shoulder slopes greater than two percent are normally required. Shoulder cross slopes steeper than two percent are also needed where the traveled way cross slope exceeds two percent, which is typical of roads in areas of intense rainfall and roads with three or more lanes in one direction.

Sufficient space must be provided at bus stops on rural roads to accommodate people waiting at the roadside for the bus.

There is a desire in some residential developments to retain a "rural" atmosphere. Often this occurs in places that are not truly rural but rather suburban or exurban, though they

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may have been rural before being developed. To address both the goal of having safe places to walk and the community goal to retain a certain atmosphere, path systems can be developed that do not look like traditional sidewalks but do meet walking needs (4).

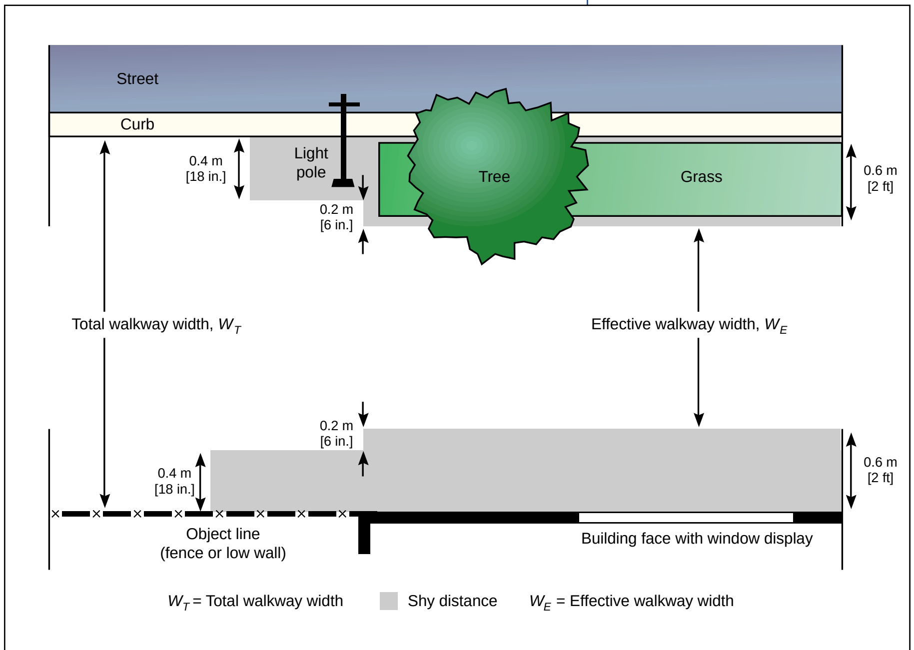

Exhibit 3-4. Effective Walkway Width (27).

Local Urban and Suburban Streets

A local urban or suburban street generally serves individual residences and distributes traffic within that localized urban or suburban area. These types of streets can receive a moderate level of pedestrian activity. However, because of the differing characteristics of urban and suburban local streets, the recommended practices can vary.

In outlying suburban areas, even those with no developed pedestrian facilities, people may walk for exercise, go to a friend's house, or access transit. Development of such areas should make appropriate provision for people to walk.

Urban Collectors and Arterials

Collectors and arterials are typically the streets that serve the largest number of vehicles and pedestrians, as well as being the primary location for businesses and other attractions. They typically require the greatest amount of available walking area. Sidewalks should be provided on each side of the street along collectors and arterials wherever the frontage is developed.

Even though collectors and arterials that serve industrial areas may have low pedestrian volumes, it is recommended that sidewalks be provided on at least one side of the street. However, to facilitate overall connectivity and safety, consideration should be given to providing sidewalks on each side of the street wherever the frontage is developed.

Sidewalks on Only One Side of the Street

Sidewalks should connect to street systems and destinations in a safe and convenient manner. Where sidewalks are provided on only one side of a roadway, the overall connectivity of the sidewalk is weakened, as well as pedestrian safety and accessibility. Sidewalks provided on only one side of the street often require pedestrians to cross streets unnecessarily to meet their travel needs. As a result, the level of exposure of pedestrians to potential conflicts is increased. Therefore, sidewalks on only one side of the street are not generally recommended. However, a sidewalk on one side of the street may be appropriate where only that side of the street is developed. A sidewalk on one side of the street may also be

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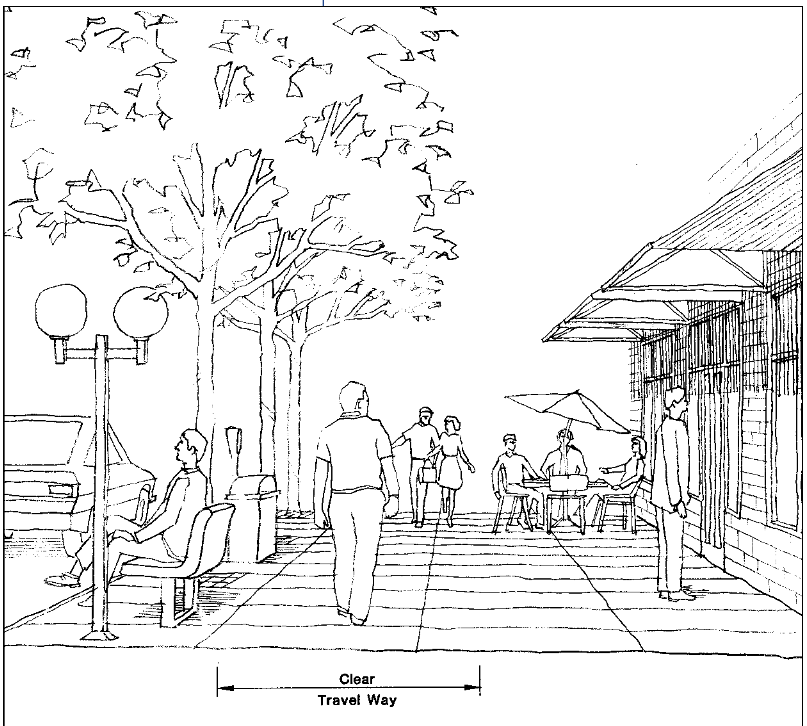

Exhibit 3-5.
Pedestrian Travel Way Clear of Obstructions (29).

adequate for some local streets on an interim basis, especially when this improves a condition where there were no sidewalks previously (28).

3.2.3 Sidewalk Widths

The minimum clear width for a sidewalk is 1.2 m [4 ft], not including any attached curb, and all sidewalks must be constructed with at least this clear width. Where sidewalks are less than 1.5 m [5 ft] in width, passing spaces at least 1.5 m [5 ft] in width should be provided at reasonable intervals. This width is needed for wheelchair users to pass one another or to turn around.

There are many locations where clear sidewalk widths greater than the minimum are desirable. Along arterials not in the central business district (CBD), sidewalk widths of 1.8 to 2.4 m [6 to 8 ft] are desirable where a planting strip is provided between the sidewalk and the curb, and sidewalk widths of 2.4 to 3.0 m [8 to 10 ft] are desirable where the sidewalk is flush against the curb. In CBD areas, the desirable sidewalk width is 3.0 m [10 ft] or sufficiently wide to provide the desired level of service (see discussion below). These widths represent a clear or unobstructed pedestrian travel way. Point narrowings in the desired widths may be acceptable in isolated instances as long as there is at least 1.2 m [4 ft] for accessible passage. However, where practical, street lights, utility poles, sign posts, fire hydrants, mailboxes, parking meters, bus benches, and other street furniture should be located so they do not obstruct the desirable sidewalk width (4).

Chapter 18 of the Institute of Transportation Engineers' *Highway Capacity Manual* (HCM) (27) provides procedures to assess the sidewalk width needed to accommodate particular volumes at a desired level of service. Exhibit 3-4 illustrates the method used by the HCM to define effective walkway width, deducting shy distances from building faces, fences, walls, and other lateral obstructions.

The principal performance measure for sidewalks and walkways is space. Two criteria that are used to determine sidewalk level of service (LOS) are available area per person and flow rate. These performance measures are designated by six levels of service from A to F. LOS A represents an almost empty sidewalk, LOS C to D usually provide maximum pedestrian flow conditions, while LOS F is total breakdown.

In areas where high pedestrian volumes are expected, it may be appropriate to provide sidewalks with widths of 3.0 to 4.5 m [10 to 15 ft] or more to accommodate pedestrian flows. Conversely, when excessively wide sidewalks are located in areas where there are low pedestrian volumes, the expansive pavement and empty-looking sidewalks may seem uninviting to pedestrians (28).

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Exhibit 3-5 illustrates a variety of potential obstructions and how the sidewalk can be designed with adequate clearance. For example, when the sidewalk abuts storefronts, it is desirable to provide about 0.6 m [2 ft] of additional width to accommodate shy distance from walls, shoppers stopping to look into windows, and to avoid conflicts with doors opening and pedestrians entering and leaving the adjacent buildings (14). The provision of shy distance along building fronts is illustrated in Exhibit 3-6. Similar width accommodations may be needed adjacent to sidewalk vendors and newsstands. The use of any sidewalk width for cafes, newsstands, or other vendors should be regulated under an encroachment permit process that considers accessibility and pedestrian level of service.

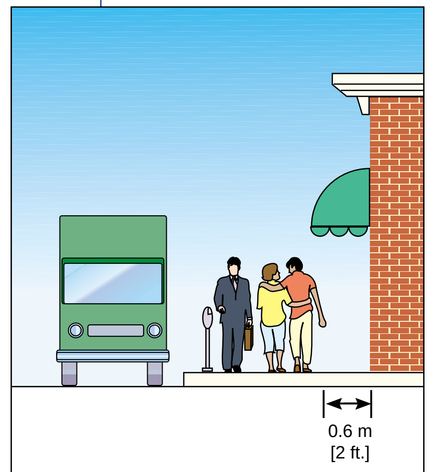

Exhibit 3-6.
Shy Distance Between Building and Walkway (29).

3.2.4 Buffer Widths

Providing a buffer can improve pedestrian safety and enhance the overall walking experience. Buffer width is the distance between the sidewalk and the adjacent roadway. The buffer width in a commercial area will be different from the buffer needs of a residential area. Landscaped buffers can serve to provide a snow storage area and splash protection for pedestrians, and space for curb ramps, street light poles, trash pick up, and traffic signs. Additionally, buffer area plantings and benches can aid in creating an inviting social setting for the pedestrian.

On-street parking or bike lanes can also act as a sidewalk buffer. In areas where there is no on-street parking or bike lane, the ideal width of a planting strip is 1.8 m [6 ft]. Desirable landscape buffer widths as measured from the edge of the traveled way are:

- Local or collector streets—0.6 to 1.2 m [2 to 4 ft]
- Arterial or major streets—1.5 to 1.8 m [5 to 6 ft]

If a planting strip is not provided, then the desirable total width for a curb-attached sidewalk in residential areas should be at least 1.8 m [6 ft]. In commercial areas or along busy arterial streets, the desirable total curb-attached sidewalk width should be 2.4 m [8 ft] to provide space for light poles and other street furniture, as well as protection from splashing, car door openings, and snow storage in northern climates (4).

Where there is a landscaped buffer area at a bus stop between the sidewalk and street, accessible paved loading/waiting pads and connections to the sidewalk for both front and rear doors of a bus should be provided. Accessibility requirements for bus stops are presented in ADAAG Section 10 (12).

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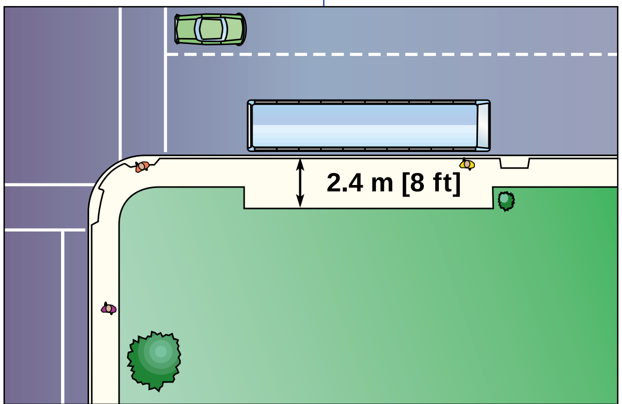

Exhibit 3-7. Sidewalk Dimensions at Bus Stops (11).

3.2.5 Transit Connections

Transit stops and bus pullouts provide a designated space for loading and unloading passengers. A zone accommodating one bus is normally from 24 to 48 m [80 to 160 ft] in length. Bus stops can be as simple as a sign and a designated space at the curb, a pullout area, or a shoulder for the bus to stop. Bus stops may also include other facilities, such as shelters, benches, and other furnishings. To discourage midblock crossings by pedestrians, bus stops at or near intersections are generally preferred to midblock bus stops.

A newly constructed transit stop must be accessible to all users; thus, a 2.4-m [8-ft] by 1.5-m [5-ft] landing pad must be provided as required by ADAAG 10.2.1 (12). It is also desirable to provide a continuous 2.4-m [8-ft] pad or sidewalk the length of the bus stop, or at least to the front and rear bus doors (see Exhibit 3-7). At stops in areas without curbs, a 2.4-m [8-ft] shoulder should be provided as a landing pad. Care should be taken to ensure that utility poles, fire hydrants, and other street furniture do not impede access to the bus stop and loading areas (17).

Curb ramps at bus stops will allow waiting passengers to board a lift from the street in those instances where the bus cannot pull up to deploy the lift directly to the sidewalk due to illegally parked cars or other obstructions. At transit stops, sidewalks should be constructed to the nearest intersection or to the nearest section of existing sidewalk. Even if a transit route does not have complete sidewalks, it is still important to provide a suitable waiting area for pedestrians (24).

Bus shelters should be provided where practical to provide visible, comfortable seating and waiting areas for passengers. Bus shelters must have a minimum clear floor area of 0.8 m by 1.2 m [2.5 ft by 4 ft], entirely within the perimeter of the shelter, connected by a pedestrian access route to the boarding area.

3.2.6 Driveway Access Management

Uncontrolled access across a sidewalk not only degrades the quality of the pedestrian environment, but also increases the potential for vehicle-pedestrian conflicts. Unsignalized intersections, alleys, and driveways can present an uncomfortable environment to the pedestrian, and the number of access points available for motor vehicles should be kept to a minimum while still providing needed access to adjacent property.

Driveway Types

Commercial driveways generally have higher volumes than other driveway types and, therefore, have the greatest potential for vehicle-pedestrian conflicts. Not only is the design of the driveway ramp important to accessibility for pedestrians with disabilities, but the number of commercial driveways and their proximity to one another will have a direct effect on the quality of the overall pedestrian environment.

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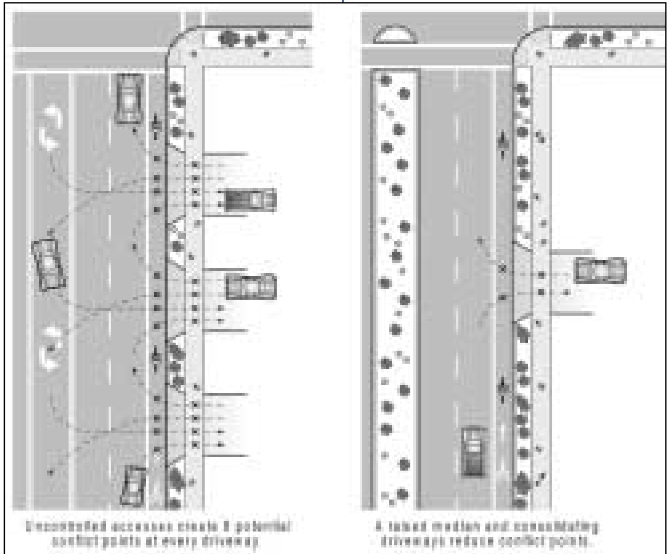
Limiting and consolidating vehicle access points benefit pedestrians in several ways. One important improvement is the reduction in the number of conflict points created by consolidated driveway access areas. Exhibit 3-8 illustrates this principle. Access management can also assist by redirecting motor vehicles to intersections with appropriate control devices. The benefits of access management are discussed further in the AASHTO Green Book (3).

Residential driveways to individual homes pose less conflict potential to pedestrians than commercial driveways because of their much lower usage rates. However, care should be taken to ensure that there is enough space outside the public right-of-way to discourage sidewalk blockage by parked vehicles. Multiple-unit apartment and condominium buildings can have traffic volumes approaching those of commercial driveways.



Note: Vehicle conflict points in diagram include both pedestrians and bicyclists.

Exhibit 3-8. Uncontrolled Access vs. Controlled Access. (24).

Driveway Design

Where a driveway crosses a sidewalk, the driveway must conform in width, cross slope, and grade to the design requirements for sidewalks in order to maintain accessibility for pedestrians with disabilities. Unramped curb returns are not permitted. Wheelchairs, strollers, and those who use walkers need a relatively flat surface to travel. Side flares and cross slopes at driveway aprons may cause a drive wheel, caster, or leg tip to lose contact with the surface (see Exhibit 3-9.) Cross slopes in new construction, reconstruction, or alterations must not exceed 1V:48H (two percent) per ADA requirements.

There are four basic driveway designs that meet accessibility requirements. Each design maintains a level, or nearly level, surface by either maintaining a minimum 1.2-m [4-ft] wide continuous path, or by providing a 1.2-m [4-ft] area adjacent to the main walk, without exceeding a two percent cross slope. Exhibit 3-10 illustrates four acceptable alternatives (Options A through D) and, for contrast, a design that is **not** acceptable for new construction or alterations.

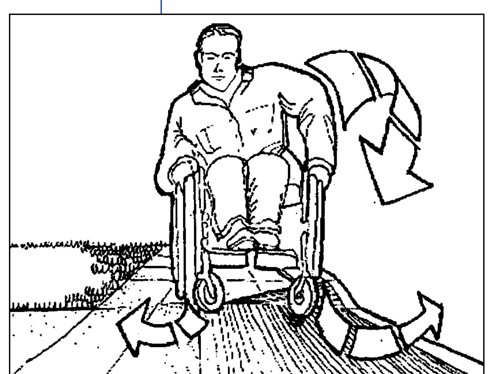


Exhibit 3-9. Effect of Warped Surface on Wheelchairs (24).

- Option A illustrates how planting buffer strips can greatly improve the safety of driveway access areas for both the pedestrian and motorist. Wide planting strips allow more turning area for entering and exiting vehicles. Placing the driveway slope in the planting strip provides a continuous level walkway.
- Option B incorporates a sidewalk at the driveway that is narrower than the sidewalk on either side of the driveway, but still maintains the minimum clear sidewalk width of 1.2 m [4 ft].
- In areas where the distance from the edge of the sidewalk to the face of curb is insufficient to provide a cross slope of two percent, Option C should be considered; this option incorporates appropriately designed curb ramps from the sidewalk to the driveway and back.

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- Purchasing or obtaining an easement from the adjacent property to provide a level sidewalk area next to the driveway may be appropriate, as shown in Option D, although this design may not be practical at some sites because of physical constraints.

In reconstruction work at some locations, the driveway slope may need to be increased to maintain a 1.2-m [4-ft] clear sidewalk width. However, the policies of state and local agencies concerning driveway slope should be consulted.

Where a parking garage exit crosses a sidewalk, exiting drivers should be reminded that they need to yield to pedestrians. This can be accomplished with Stop or Yield signs and can be supplemented with mirrors, electronic animated eyes, displays, audible signals, and/or flashing lights. Such signs and signals should be directed to the drivers, not the pedestrians. Using audible or visible signals to require pedestrians to yield to vehicles at driveways is confusing and inappropriate. Sufficient sight distance for drivers to see pedestrians at such locations is needed.

Driveways for large traffic generators are often designed as intersections with curb returns, curb ramps, and marked crosswalks. Unless such high-volume, private-access driveways are signalized, the standard driveway treatments described above are preferred to clearly indicate the pedestrian right-of-way.

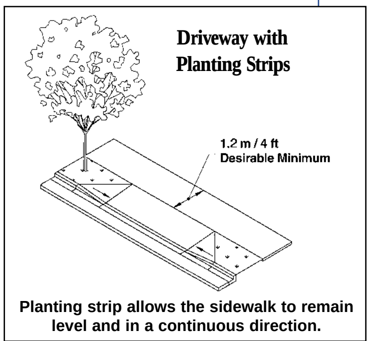
When an intersection-type design is used at a driveway, the design guidelines in the next section on Intersections Design should be applied.

3.2.7 Grade and Cross Slope

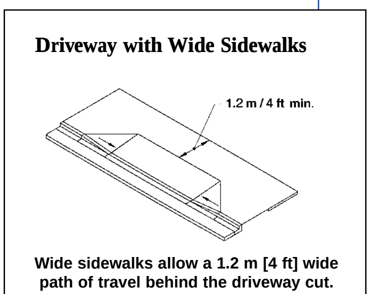
Steep sidewalk grades create problems for all pedestrians, especially under adverse weather conditions. Extremes of terrain exact a cost in energy or battery reserves for pedestrians with mobility impairments. Sidewalks and other walkways that incorporate pedestrian access routes must be designed with maximum grades of five percent (1V:20H); where a sidewalk runs along a roadway with a grade that exceeds five percent, the sidewalk grade may exceed five percent but must be less than or equal to the roadway grade. Maximum grades and cross slopes applicable to specific design situations are indicated in Exhibit 3-11.

Where steep sidewalk grades are present, they will be avoided by pedestrians with mobility impairments if alternative routings are available and known. A few cities have developed and publicized routings that use existing building elevators.

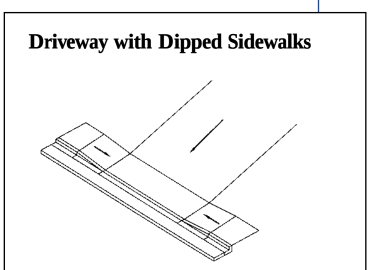
The cross slope of a sidewalk is the slope that is measured perpendicular to the direction of travel. Cross slopes are needed for drainage. However, sidewalks must be constructed with a maximum cross slope of two percent (1V:48H) to ensure a relatively level area for travel and maneuverability for walkers and wheelchair users. This is particularly desirable in cases of steep grades. At corners, sidewalks should have slopes of two percent or less in both perpendicular travel directions.



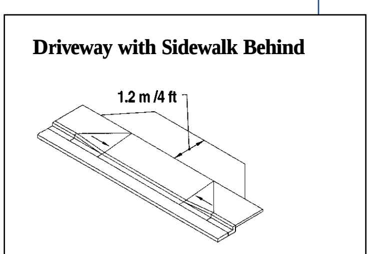
Option: A (Best)



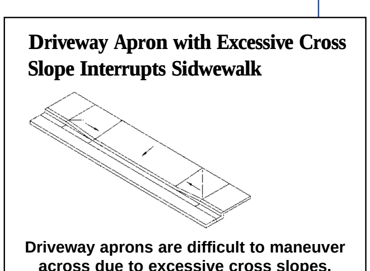
Option: B (Acceptable)



Option: C (Where necessary)



Option: D (Where necessary)



Not Acceptable in New Construction/Reconstruction/ Alteration

Figure 3-10.
Sidewalk Design Options at Driveway Crossing (29).

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3.2.8 Stairs

Stairs should be avoided along a sidewalk route. When unavoidable, the steps or stairs must follow current ADAAG (12) requirements. The construction of stairs may also be regulated in greater detail by local building codes.

While it is not the responsibility of public agencies to design building entryways, aligning the level of an adjoining sidewalk with an entry when the sidewalk is constructed, repaved, or repaired, can dramatically improve accessibility and eliminate potential tripping problems (14). Title II of the ADA requires state and local agencies to consider changes to their practices, procedures, and policies if doing so would provide needed accessibility.

Adjacent to Public ROW	
Maximum Sidewalk Grade Adjacent to Roadway	No limit if it follows the grade of the street
Maximum Cross Slope	2% (1V:48H)
Not Adjacent to Public ROW	
Maximum Grade Without Railings	5% (1V:20H)
Maximum Ramp Grade with Handrails and Landings	8.3% (1V:12H)

Exhibit 3-11. Sidewalk Grade Criteria.

3.2.9 Sidewalks for Highway Bridges, Underpasses, and Tunnels

Provisions should always be made to include some type of walking facility as a part of vehicular bridges, underpasses, and tunnels, if the facility is intended to be part of a pedestrian access route. Sidewalks along bridges and underpasses are more difficult to design than sidewalks along streets because overall space is at a premium and the edges of the sidewalk are limited by the roadway and a wall or railing. Where practical, pedestrians should not be forced to walk uncomfortably close to a wall, and a protective barrier may be desirable at the curb (see Exhibit 3-12), as described in the AASHTO *Roadside Design Guide* (4).

Where practical, sidewalk widths across bridges and through underpasses should be the same as or wider than the clear width of the existing connecting sidewalks. The minimum clear width for a curb-attached sidewalk on a bridge is 1.2 m [4 ft]; a width of 2.4 m [8 ft] is desirable.

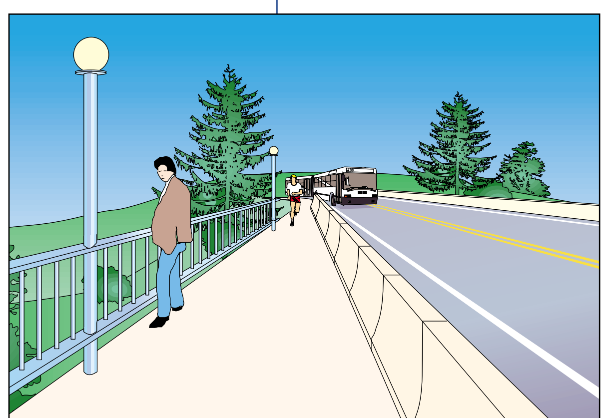

Exhibit 3-12. Bridge with Protective Barrier at Curb (20).

Underpasses can pose a problem if the sidewalk is located between the abutment wall and supporting columns next to the roadway. Here the concern is more about security due to the blind spots created by the large columns or pillars, particularly if the length of the underpass exceeds 30 m [100 ft]. Where practical, underpasses should be designed with a clear span from abutment to abutment (or to center columns). Where columns are placed on either side of the roadway, it is desirable for pedestrian security reasons to place the sidewalk between the columns and the roadway. Where columns must be located adjacent to the curb, the sidewalk behind the columns should be made as wide as practical depending on the length of the structure, and/or include additional vandal-proof lighting (including daytime lighting for long underpasses) in order to increase the feeling of security. In addition, underpasses should be designed to drain properly so that standing water is not splashed onto pedestrians by passing vehicles.

Because sidewalks require less vertical clearance than roadways, sidewalks through underpasses do not need to be at the same grade as the roadway. This can be important

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Exhibit 3-13.
Brick Sidewalk.
Photo courtesy of
James T. McDonnell.

where the grade of the roadway is greater than the desirable sidewalk grade. However, this would probably require railings along the roadway edge and may raise security concerns.

Normally, pedestrians are not permitted in long tunnels; however, space should be provided in the tunnel for an emergency walk and for access by maintenance personnel. Raised sidewalks are desirable beyond the shoulder areas to serve the dual purpose of a safety walk and an obstacle to prevent damage of the wall finish or the tunnel lighting fixtures by vehicle overhangs.

Bridge railings are intended to prevent motorists, pedestrians, and bicyclists from falling off the structure. AASHTO's *Standard Specifications for Highway Bridges* (5) specifies geometric, design load, and maximum allowable material stress requirements for the design of traffic railings, pedestrian/bicycle railings, and railings that combine traffic railing features with those of pedestrian/bicycle railings. Where a traffic barrier or railing is used between the roadway and the sidewalk, no part of the curbed sidewalk should extend closer to the roadway than the front of the traffic barrier.

3.2.10 Surface Treatments

The sidewalk surface treatment can have a significant impact on the overall accessibility and comfort level of the facility. Sidewalk surfaces should be smooth and continuous. It is desirable that the sidewalk surface be stable, firm, and slip resistant. The preferred materials are portland cement concrete (PCC) and asphaltic concrete (AC) pavement. PCC (typically found in urban areas) provides a smooth, long-lasting, and durable finish that is easy to grade and repair. AC has a shorter life expectancy but may be appropriate in less urban areas and park settings. Crushed aggregate may be used as an all-weather walkway surface in park settings or rural areas, but such paths generally require a higher level of maintenance to maintain accessibility (14).

Sidewalks, walkways, and crosswalks can be constructed with bricks and pavers if they are constructed to avoid settling or removal of bricks, which can create a tripping condition (see Exhibit 3-13). "Stamping" molds have also been used to create the visual appearance of bricks and pavers. The technique has the advantages of traditional concrete without some of the maintenance issues associated with bricks and pavers. Commercial products are available that produce a variety of aesthetically pleasing surfaces that are almost impossible to distinguish from real bricks and pavers (14). Stamped surface treatments are not completely without maintenance issues, however. The color has been known to fade, and when utility cuts or sidewalk repairs are made, there is usually little or no attempt made to replicate the original pattern and color. Crosswalks that are constructed with bricks or pavers may be outlined with white lines, per MUTCD specifications, to help motorists detect the presence of the crosswalk. A disadvantage of either real or stamped brick sidewalks is the problem that seemingly small surface irregularities pose for wheelchair users with spinal injuries. However, it is possible to enhance sidewalk aesthetics while still providing a smooth walking surface by combining a concrete main walking area with brick edging where street furniture (lights, trees, poles, etc.) can be placed. For example, in a CBD, a 4.5-m [15-ft] total sidewalk width might include a 2.4-m [8-ft] clear concrete sidewalk with a 2.1-m [7-ft] decorative brick-edging treatment (14).

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3.2.11 Pedestrian Facility Lighting

Good street lighting improves the visibility, comfort, and security of pedestrians. Consideration should be given to lighting at least the intersections and other pedestrian crossing areas. Lighting is also recommended in areas where there is a high concentration of dusk or nighttime pedestrian activity, such as places of worship, shops, schools, and community centers.

Exhibit 3-14. Newspaper Boxes Consolidated Out of Pedestrian Path
Photo courtesy of Terry R. Short, Jr.

In urban areas, continuous lighting is encouraged. Along wide arterial streets with sidewalks on both sides of the street, it is desirable also to place the lights along both sides of the street. Streetlights should be spaced to provide a relatively uniform level of light. To improve the comfort and security of pedestrians in shopping districts or in downtown areas with high concentrations of pedestrians, it may be desirable to provide pedestrian-level lighting in addition to the street lighting. The preferred pedestrian-level lights are mercury vapor, metal halide, or incandescent. Low-pressure sodium lights may be energy-efficient, but are undesirable because they create considerable color distortion. High-pressure sodium lights produce less distortion and are a more desirable alternative. Pedestrian-level lighting may also be installed in selected areas of pedestrian activity to create a sense of intimacy and place.

For further lighting information, refer to the AASHTO *Informational Guide for Roadway Lighting* (1).

3.2.12 Obstacles and Protruding Objects

Obstacles that encroach on the pedestrian's path of travel are often beyond the control of the designer. To ensure that visibility is not compromised along sidewalks and walkways, a local government may establish ordinances that require property owners to maintain their property free of obstacles for the benefit of others.

Additional obstacles that should be avoided are utility wires that cross over the sidewalk or walkway. Guy wires and utility tie-downs should not be located in or across sidewalks at heights below 2.4 m [8 ft]. When placed parallel to sidewalks or pedestrian walkways, the guy wires should be covered with a bright yellow (or other high-visibility color) plastic "guard" to make the wire more visible (14).

Street Furniture and Other Obstacles

Improperly placed street furniture, such as benches and shelters, can create obstacles for pedestrians with vision impairments. Street furniture, including bicycle racks, should be outside the normal travel path (see Exhibit 3-14). High-contrast colors should be used for conspicuity. The following clearances, which apply to street furniture and other obstacles, are adapted from ADAAG (12) and MUTCD (15) requirements (see Exhibit 3-15):

- *Wall-Mounted Objects*—Objects shall not protrude more than 100 mm [4 in.] from a wall when located between 0.675 m [27 in.] and 2.1 m [7 ft] above the sidewalk.
- *Single-Post-Mounted Objects*—Objects shall not overhang more than 100 mm [4 in.] per side of post when located between 0.675 m [27 in.] and 2.1 m [7 ft] above the sidewalk.

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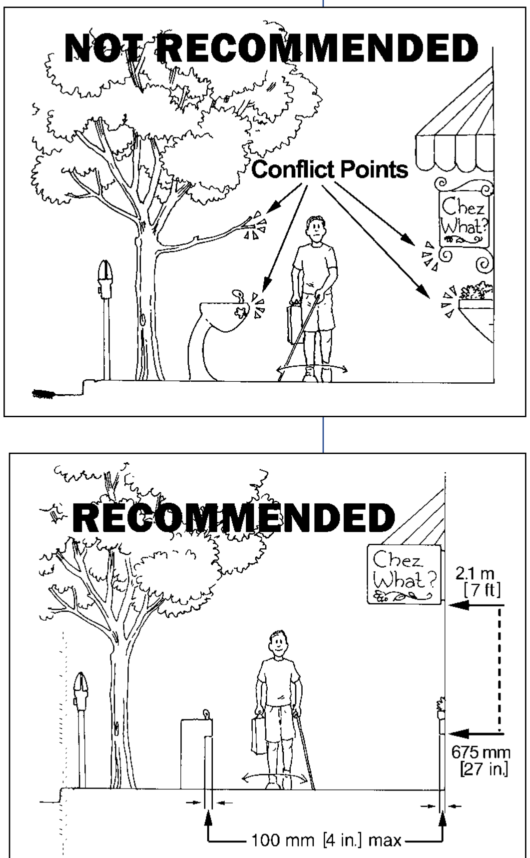

Exhibit 3-15. Proper Positioning of Street Furniture (13).

- *Multiple-Post-Mounted Objects*—The lowest edge of an object mounted on multiple posts having a clear distance between adjacent posts greater than 0.3 m [1 ft] shall be no higher than 0.675 m [27 in.] or no lower than 2.1 m [7 ft].

Another common problem is the random placement of street furniture where there is on-street parking. Such placement can make exiting a lift-equipped vehicle difficult. One remedy is to have street furniture, such as benches, telephone poles, or streetlights, placed at the ends of parking spaces rather than in the middle of parking spaces (16).

Drainage Grates

Drainage grates, particularly those with parallel bars, are concerns for wheelchair, bicycle, stroller, walker, and cane users; for example, a gap or opening that is too large may catch the tip of a cane or capture a wheelchair caster. Where practical, drainage grates should be placed outside the pedestrian travel way. However, where present in the walking surface, grates (as well as manhole covers, hatches, vaults, and other utility coverings) should be mounted flush and level with the surrounding surface. Such grate openings should not exceed 13 mm [0.5 in.] in width in one direction of travel. If grates in the walking surface have elongated openings, they must be placed so that the long dimension is perpendicular to the dominant direction of travel (12).

Railroad Crossings

Light rail vehicle (LRV) and surface commuter rail systems frequently cross roadways and sidewalks at grade. Conventional passenger and freight railroads occasionally cross streets and sidewalks as well. Pedestrian crossings at such railroads must be designed in accordance with the ADAAG (12) to avoid situations in which wheelchair casters rotate when they hit the top of a rail and drop into the flangeway. The pedestrian crossing must have clear lines of sight and good visibility so that pedestrians can see approaching trains. Coordination with the local transit authority on grade-crossing protection is essential. An effective and low-cost solution is the provision of a very high-contrast front end on the vehicle and the placement of high-intensity strobe lighting on the vehicle. The crossing must be level and flush with the top of the rail at the outer edge and between the rails. The crossing should also be as close as practical to perpendicular with tracks, and flangeway gaps that do not exceed 64 mm [2.5 in.] (75 mm [3 in.] for tracks that carry freight) must be provided. Detectable warnings to alert pedestrians with vision impairments should be placed where railways cross any accessible pedestrian route. When a raised sidewalk is adjacent to a roadway, curb ramps should be provided to bring the pedestrian walkway down to the same grade as the railroad crossing. In this type of installation, the detectable warning should be placed outside the train's dynamic envelope.

If the trains or LRVs stop close to the pedestrian crossing at bidirectional operation facilities, pedestrians should be warned of a train approaching from the opposite direction that may be blocked from view by the vehicle stopped at the station. Fencing or landscaping can be used to guide pedestrians to safer crossing points. Pedestrian-only crossing gates or other audible and visible warning devices should also be considered.

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3.2.13 Ambience, Shade, and Other Sidewalk Enhancements

The following are various design elements that can make the pedestrian sidewalk environment feel more comfortable:

- Unobstructed visibility between the pedestrian and motorist
- A pedestrian facility that is inviting to the user and provides a sense of place to the pedestrian
- Street trees and other plantings, and even curb parking, that can act as a buffer zone for the pedestrian
- Public art (e.g., sculptures, murals, etc.)
- Accessible street furniture that does not limit available space for pedestrian travel

Exhibit 3-16. Well-Designed Sidewalk Tree Grate.
Photo courtesy of James T. McDonnell.

It may not be possible to achieve all of these attributes completely, so the designer should strive for balance among them. For example, unobstructed visibility and the presence of street trees and other plantings are not fully compatible. Such incompatibilities should be resolved by the designer.

Comfort is functional, and people look for basic amenities. Is the sidewalk wide enough? Is there sufficient separation from the street? Is there an edge or a transition between uses of space? Is there shade in summer and buildings offering protection from sun, rain, or cold winds in the winter?

Comfort is also visual. A rich line of green trees not only offers shade, but enhances the street with needed color, vertical height, and an edge. Accent paving stones can offer color, texture, or pattern.

People must feel welcomed by the place. The feeling of welcome is imparted by the employees of an establishment, by the people that share the street, and by the physical presence of the street itself. The inclusion of comfortable seating, quiet spaces to contemplate and look back on the walk, and helpful navigational aids are all basic to feeling welcomed.

Street Trees

In many instances, street trees have been used as a buffer between the roadway and the sidewalk for aesthetic and traffic-calming purposes. In addition, tree canopies offer shade to pedestrians. However, care must be taken to avoid planting trees or large shrubs that will obstruct the visibility between a pedestrian attempting to cross the street or a motorist attempting to enter the street and an approaching motorist. Trees should also be placed so that they avoid interference with overhead utilities, are not too close to roadside furniture, and do not interfere with the opening of car doors. Trees with large canopies planted between the sidewalk and street should generally be trimmed up so that the branches are above the sidewalk, at least 2.1 m [7 ft] high. Trees with large trunks may not be appropriate.

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Exhibit 3-17.
Meandering Walk.
Photo courtesy of John LaPlante.

Street trees should be maintained. However, the maintenance of the tree can be reduced and its overall longevity increased if consideration is given to the type of tree that is used within different areas (e.g., urban, local, and rural). Preferred tree types vary with regional differences in climate and terrain. Local tree selection criteria established by a landscape architect or an arborist should be consulted. Tree types with root patterns that may eventually cause the sidewalk to heave and shift vertically, or may damage the foundations of nearby structures, should be avoided.

When street trees are installed within urban sidewalks, they should be placed out of the pedestrian travel way. Tree wells can vary in size depending on the width of the sidewalk, and/or the type of tree selected for planting. Tree grates adjacent to or within sidewalks must take into consideration the accessibility needs of all potential users. As such, drainage gaps within the grate must be narrow enough to prevent strollers, wheelchairs, canes, high-heeled shoes, and the like from becoming lodged, and should be flush with the sidewalk pavement (see Exhibit 3-16). For guidance on the design of tree grates, see Section 3.2.12 on Obstacles and Protruding Objects.

Buffer Zone Plantings

The amount of separation (or buffering) between the pedestrian travel way and moving traffic is a major factor in how pedestrians perceive the safety of their environment. The width and design of the buffer should be based on the specific traffic and geometric conditions of that corridor. Buffer zone plantings can greatly increase the comfort level of pedestrians walking along a sidewalk. Such plantings offer an increased sense of security, while also protecting them from roadside spray in rain and snow. Buffer plantings can also act as a tool to direct pedestrians to appropriate crossing locations.

Exhibit 3-18.
Example of Public Sidewalk Art.
Photo courtesy of Phoenix Arts Commission.

Buffer zone plantings must not limit sight distance for motorists or pedestrians. Plantings and shrubs should be maintained to no higher than 0.9 m [3 ft]. Care should be taken so that plantings do not encroach on the minimum clear sidewalk width or the roadway.

The designer should consult the AASHTO *Roadside Design Guide* (4) and the appropriate agency's design guidelines with respect to clear recovery area policies before making a final recommendation on buffer width and buffer tree locations. Proper maintenance of buffer area plantings is addressed in Section 4.3 on Sidewalk Maintenance in Chapter 4 of this guide.

Meandering side paths are sometimes used when wider rights-of-way are available and there is a desire to provide a high level of landscaping, such as in a park or along a waterway or other natural feature. However, they can cause alignment and orientation problems for pedestrians with vision impairments. They also create a longer walking distance and are more appropriate for parkways or recreational settings where pedestrians are less likely to resent the additional walking distance. In residential areas, meandering sidewalks should be kept within a 3.0-m [10-ft] band width with horizontal-curve radii no less than 90 m [300 ft] in order to maintain a convenient walking route (see Exhibit 3-17).

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Public Art

The use of public art can enhance the sense of place a pedestrian can experience within a sidewalk environment. When kept outside the normal travel path, sculptures and other forms of art can make the pedestrian environment friendlier and more comfortable (see Exhibit 3-18).

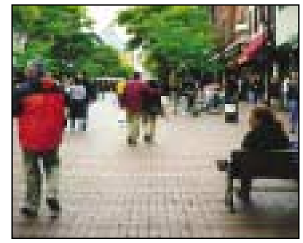

Exhibit 3-19. Example of Pedestrian Mall Design (20).

Pedestrian Malls and Transit Streets

The overwhelming majority of measures that improve pedestrian access and enhance the "curb appeal" of urban retail and commercial centers derive from balancing the needs of all travel modes in a particular corridor or subarea. However, there are conditions where transit and/or pedestrian malls can be operationally sustainable and financially successful. The ideal pedestrian mall is designed in a relatively narrow street right-of-way with concentrated shopping and commercial land uses. Excessively wide malls dilute pedestrian activity, making a mall appear dull and uninteresting, and also reduce exposure to retail edges due to the increased sight distances. A typical pedestrian mall is illustrated in Exhibit 3-19.

A successful pedestrian mall is interesting, safe, convenient, and appealing to the shopper. The most successful street malls are located in areas such as historical districts where there are established patterns of tourist and visitor activity. This pattern can be enhanced by designing storefronts and street furniture in keeping with the local "theme."

The following are some important design considerations for pedestrian malls:

- Quality of design and durability of construction materials have proven to be essential elements in the success of pedestrian malls. 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 dislodgment, which can result in tripping. 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-scale lighting, with control of overhead illumination so as to not 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 also 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.
- Other 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.

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- A popular advantage of a street mall is the ability to conduct large-scale outdoor events. Event spaces for setting up concerts, grandstands, and other activities should be considered in the mall design. Access to electrical outlets and water supplies should also be considered.
- Where existing curbs remain between the original sidewalk and street, curb ramps should be provided at intervals.

In transit malls, interrupted malls, and plazas where vehicle-pedestrian conflicts are present, crosswalks should be provided. Such conflicts may be minimized through: (1) one-way cross streets and (2) signals and warnings to the motorists such as signs, contrasting pavements, or raised crossings at the mall crossings. The mall should be designed to keep transit vehicles and other service vehicles to a slow speed. There should be ample visibility between pedestrians and other vehicles in the mall, and curbing should be provided to delineate the edge between the vehicle and pedestrian spaces.

Advantages of pedestrian malls include:

- A reduction in pedestrian delays and/or pedestrian congestion
- Enhancement of the aesthetic and social environment of the commercial 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
- An increase in the efficiency and time savings of mass transit in transit malls

Considerations before embarking on a major mall construction project include:

- Installation, maintenance, and operation costs
- Alternative through-traffic routings
- Replacement of front door parking spaces
- Economic health of the local business
- Less costly or disruptive alternatives (e.g., street narrowing, sidewalk widening, landscaping)

3.2.14 Off-Road and Shared-Use Paths

Off-road paths are intended solely for use by pedestrians. Shared-use paths have a variety of users, including pedestrians, bicyclists, in-line skaters, horseback riders, etc. AASHTO's *Guide for the Development of Bicycle Facilities* (2) provides design guidelines that should be consulted in the design of shared-use paths and include:

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- Recommended paved width of 3.0 m [10 ft], with 3.6 m [12 ft] recommended in areas with higher user volumes
- Minimum 0.6-m [2-ft] graded area adjacent to both sides of trail
- Minimum 1.5-m [5-ft] separation between the edge of the path to top of slope that is more than 1V:3H
- Vertical clearance to obstructions of 2.5 m [8 ft]
- Grades no steeper than five percent recommended, with a graduated scale up to 11 percent or more for short distances
- Separation from roadways should be a minimum of 1.5 m [5 ft]
- Cross slopes should not exceed two percent
- Path-roadway intersections should be carefully designed (see AASHTO *Guide for the Development of Bicycle Facilities*)(2)

Trails built to meet these guidelines will also serve the needs of pedestrians.

Accessibility should be a fundamental consideration in the design and development of off-road and shared-use paths. Considering accessibility at all stages of path development will help to avoid design and construction practices that inadvertently limit the opportunities provided (11, 20). The U.S. Access Board has recently issued a report providing draft *Guidelines for Outdoor Developed Areas* (6). Many off-road and shared-use paths will need to comply with these guidelines when they are finalized; the current guidance is generally less restrictive than the AASHTO bicycle guidelines summarized previously. The draft Access Board guidelines (6) generally refer to shared use paths as “trails.”

It may be difficult to make all paths fully accessible. Exceptions provided in the draft *Guidelines for Outdoor Developed Areas* (6) include the following situations:

- Where compliance would cause harm to cultural, historic, religious, or significant natural features
- Where compliance would substantially alter the nature of the setting or the purpose of the facility (or portion of the facility)
- Where compliance would require construction methods or materials that are prohibited by Federal, state, or local regulations or statutes
- Where compliance would not be feasible due to terrain or the prevailing construction practices

If an existing path is not accessible, it is desirable to remove as many barriers as practical. Signing at trail access points to identify steep grades, excessive cross slopes, narrow widths, or uneven surface conditions, will help users determine for themselves whether to use the path (2).

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3.3 Intersection Design

Street crossings are an essential component of any roadway design. A street may have excellent sidewalk facilities but, if the intersection crossings are intimidating, few pedestrians will use the street. Pedestrians, therefore, should be included as "design users" for all intersections where they can be expected to cross. Intersections are often the best and most direct place for pedestrians to cross a roadway and are the most common pedestrian crossing locations. This section discusses the various design features, as well as crossing techniques that can facilitate convenient and safe pedestrian travel at intersections. Some of the attributes associated with good intersection crossing design include:

- *Clarity*—It should be obvious to motorists that there will be pedestrians present; it should be obvious to pedestrians where best to cross.
- *Predictability*—The placement of crosswalks should be predictable. Additionally, the frequency of crossings should increase where pedestrian volumes are greater.
- *Visibility*—The location and illumination of the crosswalk allows pedestrians to see and be seen by approaching traffic while crossing.
- *Short Wait*—The pedestrian does not have to wait unreasonably long for an opportunity to cross.
- *Adequate Crossing Time*—The time available for crossing accommodates users of all abilities.
- *Limited Exposure*—Conflict points with traffic are few, and the distance to cross is short or is divided into shorter segments with crossing islands.
- *Clear Crossing*—The crosswalk is free of barriers, obstacles, and hazards and is accessible to all users. Pedestrian crossing information is available in accessible formats.

Traffic signals create gaps that allow pedestrians to cross a street. However, adequate sight distance at signalized intersections is desirable to enable motorists and pedestrians to see one another during periods when there are signal malfunctions or periods when signals are placed in a flashing operation. When this occurs, the signal often defaults to a flashing red on the minor approach and has traffic operations similar to a stop-controlled intersection. However, when the major approach defaults to a flashing yellow, adequate sight lines should be provided for pedestrians attempting to cross the major street. Additional information on traffic signal warrants and design can be found in Chapter 4.

There are three types of unsignalized intersections: (1) completely uncontrolled (usually minor local roads or streets), (2) free-flow traffic conditions along the major road with stop controls on the minor legs, or (3) stop- or yield-controlled for all approaches. When one or more legs of an intersection are uncontrolled, pedestrian crossing movements become more complex. While traffic control devices may be desired at every potential pedestrian crossing, uncontrolled intersections can operate more safely for all users if street width, traffic volume, speed, and line-of-sight issues are taken into account.

This section discusses these measures, as well as other design features that can enhance the safety and functionality of both signalized and unsignalized intersections.

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3.3.1 Curb Radii

The curb radii used at both signalized and unsignalized intersections should be selected considering safety, operations, and convenience for both motorists and pedestrians. Curb radii should be based on an appropriate balance of the needs of pedestrians and the needs of heavy vehicles, such as trucks and buses. Curb radii should be appropriate for the largest design vehicle which makes a specific turning maneuver with sufficient frequency to serve as an appropriate basis for design. At the same time, it should be recognized that larger intersection curb radii have disadvantages for pedestrians. A large radius can increase the crossing distance for pedestrians and the speeds of turning vehicles, creating increased exposure risks, which can be particularly challenging for pedestrians with impaired vision. Large radii also reduce the corner storage space for pedestrians, move pedestrians out of the driver's line of sight, and make it more difficult for pedestrians to see vehicles. On the other hand, smaller radii that limit the speeds of turning vehicles may reduce the operational efficiency of an arterial intersection. A curb that protrudes into the turning radius of the design vehicle could cause vehicles to drive over and damage the curb, as well as increase the potential of hitting a pedestrian standing at the curb. Where appropriate, bollards may be added to reduce the likelihood of vehicles driving over the curb.

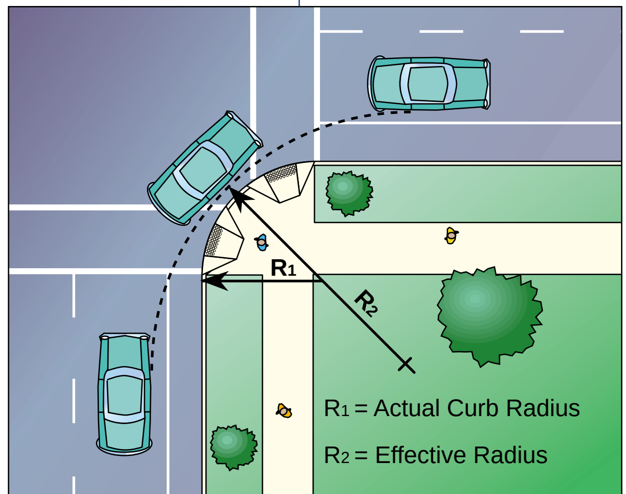

Exhibit 3-20. Effective Turning Radius (24).

Two distinct radii should be considered when designing street corners. The first is the radius of the street corner itself, and the second is the effective turning radius of the selected design turning vehicle. The effective turning radius is the radius needed for a turning vehicle to clear any adjacent parking lanes and/or to align itself with its new travel lane (see Exhibit 3-20). Using an effective turning radius allows a smaller curb radius than would be required for the motorist to turn from curb lane to curb lane. In particular, a shorter curb radius can be provided when parking lanes are present. Exhibit 3-21 shows how crossing length can be reduced by using a tighter curb radius. The purpose of Exhibit 3-21 is to illustrate the effect of curb return radius on crossing distance. The added crosswalk distances between curbs as compared to the curb-to-curb street widths are shown in Exhibit 3-21, assuming that (a) the sidewalk centerline at a right-angle intersection is in line with the middle of a border and (b) the same curb radius is used at all four corners of the intersection. The types of curb ramps that may be appropriate at an intersection are presented later in this chapter.

Curb Radius, *R*	Increased Crosswalk Distance*
5 m [16 ft]	1 m [3 ft]
10 m [33 ft]	7 m [23 ft]
15 m [49 ft]	12 m [39 ft]

** Measured along centerline of sidewalk/crosswalk as compared to curb-to-curb width.*

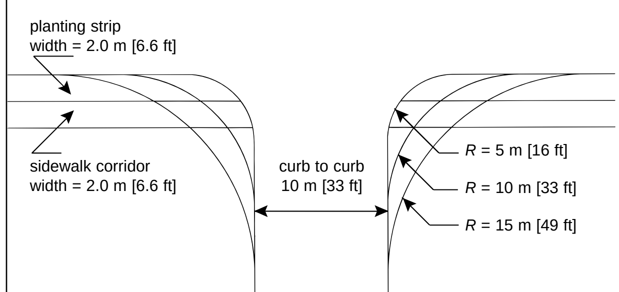

Exhibit 3-21. Advantage of Smaller Curb Radii (11).

On major arterials, the radius should be designed to allow turning vehicles to use all of the available roadway width in the direction of travel. If the receiving street is a local street, it may be preferable to allow an infrequent large vehicle to turn into an opposing travel lane instead of creating an unnaturally large street corner radius. This situation often occurs at local and collector street intersections—either signalized or unsignalized—where

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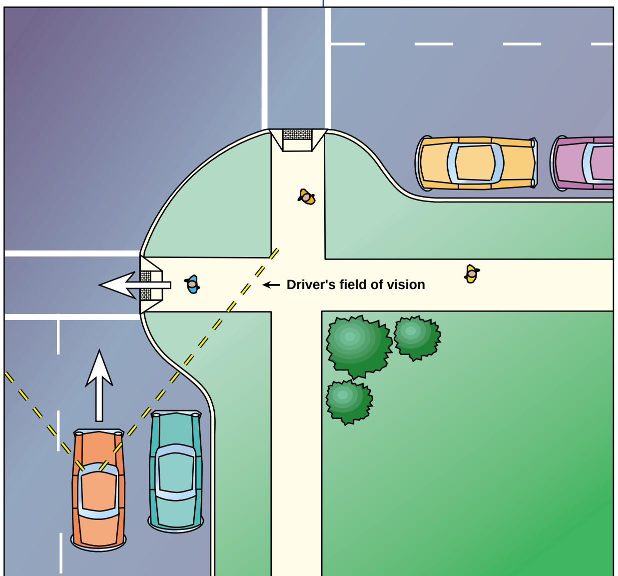

Exhibit 3-22.
Example of Curb Extension Design (13).

the only large turning vehicles are an occasional school bus, moving van, fire truck, or oversized delivery truck.

Where there is little turning truck traffic, it is recommended that a 3.0 to 4.5 m [10 to 15 ft] street corner radius (R_1) be used. Where there are heavy truck volumes, the maximum street corner radius may be increased; in this case, the stop bar should be set farther back in the receiving street so that large vehicles have ample room to complete their turn. The minimum curb return radius for effective street sweeping at intersections is 1.5 m [5 ft]. (For further curb turning radii information, see *Minimum Turning Paths of Design Vehicles* in Chapter 2 of the AASHTO Green Book (3)).

3.3.2 Crossing Distance Considerations

Short crosswalks help pedestrians cross streets. Excessive crossing distances increase the pedestrian exposure time, increase the potential of vehicle–pedestrian conflict, and add to vehicle delay. Pedestrian comfort and safety when crossing wide intersections is an essential component of good pedestrian facility design. At signalized intersections, reducing the distance a pedestrian needs to cross an intersection can usually improve the signal timing of the intersection. Where the pedestrian crossing time is the controlling factor, reducing the distance needed for a pedestrian to cross a main street permits the green time for the major street traffic to be increased proportionately. Thus, under certain conditions, reducing the arterial street throat width on an intersection approach may actually increase the capacity of that street.

Curb Extension Design

On streets with curb parking, curb extensions can:

- Reduce the crossing distance of pedestrians
- Improve the sight distance and sight lines for both pedestrians and motorists
- Prevent parked cars from encroaching into the crosswalk area
- Create adequate space for curb ramps and landings where the existing sidewalk space is too narrow

In general, curb extensions should extend the width of the parking lane, approximately 1.8 m [6 ft] from the curb. Exhibit 3-22 provides an example of a typical curb extension design. Curb extensions may not be needed or desirable on every leg of an intersection if the street leg is narrow, parking is not permitted, or the curb extension would interfere with a bicycle lane or the ability of the design vehicle to negotiate a right turn. Curb extensions may also make snow plowing more difficult. Low-level landscaping, through the use of planting strips or boxes, is recommended on curb extensions to provide alignment cues for pedestrians with vision impairments and conspicuity for approaching motorists.

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Crossing Islands and Medians

Medians are raised or painted longitudinal spaces separating the two main directions of traffic movement in the street. Triangular channelization islands adjacent to right turning lanes can also act as crossing islands. Where possible, raised crossing islands are preferred due to their increased safety and comfort benefits to pedestrians and greater detectability by motorists.

At signalized intersections, median islands provide a storage area for pedestrians to wait for the next available cycle if they are unable to cross the street entirely during a provided crossing phase. Crossing islands also help maintain or improve the efficiency of the motor vehicle level of service by permitting split signal phasing for major turning movements. Depending on the signal timing, crossing islands should be considered where the crossing distance exceeds 18.3 m [60 ft], but can be used at intersections with shorter crossing distances where a need has been recognized. Median islands should not be used to justify a signal timing that does not allow pedestrians to complete their crossing in one cycle. However, on wide streets the median can provide a refuge for those who begin crossing too late or are exceptionally slow.

At unsignalized intersections, crossing islands can also be beneficial by providing a storage area for pedestrians to wait for acceptable gaps in the flow of traffic before completing the street crossing. Some of the other attributes associated with good crossing island locations include:

- Two-way arterial streets with high traffic volumes, high travel speeds, and large pedestrian volumes
- Wide two-way intersection with high traffic volumes and significant numbers of crossing pedestrians
- Two-way collector and local access streets where they function as traffic-calming devices and street crossing aids
- 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

Design Dimensions of Crossing Islands

The width of the median or crossing island is determined by the expected pedestrian or bicycle use of the crossing and the traffic characteristics of the street to be crossed. A relatively narrow median may be acceptable in areas with limited pedestrian activity and low traffic volumes and speeds. When pedestrian volumes are greater and traffic volumes and speeds are higher, a wider crossing island may be needed to provide a larger waiting area.

The width of a newly constructed crossing island should be 1.8 m [6 ft] or more to provide space for a wheelchair user or more than one pedestrian to wait, and so that the pedestrian storage area is separated from the face of the curb. Island size can be increased based on anticipated pedestrian storage area and crosswalk level of service criteria. Existing 1.2-m [4-ft] medians may be retained, but medians should be widened to 1.8 m [6 ft] or more in reconstruction projects. Where practical, a width of 2.4 m [8 ft] may be provided

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to accommodate groups of pedestrian, bicycles, and mobility aids such as wheelchairs and scooters. Travel lanes may be narrowed to 3.3 m [11 ft], or even 3.0 m [10 ft] in constrained conditions, to provide space for the crossing island. However, considerations such as traffic volume, vehicle mix, speed, and the presence of bicyclists should be taken into account prior to narrowing lanes. Where it is not practical to widen the median, the crossing or cut-through width may be increased to provide more storage space for pedestrians and bicycles within the median. At a minimum, the clear width should be maintained in the cut-through section. Crossings through a median can be angled so that pedestrians can see and be more aware of traffic on the roadway they are about to cross. Crossing islands must include detectable warnings for 0.6 m [2 ft] at the street edge on each side of the island.

Access to the crossing island must be functional and safe for all pedestrians. A cut-through design or a ramped design large enough to enable a wheelchair to wait atop the island should be provided. The cut-through width should be the same as the complete width of the crosswalk, or at least maintain a minimum clear width. Cut-through ramps should be graded to drain quickly, up to a maximum slope of two percent, and should be provided with detectable truncated dome warning surfaces so that pedestrians with vision impairments can identify the edge of the street. Cut-through islands may also require additional maintenance such as sweeping, etc.

An approach nose, offset from the edge of the traffic lane, should be provided and appropriately treated to provide motorists with sufficient warning of the island's presence. This can be achieved through illumination, reflectorization, marking, signing, and/or size (16). See the AASHTO Green Book (3) for further information on the design of approach noses.

Skewed Intersections

Skewed intersections tend to increase the exposure time of the pedestrian to traffic, lead to increased speeds for turning vehicles, create reduced sight distance for some users, and may not provide clear orientation cues for pedestrians with visual impairments. Additional design features such as curb extensions, crossing islands, or special traffic control devices may be appropriate to accommodate pedestrians. Several jurisdictions are experimenting with linear raised guide strips in the center of a crosswalk to aid pedestrians with vision impairments. Where practical, existing skewed intersections should be rebuilt to eliminate or minimize the skew. In addition, skewed intersections should be avoided in new construction—not only are they undesirable for pedestrians, but they create significant operational problems for motorists. Modern roundabouts may provide a solution to better operation of skewed intersections, though there are concerns about the ability of vision-impaired pedestrians to navigate them. When complete, NCHRP Project 3-78, *Crossing Solutions at Roundabouts and Channelized Turn Lanes for Pedestrians with Vision Disabilities*, will provide additional information regarding these issues.

If a skewed intersection is unavoidable, the proper placement of crosswalks is essential to help reduce some of the problems listed above. Crosswalks can be placed as a continuation of the sidewalk (following the skew), perpendicular to the roadway, or anywhere in between. There is no single solution that is appropriate for every circumstance. The following factors should be considered when deciding where best to place a crosswalk at a skewed intersection.

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In many cases, the best placement will be somewhere between these two extremes. Observation of existing crosswalks at skewed intersections shows that pedestrians often cross at a location other than the marked crosswalk if it is not placed where they feel safe and comfortable. The proper design can be achieved by envisioning the natural path the pedestrian will take and analyzing the various turning movements to reach optimal visibility, driver and pedestrian expectation, and reasonable crossing distances.

Intersection Location	Advantages	Disadvantages
As a continuation of the sidewalk	In line with the approach sidewalk; continues walking path; shortest overall distance	Reduces visibility for pedestrians crossing some intersection legs where they travel on a path facing partly away from traffic approaching from the right; exposes pedestrians to traffic for a longer period of time.
At a right angle to roadway	Shortest crossing distance; pedestrians have good visibility of approaching drivers.	Longer overall walking distance, may be counterintuitive, places crosswalk away from intersection where drivers may not expect pedestrians.

3.3.3 Turning Movements

The presence of turning vehicles is an important consideration in designing pedestrian crossings. For example, at signalized intersections, 37 percent of all vehicle-pedestrian collisions involve left- or right-turning vehicles (18). At both signalized and unsignalized intersections, steps should be taken to ensure that turning speeds are kept low and that sight distance is not compromised for either the motorist or pedestrian. Some suggestions to help reduce the number of potential turning conflicts include:

- Design compact intersections with small turning radii that force slower vehicle turning speeds; this may be practical only where large vehicles are not present in substantial numbers.
- Use signing to prohibit right-turn-on-red during hours of high pedestrian traffic.
- When right-turn slip-lanes are used, place crosswalks so that a motorist has a clear view of the pedestrian. Also, highly visible markings should be used.
- Consider using a separate left-turn phase in conjunction with a WALK/DON'T WALK signal; or restrict left turns at downtown intersections and on commercial streets during certain hours when there are higher concentrations of pedestrians at intersections.
- Shorten crossing distance and exposure time with curb extensions or other geometrics.
- Provide accessible crossing islands and pedestrian signals.
- Place signs to remind motorists of their duty to yield to pedestrians while turning left or right.
- Improve marking and visibility of crosswalks.
- Provide well-illuminated crossings.

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Channelized Right-Turn Slip Lanes

Channelized right-turn slip lanes are sometimes used at unsignalized intersections to provide motorists with smoother turning maneuvers. These slip lanes are also used to allow right-turning traffic to bypass a traffic signal, thereby helping to reduce traffic congestion. More importantly, such lanes can be used to reduce the through street crossing distance by separating the crossing phases. A triangular crossing island, sometimes referred to as a "pork chop" island, separates the channelized right-turn slip lane from the through traffic lanes.

Channelized right-turn lanes are effective in reducing nonpedestrian crashes and can increase the intersection capacity for motor vehicles by removing right-turning vehicles from the signalized intersection and improving sight distance for right-turning motorists who are able to safely accept smaller gaps. The islands that separate channelized right-turn lanes from the through traffic lanes can help accommodate pedestrians if properly sized; the guidance in the previous section on Crossing Islands and Medians should be consulted in their design. However, these channelized right-turn lanes can pose a problem for pedestrians if they promote faster turning speeds. Therefore, the turn lane should be kept as narrow as the turning path of the design vehicle will allow, and should enter the receiving roadway at an angle as close to 90 degrees as the effective turning radius will allow (see previous discussion on Curb Radii in Section 3.3.1).

Pedestrian crossings to triangular crossing islands should be designed to meet the following criteria:

- The pedestrian crossings should be at 90 degrees across the turn lane and placed where the motorist can easily see the pedestrian crossing ahead.
- Pedestrians and motorists must be able to easily see each other.
- The design should encourage low-vehicle-turning speeds.

There is concern that it is difficult for pedestrians with vision impairments to obtain cues concerning gap availability for crossing channelized right-turn slip lanes. Research is underway in NCHRP Project 3-72, *Lane Widths, Channelized Right Turns, and Right-Turn Deceleration Lanes in Urban and Suburban Areas*, and further research is planned in NCHRP Project 3-78, *Crossing Solutions at Roundabouts and Channelized Turn Lanes for Pedestrians with Vision Disabilities*, to determine appropriate geometric design and traffic control guidelines to accommodate pedestrians with vision impairments at channelized right turns.

Expressway Ramps

Intersections of expressway ramps and urban and suburban streets, particularly those that are unsignalized, can create unsafe situations for pedestrians as well as bicyclists. A driver's attention is typically focused on merging into the local road system rather than anticipating potential pedestrian crossings. Pedestrians' safety can be compromised as they attempt to cross expressway entrance or exit ramps. Consider the following options to reduce potential vehicle–pedestrian conflicts:

- Provide a right-angle intersection where the ramp meets the cross street to improve visibility for both motorists and pedestrians and sharply reduce the crossing distance.

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- Where there is pedestrian use, slowing or stopping motor vehicles in these areas can greatly reduce the potential for vehicle-pedestrian conflicts. The use of stop signs, yield signs, or signals should be considered to allow pedestrians the opportunity to cross.
- Design the exits for 30 km/h [20 mph] at the ramp-street intersections in urban situations.
- Pedestrian crossing warning signs should be used at unsignalized ramp-street intersections to alert motorists and pedestrians of the potential conflict area.
- Where diamond-type ramps intersect with the local street, accessible channelization islands can be installed between the right- and left-turning movements to provide a crossing island for pedestrians.

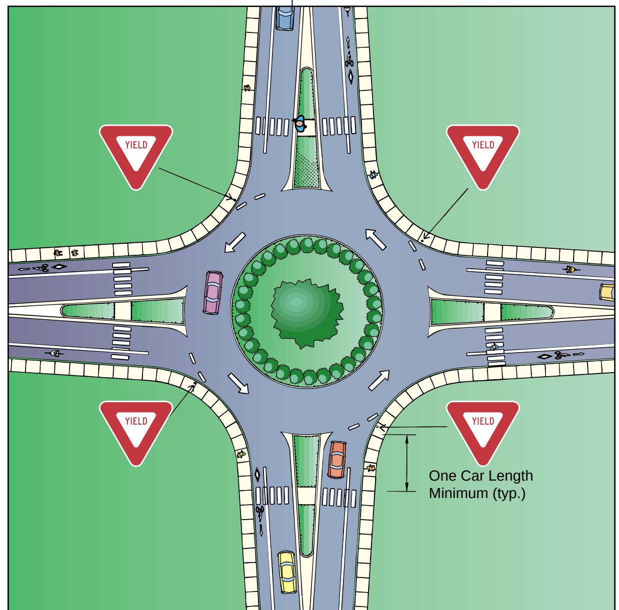

Exhibit 3-23. Modern Roundabout Design (26).

Roundabouts

Roundabouts are increasingly popular for use in place of signals at relatively busy intersections. The primary purpose of roundabouts is to provide motor vehicles with free-flowing mobility at reduced speeds through an intersection. Roundabouts are also designed to do the following:

- Increase intersection capacity for motor vehicles by maximizing vehicle time/space occupancy.
- Replace traffic signals to lower operating and maintenance costs.
- Reduce delays for motorists.
- Reduce serious collisions.
- Improve the streetscape.
- Improve safety and access by reducing vehicle speeds.

Research suggests that there may be fewer vehicle–pedestrian conflicts and crashes at properly designed single-lane roundabout intersections versus typical signalized or unsignalized intersections (26). There is some concern that is it difficult for pedestrians with vision impairments to obtain cues concerning gap availability for crossing near roundabouts. Research is underway in NCHRP Project 3-65, *Applying Roundabouts in the United States*, and further research is planned in NCHRP Project 3-78, *Crossing Solutions at Roundabouts and Channelized Turn Lanes for Pedestrians with Vision Disabilities*, to determine appropriate geometric design and traffic control guidelines to accommodate pedestrians with vision impairments at roundabouts.

Roundabout islands have outside radii ranging from 13 to 60 m [45 to 200 ft] (26), and yield signs for entering traffic are used as the primary traffic control mechanism. The MUTCD (15) also permits the use of yield "saw-tooth" pavement markings in conjunction with yield signs at roundabout entry locations. The design should enable the user to identify the designated pedestrian crossing locations and prevent crossings through the

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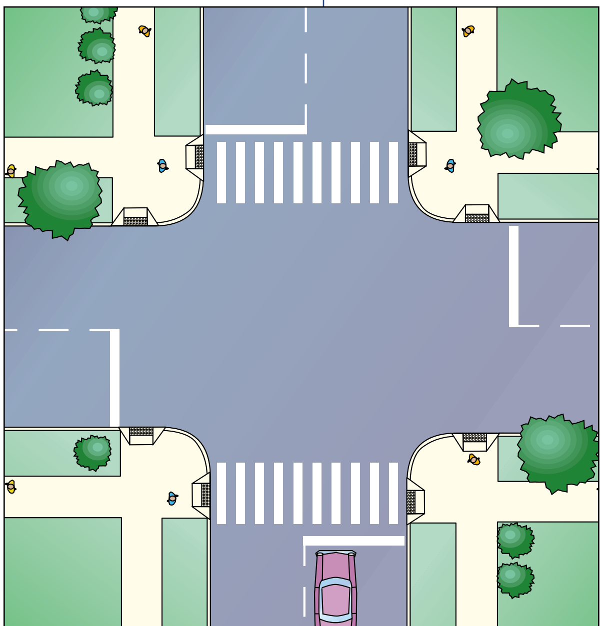

Exhibit 3-24.
Marked and Unmarked Crosswalks at Intersections (29).

center island. Considering that roundabouts provide free-flowing conditions for motor vehicles, provisions should be made to physically slow down the entering and exiting motorists to an operating speed of 20 to 35 km/h [12 to 22 mph], and to safely move the pedestrian across the entry and exiting intersections.

Crosswalks to the splitter islands should be offset a minimum of 6.0 m [20 ft] from the yield line for each of the approach intersections (see Exhibit 3-23). If parking is provided, it should be set back another 6.0 m [20 ft]. This distance will typically provide enough visibility for both the pedestrian and motorist, while also allowing the pedestrian to cross behind the first vehicle entering the roundabout. Splitter islands must be accessible, detectable, and large enough to handle the pedestrian traffic, including wheelchairs.

Multilane roundabouts usually have entries and exits that contain two or more lanes. Thus a pedestrian may be exposed to multiple conflicts when crossing in the designated area. (See *Roundabouts: An Informational Guide* (26) for further information.)

3.3.4 Crosswalks

Intersections should be designed with the premise that there will be pedestrians present, that they should be able to cross the street, and that they need to do so safely. The key design question is, “How should this task be best accomplished?” If one treatment does not fully accomplish the task, then consider others. In many cases, a combination of treatments may be the best solution.

Crosswalks Defined

Crosswalks serve as the pedestrian right-of-way across a street. An intersection crosswalk is defined as the extension of a sidewalk or shoulder across an intersection, whether it is marked or not (see Exhibit 3-24). In most jurisdictions, it is legal for a pedestrian to cross the street at any intersection, even if no crosswalk is marked, unless crossing is specifically prohibited. In addition, midblock street crossings can be designated with crosswalk markings. Marked crosswalks serve two purposes: (1) to inform motorists of the location of a pedestrian crossing so that they have time to lawfully yield to a crossing pedestrian; and (2) to assure the pedestrian that a legal crosswalk exists at a particular location. The level of connectivity between pedestrian facilities is directly related to the placement and frequency of locations where pedestrians are permitted to cross the street.

The MUTCD provides guidelines for marked crosswalks, as well as standards and guidance for various crossing improvements, including signs, signals, and other devices, which should be analyzed for appropriateness to specific intersections (15).

Relationship of Design to Traffic Laws and Their Enforcement

A key traffic law enforcement issue in many communities is the failure of motor vehicle operators to stop for pedestrians using marked and unmarked crosswalks. The most effective way to promote yielding to pedestrians by motor vehicle drivers is to use designs that

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consistently address this need in a way that is readily grasped by road users, applying the principles of speed management and crossing design articulated in this guide. When this has been done, education and traffic law enforcement programs can be more effective.

The *Uniform Vehicle Code* (UVC) serves as the primary model that many states use as a basis for providing uniformity to their laws. The UVC can serve as a good basis to establish the rights of pedestrians and then build an education and enforcement program. For example, the UVC states that specific crosswalk guidance should include direction that calls for a motorist to stop, and remain stopped, to allow a pedestrian to cross the roadway within a marked or unmarked crosswalk (23).

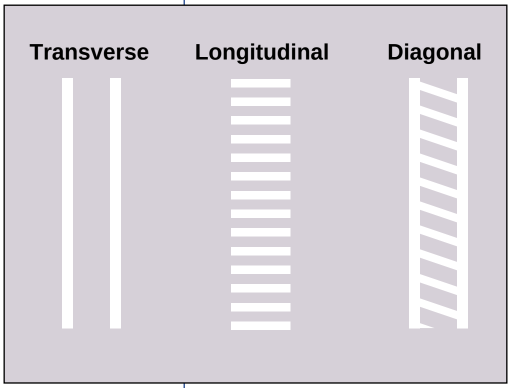

Exhibit 3-25.
Crosswalk Marking Options.

Marked Crosswalks

Marked crosswalks are one tool to get pedestrians safely across the street, though they are often best used in combination with other treatments. In most cases, marked crosswalks alone should not be installed within an uncontrolled environment when speeds are greater than 65 km/h [40 mph]. Under certain conditions, marked crosswalks may be used to supplement an existing or new traffic control feature. Research indicates that where crosswalk markings are used at uncontrolled crossing locations along multilane roads (i.e., roads with four or more lanes) on which traffic volumes exceed approximately 12,000 vehicles per day with no raised medians, or exceed 15,000 vehicles per day with raised medians that could serve as crossing islands, the potential for motor vehicle-pedestrian crashes increases (30).

Marked crosswalks can also be used to create midblock crossings. Midblock crossings may provide pedestrians with a more direct route to their destination. Both intersection and midblock crossings should be considered in assessing the frequency of crossing opportunities. The design of midblock crossings is presented later in this chapter. The following are five key issues to consider when designing pedestrian crossings:

- *Assumptions*—Assume that pedestrians want and need safe access to all destinations that are accessible to motorists. Additionally, pedestrians will want to have access to destinations not accessible to motorists such as trails and parks.
- *Generators and Destinations*—Typical pedestrian generators and destinations include residential neighborhoods, schools, parks, shopping areas, and employment centers. All transit stops require that pedestrians be able to cross the street.
- *Controlled Intersections*—All intersections that have signals, stop signs, or yield signs to facilitate motor vehicle crossing of streets and arterials must also be designed to accommodate pedestrians.
- *Uncontrolled Locations*—Pedestrians need safe access at many uncontrolled locations, including both intersections and midblock locations.
- *Frequency*—Pedestrians must be able to cross streets and highways at regular intervals. Unlike motor vehicles, pedestrians cannot be expected to go a quarter mile or more out of their way to take advantage of a controlled intersection.

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Crosswalk Design

Marked crosswalks are not only used to advise pedestrians where to cross the street, but can send the message to motorists that they are in, or approaching, a pedestrian area and to expect to encounter pedestrians crossing the street. To effectively send this message, the design of the crosswalk must be easily understood, clearly visible, and incorporate realistic crossing opportunities for all pedestrians.

The width for marked crosswalks should not be less than 1.8 m [6 ft]. In the central business districts of larger cities, a 3.0 m [10 ft] or wider crosswalk may be more appropriate, as determined by an engineering study. At marked crosswalks, curb ramps and other sloped areas should be wholly contained within the crosswalk markings, excluding any flared sides. The crosswalk lines should extend the full length of the crossing (15). There are three primary crosswalk marking options available: transverse, diagonal, and longitudinal (sometimes called "zebra") lines. Exhibit 3-25 illustrates the unique design features of each alternative. If used, diagonal or longitudinal lines should be 0.3 to 0.6 m [1 to 2 ft] wide and spaced 0.3 to 1.5 m [1 to 5 ft] apart. The placement of lines for diagonal and longitudinal markings should avoid wheel paths, and line spacing should not exceed 2.5 times the line width. Transverse crosswalk line markings consist of solid lines not less than 150 mm [6 in.] wide nor greater than 0.6 m [2 ft] wide. All crosswalk markings must be white, per the MUTCD. (15)

At unsignalized or uncontrolled crossings, in areas such as school zones, or in areas where there is a substantial pedestrian presence, special emphasis markings (i.e., longitudinal or diagonal markings) should be used to increase visibility. High-contrast markings may also aid people with vision impairments, but no MUTCD (15) guidance for use of high-contrast pavement markings has yet been developed. Durable crosswalk marking materials are preferable to paint at some locations because they last longer and may be more cost-effective.

Colored and textured crosswalk design treatments are sometimes used to improve aesthetics. In addition, care should be taken to ensure that the material used in these crosswalks is smooth, nonslip, and visible. Avoid using a paver system that may shift and/or settle or that induces a high degree of vibration in wheelchair caster or drive wheels.

An additional design treatment used in traffic-calming situations is the raised crosswalk. Raised crossings are typically used at midblock crosswalk locations to serve not only as a visual element for motorists, but also to slow traffic speeds. They are typically used on two-lane streets with posted speeds less than 55 km/h [35 mph] (see Section 3.4.2 on Traffic Calming at Midblock Crossings). Where raised crosswalks are used, detectable truncated dome warnings are needed at the curb lines and visible pavement markings are required on the roadway approach slopes.

Stop and Yield Line Setbacks

At stop or signal-controlled legs of an intersection, stop lines are solid white lines, 0.3 to 0.6 m [1 to 2 ft] wide, extending across all approach lanes. Stop lines should be set back a sufficient distance from the crosswalk to ensure that visibility is provided on all approaches

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to an intersection for both motorists and pedestrians. It is desirable for crossing pedestrians to set the stop line of the left-turn lane farther back than the stop line of the through lanes.

Stop lines are appropriate in both rural and urban areas, wherever it is important to indicate the point behind which vehicles are required to stop for a traffic control device. When used at controlled intersections, stop lines should be placed approximately 3.0 m [10 ft], and no less than 1.2 m [4 ft], in advance of and parallel to the nearest crosswalk line (15). Greater setbacks can help ensure that a motorist's view of pedestrians within the crosswalk is not screened by vehicles in the adjacent lanes.

At marked crosswalks in uncontrolled locations on multilane roads, setbacks of 6 to 15 m [20 to 50 ft] are desirable for yield lines to provide adequate sight distance between pedestrians and vehicles. Supplementary YIELD HERE TO PEDESTRIANS signing may also be used.

Another concern is the visibility of the crosswalk from high-seat vehicles (large trucks or buses) stopped at the intersection. In some cases, drivers are unable to see children and/or wheelchair users in the crosswalk. Locating the stop line in advance of the crosswalk by 3.0 m [10 ft] or more, or increasing the width of the crosswalk, may be considered where there are large numbers of trucks or pedestrians at an intersection. These greater setbacks may benefit from a supplemental sign, such as YIELD HERE TO PEDESTRIANS or the in-street sign STOP FOR PEDESTRIAN WITHIN CROSSWALK in states where stopping is required. (15) The placement of this sign, combined with the setback stop line, can improve sight distances between pedestrians and drivers.

3.3.5 Sidewalk and Curb Treatments at Pedestrian Crossings

Since most pedestrian crossings are at intersections, pedestrian needs—and particularly sidewalk and curb treatments—are a key consideration in the design of street corners. The use of curb extensions at a street corner can effectively reduce the pedestrian crossing distance, and reduced turning radii can affect the speed of motor vehicles turning right at the intersection. A properly designed street corner configuration will also improve sight distances for both pedestrians and motorists.

Utility poles, traffic signs, signals, signal control boxes, pedestrian call buttons, and street name signs should be located so they do not obstruct crosswalks, landing areas, and other parts of a pedestrian route. The attributes of well-designed street corners include:

- *Clear Space*—Corners should be clear of obstructions and have enough space to accommodate the typical number of pedestrians waiting to cross. They should also have enough room for curb ramps, pedestrian signal controls, transit stops where appropriate, and street conversations.

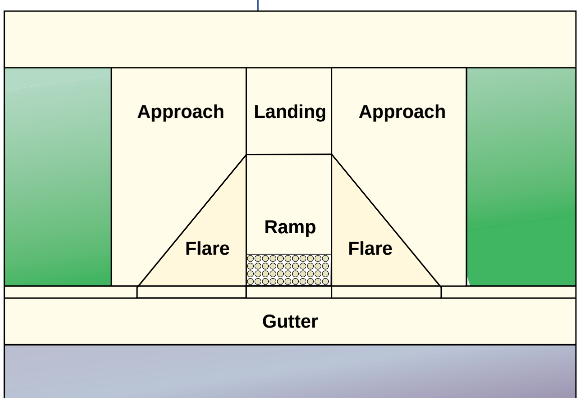

Exhibit 3-26. Standard Curb Ramp Components (13).

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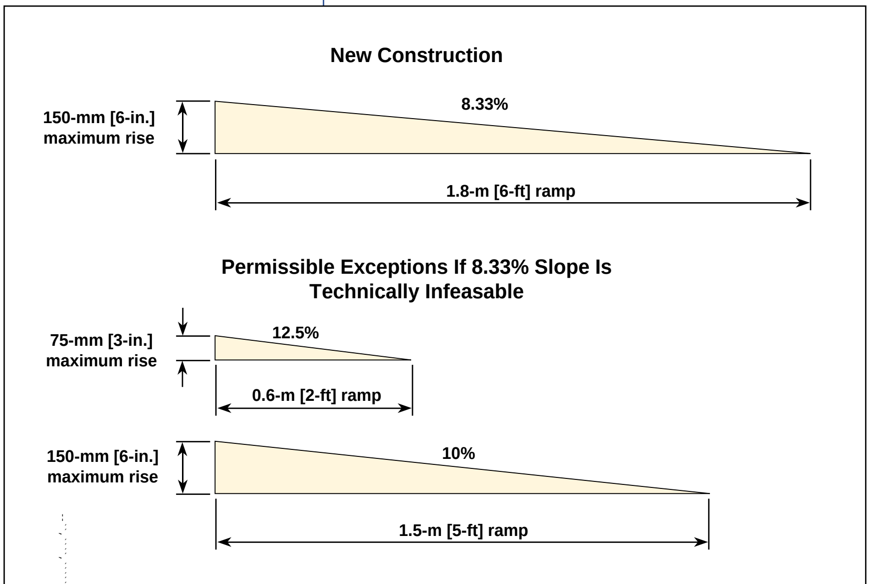

Exhibit 3-27.
Permissible Curb Ramp Grades (29).

- *Visibility*—It is critical that pedestrians at the corner have a good view of the travel lanes and that motorists in the travel lanes can easily see waiting pedestrians. Curb extensions are an excellent technique for increasing visibility.
- *Legibility*—Symbols, markings, and signs used at corners should clearly indicate what actions the pedestrian should take.
- *Accessibility*—Corners have limited slopes with required maneuvering space to use pushbuttons and curb ramps serving each crosswalk; pavement markings having high contrast and detectable warnings identify the sidewalk/street interface underfoot; accessible pedestrian signals (APSs) are utilized.
- *Small Turning Radii*—Use of effective curb turning radii can maximize the space available for waiting pedestrians, as well as reduce turning vehicle speeds.
- *Separation from Traffic*—Corner design and construction must be effective in discouraging turning vehicles from driving over the pedestrian area.

Curb Ramp Design

Curb ramps provide access between the sidewalk and the street for people who use mobility aids such as wheelchairs and scooters, people pushing strollers and pulling suitcases, children on bicycles, and delivery services. Curb ramps are required at all pedestrian crossings, including midblock crossings as well as at intersections. Curb ramps should be designed to the least slope consistent with the curb height, available corner area and underlying topography. A level landing is necessary for turning, maneuvering, or bypassing the sloped surface. Proper curb ramp design is important to users either continuing along a sidewalk path or attempting to cross the street.

There are four basic components of a standard curb ramp design—ramps, gutters, landings, and flares. Exhibit 3-26 identifies the approach area to a curb ramp. Approach area design considerations are equally applicable to any sidewalk on a pedestrian access route.

• Curb Ramps

The grade of a curb ramp must not exceed 8.33 percent (1V:12H), except in special cases discussed below. The cross slope must not be greater than two percent. A flatter slope should be used, where practical. In cases where it is not technically feasible to retrofit a curb ramp to 8.33 percent, a slope between 8.33 and 10 percent with a maximum rise of 150 mm [6 in.] or a slope between 10 and 12.5 percent for a maximum rise of 75 mm [3 in.] may be used (12) (see Exhibit 3-27).

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A curb ramp in new construction should be a minimum of 1.2 m [4 ft] wide, not including the widths of the flared sides. In existing sidewalks, a minimum width of 0.9 m [3 ft] may be all that can be achieved. If curb ramps are the full width of the sidewalk, however, people with vision impairments may have a difficult time identifying them. Detectable truncated-dome warnings, 0.6 m [2 ft] wide, must be provided for the full width of ramps and blended connections to mark the street edge (see Exhibit 3-28).

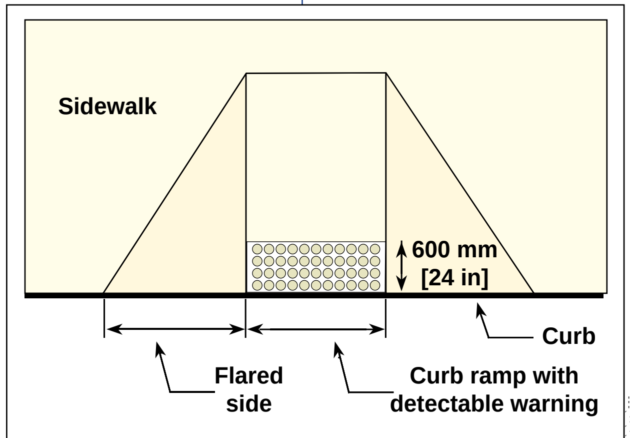

Exhibit 3-28. Detectable Warning Treatment. (12)

• Gutters

Gutters require a counter slope at the point at which the ramp meets the street (see Exhibit 3-29). This counter slope may not exceed five percent, the algebraic difference in slope between the gutter and the adjacent curb ramp should not exceed 11 percent, and the change in angle must be flush, without a lip, raised joint, or gap. Lips or gaps between the curb ramp slope and counter slope can arrest forward motion by catching wheelchair caster wheels or crutch tips.

• Landings

Landings provide a level area (less than two percent grade or cross slope) for wheelchair users to wait, maneuver into or out of a curb ramp, or to bypass the ramp altogether. A level landing 1.5 m [5 ft] square is recommended, and 1.2 m [4 ft] is the required minimum. A stationary design wheelchair is 1.2 m [4 ft] long and a scooter is 1.3 m [4.33 ft], and the wheelbase widths typically range from 0.45 m [1.5 ft] for manual chairs to 0.9 m [3 ft] for scooters and large powered chairs. Where a parallel ramp is used and the level landing separates opposing upslopes, a 1.5 m [5 ft] square landing is needed to ensure that foot rests do not hang up on the ramp ahead (see Curb Ramp Types in the next section).

Existing facilities do not always have landing areas because of right-of-way restrictions or the presence of obstructions. However, landing areas that meet the guidelines presented above should be provided in new construction, reconstruction, or alterations.

Landings should also be provided at raised medians or crossing islands adjacent to channelized right-turn slip lanes (or a level cut-through should be provided).

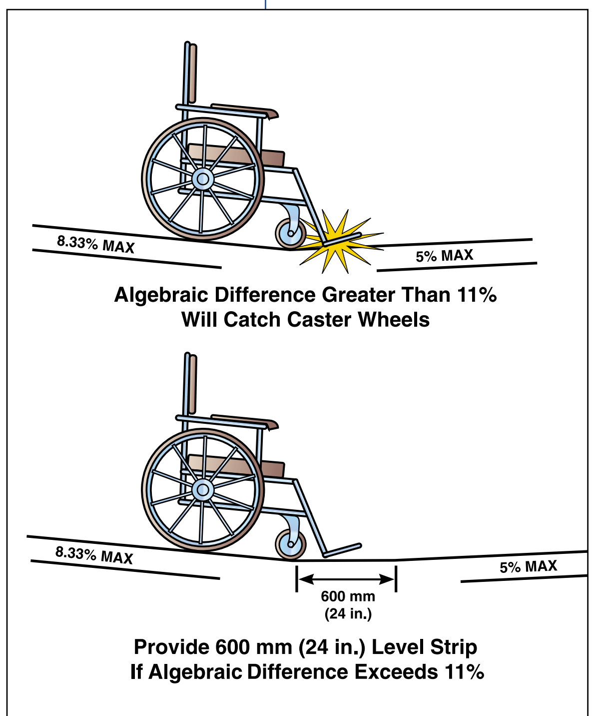

Exhibit 3-29. Counter Slope Conditions (25).

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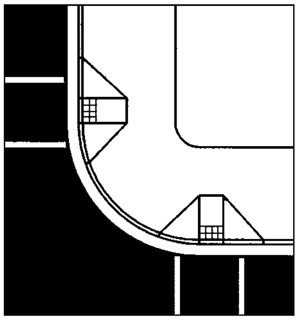

*Exhibit 3-30.
Perpendicular Ramps (13).*

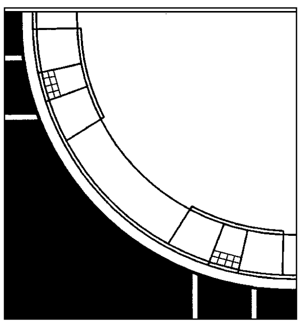

*Exhibit 3-31.
Parallel Ramps (13).*

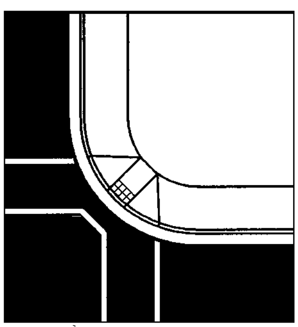

*Exhibit 3-32.
Diagonal Ramp (13).*

• Flares

Curb ramp flares are graded transitions from a curb ramp to the surrounding sidewalk. Flares are not intended to be wheelchair routes, and are typically steeper than the curb ramp with significant cross slopes. For pedestrians with vision impairments, flares may be one of the cues used to identify a curb ramp and the upcoming street edge. If the landing width is less than 1.2 m [4 ft], the slope of the flare may not exceed 8.33 percent. If the landing is wider, a flare slope of 10 percent is preferred to help prevent possible tripping.

Flares are only needed in locations where the ramp edge abuts a paved portion of the sidewalk. A curb is used where the ramp edge abuts grass or other landscaping. If the curb ramp is situated in such a way that a pedestrian cannot walk across the ramp sides, flares may be replaced with a curb adjacent to the ramp (13). Straight returned curbs are a useful orientation cue to provide direction for pedestrians with vision impairments.

Curb Ramp Types

The appropriate type of curb ramp to be used is a function of sidewalk and border width, curb height, curb radius, and topography of the street corner. Three types of ramps are currently used in street corner designs: perpendicular, parallel, and diagonal ramps. These specific ramp types are illustrated in Exhibits 3-30 through 3-32. Curb ramps should be located entirely within the marked crosswalks (where they exist). Drainage grates or inlets should not be located within the crosswalk area. Such grates are a potential problem for wheelchairs, strollers, and those who use walkers.

• Perpendicular Ramps

These ramps are perpendicular to the curb face. They are generally the best design for pedestrians, provided that a 1.2-m [4-ft] landing is available for each approach (see Exhibit 3-30). If landings are not provided, perpendicular ramps may not be accessible.

Where the sidewalk is too narrow to accommodate the length of a curb ramp with the required maximum slope or to accommodate a landing, alternatives include: (1) providing a gradual lowering of the sidewalk and curb height on the approaches to the corner; (2) purchasing or obtaining an easement from the adjacent property to provide additional right-of-way adjacent to the sidewalk; (3) installing a raised crossing; or (4) adding a curb extension. Where curb parking exists, constructing a curb extension can also create the sidewalk space needed to install a standard ramp (see Section 3.3.2 on Crossing Distance Considerations).

• Parallel Ramps

Parallel ramps are used where the available space between the curb and the property line is too tight to permit the installation of both a ramp and a landing. In some cases, merely reducing the curb radius can permit the construction of perpendicular ramps. When this is not possible, the entire sidewalk is brought down to the street grade beyond the intersection crosswalk area with only a two percent drainage slope to the gutter. A minimum 1.2 m [4 ft] landing is required between the two ramps. Detectable warning strips are needed on the landing at the curb line between the two ramps. Guide strips along the crosswalk

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lines or preferably in the middle of the crosswalks may be considered to give guidance to pedestrians with vision impairments, since the ramp slope is no longer parallel with the crosswalk (see Exhibit 3-31). This is similar to the recommended treatment for driveways with dipped sidewalks illustrated in Exhibit 3-10. (see Section 3.2.6 on Driveway Access Management).

• Diagonal Ramps

Diagonal ramps are single perpendicular curb ramps that are located at the apex of the corner. Diagonal ramps are often appropriate in retrofit projects at existing intersections where the location of drainage inlets or other design considerations make the provision of separate perpendicular ramps for each crosswalk impractical. Diagonal ramps may also be appropriate in retrofit projects at locations with low vehicle and pedestrian volumes.

A disadvantage of diagonal ramps is that they often require pedestrians to enter the intersection prior to entering a crosswalk, which creates additional exposure for the pedestrian. Diagonal ramps may also create problems for pedestrians with vision impairments by aiming them away from the crosswalk. Where used, an additional clear level space should be marked as part of the crosswalk at the base of the ramp to give pedestrians space clear of through traffic to maneuver into their desired crosswalk. This clear space should be a minimum of 1.2 m [4 ft] from the edge of the ramp and should not extend into a travel lane (3). Diagonal ramps also need a 1.2-m [4-ft] landing at the top of the ramp (see Exhibit 3-32).

Although diagonal ramps are typically less costly than perpendicular ramps, they may increase the potential of vehicle-pedestrian conflicts because of the possibility of vehicles encroaching into the clear space area at the bottom of the curb ramp. Because of the disadvantages of diagonal ramps, where space is available, new construction should include two perpendicular (or parallel) ramps rather than a single diagonal ramp. Where practical, existing diagonal ramps should be replaced with two perpendicular ramps or consideration should be given to the addition of curb extensions.

• Curb Ramp Placement

Intersections may have unique characteristics that can make the proper placement of curb ramps difficult, particularly in retrofit situations. However, there are some fundamental guidelines that should be followed:

- Perpendicular ramps should be built at an angle of 90 degrees to the curb face; their full width at the toe (exclusive of flares) must be within the crosswalk. Aligning the curb ramp with the crosswalk provides an additional cue for in-line travel across a street by pedestrians with vision impairments; however, because diagonal ramps are used at many locations, such cues cannot be relied upon.
- Curb ramps should be located away from storm drain inlets, which can catch wheelchair casters or cane tips.
- Curb ramps should be designed for adequate drainage. The presence of a puddle of water at the base of a curb ramp can hide pavement discontinuities and can lead to icy conditions during cold weather.

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Exhibit 3-33. Example of Midblock Crossing (10).

• Curb ramps should be situated so that they are adequately separated from parking lanes. Regulatory signs and parking enforcement can help prevent vehicles from blocking or backing across a crosswalk or curb ramp. Even better, curb extensions physically prevent parked cars from encroaching into the curb ramp.

In cases with large turning radii, where the radius cannot be made smaller, it may not be possible to align the ramp run entirely parallel to the crosswalk and still be perpendicular to the curb face. In these cases, it may be possible to install two perpendicular curb ramps aligned parallel to the crosswalk and by introducing a short landing at the bottom of the ramp. This will avoid directing visually impaired pedestrians into the intersection. Another alternative for large turning radii, where sufficient right-of-way is available, is to construct two perpendicular ramps leading to a single 1.5 m [5 ft] landing area just behind the curb line.

If a perpendicular approach is not provided, pedestrians who use wheelchairs face a change in cross slope with only one front or rear wheel in contact with the ground (13).

Detectable Warnings

Vertical curbs provide a reliable cue to pedestrians with vision impairments that they have arrived at an intersecting street. Detection of a vertical curb can unmistakably inform pedestrians with vision impairments that they have come to the end of the sidewalk and that their next step will be into the street.

Blended curbs, rolled curbs, and depressed corners may be provided in areas used by pedestrians as long as detectable warnings are provided. A detectable warning is a standardized feature built into, or applied to, walking surfaces to warn people with vision impairments that they have reached a location where caution should be exercised. At these locations, visually impaired pedestrians typically stop and determine their position relative to the roadway before proceeding further. The ADAAG (12) specifies that detectable warnings shall consist of raised truncated domes and specifies the dimensions and patterns of truncated domes to be used. The detectable warnings are to be installed in a 0.6-m [2-ft] strip at the curb line for the full width of the ramp or walk (see Exhibit 3-28).

Some textured surfaces intended to provide information about the location of a street or other feature are not, in fact, detectable. Grooves, crosshatching, exposed aggregate, and similar surfaces may be useful to prevent slippage, but are not detectable underfoot and are not approved for this purpose.

Another type of cue is the accessible pedestrian signal (APS). APSs include devices that emit audible sounds when the signal permits pedestrians to cross, and a locator tone at the pedestrian pushbutton can also indicate the presence of the street. These are discussed further in the section on Pedestrian Signals in Chapter 4.

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In the absence of a definitive cue (e.g., a curbed sidewalk at the sidewalk/street boundary), it becomes much more difficult for pedestrians with vision impairments to detect streets. When pedestrians with vision impairments do not encounter a curb at the end of a block, they must rely on multiple cues, which when taken together, indicate they have come to a street. One of the most reliable cues, when it is present, is the sound of traffic on the intersecting street. However, intermittent traffic on a wide street can be a misleading cue (7).

3.3.6 Street and Intersection Lighting

Proper lighting can have a beneficial effect on the safety and comfort level of the pedestrian. Adequate lighting should be included at both unsignalized and signalized intersections if pedestrians are present during nighttime hours. Lighting should not only highlight the presence of intersections, but also midblock crossings. In situations where lighting is not provided along the entire length of a roadway, lighting should be provided at intersections in urbanized areas.

In areas with heavy tree growth, lighting needs may need to be evaluated during the summer months when the potential of blockage by foliage is at its greatest. More importantly, the placement and type of trees should be evaluated ahead of time, whenever possible. A regular pruning and maintenance program is also advised.

3.4 Midblock Crossings

Designated midblock crossings can help supplement the crossing needs within an area. At specific locations where intersections are spaced relatively far apart or substantial pedestrian generators are located between intersections, midblock crossings may be utilized. Midblock crossings are preferred because pedestrians should not be expected to make excessive or inconvenient diversions in their travel path to cross at an intersection. On the other hand, because midblock crossings are not generally expected by motorists, they should be used only where truly needed and should be well signed and marked. Exhibit 3-33 shows an example of a midblock crossing.

Designated midblock crossings are located according to a number of factors including pedestrian volume, traffic volume, roadway width, traffic speed and type, desired paths for pedestrians, and adjacent land use. For example, midblock crossings may be appropriate where a high pedestrian traffic generator is located directly across the street from a significant source of pedestrians, such as a fast food restaurant across the street from a university. They may also be used at other obvious locations, such as where a multiuse trail facility crosses a roadway. In many jurisdictions, individual pedestrians may cross the roadway legally at midblock locations, even where no crossing has been established. Midblock crossings should be considered at locations where substantial pedestrian volumes are expected to cross the roadway.

Designated midblock crossings should not be installed where sight distance or sight lines are limited for either the motorist or pedestrian.

In most cases, marked crosswalks alone should not be installed within an uncontrolled environment when speeds are greater than 65 km/h [40 mph]. Under certain conditions,

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Exhibit 3-34.
Median Plantings to Discourage Midblock Crossing (16).
Photo courtesy of
James T. McDonnell.

marked crosswalks may be used to supplement an existing or new traffic control feature. Research indicates that where crosswalk markings are used at uncontrolled crossing locations along multi-lane roads (i.e., roads with four or more lanes) on which traffic volumes exceed approximately 12,000 vehicles per day with no raised medians, or exceed 15,000 vehicles per day with raised medians that could serve as crossing islands, the potential for motor vehicle-pedestrian crashes increases (30).

Attributes where midblock crossings can be most effective include:

- The location is already a source of a substantial number of midblock crossings.
- Where a new development is anticipated to generate midblock crossings.
- The land use is such that pedestrians are highly unlikely to cross the street at the next intersection.
- The safety and capacity of adjacent intersections or large turning volumes create a situation where it is difficult to cross the street.
- Spacing between adjacent intersections exceeds 200 m [660 ft].
- The vehicular capacity of the roadway may not be substantially reduced by the midblock crossing.
- Adequate sight distance is available for both pedestrians and motorists.

Midblock crossings should be identifiable to pedestrians with vision impairments. Where there is a signal, a locator tone at the pedestrian button may be sufficient. Some jurisdictions use a tactile strip across the width of the sidewalk leading to the crosswalk so that pedestrians are alerted to the presence of the crossing.

The following sections discuss various design features (e.g., pedestrian signals, signing, crossing islands, and curb extensions) that can help provide midblock crossing opportunities for pedestrians.

3.4.1 Crossing Distance Considerations

At midblock locations where the crossing exceeds 18 m [60 ft], or where there are a limited number of gaps in traffic, a median or crossing island should be considered. The use of medians or crossing islands in conjunction with a midblock crossing can reduce the crossing distance and wait time for pedestrians, as well as provide an improved crossing environment. Because the motorist does not typically expect pedestrians to cross at midblock locations, medians and crossing islands can provide added protection for the pedestrian.

A median or crossing island is a raised area separating the two main directions of traffic movement. Medians tend to be long and continuous, while crossing islands are much

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shorter. The use of medians or crossing islands is related to roadway classification, as well as the expected use of the midblock crossing. On a local road with relatively low traffic speeds and volumes, placing a median or crossing island might be done for aesthetic considerations or special pedestrian crossing characteristics and volumes. On a collector road with moderate-to-high traffic speeds and volumes, a median or crossing island installation should be strongly considered. Lastly, should a midblock crossing be provided along a multilane arterial, a median or crossing island is desirable, and consideration should be given to providing supplementary traffic control devices. However, even on low-volume, two-lane roads, crossing islands can provide traffic-calming and pedestrian crossing benefits.

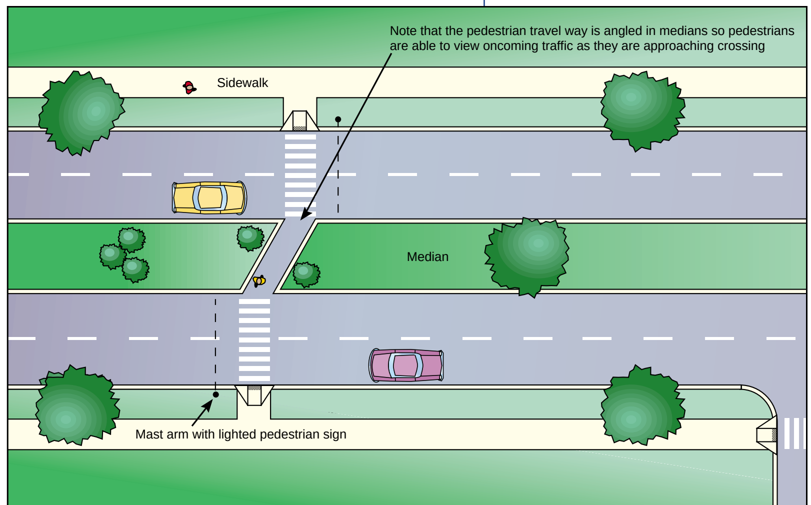

Exhibit 3-35. Midblock Crossing of Four-Lane Arterial (29).

Where pedestrians cross roadways at signalized intersections, adequate time should be provided to cross the entire roadway during the pedestrian phase. The MUTCD (15) recommends that a walking speed of 1.2 m/sec [4 ft/sec] be assumed in the development of the phasing for signalized intersections. However, where pedestrians who travel more slowly may not be able to cross the roadway in one cycle, a median or crossing island (often referred to as a refuge island) should be considered. Pedestrians who often travel more slowly than 1.2 m/sec [4 ft/sec] include very young pedestrians; older pedestrians; wheelchair, cane, and prosthesis users; and pedestrians with vision impairments.

Benefits of Medians and Crossing Islands

The primary advantage of a median or crossing island is that it separates conflicts in time and place. The pedestrian faced with one or more lanes of traffic in each direction must determine a safe gap for two, four, or even six lanes at a time. This is a complex task, requiring accurate decisions. Medians or crossing islands allow pedestrians to cross one direction of traffic at a time and provide a refuge island halfway across the street.

Design Dimensions of Crossing Islands

Islands that use ramps should have a level landing at least 1.2 m [4 ft] square to provide a rest area for wheelchair users. This level area, combined with a maximum ramp slope of 1V:12H, means that ramped islands are only feasible where the median or island width is at least 4.2 m [16 ft]. Detectable warnings should be provided at the bottom of all ramps. The length of a median island parallel to the street should be at least 6.0 m [20 ft] to protect the potential users and to be visible to approaching motorists.

Various median and crossing island design considerations include:

- Medians and crossing islands should be at least 1.8 m [6 ft] wide so that more than one pedestrian can wait and so that 0.6 m [2 ft] detectable warnings can be provided at both sides of the island. Where practical, a width of 2.4 m [8 ft] may be provided to accommodate bicycles, wheelchairs, scooters, and groups of pedestrians, and to

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Exhibit 3-36.
Midblock Crossing with Curb Extension (18).

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provide a pedestrian storage area separated by at least 0.6 m [2 ft] from the face of the curb.

- The lengths of medians and crossing islands should be as described in Section 3.4.1 Crossing Distance Considerations.
- Trees in medians and at the sides of streets can help to narrow the long-range field of vision for approaching drivers, causing them to slow down as they drive. Landscaping on the approach to the intersection on median crossing islands must not block the sight lines of pedestrians and motorists at the crossing area. Trees placed in the median should meet the requirements of the AASHTO *Roadside Design Guide* (4).

- Curb ramps or full cut-throughs should be installed in all median crossing islands. Cut-throughs are more common because the median width is often not wide enough to accommodate ramps. Cut-throughs should be designed with a slope, up to a maximum of two percent, to allow water, silt, and debris to drain from the area. Detectable warnings should be placed at both curb ramps and cut-throughs to identify the street edge for pedestrians with vision impairments.
- A pedestrian pushbutton should be placed in the median of all signalized midblock crossings with actuated controllers where the total crossing distance exceeds 18 m [60 ft]. Pedestrian pushbuttons in the median should be equipped with locator tones that pedestrians with vision impairments will be able to locate and use them.
- Roadway lighting may be used to illuminate medians and crossing islands.

Medians and crossing islands also provide an excellent opportunity to incorporate landscaping within the roadway. However, care should be taken to ensure that landscaping does not decrease visibility, and that it allows a pedestrian to be easily detected from all approaches. Motorists often react favorably to the presence of a well landscaped area, often reducing their driving speed. Thus, the use of small trees, low shrubs, colorful native plants, and other landscaping is a positive feature. Maintenance of the plantings is essential.

There may be situations where it is appropriate to prohibit midblock crossings, such as areas where traffic volumes and/or speeds make intersection crossings the preferred option. Midrise shrubs and other types of plantings can serve as an alternative to fencing in order to block midblock access to pedestrians and divert them to adjacent intersections (see Exhibit 3-34).

Signs and Pavement Markings

Midblock crossings, while providing an excellent crossing opportunity for pedestrians, are not typically expected by a motorist. As noted previously, when crosswalks are used at uncontrolled locations along multilane roads, the potential for vehicle-pedestrian crashes increases. In these cases, more substantial improvements are often needed for safe pedestrian midblock crossings, such as providing raised medians or crossing islands, curb extensions, or adding traffic signals with pedestrian signals.

Where it is considered desirable to install midblock crosswalks, pedestrian warning signs should be used (see Section 4.2 on Pedestrian-Related Signing). Refer to the MUTCD

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(15) for sign placement criteria. Other traffic control measures may also be needed to slow or stop traffic prior to the crossing. Traffic control devices such as yield signs, flashing yield signs, or traffic signals can be incorporated into the design of a midblock crossing. If used, yield lines (triangles that extend across all approach lanes) should be installed at least 1.2 m [4 ft], and desirably 3.0 m [10 ft], in advance of and parallel to the nearest crosswalk, to help prevent motorists from encroaching into the pedestrian crossing space (see Exhibit 3-35) (16).

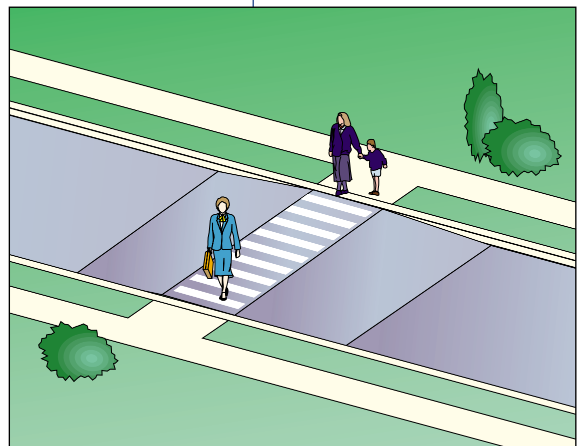

Exhibit 3-37. Raised Midblock Crossing (24).

Overhead pedestrian crossing signs on span wires or mast arms above the street can improve motorist awareness of a midblock crossing. At locations with extremely high pedestrian volume during certain times of the day, a signalized crossing with pedestrian actuation should be considered.

On-street parking can reduce sight distances and sight lines at midblock crossings. In areas with on-street parking, midblock crossings should include crosswalk markings, advance signing, and a curb extension or more extensive parking restrictions (see Exhibit 3-36).

3.4.2 Traffic Calming at Midblock Locations

The addition of available design features can make midblock crossings act as traffic-calming devices as well. The two design elements used most frequently are curb extensions and raised crossings.

Curb extensions reduce the crossing distance for pedestrians, improve sight distance for all users, and slow down traffic. Curb extensions narrow the street to provide a visual distinction to an oncoming motorist that they are approaching a pedestrian crossing. When used on arterial streets, the remaining roadway width should be adequate for both motor vehicles and bicycles. In general, curb extensions should extend approximately 1.8 m [6 ft] from the curb.

Raised crossings function as an extension of the sidewalk and allow pedestrians to cross at close to a constant grade, without the need for curb ramps (see Exhibit 3-37). Whether used in conjunction with curb extensions or used alone, raised midblock crossings serve as a type of speed hump that slows traffic across the crosswalk area. They are suitable only on low-speed local streets that are not emergency routes.

Raised crossings should have a parabolic approach transition, raising the vehicle at least 75 to 150 mm [3 to 6 in.] above the nominal pavement grade. The flat section of the crossing table should be 3.0 to 3.6 m [10 to 12 ft] wide.

Raised crossings should be highly visible and striped as a midblock crossing. The approach should be clearly marked or constructed of a contrasting pavement design. The pavement surface must be smooth and stable, without deep grooves or joints, to provide maximum accessibility. Detectable warnings should be placed at the curb lines to assist pedestrians with vision impairments. For more details, see Section 2.6 on Traffic-Calming Treatments.

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3.4.3 Midblock Signals

The placement of midblock signals may be appropriate at some locations. Such signal installations should be made in accordance with the requirements of the MUTCD (15). APSs are recommended at midblock locations, since pedestrians with vision impairments do not have the sound of cross street traffic as an indicator of the signal change. If an actuated midblock signal system is used at a location where a median is present, pedestrian actuator buttons should be provided in the median, as there will be times when some pedestrians start too late or when slower pedestrians lack time to cross. In these situations, pedestrians should be able to reactivate the signal (16). Pedestrian signals in the median should be accessible to people with vision impairments, particularly if there may not be time to cross in one cycle. Vibrotactile APSs with locator tones may be useful in medians for identifying which crossing is active where audible signal separation is inadequate.

Where there are other nearby signals, midblock signals should be made part of a coordinated signal system. Such systems not only increase the efficiency of traffic operations, but may also reduce the likelihood of rear-end crashes (29). At locations where there is no coordinated signal system, or no other nearby signals are present, it is desirable for a midblock pedestrian signal to provide a hot response (nearly immediate), in which the clearance interval (yellow signal) for motor vehicle traffic is initiated as soon as the pedestrian call actuator button is pushed. This minimal wait time is a strong inducement for pedestrians to walk out of their way to use the crossing. Pedestrians may feel frustrated if a signal is holding them back from crossing when there are ample gaps. Many will choose to cross away from the crossing, while others will dutifully push the activator button, get no immediate response, and cross as soon as there is a sufficient gap. A few seconds later, the approaching motorists must stop at a red signal for no apparent reason, which can encourage motorist disrespect for the signal in the future. Even where midblock pedestrian signals are part of a coordinated signal system, it may be possible to provide a hot response during off-peak hours.

3.5 Grade-Separated Crossings

There are locations where a grade separation for pedestrians is desirable and even necessary. The most common examples are crossing over or under freeways and railroads. Various grade-separated crossing alternatives are available that can provide facilities for the pedestrian and motorist to cross at different levels. Grade-separated structures can improve pedestrian safety when appropriately located and designed.

However, grade-separated crossings can be quite expensive, may be considered unattractive, may become sites for crime or vandalism, and may even decrease safety if not properly located and designed. It may also be difficult to get the pedestrians to use an overpass or underpass if the perceived risk to the pedestrian of crossing at grade is not apparent or the proposed pedestrian route is too inconvenient.

Where pedestrians must change elevation to use a grade-separated crossing, access to the crossing must be provided by a ramp that meets ADAAG (12) requirements or by an elevator.

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Attributes of well-designed grade-separated crossings include:

- The facility is located where it is needed and will actually be used.
- Crossing structures are built with adequate widths based on perceptions of safety as well as pedestrian volumes.
- The design is accessible for all users.
- Barriers/railings are provided to add an increased sense of safety to the pedestrian.
- The facility is well lit to provide an increased level of security to the pedestrian.

Exhibit 3-38. Undesirable Condition Due to Lack of Sidewalk Continuity (18).

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3.5.1 Sidewalk Continuity

Connectivity of the walking environment is just as important for pedestrians as a completely developed roadway network is for motorists. Even where a community has a good system of sidewalks along every developed street, the system can break down where the community is split by major highways, railroads, or rivers (see Exhibit 3-38).

Roadway system connectivity is maintained with bridges, underpasses, and tunnels, and these roadway connection structures must also include adequate and accessible pedestrian accommodation.

There are situations where pedestrian overpasses or underpasses may be needed to provide full connectivity or to avoid unusually congested or high-conflict locations. Because of the high cost of constructing pedestrian structures, they should be considered only where other more standard and/or less costly solutions are not practical or acceptable.

3.5.2 Planning Considerations

Because of the high costs associated with grade-separated facilities, they should be incorporated into the early stages of planning for new developments that are intended to generate substantial volumes of pedestrians. Grade-separated crossings can be most beneficial under the following conditions:

- Where there is moderate-to-high pedestrian demand to cross a freeway or expressway.
- Where there are a large number of children (i.e., particularly near schools) who must regularly cross a high-speed, high-volume roadway.
- Where the traffic conflicts that would be encountered by pedestrians are considered unacceptable (e.g., on wide streets with high pedestrian crossing volumes combined with high-speed traffic).
- 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

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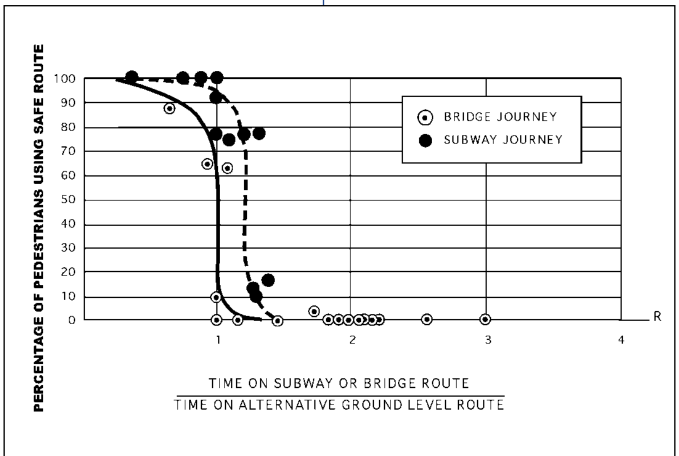

Exhibit 3-39.
Pedestrian Use of Bridges/Tunnels Based on Convenience (18).

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a busy street from a school, a parking structure affiliated with a university, a high-volume, multi-use trail, or an apartment complex near a shopping mall) (18).

Since grade-separated crossings used solely by pedestrians and other nonmotorized traffic are expensive to provide, the first priority in improving pedestrian access across a freeway is to take maximum advantage of opportunities to provide pedestrian facilities on existing roadway crossings. For example, it is desirable to have well-spaced bridges and to provide sidewalks on those bridges, especially along streets with no freeway interchanges. If pedestrian crossing needs still have not been met once all opportunities for pedestrian crossings on vehicular bridges have been provided, then additional grade-separated pedestrian crossings should be considered.

Grade-separated crossings work best in areas where pedestrian attractors such as shopping centers, large schools, recreational facilities, parking garages, or other activity centers are separated from the pedestrian generators by freeways or high-volume and/or wide high-speed arterial streets. Grade-separated facilities are sometimes found in suburban and rural areas to provide continuity for regional bikeways or to connect residential areas with shopping centers or schools that are separated by freeways or high-speed arterial highways.

The effectiveness of grade-separated crossings depends on their perceived ease of accessibility by pedestrians. An overpass or underpass will not be used simply because it improves safety. Pedestrians tend to weigh the perceived safety of using the facility against the extra effort and time required. Research has found that the degree of use of overpasses and underpasses by pedestrians depends on walking distances and the convenience of the facility. For example, a convenience measure, *R*, can be 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 Exhibit 3-39. 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, if it took 50 percent longer to cross than at an at-grade crossing ($R = 1.5$), very few pedestrians would use the facility. For this reason, grade-separated crossings work only if they are on the normal path of pedestrian movements, with the least amount of vertical difference possible (18).

3.5.3 Overpasses vs. Underpasses

Overpasses and underpasses have both advantages and disadvantages. For example, underpass vertical clearances of 3.0 m [10 ft] are half the height of required overpass clearances, and underpasses require shorter ramps and less right-of-way than overpasses (see Exhibit 3-40). However, underpasses can be more expensive if the roadway needs to be elevated, and there can also be costs related to utility relocation and drainage problems. In addition, potential security problems often discourage pedestrians from using underpasses, particularly at night (see Exhibit 3-41).

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Overpasses

• Pedestrian Overpasses/Bridges

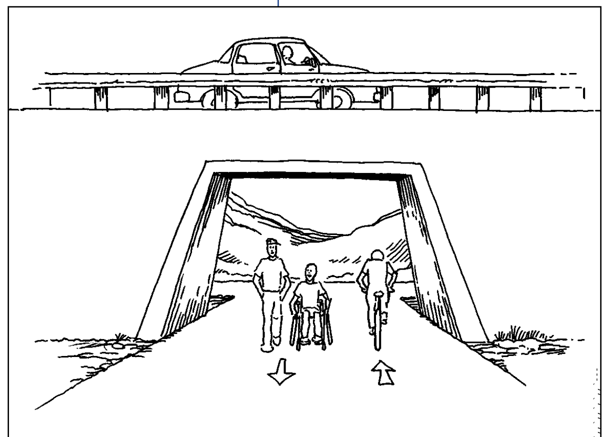

Exhibit 3-40. Convenient and Open Underpass Design (20).

Pedestrian overpasses are typically bridge structures over a major highway or railroad. Where the major highway or railroad is depressed, the bridge can be at ground level. However, in many cases, stairs and ramps are needed to provide access to the overpass. Stairs cannot be the only means to access an overpass, although they can be used to supplement a ramp. Overpasses need to either provide elevator access or meet ADA ramp criteria for maximum slope (8.33 percent), level landings for every 0.75-m [30-in.] rise in elevation, and handrails on both sides. Ramps that rise more than 1.5 m [5 ft] may not be usable by many pedestrians with mobility and stamina impairments. For extended rises, the use of elevators may be considered. In either case, there must be a level transition between the roadside sidewalk and crossing (see Exhibit 3-42). Finally, overpasses may need to be enclosed to prevent the dropping of rocks or other debris onto vehicles passing below.

The minimum inside clear width of a pedestrian bridge on a pedestrian accessible route is 2.4 m [8 ft]. However, if the contiguous sidewalks are greater than 2.4 m [8 ft], the pedestrian bridge should match that width. If the bridge is enclosed to prevent dropping of debris onto the highway below, the visual tunnel effect may require widening the bridge to 4.2 m [14 ft] to provide a feeling of security for all bridge users. This width may need to be even greater if the bridge is very long to compensate for the visual perception of narrowness (17). If the bridge is a shared facility with bicycles, a minimum width of 4.2 m [14 ft] is recommended.

• Elevated Walkways/Skywalks/Skyways

Elevated walkways, skywalks, and skyways are sidewalks or walkways above ground level. Such facilities may be freestanding or connected to adjacent buildings. When enclosed, they are often referred to as skywalks. They are typically built at least one story above ground level to connect buildings and are especially beneficial in extremes of climate. Some cities, however, have discouraged building skywalks where there is a likelihood that such a system would disrupt important architectural views or could create empty streets and/or social class divisions.

Underpasses

• Pedestrian Tunnels/Underpasses

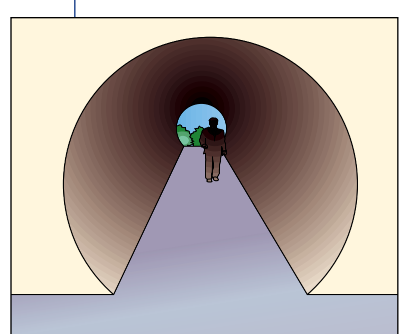

Exhibit 3-41. Uninviting Pedestrian Underpass.

Underpasses include tunnels and openings under bridge structures. Underpasses generally involve ramps that lead down to a below-grade passageway. In some cases, the underpass is at ground level and the road is elevated. If the roadway is not elevated, the end of the underpass should be opened out to provide clear lines of sight to and through the underpass (see Exhibit 3-43). Drainage also needs to be carefully considered.

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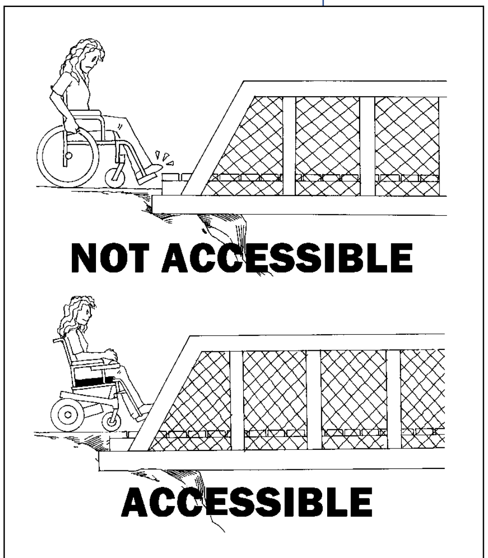

Exhibit 3-42.
Need for Level Sidewalk Transition (20).

Underpasses should be wide enough to invite use by all persons. The longer the tunnel, the wider the tunnel should be to give people a feeling of security when passing one another. A desirable minimum width in rural areas is 3.6 m [12 ft], with wider widths suggested for lengths over 18 m [60 ft]. In urban areas, a desirable minimum width is 4.2 to 4.8 m [14 to 16 ft], with wider widths suggested for lengths over 18 m [60 ft]. These widths also work well for bicycles on shared-use facilities.

The same perception phenomenon, discussed above with respect to increasing tunnel length, also applies to vertical clearances. While a 2.4-m [8-ft] vertical clearance can suffice for short distances, longer distances may require a vertical clearance of 3.0 m [10 ft] or more to maintain a feeling of openness and security for pedestrians. If equestrian use is anticipated, a vertical clearance of 3.0 m [10 ft] should be provided. If emergency or maintenance vehicles will use the tunnel, greater vertical clearance may be needed.

Underpasses can pose a security and maintenance concern. Vandal resistant lighting is important and there is a need to periodically monitor the underpass for graffiti and debris removal. It is desirable to design underpasses so that police can see all the way through them from the street without leaving their vehicles.

- **Below-Grade Pedestrian Networks**

Below-grade pedestrian networks are extensive underground walkway systems that carry pedestrians both parallel and perpendicular to the flow of motor vehicles traveling above them. These networks are usually part of central business district developments and are often used in conjunction with subway systems.

Exhibit 3-43.
Open-Ended Underpass Design.
Photo courtesy of John LaPlante.

3.5.4 Lighting

The AASHTO *Informational Guide for Roadway Lighting* (1) guides the selection of locations at which fixed-source lighting should be provided and presents design guidance for their illumination. This guide also contains a section on the lighting of tunnels and underpasses.

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Chapter 4

Pedestrian Facility Operation and Maintenance

4.1 Pedestrian Signals

Traffic signals assign the right of way to vehicular and pedestrian traffic. When installed appropriately, traffic signals benefit pedestrians by interrupting heavy volumes of motor vehicles where there are insufficient gaps to cross safely at intersections or midblock locations. Unwarranted or improperly designed traffic signals can cause excessive delay for pedestrians and motor vehicles, signal disobedience, and an increase in certain crash types. Even where warranted, traffic signal installations commonly result in an increase in rear-end and total crashes, with a corresponding reduction in the more severe right-angle crashes. The effect of traffic signal installations on pedestrian crashes is not well known, but logistical characteristics of the sites are important factors in the crash experience at signals. Pedestrians with vision impairments prefer to cross at signalized intersections, because signalized intersections provide better cues than unsignalized intersections or midblock locations for safely crossing the road.

4.1.1 Pedestrian Signal Phasing

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

1. Standard (or concurrent) timing involves a WALKING PERSON (symbolizing WALK) signal indication, followed by a flashing UPRAISED HAND (symbolizing DON'T WALK) signal indication, that are displayed concurrently with the green indication for motorists, where motor vehicles may turn left or right after yielding to pedestrians.

2. Advanced pedestrian signal operation (often referred to as Leading Pedestrian Interval (LPI)) displays a two- to four-second WALKING PERSON (symbolizing WALK) signal indication in advance of the vehicular green indication, such that vehicles have an all-red interval. This is after any intersection all-red clearance phase. This advance signal phase allows pedestrians to establish a presence in the intersection and reduces vehicle-pedestrian conflicts.

3. Lagging pedestrian signal operation displays the vehicular green indications before display of the WALKING PERSON (symbolizing WALK) signal indications, allowing queued vehicles to clear before releasing pedestrians. However, this is difficult to enforce and provides little pedestrian advantage unless all turns are then prohibited.

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4. Exclusive pedestrian phasing displays the WALKING PERSON (symbolizing WALK) and flashing UPRAISED HAND (symbolizing DON'T WALK) signal indications without green indications for any conflicting 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.

With any of the nonconcurrent signal phasings above, it must be noted that a person with a vision impairment may not know about the exclusive pedestrian phases unless an APS is installed. Incorporation of audible and vibrotactile components in an APS can help pedestrians with vision impairments have access to the same information as pedestrians with good vision.

Research has indicated that there are no significant differences in crash rates for traffic signals with no pedestrian signals and those with concurrent pedestrian signal phasing. Thus, the installation of standard-timed pedestrian signals should not necessarily be expected to improve pedestrian safety at signalized intersections. At intersections with fewer than 1,200 pedestrians per day, research has shown that there is no significant difference in pedestrian crashes between exclusive pedestrian signal phasing, concurrent pedestrian phasing, and no pedestrian signals.

One method to evaluate these alternative phasing operations includes the conversion of all pedestrian and vehicular delay to "person delay," by using a measured (or assumed) auto occupancy rate for cars and buses. Often concurrent pedestrian phasing provides minimum total delay, particularly where pedestrian volumes are not very high. Adding exclusive pedestrian signal phasing can produce higher total delay by precluding turning vehicle movements when pedestrians are not present.

One method to enable pedestrian right-of-way over turning vehicles is with the LPI. LPIs are usually two to four seconds before the vehicular traffic receives its green indication. This is particularly effective where there are heavy right-turn movements and right turn on red is restricted.

Separate left-turn phasing can often be difficult at locations with heavy pedestrian movements. In these situations, the advanced pedestrian phasing may be preferred because the lagging pedestrian phase is difficult to enforce where pedestrians begin crossing at the onset of the vehicular green in spite of the steady UPRAISED HAND (symbolizing DON'T WALK) signal indication. However, pedestrians with vision impairments who use the surge of parallel traffic may not start if there is no audible signal.

Exclusive pedestrian phasing can reduce turn-merge, multiple threat, and trapped pedestrian conflicts. A turn-merge conflict involves a vehicle that is turning and merging into a new traffic stream. A multiple threat conflict involves one or more vehicles stopped in traffic and the moving driver's vision of the pedestrian is obstructed by a stopped vehicle. A trapped pedestrian conflict occurs when they are trapped in the street during a phase change.

Scramble pedestrian phasing operates well only in very special situations. This operation works best with high pedestrian crossing volumes (i.e., 1,200 or more pedestrians per day), long right-turn queuing resulting from pedestrian conflicts, low through volumes, and narrow streets. Since the diagonal pedestrian movement across the intersection is permitted, the walking distance and resultant pedestrian clearance times are much longer than normal.

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Streets with widths greater than 16 m [60 ft] increase the length of the scramble phase such that it becomes marginally effective. Scramble phasing can produce a safer operation over conventional phasing, but delay for both pedestrians and motorists is always higher than conventional signal timing, and it is rarely practical to install.

In urban areas, the use of continuous free flow through lanes at signalized T-intersections is not recommended. Their use requires the prohibition of pedestrian movements that would cross the continuous through lane. However, the use of an actuated pedestrian phase for what is normally the prohibited movement at a T-intersection is 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 (11).

4.1.2 Pedestrian Signal Timing

The MUTCD (6) recommends that traffic signal timing for pedestrians be based on an assumed pedestrian crossing speed of 1.2 m/sec [4 ft/sec]. However, this assumed walking speed does not reflect the walking rates of many users. At crossings where older pedestrians or pedestrians with disabilities are expected, crossing speeds as low as 0.9 m/sec [3.0 ft/sec] may be assumed. Some signal devices can provide additional time, if required, often by depressing the pedestrian pushbutton for a specified period of time. In either of these two situations, engineering judgment is needed to determine the most appropriate design parameters.

4.1.3 Warrants for Pedestrian Signals

The MUTCD (6) provides eight separate warrants for installing new traffic signals:

- Warrant 1—Eight-Hour Vehicular Volume
- Warrant 2—Four-Hour Vehicular Volume
- Warrant 3—Peak Hour
- Warrant 4—Pedestrian Volume
- Warrant 5—School Crossings
- Warrant 6—Coordinated Signal System
- Warrant 7—Crash Experience
- Warrant 8—Roadway Network

The satisfaction of a traffic signal warrant, or warrants, does not in itself require the installation of a traffic signal. Warrants 4 and 5 relate directly to pedestrians, and Warrant 7 also makes some reference to pedestrian considerations.

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 may be

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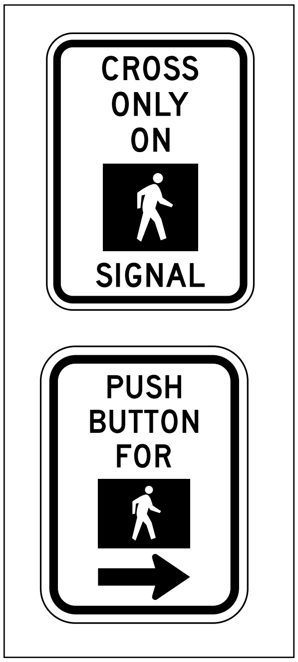

Exhibit 4-1. Pedestrian Crossing Regulatory Signs (R10-2a) and R10-4b) (6).

Exhibit 4-2. Pedestrian Crossing Information Sign (R10-3b) (6).

reduced by as much as 50 percent when the predominant crossing speed is below 1.2 m/sec [4.0 ft/sec]. A traffic signal may not be needed, however, if adjacent traffic signals consistently provide gaps of adequate length for pedestrians to cross the street at a rate of less than one per minute.

Pedestrian signal indications should be provided at traffic signals where:

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

Pedestrian Indications

Pedestrian signal heads provide signal indications exclusively intended for directing pedestrian traffic. These indications consist of the illuminated symbols of a WALKING PERSON (symbolizing WALK) and an UPRAISED HAND (symbolizing DON'T WALK). The MUTCD (6) states that the pedestrian signal head indications shall have the following meanings:

1. A steady WALKING PERSON (symbolizing WALK) signal indication means that a pedestrian facing the signal indication may start to cross the roadway in the direction of the indication, possibly in conflict with turning vehicles.
2. A flashing UPRAISED HAND (symbolizing DON'T WALK) signal indication means that a pedestrian shall not start to cross the roadway in the direction of the

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signal indication, but that any pedestrian who has already started to cross on a steady WALKING PERSON (symbolizing WALK) signal indication shall proceed out of the traveled way.

3. A steady UPRAISED HAND (symbolizing DON'T WALK) signal indication means that a pedestrian shall not enter the roadway in the direction of the signal indication.

4. A flashing WALKING PERSON (symbolizing WALK) signal indication has no meaning and shall not be used.

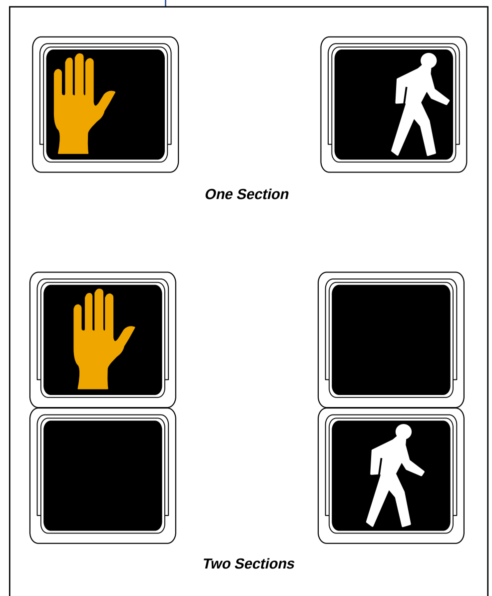

Exhibit 4-3. Various Pedestrian Signal Indications (6).

Research indicates that many pedestrians do not understand the meaning of the pedestrian signals and indications, particularly the flashing UPRAISED HAND (symbolizing DON'T WALK) signal indication. These problems highlight the need for additional research to determine if alternative signal indications would be better understood and more effective. These problems also highlight the need for more effectively educating pedestrians on the meaning of signal indications, including providing signing such as the R10-2a sign "CROSS ONLY ON PEDESTRIAN (SYMBOL) SIGNAL" and the R10-4b "PUSH BUTTON FOR (PEDESTRIAN SYMBOL)" (see Exhibit 4-1) and the R10-3b pedestrian crossing informational sign (see Exhibit 4-2). In addition to educational signs, educational flyers and brochures are recommended for schools and areas where pedestrian violations are a problem.

The MUTCD (6) requires that all new pedestrian signal head indications shall be displayed within a rectangular background and shall consist of symbolized messages, except that existing pedestrian signal indications with lettered messages may be retained for the remainder of their useful service life. Symbol designs are set forth in the Standard Highway Signs section of the MUTCD. Each signal indication shall be independently illuminated and emit a single color. The UPRAISED HAND (symbolizing DON'T WALK) signal section shall be mounted directly above or combined as one unit with the WALKING PERSON (symbolizing WALK) signal section (see Exhibit 4-3).

Exhibit 4-4. Vehicular Signal Heads Are Obscured So Pedestrian Signals Are Necessary.

Photo courtesy of James T. McDonnell.

The WALKING PERSON (symbolizing WALK) signal indication shall be white, and the UPRAISED HAND (symbolizing DON'T WALK) signal indication shall be Portland orange with all except the symbols obscured by an opaque material. (See the MUTCD for further design direction.) When not illuminated, the WALKING PERSON and UPRAISED HAND signal indications shall not be readily visible to pedestrians at the far end of the crosswalk.

For pedestrian signal indications, the symbols shall be at least 150 mm [6 in.] high. Pedestrian signal indications should be conspicuous and recognizable to pedestrians at all distances from the beginning of the controlled crosswalk to a point 3 m [10 ft] from the end of the controlled crosswalk, during both day and night. For crosswalks where the pedestrian enters the crosswalk more than 30 m [100 ft] from the pedestrian signal indications, the symbols should be at least 225 mm [9 in.] high.

Pedestrian signal heads shall be mounted with the bottom of the signal housing including brackets not less than 2.1 m [7 ft] nor more than 3 m [10 ft] above sidewalk level and shall be positioned and adjusted to provide maximum visibility at the beginning of the controlled crosswalk. If pedestrian signal heads are mounted on the same support as vehicular signal heads, there shall be a physical separation between them (6).

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Exhibit 4-5.
Animated Eyes Signal Indicators (4).

Visibility of Devices

As noted in the section on signal warrants, pedestrian signal indications are to be provided when the pedestrian cannot see the vehicular signals to determine the right of way (see Exhibit 4-4). This would include one-way streets and situations when diagonal spans, optically programmed signal heads, or tunnel visors are used. In addition, many people with vision impairments and older adults cannot see the pedestrian signal heads across wide streets (i.e., 23 m [75 ft] or wider). Thus, larger pedestrian signal heads or signals in the medians of such wide streets may be necessary (11).

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

Innovative Signal Options

Two innovative traffic signal indicators still in the experimental development stage are animated eyes and countdown clocks. Animated eyes, also known as searching eyes, are light-emitting diode (LED) signal heads showing two eyes with eyeballs that scan from left to right (see Exhibit 4-5). This signal indication is used to prompt pedestrians to look for turning vehicles at the start of the WALKING PERSON (symbolizing WALK) signal indication (10).

The countdown clock is a device located directly under the WALKING PERSON and UPRAISED HAND signal indications, with numbers large enough to be easily read from the far curb (see Exhibit 4-6). When the flashing UPRAISED HAND (symbolizing DON’T WALK) signal indication begins, the countdown clock shows the number of seconds remaining until the steady UPRAISED HAND (symbolizing DON’T WALK) signal indication begins.

Exhibit 4-6.
DON’T WALK Countdown Clock.

Photo courtesy of James T. McDonnell.

Additional information on these and other innovative devices are available from various sources (7, 8, 15). Only those traffic control devices approved in the MUTCD (6) should be installed along pedestrian facilities unless a device is being installed on an experimental basis.

4.1.4 Pedestrian-Actuated Signals

At locations where pedestrian crossings are infrequent and pedestrian signal phasing is not warranted on a full-time basis, the use of pedestrian-actuated signals (i.e., pushbutton detectors) may be justified. Pedestrian pushbuttons are appropriate where occasional pedestrian movements occur and adequate opportunities do not exist for pedestrians to cross. Actuation of the pushbuttons may be used to extend the green phase to allow pedestrians sufficient crossing time or to provide an extended walk time for a safer pedestrian crossing (11). Where actuation is used, a locator tone can help identify the availability of the pedestrian-actuated function and the location of the button.

Where a pushbutton or other operable device is provided for the use of pedestrians, the mechanism should not require more than 22 newtons [5 pounds] of force to activate.

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Since outdoor devices will often be used by pedestrians with limited use of their fingers, or whose movements may be restricted by bulky clothing or who are wearing gloves, it is advisable to select the largest available pushbutton or pushbar dimension (50 mm [2 in.] recommended minimum) and to ensure that it is raised above the surrounding surface for ease of operation. Devices that can be operated by a closed fist acting on any point on the surface will be most usable by pedestrians with mobility impairments.

Following are some recommended practices for pedestrian signal control design:

- Pedestrian signal controls should be located within reasonable proximity of the curb ramp and crosswalk and should be predictably located throughout a jurisdiction (see Exhibit 4-7).
- Buttons for different crossings should clearly indicate which crossing direction is controlled. If practical, a separate pole may be used for each button.
- Pedestrians who use wheelchairs should be able to operate the button from a level landing rather than the sloped surface of a ramp. Therefore, there should be a 0.9 m x 1.2 m [3 ft x 4 ft] level ground surface centered on each control for a forward or side approach, as appropriate.
- If a forward approach is provided, the button should be located in the same vertical plane as the leading edge of the clear ground space; if a side approach is planned, the clear ground space should be within 250 mm [10 in.] horizontally of the button.
- To ensure that the bar or button is mounted within allowable reach ranges, a maximum height of 1.05 m [3.5 ft] is recommended.

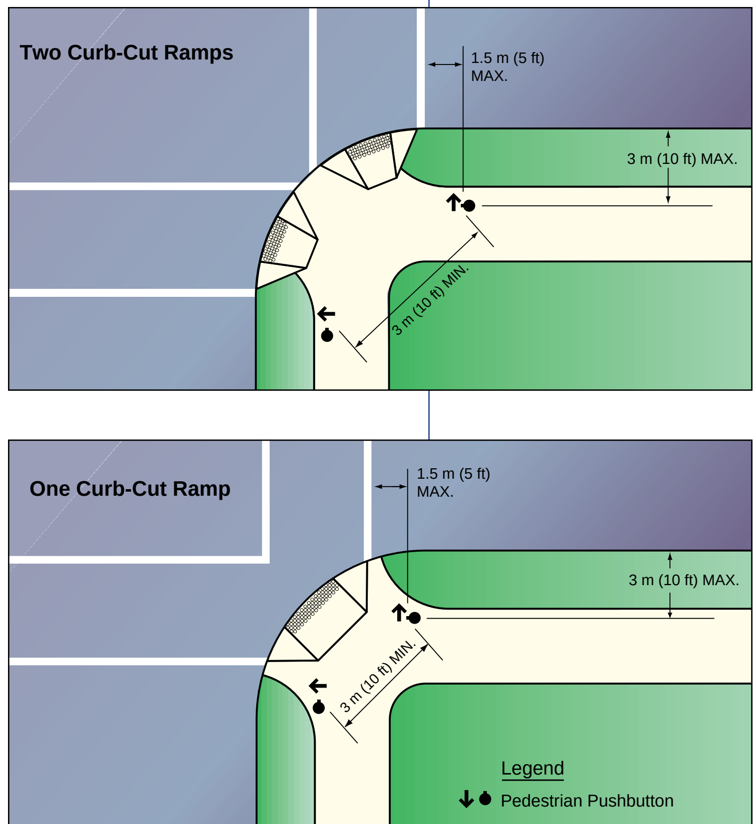

Exhibit 4-7. Location of Pedestrian Pushbuttons (6).

Accessible Pedestrian Signals (APSs)

Pedestrians with vision impairments use audible and tactile cues in independent travel. At intersections with fixed-time signal phasing and consistent traffic flow, traffic signal changes will be reflected in parallel or perpendicular traffic surges. The sounds of these surges are used by pedestrians with vision impairments to identify appropriate crossing intervals.

At actuated traffic signals or intersections with complex or irregular traffic patterns, the signals for automobile and pedestrian traffic do not automatically correspond. Frequently, a separate WALKING PERSON (symbolizing WALK) signal indication will only occur in response to a pushbutton. At this type of crossing (as well as midblock crossings where there is no parallel flow to rely on), an Accessible Pedestrian Signal (APS) may be needed

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to provide pedestrians with vision impairments an equivalent to the visual signal provided for other pedestrians (2).

APSs are currently available that provide information for pedestrians with vision impairments equivalent to the information provided to sighted pedestrians by normal traffic signals. Where pushbutton actuation is used, a locator tone (together with audible and vibrotactile signals in most models) may be integrated into the pushbutton device. Four types of APSs include signals that are audible at the pedestrian signal head, audible at the pushbutton, vibrotactile devices, and those that provide a transmitted message.

- **Audible at Pedestrian Signal Head**

The only type that has been commonly installed in the United States has a speaker on top of the pedestrian signal head. This type has a bell, buzzer, cheep, cuckoo, speech message, or some other tone during the walk interval of the signal only. Some models respond to ambient sound, becoming louder when the traffic noises are louder and quieter when the traffic is quiet. In order to be heard across the street, they must be relatively loud. Surrounding land uses need to be taken into account when considering this type of APS.

- **Audible at Pushbutton**

The second type has a speaker and often a vibrating surface or arrow at the pushbutton. The sound comes from the pedestrian pushbutton housing rather than the pedestrian signal head. This type is common in Europe and Australia.

A constant quiet locator tone, repeating once per second, provides information about the presence of a pedestrian pushbutton and its location. The locator tone is only intended to be audible 2 to 4 m [6 to 12 ft] from the pole or from the building line, whichever is less.

The walk interval may be indicated by a rapidly repeated electronic click, by a speech message, or by other tones. Most versions of this type currently available respond to ambient sound levels. These signals are intended to be heard only at the beginning of the crosswalk and, thus, do not need to be too loud. Audible signals that indicate the walk interval may also be incorporated in fixed-time APSs that do not have pushbuttons.

- **Vibrotactile**

The third type uses only vibration at the pedestrian pushbutton. The arrow or button vibrates during the walk interval. It must be installed very precisely next to the crosswalk to be of value, and the pedestrian must know where to look for it. Vibrotactile devices can be very useful if signal overlaps could give conflicting information, as at a crossing island with multiple closely-spaced devices. They are often installed as an accommodation for pedestrians who are deaf or blind.

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• Transmitted Message

The fourth type uses a message transmitted by infrared or LED technology from the pedestrian signal head to a personal individual receiver. The pedestrian points the receiver at the pedestrian signal head to receive the message. These devices may also give other types of information including information about the name of the streets or the shape of the intersection.

The MUTCD (6) allows any of the above types of APSs and provides recommendations and cautions regarding installation. Designers are encouraged to consult with pedestrians with vision impairments and/or orientation and mobility specialists to determine the most appropriate device for the location. For further information, refer to the MUTCD (6), *Accessible Pedestrian Signals* (3), and *Accessible Pedestrian Signals: Synthesis and Guide to Best Practice* (14).

4.1.5 Wide Crossings

It is highly desirable for pedestrian convenience and compliance to cross an approach in one signal cycle. However, walking distances at wide intersections are often excessive, even for mobile pedestrians, and are especially inhibiting to pedestrians with mobility impairments. These walking distances require long pedestrian change intervals. At heavily loaded intersections, especially with a high volume of 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. One solution is to provide a partial crossing. Where partial crossings are appropriate, the following are options:

1. Use curb extensions (bulb-outs) on raised channelizing islands (particularly for right-turn lanes) to reduce the curb-to-curb walking distance and signal cycle lengths.
2. Construct a median crossing island to reduce the walking distance. This may require slower pedestrians to cross the approach during two signal cycles. Pedestrian push-buttons should be installed on the median and should be accessible to persons with vision impairments. A median APS should be vibrotactile unless the audible signal can be separated sufficiently to make it clear which crossing has the walk.

Alternatively, it is possible to provide the necessary pedestrian crossing time to cross the entire street in one signal cycle and accept a reduced capacity for motor vehicle traffic. Audible beaconing can provide directional cues to pedestrians with vision impairments at wide crossings.

Another alternative is to prohibit particular pedestrian movements and direct them to a safer, nearby crossing location if the crossing distances and signal timing cannot be made acceptable. In most cases prohibition of pedestrian movements is an undesirable alternative and should only be used as a last resort. 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 make the route for the pedestrian discontinuous. It also dra-

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Exhibit 4-8.
Pedestrian Regulatory Signs (6).

matically increases pedestrian exposure, eroding any potential safety gain from prohibiting crossings across the one leg (11).

4.1.6 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 indication at each signal along the system. The use of pedestrian features in a coordinated signal system requires balancing the vehicular movement phasing with the pedestrian crossing time requirements. It is not unusual to have signalized intersections where the pedestrian timing exceeds those for its companion vehicular movements because of walk times.

When the timing demands of the walk and pedestrian change intervals are greater than the vehicle timing demand in concurrent pedestrian signal phasing, the resulting cycle lengths may be 90 seconds or greater. However, pedestrian safety and convenience should not be sacrificed for efficient vehicular movement. Where pedestrian crossings are infrequent, it may be possible to design the system timings without the pedestrian timing, and then, by the use of pedestrian pushbuttons, the local intersection can be disconnected from the system for one cycle to service the pedestrian movement. This practice will degrade the efficiency of the system if the pedestrian timing is activated frequently, since the system will consistently be transitioning into coordination.

It is recommended that one of the following guidelines for handling motor vehicles and pedestrians be used with coordinated signal systems:

1. 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 (11). Fixed-time signal timing is also highly advisable where pedestrian usage of pushbuttons is low. Pushbutton use by pedestrians is often as low as 25 to 33 percent.

2. Use actuated pedestrian signals when pedestrian volumes are very light and when crossing 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.

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4.2 Pedestrian-Related Signing

Part of providing a continuous walking environment includes providing timely information to the pedestrian. Pedestrians rely on wayfinding information, just as motorists do. This section discusses the signing types that can be used to give pedestrians the information they need and/or notify motorists that they are encroaching on a pedestrian area (i.e., crosswalks, midblock crossings, etc.).

Signing is governed by the MUTCD (6), which provides specifications on the design and placement of traffic control signs installed within the public right-of-way. ITE has published a *Traffic Control Devices Handbook* (12) to provide additional guidelines and information with respect to the MUTCD. The MUTCD provides direction for both traditional urban and low-volume rural roadway environments.

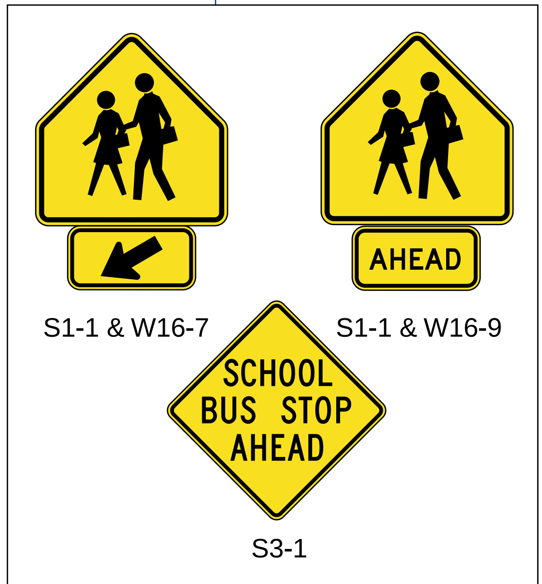

Exhibit 4-9. School Crosswalk Warnings (6).

Examples of regulatory and warning signs related to pedestrians are given in Exhibits 4-8 and 4-9. The MUTCD encourages a conservative use of signs. Signs should only be installed when they fulfill a need based on an engineering study or engineering judgment. In general, signs are often ineffective in modifying driver behavior, and overuse of signs can diminish their effectiveness.

Signs and posts may cause an obstruction to pedestrians and bicyclists, represent an ongoing maintenance cost, and may be a source of visual blight if overused. Sign placement and location criteria are contained in the MUTCD. The minimum mounting height for signs where pedestrians are present is 2.1 m [7 ft]. Diamond-shaped warning signs can be a particular problem when temporarily placed on a sidewalk during construction, as their width at head height may not be detectable at the base for pedestrians with vision impairments.

4.2.1 Regulatory Signs

Regulatory signs are used to inform motorists or pedestrians of a legal requirement and shall only be used when the legal requirement is not otherwise apparent. With the exception of STOP and YIELD signs, regulatory signs are rectangular in shape, usually contain a black legend on a white background, and are reflectorized or illuminated. STOP signs, YIELD signs, turn restrictions, and speed limits affect pedestrians.

The NO TURN ON RED (R10-11a, R10-11b) sign is often used to facilitate pedestrian movements. The MUTCD (6) lists five conditions when no-turn-on-red may be considered, two of which are directly related to pedestrians or signal timing for pedestrians. When overly restrictive, motorist compliance to NO TURN ON RED signs is low, particularly when pedestrian volumes are low and the signs are poorly located (see Exhibit 4-10) (11).

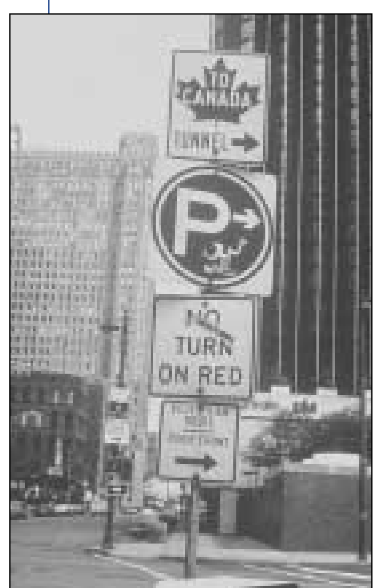

Exhibit 4-10. Poorly located NO TURN ON RED Sign (11).

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While there may be increased vehicle–pedestrian conflicts with right-turn-on-red, the use of NO TURN ON RED signs at an intersection should be evaluated on a case-by-case basis. Part-time restrictions, such as NO TURN ON RED 7 AM to 7 PM. have been found to be effective, whereas supplementary signs such as WHEN PEDESTRIANS ARE

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Posted Speed	Stop Condition
40 km/h [25 mph]	N/A*
60 km/h [35 mph]	30 m [100 ft]
70 km/h [45 mph]	70 m [230 ft]

*No suggested minimum distances are provided for this speed, as placement location is dependent on site conditions and other signing to provide an adequate advance warning for the driver.

Exhibit 4-11. Warning Sign Placement Distances (6).

PRESENT or WHEN CHILDREN ARE PRESENT have little or no effect in reducing vehicle–pedestrian conflicts (12).

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 also a number of regulatory signs directed at pedestrians:

- Pedestrians prohibited signs (R5-10c, R9-3a, R5-10a, R5-10b) are used to prohibit pedestrian entry onto freeway ramps or other potentially dangerous locations.
- Pedestrian crossing signs (R9-2, R9-3a, R9-3b) are used to direct pedestrian crossings away from undesirable locations and divert them to more optimal crossings. For example, the USE CROSSWALK (R9-3b) sign, with supplemental arrow, 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. These signs should be used judiciously at midblock locations. They should not be used to force pedestrians to make unrealistic and excessive diversions to cross at a corner or another marked crosswalk. Where there are significant numbers of pedestrians crossing at midblock locations, consideration should be given to establishing a midblock crosswalk.
- Traffic signal signs (R10-1 to R10-4) include the pedestrian pushbutton signs or other signs at signals directing pedestrians to cross only on the green indication or walk signal. Pedestrian pushbutton 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 pushbutton, and the pushbuttons should be accessible to pedestrians with disabilities.

Other signs may be used for pedestrians at traffic signals to define the meaning of the steady WALKING PERSON (symbolizing WALK), flashing UPRAISED HAND (symbolizing DON’T WALK), and steady UPRAISED HAND (symbolizing 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. This information may also be effectively converted into brochures for distribution and ongoing educational purposes (11).

4.2.2 Warning Signs

Warning signs are used to inform unfamiliar motorists and pedestrians of unusual or unexpected conditions. Although warning signs predominantly fall under the permissive category (“may” condition), when used they should be placed to provide adequate response times. Warning signs are generally diamond-shaped with black letters or symbols on a yellow background, and they are reflectorized or illuminated.

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As a rule, the placement of warning signs in advance of the subject condition should be based on the posted speed within a subject area. For example, Exhibit 4-11 indicates that within areas where the posted speed is 60 km/h [35 mph], the placement of the warning sign should be 30 m [100 ft] in advance of the stop condition (11).

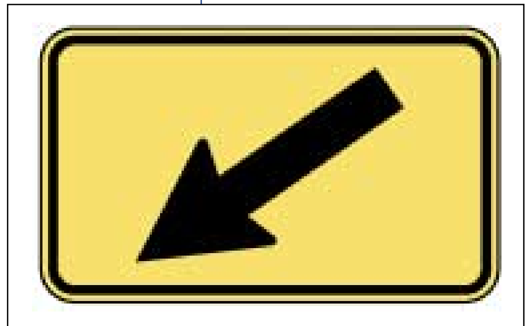

Exhibit 4-12. Diagonal Arrow Plaque (W16-7P) (6).

Pedestrian Crossing Sign

The pedestrian crossing sign (W11-2) serves two functions: to provide advance warning to motorists of possible pedestrian conflicts, and at a crosswalk, to advise motorists of the potential that pedestrians may be attempting to cross.

As an advance warning device, the Pedestrian Crossing sign should be installed in advance of midblock crosswalks or locations where unexpected entries into the roadway by pedestrians might occur. This sign may also be selectively used in advance of 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 such as AHEAD, XX FEET, or NEXT 1/4 MILE. A supplemental plaque shall have the same color, legend, and background as the warning sign with which it is displayed. Supplemental plaques shall be square or rectangular (6, 11).

When used as an advance warning device, the pedestrian crossing sign 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 (6) specifies a 0.75 m x 0.75 m [2.5 ft x 2.5 ft] sign size. However, it may be helpful to use a larger sign (0.9 m x 0.9 m [3 ft x 3 ft]) on higher speed or wider arterial streets (11).

When used at the exact location of the crossing, the pedestrian crossing sign shall be supplemented with a diagonal downward pointing arrow plaque (W16-7P) to show the location of the crossing (see Exhibit 4-12). The diagonal arrow plaque with the arrow pointing downward is used to identify the crossing location. In cases where a crossing is seasonal or temporary, the crossing sign shall be removed or covered when the crossing activity does not exist.

To enhance the visibility of this sign, the designer has the option of using a fluorescent yellow-green colored sign with a black border. If the decision is made that fluorescent yellow-green will be used within an area, it is important that the chosen style be used consistently throughout that area. The mixing of standard yellow and fluorescent yellow-green within a selected zone should be avoided.

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Exhibit 4-13.
Example of a Pedestrian Guide Sign.
Photo courtesy of Kevin J. Sylvester.

School Warning Signs

School warning signs include the advance school-crossing sign (S1-1), the SCHOOL BUS STOP AHEAD (S3-1) sign, and others. The school advance warning sign (S1-1) shall be used in advance of any school crossing. Where used, the sign shall be erected not less than 45 m [150 ft] nor more than 210 m [700 ft] in advance of the school grounds or school crossings. The school advance warning sign (S1-1) shall be used in advance of the first installation of the school speed limit sign assembly. Additionally, school advance warning signs (S1-1) should be installed in advance of locations where school buildings or grounds are adjacent to the highway. If used, the school advance warning sign (S1-1) shall be supplemented with a supplemental plaque with the legend AHEAD (W16-9P) or XXX METERS (XXX FEET) (W16-2 or W16-2a) (6).

The school crosswalk warning assembly (S1-1 with a diagonal arrow) shall be installed at the marked crosswalk, or as close to it as possible. The assembly shall consist of a school advance warning sign (S1-1) supplemented with a diagonal downward pointing arrow (W16-7). The school crosswalk warning assembly shall be used only at marked crosswalks adjacent to schools and those on established school pedestrian routes. The school crosswalk warning assembly shall not be installed on approaches controlled by a STOP sign. The school crosswalk warning assembly should be used at marked crosswalks, including those at signalized intersections, used by students going to and from school as determined by an engineering study.

The SCHOOL BUS STOP AHEAD warning sign (S3-1) should be installed on arterial or other high-speed streets in advance of locations where a school bus, when stopped to pick up or discharge passengers, is not visible for a distance of 150 m [500 ft] in advance and where there is no opportunity to relocate the bus stop to provide 150 m [500 ft] of visibility.

Additional school-related traffic control devices are discussed in detail in Part VII ("Traffic Controls for School Areas") of the MUTCD (6), including a school speed limit assembly/sign to be used to indicate the speed limit where a reduced-speed zone for a school has been established.

Specialty Warning Signs

The MUTCD (6) 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.

Pavement Word and Symbol Markings

The MUTCD (6) allows for the use of pavement word and symbol markings such as SCHOOL X-ING or PED X-ING as motorist warning devices (MUTCD: Section 3B-19). These may be helpful on high-volume or high-speed streets with unusual geomet-

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rics (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. They should consist of large letters and numerals that are 1.8 m [6 ft] or more in height. Their use should be kept to a minimum to retain effectiveness. Consideration should also be given to snow conditions that may cover 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 which may extend the width of two lanes.

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 (6).

4.2.3 Guide Signs

Most guide signs are installed for the benefit of motorists. These signs are often large, mounted fairly high, indicate destinations that are relatively far away, and may not adequately serve pedestrians. Most walking trips are short, and a pedestrian's line of sight is fairly low.

No standards have been developed yet for pedestrian guide signs. Signs are desirable in urban areas to assist pedestrians new to the area, or for residents who may not realize that the best route on foot is shorter than what they are used to driving.

To avoid adding clutter to the existing street signs, it may be preferable to cluster signs together on one post, placed in a strategic location. Distances should be given in blocks, average walking time, or other measurements meaningful to pedestrians.

Examples of key destinations to include are: libraries, schools, museums, entertainment centers, shopping districts, etc. Signs should be easy to read and aesthetic (13). Exhibit 4-13 illustrates an example of a guide sign.

4.2.4 Street Name Signs

Most street name signs adequately serve most pedestrians. However, there are situations where pedestrians cannot read signs mounted for automobile drivers:

- On one-way streets, signs should face both ways, as foot traffic will be approaching from both directions.
- Signs that are mounted high on mast arms over the roadway may need to be supplemented with conventional, smaller signs on the street corners (13).

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4.3 Sidewalk Maintenance

Proper sidewalk management is just as important as using correct design and construction techniques. A sidewalk that becomes inaccessible because of inadequate maintenance or improper construction zone provisions can be just as inconvenient or undesirable as failing to construct the proper pedestrian facility in the first place. ADA Title II implementing regulations require the maintenance of accessible features. In determining a maintenance schedule, consideration should be given to the long-range funding of pedestrian facilities.

4.3.1 Surface Repairs, Snow Removal, and Vegetation

Sidewalk surfaces that have settled or heaved over time can be a significant barrier for pedestrians. Surfaces that are smooth and accessible when newly installed may not stay that way, particularly where masonry units are installed without an adequate subbase. Knowledgeable design, wise material selection, good construction practices, and regular maintenance procedures can help ensure that differences in level between adjacent units do not exceed the limits of usability.

Public works departments should have a program for routine maintenance checks of sidewalks and should have a process in place to quickly respond to citizen reports of damaged surfaces, particularly along high-priority routes, so that pedestrians with mobility impairments do not have to seek alternate routes. Often maintenance of sidewalks is the responsibility of the adjacent property owners who need to be informed of their responsibility to repair the walk. Adjacent property owners; however, should not be responsible for sidewalk replacement or major repairs necessitated by conditions not of their making. Public agencies should establish realistic guidelines under which the agency should be responsible for major repair or replacement of severely deteriorated sidewalk, for example, in situations where repair or replacement is required due to severe heaving damage caused by street trees.

In northern climates, snow and ice blockages can force pedestrians onto the street at a time when walking in the roadway is particularly treacherous. Many localities that experience regular snowfalls have enacted legislation requiring homeowners and businesses to clear the sidewalks fronting their property within a reasonable time after the snowfall occurs. In addition, public works agencies should adopt a snow removal program that includes ensuring that the most heavily used pedestrian routes are cleared, including bus stops and curb ramps at street crossings so that snow plows do not create impassible ridges of snow. Snow should not be piled so as to create new sight distance restrictions (13). The U.S. DOJ has stated that snow removal may be required in some locations to assure program accessibility.

Care should be taken to prevent vegetation from encroaching into walkways. Roots should be controlled to prevent break-up of the sidewalk surface. Adequate clearances and sight distances should be maintained at driveways and intersections; pedestrians must be visible to approaching motorists, rather than hidden by overgrown shrubs or low-hanging branches, which can also obscure signs. Overhanging trees and shrubs can be a problem for pedestrians with vision impairments who may not see a branch overhead before walking into it. In areas with heavy tree growth, lighting requirements may need to be

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evaluated during the summer months when the potential of blockage by foliage is at its greatest. More importantly, the placement and type of trees should be evaluated ahead of time, whenever possible. A regular pruning and maintenance program is also advised. Vegetation litter such as leaves, branches, and fruit should be removed on a regular basis. A checklist of surface repair and vegetation maintenance items includes:

- Inspect walkways regularly for surface irregularities.
- Respond to citizen complaints in a timely manner.
- Repair potential tripping conditions as soon as possible.
- Prevent the edge of a repair from running through a bike lane, shoulder, or sidewalk.
- Perform preventative maintenance operations, such as keeping drains in operating condition and cutting back intrusive tree roots.
- Sweep a project area after repairs.
- Cut back vegetation to prevent encroachment.

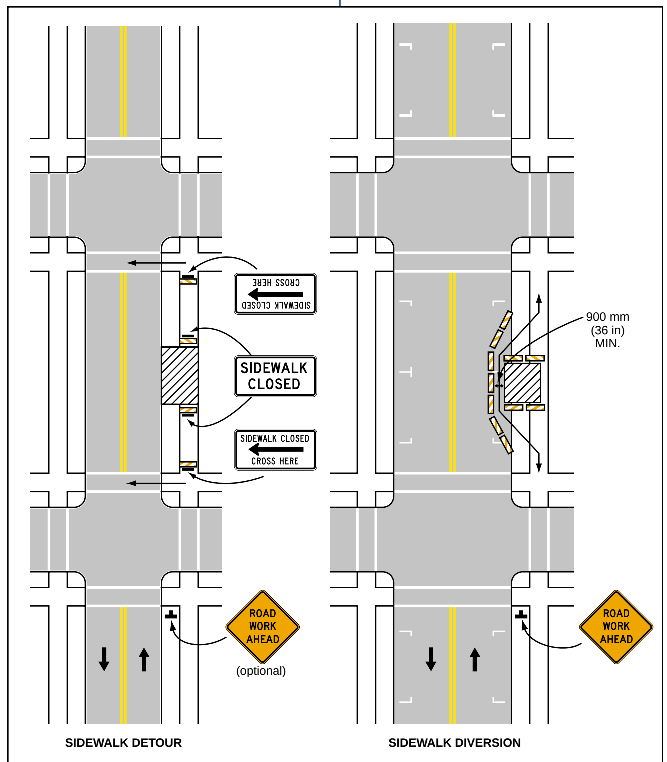

Exhibit 4-14. Accommodating Pedestrians at Midblock Construction Zones (6).

The U.S. DOJ has advised that agencies maintain a citizen request program for curb ramps, APS, snow removal, and other retrofits to provide program access in existing facilities.

4.3.2 Drainage Improvements

Sidewalk drainage is an equally important maintenance issue. Sidewalk grades that are below the adjacent ground level can collect water during and after a rain event and create a standing body of water. In northern climates, icy conditions may result. Such conditions should be remedied by regarding the adjacent ground level, reconstructing the sidewalk at a higher grade, or even adding special sidewalk drainage structures. Any drainage structure actually within the sidewalk area should be designed to be flush with the pavement with openings that are bicycle and wheelchair passable, with a maximum 13 mm [1/2 in.] gap in the direction of travel. Curbs used to divert stormwater into catch basins should be designed so they do not create a problem for wheelchair users. At intersections, there should be no puddles in pedestrian crosswalks, and faulty drains that back water up into the crosswalk or onto the curb ramp should be repaired or relocated.

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4.4 Maintenance of Pedestrian Traffic in Construction Work Zones

Proper planning for pedestrians through and along construction areas is as important as planning for vehicle traffic, especially in urban and suburban areas. Pedestrian considerations including access to entrances, bus stops, and crosswalks must be an integral part of each construction project. There are three considerations for pedestrian safety in work zones:

- Separate pedestrians from conflicts with work site vehicles, equipment, and operations.
- Separate pedestrians from conflicts with mainline traffic moving through or around the work site.
- Provide pedestrians with a safe, accessible, and convenient travel path that duplicates, as nearly as possible, the most desirable characteristics of sidewalks or footpaths (8).

Completely closing a sidewalk for construction and rerouting pedestrians to the other side of the street should only be done as a last resort. When construction requires closing existing crosswalks and walkways, contractors and other work crews must provide a safe, accessible, and convenient route. Walkways must be clearly identified and accessible, protected from motor vehicle traffic, and free from pedestrian hazards such as holes, debris, abrupt changes in grade or terrain, dust, and mud. A width of 1.5 m [5 ft] is desirable for pedestrian walkways through or past work zones. Wider walkways may be necessary where there are high pedestrian volumes. Additionally, construction traffic control signs should not be placed where they would block wheelchair access along sidewalks, or become protruding objects at head height. Sidewalks should not be used as a storage facility for construction equipment, worker's vehicles, signs, barricades, and cones (11).

Barriers to prevent pedestrians from entering the construction zones should be constructed of wood or other nonbendable material (plastic tape is not adequate) in order to be discerned by pedestrians with vision impairments. Barriers should direct pedestrians to the appropriate path. Scaffolding and other construction fencing should not have bars or supports that protrude into the clear head space for pedestrians.

When a parking lane exists next to a work site that closes a sidewalk, the parking lane may be used for the pedestrian detour route. On multilane streets, a travel lane may also be closed to provide a continuous pedestrian path. Only when there is no available parking lane or it is not possible to temporarily shift or remove a travel lane out of the curb lane (e.g., a two-lane street with no parking lanes), should pedestrians be diverted across the street by a sidewalk closure (6).

In this case, safe crossings must be provided to the opposite side of the street. Signing for these crossings should be placed at intersections so that pedestrians are not confronted with midblock work sites that will induce them to attempt walking around the work zone or making a midblock crossing. It is not appropriate to expect pedestrians to retrace their steps to a prior intersection for a safe crossing. Therefore, ample advance notification is needed. Two approaches to accommodate pedestrians in a midblock work zone are shown in Exhibit 4-14.

For temporary work zones of short duration and under low-speed conditions, it is acceptable to use traffic barricades and traffic signs to separate pedestrian traffic from work

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zone and vehicle traffic. Barricades must be continuous and provide a well-defined travel route detectable to a cane. Temporary work on sidewalks (e.g., utility openings, vaults, and sidewalk reconstruction) also needs to be barricaded.

At fixed work sites of significant duration, especially in urban areas with high pedestrian volumes, pedestrian fences or other protective barriers may be needed to prevent pedestrian access into a construction site. This is particularly important near school areas. When used, pedestrian fences should be 2.4 m [8 ft] high to discourage people from climbing the fences. If chain link fences are used, there is a need to increase the conspicuity of the barrier (i.e., putting a large SIDEWALK CLOSED/DETOUR sign at eye height). This is especially important for pedestrians with vision impairments.

For construction or demolition of buildings adjacent to sidewalks, a covered/screened walkway may be needed to protect pedestrians from falling or spraying debris. These covered/screened walkways should be sturdily constructed and adequately lit for nighttime use, with a well-defined travel route and ramps, as required. External lighting and diagonal white and orange stripes on the exterior of the pedestrian walkway may be needed when placed next to traffic.

Covered/screened walkways and pedestrian fences and other barriers must be designed to provide ample sight distance at intersections and crosswalks for both pedestrians and motorists. Solid construction fences must be angled at corners or be replaced with chain link fencing to provide adequate visibility.

In some situations, it may be necessary to use a longitudinal traffic barrier to separate the pedestrians from vehicular traffic. The barrier must be of sufficient strength to avoid intrusion by an impacting vehicle into the pedestrian space. Guidance on acceptable barriers can be found in the AASHTO *Roadside Design Guide.* (1) Short, intermittent barrier segments should be avoided and upstream ends of the system should be flared or protected with impact attenuators properly fastened to the longitudinal barrier. For work zones adjacent to high-speed traffic, continuous concrete barriers are recommended. Wooden railings, chain-link fencing with horizontal pipe railing, and other similar systems are not acceptable.

Construction work zones should be inspected daily and monitored continuously for vehicle and pedestrian needs. Security guards or flaggers may be needed to monitor work sites and help control pedestrian traffic. Where construction vehicles and equipment need to cross pedestrian paths, flaggers, police officers, or traffic signals should be used during crossing times. This is particularly important near pedestrian generators, such as schools, parks, and community centers. Officials should be contacted at these facilities to alert them of upcoming traffic control changes and accommodate special pedestrian needs, particularly for long-term and major construction activities. Use of temporary crossing guards for construction in or near school zones is recommended.

Information about construction zones that affect pedestrian circulation must be provided in ways and formats usable by all. Proximity activated voice messages can be paired with visible signage and markings to advise of detours and re-routings; detectable pedestrian barriers and channelizing devices can identify alternate or protected routes. Outreach through neighborhood and blindness organizations may be helpful.

More detailed information on accommodating pedestrians in and around construction work zones is provided in Part VI of the MUTCD (6).

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4.5 Operation and Maintenance Resources

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Glossary of Terms

Note: The definitions used in this Glossary are for use with this Guide and may not coincide with the legal definitions in the reader's jurisdiction.

Accessible Pedestrian Signal (APS)—a device that communicates information about pedestrian signal timing in a nonvisual format including audible tones, verbal messages, and/or vibrotactile information.

Americans with Disabilities Act of 1990 (ADA)—Federal law prohibiting discrimination against people with disabilities. Requires public entities and public accommodations to provide accessible accommodations for people with disabilities.

Americans with Disabilities Act Accessibility Guidelines (ADAAG)—provides scoping and technical specifications for new construction and alterations undertaken by entities covered by the ADA.

Approach—section of the accessible route that flanks the landing of a curb ramp. The approach may be slightly graded if the landing level is below the elevation of the adjoining sidewalk.

Arterial—signalized streets that serve primarily through traffic and provide access to abutting properties as a secondary function.

Audible Warning—see Accessible Pedestrian Signal.

Barrier Curb—see Vertical Curb.

Bulb-Out—see Curb Extension.

Collector—surface street providing land access and traffic circulation within residential, commercial, and industrial areas.

Commercial Facility—a facility that is intended for nonresidential use by private entities and whose operation bring about commerce.

Crossing Island—pedestrian refuge with the right-of-way and traffic lanes of a highway or street.

Crosswalk—That part of a roadway at an intersection that is included within the extensions of the lateral lines of the sidewalks on opposite sides of the roadway, measured from the curbline, or in the absence of curbs from the edges of the roadway, or in the absence of a sidewalk on one side of the roadway, the part of the roadway included within the extension of the lateral lines of the sidewalk at right angles to the centerline. Also, any portion of a roadway at an intersection or elsewhere that is distinctly indicated for pedestrian crossing by lines or other markings on the surface.

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Cross Slope—the slope measured perpendicular to the direction of travel.

Curb Extension—a section of sidewalk extending into the roadway at an intersection or midblock crossing that reduces the crossing width for pedestrians and may help reduce traffic speeds.

Curb Ramp—a combined ramp and landing to accomplish a change in level at a curb. This element provides street and sidewalk access to pedestrians using wheelchairs.

Detectable Warning—standardized surface feature built in, or applied to, walking surfaces or other elements to warn pedestrians with vision impairments of hazards on a sidewalk and or loading platform, such as the curb line or drop-off.

Diagonal Curb Ramp—curb ramp positioned at the apex of the curb radius at an intersection, bisecting the corner angle.

Drainage Inlet—site where water runoff from the street or sidewalk enters the storm drain system. The openings to drainage inlets are typically covered by a grate or other perforated surface to protect pedestrians.

Driveway Crossing—extension of sidewalk across a driveway that meets the requirements of ADAAG.

Feasible—capable of being accomplished with a reasonable amount of effort, cost, or other hardship. With regard to ADA compliance, feasibility is determined on a case-by-case basis.

Flare—sloped surface that flanks a curb ramp and provides a graded transition between the ramp and the sidewalk. Flares bridge differences in elevation and are intended to prevent ambulatory pedestrians from tripping. Flares are not considered part of the accessible route.

Gap—(1) an opening embedded in the travel surface. Railroad and trolley tracks and concrete joints are common gaps that pedestrians must negotiate. Wheelchair casters and tires of road bicycles can get caught in poorly placed gap openings; or (2) a break in the flow of vehicular traffic, sufficiently long enough for a pedestrian to cross to the other side of the street or to a place of refuge.

Grade—the slope parallel to the direction of travel that is calculated by dividing the vertical change in elevation by the horizontal distance covered, measured in percent.

Grate—a framework of latticed or parallel bars that prevents large objects from falling through a drainage inlet but permits water and some sediment to fall through the slots. Wheelchair casters and tires of road bicycles can get caught in poorly placed grate openings.

Grade-Separated Crossing—a facility such as overpass, underpass, skywalk, or tunnel that allows pedestrians and motor vehicles to cross each other at different levels.

Guidestrip—some type of raised material with grooves that pedestrians with vision impairments use for cane directional cues. For example, guidestrips may be used by pedestrians with vision impairments to navigate a crosswalk, track to an emergency exit, or access the door of a light rail system.

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Gutter—trough or dip used for drainage purposes that runs along the edge of the street and curb or curb ramp.

Hearing Impairment—condition of partial or total deafness.

Intermodalism—a transportation policy that promotes full development of multiple alternative modes of travel, and encourages the optimization of mode or combination of modes for travel mobility, efficiency, sustainability, economy, and environmental health. The availability, effectiveness, and safety of pedestrian facilities contribute to the achievement of intermodalism.

Intersection—area where two or more pathways or roadways meet.

Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA)—Federal legislation authorizing highway, highway safety, transit, and other surface transportation programs from 1991 through 1997. It provided new funding opportunities for sidewalks, shared use paths, and recreational trails. ISTEA was superseded by the Transportation Equity Act for the 21st Century in 1998.

Kinesthetic—sensory experience derived from the movement of the body or limbs.

Landing—level area of sidewalk at the top or bottom of a ramp.

Local Road—road that serves individual residences or businesses, and/or distributes traffic within a given urban or rural area.

Locator Tone—a repeating sound informs approaching pedestrians that they are required to push a button to actuate the pedestrian signal. This tone enables pedestrians with vision impairments to locate the pushbutton.

Median Island—an island in the center of a road that physically separates the directional flow of traffic and can provide pedestrians with a place of refuge and reduce the crossing distance between safety points.

Midblock Crossing—a crossing point positioned within a block rather than at an intersection.

Minimum Clearance Width—the narrowest point on a sidewalk or trail. A minimum clearance width is created when obstacles, such as utility poles or tree roots, protrude into the sidewalk and reduce the design width.

Mountable Curb—see Sloping Curb.

New Construction—project where an entirely new facility will be built from the ground up.

Obstacle—an object that limits the horizontal or vertical passage space, by protruding into the circulation route and reducing the clearance width of a sidewalk.

Parallel Curb Ramp—curb ramp design where the sidewalk slopes down on either side of a landing. Parallel curb ramps require users to turn before entering the street.

Passing Space—section of path or sidewalk wide enough to allow two wheelchair users to pass one another or travel abreast.

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Path or Pathway—track or route along which pedestrians are intended to travel.

Pedestrian—a person afoot or in a wheelchair.

Pedestrian-Access Route—a continuous, unobstructed path connecting all accessible elements of a pedestrian system that meets the requirements of ADAAG.

Pedestrian-Actuated Traffic Control—pushbutton or other control operated by pedestrians designed to interrupt the prevailing signal cycle to permit pedestrians to cross a signalized intersection or midblock crossing.

Perpendicular Curb Ramp—curb ramp design where the ramp path is perpendicular to the edge of the curb.

Ramp—sloped transition between two elevation levels.

Right-of-Way—real property rights (whether by fee-simple ownership, by easement, or by other agreement) acquired across land for a public purpose, including pedestrian use.

Rural—areas outside the boundaries of urban areas.

Shy Distance—area along sidewalk closest to buildings, retaining walls, curbs, and fences generally avoided by pedestrians.

Sidewalk—a paved pathway paralleling a highway, road, or street intended for pedestrians.

Sight Distance—the length of roadway visible to a driver or pedestrian; the distance a person can see along an unobstructed line of sight.

Sloping Curb—a curb with a sloping face, usually on the order of 30-to-45 degrees from vertical, that can be traversed in emergency situations.

Suburban—built up area surrounding a core urban area.

Tactile Warning—change in surface condition providing a tactile cue to alert pedestrians with vision impairments of a potentially hazardous situation.

Touch Technique—environmental scanning method in which a blind person arcs a cane from side to side and touches points outside both shoulders. Used primarily in unfamiliar or changing environments, such as on sidewalks and streets.

Transportation Agency—Federal, state, or local government entity responsible for planning and designing transportation systems and facilities for a particular jurisdiction.

Transportation Equity Act for the 21st Century (TEA-21)—Federal legislation authorizing highway, highway safety, transit, and other surface transportation programs from 1998 through 2003. It provides funding opportunities for pedestrian, bicycling, and public transit facilities, and emphasizes intermodalism, multimodalism, and community participation in transportation planning initiated by ISTEA.

Truncated Domes—small domes with flattened tops used as tactile warning at transit platforms and at other locations where a tactile warning is needed.

Uniform Federal Accessibility Standards—accessibility standards that all Federal agencies are required to meet. Includes scoping and technical specifications.

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Urban—places within boundaries set by state and local officials, having a population of 5,000 or more. Urban areas are often densely populated and contain a high density of built structures.

U.S. Access Board (United States Architectural and Transportation Barriers Compliance Board)—independent Federal agency responsible for developing Federal accessibility guidelines under the ADA and other laws.

Vertical Clearance—minimum unobstructed vertical passage space required along a sidewalk or trail. Vertical clearance is often limited by obstacles such as building overhangs, tree branches, signs, and awnings.

Vertical Curb—a steep-faced curb, designed with the intention of discouraging vehicles from leaving the roadway.

Vibrotactile Pedestrian Device—device that communicates information about pedestrian timing through a vibrating surface by touch.

Vision Impairment—loss or partial loss of vision.

Visual Warning—Use of contrasts in surface to indicate a change in environment, as at a curb ramp where the sidewalk changes to the street.

Walk Interval—traffic signal phase in which the WALKING PERSON (symbolizing WALK) signal indication is displayed.

Wayfinding—a system of information comprising visual, audible, and tactile elements that helps users experience an environment and facilitates getting from point A to point B.

Width, Sidewalk—*Total width* of a sidewalk includes obstructions and begins at the edge of a roadway to the side of a building. *Clear width* is the portion of sidewalk that excludes obstructions and any attached curb. *Effective width* is the portion of clear width that excludes any shy distances.

Woonerf—a common space to be shared by pedestrians, bicyclists, and low-speed motor vehicles. These are usually narrow streets without curbs and sidewalks. Plantings, street furniture, and other obstacles are placed so as to discourage and inhibit through traffic movements.

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