CHAPTER 16
Bicycle and Pedestrian Facilities

Jennifer L. Toole, AICP and Bettina Zimny, AICP
The RBA Group
Morristown, NJ

Introduction

Bicycling and walking are basic, fundamental forms of transportation that are sometimes overlooked in this age of high-tech motorized travel. Yet these human-powered transportation modes are important to the success of the transportation system as a whole. All travelers are pedestrians at some point during their trip—even if it is between their parking space and their office building. According to the 1990 Nationwide Personal Transportation Survey, one in ten households do not own a vehicle and therefore must rely on alternative forms of transportation.[1] Add to this the number of people who are either too old or too young to drive, and one realizes that for quite a sizable number of U.S. citizens, the ability to walk or bicycle to a destination is critical to their freedom of mobility. Transportation planners and engineers therefore have the same level of responsibility to provide for the safety of bicyclists and pedestrians as they do for motorists.

There are growing efforts throughout the United States to improve conditions for bicycling and walking. Congress recognized this need in 1991 when it passed the Intermodal Surface Transportation Efficiency Act (ISTEA)—a spending package that increased the responsibilities of local and state governments to plan and implement bicycle and pedestrian facilities. The funding infusion provided by ISTEA and continued by Transportation Efficiency Act for the 21st Century (TEA-21) in turn fueled even stronger efforts to build trails and to renovate streets and roadways for bicycling and walking.

Goals for Bicycling and Walking

In a comprehensive, national study on bicycling and walking, the U.S. Department of Transportation (DOT) found that "increased levels of bicycling and walking transportation would result in significant benefits in terms of health and physical fitness, the environment, and transportation-related effects." The U.S. DOT set the following goals as a result of this study:

- To double the percentage of total trips made by bicycling and walking in the United States—from 7.9 to 15.8 percent of all travel trips.
- To simultaneously reduce by ten percent the number of bicyclists and pedestrians killed or injured in traffic crashes.[2]

Current levels of bicycling and walking in the United States are low (7.9 percent of total trips) when compared to the number of people who say they would bicycle or walk if there were safe facilities available. In a 1995 poll conducted by Rodale Press, 31 percent of all Americans whose primary means of transportation is driving alone in their car would prefer to commute and run errands using some other means of transportation. Among bicyclists who do not currently commute, forty percent (representing over 25 million people) say they would start commuting if they had access to safe bicycle facilities. In the noncyclist category, over one-third (22.7 million people) say they would start riding to work if they had access to safe bike lanes on roads and highways. This represents a tremendous opportunity to reduce single occupant vehicle trips.

[1] The actual figure is probably higher than this, since low-income households have a higher nonresponse bias to surveys.

[2] U.S. Department of Transportation, Federal Highway Administration, *The National Bicycling and Walking Study—Final Report* (Washington, D.C.: U.S. DOT, Federal Highway Administration, 1994), pp. VI.

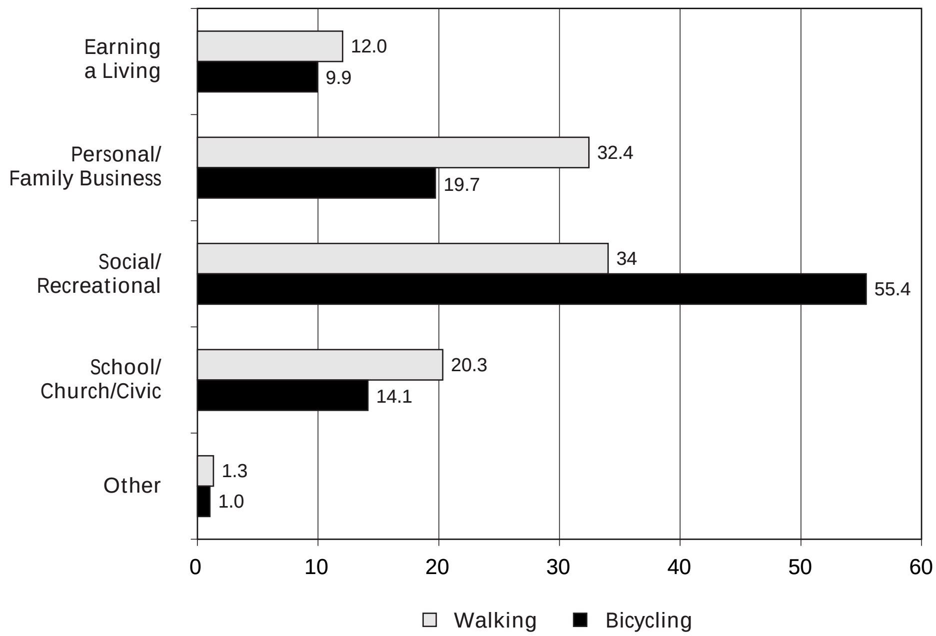

Figure 16–1 Walking and Bicycling Trips by Purpose

Source: *National Bicycling and Walking Study*, Washington, D.C.: U.S. Department of Transportation, Federal Highway Administration, 1994.

People choose to bicycle and walk every day, either out of convenience, necessity, or for other reasons. There are nine million daily bicycle trips and 56 million daily walk trips in the United States each day. Thirty-two percent of the walk trips are for personal and family business, and 55 percent of the daily bike trips are for social or recreational purposes.[3] (Figure 16–1.) The combined number of people who bicycle and walk every day is greater than the amount of people who use transit.

Bicyclists and Pedestrians at Risk

Bicycle and pedestrian safety is a growing concern for many communities. In 1996, 82,000 pedestrians were injured and over 5,400 were killed in the United States. On average, a pedestrian is injured in a traffic crash every six minutes in this country. Children and seniors are at great risk—one-third of pedestrian injuries and fatalities in 1996 were children under the age of 16.

Bicycle safety is also a problem, although far fewer are killed each year than pedestrians. In 1996, 761 bicyclists were killed and 59,000 were injured in traffic crashes. As with pedestrian crashes, children between the ages of 5 and 15 are at the highest risk—nearly one-third of the bicyclists killed in traffic crashes in 1996 were in this age range.[4] Since most crashes involve a motor vehicle, safety improvements for bicyclists and pedestrians are important for everyone on the road.

Global Perspective

The U.S. is not alone in its efforts to encourage more bicycling and walking for transportation. In 1997, the British Parliament approved the Road Traffic Reduction Act. The act requires local traffic authorities to undertake reviews of current and future traffic levels on local roads in their area, and to produce a report containing targets for reducing levels

[3] *National Personal Transportation Survey* (Washington, D.C.: U.S. DOT, Federal Highway Administration, 1995).

[4] National Highway Traffic Safety Administration, *NHTSA Traffic Safety Facts* (Washington, D.C.: NHTSA, 1996).

or rates of growth. In 1998, the British Government enacted measures to include bike lanes on all new roads and to require trains to transport bicycles. Their long-term goals are to have twenty percent of all trips conducted by bicycle.[5]

Bicycling and walking play key roles in the transportation systems of other developed nations, including Japan, the Netherlands, and many European countries. In Japan an estimated 15 percent of workers rely on bicycles for their commute to work, and in Dutch cities between twenty and fifty percent of all trips are typically made by bicycle.[6]

Many countries are finding that traffic calming plays an important role in increasing the levels of bicycling and walking. Slower traffic is a critical factor in pedestrian and bicyclists' comfort level—therefore traffic calming can often do as much to encourage bicycling and walking along a corridor as upgraded sidewalks or designated bicycle facilities. The choice to bicycle or walk has much to do with the quality of the environment between the origin and destination. The principles of traffic calming (as described in Chapter 17) should be implemented in conjunction with improvements to the streetscape and removal of barriers to bicycling and walking.

In a growing number of communities, bicycling and walking are considered as solid indicators of a community's livability. In cities and towns where people can regularly be seen out bicycling and walking, there is a palpable sense that these are safe and friendly places to live and visit.

Bicycle and Pedestrian Planning Theory

Planning opportunities for enhancing the bicycle and pedestrian experience can include many avenues: urban design, facility design, public involvement, traffic calming, traffic engineering, landscaping, funding, bicycle and pedestrian behavior studies, and more. (Figure 16–2.) Although they share some similar issues, one common misconception is that both bicycling and walking issues should be addressed under one heading. In reality they are separate and distinct modes of transportation that should be studied individually. For example, pedestrian access to transit will logically require more sidewalk connections and improvements to roadway crossings in the immediate vicinity of the station and bus stop, while bicycle improvements might include bike lanes in a wider radius and bike parking facilities at the station itself.

Bicycling and walking are not functionally different from other transportation modes: the same basic assumptions that allow planners to predict the outcome of transport decisions for other modes can be applied to bicycling and walking. After fifty years of evolution, very few stones have been left unturned in motor vehicle traffic modeling.[7] In contrast, bicycle and pedestrian transportation planning theory is in its formative years. Even the most basic planning theories for bicycling and walking are still evolving.

Providing Balance Among Transportation Modes

The underlying principle of bicycle and pedestrian planning is to provide a system that allows a choice in modes and a reasonable balance in accommodations, without favoring one mode to the expense of all others. In order to achieve this balance, bicycling and walking must become more attractive alternatives, which requires considerable retrofit in most communities.

In many cases, creating a reasonable balance means more than simply installing sidewalks or designated bicycle facilities. For the pedestrian, it means increased attention to factors that have—in the past—been beyond the domain of responsibility for engineers. It means making streetscape improvements—an area in which engineers are not typically trained, but must now become more proficient in with the assistance of planners, landscape architects, and urban designers.

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[5] "Britain Passes Historic Legislation to Reduce Traffic," *Pro-Bike News,* vol. 18, no. 2 (Washington, D.C.: Bicycle Federation of America, February 1998).

[6] U.S. Department of Transportation, Federal Highway Administration, *The National Bicycling and Walking Study—Final Report* (Washington, D.C.: U.S. DOT, Federal Highway Administration, 1994), pp. 130–132.

[7] Bruce Epperson, "Bicycle Transportation: A Qualitative Approach" (unpublished work, 1996).

It is important to remember that, despite the lack of facilities, pedestrians and bicyclists will continue to use streets that have no accommodations, and they are within their rights to do so. In some cases, they have no other choice in order to get to their destination. In other cases, they may have an alternative route, but that route is circuitous and indirect. Pedestrians and bicyclists almost always take the most direct route, because to do otherwise they must expend more of their own time and energy.

Design imperative

- *Transportation planners should not fail to provide a facility because of a concern that it would encourage walking and bicycling in a dangerous location. Pedestrian and bicycle travel will occur regardless, and the burden of responsibility is to accommodate that travel in the best way possible.*

Transportation planners should not fail to implement bicycle and pedestrian improvements because of liability concerns. National standards clearly state that, when designing bike lanes and paved shoulders for bicycle use, any additional space for bicycles is better than none. ADA also provides a clear imperative to provide facilities for the disabled within the public right-of-way, facilities that will benefit all pedestrians.

Bicycle and Pedestrian Travel Demand Simulation and LOS Analysis

While bicycle and pedestrian planning research has not yet developed to the same level as motor vehicle planning, some sketch planning techniques do exist. When planning bicycle and pedestrian facilities, it is important to remember that current volumes usually do not reflect demand for two reasons:

1) There is an overall lack of accommodations throughout most communities, resulting in fewer numbers of bicyclists and pedestrians.

2) Dispersed land uses create trip distances that are perceived as being too far to make on foot or by bicycle.

Travel demand modeling and Level of Service (LOS) analysis for bicycling and walking are emerging areas of study that are being used by more and more by transportation planning agencies to forecast areas needing improvements and to determine what types of improvements are needed. There are two statistically calibrated mathematical equations currently in use that determine the relative comfort of a bicyclist given the conditions of a particular street segment: the Bicycle Compatibility Index[8] and the Bicycle Level of Service (BLOS) model.[9] These equations are very similar. They measure variables in the street cross section that affect bicycling, such as amount of motor vehicle traffic, traffic speed, the amount of separation between the bicyclist and moving traffic, the percentage of heavy vehicles, presence of on-street parking, and the condition of the pavement surface.

Pedestrian suitability models are in a more formative stage. Early research focused primarily on quantifying walkway space, flow characteristics, and pedestrian capacity analysis.[10] *The Highway Capacity Manual* provides procedures for operational analysis of walkways, crosswalks, and intersections that illustrate the LOS for such spaces. More recent pedestrian analysis has examined factors that affect a pedestrian's level of comfort in a given road corridor. These models, such as Portland's Land Use, Transportation, Air Quality Connection (LUTRAQ) and others, examine quality-related comfort, convenience, and safety factors of the pedestrian environment. Further details on travel demand modeling and LOS analyses for the bicycle and pedestrian modes are provided later in this chapter.

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[8] Alex Sorton, "Bicycle Stress Level as a Tool to Evaluate Urban and Suburban Bicycle Compatibility," *Transportation Research Record 1438* (Washington, D.C.: Transportation Research Board, 1994).

[9] Bruce W. Landis, "Real-Time Human Perceptions: Toward a Bicycle Level of Service," *Transportation Research Record 1578* (Washington, D.C.: Transportation Research Board, 1997).

[10] John J. Fruin and G. Benz, "Pedestrian Time-Space Concept for Analyzing Corners and Crosswalks," *Transportation Research Record 959* (Washington, D.C.: Transportation Research Board, 1984).

Regional Transportation Patterns

Land Use

Facility Design/Engineering

Community Support/Encouragement

Education

Enforcement

Figure 16–2 Bicycle and Pedestrian Planning Issues

Source: The RBA Group, Morristown, N.J.

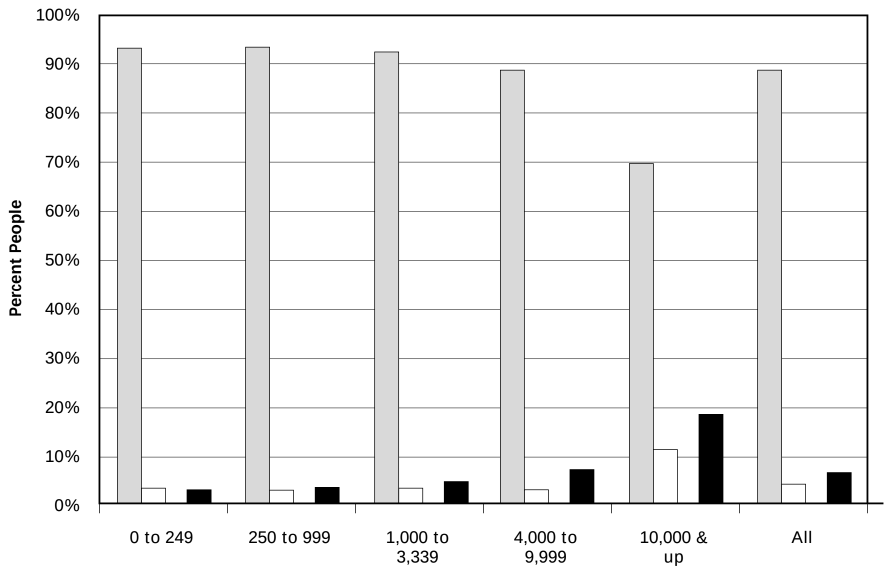

Figure 16–3 Mode of Transportation by Population Density

Source: *NHTSA Traffic Safety Facts*, Washington, D.C.: National Highway Traffic Safety Administration, 1996.

Land Use

Bicycle and pedestrian trips are typically characterized by short trip distances: approximately one quarter-mile to one mile for pedestrian trips and one quarter-mile to three miles for bicycle trips. Land use patterns therefore have a critical effect on bicycle and pedestrian circulation. Current development trends such as suburban sprawl and decentralization result in inconvenient linkages between residential areas and shopping and employment centers, and they create disincentives for bicycling and walking. The 1995 *National Personal Transportation Survey*[11] shows that levels of bicycling and walking increase as population density increases. (Figure 16–3.)

Opportunities to provide accessible, safe, convenient, and inviting environments for walking and bicycling should include adoption of effective land use planning and design standards. Research has shown that land use strategies involving mixed-use development with high densities, suitable job and housing balance, effective parking management, and transit-oriented design can reduce auto trips by as much as 18 percent.[12]

Education and Enforcement

Training and education of bicyclists, pedestrians, and motorists, and enforcement of existing laws and regulations are essential. Different types of users need different kinds of facilities, training, and programs in order to bicycle, walk, and drive safely and efficiently, with confidence. Needs vary for each user type. For example, children, older adults, recreational bicyclists and walkers, and commuters each have different skill levels, experience, and perceptions of risks. An understanding of these varying types of users and their needs is necessary in order to provide resources, programs, and facilities to accommodate everyone.[13]

Education, safety and security needs are frequently identified by communities. Bicycle and pedestrian accidents and injuries, hazardous traffic conditions, lack of enforcement of traffic laws, poor maintenance of walkways and bicycle routes, insufficient lighting and security along facilities, and lack of bicycle and pedestrian training programs are problems that contribute to confidence and security-related needs.

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[11] National Highway Traffic Safety Administration, *NHTSA Traffic Safety Facts* (Washington, D.C.: NHTSA, 1996), p. 12.

[12] Federal Transit Authority, *Planning, Developing and Implementing Community-Sensitive Transit* (Washington, D.C.: FTA, 1996).

[13] John Williams, *Balancing Engineering, Education, Law Enforcement and Encouragement—National Bicycling and Walking Case Study No. 11* (Washington, D.C.: U.S. Department of Transportation, Federal Highway Administration, 1994.)

Bicycle and Pedestrian Transportation Planning Studies

The rising awareness of bicycle and pedestrian issues in transportation planning has brought with it a new era of planning for these modes. In most states and many local and regional areas, transportation agencies are becoming more responsive to improving conditions for bicyclists and walkers. Many of these projects have started with planning studies, whether they were small scale (such as a study to improve bicycle and pedestrian access to a neighborhood bus stop) or large scale (such as a statewide master plan for bicycling and walking).

While there are some common elements (such as public participation) that nearly all bicycle and pedestrian planning projects should include, they otherwise can vary greatly depending upon the particular needs of the community. The following are a variety of different planning studies that may be initiated by transportation planners to better meet the needs of people on foot and bicycle, with descriptions of important issues and topics to cover in these studies.

The Statewide Bicycle and Pedestrian Master Plan

Many parts of the United States have programs to promote bicycling and walking. Generally, the focus has been on bicycling, with the recent addition of pedestrian programs. The more successful programs are characterized by comprehensiveness, stable funding, development of facilities, and other components. These have evolved in response to a variety of circumstances. In Florida, accident statistics have been the spur to action. In Minnesota, the economics of encouraging bicycle use have appealed to advocates, politicians, and agency staff alike.[14] More recent plans and programs, such as New Jersey, Pennsylvania, and Oregon are based on target usage goals, performance measures and implementation programs.

The following elements should be part of a statewide planning process:

- *Vision*—an overall statement of the state's desires for nonmotorized travel.
- *Goals and objectives*—detailed steps for how the agency plans to fulfill the vision.
- *Performance measures*—– the "report card" by which progress towards the objectives, goals, and vision can be measured.
- *Current conditions*—data relating to levels of use, safety problems, the suitability of the existing on- and off-road physical network of facilities, and policies and practices for nonmotorized travel.
- *Strategies and actions*—potential and proposed bicycle- and pedestrian-related changes to the physical environment and institutional practices.
- *Implementation*—identification of physical and programmatic activities that can be funded to help reach the vision, goals, and objectives. These may include both pilot projects and implementation tools, such as facility design guidelines, mapping, and technical training and assistance.
- *Evaluation*—assessment of progress in moving towards the vision and goals, using the performance measures as guides.[15]

Local Bicycle Network Plans

The first step in improving local conditions is to determine where improvements should go and what they should consist of. In most communities, there's no shortage of locations that need sidewalks and bikeways, therefore decisions must be made as to which locations should receive first priority for funding, and which improvements can be incorporated

[14] U.S. Department of Transportation, Federal Highway Administration, *The National Bicycling and Walking Study—Final Report* (Washington, D.C.: U.S. DOT, Federal Highway Administration, 1994).

[15] U.S. Department of Transportation, Federal Highway Administration, *Bicycle and Pedestrian Planning Under ISTEA*, FHWA Publication No. FHWA-HI-94-028 (Washington, D.C.: U.S. DOT, FHWA, 1994.)

in other ongoing highway or development projects. Some communities develop independent bicycle and pedestrians master plans, while others address these issues in conjunction with their overall transportation planning effort.

A route improvement plan is a critical first step in developing a network of local and regional facilities. A bicycle network plan typically identifies streets that need improvements and establishes a prioritized schedule for installing the new facilities.

Local bicycle network plans primarily focus on improvements within the street cross section ("on-road" improvements), however they may sometimes include a trail and greenway ("off-road") element (see the following description of a trail plan). In addition to providing a more efficient network for bicycle transportation, planning and installing on-road bicycle facilities can help to alleviate conflicts between bicyclists and pedestrians in areas where sidewalk bicycling is common.

There are several key issues in determining which streets should receive the highest priority for new bicycle facilities.

1) *Bicycle travel demand:* an estimate of latent demand for bicycling should be made in order to determine locations where bicycle facilities are most needed to serve travel needs. As mentioned earlier in this chapter, demand cannot be accurately measured by counting the numbers of bicyclists using streets that are currently unimproved, since they are often in poor condition and discourage bicycle travel. A more detailed description of bicycle travel demand analysis is provided later in this chapter.

2) *Existing conditions and bicycle suitability analysis*: an important step in determining locations that are in need of bicycle facilities is to evaluate current conditions on candidate roadways. This should include both an overall assessment of compatibility as well as locations with special problems for bicyclists, such as narrow bridges, freeway interchanges, or other obstacles. With this information, decisions can be made regarding locations that may need only minimal improvements to serve bicyclists, versus streets that would require more extensive improvements. A more detailed description of bicycle suitability analysis is provided later in this chapter.

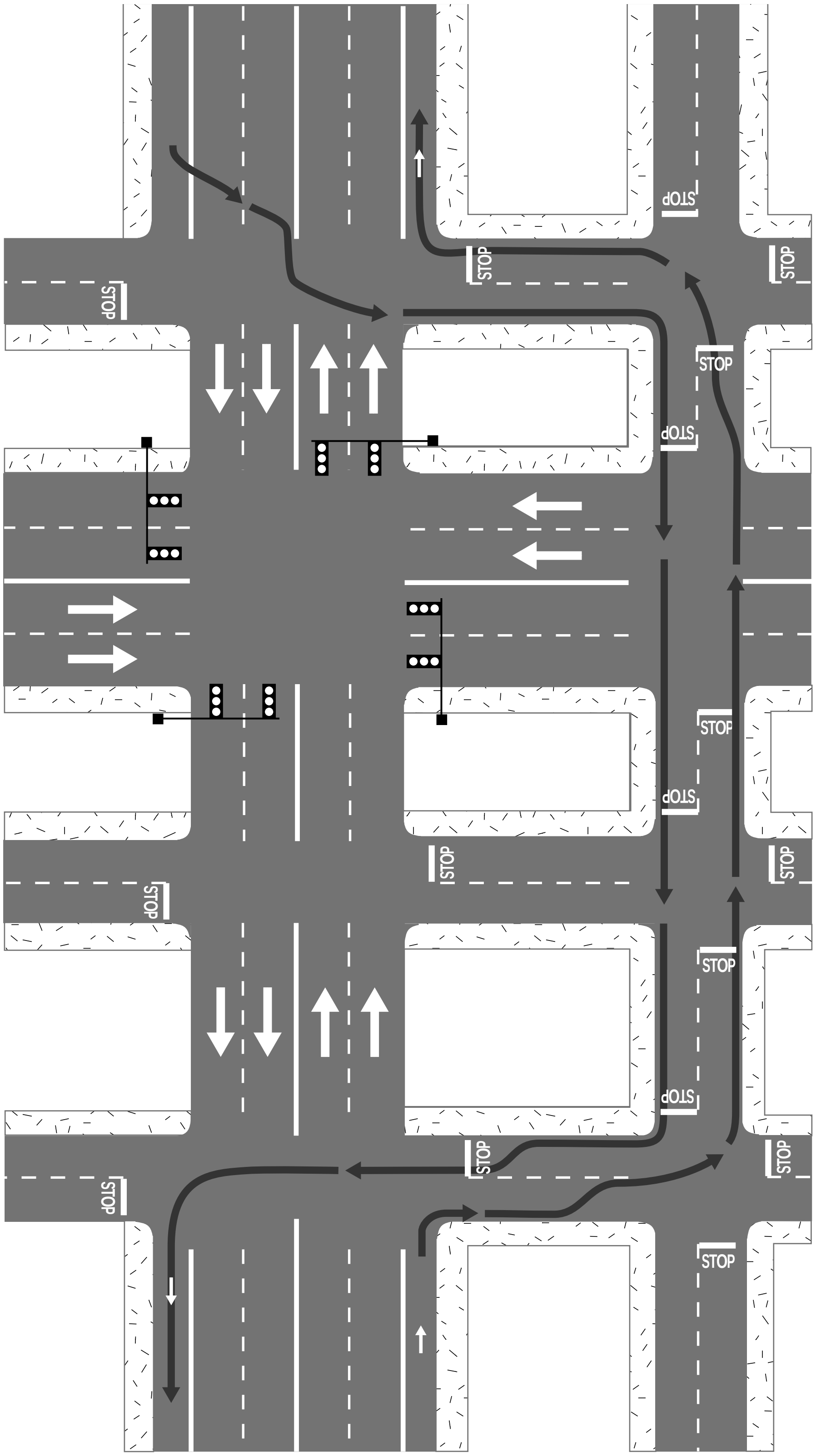
3) *Public opinion and political support:* public opinion is important during the development of a bicycle network plan, not only for the sake of knowing the public's preferences for new facilities, but also in order to develop a base of popular support for alternative transportation. Local community groups, bicycle advocates, and other interested citizens should be given the opportunity to set goals and objectives for planning efforts, and to provide meaningful ideas on locations needing improvements throughout the community.

4) *Route continuity and directness:* a successful bicycle network includes continuous routes that provide direct access to destinations throughout the community. Although during the early stages of implementation gaps in the system are inevitable, eventually the bicycle network should enable a bicyclist to travel between destinations and residential areas with a high level of comfort, and with few delays. Detours that route cyclists a considerable distance away are not desirable, since bicyclists will usually continue to take the most direct route or not ride at all. (Figure 16–4.)

   Connections between the on-road network and local trails are critical, since trail entrances often attract bicyclists from nearby residential areas. The bicycle network plan should link trails to nearby employment centers and transit stations as well.

5) *Cost effectiveness:* one of the most important factors in developing an on-road bicycle facility network is cost effectiveness. In addition to developing special bicycle improvement projects that may involve roadway widening, opportunities can be sought to implement facilities during regularly scheduled roadway improvements, such as the following.

   - Capacity improvements: when adding lanes and improving intersections to ease motor vehicle congestion, additional width can be provided for bike lanes or wide curb lanes.



Why bicyclists and pedestrians prefer to stay on the thoroughfare:

- The thoroughfare provides the most direct route for bicyclists and pedestrians;
- There may be destinations along the thoroughfare that are inaccessible from side streets;
- Less-traveled streets will often have many stop signs, whereas traffic on the through street has the right-of-way or signals that favor through traffic; and
- Potential conflict points are increased with rerouting, especially for cyclists and pedestrians who must cross the thoroughfare (some cyclists have the added difficulty of additional left turns).

Consequences of rerouting without providing adequate facilities:

- Many cyclists and pedestrians stay on the thoroughfare, causing possible safety problems and reduced capacity (bicyclists riding slowly in a narrow travel lane can cause traffic delays);
- Pedestrians and bicyclists may be routed through uncontrolled crossings of thoroughfares;
- Circuitous route signing that is ignored breeds disrespect for other signing;
- Some motorists will not respect bicyclists or pedestrians who are perceived to be where they don't belong; and
- The importance of bicyclists and pedestrians in the transportation network in diminished.

Figure 16–4 Routing of Bicyclists on Thoroughfares

Source: *Oregon Bicycle and Pedestrian Plan*, Salem, Ore.: Oregon Department of Transportation, 1995.

Route Name	From (N or W)	To (S or E)	Len. (Ls) (Mi)	Lanes (L) Th #	Con	Traffic Data Vol. (ADT) (vpd)	Pct. (HV) (%)	Post. Spd. (SPp mph	Width of Pavement (Wt) (ft)	(Wl) (ft)	(Wps) (ft)	Occu. OSP % (OSPA) (%)	Pvmt. Cond. (PR_5) (1..5)	▲ Lane? (Y/N)	BLOS Score	BLOS Grade (A..F)
Existing Conditions																
															####	####
Transit Road	Sheridan Road	Main Street	1.00	4	U	15,000	3	40	12.0			0	4.0		**4.27**	**D**
Alternatives Evaluation																
Alternative A :															####	####
Example: 14 foot curb lane			1.00	6	D	17,140	3	45	14.0			0	5.0		**3.80**	**D**
Alternative B :															####	####
Example: 12 foot outside lane and 3 foot paved shoulder			1.00	6	D	17,140	3	45	15.0	3.0		0	5.0		**3.16**	**C**
Alternative C :															####	####
Example: 12 foot outside lane and 6 foot bike lane			1.00	6	D	17,140	3	45	18.0	6.0		0	5.0		**1.90**	**B**

Figure 16–5 BLOS Alternatives Comparison

Source: New York State Department of Transportation, Albany, N.Y.: 1997.

- Street resurfacing: when resurfacing and restriping streets, roadway space can be reallocated to provide on-road bicycle facilities without physically widening the road. Capacity analysis should be done to insure that changes to lane configuration do not create unacceptable delays for motorists. If a bicycle suitability analysis has been done for the roadway, it is also possible to calculate the resulting benefits to bicycle LOS. (Figure 16–5.) More information on street restriping is provided later in this chapter.

- Shoulder paving: a few extra feet of paved roadway shoulder can greatly benefit bicycle travel—as little as three feet of smoothly paved shoulder to the right of the edge line can enable the bicyclist to move out of the travel lane, given that this area does not include rumble strips, which make the shoulder impassable for bicyclists. Paved shoulders of four to six feet in width are preferred.

Upon developing a target network of proposed bicycle facilities, a list of short-term projects can be developed for early implementation. Decisions about which projects should receive the highest priority are usually based on a combination of the factors listed above. These projects will move forward into the funding and design development phases.

Local Pedestrian Plans

It is important for local governments to assess the current condition of the pedestrian transportation system and develop a master plan for future pedestrian improvements. Current conditions may be measured by a variety of factors. These include security and safety factors that relate to properly designed facilities, such as sidewalks and crossings; convenience and access factors that are associated with connectivity between land uses, access to destinations and intermodal links; and qualitative factors such as aesthetics, streetscape treatments, and pedestrian-scale amenities that are associated with pedestrian comfort levels. Elements of the local pedestrian plan that provide both a qualitative and quantitative assessment of these factors include the following.

- *Sidewalk and crosswalk inventory and improvements*: an inventory should be conducted to identify locations of existing sidewalks and crossings, as well as those that are in need of repair. A plan for pedestrian improvements should be developed, with a phased implementation schedule. Municipally funded sidewalk construction should focus on gaps in the existing sidewalk system, particularly in areas that show a high demand. Sidewalks and safe crossings should also be installed within a one-mile radius of schools, in business districts, and in areas where connections between existing facilities are not likely to occur through new development. Techniques such as "walkability audits" and tools that assess a community's walkability, such as the checklist in Figure 16–6 are readily available and easily adapted to any community. [16]

[16] Dan Burden and Michael Wallwork, *Handbook for Walkable Communities and Pedestrian Facilities Design* (High Springs, Fla.: Campaign to Make America Walkable, 1997).

- *Pedestrian LOS and travel demand:* transportation modeling and quantitative travel demand tools for pedestrian planning have only recently begun to be researched, developed, and utilized. Though research exists for pedestrian capacity analysis *(Highway Capacity Manual)*[17] and travel demand (Zupan and Pushkarev)[18], findings are primarily related to very defined urban environs (e.g., sidewalks, crosswalks, street corners) or geographic areas. A detailed discussion of these pedestrian planning studies may be found in Chapter 5.

More recent efforts in pedestrian trip generation research include Portland's LUTRAQ travel demand model [19] and a "Sketch Plan Method for Estimating Pedestrian Traffic."[20] Also emerging is a Roadside Pedestrian Conditions model[21] that begins to quantify the "perceived safety" of pedestrians through utilization of a number of factors relating to safety, comfort, and convenience.

Components of many of these tools include:

- relationships between land use patterns and household travel behavior,
- ease of street crossings,
- sidewalk continuity,
- local street characteristics and configurations,
- topography,
- trip purpose,
- trip distance,
- weather,
- time of day and illumination. [22]

[17] Transportation Research Board, *Highway Capacity Manual*, National Research Council (Washington, D.C.: TRB, 1988).

[18] Zupan and Pushkarev, *Urban Space for Pedestrians* (Cambridge, Mass.: MIT Press, 1975).

[19] Friends of Oregon, *Making the Land Use Transportation Air Quality Connection—Modeling Practices* (Portland, Ore.: 1000 Friends of Oregon, 1993).

[20] Ercolano, Olson and Spring, "Sketch Plan Method for Estimating Pedestrian Traffic," 1997 Pedestrian Conference (Washington, D.C.: unpublished paper).

[21] Landis, Ottenberg and Vattikuti, "The Roadside Pedestrian Environment: Toward a Comprehensive Level of Service" (Washington, D.C.: Transportation Research Board, 1999).

[22] U.S. Department of Transportation, Federal Highway Administration, *A Compendium of Available Bicycle and Pedestrian Trip Generation Data in the U.S.* (Washington, D.C.: U.S. DOT, FHWA, 1994).

Pedestrian Task Force Committee

Walkability Checklist

The goal of the pedestrian audit is to assess the quality of the walkable environment in our chosen study areas. Facilities, safety, security, aesthetics, pleasure, motorist behavior, and access to transit all contribute to walkability. Furthermore, a good pedestrian environment should be useable and safe for all including the young, the elderly and those with disabilities.

Getting Started:
Go to your designated starting area. Look over the checklist and the map so that you are familiar with the questions and your route. As you walk, check the problems you encounter for each section of the route. The sections are marked on the map. Note locations of things you would like to see changed right on the map.

How to use the Audit:
◊ Note section numbers (from map) on the audit form.
◊ For each section, use a check mark to indicate the specific problems encountered.
◊ Note comments and mark problem locations on map.
◊ Assign an overall rating for each of the six basic questions by circling one option.

	Section	Section	Section	Section	Section
1. Is there a place to walk?					
• No sidewalks					
• Sidewalks are discontinuous					
• Sidewalks are blocked					
• Sidewalks are in bad shape					
• **Overall Rating:** **1** awful; **2** many problems; **3** some problems, not too bad; **4** good; **5** very good.					
2. Is it possible to cross the street safely?					
• No crosswalks where needed					
• No ped signal on traffic light					
• Light not timed adequately					
• Road/intersection too wide					
• **Overall Rating:** **1** awful; **2** many problems; **3** some problems, not too bad; **4** good; **5** very good.					
3. ADA access, needs of elderly and children are accommodated?					
• Curb cuts/ramps not available					
• Ramps lead to traffic lane rather than crosswalk					
• Width or condition of sidewalk inadequate					
• Sidewalk/street boundary is not discernable to blind					
• Signal actuators are not accessible					
• Timing of lights is inadequate for slower walkers					
• **Overall Rating:** **1** awful; **2** many problems; **3** some problems, not too bad; **4** good; **5** very good.					
4. Is it pleasant and convenient to walk?					
• Needs more grass, flowers, trees					
• Dirty, litter and trash					
• Not well lit					
• Too much traffic					
• Pedestrian access lacking to key destinations					
• Walkways do not access buildings					
• **Overall Rating:** **1** awful; **2** many problems; **3** some problems, not too bad; **4** good; **5** very good.					
5. Do drivers behave well?					
• Do not yield to crossing pedestrians					
• Block crosswalk with turning movements					
• Drive too fast for conditions					
• Back up without looking					
• **Overall Rating:** **1** awful; **2** many problems; **3** some problems, not too bad; **4** good; **5** very good.					
6. Is transit access convenient?					
• Bus stop not served by sidewalk					
• Bus stop not close to destination					
• Difficult to get to bus stop					
• Bus shelter difficult to use					
• **Overall Rating:** **1** awful; **2** many problems; **3** some problems, not too bad; **4** good; **5** very good.					

Figure 16–6 Walkability Checklist

Source: Suzan A. Pinsof, Evanston, Ill.

These methodologies may be used to:

- evaluate pedestrian facilities' LOS,

- determine pedestrian trip generation rates for various types of pedestrian activity centers.

A local pedestrian planning process is also an excellent way to bring pedestrian issues into the public forum. The process should include opportunities for local citizens to voice their concerns. It is particularly important to solicit the involvement of the less affluent portions of town: the urban poor are often pedestrians out of necessity. They can provide valuable insights regarding barriers to pedestrian travel. A pedestrian master planning project also provides the opportunity to discuss and implement policy changes.

State and Local Policy Plans

Some states and local governments find that in addition to making physical improvements to their transportation infrastructure, a variety of their policies affecting bicycle and pedestrian transportation have become outdated or do not support alternative transportation. Policy changes can include a number of elements, such as the following.

- *Goals that emphasize alternative transportation*: revisions to transportation goals and objectives that include encouraging alternative transportation. It is helpful to establish measurable goals for increasing bicycle and pedestrian travel and reducing crashes.

- *Changes to standard operating procedures:* policies for standardizing bicycle and pedestrian improvements through the regular activities of local, regional, and state governments. For example, some communities have made it standard transportation policy to include bicycle and pedestrian concerns during all transportation improvement studies, and to provide bicycle facilities and sidewalks whenever streets are constructed or maintained.

- *Revisions to zoning ordinance and street design standards*: revisions to zoning ordinances, subdivision regulations, and local street design standards to encourage or require development of bicycle and pedestrian facilities during development projects. Examples include bicycle parking ordinances, trail development ordinances, and residential street layout requirements that ensure continuity between adjacent developments so that bicyclists and walkers are provided with through-routes. (Figure 16–7). At the state level, roadway design standards can be revised to address bicycle and pedestrian needs as well as those for motor vehicles.

- *Changes to the motor vehicle code:* it is important to eliminate laws that are problematic for bicyclists and pedestrians, such as mandatory sidepath laws (requiring bicyclists to use sidepaths if they exist), or laws that require bicyclists to ride in bike lanes if they exist (this is a problem because bicyclists must merge into travel lanes when making left turns, or when there is debris in the bike lane). Motor vehicle laws should be designed to give pedestrians the right-of-way when crossing the street, and they should limit right-turn on red where appropriate.

Trail and Greenway Plans

Trails and greenways are becoming increasingly important as transportation corridors that traverse all types of land uses. In some communities, trail planning efforts begin with a single project, with additional trail projects coming to the surface after the first trail is successfully completed. Other communities develop a trails and greenway master plan that identifies a variety of potential off-road corridors that could be used for trail connections, such as river and stream floodplains, abandoned railroad corridors, utility rights-of-way, and public or private open space lands.

Greenway and trail projects typically proceed through a feasibility study process (or pre-engineering phase) during which a number of issues are addressed:

- physical suitability of the proposed trail route,
- requirements for land acquisition,
- ideas from local citizens and adjacent land owners,
- trail design features,
- marketing plan and funding strategy,
- maintenance and management plan,
- action plan and phased development strategy.

Final products of the planning process should include a thorough inventory and analysis, a graphic map showing the proposed location of the trail in relationship to adjacent properties, streets, built structures, and other features, and an action plan that defines how the project will move forward.

Transit Access Studies

Improving bicycle and pedestrian access to transit can broaden the service area for transit and provide people with a greater variety of travel options. The economic, transportation, and environmental benefits of pedestrian and bicycle-friendly transit have been well documented in both the United States and other countries.[23] Transit access improvements are relatively low-cost strategies that both promote public transit and lengthen distances for a typical bicycle or walking trip.

Elements of transit access studies include:

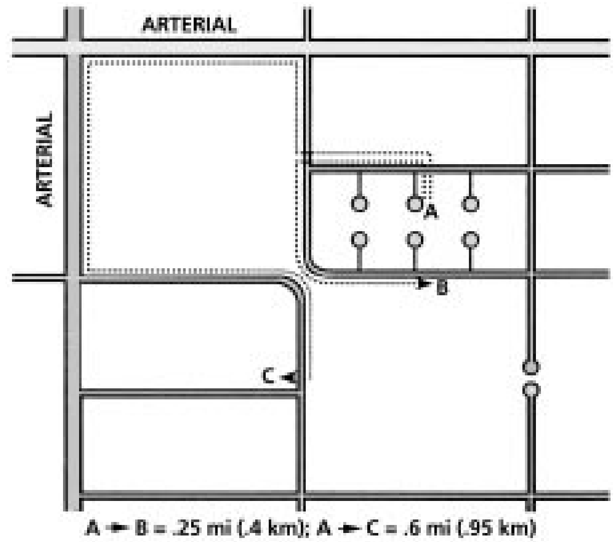
- bike-on-transit programs (Figure 16–8),
- bicycle and pedestrian access route improvements,
- bicycle storage facility plans,
- pedestrian-friendly site and station facility plans.

Arterial Corridor Plans

Corridor-wide bicycle and pedestrian plans are designed to improve the mobility of pedestrians and bicyclists, reduce traffic congestion, improve air quality, and enhance quality of life. For the purposes of this chapter, corridors are defined as urban or suburban, heavily trafficked arterials that act as a barrier to nonmotorized travel.

An open grid system (like the one in the bottom diagram) offers direct routes for bicyclists and pedestrians with minimal out-of-direction travel. Street patterns that include cul-de-sacs and dead-end streets (see top diagram) require a long circuitous route to cover a short distance, increasing travel distances for what could otherwise be a fairly short bicycle or walking trip.

One solution is to include off-road paths that link cul-de-sacs and dead-end streets, providing short cuts for bicyclists and pedestrians.



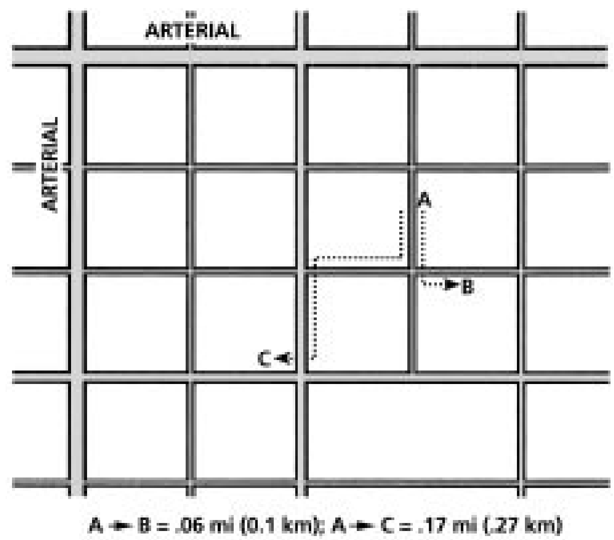


Figure 16–7 Travel Distance Savings with an Open Street Grid

Source: *Oregon Bicycle and Pedestrian Plan*, Salem, Ore: Oregon Department of Transportation, 1995.

[23] Replogle and Parcells, *The National Bicycling and Walking Study—Case Study No. 9: Linking Bicycle/Pedestrian Facilities with Transit* (Washington, D.C.: U.S. Department of Transportation, Federal Highway Administration, 1992).

Figure 16–8 Bike-on-Transit

Source: Greenways Incorporated, Cary, N.C.

Primarily three types of pedestrian and bicycle travel patterns or movements occur in these corridors:

1) Movements along the corridor associated with sidewalks, shoulders, and bikeways.

2) Movements across the corridor associated with intersections, crosswalks, underpasses, and overpasses.

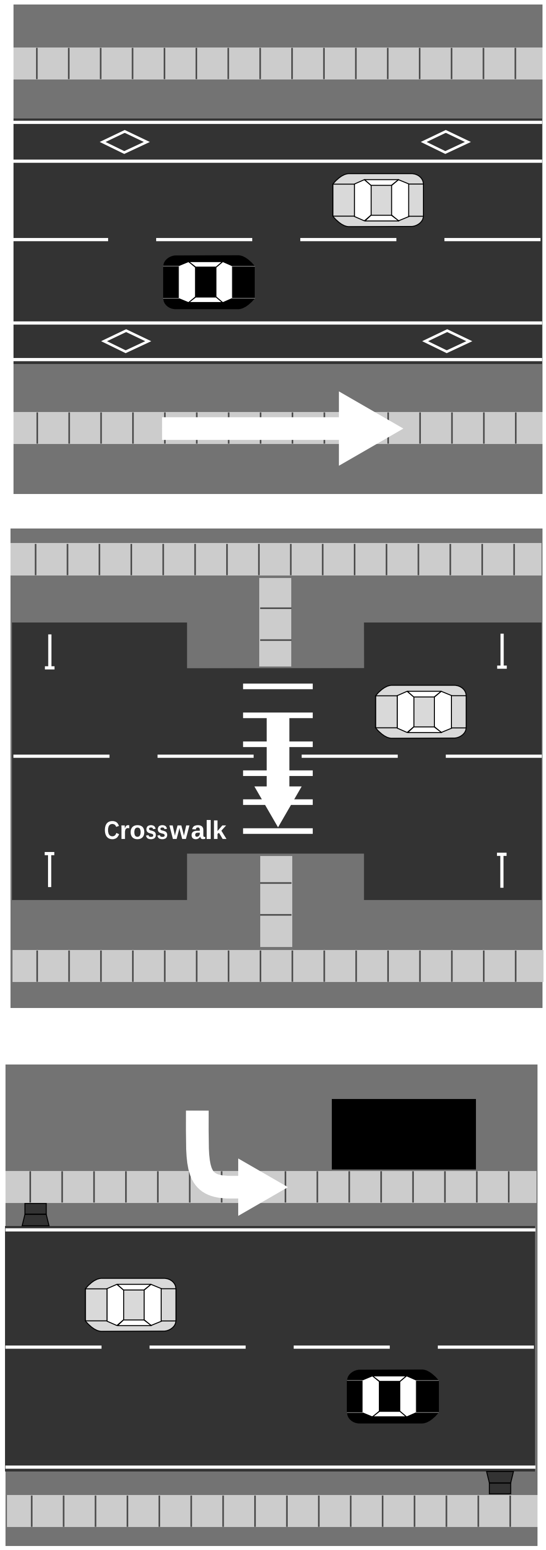
3) Movements to destinations within the corridor associated with on- and off-road linkages and between adjacent land uses. (Figure 16–9.)

Problems associated with each type of movement are design-related and operational. They include:

- Sprawling land uses that discourage walking and bicycling by increasing distances between origins and destinations.
- Wide, high-speed, at-grade crossings or intersections with high-speed merge areas, free right turns, double left turn bays, and other obstacles.
- Lack of sidewalks or bikeways and missing links or gaps in the network of bicycle and pedestrian facilities.
- Lack of aesthetic treatments such as lighting, landscaping, and other streetscape amenities that create an attractive, comfortable, and secure environ.
- Numerous driveway openings and curb-cuts that create conflicts between pedestrians, bicyclists, and motor vehicles.
- Inadequate signal timing that does not accommodate slower pedestrians.
- Marginal or inadequate facility provisions, such as narrow sidewalks with little or no separation from the travel lane.

Pedestrian and bicycle-friendly planning and design solutions include:

- Installation of striped crosswalks, medians and pedestrian signals, and adjustment of signal timing.
- Traffic calming treatments such as curb extensions that shorten crossing distances and increase the visibility of pedestrians.



Axial Trips

Cross-Corridor Trips

Radial Trips

Figure 16–9 Bicycle and Pedestrian Corridor Travel Patterns

Source: The RBA Group, Morristown, N.J.: 1998.

- Upgrading or enhancement of marginal facilities or substandard utility treatments to provide for bicycle-friendly drainage grates and remove poles and signs from the travelway.
- Provision of sidewalks, wide shoulders, or off-route trails parallel to corridors.
- Improved lighting and signage at over- and under-passes.

Further research and studies documenting these issues can be found in *TRB Report 294A-Planning and Implementing Pedestrian Facilities in Suburban and Developing Suburban and Rural Areas.*

Bicycle Travel Demand Analysis

There are two methods of determining demand for bicycle facilities: the intuitive approach versus the use of a demand forecasting model. The intuitive approach is less time consuming, however it does not yield precise results. For this method, destinations throughout the study area that would attract bicyclists are shown on a base map. Routes are selected that serve higher concentrations of destination points or that serve destinations that typically yield high numbers of bicyclists, such as universities. Emphasis should be placed on routes that link residential communities with destinations in a three-mile radius, since these represent a 10–15 minute bike ride for an average bicyclist.

Destinations should include colleges and universities, shopping centers, major employment centers (e.g., hospitals, business parks, major industries and corporations), schools (public and private), parks and recreation facilities, and trails or greenway connections. Public opinion is important to the success of this method. It is particularly important to gain opinions from a wide variety of local citizens (representing different geographic areas) who represent basic adult and youth riders as well as recreational bicycle enthusiasts.

The other method of estimating latent bicycle travel demand is to adjust conventional motor vehicle travel demand theory so that it applies to bicycle travel. Using a gravity model to measure latent bicycle travel demand can yield results that are more precise than the intuitive approach and compliment the type of analysis that is typically done for motor vehicle and transit travel simulation. This can be particularly important in cases where bicycle improvements are competing for similar funding mechanisms as other modes, since most transportation improvement programs make funding decisions based upon quantifiable results.

When evaluating a system of candidate routes, a model currently exists that effectively measures latent bicycle travel demand. The Latent Demand Score (LDS) has been used for a number of metropolitan bicycle network plans, including Birmingham, Alabama; Philadelphia, Pennsylvania; and Tampa, Florida. (Figure 16–10.) It is a probabilistic gravity model that estimates the relative amount of bicycle travel that would occur if conditions were ideal for bicycling. Similar to motor vehicle travel demand models, the LDS measures latent demand for four trip types:

- home-based work trips,
- home-based shopping trips,
- home-based recreational and social trips,
- home-based school trips.

Not only can a gravity model be used to justify expenditures, it can also help to prioritize future improvements. In addition, the LDS model can be used on trails that are proposed as part of the bicycle transportation network.[24]

Bicycle Route Suitability Analysis

Much progress has been made in developing statistically accurate models that measure bicycle route suitability. These equations measure the relative comfort of bicyclists given the conditions of a particular street segment. The scoring method is derived from a formula that uses variables in the street cross section that affect bicycling, including:

[24] Bruce W. Landis, “Bicycle System Performance Measures: The Interaction Hazard and Latent Demand Score Models,” *ITE Journal,* vol. 66, no. 2 (Washington, D.C.: Institute of Transportation Engineers, Feb. 1996), pp. 18–26.

$$
LDS = \sum_{n=1}^{4} TTS_n \times \frac{\sum_{n=1}^{4} (GA_n \times \overline{TG}_n)}{(GA_n \times \overline{TG}_n)} \times \left[\overline{TG}_n \sum_{d=1}^{l} P_{nd} \times ga_n \right]
$$

n = bicycle trip purpose (e.g., work, personal/business, recreation, school)
TTS = trip purpose share of all bicycle trips
GA = number of generators or attractors per trip purpose
TG = average trip generation of attractor or generator
P = effect of travel distance on trip interchange, expressed as a probability
ga = number of generators or attractors within specified travel distance range
d = travel distance range from generator or attractor

Figure 16–10 Latent Demand Score

Source: "Bicycle System Performance Measures: The Interaction Hazard and Latent Demand Score Models," *ITE Journal*, Washington, D.C.: Institute of Transportation Engineers, February 1996.

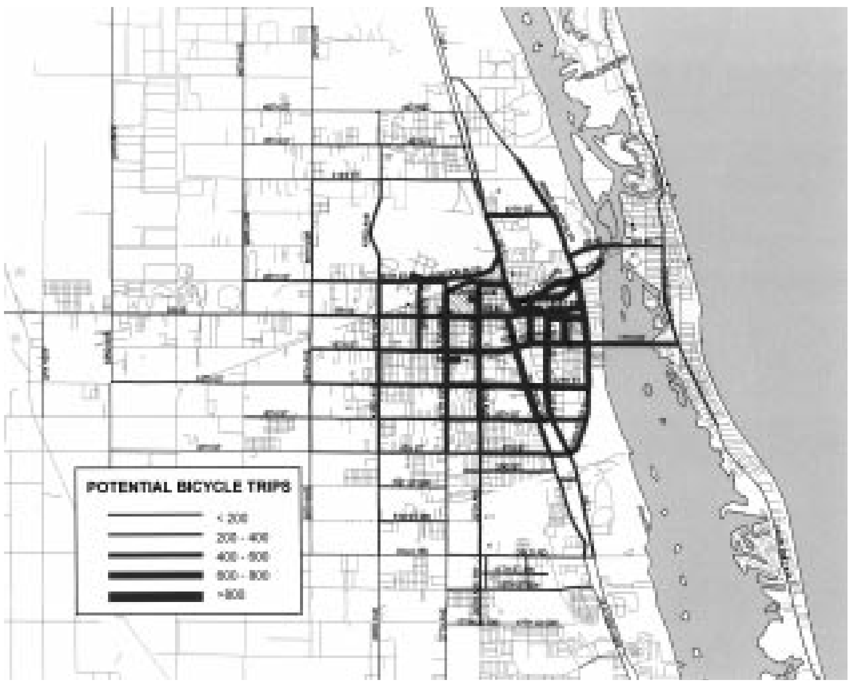


Figure 16–11 Potential Bicycle Trips

Source: *Bicycle and Pedestrian Transportation Plan,* Vero Beach, Fla.: Indian River County Metropolitan Planning Organization, 1997.

- amount of motor vehicle traffic,
- traffic speed,
- width of the right-hand travel lane,
- percentage of heavy vehicles,
- presence of on-street parking,
- condition of the pavement surface.

The formula for the BLOS model[25] is as follows:

$$BLOS = a_1 \ln(Vol_{15}/L_n) + a_2 SP_t (1 + 10.38HV)^2 + a_3 (1/PR_5)^2 + a_4 (W_e)^2 + C$$

Where:

BLOS	=	Bicycle Level of Service
Vol_{15}	=	volume of directional traffic in 15-minute time period

$Vol_{15} = (ADT \times D \times K_d)/(4 \times PHF)$

Where:

ADT	=	average daily traffic on the segment or link
D	=	directional factor
K_d	=	peak to daily factor
PHF	=	peak hour factor

L_n	=	total number of directional *through* lanes
SP_t	=	effective speed limit

$SP_t = 1.1199 \ln(SP_p - 20) + 0.8103$

Where:

SP_p	=	posted speed limit (a surrogate for average running speed)

HV	=	percentage of heavy vehicles (as defined in the 1994 Highway Capacity Manual)
PR5	=	FHWA's five-point pavement surface condition rating
W_e	=	average effective width of outside through lane:

Where:

W_e	=	$W_v - (10\text{ ft} \times \%\text{ OSPA}) - (W_g \times G_n/66L_s)$	for cases where $W_l = 0$
W_e	=	$W_v + W_l(1 - 20 \times \%\text{ OSPA}) - (W_g \times G_n/66L_s)$	for cases where $W_l > 0$ and $W_{ps} = 0$
W_e	=	$W_v + W_l - 2(10 \times \%\text{ OSPA}) - (W_g \times G_n/66L_s)$	for cases where $W_l > 0$ and $W_{ps} > 0$ and a bike lane exists

Where:

W_t	=	total width of outside lane (and shoulder) pavement
OSPA	=	percentage of segment with occupied on-street parking
W_l	=	width of paving between the outside lane stripe and the edge of pavement
W_{ps}	=	width of pavement striped for on-street parking
W_v	=	effective width as a function of traffic volume
W_g	=	average width of stormwater grates

[25] Bruce W. Landis, "Real-Time Human Perceptions: Toward a Bicycle Level of Service," *Transportation Research Record 1578* (Washington D.C.: Transportation Research Board, 1997).

G_n = Number of stormwater grates

L_s = Length of segment in miles

Where:

$W_v = W_t$ if ADT > 4,000 veh/day

$W_v = W_t\,(1\text{-}0.00025 \times \text{ADT})$ if ADT ≤ 4,000 veh/day, and if the street or road is undivided and unstriped

a_1: 0.507 a_2: 0.199 a_3: 7.066 a_4: –0.005 C: –0.005

($a_1 - a_4$) are coefficients established by a multivariate regression analysis

The equation defined above has a correlation coefficient of $R^2 = 0.77$.

The numerical result of the BLOS model is stratified into service categories “A, B, C, D, E, and F” according to the ranges shown in Figure 16–12. This stratification was established according to a linear scale that represents the aggregate response of bicyclists to roadway and traffic stimuli (for more information about the research methods used for this model or the Bicycle Compatibility Index, see the reading list at the end of this chapter).

Bicycle Facility Design

There are several sources of national design guidelines and standards that apply to bicycle facilities. The American Association of State Highway and Transportation Officials’ (AASHTO’s) *Guide for the Development of Bicycle Facilities* is a comprehensive, basic guideline to bicycle facility planning and design. The *Manual on Uniform Traffic Control Devices* (MUTCD) addresses bicycle facility signage and striping, both for on-road and off-road bicycle facilities. The *Americans with Disabilities Act Accessibility Guidelines* (ADAAG) should be consulted if the particular bicycle facility is also expected to accommodate pedestrians, such is the case with most trails.

When designing bicycle facilities, it is important to:

1. Know the operating characteristics of the bicyclist.
2. Follow design guidelines and standards that have been established in the United States for all bikeway types.
3. Make certain that transition areas (where facilities begin and end) are clear for both bicyclists and motorists.
4. Address not only the need for additional operating space, but also any existing spot hazards as well as ongoing maintenance of the facility.

Bicycles are legally classified as vehicles in most states and are therefore subject to the same rules and responsibilities as all other vehicles. One of the first steps in determining appropriate design for bicycle facilities is to determine the characteristics of the users. In a 1994 document, *Selecting Roadway Design Treatments to Accommodate Bicyclists*, the FHWA stated that “any roadway treatments intended to accommodate bicycle use must address the needs of both experienced and less experienced riders.”[26] To implement this policy, the agency proposed the development of three different design cyclists—Groups A, B, and C.

Figure 16–12 Stratified Categories for the BLOS Model

LEVEL-OF-SERVICE	BLOS Score
A	≤ 1.5
B	> 1.5 and ≤ 2.5
C	> 2.5 and ≤ 3.5
D	> 3.5 and ≤ 4.5
E	> 4.5 and ≤ 5.5
F	> 5.5

[26] W.C. Wilkinson and others, *Selecting Roadway Design Treatments to Accommodate Bicycles* (Washington, D.C.: U.S. Department of Transportation, Federal Highway Administration, 1994), p. 1.

BLOS A

BLOS B

BLOS C

BLOS D

BLOS E

BLOS F

Figure 16–13 Bicycle Levels of Service A–F

Source: The RBA Group, Morristown, N.J.

- *Group A—advanced adult bicyclists*: Group A bicyclists are experienced riders who generally use their bicycle as they would a motor vehicle. Research has shown that Group A bicyclists are not necessarily more comfortable in traffic since they have a heightened awareness of potential danger. Despite this, Group A bicyclists are generally more willing to ride on roadways that have no bicycle accommodations. They ride for convenience and speed and want direct access to destinations with a minimum of detour or delay. They prefer to have sufficient operating space within the street cross section to eliminate the need for either themselves or a passing motor vehicle to shift position. The Bicycle Federation of America estimates that five percent of all bicyclists fall into the Group A category.[27]

- *Group B—basic adult riders*: Basic or less confident adult riders may still be using their bicycles for transportation purposes but have a relatively high aversion to interaction with traffic. These bicyclists have both a wide variation in skill and strength, and great differences in their self-assessment of skills. For these reasons, this category contains the broadest cross section of user profiles and operating characteristics.[28]

Basic riders are more comfortable riding on neighborhood streets and multi-use paths and prefer designated facilities such as bike lanes on busier streets. If possible, they avoid roads with fast and busy traffic unless they have additional space in which to operate. Despite their aversion to traffic, basic adult riders can still be expected to use major arterials. Many bicycle-dependent users are forced to travel on high-speed, high-volume streets in order to reach jobs or basic needs. Further compounding this problem is the fact that many of these bicycle dependents live in central city areas and are employed in service industries with nontraditional work hours, requiring them to make one or both commutes in the dark. Many bicycle-dependent users have little enthusiasm or skills for bicycling, and in many cases they are not aware that they are required to follow traffic laws.[29]

- *Group C—children riders*: For most children, bicycle use is initially monitored by their parents. While they may not travel as far as their adult counterparts, they still require access to key destinations in their community, such as schools, convenience stores, and recreational facilities. Child riders enter and exit the roadway frequently, often in crosswalks and from driveways. After age ten, the operating characteristics of Group C cyclists increasingly resemble those of Group B cyclists, especially for boys. By age twelve, children have acquired most of their adult-level physical skills, but continue to show a lower level of judgmental abilities in such tasks as gap acceptance and risk acceptance.[30] Residential streets with low vehicle speeds, linked with multi-use paths and busier streets with well-defined separation between bicycles and motor vehicles, can accommodate children without encouraging them to ride in the travel lane of a major arterial roadway.

The FHWA proposed a set of design treatments for roadways based on a two-tier system, with one set recommended as a minimum for all streets and highways where bicyclists are permitted to operate (based on the needs of Group A cyclists), and a second set of treatments for routes expected to serve Group B/C cyclists. These tables can be used as a guide for choosing design treatments (for more information, refer to FHWA Publication No. FHWA-RD-92-073, Selecting Roadway Design Treatments to Accommodate Bicycles).[31]

Choosing the Appropriate Bicycle Facility Type

When funding for new bicycle facilities is imminent and projects are ready to proceed to the design phase, the next step in the process is to select the appropriate type of bicycle facility. This has been the topic of some controversy over the years, as transportation planners in the United States have begun to learn more about bicycle travel behavior and preferences.

[27] Ibid, p. 5.

[28] Bruce Epperson, "Bicycle Transportation: A Qualitative Approach" (unpublished work, 1996).

[29] Ibid.

[30] Ibid.

[31] W.C. Wilkinson and others, *Selecting Roadway Design Treatments to Accommodate Bicycles* (Washington, D.C.: U.S. Department of Transportation, Federal Highway Administration, 1994), pp. 16–21.

There are basically four types of on-road bicycle facilities: bike lanes, wide curb lanes, bike routes (shared roadways), and paved shoulders for bicycle use (definitions of each type follow). It is not appropriate to choose one facility type and apply it to the entire bicycle network—for example, it is not recommended that communities only install wide outside lanes and no bicycle lanes, or vice versa. Several factors should be taken into consideration in choosing the target facility type.

- *What type of bicyclist is most likely to use this facility?*
  The Federal Highway Administration provides guidance in choosing the appropriate facility type based on the skills of the likely users, traffic volumes, traffic speeds and other factors in *Selecting Roadway Design Treatments to Accommodate Bicyclists.*[32] As a general guide, most communities choose to design their bicycle network to meet the needs of basic adult riders and youth bicyclists.

- *What type of improvement would work best to increase the comfort level of bicyclists on this particular segment?*
  If a bicycle suitability analysis has been performed, it is possible to show different design scenarios and their effect on the bicycle LOS for the given roadway segment. (Figure 16–5.)

- *What type of facility can be installed given current cost and right-of-way constraints for this roadway?*
  Cost constraints are an inevitable and important factor in the decision-making process

Effects of Bike Lane Striping on Comfort Level and Behavior

As recent polls have shown, most Americans are reluctant to ride bicycles in absence of designated bike lanes and separated pathways.[33] In fact, more and more communities have begun installing bike lanes not only for the additional operating space they provide for bicyclists, but also as a method to *encourage* more bicycle travel. In the past, Americans' preference for striped bike lanes was largely anecdotal with no solid evidence of bike lanes' effect on travel behavior or comfort level.

Several studies in recent years have shown results that quantify the benefits of providing bike lanes. A 1997 study on bicyclists' comfort level (as part of the BLOS model) indicates that a stripe between the travel lane and the area where a bicyclist typically rides increases the bicyclist's comfort level by more than thirty percent.[34] A 1996 study by the University of North Carolina Highway Safety Research Center for Florida DOT compared motorist and bicyclist interactions on wide curb lanes, bike lanes, and paved shoulder facilities. The study found several advantages to bike lanes and paved shoulders:

1) Motorists are less likely to encroach into the adjacent lane when passing a bicyclist on facilities with paved shoulders or bicycle lanes.

2) Motorists have less variation in their lane placement when passing a bicyclist on a paved shoulder or bicycle lane facility.

3) Bicyclists are more likely to ride further from the edge of the roadway in a bicycle lane or on a paved shoulder than they are in a wide curb lane. This increased distance only marginally reduces the separation distance between the bicyclists and motorists, but it significantly increases the distance to the right of the bicyclist that can be used, if needed, to maneuver around an object or debris in the lane.

4) In general, the presence of the stripe separating bicyclists from motor vehicles results in fewer erratic maneuvers on the part of motorists and enhances the comfort level for all roadway users.[35]

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[32] W.C. Wilkinson and others, *Selecting Roadway Design Treatments to Accommodate Bicycles* (Washington, D.C.: U.S. Department of Transportation, Federal Highway Administration, 1994).

[33] Rodale Press, "Pathways for People" (Washington, D.C.: Rodale Press, 1995).

[34] Bruce W. Landis, "Real-Time Human Perceptions: Toward a Bicycle Level of Service," *Transportation Research Record 1578* (Washington, D.C.: Transportation Research Board, 1997).

[35] David L. Harkey and others, *Evaluation of Shared-Use Facilities for Bicycles and Motor Vehicles* (Chapel Hill, N.C.: University of North Carolina, 1996), pp. 22–23.

These results confirmed an earlier (1985) study by the Maryland State Highway Administration, which concluded that a bike lane stripe has a significant and positive effect on motor vehicle and bicycle tracking. Based on the observations made in that study, both vehicles appear to guide off the lane stripe rather than the other vehicle; and each appeared to have more confidence in the passing maneuver since the space in which each vehicle traveled was well-defined.[36]

Bikeway Types

There are a variety of types of facilities or roadway treatments that can be used to accommodate bicycles, as described in the following sections. This chapter gives an overview of design practices for these bikeways—for a more technical information on facility design the reader should reference the latest version of AASHTO's *Guide for the Development of Bicycle Facilities* and U.S. DOT's MUTCD.

The designer should note that lighting is an important consideration in the development of a bicycle transportation network. Utilitarian bicyclists often have no other choice than to ride at night during certain times of the year. Unlit roadways can be very dangerous for bicyclists, who despite standard bicycle headlamps and tail-lights are still nearly invisible to motorists until they are very close.

Shared Roadways

On shared roadways, bicyclists and motorists share the same travel lanes. A motorist will usually have to cross over into the adjacent travel lane to pass a bicyclist. All streets where bicyclists are permitted to ride are technically classified as shared roadways. However, there are several treatments that can enhance shared roadways for cyclists: bike routes, wide outside lanes, and bicycle boulevards.[37]

Bike Routes (Signed Shared Roadways)

Bike routes are shared roadways that meet a set of minimum design and operational criteria for bicycle compatibility, and which have been designated with bicycle route signs as connector routes within the bicycle facility network. Criteria are defined as:

- The street should provide a reasonably good LOS to bicyclists, as measured through a suitability rating system.
- Obstacles and barriers to bicycle travel should be addressed, including hazardous drainage grates, potholes, uneven manhole covers, angled rail-road crossings, and narrow bridges. Where certain obstacles cannot be improved but do not pose an undue risk to bicyclists, advance warning signs (as recommended by the MUTCD) should be used to alert bicyclists of their presence.
- The proposed bike route should be part of an interconnected system of bicycle facilities. Bicycle routes should not abruptly end at barriers.
- Future street maintenance and construction activities should consider and plan for safe transport by bicycles along this route.

Bicycle route signage should always include directional information such as an arrow and the name of the destination served and, if appropriate, the distance to the destination. Some communities have developed unique bike route signs, which is acceptable given that the design does not include an elaborate map that cyclists are unable to read without stopping.

[36] Steven R. McHenry and Michael J. Wallace, *Evaluation of Wide Curb Lanes as Shared Lane Bicycle Facilities* (Baltimore, Md.: Maryland State Highway Administration, 1985), p. 55.

[37] Oregon Department of Transportation, *Oregon Bicycle and Pedestrian Plan* (Salem, Ore.: Oregon DOT, 1995).

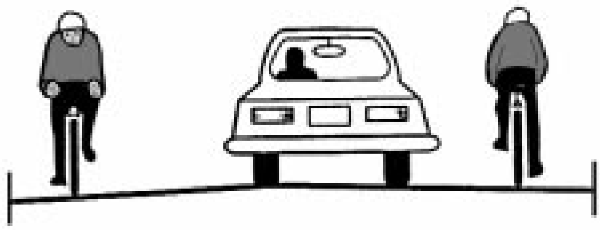


Figure 16–14 Shared Roadway Cross Section

Source: *Oregon Bicycle and Pedestrian Plan*, Salem, Ore.: Oregon Department of Transportation, 1995.

Figure 16–15 Bike Route Sign

Source: *Manual on Uniform Traffic Control Devices*, Washington, D.C.: U.S. Department of Transportation, 1988.

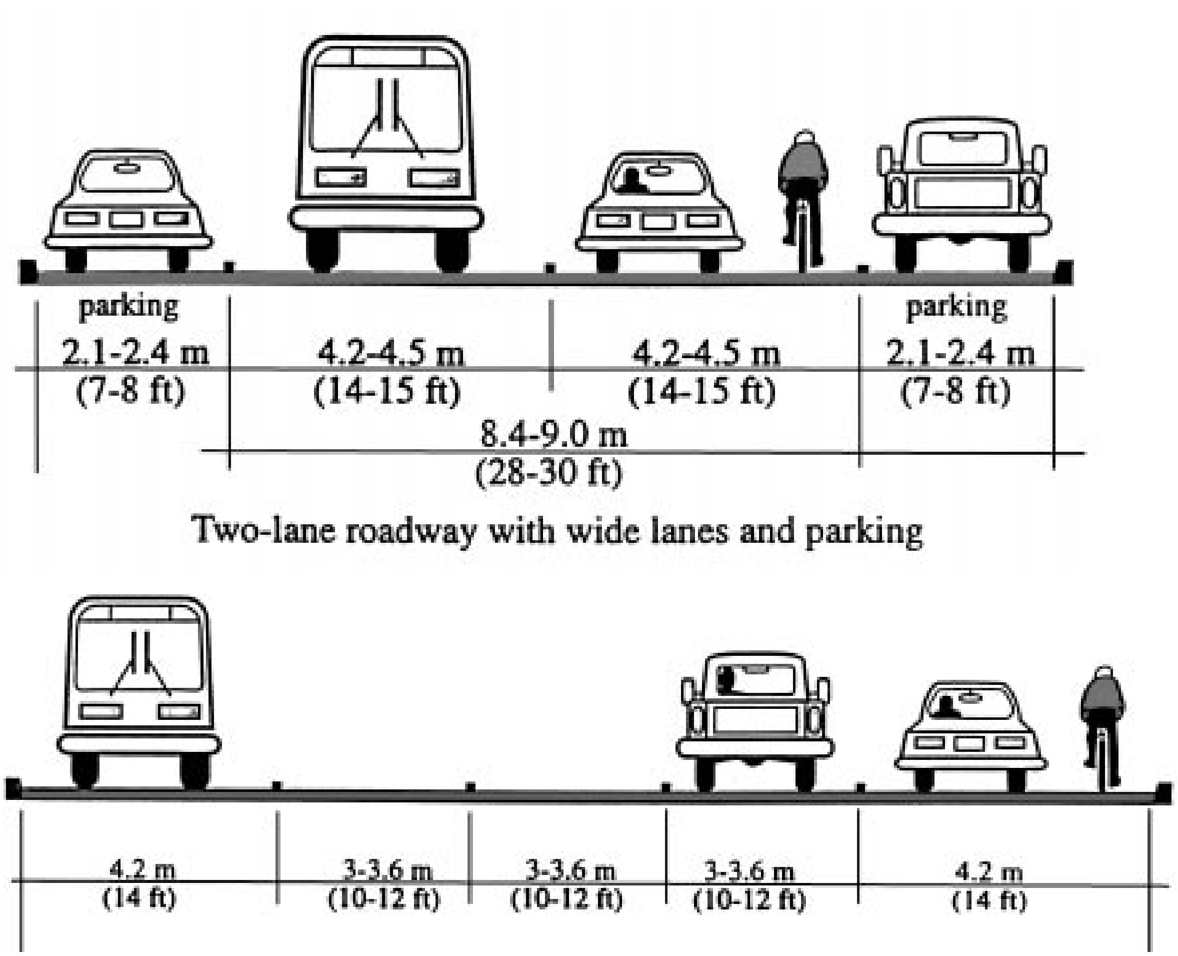


Figure 16–16 Wide Curb Lane Cross Section

Source: *Oregon Bicycle and Pedestrian Plan*, Salem, Ore.: Oregon Department of Transportation, 1995.

Wide Outside Lane

Outside lanes that are 4.3 m (14 ft) wide may be provided to allow an average size motor vehicle to pass a bicyclist without crossing over into the adjacent lane. Wide outside lanes are generally considered an appropriate facility for Group A advanced riders on busy urban arterials.

The wide curb lane is always the furthest right-hand *through* lane. There is no special "wide curb lane" sign; however, on high-volume urban arterials, the designer may choose to install "Share the Road" warning signs (standard bicycle warning plate with a subplate stating "Share the Road"). Where wide curb lane streets meet the minimum requirements for bike routes, they may be designated with signage as a bike route.

For retrofit projects where wide outside lanes are to be installed, the roadway may either be physically widened or re-striped to reduce the lane width of inner lanes and increase the width of outer lanes.

Bike Lanes

A bike lane is a portion of the roadway designated for preferential use by bicyclists, typically with a width of 1.2–1.5 m (4–5 ft). Bicycle lanes serve the needs of all types of cyclists in urban and suburban areas, providing them with their own travel lane on the street surface. They are designated with signage, edge striping, and bicycle icons to call attention to their preferential use by bicyclists. On two-way streets, bike lanes are always installed on both sides. Two-way bike lanes on one side of two-way streets create hazardous conditions for bicyclists and are not recommended.[38] In cases where a 1.5 m (5 ft) cannot be achieved for a bike lane, an unmarked lane of lesser width can be installed as an interim measure.

Regular maintenance is of the utmost importance to the success of a bicycle lane. A bicycle lane that has collected broken glass and debris is rendered useless and is unsuitable for bicyclists. A regular schedule of maintenance should be established for bike lanes. Some communities have developed "spot improvement" programs that enable local bicyclists to keep maintenance agencies informed of potholes and other maintenance problems by filling out a request card.

The needs of cyclists can be accommodated by retrofitting bike lanes onto existing urban streets. In many cases this can be accomplished without physically widening the roadway, but instead by restriping the existing cross section to add bike lanes. Significant opportunities are available in many parts of the country to do this, particularly in urban center city areas where traffic volumes are getting lower. In areas with higher traffic volumes, a cost-benefit analysis can be done to determine the relative benefits to the bicyclist versus the reduction in LOS for the motorist.

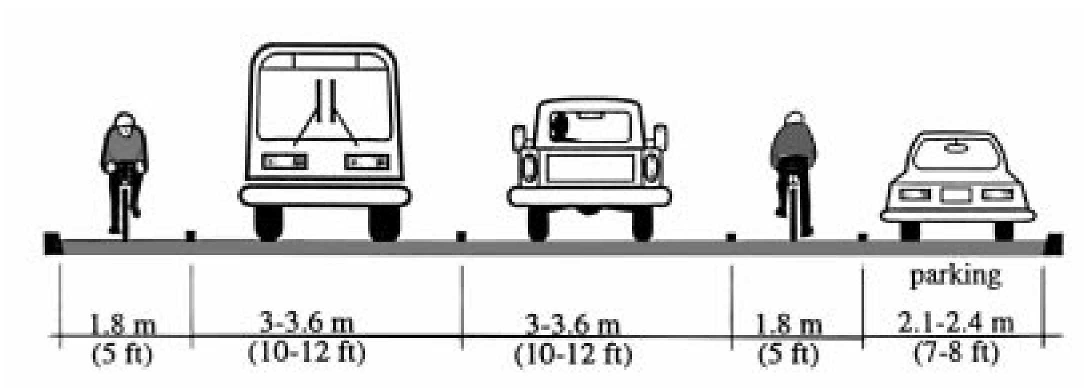


Figure 16–17   Bike Lane Cross Section

Source: *Oregon Bicycle and Pedestrian Plan*, Salem, Ore.: Oregon Department of Transportation, 1995.

38 American Association of State Highway and Transportation Officials, *Guide for the Development of Bicycle Facilities* (Washington, D.C.: AASHTO, 1991).

In Figure 16–19 (before restriping the road), the current motor vehicle LOS is C, and the bicycle LOS is D. In Figure 16–20 (after restriping the road), the motor vehicle LOS is D, and the BLOS rises to a B.[39]

When bike lanes are placed adjacent to parallel parked cars, bicyclists run the risk of getting "doored" by motorists who are getting out of their cars. Some communities have developed a bicycle lane design that uses a portion of their bike lane space as a "deterrent strip" next to parallel parked cars. This space is typically 0.6 m–0.7 m (2–2.5 ft) in width, and is distinguished by a different pavement surface (such as brick pavers) or marking.

Bike lane striping and signage are addressed in the MUTCD. For more detailed solutions on lane configurations, solutions for retrofitting urban streets to include bike lanes, and intersection layouts, the *Oregon Bicycle and Pedestrian Plan* (1995) is a comprehensive source of information.

PORTLAND BICYCLE PROGRAM
FACILITY IMPROVEMENT REQUEST FORM

The bicycle facility improvement program is intended to enhance bicycle safety and encourage bicycling through low-cost, small scale improvements suggested by concerned bicyclists (e.g., pavement maintenance and sweeping, hazard removal, bike rack installation, and grating repair).

Location: ______________________
STREET
____
CROSS STREET, ADDRESS, OR LANDMARK

Suggestion: ______________________

Requested by: ______________________
NAME
____
STREET CITY ZIP
____
DAY PHONE DATE

DO NOT WRITE BELOW THIS LINE—FOR OFFICE USE ONLY

Referred to: ______________________

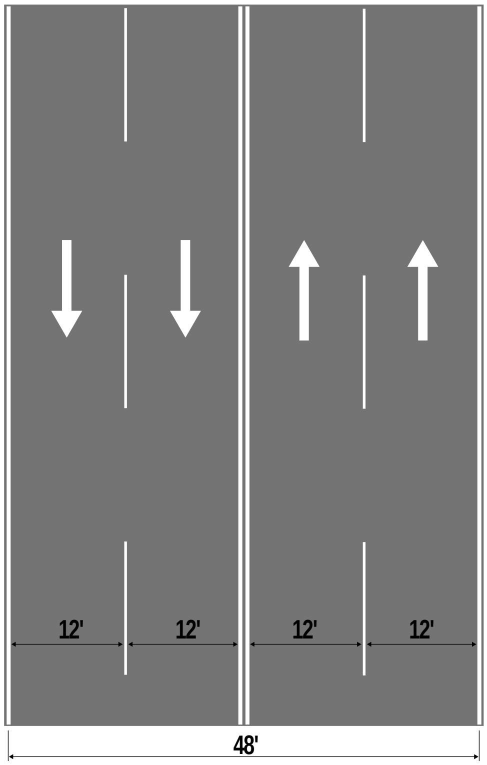
Investigation: ______________________
PDOT STAFF: LIST CONDITION BEFORE AND AFTER JOB IS COMPLETED

Signed ______________ Date ______________

Figure 16–18 Spot Improvement Request Form

Source: Oregon Bicycle and Pedestrian Plan, Salem, Ore.: Oregon Department of Transportation, 1995.

[39] Baltimore Metropolitan Council, *Baltimore Regional Bicycle Suitability Analysis Report* (Baltimore, Md.: Baltimore Metropolitan Council, 1998).



4 Lane Undivided — Before

ADT = 13,500

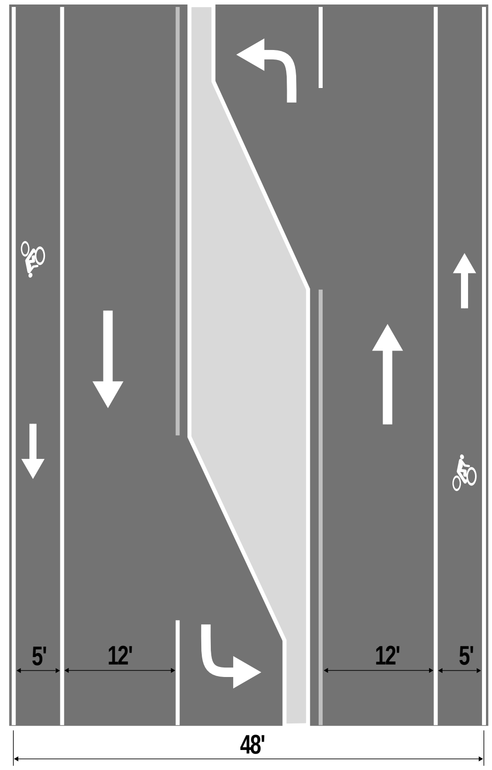
Motor Vehicle LOS = C

V/C Ratio = 0.40

Bicycle LOS = D

Figure 16–19 Four-Lane Undivided (Before)

Source: *Baltimore Regional Bicycle Suitability Analysis Report*, Baltimore, Md.: 1998.



4 Lane Undivided — After

ADT = 13,500

Motor Vehicle LOS = D

V/C Ratio = 0.83

New Bicycle LOS = B

Figure 16–20 Four-Lane Undivided (After)

Source: *Baltimore Regional Bicycle Suitability Analysis Report*, Baltimore, Md.: 1998.

Paved Shoulders

Paved shoulders can also serve bicyclists' needs on streets with no curb and gutter, and particularly in rural areas. While any additional space is beneficial, a 1.2 m–1.8 m (4 ft–6 ft) shoulder is preferred. Paved shoulders should be included on both sides of the roadway. In addition to the benefits to bicyclists, paved shoulders can also serve the needs of motorists by extending pavement life and providing a break-down area. As with bike lanes, paved shoulders should be constructed to withstand heavy loadings (since trucks and service vehicles will occasionally use them) and should be free of surface irregularities. Regular maintenance is essential if paved shoulders are to be useful to bicyclists.

Paved shoulders that include rumble strips can be essentially useless to bicyclists. On shoulders where the rumble strip extends across the whole width of the shoulder, bicyclists typically ride in the travel lane rather than face the jarring effect of the strip. In most cases, rumble strips are not recommended on bicycle facilities unless they can be designed to provide bicyclists with an adequate amount of space in which to operate.

Spot Improvements for Obstacles to Bicycling

Sudden changes in pavement conditions can have a very detrimental effect on bicyclists, particularly when they occur with no forewarning. Unless quick evasive actions are taken, such obstacles and irregularities can cause bicyclists to crash. It can also be a problem when bicyclists suddenly swerve to avoid a hazardous condition, since this is an unpredictable movement and can result in a crash with a motor vehicle. The following are some examples of bicycle hazards (consult AASHTO's *Guide for the Development of Bicycle Facilities* for further detailed solutions).

Street Maintenance Work

Many urban streets are laid upon a maze of storm sewers and utilities. Maintenance on this vast infrastructure is frequent, causing problems for bicyclists who must maneuver across milled pavement, over sudden pavement changes and steel plate covers (which are slippery when wet), and through narrowed-down lanes. In general, bicycles are far more susceptible to sudden pavement changes in construction areas than motorists, since they have no suspension. Warning signs can help to give bicyclists advanced notice of upcoming pavement changes. When at all possible, a clear path should be maintained through construction areas for bicycle travel.[40]

At-Grade Railroad Crossings

Rough and uneven railroad crossings and those that are set at an acute angle to the roadway and are obstacles to bicyclists. Streets with inlaid rails (trolley streets) can also be difficult to negotiate on bike, if the rail is in the normal operating area for bicyclists or if pavement adjacent to the rail has deteriorated and left open cracks. Rail crossings should be made as smooth as possible. In some cases, filler material can be used to reduce the gap next to the rail. For diagonal crossings, the bicyclist should be given the alternative to cross the rail at a ninety-degree angle, by flaring the shoulder.

Bridge Crossings

Adequate space for bicycles and pedestrians should be a standard element for all new bridges where bicycles are permitted to operate, including both major and minor bridges. These guidelines should apply regardless of whether bicycle lanes or sidewalks connect to the bridge at the time it is built. Minimum accommodations for bicycles should include bike lanes and sidewalks on each side. It is also important to provide bike lanes where roadways pass beneath bridges, so that these areas do not present a barrier as well.

Surface conditions on bridges can also cause problems for cyclists. Steel decks are slippery when wet, and expansion joints can create a gap that is too wide.

Manholes and Utility Covers

Manholes that are lower or higher than the surrounding pavement create an obstacle to cyclists. This sometimes occurs during roadway resurfacing when a manhole is not raised to the new surface level. Local roadway engineers should develop specific design solutions to address the need for a level pavement surface, including raising manholes to meet the same grade as newly laid pavement.

Bicycle-Safe Drainage Grates

Some types of drainage grates can trap a bicycle wheel and cause a crash, particularly those with bars that are parallel to the direction of travel and with wide openings between the bars. Bicycle-safe drainage grate designs have been developed by many transportation agencies, and should be used wherever bicyclists are expected to ride. It is also important that drainage grates be placed on an even grade with the surrounding pavement.[41]

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[40] Oregon Department of Transportation, *Oregon Bicycle and Pedestrian Plan* (Ore.: Oregon DOT, 1995).

[41] Ibid.

Multi-Use Trails

Multi-use trails are physically separated from motor vehicle traffic (except at crossings with streets) by an open space or barrier. They are usually built either within an independent right-of-way (such as a utility or railroad right-of-way), or along easements across private lands. Trails accommodate a variety of users for both recreation and transportation purposes. User groups can include pedestrians, joggers, skaters, bicyclists, horseback riders, and people in wheelchairs. Multi-use paths can provide a linkage through corridors not well served by the street system, and they are particularly helpful to bicyclists if they provide a direct, traffic-free route linking origin and destination points.

National guidelines for the design of multi-use trails are provided by AASHTO's *Guide for the Development of Bicycle Facilities* (1999). Nearly one-third of the guide is devoted to trail design, and the requirements are quite detailed.

The minimum width for two-directional trails is 3 m (10 ft), however 3.7 m–4.3 m (12–14 ft) widths are preferred where heavy or mixed traffic is expected. Due to the popularity of off-road trails, centerline stripes should be considered for paths that generate substantial amounts of pedestrian traffic. Trail etiquette signage should clearly state that bicycles should give an audible warning before passing other trail users, since they often travel considerably faster than other users.

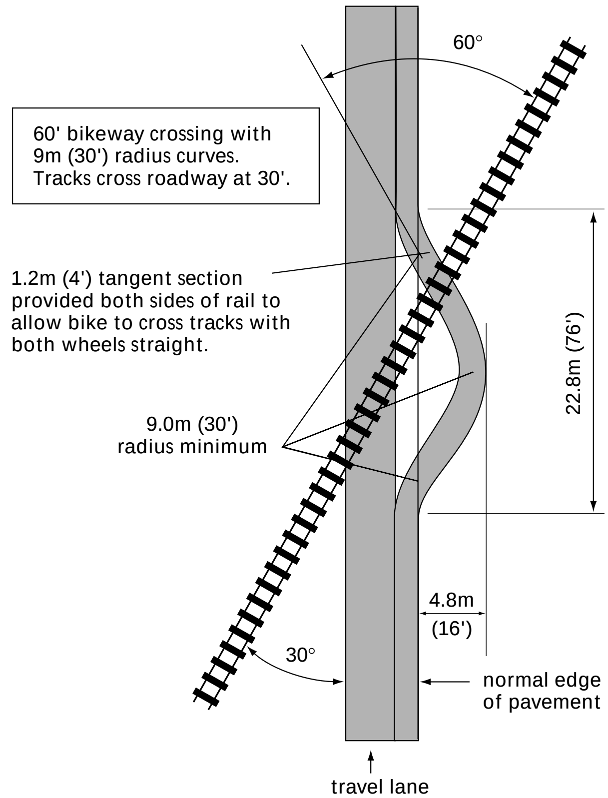


Figure 16–21 Bike Lane at Railroad Crossing

Source: *Oregon Bicycle and Pedestrian Plan*, Salem, Ore.: Oregon Department of Transportation, 1995.

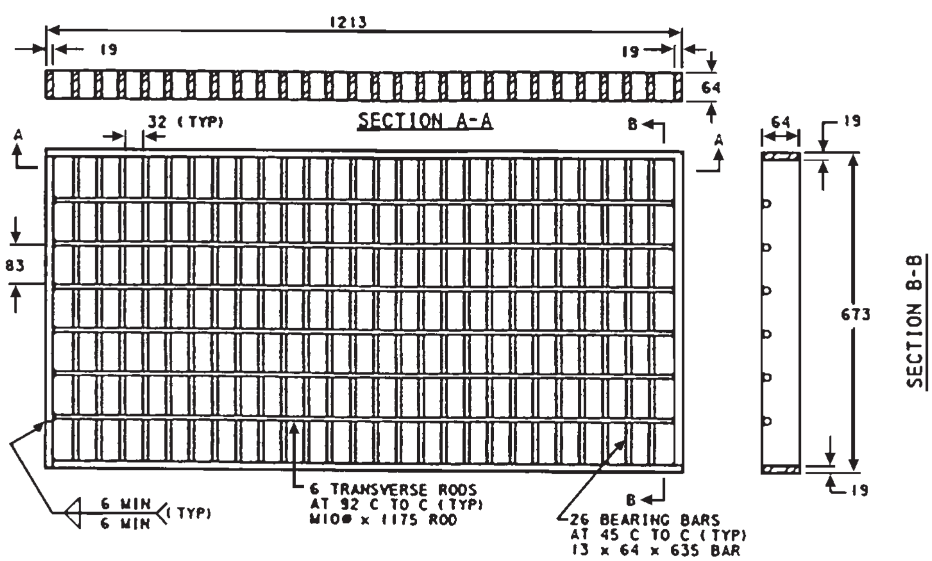


Figure 16–22 Bicycle-Safe Drainage Grate

Source: *Pennsylvania Bicycle Facility Design Guidelines*, Harrisburg, Pa.: Pennsylvania Department of Transportation, 1996.

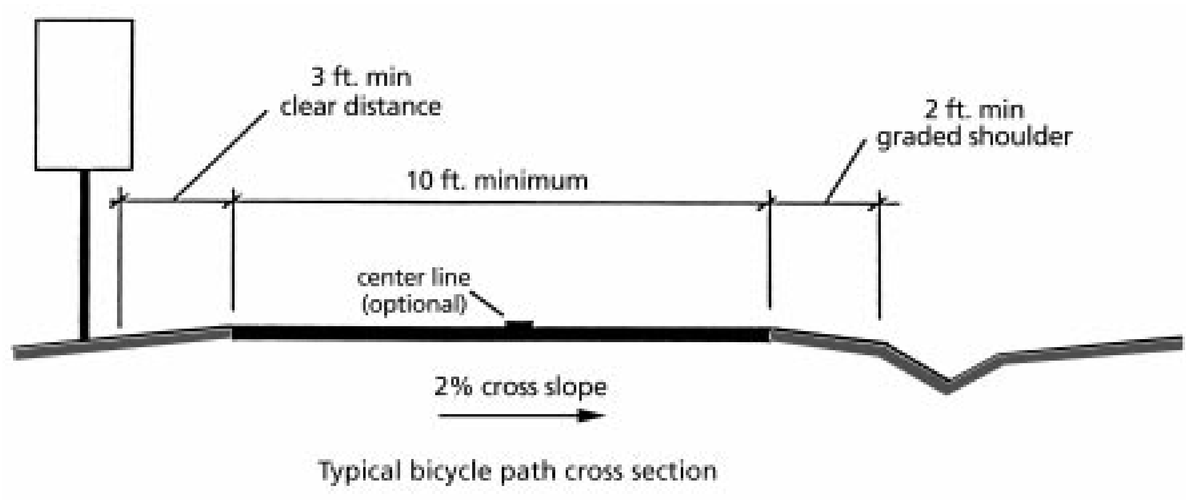


Figure 16–23 Multi-Use Trail Cross Section

Source: The RBA Group, Morristown, N.J.

In the past, bicycle sidepaths (bikeways immediately adjacent to roadways) were developed with the concept of separating cyclists from roadways in order to reduce opportunities for conflict. It is now widely accepted that bicycle paths immediately adjacent to roads or on sidewalks actually cause greater conflicts. For this reason, they are not recommended.[42]

Trail and roadway intersections can become areas of conflict if not carefully designed. For at-grade intersections, there are usually several objectives.

1. *Site the crossing area at a logical and visible location*. When at all possible, trails should be designed to meet roadways at existing intersections. If alternate locations for a bicycle path are available, the one with the most favorable intersection conditions should be selected. Midblock crossings should not be sited in close proximity to major intersections with other highways.

2. *Warn motorists and trail users of the upcoming crossing*. Warning signage and pavement markings that alert motorists and trail users of the upcoming trail crossing should be used in accordance with the MUTCD. Consistency in the use of this type of signage can help to alert bicyclists in advance of intersections.

3. *Maintain visibility between trail users and motorists*. Vegetation, highway signage, and other objects in the right-of-way should be removed or relocated so that trail users can observe traffic conditions, and motorists can see approaching trail users. Every effort should be made to locate midblock crossings on straight sections of roadway, rather than near curves where sight distance is limited.

4. *Intersections and approaches should be on relatively flat grades*. Bicyclists should not be required to stop at the bottom of a hill. Crossings should be made at a ninety-degree angle, in order to lessen the amount of exposure time for trail users.

5. *Wide intersections should be re-designed to provide adequate crossing time for trail users*. For wider crossings, a gap analysis should be done to determine the appropriate design treatment at intersections. If trail crossings are expected to be frequent (such as on the weekends), it may be necessary to provide a traffic signal that responds to bicycles or can be pedestrian-activated. Generally, if the intersection is more than 22.5 m (75 ft)

[42] American Association of State Highway and Transportation Officials, *Guide for the Development of Bicycle Facilities* (Washington, D.C.: AASHTO, 1991).

from curb to curb, it is preferable to provide a center median refuge area for trail users, per ADA (Americans with Disabilities Act) or ANSI (American National Standards Institute) standards.

6. *Intersections should be evaluated to determine if it would be more appropriate to give trail users the right-of-way and require motor vehicles to stop or yield*. Particularly in rural areas, trails sometimes cross roadways with extremely low volumes of traffic. In some cases, it is more appropriate to require motor vehicle traffic to stop or yield.

For high-speed, multilane arterials and freeways, the only viable solution may be a grade-separated crossing. Overpasses can be extremely expensive and marginally successful if users are expected to climb long entrance ramps. Underpasses should be of adequate width and should be well-lit with vandal-resistant fixtures. Approach ramps for grade-separated crossings must meet ADA or ANSI standards.

Bicycle Storage and Parking

Bicycle parking is an important investment to improve and encourage bicycle travel in urban areas. There is a severe shortage of bicycle parking in most parts of the country. Appropriate locations for bicycle parking facilities should be considered on a case-by-case basis, with an analysis of the specific design constraints at each location. The following general location criteria are recommended:

- Parking facilities should be located within 15 m (50 ft) of building entrances (where bicyclists would naturally transition into pedestrian mode).
- Parking facilities should be installed in a public area within easy viewing distance from a main pedestrian walkway, usually on a wide sidewalk with five or more feet of clear sidewalk space remaining. In general, sidewalks that are narrower than 3.7 m (12 ft) in width cannot accommodate bike racks.
- For bike parking facilities placed near walls or buildings, a minimum of 0.6 m (2 ft) clear space is needed between the bicycle rack and a parallel wall, and 0.8 m (2.5 ft) from a perpendicular wall.
- Bike racks should be placed on hard surfaces rather than in grassy medians or unpaved areas.
- Racks should be placed to avoid conflicts with pedestrians. They are usually installed near the curb and at a reasonable distance from building entrances. They should not be placed in a manner that interferes with pedestrian traffic exiting crosswalks.
- Bicycle rack placement within the right-of-way should not block access or obstruct movement. In general, bike racks should not be placed in front of doors (including cellar doors in urban downtowns) or in close proximity to fire hydrants, bus stop shelters, telephones, mailboxes, benches, newsstands, or subway exits. On streets with metered parking, racks placed between meter poles should be as close to mid-way as possible.[43]

Bicycle Parking Types

It is important to choose a bicycle rack design that is simple to operate. Bicycle racks should be designed to allow use of a variety of lock types. It may be difficult initially to determine the number of bicycle parking spaces needed: bicycle racks should be situated on-site so that more racks can be added if bicycle usage increases. There are three general types of bicycle parking facilities. The following provides information on each style.[44]

[43] Philadelphia Department of Streets, *Philadelphia Bicycle Facility Design Guidelines* (Philadelphia, Pa.: Philadelphia Department of Streets, 1998).

[44] “Bicycle Parking,” *Pro-Bike News* (April 1996).

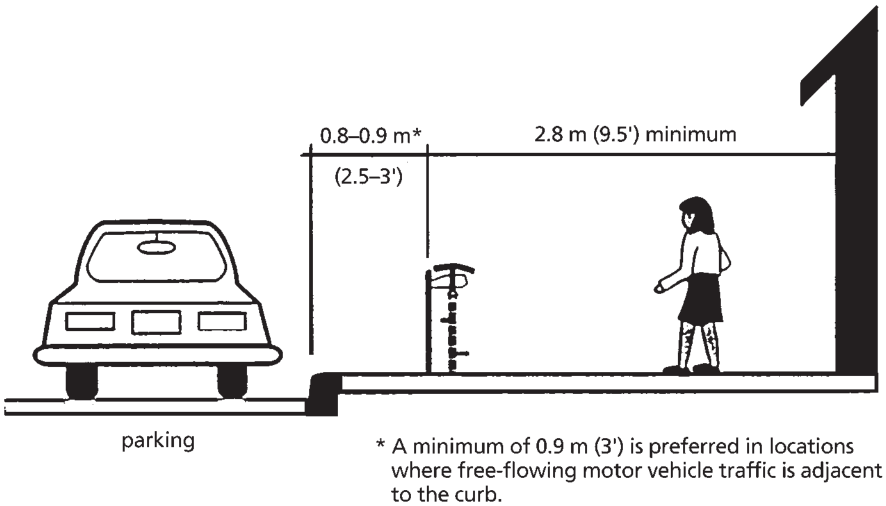


Figure 16–24 Bicycle Rack in the Right-of-Way

Source: *Philadelphia Bicycle Facility Design Guidelines*, Philadelphia, Pa.: Philadelphia Department of Streets, 1988.

- *Class I bicycle parking:* This category includes bike lockers or locked and guarded storage areas that provide high-security protection.
  - *Advantages*—High-security storage and ideal for long-term storage.
  - *Disadvantages*—Expensive.
- *Class II bicycle parking:* This category includes racks that secure both wheels and bicycle frame, which usually have moving parts and provide medium security with a user-supplied lock.
  - *Advantages*—Medium security and great when coupled with covered protection from the elements.
  - *Disadvantages*—Moving parts, complex design, and may not work with the common U-lock.
- *Class III bicycle parking:* The most common type of Class III rack are inverted "U"s.
  - *Advantages*—Simple design, affordable, can be manufactured by a local welder, and supports frame as well as wheel.
  - *Disadvantages*—Offers low-security for long-term parking.

Pedestrian Facility Design

There are a number of information sources for design guidelines that apply to pedestrian facilities. *Design and Safety of Pedestrian Facilities,* published by the Institute of Transportation Engineers, contains recommended practices for pedestrian improvements. The MUTCD and ADAAG also address a range of pedestrian facility design standards. However, many of these national resources have been written to deal primarily with motor vehicle design and contain limited pedestrian-related material, such as AASHTO's *A Policy on the Geometric Design of Streets and Highways* (also known as the *Green Book*). At the local level, it is often more common to find examples of comprehensive design practices that recognize pedestrian needs.

Pedestrian Characteristics

There are basic definitions of concepts and characteristics of pedestrian movement, their relationship to various land use contexts, and common pedestrian crash types to be considered when planning for pedestrian movement. These characteristics can be found in the AASHTO's *Green Book* and *Highway Capacity Manual* and include information on:

- Average pedestrian dimensions (the average pedestrian occupies a space of 450 mm × 600 mm or 18″ × 24″).
- Walking speeds.
- Capacities for pedestrian-related facilities.

Where pedestrian movement is very dense, such as on pedestrian bridges or tunnels, at intermodal connections, outside stadiums, or in the middle of downtown, then pedestrian capacity analysis may be needed. Research has developed a LOS concept for pedestrians that relates flow rate to spacing and walking speed.

An average walking speed of 1.2 m per sec. (4 ft per sec.) has been used for many years. There is a growing tendency to use 1.1 meters per second (3.5 ft per sec.) as a general value and 0.9 or 1.0 meters per second (3.0 or 3.25 ft per sec.) for specific applications such as facilities used by the elderly or handicapped.

Design consideration must also take into account characteristics of pedestrians with physical, visual, or mental disabilities. For example, average pedestrian dimensions increase for individuals using canes, walkers, wheelchairs, shopping carts, or baby carriages.[45] Pedestrians with ambulatory difficulties are sensitive to walking surfaces. Persons with hearing or visual impairments or learning disabilities may be less able to process typical sensory information, such as colors or signing.[46]

Pedestrian trip generation rates have been defined for different land uses. Where roads abut such uses, either existing or proposed, these numbers provide an indication of potential trip making activity. Chapter 7 of this handbook provides a summary of capacity; and the *Highway Capacity Manual* provides procedures for the operational analysis of walkways, crosswalks and street corners.

Specific crash classification types have been developed for pedestrian collisions.[47] Crashes often occur because of deficient roadway designs or traffic control measures, or they may result from improper behavior on the part of motorists and pedestrians. Examples of some of the more common types of pedestrian crashes and their likelihood of occurrence are shown in Figure 16–25.

Guidelines on the design of a range of specific pedestrian facilities, including sidewalks, shoulders, medians, crosswalks, curb ramps, and so forth are provided in this chapter.

Pedestrian Facilities

An individual's decision to walk is as much a factor of security, safety, and convenience as it is the *perceived quality* of the experience. Pedestrian facilities should be designed with the following factors in mind:

- *Sufficient width*: sidewalks should accommodate anticipated volumes based on adjacent land uses, and they should at a minimum allow for two adults to walk abreast. Greater detail on sidewalk dimensions is provided later in this chapter.

- *Protection from traffic:* high-volume or high-speed (>56 km/h or 35 mph) motor vehicle traffic creates dangerous and uncomfortable conditions for pedestrians. Physical (and perceptual) separation can be achieved through a

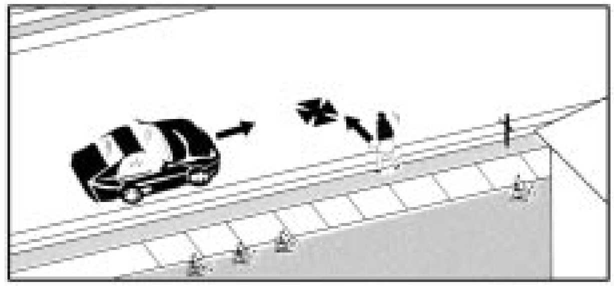
[45] Institute of Transportation Engineers, *Design and Safety of Pedestrian Facilities* (Washington, D.C.: ITE, 1998).

[46] Ibid, pp. 20–27.

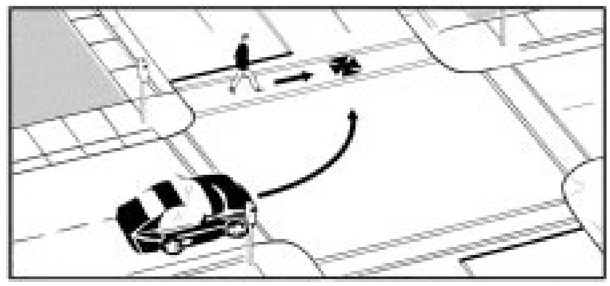
[47] U.S. Department of Transportation, Federal Highway Administration, *Pedestrian Crash Types: A 1990's Information Guide,* FHWA Report No. FHWA-RD-96-163 (Washington, D.C.: U.S. DOT, FHWA, 1997).

combination of methods: a grassy planting strip with street trees, a raised planter, bicycle lanes, on-street parallel parking, and others. Intersection design should facilitate both vehicular and pedestrian movement with geometric dimensions that reduce pedestrian crossing distances and provision of median refuge islands.

- *Street trees:* street trees are an essential element in a high quality pedestrian environment. Not only do they provide shade, they also give a sense of enclosure to the sidewalk environment, which enhances the pedestrian's sense of walking in a protected environment.
- *Pedestrian-scale design:* large highway-scale signage reinforces the general notion that pedestrians are out of place. Signage should be designed to be seen by the pedestrian. Street lighting should likewise be scaled to the level of the pedestrian, instead of providing light poles that are more appropriate on high-speed freeways. Components such as street furniture, vistas, and landmarks should be incorporated into designs to help make walking routes interesting.
- *Continuity:* pedestrian facilities are often discontinuous, particularly when private developers are not encouraged to link on-site pedestrian facilities to adjacent developments and nearby sidewalks or street corners. New developments should be designed to encourage pedestrian access from nearby streets. Existing gaps in the system should be placed on a prioritized list for new sidewalk construction.



Midblock Dash
Frequency: 442 cases; 8.7% of all crashes
Severity: 37% resulted in serious or fatal injuries.



Vehicle Turn/Merge
Frequency: 497 cases; 9.8% of all crashes
Severity: 18% resulted in serious or fatal injuries.

Figure 16–25 Common Types of Pedestrian Crashes

Source: *Pedestrian Crash Types: A 1990's Informational Guide,* Washington, D.C.: U.S. Department of Transportation, Federal Highway Administration, 1997.

- *Clearances:* vertical clearance above sidewalks for landscaping, trees, signs, and similar obstructions should be at least 2.4 m (8 ft). In commercial areas and Central Business Districts (CBDs), the vertical clearance for awnings should be 2.7 m (9 ft). The vertical clearance for building overhangs that cover the majority of the sidewalk should be 3.6 m (12 ft).
- *Conformance with National Standards*: all pedestrian facilities should be consistent with *Americans with Disabilities Act* requirements. Specific guidance is provided by Architectural and Transportation Barriers Compliance Board's *Americans with Disabilities Act Accessibility Guidelines.*

Sidewalk Design Overview

Sidewalks not only encourage walking, but they also improve the safety of pedestrians. The safety benefits of sidewalks are well-documented: one study found that streets without sidewalks had 2.6 times more pedestrian and automobile collisions than expected on the basis of exposure, while streets with sidewalks on only one side had 1.2 times more pedestrian crashes.[48] In the United States 5,412 pedestrians were killed and 82,000 were injured in 1996. Most pedestrian fatalities in 1996 occurred in urban areas (71 percent).[49]

[48] Richard L. Knoblauch, et. al., "Investigation of Exposure Based Pedestrian Areas: Crosswalks, Sidewalks, Local Streets and Major Arterials," FHWA Report No. FHWA-RD-88-038 (Washington, D.C.: U.S. DOT, FHWA, 1988).

[49] National Highway Traffic Safety Administration, *NHTSA Traffic Safety Facts* (Washington, D.C.: NHTSA, 1996).

All roadways should have some type of walking facility out of the traveled way. A separate walkway is often preferable, but a roadway shoulder will also provide a safer pedestrian accommodation than walking in the travel lane.

Direct pedestrian connections should be provided between residences and activity areas. It is usually not difficult to ascertain where connections between residential areas and activity centers will be required during the early stages of development.

Development density can be used as a surrogate for pedestrian usage in determining the need for sidewalks. Local residential streets, especially cul-de-sacs, can accommodate extensive pedestrian activity on the street because there is little vehicular activity. Collector streets are normally used by pedestrians to access bus stops and commercial developments on the arterial to which they feed.

Sidewalks should be provided on all streets within a 0.4 kilometers (one quarter-mile) of a transit station. Sidewalks should also be provided along developed frontages of arterial streets in zones of commercial activity. Collector and arterial streets in the vicinity of schools should be provided with sidewalks to increase school trip safety.[50]

Sidewalk Obstacles

Street furniture and utility poles create obstacles to pedestrian travel when located directly on the sidewalk. At the very minimum there should be 0.9 m (3 ft) of sidewalk width to allow wheelchairs to pass. Where possible, utilities should be relocated so as not to block the sidewalk. Benches should not be sited directly on the sidewalk, but set back at least 0.9 m (3 ft).

The design of new intersections or re-design of existing intersections presents an opportunity to improve pedestrian circulation. Street furniture located near intersections can block sight lines. In general, the designer should consider the effect on sight distance for all features located in the vicinity of roadway intersections.

Sidewalk Pavement Design

Sidewalks and roadside pathways should be constructed of a solid, debris-free surface. Regardless of the type of surface chosen, it must be designed to withstand adequate load requirements. Standard depth of pavement should consider site-specific soil conditions and is therefore left to local discretion. Brick and concrete pavers are popular materials for more decorative sidewalks. (Figure 16–26.) The use of stylized surfaces is encouraged, however, they must be installed properly or they will deteriorate over time.

Pedestrian Facility Maintenance

Maintenance is an important aspect of creating adequate and comfortable facilities for pedestrians. A crumbling sidewalk is not only an eyesore but also a hazard to the pedestrian and a barrier to the disabled. Regular maintenance protects public investment and reduces liability risk.

A periodic inspection schedule for pedestrian facilities should be adopted by local jurisdictions. Crosswalks will need re-striping. A general maintenance budget should be allocated by each local government for use on a yearly basis, perhaps combined with a maintenance budget for bicycle facilities.

Sidewalk Width and Setback Guidelines

The following are recommended guidelines for sidewalk width and setback for a typical community. It is important to note that there are some areas that warrant wider sidewalks than the minimum. For example, sidewalks in and around local universities and colleges must accommodate a much higher volume of pedestrians, and therefore they warrant

[50] Transportation Research Board, *Planning and Implementing Pedestrian Facilities in Suburban and Rural Areas,* TRB Report No. 294A (Washington, D.C.: TRB, 1987).

Figure 16–26 Decorative Sidewalk Treatments

Source: The RBA Group, Morristown, N.J., Greenways Incorporated, Cary, N.C.

additional width. The recommendations below are based on ITE and ADA guidelines and common practices used by other pedestrian-friendly communities in the United States.

- *Sidewalks in CBDs*. Sidewalk widths in CBDs are, for the most part, already determined by building setback and street width. Should a reconstruction project warrant further study of sidewalk width in a CBD, service standards have been set by AASHTO's *Green Book.*
- *Arterial and collector streets in commercial and residential areas*. Sidewalks on arterial and collector streets in commercial and residential areas should be a minimum of 1.5 m (5 ft) wide. A minimum of a 0.6 m (2 ft) wide planting strip should be provided. If no planting strip is possible, the minimum width of the sidewalk should be 2.1 m (7 ft).
- *Sidewalks on local streets in residential areas.* On local streets in residential areas, sidewalk width may be based on the number of units per acre. For multifamily developments and single-family homes with densities that exceed 4 units per acre, the sidewalk should be a minimum of 1.5 m (5 ft) wide with a minimum setback of 0.6 m (2 ft). For densities up to 4 dwelling units per acre, the sidewalk should be a minimum of 1.2 m (4 ft) wide with a 0.6 m (2ft) setback.
- *Sidewalks on streets with no curb and gutter*. The setback requirements in this section are based on roadway cross sections that include curb and gutter. Sidewalks located adjacent to "ribbon pavement" (pavement with no curb and gutter) are not recommended. However, if no other solution is possible, sidewalks adjacent to ribbon pavement should have a much greater setback requirement, depending on roadway conditions. Engineers should consult AASHTO's *Policy on Geometric Design of Highways and Streets* for more specific guidelines.
- *Sidewalks in rural areas*. In most rural areas, the low volume of pedestrians does not warrant sidewalk construction. In most cases, 1.2 m (4 ft) wide paved shoulders can provide an adequate area for pedestrians to walk on rural roadways, while also serving the needs of bicyclists. Exceptions should be made in areas where isolated developments such as schools, ballparks, or housing communities create more pedestrian use. For example, motorists might regularly park along a rural road to access a nearby ballpark. A sidewalk may be warranted in this circumstance so that pedestrians can walk separately from traffic. Sidewalks in rural areas should be provided at a width based on the anticipated or real volume of pedestrians, with 1.5 m (5 ft) being the minimum width.

Continuity in Construction Zones

Work zone areas can disrupt pedestrian and bicycle circulation, and they often create total barriers for pedestrians. Just as traffic is re-routed during roadway construction, pedestrians and bicyclists should be provided a safe alternative through the work zone. If a safe alternative is not provided, they will often try to make their way across the site unprotected.

Pedestrians and bicyclists should be re-routed well in advance of the construction barriers, since most are unlikely to retrace their steps to get around the work zone. The MUTCD provides appropriate signage for these situations, and it provides limited guidance for pedestrian detours in Section 6C-9. If a path is to be provided within the work zone, it should be constructed of a smooth and even surface, with no gaps. Pedestrians should be protected from construction vehicle traffic, roadway traffic, and falling debris.

Construction sites are particularly difficult to traverse for disabled pedestrians. An alternate accessible route should always be provided when the main accessible route is interrupted by construction activities.

Intersection Design and Pedestrian Crossings

Intersection design is extremely important for the safety of pedestrians. No single feature creates a safe intersection for pedestrians—the design elements described in the next sections should be combined as site conditions warrant.

Crosswalks

Marked crosswalks should be provided at intersections that carry significant pedestrian volumes, or where newly installed sidewalks are likely to generate more pedestrian traffic.

Crosswalks can serve to channel pedestrian traffic through an intersection, as well as heighten the awareness of motorists of possible pedestrian crossing movements. It is important to note that, although crosswalks are an important element in intersection design, a crosswalk alone does not insure the safety of a pedestrian. Too often, crosswalks are the sole provision for pedestrians at intersections when other safety measures are also needed.

Paragraph 3B-18 of the MUTCD provides guidance on crosswalk design. High visibility designs are recommended. (Figure 16–27.) Crosswalk lines should be 0.3–0.6 m (1–2 ft) in width and spaced be 0.3–0.6 m (1–2 ft) apart. A nonskid, long-life striping material is the preferable marking material for bicycle and pedestrian facilities.

The optimum width of crosswalks is 3 m (10 ft) wide, with a minimum width (as set by the MUTCD) of 1.8 m (6 ft) wide. Wider crosswalks should be installed at locations with higher pedestrian volumes. At signalized intersections with stop bars, a minimum separation of 1.2 m (4 ft) is necessary between the stop bar and edge of the crosswalk. At midblock locations stop or yield bars should be placed to allow motorists adequate stopping time, particularly on multilane sections. Criteria for installing crosswalks is shown in Figure 16–28.

Curb Ramps

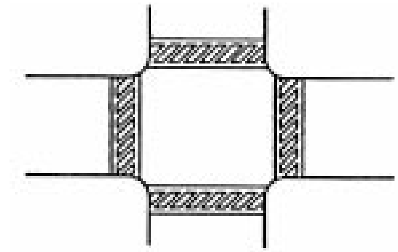
A deciding factor in the location and design of crosswalks is the placement of curb ramps at street corners. Curb ramps should always be placed so to lead the pedestrian directly into a striped crosswalk area. Corners should either include two curb ramps or one broad ramp that serves both crosswalks. Curb ramps should always be provided with a matching ramp on the opposite side of the road, as well as ramps at pedestrian refuge islands.

ADA provides federal guidance for curb ramp installation, and use of either guideline is acceptable. Current ADA standards state that the slope of curb ramps cannot exceed 1:12, with a maximum rise of 0.76 m (30 in). If the curb ramp is located in an area where pedestrians might typically walk, it must have flared sides that do not exceed a slope of 1:10. It is also extremely important that the bottom of the curb ramp be even with the street surface. A raised lip at the street edge can cause a wheelchair to tip over, even if it is only 6 mm (0.25 in) high.

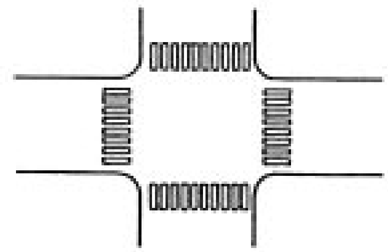
Traffic Signals

Pedestrian safety at intersections depends in part on minimizing the length of time that the pedestrian is exposed in the street. One way of minimizing conflict and exposure at intersections is to improve the phasing of traffic signals. Traffic signal improvements for pedestrians may include the following provisions:

- Improvements to timing options and turn phasing.
- Elimination of right-turn-on-red movements.
- Elimination of free-right turning movements (with yield signs).
- Addition of pedestrian signals (walk and don't walk).
- Push-button signals that can be tripped by pedestrians.
- Reduced corner radii to shorten the distance the pedestrian must cross, therefore also shortening the signal interval.
- Construction of curb extensions to reduce “in-street” walking distance.



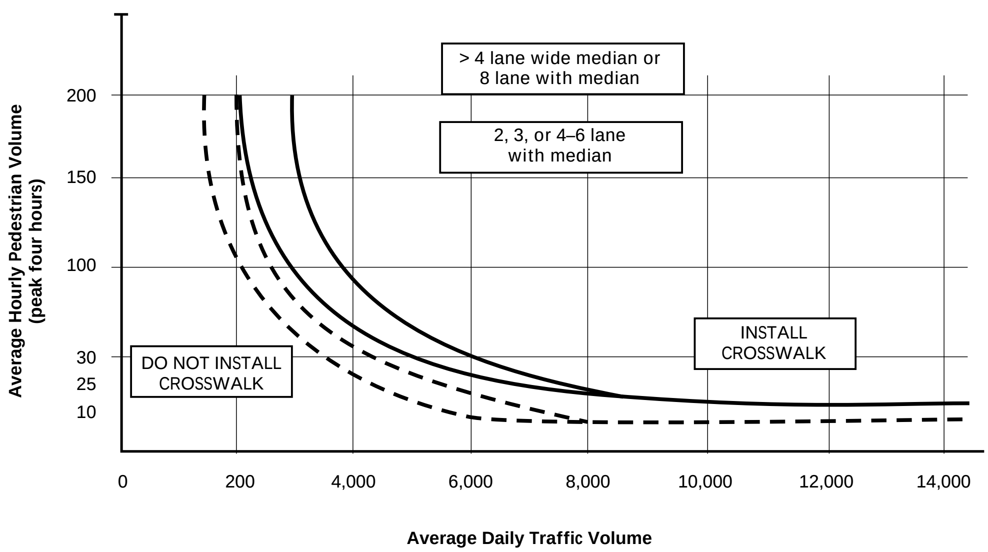
Crosswalk marking with diagonal lines for added visibility



Crosswalk marking with longitudinal lines for added visibility

Figure 16–27 High Visibility Crosswalk Patterns

Source: *Manual on Uniform Traffic Control Devices*, Washington, D.C.: U.S. Department of Transportation, 1988.



Criteria for Installing Crosswalks

- - Location with predominantly young, elderly or handicapped Pedestrians.

— Other locations

Basic Criteria

1. Speed limit of 5 mph.
2. Adequate stopping sight distance.
3. For mid block preferred block lengths > .
4. Crosswalk adequately illuminated.
5. Minimal conflicting attention demands.

Figure 16–28 Criteria for Installing Crosswalks

Source: *Manual on Uniform Traffic Control Devices,* Washington, D.C.: U.S. Department of Transportation, 1988.

Extensive guidelines for traffic signalization to accommodate pedestrian crossings are provided in the MUTCD. Traffic engineering analysis is necessary on a case-by-case basis in order to determine the best signal option. Signalized intersection design and audible signals should be given special consideration in areas with higher numbers of senior citizens, school-age children, and disabled persons.

On-Street Parking

The presence of parked cars near intersections have been cited as a contributing factor in many pedestrian crashes in urban areas. Parked cars block visual access to oncoming traffic, so that both pedestrians and motor vehicles cannot see each other. Consideration should be given to removing parking in the immediate vicinity of crosswalks.

Corner Curb Radius

One aspect of intersection design that is often overlooked is the turning radii of corners. A wide turning radius can increase crossing distance, as well as increase the speed of turning traffic. However, a turning radius that is too small can cause long vehicles (such as flatbed trucks or buses) to jump the curb edge and eventually cause the curb to crumble, hit pedestrians waiting to cross, or hit and demolish street furniture (especially signal and lighting poles). The optimum design is a compromise between the two.

Curb Extensions

Curb extensions or “bulb-outs” are extensions of the sidewalk and curb into the street on both sides of a pedestrian crosswalk. Curb extensions have several advantages for the pedestrian. The primary benefit is a shorter crossing distance at an intersection. (Figure 16–29.) Shortening this distance decreases the amount of time the pedestrian is exposed to traffic. By narrowing the traffic lane and creating a smaller corner radius, curb extensions also reduce traffic speeds at the intersection. Curb extensions increase visibility for the pedestrian in areas with on-street parking by offering an unimpeded view of oncoming traffic (and allowing on-coming traffic to also see approaching pedestrians). Lastly, curb extensions can provide additional space for landscaping to improve the visual quality of the street.

Medians and Refuge Areas

In general, pedestrians are better accommodated when roadway width at intersections is narrower, thereby making medians unnecessary. Pedestrian refuge areas can be essential for large, multilane, urban and suburban intersections. These islands serve several purposes. They allow a resting area for slower pedestrians who cannot make it across the intersection within the time allotted. In wider urban intersections, refuge areas allow pedestrians to cross one direction of traffic at a time, and they provide a place to wait for the next pedestrian cycle. In this case, they also reduce the overall delay to motor vehicles that would otherwise have to stop for an interval in order to allow a pedestrian to cross the entire length of the intersection.

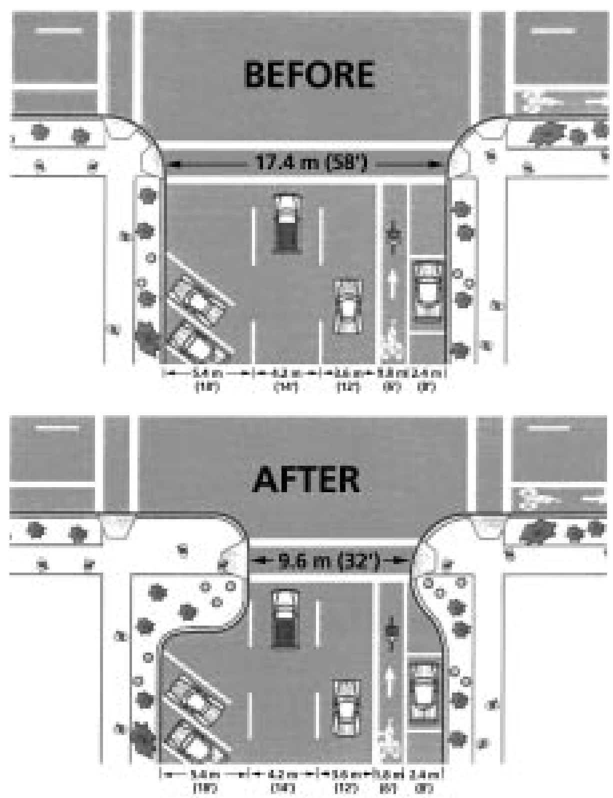


Figure 16–29 Curb Extension Reduced Crossing Distance

Source: *Oregon Bicycle and Pedestrian Plan,* Salem, Ore.: Oregon Department of Transportation, 1995.

Medians and refuge areas can be particularly important for urban intersections with center turn lanes and left turn signals. Traffic signals that serve these intersections often do not allow adequate time for the pedestrian to traverse the length of the intersection. The center median therefore provides a refuge for pedestrians who must wait through several cycles to complete a crossing.

A pedestrian refuge should be provided at intersections with crossing distances that cannot be made within the time allotted by the signal phasing (assuming a standard rate of travel at 1 m/3.5 ft per sec). Refuge areas should also be installed at intersections with crossing distances that exceed 22.8 m (75 ft), or with a high volume of elderly or disabled pedestrians.

The preferred width for medians is 1.8 m (6 ft), with 1.2 m (4 ft) being the minimum width. The length of the island should be based in part on the geometric design of the approaching traffic lanes, but it should not be less than 6 m (20 ft). The design of the island should meet ADA standards, with curb cuts provided. (Figure 16–30.)

Midblock Crossings

In situations where a midblock crossing formalizes a pedestrian activity that is already occurring on a frequent basis, midblock crossing provisions can be used to improve the visibility of the pedestrian. Midblock crossings are most appropriate in locations where a high pedestrian traffic generator is located directly across the street from a significant source of pedestrians. Examples would include a commercial area with fast food restaurants across the street from a university, or a shopping center across from a high school. However, due to the increased safety risk of a pedestrian crossing in midstream traffic, midblock crossings should be generally discouraged unless one or more of the following conditions apply:

- The location is already a source of a substantial number of midblock crossings, or it is anticipated to generate midblock crossings (for a new development).
- The land use is such that a pedestrian is highly unlikely to cross the street at an adjacent intersection, and when midblock crossings would be frequent.
- The safety and capacity of adjacent intersections creates a situation where it is dangerous to cross the street, except at a designated midblock location.
- Spacing between adjacent signals exceeds 600 feet.
- Other lesser measures to encourage pedestrians to cross at adjacent intersections have been unsuccessful.

Figure 16–30 Median Refuge Island

Source: The RBA Group, Morristown, N.J.

On-street parking can reduce sight distances at midblock crossings. In areas with on-street parking, midblock crossings should include highly visible crosswalk markings and a flared-out curb extension. (Figure 16–31.)

Another measure to improve motorist awareness of the midblock crossing is to erect overhead pedestrian crossing signs on span wires or mast arms above the street. In cases of extremely high pedestrian volume during certain times of the day, a signalized intersection with pedestrian push-buttons should be considered.

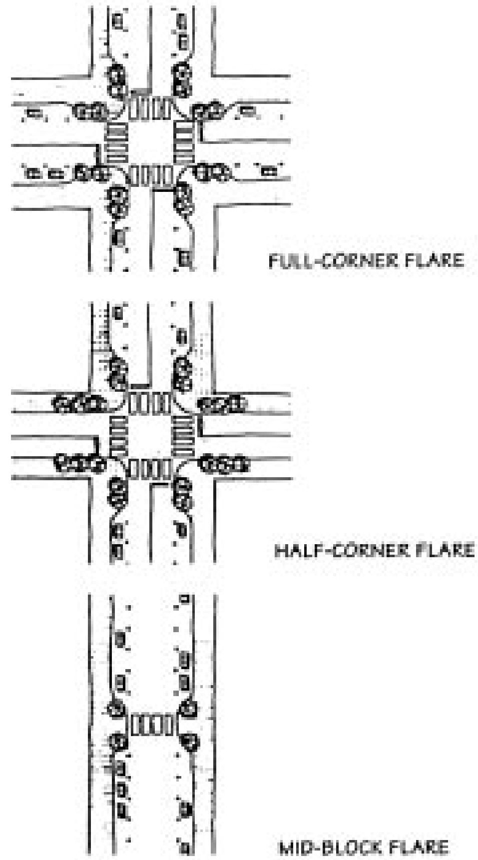


Figure 16–31 Midblock Flare

Source: *Planning and Implementing Pedestrian Facilities in Suburban and Developing Rural Areas,* TRB Report 294A,Washington, D.C.: Transportation Research Board, 1987.

Grade-Separated Crossings

Convenience is essential in designing overpasses and underpasses. Studies have shown that pedestrians can rarely be convinced to use a poorly located crossing—and will almost never use an overpass if it takes fifty percent longer to cross than an at-grade crossing. Grade-separated crossings should be provided within the normal path of pedestrians wherever possible. Even for the most ideal overpass location, it may still be necessary to block pedestrian access to the at-grade crossing with fencing.

A 1988 study concluded that state and local governments usually consider grade-separated crossings in the following situations:

- Where there is moderate to high pedestrian demand to cross a freeway or expressway.
- Where there is a large number of young children (i.e., particularly near schools) who must regularly cross a high-speed or high-volume roadway.
- On streets having high vehicle volumes, high pedestrian crossing volumes, and where there is an extreme hazard for pedestrians (e.g., on wide streets with high-speed traffic and poor sight distance).
- Where one or more of the conditions stated above exists in conjunction with a well-defined pedestrian origin and destination (e.g., a residential neighborhood across a busy street from a school, a parking structure affiliated with a university, or apartment complex near a shopping mall).[51]

It is important to provide adequate lighting of the crossing to prevent crime and vandalism. Underpasses often need lighting 24 hours a day. Topography should be a major consideration in determining whether an underpass or overpass is more appropriate. These facilities are regulated by ADA standards, therefore extensive ramping is usually necessary to meet the grade requirements.

Expressway Ramps

Pedestrian safety is often jeopardized in areas where expressway ramps intersect with arterial, collector, and local streets. For new roadways and roadway widening projects, a pedestrian circulation plan should be developed for interchange exit and entrance ramp locations, particularly for areas with the following characteristics:

[51] C.V. Zegeer and S.F. Zegeer, “Pedestrians and Traffic Control Measures” (Washington, D.C.: Transportation Research Board, 1988).

- Areas with substantial pedestrian volume or nearby pedestrian attractors.
- Where existing sidewalks are located in the vicinity of expressway exits and entrances.
- Where new sidewalks are planned for the vicinity of expressway exits and entrances.

Several measures can increase the awareness of motorists and improve conditions for pedestrians at interchanges. Ramp width should be minimized to reduce the crossing distance for pedestrians. Warning signs should be posted on exit ramps to warn motorists of upcoming pedestrian crossings. Motorists should be encouraged to quickly reduce their vehicle speed after exiting the highway, both through signage and traffic calming methods.

It should be noted that it is difficult to correct all of the problems associated with expressway entrance and exit ramps on local streets. In some cases, these areas will always be unfriendly for pedestrians due to the limiting factors of high speed exiting traffic and poor sight distance. Extra care should be taken to improve these areas for pedestrians wherever possible.

Traffic Calming

Traffic calming is a relatively new and very different approach to managing the roadway environment. Traffic calming seeks to reduce the negative effects of motor vehicles. It employs a variety of physical measures or techniques to reduce vehicle speeds, alter driver behavior, and improve conditions for nonmotorized street users.[52] By their nature, therefore, "traffic calmed" roadways are more conducive to bicycling and walking. For a more detailed discussion of traffic calming practices, see Chapter 17 of this handbook.

Pedestrian Linkages

When a grid or other dense street network is not available, pedestrian linkages should be provided to maintain walking continuity. Cul-de-sacs, loop roads, and similar treatments that disrupt pedestrian continuity should incorporate pedestrian linkages such as "cut-throughs" to adjoining developments. (Figures 16–32 and 16–33.) These shortcuts enable pedestrians to travel by the most direct route between destinations. In most cases, routes will have fewer vehicular conflicts since the pedestrian does not have to use an arterial to get from one local street to another.

Similarly, large lot commercial developments, such as office buildings or shopping centers, should provide numerous linkages with surrounding residential areas to permit nearby residents to walk to the site. Linkages should also be provided between adjoining commercial, residential, and office uses; for example, walkways connecting an office building parking area with an adjacent restaurant. It is not necessary to demonstrate that there is a latent demand for walking. The linkage is required to service even the single trip if it is generated.

Policy for linkages can be defined in the land use element of municipal master plans, in the circulation element of municipal master plans, and on the official map.

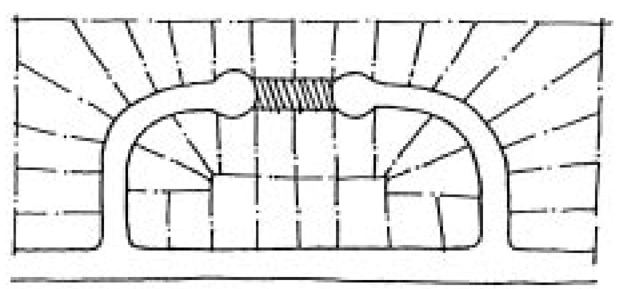


Figure 16–32 Pedestrian Linkages

Source: *Accommodating the Pedestrian,* New York, N.Y.: Van Nostrand Reinhold Co., 1984.

Summary and Conclusions

The mandates of ISTEA, TEA-21, and other transportation-related and legislative measures, such as the Clean Air Act Amendments of 1990, provide planners with both flexibility and funding to implement a comprehensive planning approach that will result in a transportation infrastructure that is capable of accommodating the transportation and recreation needs of both bicyclists and pedestrians.

[52] Ian Lockwood, "ITE Traffic Calming Definition", *ITE Journal*, vol. 67, no. 7 (Washington, D.C. Institute of Transportation Engineers, July 1997) p. 22.

As described in this chapter, state-of-the-practice tools and guidelines relating to facilities design and the planning and maintenance of bicycle and pedestrian facilities have been developed and tested in a number of states, regions, and communities. Though these tools and guidelines exist, transportation policy changes at the state and local levels are also required to fully integrate bicycle and pedestrian concepts into the transportation planning process and move bicycle and pedestrian design beyond just marginal improvements.

It is important that bicycling and walking become a routine part of the transportation system rather than being treated as modes separate from other transportation systems. In the long term it would be preferable for bicycle and pedestrian facilities to be incorporated directly, based on their own merits, in all transportation plans, projects, and programs. Similarly, separate, dedicated funding for bicycle and pedestrian facilities, which may currently be needed to assure that improvements will be constructed, should over time cease to be needed as the merit of funding these improvements becomes generally accepted. It is necessary to address both bicycle and pedestrian transportation issues in a more systematic manner.

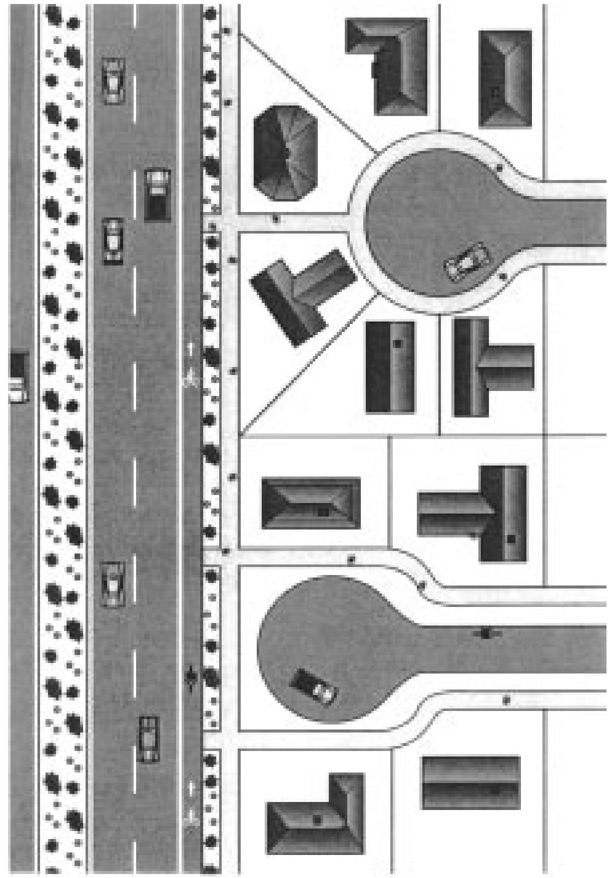


Figure 16–33 Cul-de-sac Connections

Source: *Oregon Bicycle and Pedestrian Plan,* Salem, Ore.: Oregon Department of Transportation, 1995.

Suggested References for Further Reading

In addition to the following suggested references, also see the publications that are cited in the footnotes.

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