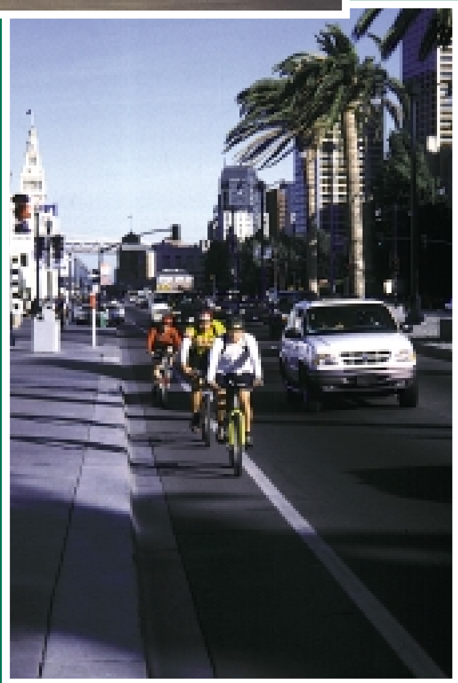
guide for the development of bicycle facilities



american association
of state highway and
transportation officials

1999

guide for the development of bicycle facilities

american association of state highway and transportation officials

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1999 **prepared by the aashto task force on geometric design**

Printed in the United States of America.

ISBN: 1-56051-102-8

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Introduction

Bicycle travel has played an historic role in transportation. Even before the invention of the automobile, the League of American Wheelmen promoted improved traveled ways.

Increasingly, transportation officials throughout the United States are recognizing the bicycle as a viable transportation mode. While recreational cycling is still the primary use of bicycles in this country, the number of people using bicycles for commuting and other travel purposes has been increasing since the early 1970s. Nationwide, people are recognizing the energy efficiency, cost effectiveness, health benefits and environmental advantages of bicycling.

Local, state and federal agencies are responding to the increased use of bicycles by implementing a wide variety of bicycle-related projects and programs. The emphasis now being placed on bicycle transportation requires an understanding of bicycles, bicyclists and bicycle facilities. This manual addresses these issues and clarifies the elements needed to make bicycling a viable transportation alternative.

All highways, except those where cyclists are legally prohibited, should be designed and constructed under the assumption that they will be used by cyclists. Therefore, bicycles should be considered in all phases of transportation planning, new roadway design, roadway reconstruction, and capacity improvement and transit projects.

Research continues to provide additional criteria for the design of appropriate bicycle facilities. The selection of a bicycle facility may depend on many factors, including vehicular and bicycle traffic characteristics, adjacent land use and expected growth patterns.

Chapter 1 provides an overview of planning considerations for bicycles, a discussion of types of facility improvements and a description of factors to consider when locating a facility. Chapter 2, which is organized around the various types of bicycle facilities, provides guidelines to follow when constructing or improving highways and designing and constructing bicycle facilities. Chapter 3 provides recommendations for the operation and maintenance of bicycle facilities. The Appendix reviews the legal status of bicycles under the *Uniform Vehicle Code (UVC*[3]*)*.

Purpose

Safe, convenient and well-designed facilities are essential to encourage bicycle use. This guide is designed to provide information on the development of facilities to enhance and encourage safe bicycle travel. The majority of bicycling will take place on ordinary roads with no dedicated space for bicyclists. Bicyclists can be expected to ride on almost all road-

ways, as well as separated shared use paths and even sidewalks, where permitted to meet special conditions.

This guide provides information to help accommodate bicycle traffic in most riding environments. It is not intended to set forth strict standards, but, rather, to present sound guidelines that will be valuable in attaining good design sensitive to the needs of both bicyclists and other highway users. However, in some sections of this guide, design criteria include suggested minimum guidelines. These are recommended only where further deviation from desirable values could result in unacceptable safety compromises.

Scope

This book provides part of the information necessary for a safe bicycling environment. Facilities are only one of several elements essential to a community's overall bicycle program. Bicycle safety education and training, encouraging bicycle use, and the application and enforcement of the rules of the road as they pertain to bicyclists and motorists should be combined with facilities to form a comprehensive community approach to bicycle use. This guide provides information on facilities. Information on other elements of an overall bicycle program can be obtained from state or local bicycle coordinators and other publications. (See References at the end of this Guide.)

The provisions for bicycle travel are consistent with, and similar to, normal highway engineering practices. Signs, signals and pavement markings for bicycle facilities which are presented in the *Manual on Uniform Traffic Control Devices (MUTCD*[2]*)* should be used in conjunction with this guide. For construction of bicycle facilities, state and local construction specifications should be used.

Definitions

BICYCLE—Every vehicle propelled solely by human power upon which any person may ride, having two tandem wheels, except scooters and similar devices. The term "bicycle" for this publication also includes three- and four-wheeled human-powered vehicles, but not tricycles for children.

BICYCLE FACILITIES—A general term denoting improvements and provisions made by public agencies to accommodate or encourage bicycling, including parking and storage facilities, and shared roadways not specifically designated for bicycle use.

BICYCLE LANE or BIKE LANE—A portion of a roadway which has been designated by striping, signing and pavement markings for the preferential or exclusive use of bicyclists.

BICYCLE PATH or BIKE PATH—See *Shared Use Path*.

BICYCLE ROUTE SYSTEM—A system of bikeways designated by the jurisdiction having authority with appropriate directional and informational route markers, with or without specific bicycle route numbers. Bike routes should establish a continuous routing, but may be a combination of any and all types of bikeways.

BIKEWAY—A generic term for any road, street, path or way which in some manner is specifically designated for bicycle travel, regardless of whether such facilities are designated for the exclusive use of bicycles or are to be shared with other transportation modes.

HIGHWAY—A general term denoting a public way for purposes of vehicular travel, including the entire area within the right-of-way.

RAIL–TRAIL—A shared use path, either paved or unpaved, built within the right-of-way of an existing or former railroad.

RIGHT-OF-WAY—A general term denoting land, property or interest therein, usually in a strip, acquired for or devoted to transportation purposes.

RIGHT OF WAY—The right of one vehicle or pedestrian to proceed in a lawful manner in preference to another vehicle or pedestrian.

ROADWAY—The portion of the highway, including shoulders, intended for vehicular use.

RUMBLE STRIPS—A textured or grooved pavement sometimes used on or along shoulders of highways to alert motorists who stray onto the shoulder.

SHARED ROADWAY—A roadway which is open to both bicycle and motor vehicle travel. This may be an existing roadway, street with wide curb lanes, or road with paved shoulders.

SHARED USE PATH—A bikeway physically separated from motorized vehicular traffic by an open space or barrier and either within the highway right-of-way or within an independent right-of-way. Shared use paths may also be used by pedestrians, skaters, wheelchair users, joggers and other non-motorized users.

SHOULDER—The portion of the roadway contiguous with the traveled way for accommodation of stopped vehicles, for emergency use and for lateral support of sub-base, base and surface courses.

SIDEWALK—The portion of a street or highway right-of-way designed for preferential or exclusive use by pedestrians.

SIGNED SHARED ROADWAY (SIGNED BIKE ROUTE)—A shared roadway which has been designated by signing as a preferred route for bicycle use.

TRAVELED WAY—The portion of the roadway for the movement of vehicles, exclusive of shoulders.

UNPAVED PATH—Paths not surfaced with asphalt or Portland cement concrete.

Chapter 1 Planning

Bicyclists have the same mobility needs as every other user of the transportation system and use the highway system as their primary means of access to jobs, services and recreational activities. Planning for existing and potential bicycle use should be integrated into the overall transportation planning process.

All highway improvements provide an opportunity to enhance the safety and convenience of bicycle travel and most improvements for bicycle travel also benefit other modes of travel. For example, paved shoulders have many safety, operational and maintenance benefits and may also provide a place for bicyclists to ride. Even minor intersection improvements can incorporate the needs of bicyclists through a few simple measures. The opportunity to improve conditions for bicyclists should be considered during the initial planning and design phases of all new highway projects and highway improvements.

Plans for implementing bicycle projects should be consistent with a community's transportation plan and should reflect overall community goals. Some zoning ordinances and subdivision regulations inhibit bicycle use and may need to be amended to support shared use paths and bicycle-compatible roadway design, bicycle parking and land use policies that keep destinations closer to home and work.

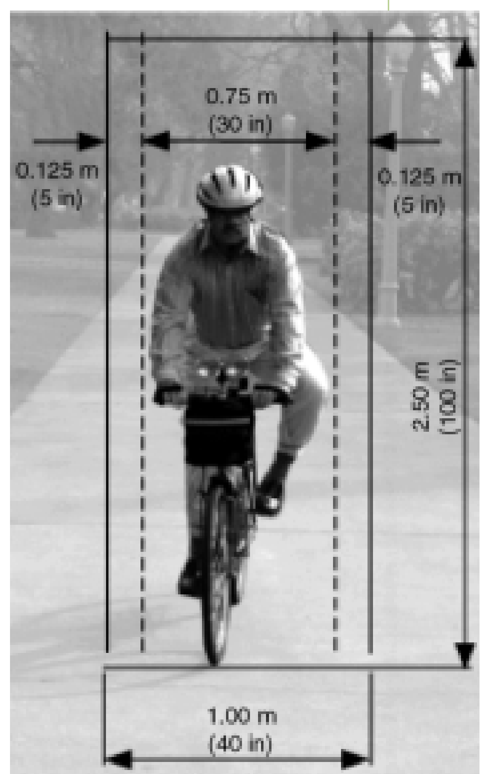


Figure 1. Bicyclist Operating Space

The Bicycle

As Figure 1 shows, bicyclists require at least 1.0 m (40 inches) of essential operating space based solely on their profile. An operating space of 1.2 m (4 feet) is assumed as the minimum width for any facility designed for exclusive or preferential use by bicyclists. Where motor vehicle traffic volumes, motor vehicle or bicyclist speed, and the mix of truck and bus traffic increase, a more comfortable operating space of 1.5 m (5 feet) or more is desirable.

The Bicycle User

Although their physical dimensions may be relatively consistent, the skills, confidence and preferences of bicyclists vary dramatically. Some riders are confident riding anywhere they are legally allowed to operate and can negotiate busy and high speed roads that have few, if any, special accommodations for bicyclists. Most adult riders are less confident and prefer to use roadways with a more comfortable amount of operating space, perhaps with designated space for bicyclists, or shared use paths that are away from motor vehicle traffic. Children may be confident riders and have excellent bike handling skills, but have yet to develop the traffic sense and experience of an everyday adult rider. All categories of

rider require smooth riding surfaces with bicycle-compatible highway appurtenances, such as bicycle-safe drainage inlet grates.

A 1994 report by the Federal Highway Administration[11] used the following general categories of bicycle user types (A, B and C) to assist highway designers in determining the impact of different facility types and roadway conditions on bicyclists:

Advanced or experienced riders are generally using their bicycles as they would a motor vehicle. They are riding for convenience and speed and want direct access to destinations with a minimum of detour or delay. They are typically comfortable riding with motor vehicle traffic; however, they need sufficient operating space on the traveled way or shoulder to eliminate the need for either themselves or a passing motor vehicle to shift position.

Basic or less confident adult riders may also be using their bicycles for transportation purposes, e.g., to get to the store or to visit friends, but prefer to avoid roads with fast and busy motor vehicle traffic unless there is ample roadway width to allow easy overtaking by faster motor vehicles. Thus, basic riders are comfortable riding on neighborhood streets and shared use paths and prefer designated facilities such as bike lanes or wide shoulder lanes on busier streets.

Children, riding on their own or with their parents, may not travel as fast as their adult counterparts but still require access to key destinations in their community, such as schools, convenience stores and recreational facilities. Residential streets with low motor vehicle speeds, linked with shared use paths and busier streets with well-defined pavement markings between bicycles and motor vehicles, can accommodate children without encouraging them to ride in the travel lane of major arterials.

Choosing the Appropriate Facility Type

These three bicycle user types are a helpful guide to the highway designer. However, no one type of bicycle facility or highway design suits every bicyclist and no designated bicycle facility can overcome a lack of bicycle operator skill. Within any given transportation corridor, bicyclists may be provided with more than one option to meet the travel and access needs of all potential users.

Planners and engineers should recognize that the choice of highway design will affect the level of use, the types of user that can be expected to use any given road, and the level of access and mobility that is afforded bicyclists. For example, a four-lane divided highway with 3.6-m (12-foot) travel lanes, no shoulder and an 85 km/hr (55 mph) speed limit will attract only the most confident of riders. The same road with a 1.5-m (5-foot) shoulder or bike lane might provide sufficient "comfortable operating space" for many more adult riders, but would still not be comfortable for children or less confident adults. This latter group might only be accommodated through an alternative route using neighborhood streets linked by short sections of shared use path. If such an alternative route is provided and the four-lane road has a continuous paved shoulder, most experienced and many casual adult riders will continue to use the shoulder for the sake of speed and convenience.

Facilities for bicyclists should also be planned to provide continuity and consistency for all users. Children using a path to get to school should not have to cross a major arterial without some intersection controls, and shoulders and bike lanes should not end abruptly and unannounced at a difficult intersection or busy stretch of highway.

Types of Bicycle Facilities

Selection of a bicycle facility type is dependent on many factors, including the ability of the users, specific corridor conditions and facility cost. The descriptions below provide an overview of each facility type and general design.

Shared Roadway (No Bikeway Designation). Most bicycle travel in the United States now occurs on streets and highways without bikeway designations. This probably will be true in the future as well. In some instances, a community's existing street system may be fully adequate for efficient bicycle travel, and signing and striping for bicycle use may be unnecessary. In other cases, some streets and highways may be unsuitable for bicycle travel at present, and it would be inappropriate to encourage bicycle travel by designating the routes as bikeways. Finally, some routes may not be considered high bicycle demand corridors, and it would be inappropriate to designate them as bikeways regardless of roadway conditions (e.g., minor residential streets).

Some rural highways are used by touring bicyclists for intercity and recreational travel. In most cases, such routes should only be designated as bikeways where there is a need for enhanced continuity with other bicycle routes. However, the development and maintenance of 1.2-m (4-foot) paved shoulders with a 100-mm (4-inch) edge stripe can significantly improve the safety and convenience of bicyclists and motorists along such routes.

Signed Shared Roadway. Signed shared roadways are designated by bike route signs, and serve either to:

a. Provide continuity to other bicycle facilities (usually Bike Lanes); or
b. Designate preferred routes through high-demand corridors.

As with bike lanes, signing of shared roadways should indicate to bicyclists that particular advantages exist to using these routes compared with alternative routes. This means that responsible agencies have taken actions to assure that these routes are suitable as shared routes and will be maintained in a manner consistent with the needs of bicyclists. Signing also serves to advise vehicle drivers that bicycles are present.

Bike Lane or Bicycle Lane. Bike lanes are established with appropriate pavement markings and signing along streets in corridors where there is significant bicycle demand and where there are distinct needs that can be served by them. The purpose should be to improve conditions for bicyclists on the streets. Bike lanes are intended to delineate the right of way assigned to bicyclists and motorists and to provide for more predictable movements by each. Bike lanes also help to increase the total capacities of highways carrying mixed bicycle and motor vehicle traffic. Another important reason for constructing bike lanes is to better accommodate bicyclists where insufficient space exists for comfortable bicycling on existing streets. This may be accomplished by reducing the width of vehicular lanes or prohibiting parking in order to delineate bike lanes. In addition to lane striping, other measures should be taken to ensure that bicycle lanes are effective facilities. In particular, bicycle-safe drainage inlet grates should be used, pavement surfaces should be smooth, and traffic signals should be responsive to bicyclists. Regular maintenance of bicycle lanes should be a top priority, since bicyclists are unable to use a lane with potholes, debris or broken glass.

If bicycle travel is to be improved, special efforts should be made to assure that a high quality network is provided with these lanes. However, the needs of both the motorist and the bicyclist must be considered in the decision to provide bike lanes.

Shared Use Path. Generally, shared use paths should be used to serve corridors not served by streets and highways or where wide utility or former railroad right-of-way exists, permitting such facilities to be constructed away from the influence of parallel streets. Shared use paths should offer opportunities not provided by the road system. They can provide a recreational opportunity or, in some instances, can serve as direct commute routes if cross flow by motor vehicles and pedestrians is minimized. The most common applications are along rivers, ocean fronts, canals, utility rights-of-way, former or active railroad rights-of-way, within college campuses, or within and between parks. There may also be situations where such facilities can be provided as part of planned developments. Another common application of shared use paths is to close gaps in bicycle travel caused by construction of cul-de-sacs, railroads and freeways or to circumvent natural barriers (rivers, mountains, etc.). While shared use paths should be designed with the bicyclist's safety in mind, other users such as pedestrians, joggers, dog walkers, people pushing baby carriages, persons in wheelchairs, skate boarders, in-line skaters and others are also likely to use such paths.

In selecting the proper facility, an overriding concern is to assure that the proposed facility will not encourage or require bicyclists or motorists to operate in a manner that is inconsistent with the rules of the road. The needs of both motorists and bicyclists must be considered in selecting the appropriate type of facility.

An important consideration in selecting the type of facility is continuity. Alternating segments of shared use paths and bike lanes along a route are generally inappropriate and inconvenient because street crossings by bicyclists may be required when the route changes character. Also, wrong-way bicycle travel with a higher potential for crashes may occur on the street beyond the ends of shared use paths because of the inconvenience of having to cross the street.

Sidewalks generally are not acceptable for bicycling. However, in a few limited situations, such as on long and narrow bridges and where bicyclists are incidental or infrequent users, the sidewalk can serve as an alternate facility, provided any significant difference in height from the roadway is protected by a suitable barrier between the sidewalk and roadway.

Inventory of Existing Conditions

Planning for bicycle facilities begins with observing and gathering data on the existing conditions for bicycle travel. Problems, deficiencies, safety concerns and bicyclists' needs should be identified. The existing bicycling environment should be observed. Bicycle facilities as well as roads not typically used by bicyclists should be examined for their suitability for bicycling. Motor vehicle traffic volume, the percentage and volume of bus and truck traffic, and the speed of traffic should be considered, since they have a significant impact on bicyclists. In addition, obstructions and impediments to bicycle travel should be noted, such as incompatible grates, debris, shoulder rumble strips, narrow lanes, driveways, rough pavements, curbside auto parking, bridge expansion joints, metal grate bridge decks, railroad tracks, poor sight distance and traffic signals that are not responsive to bicycles. Potential corridors for off-road shared use paths should be explored, such as former and active railroads' rights-of-way, stream and river corridors, canal towpaths and utility corridors. Bicycle parking facilities should be examined for adequacy in both number and theft prevention. Barriers such as rivers, railroads and freeways should also be identified and examined for their effects on bicycle traffic.

Bicycle traffic usually is generated where residential areas are close to accessible destinations. Areas near bicycle traffic generators should be reviewed, and existing and potential bicycle users identified. Examples of bicycle traffic generators include major employment centers, schools, parks, shopping centers, neighborhoods, recreational facilities, colleges and military bases. Convenient access and bicycle parking should be provided at transit stations, ferries and other intermodal transfer points.

Bicycle counts can be used to identify locations of high use. However, caution should be exercised when using bicycle counts as a measure of current demand. These numbers can considerably underestimate potential users. Traffic generators along the prospective route should be evaluated as to the potential bicycle traffic they would generate, given better conditions for bicycling. Bicycle crash studies can also be useful in determining locations needing improvement.

Public participation is essential during the inventory of existing conditions. Observations and surveys of existing bicyclists, as well as the non-bicycling public, can be very useful. Additional sources of information include citizen bicycle advisory committees, citizen groups, and individuals responsible for recreation planning.

Education programs, existing laws affecting bicycling, and enforcement programs should also be examined for their appropriateness and effectiveness.

Plans for Improvements

The inventory of existing conditions provides a foundation of knowledge from which to develop a plan for system-wide improvements for bicycling. Improvements and programs should address both the physical aspects of the bicycling environment as well as the education and accommodation of bicycling in the community. In the most successful examples, bicycle-friendly policies have been institutionalized in the systematic, everyday work of agencies at all levels of government.

The physical improvement plan should address the physical conditions, barriers and inconveniences to bicycling throughout the community, as well as make the best use of existing bicycle-friendly facilities. The plan should make specific recommendations for a network of on-road and off-road bicycle facilities, locations for “spot improvements” such as drainage grate replacement, bridge expansion joints, or intersection signal modification, and improvements needed to existing bicycle facilities that are substandard or in disrepair. Physical improvements should be based on the inventory of existing conditions and public input. This physical improvement plan should also address maintenance needs for both on-road and off-road bikeways, and establish policies for coordinating maintenance activities among different agencies and jurisdictions.

The physical improvement plan should also identify locations in need of bicycle parking and storage facilities. In general, provisions for bicycle parking should be considered at all major traffic generators and at transit stations and bus stops to encourage intermodal travel.

Selection of a Bicycle Facility

Many factors should be considered in determining the appropriate bicycle facility type, location and priority for implementation. In addition to the guidelines below, the Federal Highway Administration provides guidance on facility selection in the 1994 publication *Selecting Roadway Design Treatments to Accommodate Bicycles*.[11]

- *Skill Level of Users*—As described in the section on Bicycle Users earlier in this chapter, consideration should be given to the skills and preferences of the types of bicyclists who will use the facility. Facilities near schools, parks and residential neighborhoods are likely to attract a higher percentage of basic and child bicyclists than advanced bicyclists.

- *Motor Vehicle Parking*—The turnover and density of on-street parking can affect bicyclist safety (e.g., opening car doors and cars leaving parallel parking spaces). Diagonal and perpendicular parking arrangements are not compatible with bicycle facilities because of restricted sight distance and the related potential for bicycle-motor vehicle conflicts. They should be avoided wherever possible.

- *Barriers*—In some areas, there are physical barriers to bicycle travel caused by topographical features, such as rivers, railroads, freeways or other impediments. In such cases, providing a facility to overcome a barrier can create new opportunities for bicycling.

- *Crash Reduction*—The reduction or prevention of bicycle crashes (i.e., bicycle/motor vehicle, bicycle/bicycle, bicycle/pedestrian and single bicycle crashes) is important. Therefore, the potential for reducing crash problems through the improvement of a facility should be assessed. Plans for constructing new bicycle facilities should be reviewed to identify and resolve potential safety issues.

- *Directness*—Particularly for utilitarian bicycle trips, facilities should connect traffic generators and should be located along a direct line of travel that is convenient for users.

- *Accessibility*—In locating a bicycle facility, consideration should be given to the provision for frequent and convenient bicycle access, especially in residential areas. Adequate access for emergency, maintenance and service vehicles should also be considered. Other major traffic generators such as educational facilities, office buildings, shopping areas, parks and museums should also be considered when evaluating bicycle accessibility.

- *Aesthetics*—Scenery is an important consideration along a facility, particularly for a facility that will serve a primarily recreational purpose. Trees can also provide cooler riding conditions in summer and can provide a windbreak.

- *Personal Safety/Security*—The potential for criminal acts against bicyclists, especially along isolated shared use paths, and the possibility of theft or vandalism at parking locations, should be considered.

- *Stops*—Bicyclists have a strong inherent desire to maintain momentum. If bicyclists are required to make frequent stops, they may avoid the route or disregard traffic control devices.

- *Conflicts*—Different types of facilities introduce different types of conflicts. Facilities on the roadway can result in conflicts between bicyclists and motorists. Shared use paths can involve conflicts between bicyclists, horseback riders, skaters, runners and pedestrians on the facility. Conflicts between bicyclists and motorists may also occur at highway and driveway intersections.

- *Maintenance*—Designs which facilitate and simplify maintenance will improve the safety and use of a facility. A local or regional bikeway maintenance program is essential.

- *Pavement surface quality*—Bikeways should be free of bumps, holes and other surface irregularities if they are to attract and satisfy the needs of bicyclists. Utility covers and drainage grates should be at grade and, if possible, outside the expected path of travel. Railroad crossings should be improved as necessary to provide for safe bicycle crossings.

- *Truck and Bus Traffic*—Because of their width, high–speed trucks, buses, motor homes and trailers can cause special problems for bicyclists. Where bus stops are located along a bicycle route, conflicts with bus loading and unloading and pavement deterioration, such as asphalt pavement shoving, may also be problems.

- *Traffic Volumes and Speeds*—For facilities on roadways, motor vehicle traffic volumes and speeds must be considered along with the roadway width. Commuting bicyclists frequently use arterial streets because they minimize delay and offer continuity for long trips. If adequate width for all vehicles is available on the more heavily traveled streets, it can be more desirable to improve such streets than adjacent streets. When this is not possible, a nearby parallel street may be improved for bicyclists, if stops are minimal and other route conditions are adequate. When such a parallel facility is improved, care must be taken that motor vehicle traffic is not diverted. While inexperienced bicyclists prefer more lightly-traveled streets, it should be remembered that preferred routes may change over time as skill levels change.

- *Bridges*—Bridges can serve an important function by providing bicycle access across barriers. However, some bridge features restrict bicycle access and/or create unfavorable conditions for bicyclists. The most common of these are curb-to-curb widths that are narrower than the approach roadways (especially where combined with relatively steep grades), open grated metal decks found on many spans, low railings or parapets, and certain types of expansion joints such as finger-type joints, that can cause steering difficulties.

- *Intersection Conditions*—A high proportion of bicycle crashes occur at intersections. Facilities should be selected so as to minimize the number of crossings, or intersections should be improved to reduce crossing conflicts. At-grade intersections on high-volume (or high-speed) roadways and mid-block crossings should be analyzed with bicyclists' needs in mind to determine the most appropriate crossing design treatments.

- *Costs/Funding*—Facility selection normally will involve a cost analysis of alternatives. Funding availability can limit the alternatives; however, it is very important that a lack of funds not result in a poorly designed or constructed facility. The decision to implement a bikeway plan should be made with a conscious, long-term commitment to a proper level of maintenance. When funding is limited, emphasis should be given to low-cost improvements such as bicycle parking, removal of barriers and obstructions to bicycle travel, and roadway improvements. Facility selection should seek to maximize user benefits per dollar funded.

- *State and Local Laws and Ordinances*—Bicycle programs must reflect state and local laws and ordinances. Bicycle facilities must not encourage or require bicyclists to operate in a manner that is inconsistent with these laws and ordinances.

Education Programs for Bicyclists and Motorists

Bicyclist and motorist education programs are key ingredients to building a successful bicycle transportation system and fostering the growth of bicycle use in a community. A primary reason is the great amount of misinformation that has spread about bicycling. Education programs can help to dispel the myths, encourage courteous and lawful behavior among motorists and bicyclists of all ages, and enhance the skill level of bicyclists and motorist awareness, thus leading to a reduction in crashes. The education program can be administered through a number of different agencies and interest groups, such as police departments, schools, libraries, bicycle clubs, and parks and recreation departments.

There are four primary audiences for bicycle safety education and awareness efforts. For each group, an education program can stress basic messages that focus on the most frequent causes of crashes and injury. The following represent messages and skills that should be stressed for each group:

Young Bicyclists:

- How to ride in a straight line without wobbling or swerving
- Importance of stopping, looking and yielding before entering or crossing a roadway
- Importance of riding with traffic (on the right-hand side of the road), rather than against traffic
- How to scan behind for traffic before moving or turning left
- Importance of helmet use
- Importance of using hand signals
- Knowledge and understanding of traffic control devices
- Methods of crossing intersections

Parents of Young Bicyclists:

- Age and developmental factors in bicycle safety

- Common cause of crashes
- Importance of riding with traffic (on the right-hand side of the road), rather than against traffic
- Driveway intersection sight distance problems
- Importance of helmet use for themselves and their children
- Importance of setting a good example

Adult Bicyclists:

- Bicycles are vehicles and should be operated according to traffic laws
- Importance of riding with traffic (on the right-hand side of the road), rather than against traffic
- Importance of helmet use
- Importance of using lights and reflectors at night
- Importance of using hand signals
- Importance of courtesy toward other road users, motorists and pedestrians
- Knowledge and understanding of traffic control devices

Motorists:

- Bicycles are vehicles and have legal rights to use the roadway
- Skills for sharing the road with bicyclists
- Improper turning movements that endanger bicyclists (do not turn in front of bicyclists)
- Importance of courtesy toward other road users including bicyclists and pedestrians

Chapter 2 Design

Design of new bicycle facilities, as well as improvements to existing facilities, is an ongoing process that should be consistent with a comprehensive plan considering the different bicycle users, existing conditions and community goals. A wide range of facility improvements can enhance bicycle transportation. An improvement can be simple and involve minimal design considerations (e.g., changing drainage grate inlets) or it can be more extensive (e.g., providing a shared use path). For example, improvements such as bicycle lanes depend on the roadway's design. On the other hand, shared use paths are located on independent alignments; consequently, their design depends on many factors, including right-of-way, available funding, topography and expected use.

A community's overall goals for transportation improvements should include provisions for bicycle travel. Through appropriate planning and design, general improvements for motor vehicles can also be designed to enhance bicycle travel. For all roadways where bicycle travel is permitted, planning and design should consider provisions for bicycling. Roadway projects that extend near or intersect existing or planned shared use paths should include careful analysis and design measures to ensure the continued access and safety of path users. Public involvement in the form of public meetings, hearings or bicycle advisory groups is encouraged during the planning and design processes.

Guidelines are presented in this chapter to help design and implement bicycle facilities that accommodate the operating characteristics of bicycles as defined in this guide. Modifications to facilities (e.g., widths, curve radii, superelevations, etc.) that are necessary to accommodate adult tricycles, bicycle trailers, and other special purpose human-powered vehicles and accessories should be made in accordance with the expected use, using sound engineering judgment.

This chapter has been organized around the various classifications of bikeways:

- Shared Roadways
- Signed Shared Roadways
- Bike Lanes
- Shared Use Paths
- Other Design Considerations

Where guidelines overlap across classifications, reference is made to the appropriate section to eliminate repeating text.

Figure 2. Example of a Shared Use Roadway

Shared Roadways

To varying extent, bicycles will be used on all highways where they are permitted. Bicycle-safe design practices, as described in this guide, should be followed during initial roadway design to avoid costly subsequent improvements. Because most existing highways have not been designed with bicycle travel in mind, roadways can often be improved to more safely accommodate bicycle traffic. Design features that can make roadways more compatible to bicycle travel include bicycle-safe drainage grates and bridge expansion joints, improved railroad crossings, smooth pavements, adequate sight distances, and signal timing and detector systems that respond to bicycles. In addition, more costly shoulder improvements and wide curb lanes can be considered. Also see Chapter 2, Other Design Considerations.

Width is the most critical variable affecting the ability of a roadway to accommodate bicycle traffic. In order for bicycles and motor vehicles to share the use of a roadway without compromising the level of service and safety for either, the facility should provide sufficient paved width to accommodate both modes. This width can be achieved by providing wide outside lanes or paved shoulders.

Paved Shoulders

Adding or improving paved shoulders often can be the best way to accommodate bicyclists in rural areas and benefit motor vehicle traffic. Paved shoulders can extend the service life of the road surface since edge deterioration will be significantly reduced. Paved shoulders also provide a break-down area for motor vehicles. Where funding is limited, adding or improving shoulders on uphill sections will give slow-moving bicyclists needed maneuvering space and will decrease conflicts with faster moving motor vehicle traffic.

Paved shoulders should be at least 1.2 m (4 feet) wide to accommodate bicycle travel. However, where 1.2-m (4-foot) widths cannot be achieved, any additional shoulder width is better than none at all. The measurement of usable shoulder width should not include the width of a gutter pan, unless the pan width is 1.2 m (4 feet) or greater. Shoulder width of 1.5 m (5 feet) is recommended from the face of guardrail, curb or other roadside barriers. It is desirable to increase the width of shoulders where higher bicycle usage is expected. Additional shoulder width is also desirable if motor vehicle speeds exceed 80 km/h (50 mph), or the percentage of trucks, buses and recreational vehicles is high, or if static obstructions exist at the right side of the roadway.

In general, AASHTO's recommendations for shoulder width (as described in *A Policy on Geometric Design of Highways and Streets (Green Book*[1]*))* are the best guide for bicycles as well, since wider shoulders are recommended on heavily traveled and high-speed roads and those carrying large numbers of trucks. However, in order to be usable by bicyclists the shoulder must be paved.

Rumble strips or raised pavement markers, where installed to discourage or warn motorists they are driving on the shoulder, are not recommended where shoulders are used by bicyclists unless there is a minimum clear path of 0.3 m (1 foot) from the rumble strip to the traveled way, 1.2 m (4 feet) from the rumble strip to the outside edge of paved shoulder, or 1.5 m (5 feet) to adjacent guardrail, curb or other obstacle. If existing conditions preclude achieving the minimum desirable clearance, the width of the rumble strip may be decreased or other appropriate alternative solutions should be considered.

Increased Lane Width

Wide curb lanes for bicycle use are usually preferred where shoulders are not provided, such as in restrictive urban areas. On highway sections without designated bikeways, an outside or curb lane wider than 3.6 m (12 feet) can better accommodate both bicycles and motor vehicles in the same lane and thus is beneficial to both bicyclists and motorists. In many cases where there is a wide curb lane, motorists will not need to change lanes to pass a bicyclist. Also, a wide curb lane provides more maneuvering room when drivers are exiting from driveways or in areas with limited sight distance.

In general, 4.2 m (14 feet) of usable lane width is the recommended width for shared use in a wide curb lane. Usable width normally would be from edge stripe to lane stripe or from the longitudinal joint of the gutter pan to lane stripe (the gutter pan should not be included as usable width). On stretches of roadway with steep grades where bicyclists need more maneuvering space, the wide curb lane should be slightly wider where practicable [4.5 m (15 feet) is preferred]. The 4.5-m (15-foot) width may also be necessary in areas where drainage grates, raised reflectors on the right-hand side of the road, or on-street parking effectively reduce the usable width. With these exceptions in mind, widths greater than 4.2 m (14 feet) that extend *continuously* along a stretch of roadway may encourage the undesirable operation of two motor vehicles in one lane, especially in urban areas, and therefore are not recommended. In situations where more than 4.5 m (15 feet) of pavement width exists, consideration should be given to striping bike lanes or shoulders.

Restriping to provide wide curb lanes may also be considered on some existing multi-lane facilities by making the remaining travel lanes and left-turn lanes narrower. This should only be considered after careful review of traffic characteristics along the corridor and supported by a documented engineering analysis based on applicable design criteria.

On-Street Parking

On-street parking increases the potential for conflicts between motor vehicles and bicyclists. The most common bicycle riding location on urban roadways is in the area between parked cars and moving motor vehicles. Here, bicyclists are subjected to opening car doors, vehicles exiting parking spaces, extended mirrors that narrow the travel space, and obscured views of intersecting traffic. Therefore, 3.6 m (12 feet) of combined bicycle travel and parking width should be the minimum considered for this type of shared use.

Pavement Surface Quality

The smoothness of the riding surface affects the comfort, safety and speed of bicyclists. Pavement surface irregularities can do more than cause an unpleasant ride. Pavement surfaces should be smooth, and the pavement should be uniform in width. Wide cracks, joints or drop-offs at the edge of traveled way parallel to the direction of travel can trap a bicycle wheel and cause loss of control; holes and bumps can cause bicyclists to swerve into the path of motor vehicle traffic. In addition, a reduction in the operating speed of the bicyclist below a comfortable level results in less stability of the bicycle. As pavements age it may be necessary to fill joints or cracks, adjust utility covers or even overlay the pavement in some cases to make it suitable for bicycling.

Drainage Inlet Grates

Drainage inlet grates and utility covers are potential obstructions to bicyclists. Therefore, bicycle-safe grates should be used, and grates and covers should be located in a manner which will minimize severe and/or frequent maneuvering by the bicyclist. When new highway facilities are constructed, curb opening inlets should be considered to minimize the number of potential obstructions. Drainage inlet grates and utility covers should be placed or adjusted to be flush with the adjacent pavement surface.

Drainage inlet grates with slots parallel to the roadway, or a gap between the frame and the grate, can trap the front wheel of a bicycle, causing loss of steering control. If the slot spacing is wide enough, narrow bicycle wheels can drop into the grates. Conflicts with grates may result in serious damage to the bicycle wheel and frame and/or injury to the bicyclist. These grates should be replaced with bicycle-safe, hydraulically-efficient versions. When this is not immediately possible, a temporary correction is to weld steel cross straps or bars perpendicular to the parallel bars at 100-mm (4-inch) center-to-center maximum spacing to provide a maximum safe opening between straps.

While identifying a grate with pavement markings would be acceptable in some situations, as indicated in the *MUTCD*[2], bar grates with bars parallel to the direction of travel deserve special attention. Because of the serious consequences of a bicyclist missing the pavement marking in the dark or being forced over such a grate inlet by other traffic, these grates should be physically corrected, as described above, as soon as practicable after they are identified.

Signed Shared Roadways

Signed shared roadways are those that have been identified by signing as preferred bike routes. There are several reasons for designating signed bike routes:

a. The route provides continuity to other bicycle facilities such as bike lanes and shared use paths.

b. The road is a common route for bicyclists through a high demand corridor.

c. In rural areas, the route is preferred for bicycling due to low motor vehicle traffic volume or paved shoulder availability.

d. The route extends along local neighborhood streets and collectors that lead to an internal neighborhood destination such as a park, school or commercial district.

Bike route signs may also be used on streets with bike lanes, as well as on shared use paths. Regardless of the type of facility or roadway where they are used, it is recommended that bike route signs include destination information, as shown in Figure 4.

Signing of shared roadways indicates to cyclists that there are particular advantages to using these routes compared to alternate routes. This means the responsible agencies have taken action to ensure these routes are suitable as shared routes and will be maintained.

The following criteria should be considered prior to signing a route:

a. The route provides through and direct travel in bicycle-demand corridors.

b. The route connects discontinuous segments of shared use paths, bike lanes and/or other bike routes.

c. An effort has been made to adjust traffic control devices (e.g., stop signs, signals) to give greater priority to bicyclists on the route, as opposed to alternative streets. This could include placement of bicycle-sensitive detectors where bicyclists are expected to stop.

d. Street parking has been removed or restricted in areas of critical width to provide improved safety.

e. A smooth surface has been provided (e.g., adjust utility covers to grade, install bicycle-safe drainage grates, fill potholes, etc.)

f. Maintenance of the route will be sufficient to prevent accumulation of debris (e.g., regular street sweeping).

g. Wider curb lanes are provided compared to parallel roads.

h. Shoulder or curb lane widths generally meet or exceed width requirements included under *Shared Roadways*, page 17.

Figure 3. Example of a Signed Shared Roadway

Designating Sidewalks as Signed Bikeways

In general, the designated use of sidewalks (as a signed shared facility) for bicycle travel is unsatisfactory. (See *Undesirability of Sidewalks as Shared Use Paths*, page 58.)

It is important to recognize that the development of extremely wide sidewalks does not necessarily add to the safety of sidewalk bicycle travel, since wide sidewalks encourage higher speed bicycle use and increase potential for conflicts with motor vehicles at intersections, as well as with pedestrians and fixed objects.

Sidewalk bikeways should be considered only under certain limited circumstances, such as:

a. To provide bikeway continuity along high speed or heavily traveled roadways having inadequate space for bicyclists, and uninterrupted by driveways and intersections for long distances.

b. On long, narrow bridges. In such cases, ramps should be installed at the sidewalk approaches. If approach bikeways are two-way, sidewalk facilities also should be two-way.

Whenever sidewalk bikeways are established, unnecessary obstacles should be removed. Whenever bicyclists are directed from signed shared roadways to sidewalks, curb cuts should be flush with the street to assure that bicyclists are not subjected to problems associated with crossing a vertical lip at a flat angle. Curb cuts at every intersection are necessary, as well as bikeway yield or stop signs at uncontrolled intersections. Curb cuts should be wide enough to accommodate adult tricycles and two-wheel bicycle trailers.

In residential areas, sidewalk riding by young children is common. With lower bicycle speeds and lower cross street auto speeds, potential conflicts are somewhat lessened, but still exist. Nevertheless, this type of sidewalk bicycle use is accepted. It is inappropriate to sign these facilities as bicycle routes. In general, bicyclists should not be encouraged through signing to ride facilities that are not designed to accommodate bicycle travel.

Signing of Shared Roadways

Typical bicycle route signing is shown in Figure 4. For these signs to be more functional, supplemental destination plates should be placed beneath them when located along routes leading to high demand destinations (e.g., “To Downtown”, “To State College”, etc.).

There are instances where it is necessary to sign a route to direct bicyclists to a logical destination; however, the route does not offer any of the above signed shared roadway criteria. In such cases, the route should not be signed as a bike route, although destination signing may be advisable. A typical application of destination signing would be where bicyclists are directed off a highway to bypass a section of freeway. Special signs would be placed to guide bicyclists to the next logical destination, much as motorists would be directed if a highway detour were required. In urban areas, signs typically would be placed every 500 m (approximately every 1/4 mile), at all turns, and at major signalized intersections.

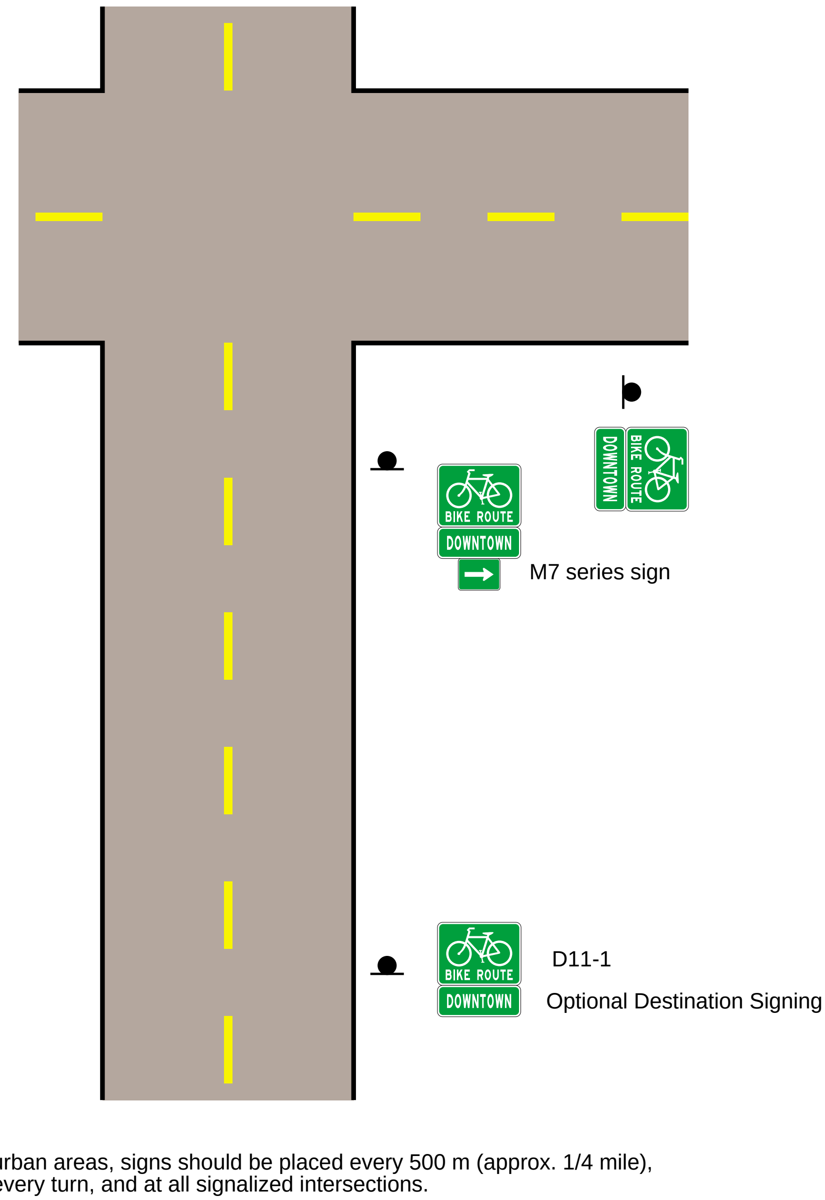


Figure 4. Typical Signed Shared Route Signing


Figure 5. Bicycle Lane Markings

Bike Lanes

Bike lanes can be incorporated into a roadway when it is desirable to delineate available road space for preferential use by bicyclists and motorists, and to provide for more predictable movements by each. Bike lane markings, as exemplified in Figure 5, can increase a bicyclist's confidence in motorists not straying into their path of travel. Likewise, passing motorists are less likely to swerve to the left out of their lane to avoid bicyclists on their right. Also see Chapter 2, Other Design Criteria, for additional information which applies to bike lanes. Drainage grates, railroad crossings, traffic control devices, etc., need to be evaluated and upgraded if necessary for bicycle use.

Bike lanes should be one-way facilities and carry bike traffic in the same direction as adjacent motor vehicle traffic. Two-way bike lanes on one side of the roadway are not recommended when they result in bicycles riding against the flow of motor vehicle traffic. Wrong-way riding is a major cause of bicycle crashes and violates the rules of the road as stated in the *UVC*[3]. Bicycle-specific wrong-way signing may be used to discourage wrong-way travel. However, there may be special situations where a two-way bike lane for a short distance can eliminate the need for a bicyclist to make a double crossing of a busy street or travel on a sidewalk. This should only be considered after careful evaluation of the relative risks and should be well documented in the project file.

On one-way streets, bike lanes should generally be placed on the right side of the street. Bike lanes on the left side are unfamiliar and unexpected for most motorists. This should only be considered when a bike lane on the left will substantially decrease the number of conflicts, such as those caused by heavy bus traffic or unusually heavy turning movements to the right, or if there are a significant number of left-turning bicyclists. Thus, left-side bike lanes should only be considered after careful evaluation. Similarly, two-way bike lanes on the left side of a one-way street could be considered with a suitable separation from the motor vehicle traffic after a complete engineering study of other alternatives and relative risks.

Bike Lane Widths

To examine the width requirements for bike lanes, Figure 6 shows four typical locations for such facilities in relation to the roadway. For roadways with no curb and gutter, the minimum width of a bike lane should be 1.2 m (4 feet). If parking is permitted, as in Figure 6(1), the bike lane should be placed between the parking area and the travel lane and have a minimum width of 1.5 m (5 feet). Where parking is permitted but a parking stripe or stalls are not utilized, the shared area should be a minimum of 3.3 m (11 feet) without a curb face and 3.6 m (12 feet) adjacent to a curb face as shown in Figure 6(2). If the parking volume is substantial or turnover is high, an additional 0.3 to 0.6 m (1 to 2 feet) of width is desirable.

Bike lanes should never be placed between the parking lane and curb lane. Bike lanes between the curb and parking lane can create obstacles for bicyclists from opening car doors and poor visibility at intersections and driveways and they prohibit bicyclists from making left turns.

Figure 6(3) depicts a bike lane along the outer portion of an urban curbed street where parking is prohibited.

The recommended width of a bike lane is 1.5 m (5 feet) from the face of a curb or guardrail to the bike lane stripe. This 1.5-m (5-foot) width should be sufficient in cases where a 0.3-0.6 m (1-2 foot) wide concrete gutter pan exists, given that a minimum of 0.9 m (3 feet) of ridable surface is provided, and the longitudinal joint between the gutter pan and pavement surface is smooth. The width of the gutter pan should not be included in the measurement of the ridable or usable surface, with the possible exception of those communities that use an extra wide, smoothly paved gutter pan that is 1.2 m (4 feet) wide as a bike lane. If the joint is not smooth, 1.2 m (4 feet) of ridable surface should be provided.

Since bicyclists usually tend to ride a distance of 0.8-1.0 m (32-40 inches) from a curb face, it is very important that the pavement surface in this zone be smooth and free of structures. Drain inlets and utility covers that extend into this area may cause bicyclists to swerve, and have the effect of reducing the usable width of the lane. Where these structures exist, the bike lane width may need to be adjusted accordingly.

Figure 6(4) depicts a bike lane on a roadway in an outlying area without curbs and gutters. This location is in an undeveloped area where infrequent parking is handled off the pavement. Bike lanes should be located within the limits of the paved shoulder at the outside edge. Bike lanes may have a minimum width of 1.2 m (4 feet), where the area beyond the paved shoulder can provide additional maneuvering width. A width of 1.5 m (5 feet) or greater is preferable and additional widths are desirable where substantial truck traffic is present, or where motor vehicle speeds exceed 80 km/h (50 mph).

A bike lane should be delineated from the motor vehicle travel lanes with a 150-mm (6-inch) solid white line. Some jurisdictions have used a 200-mm (8-inch) line for added distinction. An additional 100-mm (4-inch) solid white line can be placed between the parking lane and the bike lane (see Figure 7). This second line will encourage parking closer to the curb, providing added separation from motor vehicles, and where parking is light it can discourage motorists from using the bike lane as a through travel lane.

Bike lanes should be provided with adequate drainage to prevent ponding, washouts, debris accumulation and other potentially hazardous situations for bicyclists. The drainage grates should be bicycle-safe. When an immediate replacement of an incompatible grate is not possible, a temporary correction of welding thin metal straps across the grates perpendicular to the drainage slots at 100-mm (4-inch) center-to-center spacing should be considered.

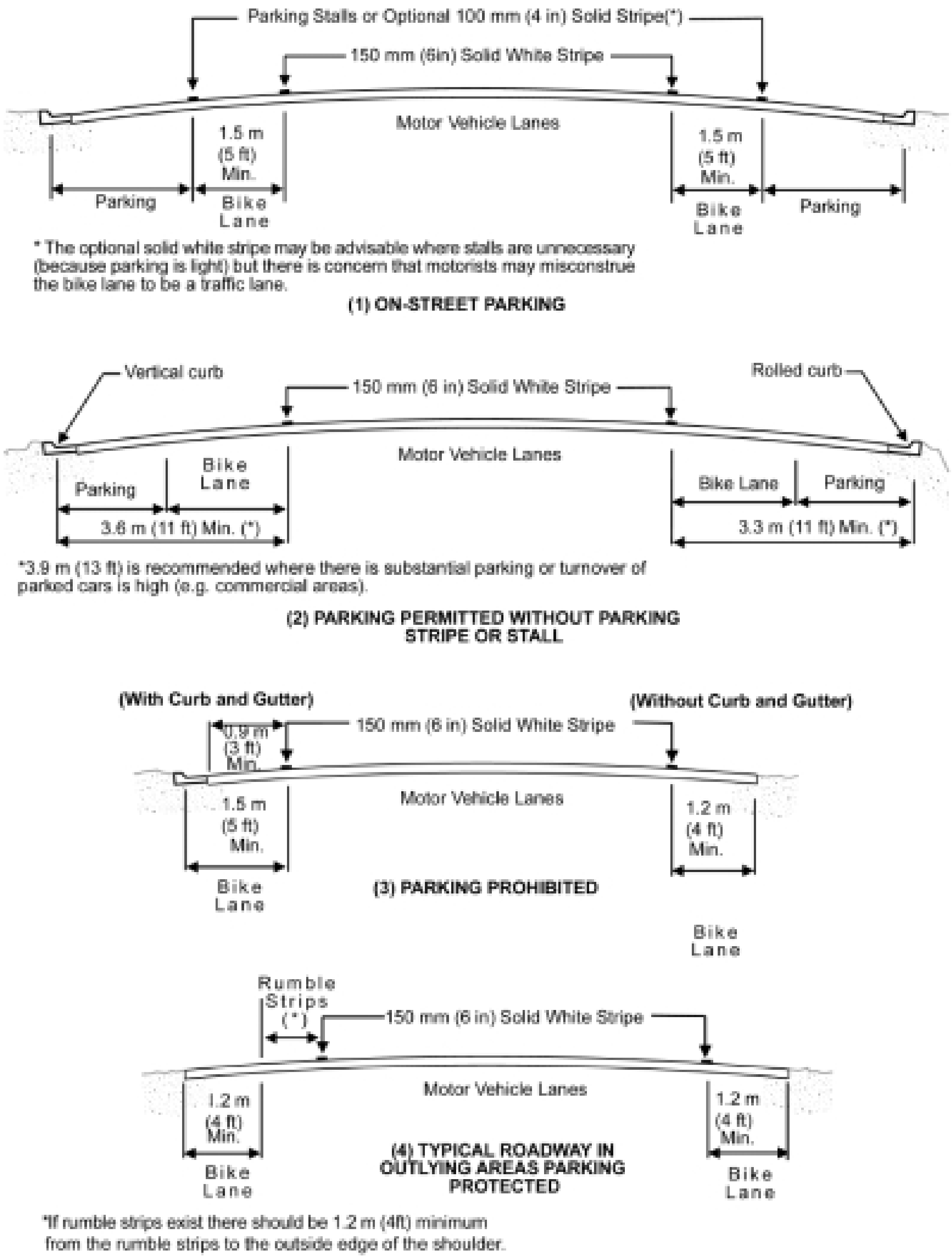


Figure 6. Typical Bike Lane Cross Sections

A smooth riding surface should be provided and utility covers should be adjusted flush with the surface.

Raised pavement markings and raised barriers can cause steering difficulties for bicyclists and should not be used to delineate bicycle lanes.

Bike Lanes at Intersections

Bike lane striping should not be installed across any pedestrian crosswalks, and, in most cases, should not continue through any street intersections. If there are no painted crosswalks, the bike lane striping should stop at the near side cross street property line extended and then resume at the far side property line extended. The only exception to this caveat might be the extension of dotted guidelines through particularly complex intersections or multi-lane roundabouts. The same bike lane striping criteria apply whether parking is permitted or prohibited in the vicinity of the intersection.

At signalized or stop-controlled intersections with right-turning motor vehicles, the solid striping to the approach should be replaced with a broken line with 0.6-m (2-foot) dots and 1.8-m (6-foot) spaces. The length of the broken line section is usually 15 m to 60 m (50 feet to 200 feet).

Since there are usually small volumes of right-turning motor vehicles at nonsignalized minor intersections with no stop controls, solid bike lane striping can continue all the way to the crosswalk on the near side of the intersection. However, if there is a bus stop or high right-turn volume, the 150-mm (6-inch) solid line should be replaced with a broken line with 0.6-m (2-foot) dots and 1.8-m (6-foot) spaces for the length of the bus stop. The bike lane striping should resume at the outside line of the crosswalk on the far side of the intersection. (See Figure 7.)

If a bus stop is located on a far side of the intersection rather than on a near side approach, the solid white line can also be replaced with a broken line for a distance of at least 24 m (80 feet) from the crosswalk on the far side of the intersection. Figure 7 illustrates typical bike lane striping at intersections without bus stops, at intersections with near side bus stops (right-hand side of the figure) and at intersections with far side bus stops (left-hand side of the figure).

At T-intersections with no painted crosswalks, the bike lane striping on the side across from the T-intersection should continue through the intersection area with no break. If there are painted crosswalks, the bike lane striping on the side across from the T-intersection should be discontinued only at the crosswalks. (See Figure 8).

Bike Lanes and Turning Lanes

Bike lanes sometimes complicate bicycle and motor vehicle turning movements at intersections. Because they encourage bicyclists to keep

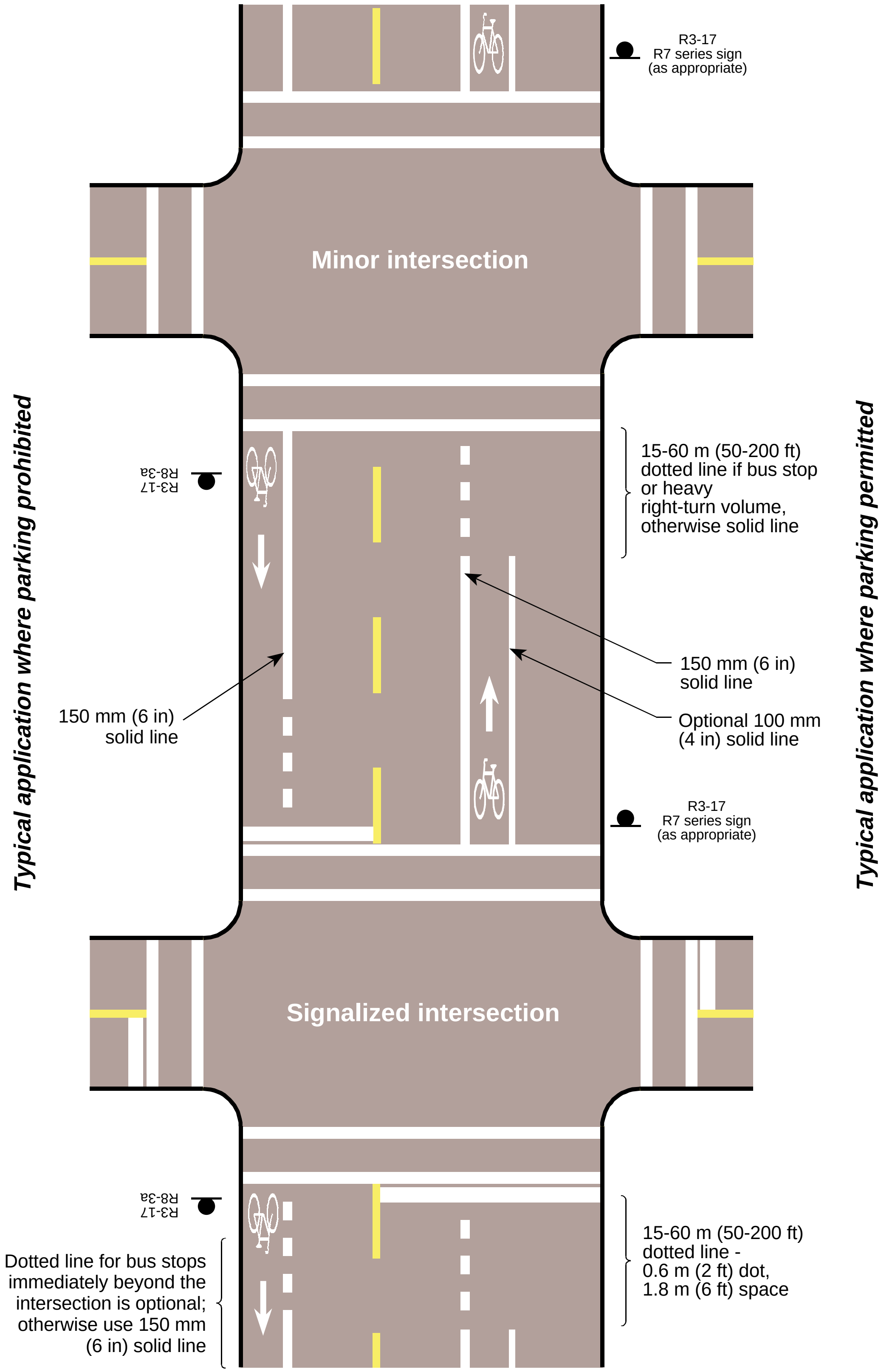


Figure 7. Typical pavement markings for bike lane on two-way street

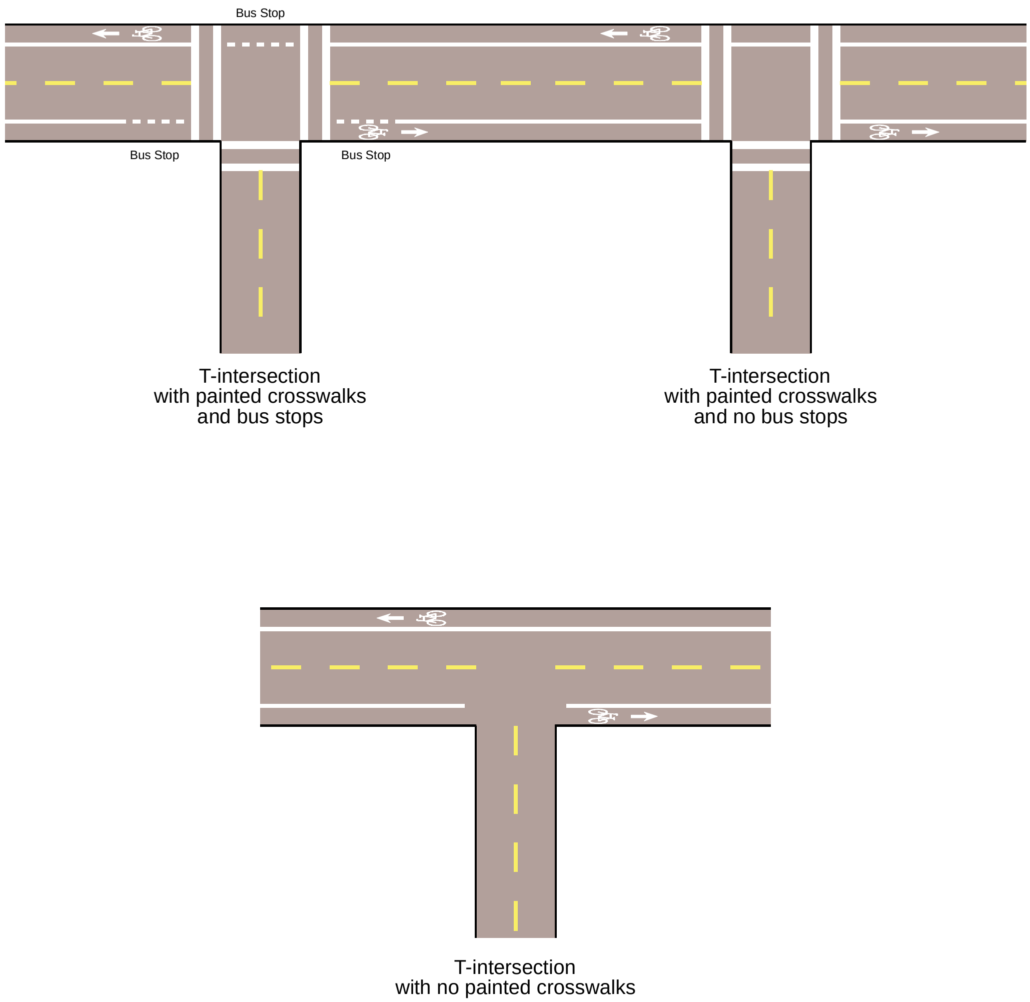


Figure 8. Typical Bike Lane Striping at T-intersections

to the right and motorists to keep to the left, both operators are somewhat discouraged from merging in advance of turns. Thus, some bicyclists may begin left turns from the right-side bike lane and some motorists may begin right turns from the left of the bike lane. Both maneuvers are contrary to established rules of the road and may result in conflicts; however, these can be lessened by signing and striping.

At intersections, bicyclists proceeding straight through and motorists turning right must cross paths. Striping and signing configurations which encourage crossings in advance of the intersection, in a merging fashion, are preferable to those that force the crossing in the immediate vicinity of the intersection. One example of such a configuration is given in Figure 9. To a lesser extent, the same is true for left-turning bicyclists; however, in this maneuver, most vehicle codes allow the bicyclist the option of making either a “vehicular style” left turn (where the bicyclist merges leftward to the same lane used for motor vehicle left turns) or a “pedestrian style” left turn (where the bicyclist proceeds straight through the intersection, turns left at the far side, then proceeds across the intersection again on the cross street). (See Figure 10.)

Figure 9. Markings for Bike Lane Merge in Advance of Intersection

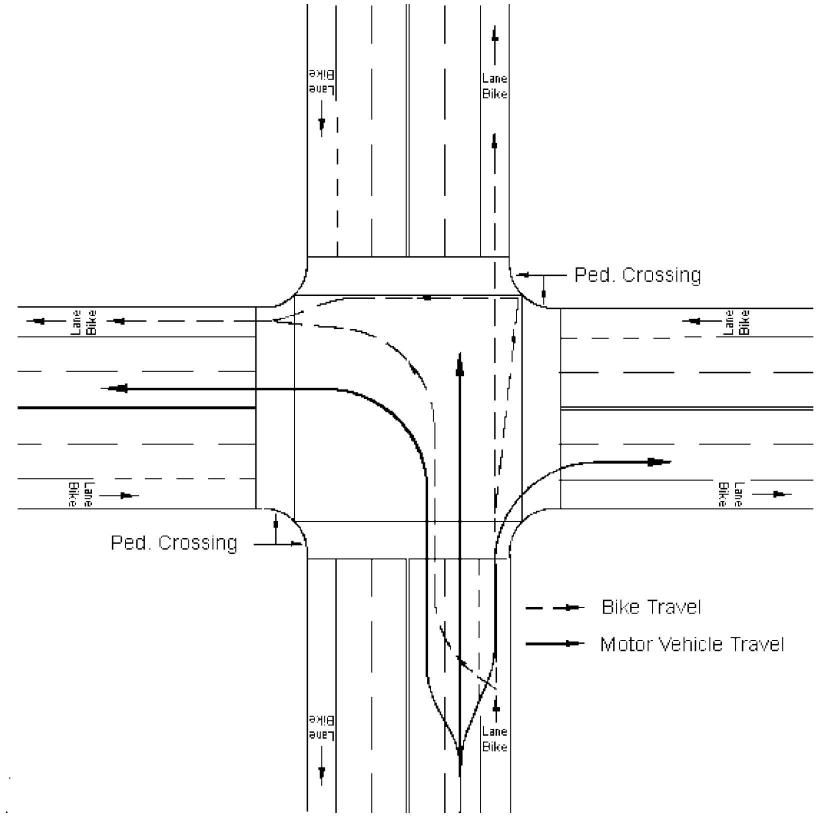
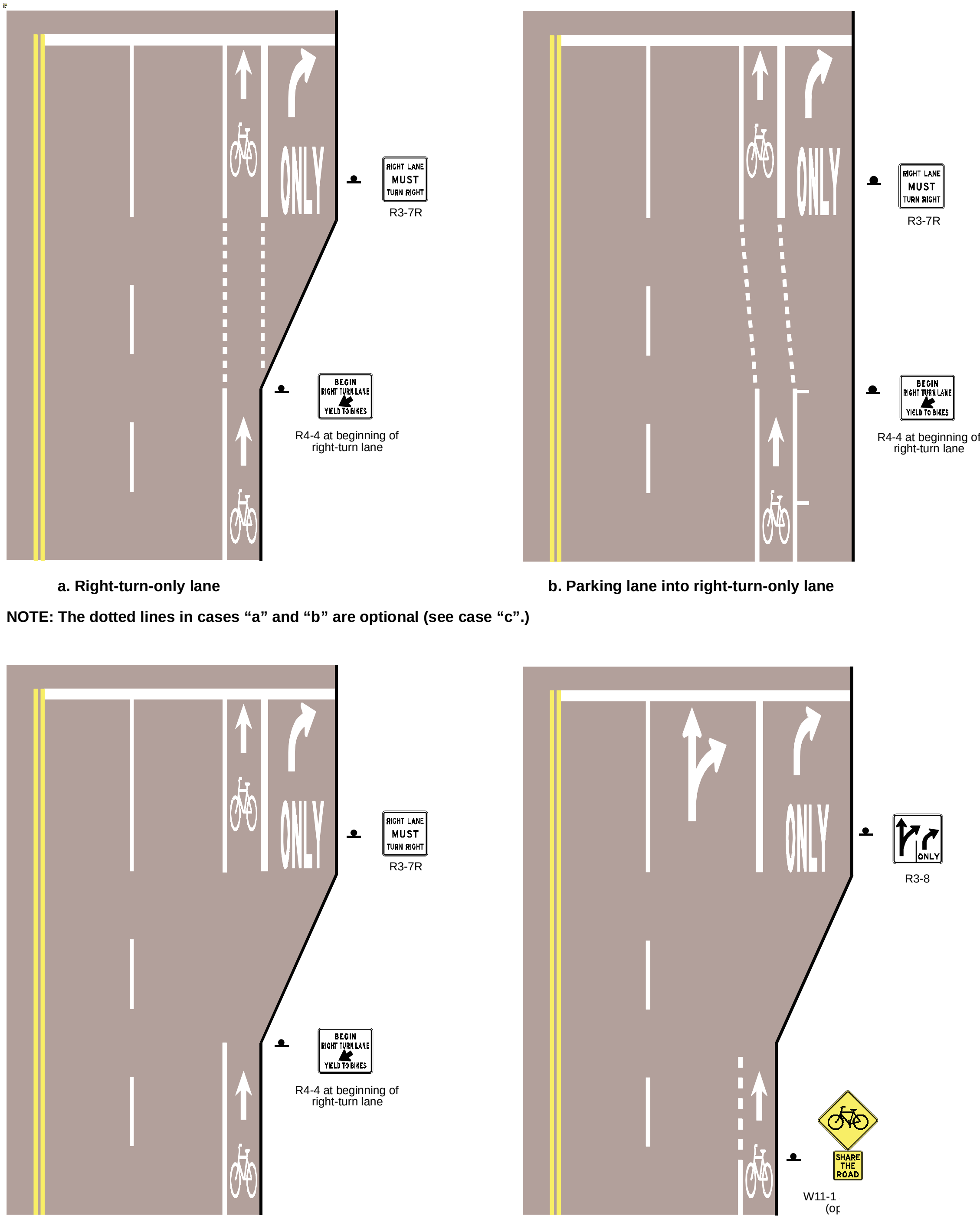


Figure 10. Typical Bicycle and Auto Movements at Major Intersections

Figure 11 presents optional treatments for pavement markings where a bike lane approaches a motorist right-turn-only lane (or lanes). Where there are numerous left-turning bicyclists, a separate turning lane can also be considered. The design of bike lanes should also include appropriate signing at intersections to warn of conflicts. General guidance for pavement marking of bike lanes is contained in the *MUTCD* 2. The approach shoulder width should be provided through the intersection, where feasible, to accommodate right-turning bicyclists or bicyclists who prefer to use crosswalks to negotiate the intersection.

Intersections with throat widening at approaches that provide an exclusive left-turn bay can also provide an exclusive right-turn lane for motor vehicles. In those cases where throat widening has reduced the available pavement width below the minimum requirements for bike lane operation and it is not possible to widen the pavement, the bike lane striping should be discontinued following a regulatory sign. Bicyclists proceeding straight through the intersection should be directed to merge with motor vehicle traffic to cross the intersection. (See Figure 12.) Where sufficient width exists, a separate through bike lane should be placed to the right of the through lane as shown in Figure 11.



a. Right-turn-only lane

b. Parking lane into right-turn-only lane

NOTE: The dotted lines in cases "a" and "b" are optional (see case "c".)

c. Right-turn-only lane

d. Optional right/straight and right-turn-only l

Figure 11. Bike Lanes Approaching Right-Turn-Only Lanes

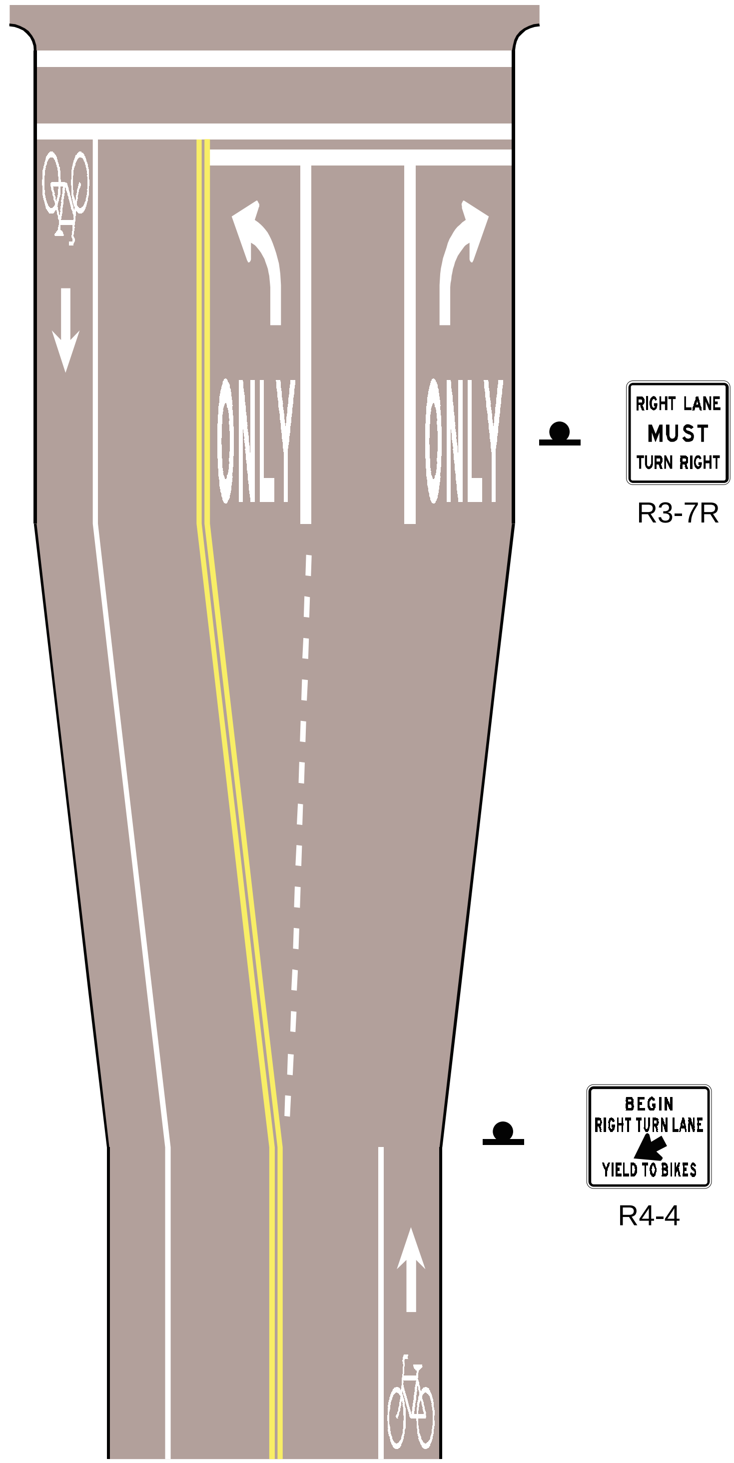


Figure 12. Bike Lane Approaching an Intersection with Throat Widening

Bike Lane Symbol Guidelines

A bike lane should be painted with standard pavement symbols to inform bicyclists and motorists of the presence of the bike lane. The standard pavement symbols are one of two bicycle symbols (or the words “BIKE LANE”) and a directional arrow. (See Figure 13.) These symbols should be painted on the far side of each intersection. (See Figure 14.) Additional stencils may be placed on long, uninterrupted sections of roadway. All pavement markings are to be white and reflectorized.

The Preferential Lane Symbol (“diamond”) previously used as a pavement marking and on signs to show preferential use by different classes of vehicles should no longer be used for bikeways, due to the confusion with the use of the diamond for High Occupant Vehicle (HOV) lanes, and the misinterpretation of the diamond as a two-way arrow. These symbols should be eliminated through normal maintenance practices.

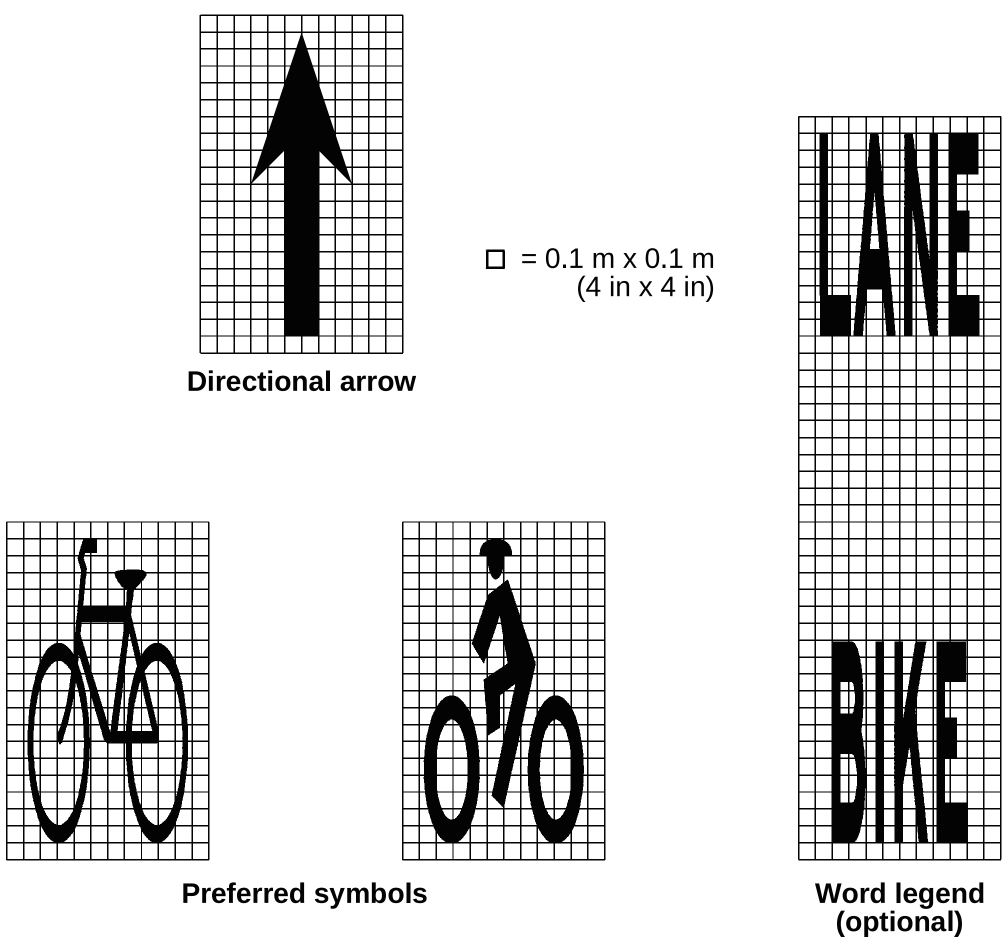
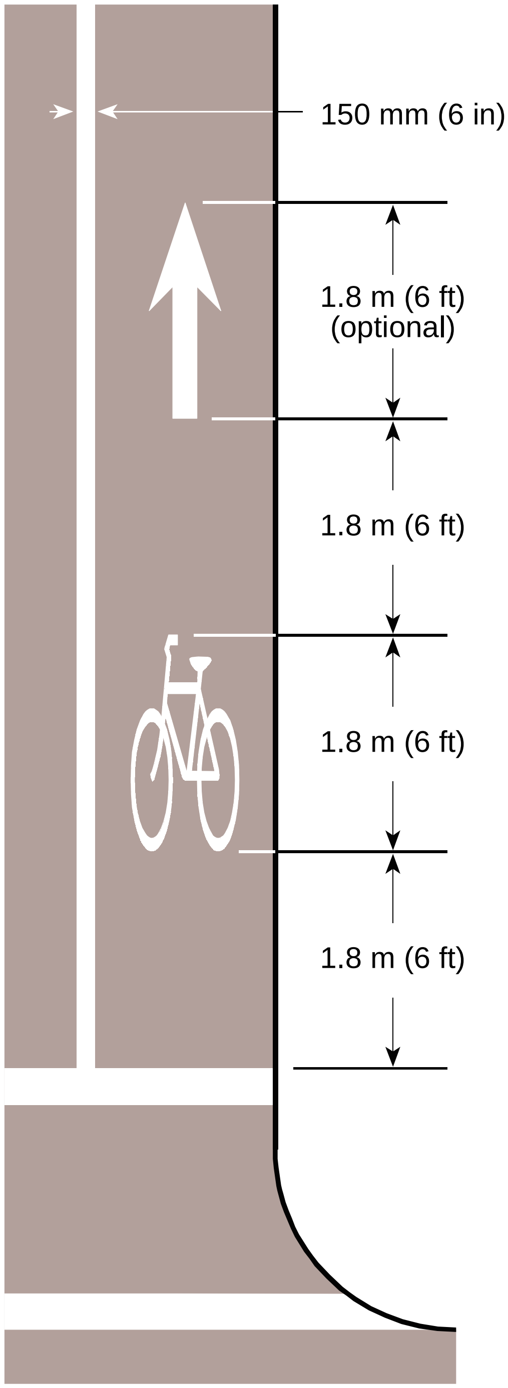


Figure 13. Typical Bike Lane Symbols



Notes:

1. The bicycle rider symbol or the word pavement marking "BIKE LANE" may be used instead of the bicycle-only symbol.
2. See Figures 7 and 13 for additional information.

Figure 14. Typical Bike Lane Marking on Far Side of Intersection

Shared Use Paths

Shared use paths are facilities on exclusive right-of-way and with minimal cross flow by motor vehicles. Shared use paths are sometimes referred to as trails; however, in many states the term *trail* means an unimproved recreational facility. Care should be taken in using these terms interchangeably. Where shared use paths are called trails, they should meet all design criteria for shared use paths to be designated as bicycle facilities. Users are non-motorized and may include but are not limited to: bicyclists, in-line skaters, roller skaters, wheelchair users (both non-motorized and motorized) and pedestrians, including walkers, runners, people with baby strollers, people walking dogs, etc. These facilities are most commonly designed for two-way travel, and the guidance herein assumes a two-way facility is planned unless otherwise stated.

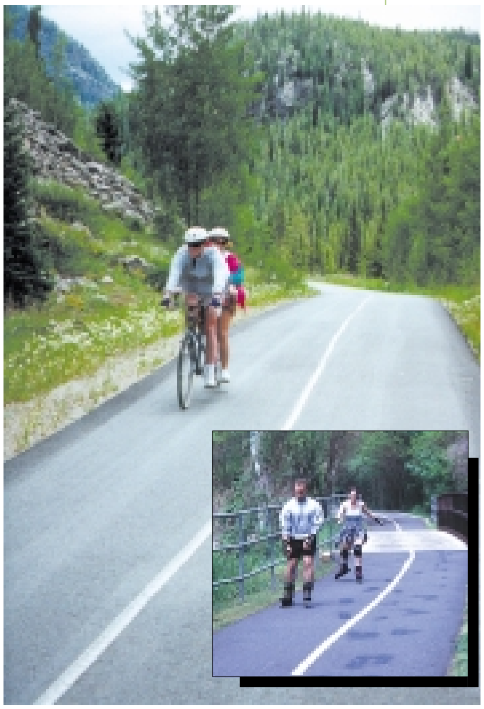


Figure 15. Example of a Shared Use Path

Shared use paths can serve a variety of purposes. They can provide users with a shortcut through a residential neighborhood (e.g., a connection between two cul-de-sac streets). Located in a park, they can provide an enjoyable recreational opportunity. Shared use paths can be located along rivers, ocean fronts, canals, abandoned or active railroad and utility rights-of-way, limited access freeways, within college campuses or within and between parks. Shared use paths can also provide bicycle access to areas that are otherwise served only by limited access highways closed to bicycles. Appropriate locations can be identified during the planning process. Examples of shared use paths are shown in Figures 15 and 16.

Figure 16. Example of a Shared Use Path

Shared use paths should be thought of as a complementary system of off-road transportation routes for bicyclists and others that serves as a necessary extension to the roadway network. Shared use paths should not be used to preclude on-road bicycle facilities, but rather to supplement a system of on-road bike lanes, wide outside lanes, paved shoulders and bike routes. There are some similarities between the design criteria for shared use paths and highways (e.g., horizontal alignment, sight distance requirements, signing and markings). On the other hand, some criteria (e.g., horizontal and vertical clearance requirements, grades and pavement structure) are dictated by operating characteristics of bicycles that are substantially different from those of motor vehicles. The designer should always be aware of the similarities and differences between bicycles and motor vehicles and of how these similarities and differences influence the design of shared use paths. The remainder of this section provides guidance on each of the factors that should be considered in designing safe and functional shared use paths.

Separation Between Shared Use Paths and Roadways

When two-way shared use paths are located immediately adjacent to a roadway, some operational problems are likely to occur. In some cases, paths along highways for short sections are permissible, given an appropriate level of separation between facilities, as in Figure 16. Some problems with paths located immediately adjacent to roadways are as follows:

1. Unless separated, they require one direction of bicycle traffic to ride against motor vehicle traffic, contrary to normal rules of the road.

2. When the path ends, bicyclists going against traffic will tend to continue to travel on the wrong side of the street. Likewise, bicyclists approaching a shared use path often travel on the wrong side of the street in getting to the path. Wrong-way travel by bicyclists is a major cause of bicycle/automobile crashes and should be discouraged at every opportunity.

3. At intersections, motorists entering or crossing the roadway often will not notice bicyclists approaching from their right, as they are not expecting contra-flow vehicles. Motorists turning to exit the roadway may likewise fail to notice the bicyclist. Even bicyclists coming from the left often go unnoticed, especially when sight distances are limited.

4. Signs posted for roadway users are backwards for contra-flow bike traffic; therefore these cyclists are unable to read the information without stopping and turning around.

5. When the available right-of-way is too narrow to accommodate all highway and shared use path features, it may be prudent to consider a reduction of the existing or proposed widths of the various highway (and bikeway) cross-sectional elements (i.e., lane and shoulder widths, etc.). However, any reduction to less than AASHTO *Green Book*[1] (or other applicable) design criteria must be supported by a documented engineering analysis.

6. Many bicyclists will use the roadway instead of the shared use path because they have found the roadway to be more convenient, better maintained, or safer. Bicyclists using the roadway may be harassed by some motorists who feel that in all cases bicyclists should be on the adjacent path.

7. Although the shared use path should be given the same priority through intersections as the parallel highway, motorists falsely expect bicyclists to stop or yield at all cross-streets and driveways. Efforts to require or encourage bicyclists to yield or stop at each cross-street and driveway are inappropriate and frequently ignored by bicyclists.

8. Stopped cross-street motor vehicle traffic or vehicles exiting side streets or driveways may block the path crossing.

9. Because of the proximity of motor vehicle traffic to opposing bicycle traffic, barriers are often necessary to keep motor vehicles out of shared use paths and bicyclists out of traffic lanes. These barriers can represent an obstruction to bicyclists and motorists,

can complicate maintenance of the facility, and can cause other problems as well.

For the above reasons, other types of bikeways are likely to be better suited to accommodate bicycle traffic along highway corridors, depending upon traffic conditions. Shared use paths should not be considered a substitute for street improvements even when the path is located adjacent to the highway, because many bicyclists will find it less convenient to ride on these paths compared with the streets, particularly for utility trips.

When two-way shared use paths are located adjacent to a roadway, wide separation between a shared use path and the adjacent highway is desirable to demonstrate to both the bicyclist and the motorist that the path functions as an independent facility for bicyclists and others. When this is not possible and the distance between the edge of the shoulder and the shared use path is less than 1.5 m (5 feet), a suitable physical barrier is recommended. Such barriers serve both to prevent path users from making unwanted movements between the path and the highway shoulder and to reinforce the concept that the path is an independent facility. Where used, the barrier should be a minimum of 1.1 m (42 inches) high, to prevent bicyclists from toppling over it. A barrier between a shared use path and adjacent highway should not impair sight distance at intersections, and should be designed to not be a hazard to errant motorists.

Width and Clearance

The paved width and the operating width required for a shared use path are primary design considerations. Figure 17 depicts a shared use path on a separated right of way. Under most conditions, a recommended paved width for a two-directional shared use path is 3.0 m (10 feet). In

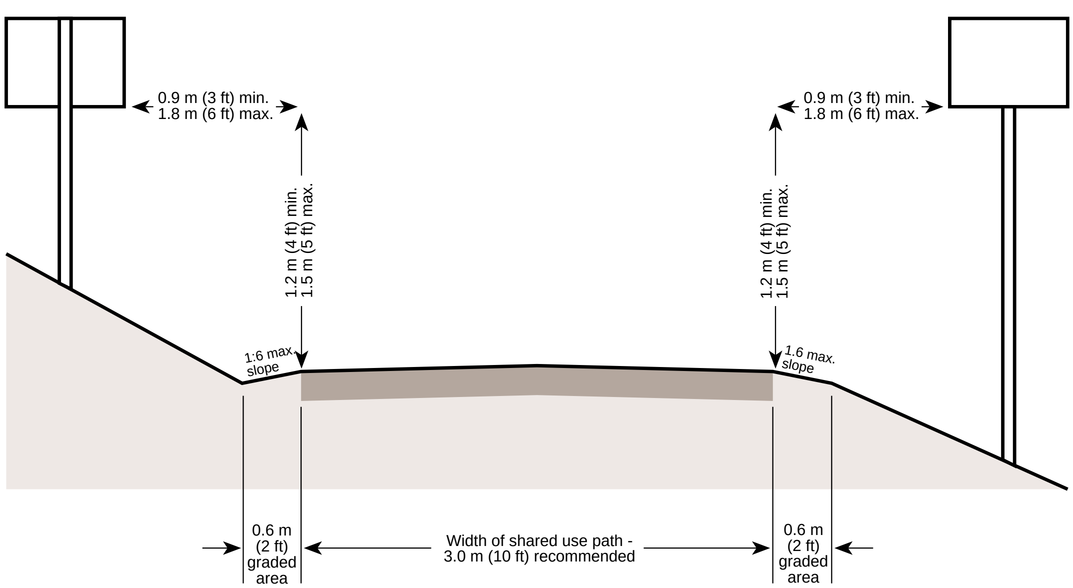


Figure 17. Cross Section of Two-Way Shared Use Path on Separated Right-of-Way

rare instances, a reduced width of 2.4 m (8 feet) can be adequate. This reduced width should be used only where the following conditions prevail: (1) bicycle traffic is expected to be low, even on peak days or during peak hours, (2) pedestrian use of the facility is not expected to be more than occasional, (3) there will be good horizontal and vertical alignment providing safe and frequent passing opportunities, and (4) during normal maintenance activities the path will not be subjected to maintenance vehicle loading conditions that would cause pavement edge damage. Under certain conditions it may be necessary or desirable to increase the width of a shared use path to 3.6 m (12 feet), or even 4.2 m (14 feet), due to substantial use by bicycles, joggers, skaters and pedestrians, use by large maintenance vehicles, and/or steep grades.

The minimum width of a one-directional shared use path is 1.8 m (6 feet). It should be recognized, however, that one-way paths often will be used as two-way facilities unless effective measures are taken to assure one-way operation. Without such enforcement, it should be assumed that shared use paths will be used as two-way facilities by both pedestrians and bicyclists and designed accordingly.

Figure 18. Safety Rail Between Shared Use Path and Adjacent Slope and Waterway

A minimum 0.6-m (2-foot) wide graded area with a maximum 1:6 slope should be maintained adjacent to both sides of the path; however, 0.9 m (3 feet) or more is desirable to provide clearance from trees, poles, walls, fences, guardrails or other lateral obstructions. Where the path is adjacent to canals, ditches or slopes down steeper than 1:3, a wider separation should be considered. A minimum 1.5 m (5-foot) separation from the edge of the path pavement to the top of the slope is desirable. Depending on the height of embankment and condition at the bottom, a physical barrier, such as dense shrubbery, railing or chain link fence, may need to be provided. (See Figure 18.)

The vertical clearance to obstructions should be a minimum of 2.5 m (8 feet). However, vertical clearance may need to be greater to permit passage of maintenance and emergency vehicles. In undercrossings and tunnels, 3.0 m (10 feet) is desirable for adequate vertical shy distance.

Design Speed

The speed a bicyclist travels is dependent on several factors, including the type and condition of the bicycle; the purpose of the trip; the condition, location and grade of the path; the speed and direction of any prevailing winds; the number and types of users on the path; and the physical condition of the bicyclist. Shared use paths should be designed for a selected speed that is at least as high as the preferred speed of the faster bicyclists. In general, a minimum design speed of 30 km/h (20 mph) should be used. Although bicyclists can travel faster than this, to do so would be inappropriate in a mixed-use setting. Design and traffic controls can be used to deter excessive speed and faster cyclists can be encouraged to use the roadway system. Lower design speeds should not be selected to artificially lower user speeds. When a downgrade exceeds 4 percent, or where strong prevailing tailwinds exist, a design speed of 50 km/h (30 mph) or more is advisable.

On unpaved paths, where bicyclists tend to ride more slowly, a lower design speed of 25 km/h (15 mph) can be used. Similarly, where the grades or the prevailing winds dictate, a higher design speed of 40 km/h (25 mph) can be used. Since bicycles have a higher tendency to skid on unpaved surfaces, horizontal curvature design should take into account lower coefficients of friction.

Horizontal Alignment

Unlike an automobile, a bicycle must be leaned while cornering to prevent it from falling outward due to the generation of centrifugal force. The balance of centrifugal force due to cornering, and the bicycle's downward force due to its weight, act through the bicycle/operator combined center of mass and must intersect a line that connects the front and rear tire contact points.

If bicyclists pedal through sharp turns and lean too far, the pedal will strike the ground because of a sharp lean angle. Although pedal heights are different for different makes of bikes, the pedal generally will strike the ground when the lean angle reaches about 25^{o}. However, casual bicyclists usually do not like to lean too drastically, and $15\text{-}20^{o}$ is considered the maximum lean angle. Assuming an operator who sits straight in the seat, a simple equation can determine the minimum radius of curvature for any given lean angle:

For Metric Units:

$$R = \frac{0.0079\,V^2}{\tan\theta}$$

Where:
- R = Minimum radius of curvature (m)
- V = Design Speed (km/h)
- θ = Lean angle from the vertical (degrees)

For English Units:

$$R = \frac{0.067\,V^2}{\tan\theta}$$

Where:
- R = Minimum radius of curvature (ft)
- V = Design Speed (mph)
- θ = Lean angle from the vertical (degrees)

However, when the lean angle approaches 20^{o}, the minimum radius of curvature negotiable by a bicycle becomes a function of the superelevation rate of the pathway surface, the coefficient of friction between the bicycle tires and the surface, and the speed of the bicycle. For this situation, the minimum design radius of curvature can be derived from the following formula:

For Metric Units:

$$R = \frac{V^2}{127\left(\frac{e}{100} + f\right)}$$

Where:
- R = Minimum radius of curvature (m)
- V = Design Speed (km/h)
- e = Rate of bikeway superelevation (percent)
- f = Coefficient of friction

For English Units:

$$R = \frac{V^2}{15\left(\frac{e}{100} + f\right)}$$

Where:
- R = Minimum radius of curvature (ft)
- V = Design Speed (mph)
- e = Rate of bikeway superelevation (percent)
- f = Coefficient of friction

Since most shared use paths built in the United States must also meet the requirements of the Americans with Disabilities Act (ADA), ADA guidelines require that cross slopes not exceed 2-3 percent to avoid the severe difficulties that greater cross slopes can create for people using wheelchairs. Thus, for most shared use paths, the maximum superelevation rate will be 3 percent. When transitioning a 3 percent superelevation, a minimum 7.5-m (25-foot) transition distance should be provided between the end and beginning of consecutive and reversing horizontal curves.

The coefficient of friction depends upon speed; surface type, roughness, and condition; tire type and condition; and whether the surface is wet or dry. Friction factors used for design should be selected based upon the point at which centrifugal force causes the bicyclist to recognize a feeling of discomfort and instinctively act to avoid higher speed. Extrapolating from values used in highway design, design friction factors for paved shared use paths can be assumed to vary from 0.31 at 20 km/h (12 mph) to 0.21 at 50 km/h (30 mph). Although there are no data available for unpaved surfaces, it is suggested that friction factors be reduced by 50 percent to allow a sufficient margin of safety.

Based upon various design speeds of 20-50 km/h (12-30 mph) and a desirable maximum lean angle of 15°, minimum radii of curvature for a paved path can be selected from Table 1.

Table 1. Desirable Minimum Radii for Paved Shared Use Paths Based on 15° Lean Angle

Design Speed (V)		Minimum Radius (R)	
km/h	**(mph)**	**m**	**(ft)**
20	(12)	12	(36)
30	(20)	27	(100)
40	(25)	47	(156)
50	(30)	74	(225)

Where a greater lean angle can be tolerated, the minimum radii of curvature for a 2 percent superelevation rate and various design speeds of 20-50 km/h (12-30 mph) can be taken from Table 2.

Table 2. Minimum Radii for Paved Shared Use Paths Based on 2% Superelevation Rates and 20° Lean Angle

Design Speed (V)		Friction Factor (f) (paved surface)	Minimum Radius (R)	
km/h	**(mph)**		**m**	**(ft)**
20	(12)	0.31	10	(30)
30	(20)	0.28	24	(90)
40	(25)	0.25	47	(155)
50	(30)	0.21	86	(260)

However, when a lean angle of 20° is used, more horizontal space will be taken up by the bicyclist taking the curve and more width needs to be provided. In these cases the pathway width should be increased and a center line placed down the middle of the path.

When curve radii smaller than those shown in Table 2 must be used because of limited right-of-way, topographical features or other considerations, standard curve warning signs and supplemental pavement markings should be installed in accordance with the *MUTCD*[2]. The negative effects of sharper curves can also be partially offset by widening the pavement through the curves.

Grade

Grades on shared use paths should be kept to a minimum, especially on long inclines. Grades greater than 5 percent are undesirable because the ascents are difficult for many bicyclists to climb and the descents cause some bicyclists to exceed the speeds at which they are competent or comfortable. On some shared use paths, where terrain dictates, designers may need to exceed the 5 percent grade recommended for bicycles for some short sections. As a general guide, the following grade restrictions and grade lengths are suggested:*

5-6%	for up to 240 m (800 ft)
7%	for up to 120 m (400 ft)
8%	for up to 90 m (300 ft)
9%	for up to 60 m (200 ft)
10%	for up to 30 m (100 ft)
11+%	for up to 15 m (50 ft)

Grades steeper than 3 percent may not be practical for shared use paths with crushed stone or other unpaved surfaces for both handling and drainage erosion reasons.

Options to mitigate excessive grades:

- When using a longer grade, an additional 1.2-1.8 m (4-6 feet) of width to permit slower speed bicyclists to dismount and walk may be considered.
- Provide signing that alerts bicyclists to the maximum percent of grade (*MUTCD*[2]).
- Provide recommended descent speed signing.
- Exceed minimum stopping sight distances.
- Exceed minimum horizontal clearances, recovery area and/or protective bike rails.

*****See Chapter 2—Other Design Considerations, Accessibility Requirements, p. 69.

- When possible, use a wider path [1.2-1.8 m (4-6 feet) addition recommended] and a series of short switchbacks to contain the speed of descending bicyclists.

Sight Distance

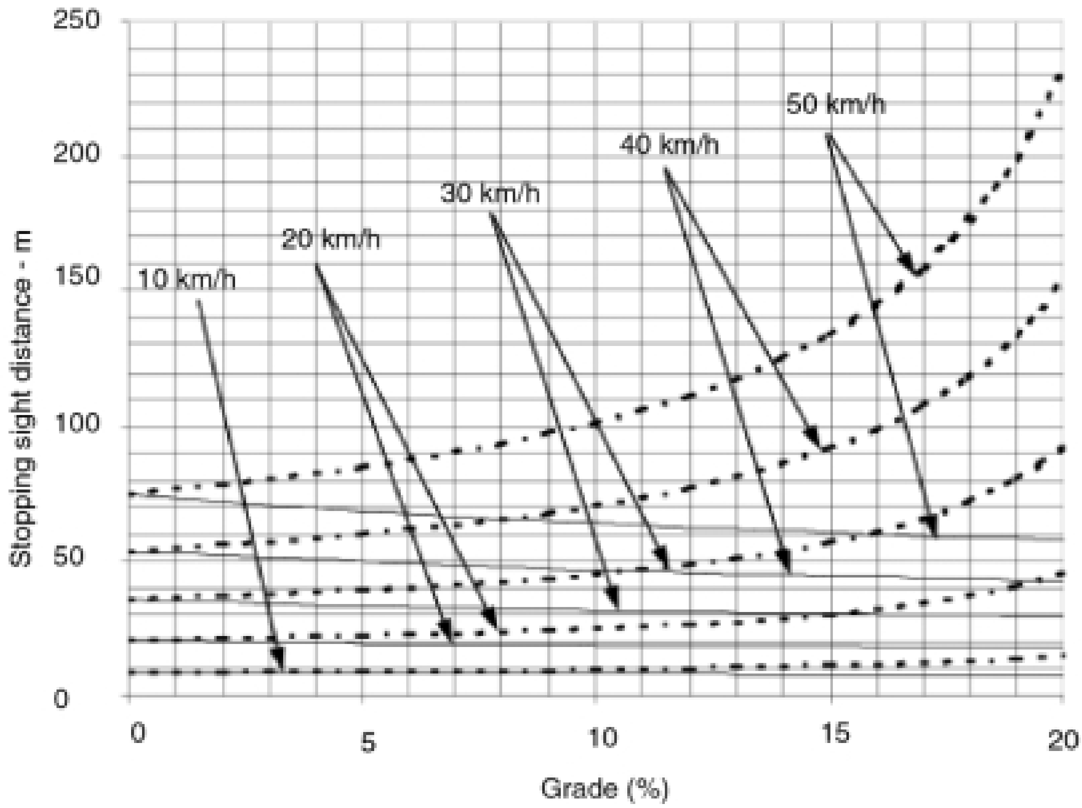
To provide bicyclists with an opportunity to see and react to the unexpected, a shared use path should be designed with adequate stopping sight distances. The distance required to bring a bicycle to a full controlled stop is a function of the bicyclist's perception and brake reaction time, the initial speed of the bicycle, the coefficient of friction between the tires and the pavement, and the braking ability of the bicycle.

Figure 19 indicates the minimum stopping sight distance for various design speeds and grades based on a total perception and brake reaction time of 2.5 seconds and a coefficient of friction of 0.25 to account for the poor wet weather braking characteristics of many bicycles. For two-way shared use paths, the sight distance in the descending direction, that is, where "G" is negative, will control the design.

Table 3 is used to select the minimum length of vertical curve necessary to provide minimum stopping sight distance at various speeds on crest vertical curves. The eye height of the bicyclist is assumed to be 1400 mm (4 1/2 feet) and the object height is assumed to be 0 mm (0 inches) to recognize that impediments to bicycle travel exist at pavement level.

Table 4 indicates the minimum clearance that should be used for line of sight obstructions for horizontal curves. The lateral clearance is obtained by entering Table 4 with the stopping sight distance from Figure 19 and the proposed horizontal radius of curvature.

Bicyclists frequently ride side-by-side on shared use paths, and on narrow paths bicyclists have a tendency to ride near the middle of the path. For these reasons, and because of the higher potential for bicycle crashes, lateral clearances on horizontal curves should be calculated based on the sum of the stopping sight distances for bicyclists traveling in opposite directions around the curve. Where this is not possible or feasible, consideration should be given to widening the path through the curve, installing a yellow center line stripe, installing a "Curve Ahead" warning sign in accordance with the *MUTCD*[2], or some combination of these alternatives.

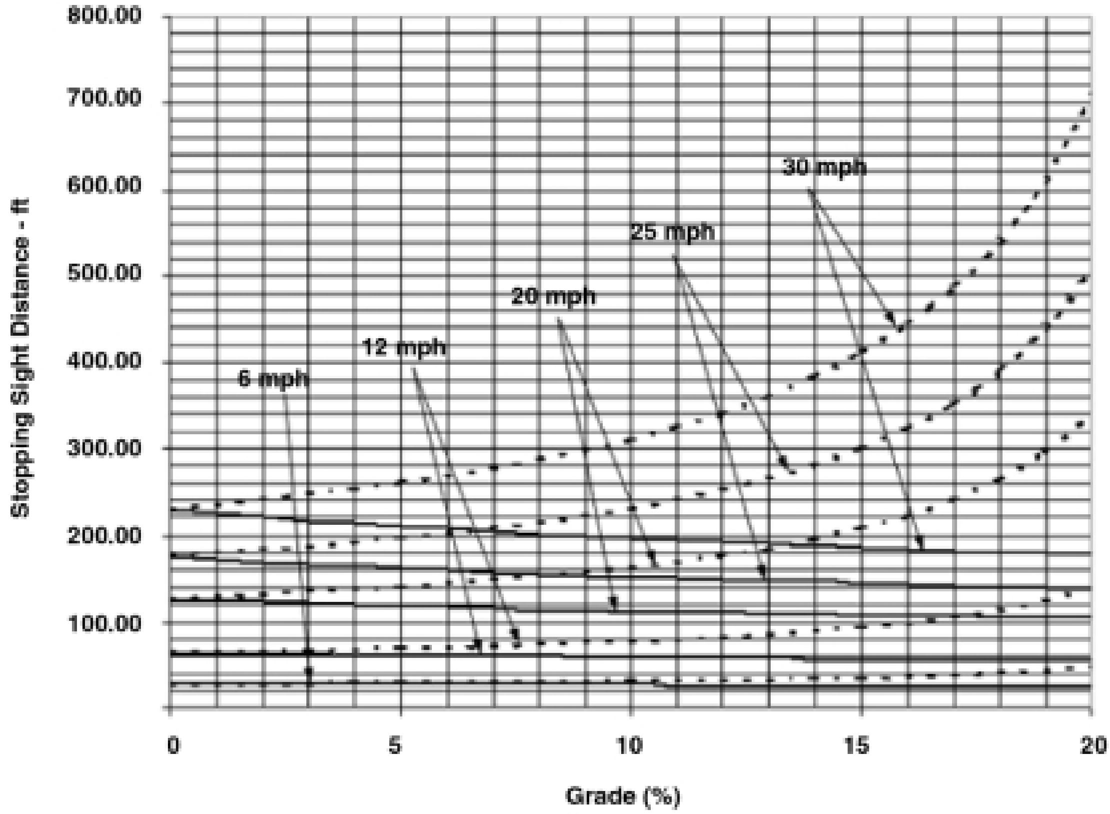


$$S = \frac{V^2}{254\,(f \pm G)} + \frac{V}{1.4}$$

Descend - - - - - -
Ascend ———

Where: S = stopping sight distance (m)
V = velocity (km/h)
f = coefficient of friction (use 0.25)
G = grade (m/m) (rise/run)

Figure 19. Metric Units.
Minimum Stopping Sight Distance
vs. Grades for Various Design Speeds



Descend - - - - - -
Ascend ———

$$S = \frac{V^2}{30(f \pm G)} + 3.67V$$

Where:	S	=	stopping sight distance (ft)
	V	=	velocity (mph)
	f	=	coefficient of friction (use 0.25)
	G	=	grade (ft/ft) (rise/run)

Figure 19. English Units.
Minimum Stopping Sight Distance
vs. Grades for Various Design Speeds.

Table 3. Metric Units. Minimum Length of Crest Vertical Curve (L) Based on Stopping Sight Distance

A (%)	S = Stopping Sight Distance (m)																	
	10	**15**	**20**	**25**	**30**	**35**	**40**	**45**	**50**	**55**	**60**	**65**	**70**	**75**	**80**	**85**	**90**	**95**	**100**
2														10	20	30	40	50	60
3									7	17	27	37	47	57	67	77	87	97	107
4							10	20	30	40	50	60	70	80	91	103	116	129	143
5					4	14	24	34	44	54	64	75	88	100	114	129	145	161	179
6				3	13	23	33	43	54	65	77	91	105	121	137	155	174	193	214
7				10	20	30	40	51	63	76	90	106	123	141	160	181	203	226	250
8			5	15	25	35	46	58	71	86	103	121	140	161	183	206	231	258	286
9			9	19	29	39	51	65	80	97	116	136	158	181	206	232	260	290	321
10		2	12	22	32	44	57	72	89	108	129	151	175	201	229	258	289	322	357
11		5	15	25	35	48	63	80	98	119	141	166	193	221	251	284	318	355	393
12		7	17	27	39	53	69	87	107	130	154	181	210	241	274	310	347	387	429
13		8	18	29	42	57	74	94	116	140	167	196	228	261	297	335	376	419	464
14		10	20	31	45	61	80	101	125	151	180	211	245	281	320	361	405	451	500
15	1	11	21	33	48	66	86	108	134	162	193	226	263	301	343	387	434	483	536
16	3	13	23	36	51	70	91	116	143	173	206	241	280	321	366	413	463	516	571
17	4	14	24	38	55	74	97	123	152	184	219	257	298	342	389	439	492	548	607
18	4	14	26	40	58	79	103	130	161	194	231	272	315	362	411	464	521	580	643
19	5	15	27	42	61	83	109	137	170	205	244	287	333	382	434	490	550	612	679
20	6	16	29	45	64	88	114	145	179	216	257	302	350	402	457	516	579	645	714
21	7	17	30	47	68	92	120	152	188	227	270	317	368	422	480	542	608	677	750
22	7	18	31	49	71	96	126	159	196	238	283	281	385	442	503	568	636	709	786
23	8	18	33	51	74	101	131	166	205	248	296	347	403	462	526	593	665	741	821
24	8	19	34	54	77	105	137	174	214	259	309	362	420	482	549	619	694	774	857
25	9	20	36	56	80	109	143	181	223	270	321	377	438	502	571	645	723	806	893

when S > L $L = 2S - \frac{280}{A}$

when S < L $L = \frac{AS^2}{280}$

Height of cyclist eye - 1400 mm
Height of object - 0 mm

Shaded area represents S = L

L = Minimum Length of Vertical Curve (m)
A = Algebraic Grade Difference (%)
S = Stopping Sight Distance (m)

Minimum Length of Vertical Curve = 1 m

Table 3. English Units. Minimum Length of Crest Vertical Curve (L) Based on Stopping Sight Distance

A	S = Stopping Sight Distance (ft)														
(%)	**20**	**40**	**60**	**80**	**100**	**120**	**140**	**160**	**180**	**200**	**220**	**240**	**260**	**280**	**300**
2												30	70	110	150
3								20	60	100	140	180	220	260	300
4						15	55	95	135	175	215	256	300	348	400
5					20	60	100	140	180	222	269	320	376	436	500
6				10	50	90	130	171	216	267	323	384	451	523	600
7				31	71	111	152	199	252	311	376	448	526	610	700
8			8	48	88	128	174	228	288	356	430	512	601	697	800
9			20	60	100	144	196	256	324	400	484	576	676	784	900
10			30	70	111	160	218	284	360	444	538	640	751	871	1000
11			38	78	122	176	240	313	396	489	592	704	826	958	1100
12		5	45	85	133	192	261	341	432	533	645	768	901	1045	1200
13		11	51	92	144	208	283	370	468	578	699	832	976	1132	1300
14		16	56	100	156	224	305	398	504	622	753	896	1052	1220	1400
15		20	60	107	167	240	327	427	540	667	807	960	1127	1307	1500
16		24	64	114	178	256	348	455	576	711	860	1024	1202	1394	1600
17		27	68	121	189	272	370	484	612	756	914	1088	1277	1481	1700
18		30	72	128	200	288	392	512	648	800	968	1152	1352	1568	1800
19		33	76	135	211	304	414	540	684	844	1022	1216	1427	1655	1900
20		35	80	142	222	320	436	569	720	889	1076	1280	1502	1742	2000
21		37	84	149	233	336	457	597	756	933	1129	1344	1577	1829	2100
22		39	88	156	244	352	479	626	792	978	1183	1408	1652	1916	2200
23		41	92	164	256	368	501	654	828	1022	1237	1472	1728	2004	2300
24	3	43	96	171	267	384	523	683	864	1067	1291	1536	1803	2091	2400
25	4	44	100	177	278	400	544	711	900	1111	1344	1600	1878	2178	2500

when S > L $L = 2S - \frac{900}{A}$

when S < L $L = \frac{AS^2}{900}$

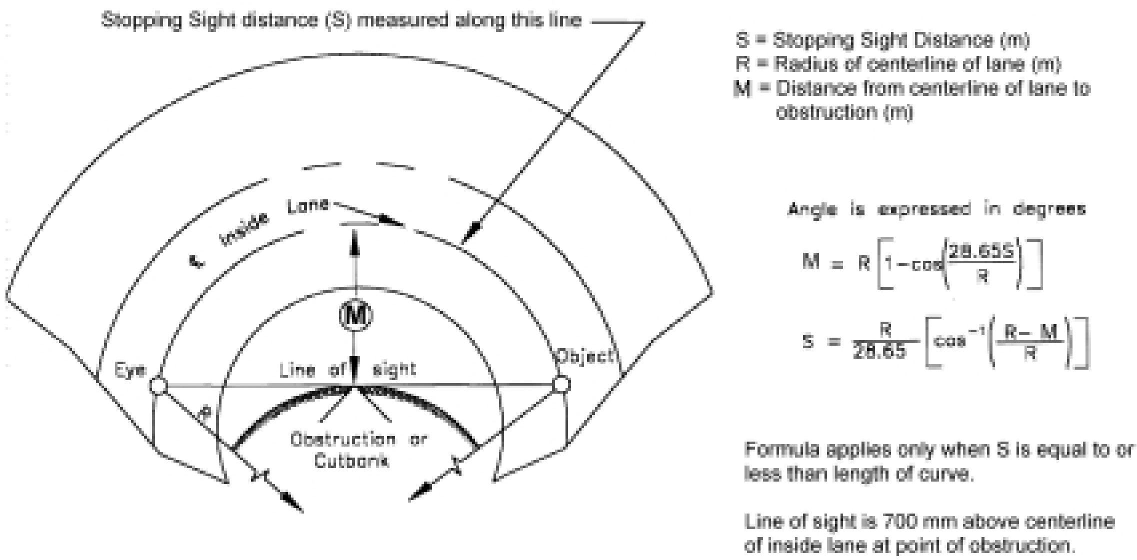
Height of cyclist's eye – 4 1/2 ft
Height of object – 0 ft

Shaded area represents S = L

L = Minimum Length of Vertical Curve (ft)
A = Algebraic Grade Difference (%)
S = Stopping Sight Distance (ft)

Minimum Length of Vertical Curve = 3 ft.

Table 4. Metric Units. Minimum Lateral Clearance (M) for Horizontal Curves



For Metric Units:

S = Stopping Sight Distance (m)
R = Radius of centerline of lane (m)
M = Distance from centerline of lane to obstruction (m)

For English Units:

S = Stopping Sight Distance (ft)
R = Radius of centerline of lane (ft)
M = Distance from centerline of lane to obstruction (ft)

R (m)	**S = Stopping Sight Distance (m)**																		
	10	**15**	**20**	**25**	**30**	**35**	**40**	**45**	**50**	**55**	**60**	**65**	**70**	**75**	**80**	**85**	**90**	**95**	**100**
10	1.2	2.7	4.6	6.8	9.3														
15	0.8	1.8	3.2	4.9	6.9	9.1	11	14											
20	0.6	1.4	2.4	3.8	5.4	7.2	9.2	11	14	16	19								
25	0.5	1.1	2	3.1	4.4	5.9	7.6	9.5	11	14	16	18	21	23					
50	0.3	0.6	1	1.6	2.2	3	3.9	5	6.1	7.4	8.7	10	12	13	15	17	19	21	23
75	0.2	0.4	0.7	1	1.5	2	2.7	3.4	4.1	5	5.9	6.9	8	9.2	10	12	13	15	16
100	0.1	0.3	0.5	0.8	1.1	1.5	2	2.5	3.1	3.8	4.5	5.2	6.1	7	7.9	8.9	10	11	12
125	0.1	0.2	0.4	0.6	0.9	1.2	1.6	2	2.5	3	3.6	4.2	4.9	5.6	6.3	7.2	8	8.9	9.9
150		0.2	0.3	0.5	0.7	1	1.3	1.7	2.1	2.5	3	3.5	4.1	4.7	5.3	6	6.7	7.5	8.3
175		0.2	0.3	0.4	0.6	0.9	1.1	1.4	1.8	2.2	2.6	3	3.5	4	4.6	5.1	5.8	6.4	7.1
200		0.1	0.3	0.4	0.6	0.8	1	1.3	1.6	1.9	2.2	2.6	3.1	3.5	4	4.5	5	5.6	6.2
225		0.1	0.2	0.3	0.5	0.7	0.9	1.1	1.4	1.7	2	2.3	2.7	3.1	3.5	4	4.5	5	5.5
250		0.1	0.2	0.3	0.5	0.6	0.8	1	1.2	1.5	1.8	2.1	2.4	2.8	3.2	3.6	4	4.5	5
275		0.1	0.2	0.3	0.4	0.6	0.7	0.9	1.1	1.4	1.6	1.9	2.2	2.6	2.9	3.3	3.7	4.1	4.5
300			0.2	0.3	0.4	0.5	0.7	0.8	1	1.3	1.5	1.8	2	2.3	2.7	3	3.4	3.8	4.2

R (ft)	S = Stopping Sight Distance (ft)														
	20	**40**	**60**	**80**	**100**	**120**	**140**	**160**	**180**	**200**	**220**	**240**	**260**	**280**	**300**
25	2.0	7.6	15.9												
50	1.0	3.9	8.7	15.2	23.0	31.9	41.5								
75	0.7	2.7	5.9	10.4	16.1	22.8	30.4	38.8	47.8	57.4	67.2				
95	0.5	2.1	4.7	8.3	12.9	18.3	24.7	31.8	39.5	48.0	56.9	66.3	75.9	85.8	
125	0.4	1.6	3.6	6.3	9.9	14.1	19.1	24.7	31.0	37.9	45.4	53.3	61.7	70.6	79.7
155	0.3	1.3	2.9	5.1	8.0	11.5	15.5	20.2	25.4	31.2	37.4	44.2	51.4	59.1	67.1
175	0.3	1.1	2.6	4.6	7.1	10.2	13.8	18.0	22.6	27.8	33.5	39.6	46.1	53.1	60.5
200	0.3	1.0	2.2	4.0	6.2	8.9	12.1	15.8	19.9	24.5	29.5	34.9	40.8	47.0	53.7
225	0.2	0.9	2.0	3.5	5.5	8.0	10.8	14.1	17.8	21.9	26.4	31.3	36.5	42.2	48.2
250	0.2	0.8	1.8	3.2	5.0	7.2	9.7	12.7	16.0	19.7	23.8	28.3	33.1	38.2	43.7
275	0.2	0.7	1.6	2.9	4.5	6.5	8.9	11.6	14.6	18.0	21.7	25.8	30.2	34.9	39.9
300	0.2	0.7	1.5	2.7	4.2	6.0	8.1	10.6	13.4	16.5	19.9	23.7	27.7	32.1	36.7
350	0.1	0.6	1.3	2.3	3.6	5.1	7.0	9.1	11.5	14.2	17.1	20.4	23.9	27.6	31.7
390	0.1	0.5	1.2	2.1	3.2	4.6	6.3	8.2	10.3	12.8	15.4	18.3	21.5	24.9	28.5
500	0.1	0.4	0.9	1.6	2.5	3.6	4.9	6.4	8.1	10.0	12.1	14.3	16.8	19.5	22.3
565		0.4	0.8	1.4	2.2	3.2	4.3	5.7	7.2	8.8	10.7	12.7	14.9	17.3	19.8
600		0.3	0.8	1.3	2.1	3.0	4.1	5.3	6.7	8.3	10.1	12.0	14.0	16.3	18.7
700		0.3	0.6	1.1	1.8	2.6	3.5	4.6	5.8	7.1	8.6	10.3	12.0	14.0	16.0
800		0.3	0.6	1.0	1.6	2.2	3.1	4.0	5.1	6.2	7.6	9.0	10.5	12.2	14.0
900		0.2	0.5	0.9	1.4	2.0	2.7	3.6	4.5	5.6	6.7	8.0	9.4	10.9	12.5
1000		0.2	0.5	0.8	1.3	1.8	2.4	3.2	4.0	5.0	6.0	7.2	8.4	9.8	11.2

Table 4. English Units. Minimum Lateral Clearance (M) for Horizontal Curves

Path-Roadway Intersections

Intersections between paths and roadways are often the most critical issue in shared use path design. Due to the potential conflicts at these junctions, careful design is of paramount importance to the safety of path users and motorists alike. The solutions provided in this chapter should be considered guidelines, not absolutes. Each intersection is unique and will require sound engineering judgment on the part of the designer as to the appropriate solution.

There are three basic categories of path-roadway intersections: midblock, adjacent path and complex. The following discussion provides guidance for each of these categories. Each of these intersection types may cross any number of roadway lanes, divided or undivided, with varying speeds and volumes of motor vehicle traffic, and may be uncontrolled, or more typically, sign or signal controlled. Only at-grade crossings are addressed in this section.

Midblock Crossings

Midblock type crossings are the most straightforward of the three configurations. Figure 20 shows an example of a midblock crossing. Midblock crossings should be far enough away from existing intersections between roadways to be clearly separate from the activity that occurs as motorists approach these intersections (such as merging movements, acceleration/deceleration or preparations to enter turn lanes). There are many other variables to consider when designing this type of intersection, including right of way assignment, traffic control devices, sight distance for both bicyclists and motor vehicle operators, refuge island use, access control, and pavement marking. These issues are discussed in more detail later in this section.

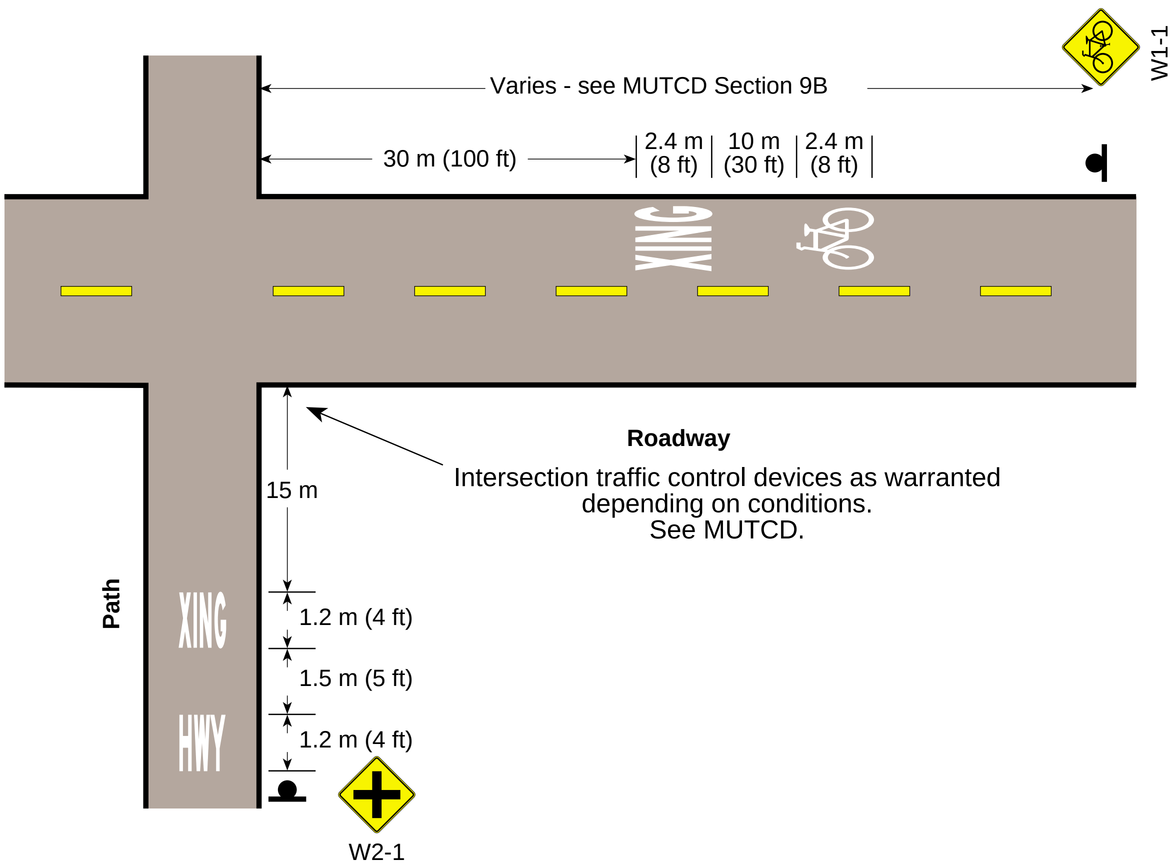


Figure 20. Midblock Type Path Crossing

Another important consideration for midblock crossings is the treatment for a skewed crossing. Figure 21 depicts a path realignment to achieve a 90-degree crossing. A minimum 45-degree crossing angle may be acceptable to minimize right-of-way requirements.

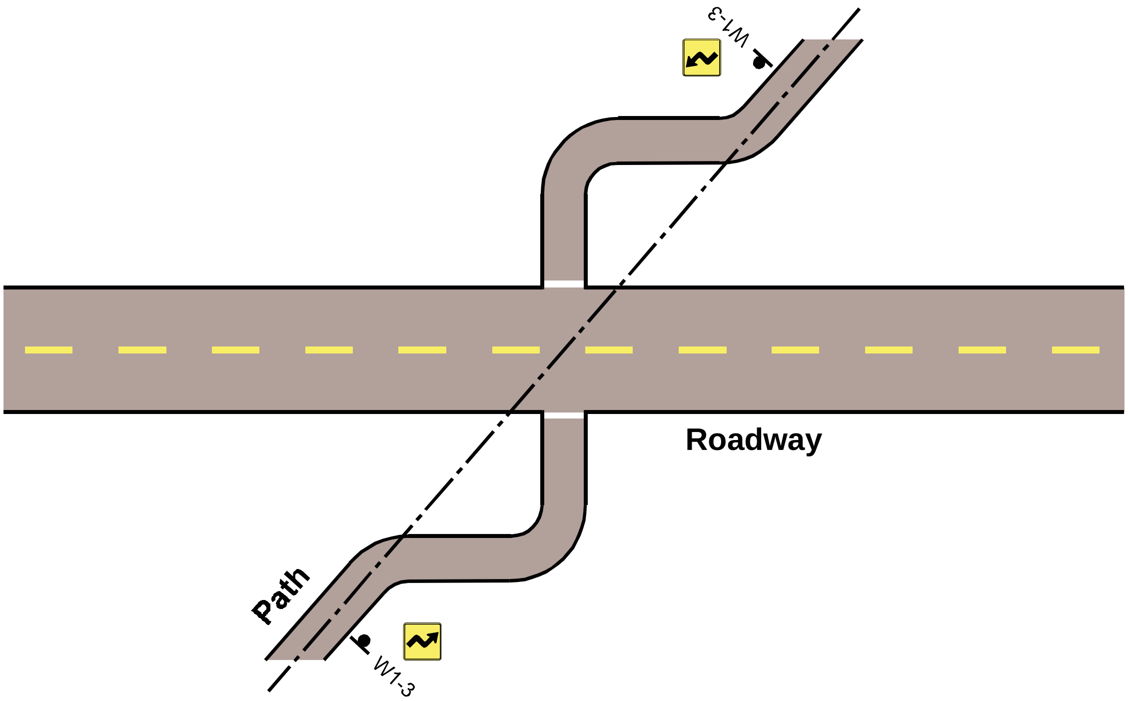


Figure 21. Typical Redesign of a Diagonal Road Crossing

Adjacent Path Crossings

Adjacent path crossings occur where a path crosses a roadway at an existing intersection between two roadways, whether it is a T-intersection (including driveways) or a simple four-legged intersection (Figure 22). It is preferable that this type of crossing be carefully integrated close to the intersection so as to allow motorists and path users alike to recognize each other as intersecting traffic. With this configuration, the path user is faced with potential conflicts with motor vehicles turning left (A) and right (B) from the parallel roadway, and on the crossed roadway (C, D, E).

The major road may be either the parallel or crossed roadway. Right-of-way assignment, traffic control devices, and separation distance between the roadway and path are also important variables which greatly affect the design of this intersection. Further complicating the situation is the possibility of the conflicts being unexpected by both path users and motorists. Clear sight lines across corners are especially important.

In a Type A turning movement (see Figure 22), it may be advisable to prohibit permissive left turns on a high-volume parallel roadway and high-use path crossings. For turning movement Type B, as small as practical corner turning radius may be required to reduce the speeds of motor vehicles. For Type C and D movements, it may be advisable to prohibit right-turns-on-red and place a stop bar in advance of the path crossing. To account for vehicle movement E, it may require an all-red phase to protect the path users.

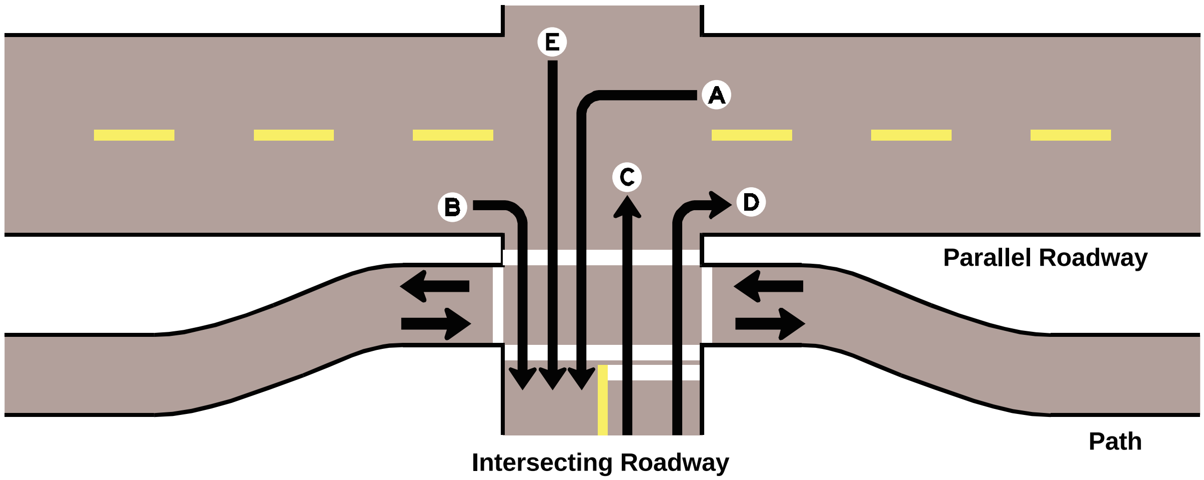


Figure 22. Example of Adjacent Path Intersection

Complex Intersection Crossings

Complex intersection crossings constitute all other path-roadway or driveway junctions. These may include a variety of configurations at which the path crosses directly through an existing intersection between two (or more) roadways and there may be any number of motor vehicle turning movements.

Improvements to complex crossings must be considered on a case-by-case basis. Some suggested treatments which may be considered include: (1) move the crossing, (2) install a signal, (3) change signalization timing, or (4) provide a refuge island and make a two-step crossing for path users. Particularly for complex intersection crossings, it is critical that the designer treat each situation as a unique challenge which requires creativity as well as sound engineering judgment. The safe passage of all modes through the intersection is the goal to be achieved.

Assigning Right of Way

Volume, speed and highway classification should not be the only criteria to consider when assigning right of way at a path crossing. The comfort and convenience of the path user, and the unique behavioral characteristics of the path user and motorist alike, must also be taken into consideration.

Regarding behavior, it must be recognized that some path users may have:

- very low delay tolerance
- a strong desire to maintain momentum

- little traffic knowledge (particularly children)
- sometimes a “regulations don’t apply to me” mentality

Assigning incorrect priority or being overly restrictive in an attempt to protect the path user can lead to confusion and unsafe practices by both path users and motorists, increasing the potential for a collision.

Other Intersection Design Issues

Regardless of the type of path-roadway intersection, there are several other design issues to consider.

Traffic Signals/Stop Signs: A regulatory traffic control device should be installed at all path-roadway intersections. Warrants from the *MUTCD*[2] combined with sound engineering judgment should also be considered when determining the type of traffic control device to be installed.

Traffic signals for path-roadway intersections are appropriate under certain circumstances. The *MUTCD*[2] lists 11 warrants for traffic signals, and although path crossings are not addressed, bicycle traffic on the path may be functionally classified as vehicular traffic and the warrants applied accordingly.

For manually-operated signal actuation mechanisms, the bicyclist signal button should be located in a position that is easily accessible from the path and 1.2 m (4 feet) above the ground, so that bicyclists will not have to dismount to activate the signal. Another method of activating the signal is to provide a detector loop in the path pavement; however, this must be supplemented with a manually-activated signal, since the loop detector will not respond to pedestrians. On signalized divided roadways, a push button should also be located in the median to account for those path users who may have been trapped in the refuge area.

Path stop signs should be placed as close to the intended stopping point as possible, and should be supplemented with a stop bar. Four-way stops at path-roadway intersections are not recommended because of frequent confusion about or disregard for right of way rules. Yield signs may be acceptable at some locations, such as low-volume, low-speed neighborhood streets. Sign type, size and location should be in accordance with the *MUTCD*[2]. Care should be taken to ensure that shared use path signs are located so that motorists are not confused by them, and that roadway signs are placed so that bicyclists are not confused by them.

Transition Zones: Where shared use paths terminate at existing roads, it is important to integrate the path into the existing system of roadways. Care should be taken to properly design the terminals to transition the traffic into a safe merging or diverging situation. Appropriate signing is necessary to warn and direct both bicyclists and motorists regarding these transition areas.

With this in mind, the designer should consider each path-roadway intersection along the length of the path as a potential entry/exit point.

Intersection design should also consider the movements of path users who either enter the path from the road, or plan to exit the path and use the roadway for the remainder of their trip.

Sight Distance: Sight distance is a principal element of roadway and path intersection design. There are generally three sight distance issues that apply to junctions: (1) stopping sight distance, (2) intersection sight distance, and (3) decision sight distance.

Stopping sight distance is covered by Figure 19 and Table 3 of this chapter, along with the accompanying text in that section. Improving appropriate intersection sight distances for approaching motorists can increase the likelihood that they will notice path users who are approaching the intersection. This can be achieved by increasing the standard perception-reaction time value of 2.5 seconds for motorists' stopping sight distance or by using the most appropriate decision sight distance value from Table III-3 in the *AASHTO Policy on Geometric Design of Highways and Streets (Green Book*[1]*)*, although none of these specifically address path crossings.

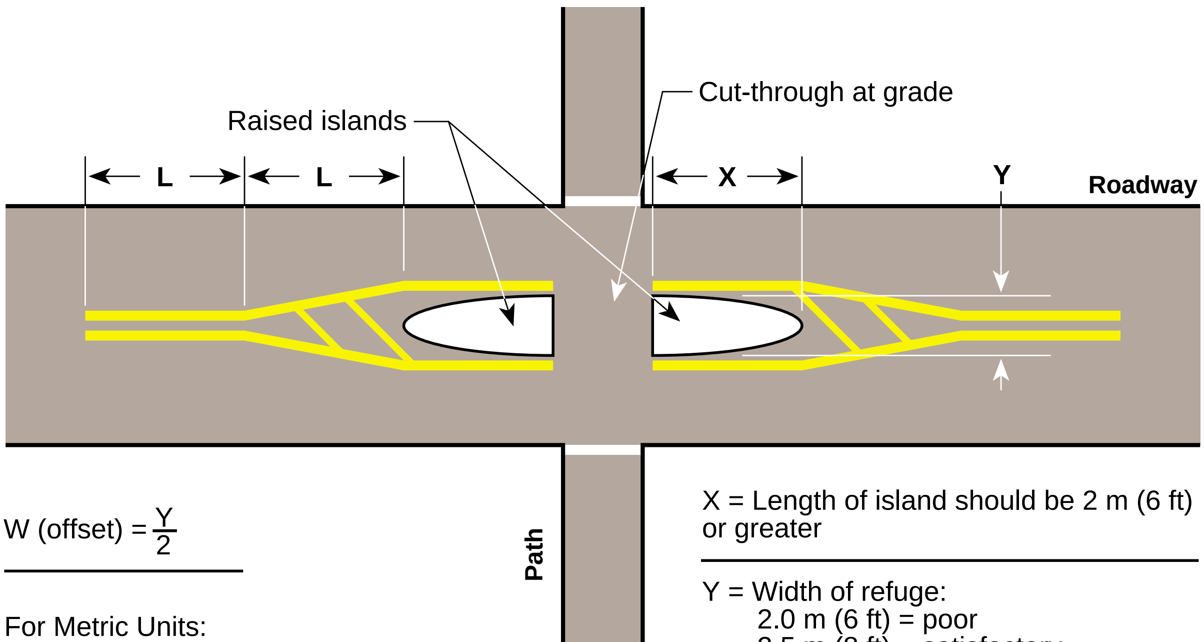
Decision sight distance may also be applied to bicyclists, but differs in concept from the motorist-based application. For bicyclists, it involves providing clear sight lines that are based on the distances that approaching motor vehicles will travel in the amount of time a bicyclist takes to fully clear the intersection from a "stop-go" decision point located at the stopping sight distance from the pavement edge. This concept acknowledges bicyclists' desire to maintain momentum.

Approach Treatments: Shared use path intersections and approaches should be on relatively flat grades. Stopping sight distance at intersections should be evaluated and adequate warning signs should be provided to allow bicyclists to stop before reaching the intersection, especially on downgrades. Unpaved shared use paths should be provided with paved aprons extending a minimum of 3 m (10 feet) from paved road surfaces.

Ramp Widths: Ramps for curbs at intersections should be at least the same width as the shared use path. Curb cuts and ramps should provide a smooth transition between the shared use path and the roadway. A 1.5 m (5-foot) radius or flare may be considered to facilitate right turns for bicycles. This same consideration could also be applied to intersections of two shared use paths.

Refuge Islands: Refuge islands should be considered for path-roadway intersections in which one or more of the following apply: (1) high volumes of roadway traffic and/or speeds create unacceptable conditions for path users, (2) roadway width is excessive given the available crossing time, or (3) the crossing will be used by a number of people who cross more slowly, such as the elderly, schoolchildren, persons with disabilities, etc.

The refuge area should be large enough to accommodate platoons of users, including groups of pedestrians, groups of bicyclists, individual tandem bicycles (which are considerably longer than standard bicycles), wheelchairs, people with baby strollers and equestrians (if this is a permitted path use). The area may be designed with the storage aligned across the island or longitudinally (see example in Figure 23). Adequate space should be provided so that those in the refuge area do not feel threatened by passing motor vehicles while waiting to finish the crossing.



W (offset) = $\frac{Y}{2}$

For Metric Units:

$L = \frac{WV^2}{155}$, where $V < 70$ km/h

$L = 0.62\ WV$, where $V \geq 70$ km/h

For English Units:

$L = \frac{WV^2}{60}$, where $V < 45$ mph

$L = WV$, where $V \geq 45$ mph

X = Length of island should be 2 m (6 ft) or greater

Y = Width of refuge:
- 2.0 m (6 ft) = poor
- 2.5 m (8 ft) = satisfactory
- 3.0 m (10 ft) = good

Figure 23. Specification for a Created Refuge Area

Signing and Marking

Adequate signing and marking are essential on shared use paths, especially to alert bicyclists to potential conflicts and to convey regulatory messages to both bicyclists and motorists at highway intersections. In addition, guide signing, such as to indicate directions, destinations, distances, route numbers and names of crossing streets, should be used in the same manner as on highways. In general, uniform application of traffic control devices, as described in the *MUTCD*[2], provides minimum traffic control measures which should be applied.

A designer should consider a 100-mm (4-inch) wide yellow center line stripe to separate opposite directions of travel. This stripe should be broken where adequate passing sight distance exists, and solid in other locations, or where passing by bicycles should be discouraged. This may be particularly beneficial in the following circumstances: (1) for heavy volumes of bicycles and/or other users, (2) on curves with restricted sight distance, and (3) on unlighted paths where nighttime riding is expected. White edge lines can also be very beneficial where bicycle traffic is expected during early evening hours.

General guidance on signing and marking is provided in the *MUTCD*[2]. Care should be exercised in the choice of pavement marking materials. Additional signing can also be helpful to encourage users to share the path and follow path user etiquette such as giving audible signals before passing on the left. Warning signs should also be used in areas where the recommended criteria herein cannot be met due to physical constraints. Reduced versions [450 mm x 450 mm (18” x 18”)] of the signs in Section 9B-13 of the *MUTCD*[2] may be used to warn users of sharp curves, intersections, etc.

Pavement markings at a crossing should accomplish two things: channel path users to cross at a clearly defined location and provide a clear message to motorists that this particular section of the road must be shared with other users.

For the path user, stop signs, stop bar pavement markings, yield signs, caution signs or other devices should be used as applicable.

For a roadway user, a clear message must be presented in a location where it will be seen by that user. Traditional treatments have included the bicycle crossing sign (WII-I), the pedestrian crossing sign (WIIA-2), the pedestrian crosswalk lines [double 150-mm (6-inch) lines spaced not less than 1.8 m (6 feet) apart], or flashing yellow lights at the crosswalk. However, signs are frequently placed at the side of the road, out of motorists’ line of sight, and historically, flashing yellow lights have also been used at non-crosswalk applications. In recent years, new applications have been developed, including the following, which may be suitable for urban and suburban settings, but may not be suitable for rural areas:

- “Zebra-style" or colorized pavement crosswalks, which are far more visible than traditional designs.

- Raised platform crosswalks, which can be useful to define roadway space for non-motorized users and stress the need for motorists to yield to that space.

- Pedestrian-friendly intersection crossings, which incorporate appropriate signal heads and infrared motion detectors, pressure mats or other technologies.

- Midblock neck-downs or intersection curb-bulbs at the crossing to shorten the crossing distance.

The above suggestions should be considered on a case-by-case basis and should always be evaluated with regard to the safest overall method for accommodating both path users and roadway users.

Pavement Structure

Hard, all-weather pavement surfaces are usually preferred over those of crushed aggregate, sand, clay or stabilized earth since these materials provide a much lower level of service and require higher maintenance. However, operating agencies that have chosen crushed aggregate as their surface material have found that they can achieve a completed path in less time and at less cost than with asphalt or concrete. Also, they have found that skaters were not drawn to the path, and bicyclists' speeds were lower, making the path more comfortable for other users. In areas that are subjected to frequent or even occasional flooding or drainage problems, or in areas of steep terrain, unpaved surfaces will often erode and are not recommended.

Good quality all-weather pavement structures can be constructed of asphalt or Portland cement concrete. Because of wide variations in soils, loads, materials, construction practices and varying costs of pavement materials, it is not practical to present specific or recommended typical structural sections that will be applicable nationwide. In areas where climates are extreme, the effects of freeze-thaw cycles should be anticipated in the design phase. Attention to local governing conditions and the principles outlined in this section is needed. Experience in highway pavement, together with sound engineering judgment, can assist in the selection and design of a proper path pavement structure and may identify energy-conserving practices, such as the use of sulfur-extended asphalt, asphalt emulsions and fused waste.

Designing and selecting pavement sections for shared use paths is in many ways similar to designing and selecting highway pavement sections. A soils investigation should be conducted to determine the load-carrying capabilities of the native soil, unimproved shoulder or former railroad bed (if ballast has been removed), and the need for any special provisions.

While loads on shared use paths will be substantially less than highway loads, paths should be designed to sustain without damage wheel loads of occasional emergency, patrol, maintenance and other motor vehicles expected to use or cross the path.

It is important to construct and maintain a smooth riding surface on shared use paths. Pavements should be machine laid; soil sterilants should be used where necessary to prevent vegetation from erupting through the pavement. On Portland cement concrete pavements, the transverse joints, necessary to control cracking, should be saw cut to provide a smooth ride. On the other hand, skid resistance qualities should not be sacrificed for the sake of smoothness. Broom finish or burlap drag concrete surfaces are preferred.

When motor vehicles are driven on shared use paths, their wheels often will be at or very near the edges of the path. Since this can cause edge damage that, in turn, will reduce the effective operating width of the path, adequate edge support should be provided. Edge support can be either in the form of stabilized shoulders or constructing additional pavement width or thickness. Constructing a typical pavement width of 3.0 m (10 feet), where right-of-way and other conditions permit, lessens the edge raveling problem and offers two additional advantages over shoulder construction on shared use paths. First, it allows additional maneuvering space for bicyclists, and second, the additional construction cost can be less than the cost of constructing shoulders because a separate construction operation is eliminated.

At unpaved highway or driveway crossings of shared use paths, the highway or driveway should be paved a minimum of 3 m (10 feet) on each side of the crossing to reduce the amount of gravel being scattered along the path by motor vehicles. The pavement structure at the crossing should be adequate to sustain the expected loading at that location.

Figure 24. Bridge Structure to Provide Bike Path Continuity

Structures

An overpass, underpass, bridge or facility on a highway bridge may be necessary to provide continuity to a shared use path. An example of a small bridge structure used to provide path continuity is shown in Figure 24. A bicycle facility on a highway structure is shown in Figure 25.

On new structures, the minimum clear width should be the same as the approach paved shared use path, plus the minimum 0.6-m (2-foot) wide clear areas. Carrying the clear areas across the structures has two advantages.

First, the clear width provides a minimum horizontal shy distance from the railing or barrier, and second, it provides needed maneuvering space to avoid conflicts with pedestrians and other bicyclists who are stopped on the bridge. Access by emergency, patrol and maintenance vehicles should be considered in establishing the design clearances of structures on shared use paths. Similarly, vertical clearance may be dictated by occasional motor vehicles using the path. Where practical, a vertical clearance of 3 m (10 feet) is desirable for adequate vertical shy distance.

Railings, fences or barriers on both sides of a path on a structure should be a minimum of 1.1 m (42 inches) high.

Figure 25. Shared Use Path (Far Right) on a Grade Separation Structure; Note Bike Lane and Sidewalk.

Bridges should be designed for pedestrian live loadings. Where maintenance and emergency vehicles may be expected to cross the bridge, the design should accommodate them. On all bridge decks, special care should be taken to ensure that bicycle-safe expansion joints are used, and that decking materials that become slippery when wet are avoided.

Where it is necessary to retrofit a shared use path onto an existing highway bridge, several alternatives should be considered in light of what the geometrics of the bridge will allow.

One option is to carry the shared use path across the bridge on one side. This should be done where 1) the bridge facility will connect to a path at both ends, 2) sufficient width exists on that side of the bridge or can be obtained by widening or restriping lanes, and 3) provisions are made to physically separate bicycle traffic from motor vehicle traffic as discussed previously.

A second option is to provide either wide curb lanes or bicycle lanes over the bridge. This may be advisable where 1) the shared use path transitions into bicycle lanes at one end of the bridge and 2) sufficient width exists or can be obtained by widening or restriping. This option should only be exercised if the bike lane or wide outside lane can be accessed without increasing the potential for wrong-way riding or inappropriate crossing movements.

Because of the large number of variables involved in retrofitting bicycle facilities onto existing bridges, compromises in desirable design criteria are often inevitable. Therefore, the width to be provided is best determined by the designer, on a case-by-case basis, after thoroughly considering all the variables.

Drainage

The recommended minimum pavement cross slope of 2 percent adequately provides for drainage. Sloping in one direction instead of crowning is preferred and usually simplifies the drainage and surface construction. A smooth surface is essential to prevent water ponding and ice formation. On unpaved shared use paths, particular attention should be paid to drainage to avoid erosion.

Where a shared use path is constructed on the side of a hill, a ditch of suitable dimensions should be placed on the uphill side to intercept the hillside drainage. Such ditches should be designed so that no undue obstacle is presented to bicyclists. Where necessary, catch basins with drains should be provided to carry the intercepted water under the path. Drainage grates and manhole covers should be located outside the travel path of bicyclists. To assist in preventing erosion in the area adjacent to the shared use path, the design should include considerations for preserving the natural ground cover. Seeding, mulching and sodding of adjacent slopes, swales and other erodible areas should be included in the project plans. Also see Chapter 2, *Shared Roadways*, for information on drainage grates.

Lighting

Fixed-source lighting improves visibility along paths and at intersections. In addition, lighting allows the bicyclist to see the path direction, surface conditions and obstacles. Lighting for shared use paths is important and should be considered where night usage is expected, such as paths serving college students or commuters, and at highway intersections. Lighting should also be considered through underpasses or tunnels, and when nighttime security could be an issue. Depending on the location, average maintained horizontal illumination levels of 5 lux to 22 lux should be considered. Where special security problems exist, higher illumination levels may be considered. Light standards (poles) should meet the recommended horizontal and vertical clearances. Luminaires and standards should be at a scale appropriate for a pedestrian.

Restriction of Motor Vehicle Traffic

Shared use paths may need some form of physical barrier at highway intersections to prevent unauthorized motor vehicles from using the facilities. Provisions can be made for a lockable, removable (or reclining) barrier post to permit entrance by authorized vehicles. Posts or bollards should be set back beyond the clear zone on the crossing highway or be of a breakaway design. The post should be permanently reflectorized for nighttime visibility and painted a bright color for improved daytime visibility. Striping an envelope around the post is recommended as shown in Figure 26. When more than one post is used, an odd number of posts at 1.5-m (5-foot) spacing is desirable. Wider spacing can allow entry to motor vehicles, while narrower spacing might prevent entry by adult tricycles, wheelchair users, and bicycles with trailers.

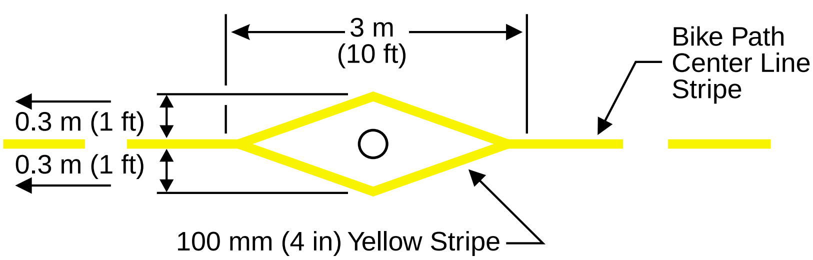


Figure 26. Barrier Post Striping

An alternative method of restricting entry of motor vehicles is to split the entry way into two 1.5-m (5-foot) sections separated by low landscaping. Emergency vehicles can still enter if necessary by straddling the landscaping. The higher maintenance costs associated with landscaping should be acknowledged before this alternative method is selected.

Undesirability of Sidewalks as Shared Use Paths

Utilizing or providing a sidewalk as a shared use path is unsatisfactory for a variety of reasons. Sidewalks are typically designed for pedestrian speeds and maneuverability and are not safe for higher speed bicycle use. Conflicts are common between pedestrians traveling at low speeds (exiting stores, parked cars, etc.) and bicyclists, as are conflicts with fixed objects (e.g., parking meters, utility poles, sign posts, bus benches, trees, fire hydrants, mail boxes, etc.) Walkers, joggers, skateboarders and roller skaters can, and often do, change their speed and direction almost instantaneously, leaving bicyclists insufficient reaction time to avoid collisions.

Similarly, pedestrians often have difficulty predicting the direction an oncoming bicyclist will take. At intersections, motorists are often not looking for bicyclists (who are traveling at higher speeds than pedestrians) entering the crosswalk area, particularly when motorists are making a turn. Sight distance is often impaired by buildings, walls, property fences and shrubs along sidewalks, especially at driveways. In addition, bicyclists and pedestrians often prefer to ride or walk side-by-side when traveling in pairs. Sidewalks are typically too narrow to enable this to occur without serious conflicts between users.

It is especially inappropriate to sign a sidewalk as a shared use path or designated bike route if to do so would prohibit bicyclists from using an alternate facility that might better serve their needs.

It is important to recognize that the development of extremely wide sidewalks does not necessarily add to the safety of sidewalk bicycle travel. Wide sidewalks might encourage higher speed bicycle use and can increase potential for conflicts with motor vehicles at intersections, as well as with pedestrians and fixed objects. For guidance on when and how to designate sidewalks as signed bikeways, see page 20.

Shared Use with Motorbikes, Horses and Snowmobiles

Even where lawful, it is undesirable to mix mopeds or motorbikes with bicycles and pedestrians on the same facility. In general, mopeds should not be allowed on shared use paths because of conflicts with the slower moving bicyclists and other users. Mopeds also diminish the quiet, relaxing experience most users desire on shared use paths. In some cases where an alternate route for mopeds does not exist, additional width, signing and striping should be used to minimize conflicts. Increased patrolling by law enforcement personnel is also recommended to enforce speed limits and other rules of the road.

It is usually not desirable to mix horse riding and bicycle traffic on the same shared use path. Bicyclists are often not aware of the need for slower speeds and additional operating space near horses. Horses can be startled easily and may be unpredictable if they perceive approaching bicyclists as a danger. In addition, pavement requirements for bicycle travel are not suitable for horses. For these reasons, a bridle trail separate from the shared use path is recommended to accommodate horses.

In winter sports areas during the winter months there is usually insufficient bicycle traffic to justify plowing snow, and managers of shared use paths may allow them to be used by cross country skiers or snowmobile operators.

Other Design Considerations

Railroad Crossings

Railroad-highway grade crossings should ideally be at a right angle to the rails. This can be accomplished either as a separate path or a widened shoulder, as shown in Figure 27. The greater the crossing deviates from this ideal crossing angle, the greater is the potential for a bicyclist's front wheel to be trapped in the flangeway, causing loss of steering control. If the crossing angle is less than approximately 45 degrees, an additional paved shoulder of sufficient width should be provided to permit the bicyclist to cross the track at a safer angle, preferably perpendicularly. Where this is not possible, and where train speeds are low, commercially available compressible flangeway fillers may enhance bicyclist operation. It is also important that the roadway approach be at the same elevation as the rails.

Consideration should be given to the crossing surface materials and to the flangeway depth and width. Rubber or concrete crossing materials are longer lasting than wood or asphalt and require less maintenance. In some cases, abandoned tracks can be removed. Warning signs and pavement markings should be installed in accordance with the MUTCD[2].

Bicycles on Freeways

In some instances, bicyclists are permitted to operate on freeways. Normally, a freeway would not be signed or marked as a bikeway, but in some states it can be opened for use if it meets certain criteria. Essentially, the criteria involve assessing the safety and convenience of the freeway compared with available alternate routes. However, a freeway should not be available to bicycle use if it is determined to be incompatible.

If a suitable alternate route exists, it would normally be unnecessary to open the freeway to bicycle use. However, if alternate routes are unsuitable for bicycle travel, the freeway may be a better or the only alternative for bicyclists. In determining the suitability of an alternate route, safety should be the paramount consideration. The following factors should be considered:

- Number or frequency of intersections
- Shoulder width on roadway and across structures
- Traffic volumes
- Vehicle speeds
- Bus, truck and recreational vehicle volumes
- Grades
- Travel time

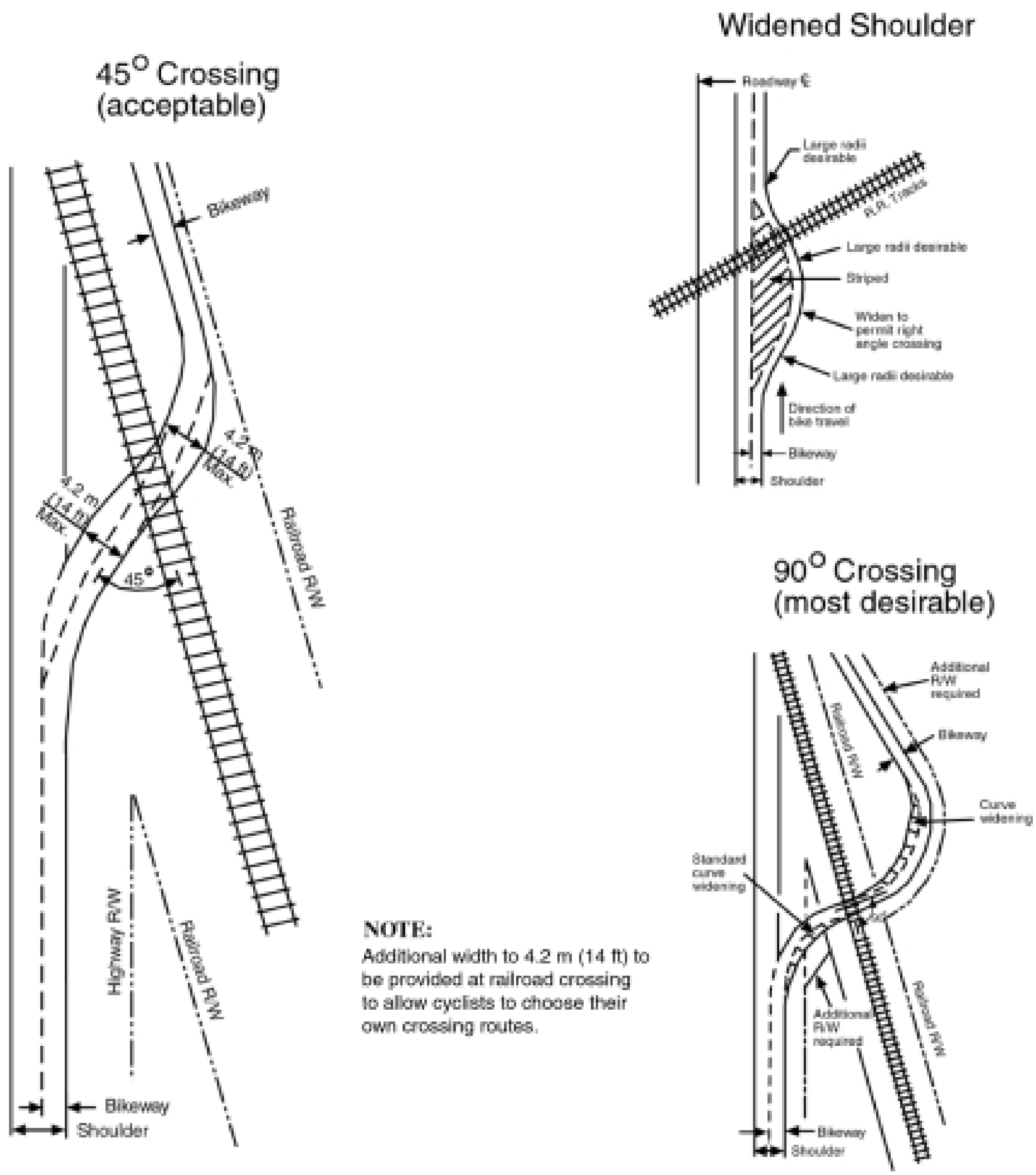


Figure 27. Railroad Crossings

When a suitable alternate route does not exist, a freeway shoulder may be considered for bicycle travel. Normally, freeways in urban areas will have characteristics making them highly undesirable to permit bicycle use. In determining if the freeway shoulder is suitable for bicycle travel, the following factors should be considered:

- Paved shoulder widths [a minimum of 1.5 m (5 feet) of ridable space, free of rumble strips]
- Shoulder surface conditions (drainage grates, expansion joints, rumble strips, cracks, etc.)
- Number and location of entrance/exit ramps
- Design of exit ramps
- Traffic volumes on entrance/exit ramps
- Truck volumes
- Grades

When bicyclists are permitted on segments of freeway, it will be necessary to modify and supplement freeway regulatory signs, particularly those at freeway ramp entrances.

Where no reasonable alternative exists within a freeway corridor, alternatives should be developed to improve existing routes or provide a parallel separated bikeway within or adjacent to the freeway right-of-way. The long-term goal should be to provide a safe and convenient non-freeway route for bicycle travel.

Bicycle Facilities through Interchange Areas

Turning roadways provided for interchange ramp ingress and egress often require bicyclists on the cross streets to perform merging, weaving or crossing maneuvers with ramp vehicles. These conflict points are made challenging when a wide disparity in speed exists between traffic on the ramp and cross street bicycle traffic crossing the ramp, and when grade separations create significant profile gradients. If a bike lane or route must traverse an interchange area, these intersection or conflict points should be designed to limit the conflict areas or to eliminate unnecessary uncontrolled ramp connections to urban roadways.

One possible method of delineating a bike lane through the entire interchange area across the turning roadway intersections is shown in Figure 28, Option 1. When it is more desirable to allow the bicyclist to choose his/her own merge, weave or crossing maneuvers, it is recommended that the pavement markings be discontinued through the crossing area, as depicted in Figure 28, Option 2.

In the case of a bike lane along the shoulder of a freeway, these same two methods of delineating the bike lane through the interchange area can be used. In addition, if the freeway interchange with the cross roadway is a standard diamond-type, another alternative would be to continue the freeway shoulder bike lane along the shoulders of the ramps through the cross road intersection. This would be particularly appropriate if the cross road was a potential bicycle destination access road.

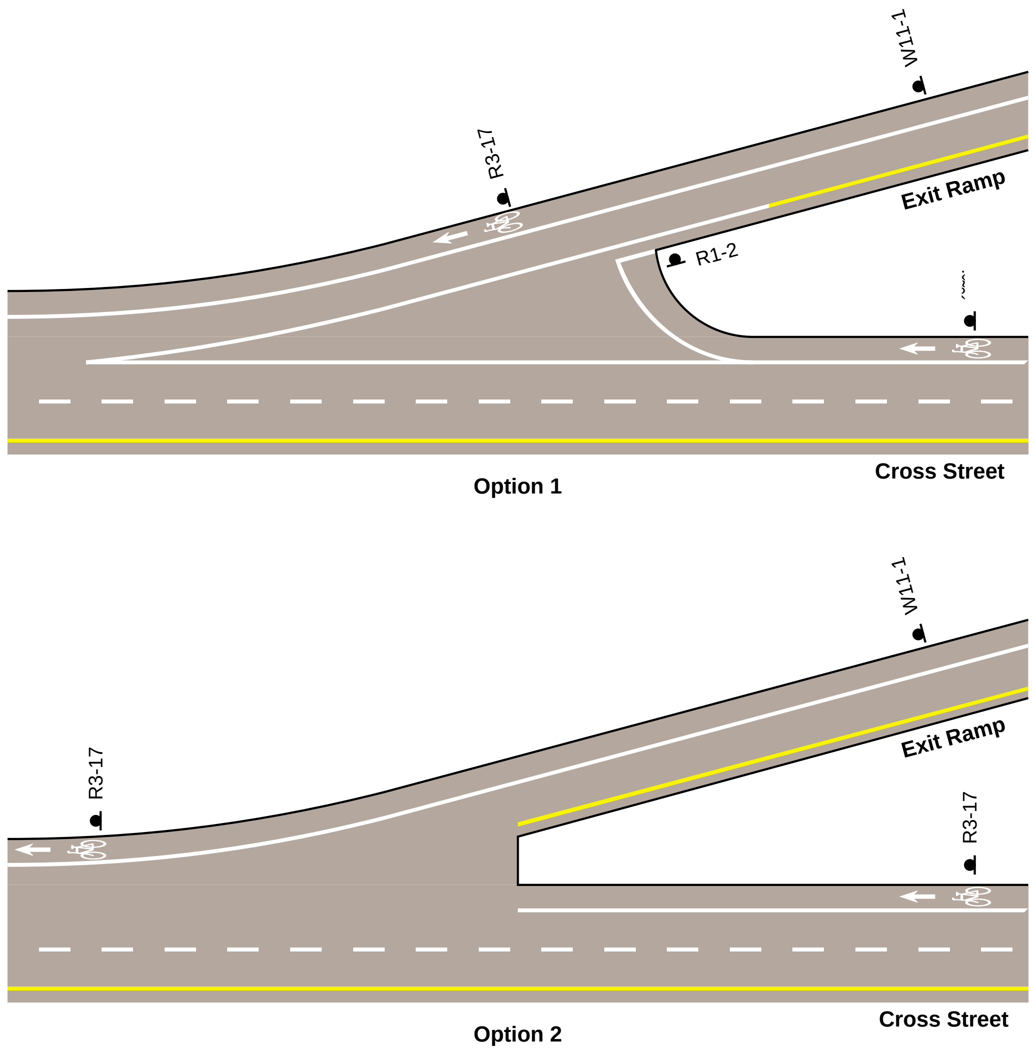


Figure 28. Bicycle Crossing of Interchange Ramp

Bicycles at Modern Roundabouts

Generally there are three ways to accommodate bicyclists in roundabouts: 1) in mixed flow with vehicular traffic, 2) along separate bicycle paths, and 3) on bicycle lanes along the outside diameter of roundabouts (not currently recommended).

The following safety issues should be considered when contemplating bicycles in roundabouts:

- Bicyclists are vulnerable users of roundabouts and consideration should be given for their accommodation.
- In low-speed [approximately 20 km/hr (12 mph)], single-lane roundabouts, few negative safety impacts have been observed when bicycles are mixed in the traffic stream. Because of the small speed differential, bicyclists are expected to circulate in the traffic lane at approximately the same speed as vehicles. When bike lanes lead to this type of roundabout, it is preferable to discontinue them 10 to 20 m (35 to 65 feet) before reaching the roundabout, rather than continuing the lane through the roundabout.
- Bicycle safety tends to deteriorate at higher speed, multi-lane roundabouts and at flared entries. At these roundabouts, special solutions should be sought when warranted by bicycle volumes. Among the possible solutions are separate bikeways, shared use of the pedestrian facility, separate bike routing through other intersections, or grade separation for the vulnerable modes.

A majority of bike crashes at roundabouts involve entering vehicles and circulating bicycles, reinforcing the need to reduce entering speeds by providing ample deflection, to maintain good visibility for entering traffic and to enforce yield conditions for entering traffic.

Traffic Signals

At signalized intersections where bicycle traffic exists or is anticipated, the timing of the traffic signal cycle, as well as the method of detecting the presence of the bicyclists, should be considered. In mixed traffic flow the bicyclist normally can cross the intersection under the same signal phase as motor vehicles. The greatest risk to bicyclists is during the clearance interval and during the actuated phases during periods of low traffic flow. Signals should be designed to provide an adequate clearance interval for bicyclists who enter at the end of the green and a total crossing time (minimum green plus clearance interval) long enough to accommodate bicyclists starting up on a new green.

The length of the yellow change interval is dependent upon the speed of approaching traffic. Yellow change intervals adequate for motorists (generally 3.0 s to 6.0 s) are usually adequate for bicyclists. Generally, an all-red clearance interval is not required, but can be used to allow the cyclist who entered the intersection during the yellow interval to clear the intersection before the conflicting movement receives the green signal. The all-red clearance interval normally ranges from 1.0 s to 2.0 s. The total clearance interval (yellow change interval plus red clearance interval) can be calculated from:[12]

For Metric Units:

$$y + r_{clear} \geq t_r + \frac{v}{2b} + \frac{w + l}{v}$$

where:

- y = yellow interval(s)
- r_{clear} = red clearance interval(s)
- t_r = reaction time (1.0 s)
- v = bicyclist speed (m/s)
- b = bicyclist braking deceleration (1.2 to 2.5 m/s^2)
- w = width of crossing (m)
- l = bicycle length (1.8 m)

For English Units:

$$y + r_{clear} \geq t_r + \frac{v}{2b} + \frac{w + l}{v}$$

- y = yellow interval(s)
- r_{clear} = red clearance interval(s)
- t_r = reaction time (1.0 s)
- v = bicyclist speed (mph)
- b = bicyclist braking deceleration (4 to 8 ft/s^2)
- w = width of crossing (ft)
- l = bicycle length (6 ft)

If field observations are not available, approximately 98 percent of cyclists should be able to clear signals timed for the following speeds: 19 km/h (5.3 m/s) [12 mph (17.6 ft/sec)] for Group A cyclists, 13 km/h (3.6 m/s) [8 mph (12.0 ft/sec)] for Group B cyclists, and 10 km/h (2.8 m/s) [6 mph (9.1 ft/sec)] for Group C cyclists. Approximately 85 percent of cyclists can clear signals timed for speeds 20 percent higher. If local practice does not permit this long a red clearance interval (as given by the equation), the longest red clearance interval consistent with local practice should be used.

When an approach receives a green signal, the bicyclist needs enough time to react, accelerate and cross the intersection. The general equation to determine the minimum green time is:[12]

For Metric Units:

$$g + y + r_{clear} \geq t_{cross} = t_r + \frac{v}{2a} + \frac{w + l}{v}$$

where;

- g = minimum green
- y, r_{clear} = yellow and red clearance intervals actually used
- t_{cross} = Time to cross the intersection
- t_r = Reaction time (2.5 s)
- v = Bicycle speed (m/s)
- a = Bicycle acceleration (0.5 – 1.0 m/s^2)
- w = Width of crossing (m)
- l = Bicycle length (1.8 m)

For English Units:

$$g + y + r_{clear} \geq t_{cross} = t_r + \frac{v}{2a} + \frac{w + l}{v}$$

- g = minimum green
- y, r_{clear} = yellow and red clearance intervals actually used
- t_{cross} = Time to cross the intersection
- t_r = Reaction time (2.5 s)
- v = Bicycle speed (ft/s)
- a = Bicycle acceleration (1.5 - 3 ft/s^2)
- w = Width of crossing (ft)
- l = Bicycle length (6 ft)

However, as with all calculated signal timing, actual field observations should be undertaken prior to making any adjustments to the minimum green or clearance intervals. Acute angle intersections require longer crossing times for bicyclists.

Detection of bicycles at traffic-actuated signals is crucial for bicyclists' safety and for compliance with traffic laws. Detectors that have been placed for vehicular traffic can usually detect the presence of bicycles. Quadrupole and diagonal-type loop detectors are examples of induction loops that provide bicycle detection. Dipole and rectangular loops can also detect bicycles if the detector sensitivity is adjusted. Efforts should be made to ensure that signal detection devices are capable of detecting a bicycle and that the total green plus clearance time (yellow plus all-red) is sufficient for the bicyclist to cross the intersection safely.

Detectors for traffic-actuated signals should be located in the bicyclist's expected path, including left-turn lanes and shoulders. It may also be helpful to the bicyclist if the road surface is marked to indicate the optimum location for bicycle detection. Figure 29 shows the standard pavement symbol which should be placed at the location of a bicycle loop detector to notify the cyclist where to stop.

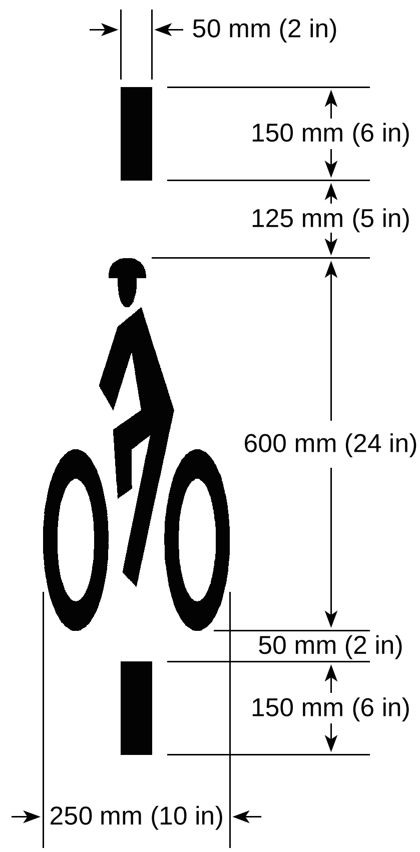


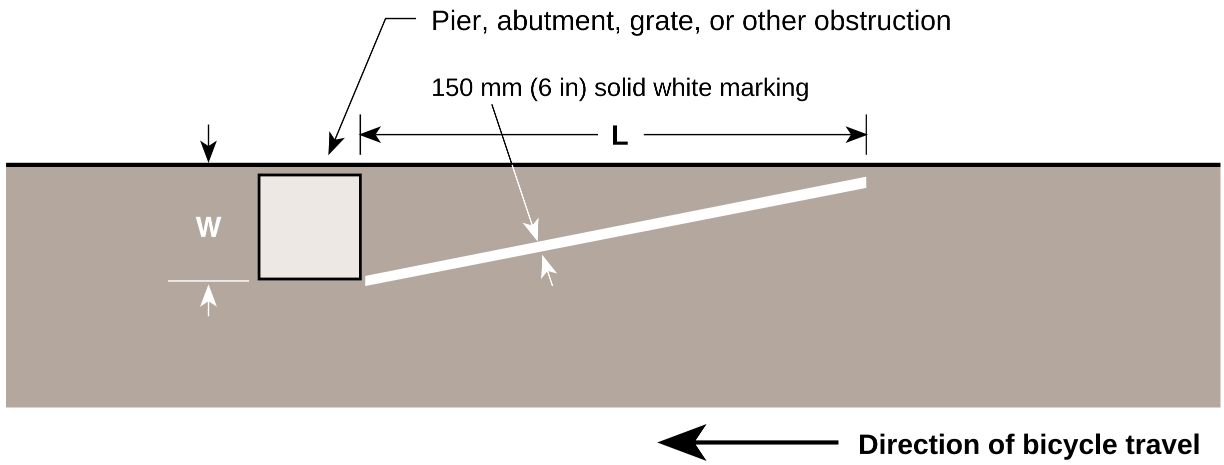
Figure 29. Bicycle detector pavement marking

In some situations, the use of pedestrian- or bicyclist-actuated buttons may be an acceptable alternative to the use of detectors provided they do not require bicyclists to dismount or make unsafe leaning movements. However, actuated buttons should not be considered a substitute for detectors.

Where programmed visibility signal heads are used, they should be checked to ensure that they are visible to bicyclists who are properly positioned on the road.

Obstruction Markings

Vertical barriers and obstructions, such as abutments, piers and other features causing bikeway constriction, should be clearly marked to gain the attention of approaching bicyclists. This treatment should be used only where the obstruction is unavoidable, and is by no means a substitute for good bikeway design. An example of an obstruction marking is shown in Figure 30. Signs, reflectors, diagonal yellow markings or other treatments may be appropriate to alert bicyclists to potential obstructions.



For Metric Units:

L = 0.62 WV, where V is bicycle approach speed (km/h)

For English Units:

L = WV, where V is bicycle approach speed (mph)

Figure 30. Obstruction Marking

Bicycle Parking Facilities

Providing bicycle parking facilities is an essential element in an overall effort to promote bicycling. People are discouraged from bicycling unless adequate parking is available. Bicycle parking facilities should be provided at both the trip origin and trip destination and should offer protection from theft and damage. The wide variety of bicycle parking devices are generally grouped into two classes, long-term and short-term. The minimum needs for each differ in their placement and protection.

Long-term bicycle parking facilities provide a high degree of security and protection from the weather. They are intended for situations where the bicycle is left unattended for long periods of time, such as apartments and condominium complexes, schools, places of employment and transit stops. These bicycle parking facilities are usually lockers, cages or rooms in buildings.

Short-term facilities provide a means of locking the bicycle frame and both wheels, but do not provide accessory and component security or weather protection (unless covered). They are for decentralized parking where the bicycle is left for a short period of time and is visible and convenient to the building entrance.

Bicycle racks should be designed so that they:

- Do not bend wheels or damage other bicycle parts
- Accommodate high security U-shaped bike locks
- Accommodate locks securing the frame and both wheels (preferably without removing the front wheel from the bicycle)
- Do not impede or interfere with pedestrian traffic
- Are easily accessed from the street and protected from motor vehicles
- Are visible to passers-by to promote usage and enhance security
- Are covered where users will leave their bikes for a long time
- Have as few moving parts as possible

Facilities should be able to accommodate a wide range of bicycle shapes and sizes, including tricycles and trailers if used locally. Finally, facilities should be simple to operate. If possible, signs depicting how to operate the facility should be posted.

Additional Bicycle Amenities

There are several other improvements that complement bicycle facilities. For example, turnouts or rest areas may be provided on long, uninterrupted shared use paths. Provisions should be considered for interfacing bicycle travel with public transit, such as racks on buses, buses converted to carry bicycles aboard, or allowing bicycles on ferries and rapid rail facilities.

Printing and distributing bikeway maps is a high-benefit, low-cost project that is easily accomplished. Maps can help bicyclists locate bikeways and parking facilities and identify the relative suitability of different segments of the road system. Also, maps can help bicyclists avoid narrow, high-speed, or high-volume roads, one-way streets, barriers and other problems. In addition, maps can provide information on Rules of the Road, bicycle safety tips and interfacing with mass transit.

Accessibility Requirements

The Americans with Disabilities Act (ADA) of 1990 is civil rights legislation that prohibits discrimination against people with disabilities. It guarantees the right to participate fully and equally in all aspects of life. Accessibility to transportation systems means providing usable facilities for the highest number of people possible.

Accessible features can benefit almost everyone. What is helpful for a wheelchair user, e.g., curb ramps, will also benefit bicyclists. Low grades and cross slopes not only make a facility usable for people with mobility impairments, but can also improve a transportation circulation system for all pedestrians, bicyclists and inline skaters. There are 48.9 million Americans with disabilities; 70 percent of all Americans will at some time in their lives have a temporary or permanent disability that makes such activities as stair climbing impossible. People may have mobility, visual and cognitive disabilities that affect how usable a facility may be for them. As our population grows older, the percentages of people with disabilities will increase. What we build today will be with us for many years. These designs need to accommodate as many users as possible.

When choosing bicycling or walking as a transportation mode, users often want a convenient, direct route that will not exhaust their energy in getting to their destination. This can be especially true for people with disabilities. Saving energy often is the reason a person chooses driving over cycling and walking. Designers of shared use paths need to keep in mind that well-designed accessible facilities are usually more functional for all users, with and without disabilities.

Federal ADA standards have been developed for buildings and their sites, but not for outdoor developed areas. Some states and localities have developed their own standards for outdoor accessibility that must be followed. Federal standards for this development, which would include shared use paths, are in the process of being drafted by a Committee of Federal agencies and interested organizations. It is understood that constructing facilities in the outdoors may have certain limitations that may make it difficult to build fully accessible paths. The conditions that would prevent full accessibility include those that:

- Cause harm to significant natural, cultural, historic or religious characteristics of a site
- Alter the fundamental experience of the setting or intended purpose of the trail
- Require construction methods that are prohibited by federal, state or local regulations
- Involve terrain characteristics (e.g., slope, soils, geologic or aquatic) that prevent compliance with the technical provision

Many of the provisions being developed by the Regulatory Negotiation Committee on Outdoor Developed Areas, such as surface treatment, minimum path width, changes in the level surface, and passing space, will automatically be met in the construction of a path suitable for bicycle travel.

Once these provisions are adopted, they should be consulted when designing bicycle facilities.

What if an existing path is not accessible? Do as much as possible to remove the barriers. Good signing at the trail access points that identify situations that could be difficult to traverse (such as steep grade and cross slope, narrow width and uneven surface conditions) will help users determine for themselves whether to use the path.

Rationale for Accessible Design

Understanding how people with various disabilities function in the outdoor transportation environment is the first step in trying to accommodate their design needs.

Wheelchair Users—Low running grades, preferably below 5 percent, are desirable because exertion is needed to push up, and controlling the wheelchair going down on steep grades is a problem.

Cross slopes should be no more than 2-3 percent. The greater the cross slope the greater the gravity pull on the wheelchair to turn into the slope. Combining a steep running grade with a steep cross slope increases the difficulty of maneuvering a wheelchair. On a hardened or paved surface, a 2 percent cross slope will drain off water in most cases.

Amenities, such as phones, water fountains and pedestrian-actuated signal controls, need to be placed no higher than 2.4 m (4 feet) from the ground level. Wheelchair users have a lower reach range and a lower sight perspective of the environment. The buttons on actuated signals need to be large, protruding and easy to push for those who have limited mobility in their hands. The buttons also need to be placed in an accessible path of travel for a wheelchair user.

Visually Impaired—Most sighted people get their directional and spatial cues visually. People who are totally blind get their cues from sound and touch. People with low vision (78 percent of the legally blind population) may have an additional advantage of detecting contrasting colors. Older people often lose their hearing and vision at the same time, creating a compound difficulty. Older individuals, who lose their vision gradually, may not be trained in wayfinding techniques. Cars are getting quieter, curb radii wider, and street crossings longer. All these factors contribute to a hostile pedestrian environment, especially for the visually impaired.

Curb ramps are typically thought of as an accommodation for bicyclists and wheelchair users, but they can be used by the visually impaired as a warning of the transition from the path to the street. If they fail to detect the ramp, they are at risk of walking into the street, which may result in serious consequences. If the ramp grade is low, a visually impaired person may not detect the transition. Detectable warnings and contrasting colors at the bottom of ramps may help detect the presence of a curb ramp. A tradeoff may exist between the visually impaired and mobility impaired when using truncated domed surfaces, because maneuverability may be more difficult for both the bicyclist and the mobility impaired.

People with Limited Cognitive Abilities—We are learning that children under the age of 12 do not often think about the rules of the road (path), even when they have been taught. Their ability to take in and perceive the road environment, and then perform the multiple tasks needed to make fast decisions, may not be developed. Planners and designers need to take into account the mixing of faster moving modes with pedestrians when determining facility design, especially if the path is a school route. Adults with cognitive disabilities may benefit from easy-to-interpret signs. This may be particularly important when a path intersects with another path or street.

Chapter 3 Operation and Maintenance

The jurisdictions responsible for the operation, maintenance and policing of bicycle facilities should be established prior to construction. In addition to construction costs, operating and maintenance costs should be considered and included in the overall budget for the facility. Neglecting routine maintenance eventually may render bicycle facilities unridable and such deteriorating facilities may become a liability to the state or community. Bicyclists should be encouraged to report bicycle facilities that are in need of maintenance. A central contact person who can authorize maintenance work should be designated to receive such reports.

A smooth surface, free of potholes and debris, should be provided on all bikeways. Glass, sand, litter and fallen leaves often accumulate on bike lanes, paved shoulders and shared use paths; therefore, regular sweeping is desirable. Pavement edges should be uniform and should not have abrupt drop-offs. Signs and pavement markings should be inspected regularly and kept in good condition, and if determined to be no longer necessary, promptly removed. Highways with bicycle traffic may require a more frequent and higher level of maintenance than other highways.

For shared use paths, attention should be given to maintaining the full paved width and not allowing the edges to ravel. Trees, shrubs and other vegetation should be controlled to provide adequate clearances and sight distances. Trash receptacles should be placed and maintained at convenient locations. Seeded and sodded areas in the vicinity of shared use paths should be mowed regularly. Snow plowing should be used to remove snow from bikeways because de-icing agents and abrasives can damage bicycles. Also, enforcement is often necessary to prevent unauthorized motor vehicles from using a shared use path.

The routine maintenance of roadways and bikeways will usually provide good riding conditions. Several bicycle facility improvements described in this guide can be implemented during routine maintenance activities. Consideration also can be given to adjusting lane widths and providing wider outside curb lanes for bicyclists during restriping operations. The addition of edge lines can better delineate a shoulder, especially at night. When shoulders are resurfaced, a smooth surface suitable for bicycle riding should be considered.

Appendix

Review of Legal Status

Bicycle programs must reflect applicable laws and ordinances. Bicycle facilities must not encourage or require bicyclists, pedestrians or motorists to operate in a manner inconsistent with the adopted Rules of the Road as described in Chapter 11 of the *Uniform Vehicle Code (UVC).*

The National Committee on Uniform Traffic Laws and Ordinances, a group of more than 140 individuals involved in the complex problems of highway transportation, has developed and recommended the *UVC* as a comprehensive guide for state motor vehicle and traffic laws. In addition, the provisions of the *Model Traffic Ordinance (MTO)* have been designed as a guide for municipalities to follow in considering the development or revision of their traffic ordinances. Since bicycles are defined as vehicles, familiarity with the provisions in the *UVC* and *MTO* is important when developing bicycle facilities. The *UVC* and state and local laws and ordinances should be reviewed before decisions are made on the type of facilities desired. Sections 1-158, 11-201, 11-313, 11-1202, 11-1205, 11-1209, 11-1210, 11-1211 and 11-1213 of the UVC should be compared with corresponding state and municipal provisions.

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GBF-3
ISBN 1-56051-102-8