BEFORE THE HEARING EXAMINER
FOR THE CITY OF SAMMAMISH

In the Matter of: SHORELINE SUBSTANTIAL DEVELOPMENT PERMIT, City of Sammamish File No. SSDP2016-00414	)	No. 2016-00414 APPLICANT KING COUNTY'S SUBMITTAL OF EXHIBITS

Per Hearing Examiner Rule of Procedure 216, the following supplemental exhibits are provided by the applicant, King County, for consideration by the examiner in reaching a decision on SSDP 2016-00414.

KING COUNTY'S EXHIBITS

EXH. No.	DESCRIPTION
1.	AASHTO, Guidelines for the Development of Bicycle Facilities, 2012.
2.	2017 WSDOT Construction Manual M 41-01.29 Page 2-1.
3.	2016 WSDOT Standard Specifications for Road, Bridge and Municipal Construction Pages 1, 16-17.
4.	East Lake Sammamish Trail, Demand Analysis, May 19, 2016, Bill Schultheiss, P.E.
5.	King County Regional Trail Standard, 3/20/2017.
6.	IHR Tree Preservation Plan.

Daniel T. Satterberg,
King County Prosecuting Attorney
CIVIL DIVISION
W400 King County Courthouse
516 Third Avenue
Seattle, Washington 98104

DATED this 16th day of October, 2017.

DANIEL T. SATTERBERG,
King County Prosecuting Attorney

By: ____________________
Barbara Flemming, WSBA #20485
Devon Shannon, WSBA #345347
Senior Deputy Prosecuting Attorneys
Attorneys for King County
900 King County Administration Building
500 Fourth Avenue
Seattle, WA 98104
Telephone: 206 477-1084
Fax: 206 296 0415
E-Mail: Barbara.Flemming@kingcounty.gov
Devon.Shannon@kingcounty.gov

Guide for the Development of Bicycle Facilities

2012 • Fourth Edition

AMERICAN ASSOCIATION OF
STATE HIGHWAY AND
TRANSPORTATION OFFICIALS
AASHTO
THE VOICE OF TRANSPORTATION

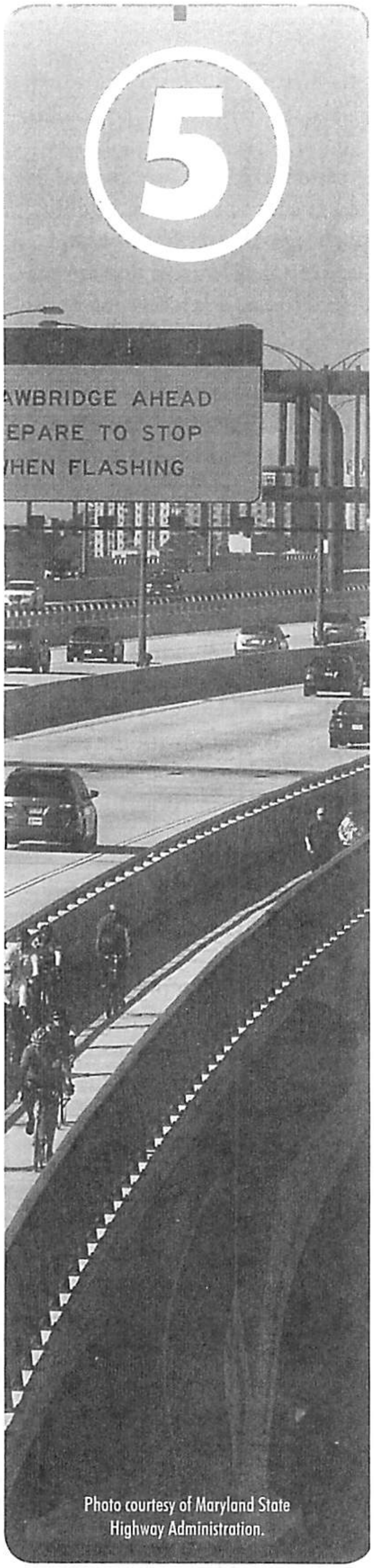

Photo courtesy of Maryland State Highway Administration.

Design of Shared Use Paths

5.1 INTRODUCTION

Shared use paths are bikeways that are 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 are sometimes referred to as "trails." However, in many states the term "trail" means an unimproved recreational facility. Care should be taken not to use these terms interchangeably because they have distinctly different design guidelines. Shared use paths should be designed based on the guidance in this guide.

Path users are generally non-motorized and may include but are not limited to:

- Typical upright adult bicyclists
- Recumbent bicyclists
- Bicyclists pulling trailers
- Tandem bicyclists
- Child bicyclists
- Inline skaters
- Roller skaters
- Skateboarders
- Kick scooter users
- Pedestrians (including walkers, runners, people using wheelchairs (both non-motorized and motorized), people with baby strollers, people walking dogs, and others.

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Paths are most commonly designed for two-way travel, and the guidance herein assumes a two-way facility is planned unless otherwise stated.

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) or access to schools. They can provide a commuting route between residential areas and job centers or schools. Located in a park or a greenway, 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, roadway corridors, limited access freeways, within college campuses, or within parks and open space areas. Shared use paths can also provide bicycle access to areas that are otherwise served only by limited-access highways. Shared use paths that run adjacent to a roadway are called sidepaths. These are discussed further in Section 5.2.2.

Shared use paths should be thought of as a system of off-road transportation routes for bicyclists and other users that extends and complements the roadway network. Shared use paths should not be used to preclude on-road bicycle facilities, but rather to supplement a network of on-road bike lanes, shared roadways, bicycle boulevards, and paved shoulders. Shared use path design is similar to roadway design, but on a smaller scale and with typically lower design speeds.

5.1.1 Accessibility Requirements for Shared Use Paths

Due to the fact that nearly all shared use paths are used by pedestrians, they fall under the accessibility requirements of the Americans with Disabilities Act (ADA). The technical provisions herein either meet or exceed those recommended in current accessibility guidelines. Paths in a public right-of-way that function as sidewalks should be designed in accordance with the proposed *Public Rights-of-Way Accessibility Guidelines* (PROWAG) (*13*), or subsequent guidance that may supersede PROWAG in the future. These guidelines also apply to street crossings for all types of shared use paths.

Shared use paths built in independent rights-of-way should meet the draft accessibility guidelines in the *Advance Notice of Proposed Rulemaking (ANPRM) on Accessibility Guideline for Shared Use Paths* (*12*), or any subsequent rulemaking that supersedes the ANPRM. The ANPRM separates shared use paths from recreational trails and more closely aligns draft accessibility provisions with those provided for sidewalks and other pedestrian facilities. Refer to the U.S. Access Board website (www.access-board.gov) for up-to-date information regarding the accessibility provisions for shared use paths and other pedestrian facilities covered by the Americans with Disabilities Act and the Architectural Barriers Act.

5.2 ELEMENTS OF DESIGN

Shared use path design criteria are based on the physical and operating characteristics of path users, which are substantially different than motor vehicles. Due to a large percentage of path users being adult bicyclists, they are the primary design user for shared use paths and are the basis for most of the design recommendations in this chapter. This chapter also provides information on critical design issues and values for other potential design users, which should be used in the event that large volumes of these other user types are anticipated.

Some paths are frequently used by children. The operating characteristics of child bicyclists are highly variable, and their specific characteristics have not yet been fully defined through research studies. However, it is generally assumed that the speed of youth bicyclists is lower than adult bicyclists. Since much of the design criteria in this guide is based on design speed, children will be accommodated to a large extent. When considering criteria unrelated to design speed, engineering judgment should be used when modifying these values for children. Throughout this chapter, several design measures are recommended which are based primarily on pedestrian research. It is presumed that these measures will also benefit bicyclists and other path users, although the research has not been conducted to support this assumption.

5.2.1 Width and Clearance

The usable width and the horizontal clearance for a shared use path are primary design considerations. Figure 5-1 depicts the typical cross section of a shared use path. The appropriate paved width for a shared use path is dependent on the context, volume, and mix of users. The minimum paved width for a two-directional shared use path is 10 ft (3.0 m). Typically, widths range from 10 to 14 ft (3.0 to 4.3 m), with the wider values applicable to areas with high use and/or a wider variety of user groups.

In very rare circumstances, a reduced width of 8 ft (2.4 m) may be used where the following conditions prevail:

- Bicycle traffic is expected to be low, even on peak days or during peak hours.
- Pedestrian use of the facility is not expected to be more than occasional.
- Horizontal and vertical alignments provide frequent, well-designed passing and resting opportunities.
- The path will not be regularly subjected to maintenance vehicle loading conditions that would cause pavement edge damage.

In addition, a path width of 8 ft (2.4 m) may be used for a short distance due to a physical constraint such as an environmental feature, bridge abutment, utility structure, fence, and such. Warning signs that indicate the pathway narrows (W5-4a), per the MUTCD (*7*) should be considered at these locations.

A wider path is needed to provide an acceptable level of service on pathways that are frequently used by both pedestrians and wheeled users. The *Shared Use Path Level of Service Calculator* is helpful in determining the appropriate width of a pathway given existing or anticipated user volumes and mixes (*9*). Wider pathways, 11 to 14 ft (3.4 to 4.2 m) are recommended in locations that are anticipated to serve a high percentage of pedestrians (30 percent or more of the total pathway volume) and high user volumes (more than 300 total users in the peak hour). Eleven foot (3.4 m) wide pathways are needed to enable a bicyclist to pass another path user going the same direction, at the same time a path user is approaching from the opposite direction (see Figure 5-2) (*8*). Wider paths are also advisable in the following situations:

- Where there is significant use by inline skaters, adult tricycles, children, or other users that need more operating width (see Chapter 3);
- Where the path is used by larger maintenance vehicles;

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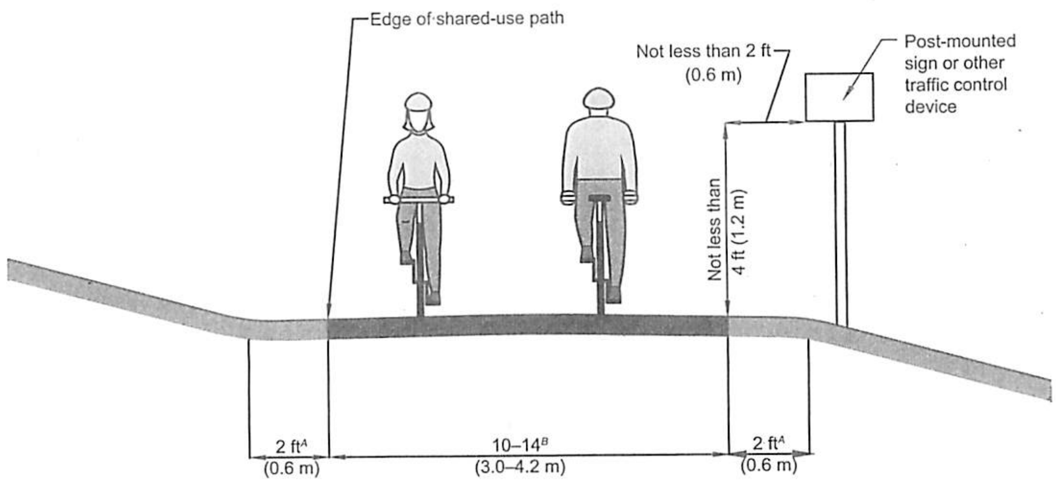
- On steep grades to provide additional passing area; or
- Through curves to provide more operating space.



Notes:
A (1V:6H) Maximum slope (typ.)
B More if necessary to meet anticipated volumes and mix of users, per the *Shared Use Path Level of Service Calculator* (9)

Figure 5-1. Typical Cross Section of Two-Way, Shared Use Path on Independent Right-of-Way

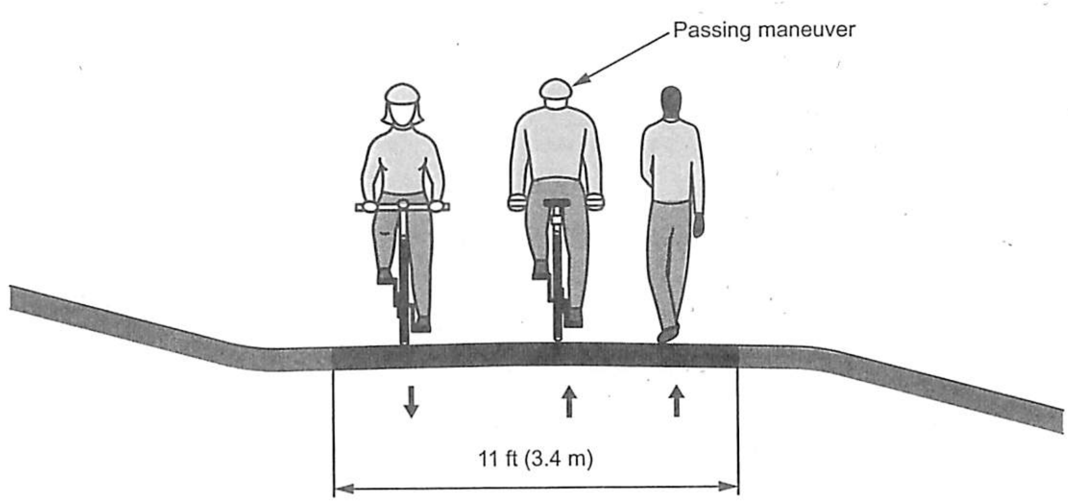


Figure 5-2. Minimum Width Needed to Facilitate Passing on a Shared Use Path

Under most conditions, there is no need to segregate pedestrians and bicyclists on a shared use path, even in areas with high user volumes—they can typically coexist. Path users customarily keep right except to pass. Signs may be used to remind bicyclists to pass on the left and to give an audible warning prior to passing other slower users. Part 9 of the MUTCD (7) provides a variety of regulatory signs that can be used for this purpose.

On pathways with heavy peak hour and/or seasonal volumes, or other operational challenges such as sight distance constraints, the use of a centerline stripe on the path can help clarify the direction of travel and organize pathway traffic. A solid yellow centerline stripe may be used to separate two directions of travel where passing is not permitted, and a broken yellow line may be used where passing is permitted. The centerline can either be continuous along the entire length of the path, or may be used only in locations where operational challenges exist. Per the MUTCD, all markings used on bikeways shall be retroreflective.

In areas with extremely heavy pathway volumes, segregation of pedestrians from wheeled users may be appropriate; however, care should be taken that the method of segregation is simple and straightforward. Pedestrians are typically provided with a bi-directional walking lane on one side of the pathway, while bicyclists are provided with directional lanes of travel. This solution should only be used when a minimum path width of 15 ft (4.6 m) is provided, with at least 10 ft (3 m) for two-way wheeled traffic, and at least 5 ft (1.5 m) for pedestrians.

Where this type of segregation is used on a path with a view (e.g., adjacent to a lake or river), the pedestrian lane should be placed on the side of the path with the view. Again, this solution should only be used for pathways with heavy volumes, as pedestrians will often walk in the "bicycle only" portion of a pathway unless it is heavily traveled by bicycles.

Another solution is to provide physically separated pathways for pedestrians and wheeled users. A number of factors should be considered when determining whether to provide separate paths, such as general site conditions (i.e., the width of separation and setting), origins and destinations of different types of path users, and the anticipated level of compliance of users choosing the appropriate path. In some instances, the dual paths may have to come in close proximity or be joined for a distance due to site constraints. As allowed by the MUTCD (7) and described in more detail in Section 5.4.2, mode-specific signs may be used to guide users to their appropriate paths.

Ideally, a graded shoulder area at least 3 to 5 ft (0.9 to 1.5 m) wide with a maximum cross-slope of 1V:6H, which should be recoverable in all weather conditions, should be maintained on each side of the pathway. At a minimum, a 2 ft (0.6 m) graded area with a maximum 1V:6H slope should be provided for clearance from lateral obstructions such as bushes, large rocks, bridge piers, abutments, and poles. The MUTCD requires a minimum 2 ft (0.6 m) clearance to post-mounted signs or other traffic control devices (7). Where "smooth" features such as bicycle railings or fences are introduced with appropriate flaring end treatments (as described below), a lesser clearance (not less than 1 ft [0.3 m]) is acceptable. If adequate clearance cannot be provided between the path and lateral obstructions, then warning signs, object markers, or enhanced conspicuity and reflectorization of the obstruction should be used.

Where a path is adjacent to parallel bodies of water or downward slopes of 1V:3H or steeper, a wider separation should be considered. A 5 ft (1.5 m) separation from the edge of the path pavement to the top of the slope is desirable. Depending on the height of the embankment and condition at the bottom, a physical barrier, such as dense shrubbery, railing, or fencing may be needed. This is an area where engineering judgment should be applied, as the risk for a bicyclist who runs off the path should be compared to the risk posed by the rail. Where a recovery area

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(i.e., distance between the edge of the path pavement and the top of the slope) is less than 5 ft (1.5 m), physical barriers or rails are recommended in the following situations (see Figure 5-3):

- Slopes 1V:3H or steeper, with a drop of 6 ft (1.8 m) or greater;
- Slopes 1V:3H or steeper, adjacent to a parallel body of water or other substantial obstacle;
- Slopes 1V:2H or steeper, with a drop of 4 ft (1.2 m) or greater; and
- Slopes 1V:1H or steeper, with a drop of 1 ft (0.3 m) or greater.

The barrier or rail should begin prior to, and extend beyond the area of need. The lateral offset of the barrier should be at least 1 ft (0.3 m) from the edge of the path. The ends of the barrier should be flared away from the path edge. Barrier or rail ends that remain within the 2 ft (0.6 m) clear area should be marked with object markers.

Railings that are used to protect users from slopes or to discourage path users from venturing onto a roadway or neighboring property can typically have relatively large openings. A typical design includes two to four horizontal elements with vertical elements spaced fairly widely, but frequently enough to provide the needed structural support and in accordance with applicable building codes. Where there is a high vertical drop or a body of water adjacent to the path where a railing is provided, engineering judgment should be used to determine whether a railing suitable for bridges (as described in Section 5.2.10) should be provided.

Other materials in addition to railings can be used to separate paths from adjacent areas, either due to substantial obstacles or to discourage pathway users from venturing onto adjacent properties. Berms and/or vegetation can serve this function.

It is not desirable to place the pathway in a narrow corridor between two fences for long distances, as this creates personal security issues, prevents users who need help from being seen, prevents path users from leaving the path in an emergency, and impedes emergency response.

The desirable vertical clearance to obstructions is 10 ft (3.0 m). Fixed objects should not be permitted to protrude within the vertical or horizontal clearance of a shared use path. The recommended minimum vertical clearance that can be used in constrained areas is 8 ft (2.4 m). In some situations, vertical clearance greater than 10 ft (3.0 m) may be needed to permit passage of maintenance and emergency vehicles.

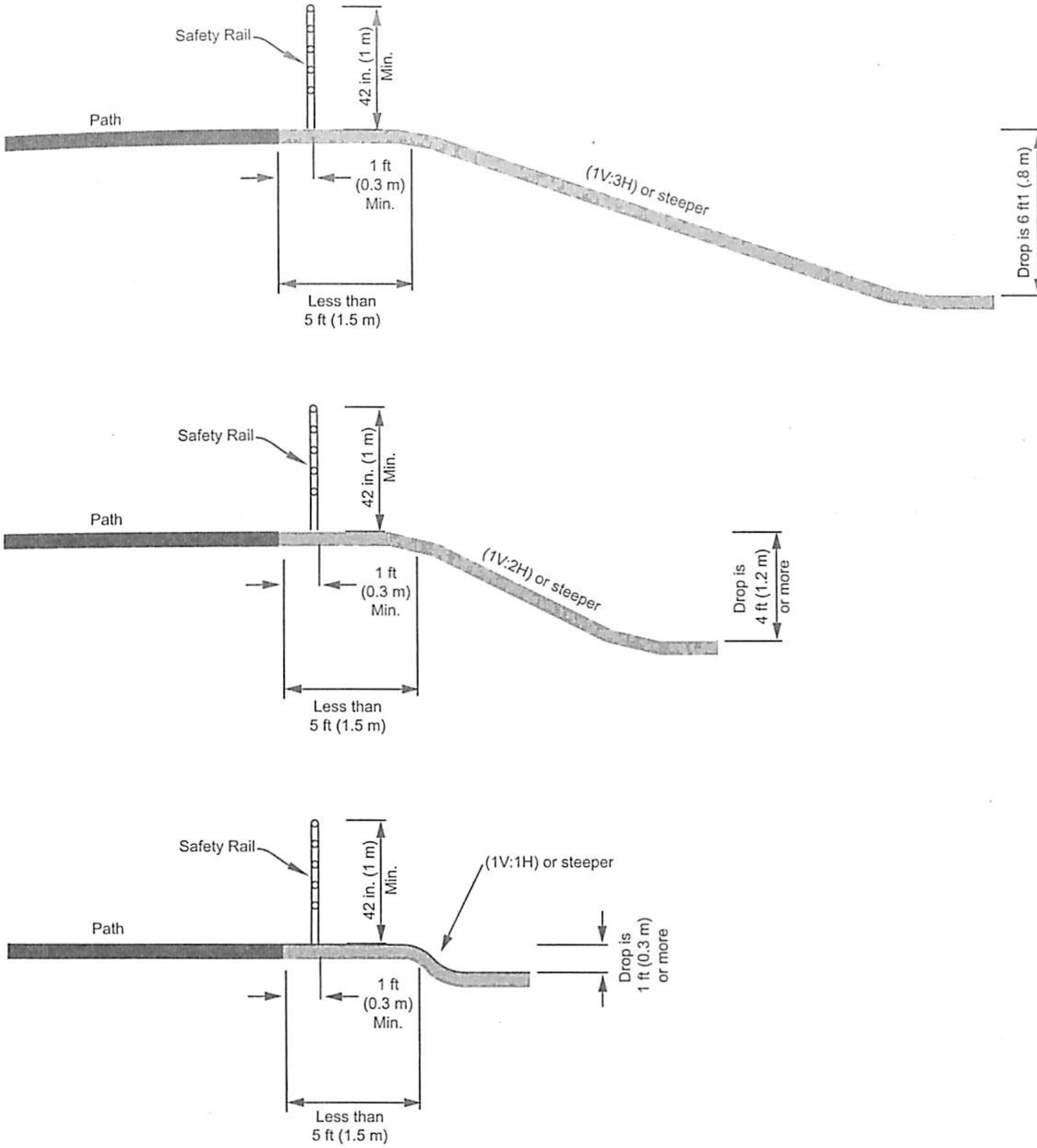


Figure 5-3. Safety Rail Between Path and Adjacent Slope

5.2.2 Shared Use Paths Adjacent to Roadways (Sidepaths)

While it is generally preferable to select path alignments in independent rights-of-way, there are situations where existing roads provide the only corridors available. Sidepaths are a specific type of shared use path that run adjacent to the roadway, where right-of-way and other physical constraints dictate. Children often prefer and/or are encouraged to ride on sidepaths because they provide an element of separation from motor vehicles. As stated in Chapter 2, provision of a pathway adjacent to the road is not a substitute for the provision of on-road accommodation such as paved shoulders or bike lanes, but may be considered in some locations in addition to on-road bicycle facilities. A sidepath should satisfy the same design criteria as shared use paths in independent rights-of-way.

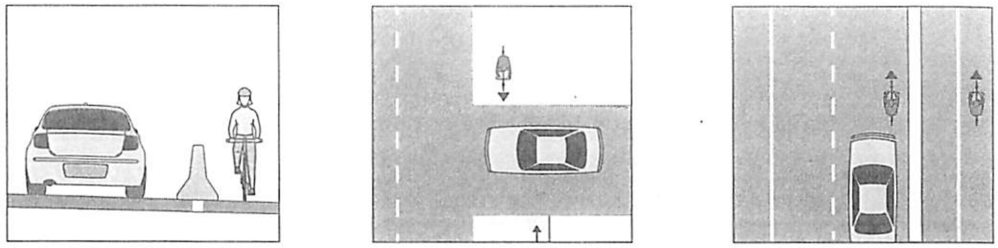
The discussion in this section refers to two-way sidepaths. Additional design considerations for sidepaths are provided in Section 5.3.4. Utilizing or providing a sidewalk as a shared use path is undesirable. Section 3.4.2 highlights the reasons sidewalks generally are not acceptable for bicycling. It is especially inappropriate to sign a sidewalk as a shared use path if doing so would prohibit bicyclists from using an alternate facility that might better serve their needs. In general, the guiding principle for designing sidewalks should be that sidewalks intended for use by bicyclists should be designed as sidepaths, and sidewalks not intended for use by bicyclists should be designed according to the AASHTO *Guide for the Planning, Design, and Operation of Pedestrian Facilities* (*2*).

Paths can function along highways for short sections, or for longer sections where there are few street and/or driveway crossings, given appropriate separation between facilities and attention to reducing crashes at junctions. However before committing to this option for longer distances on urban and suburban streets with many driveways and street crossings, practitioners should be aware that two-way sidepaths can create operational concerns. See Figure 5-4 for examples of potential conflicts associated with sidepaths. These conflicts include:

1. At intersections and driveways, motorists entering or crossing the roadway often will not notice bicyclists approaching from their right, as they do not expect wheeled traffic from this direction. Motorists turning from the roadway onto the cross street may likewise fail to notice bicyclists traveling the opposite direction from the norm.
2. Bicyclists traveling on sidepaths are apt to cross intersections and driveways at unexpected speeds (i.e., speeds that are significantly faster than pedestrian speeds). This may increase the likelihood of crashes, especially where sight distance is limited.
3. Motorists waiting to enter the roadway from a driveway or side street may block the sidepath crossing, as drivers pull forward to get an unobstructed view of traffic (this is the case at many sidewalk crossings, as well).
4. Attempts to require bicyclists to yield or stop at each cross-street or driveway are inappropriate and are typically not effective.
5. Where the sidepath ends, bicyclists traveling in the direction opposed to roadway traffic may continue on the wrong side of the roadway. Similarly, bicyclists approaching a path may travel on the wrong side of the roadway to access the path. Wrong-way travel by bicyclists is a common factor in bicycle-automobile crashes.

6. Depending upon the bicyclist's specific origin and destination, a two-way sidepath on one side of the road may need additional road crossings (and therefore increase exposure); however, the sidepath may also reduce the number of road crossings for some bicyclists.
7. Signs posted for roadway users are backwards for contra-flow riders, who cannot see the sign information. The same applies to traffic signal faces that are not oriented to contra-flow riders.
8. Because of proximity of roadway traffic to opposing path traffic, barriers or railings are sometimes needed to keep traffic on the roadway or path from inappropriately encountering the other. These barriers can represent an obstruction to bicyclists and motorists, impair visibility between road and path users, and can complicate path maintenance.
9. Sidepath width is sometimes constrained by fixed objects (such as utility poles, trash cans, mailboxes, and etc.).
10. Some bicyclists will use the roadway instead of the sidepath because of the operational issues described above. Bicyclists using the roadway may be harassed by motorists who believe bicyclists should use the sidepath. In addition, there are some states that prohibit bicyclists from using the adjacent roadway when a sidepath is present.
11. Bicyclists using a sidepath can only make a pedestrian-style left turn, which generally involves yielding to cross traffic twice instead of only once, and thus induces unnecessary delay.
12. Bicyclists on the sidepath, even those going in the same direction, are not within the normal scanning area of drivers turning right or left from the adjacent roadway into a side road or driveway.
13. Even if the number of intersection and driveway crossings is reduced, bicycle–motor vehicle crashes may still occur at the remaining crossings located along the sidepath.
14. Traffic control devices such as signs and markings have not been shown effective at changing road or path user behavior at sidepath intersections or in reducing crashes and conflicts.

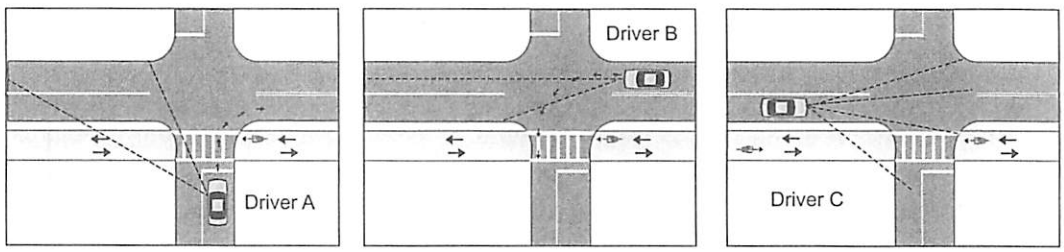
For these reasons, other types of bikeways may be better suited to accommodate bicycle traffic along some roadways.



Barriers, while needed in tight spaces, can narrow both roadway and path, and create hazards.

Stopped motor vehicles on side streets or driveways may block the path.

Some bicyclists may find the road cleaner, safer, and more convenient. Motorists may believe bicyclists should use a sidepath.



Right turning Driver A is looking for traffic on the left. A contraflow bicyclist is not in the driver's main field of vision.

Left turning Driver B is looking for traffic ahead. A contraflow bicyclist is not in the driver's main field of vision.

Right turning Driver C is looking for left turning traffic on the main road and traffic on the minor road. A bicyclist riding with traffic is not in the driver's main field of vision.

Figure 5-4. Sidepath Conflicts

Shared use paths in road medians are generally not recommended. These facilities result in multiple conflicting turning movements by motorists and bicyclists at intersections. Therefore, shared use paths in medians should be considered only where these turning conflicts can be avoided or mitigated through signalization or other techniques.

Guidelines for Sidepaths

Although paths in independent rights-of-way are preferred, sidepaths may be considered where one or more of the following conditions exist:

- The adjacent roadway has relatively high-volume and high-speed motor vehicle traffic that might discourage many bicyclists from riding on the roadway, potentially increasing sidewalk riding, and there are no practical alternatives for either improving the roadway or accommodating bicyclists on nearby parallel streets.
- The sidepath is used for a short distance to provide continuity between sections of path in independent rights-of-way, or to connect local streets that are used as bicycle routes.
- The sidepath can be built with few roadway and driveway crossings.
- The sidepath can be terminated at each end onto streets that accommodate bicyclists, onto another path, or in a location that is otherwise bicycle compatible.

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In some situations, it may be better to place one-way sidepaths on both sides of the street or highway, directing wheeled users to travel in the same direction as adjacent motor vehicle traffic. Clear directional information is needed if this type of design is used, as well as appropriate intersection design to enable bicyclists to cross to the other side of the roadway. This can reduce some of the concerns associated with two-way sidepaths at driveways and intersections; however, it should be done with the understanding that many bicyclists will ignore the directional indications if they involve additional crossings or otherwise inconvenient travel patterns.

A wide separation should be provided between a two-way sidepath and the adjacent roadway to demonstrate to both the bicyclist and the motorist that the path functions as an independent facility for bicyclists and other users. The minimum recommended distance between a path and the roadway curb (i.e., face of curb) or edge of traveled way (where there is no curb) is 5 ft (1.5 m). Where a paved shoulder is present, the separation distance begins at the outside edge of the shoulder. Thus, a paved shoulder is not included as part of the separation distance. Similarly, a bike lane is not considered part of the separation; however, an unpaved shoulder (e.g., a gravel shoulder) can be considered part of the separation. Where the separation is less than 5 ft (1.5 m), a physical barrier or railing should be provided between the path and the roadway. Such barriers or railings serve both to prevent path users from making undesirable or unintended movements from the path to the roadway and to reinforce the concept that the path is an independent facility. A barrier or railing between a shared use path and adjacent highway should not impair sight distance at intersections, and should be designed to limit the potential for injury to errant motorists and bicyclists. (The barrier or railing need not be of size and strength to redirect errant motorists toward the roadway, unless other conditions indicate the need for a crashworthy barrier.) Barriers or railings at the outside of a structure or a steep fill embankment that not only define the edge of a sidepath but also prevent bicyclists from falling over the rail to a substantially lower elevation should be a minimum of 42 in. (1.05 m) high. Barriers at other locations that serve only to separate the area for motor vehicles from the sidepath should generally have a minimum height equivalent to the height of a standard guardrail.

When a sidepath is placed along a high-speed highway, a separation greater than 5 ft (1.5 m) is desirable for path user comfort. If greater separation cannot be provided, use of a crashworthy barrier should be considered. Other treatments such as rumble strips can be considered as alternatives to physical barriers or railings, where the separation is less than 5 ft (1.5 m). However, as in the case of rumble strips, an alternative treatment should not negatively impact bicyclists who choose to ride on the roadway rather than the sidepath. Providing separation between a sidepath and the adjacent roadway does not necessarily resolve the operational concerns for sidepaths at intersections and driveways. See Section 5.3.4 for guidance on the design of sidepath intersections.

5.2.3 Shared Use with Mopeds, Motorcycles, Snowmobiles, and Horses

Although in some jurisdictions it may be permitted, it is undesirable to mix mopeds, motorcycles, or all-terrain vehicles with bicyclists and pedestrians on shared use paths. In general, these types of motorized vehicles should not be allowed on shared use paths because of conflicts with slower moving bicyclists and pedestrians. Motorized vehicles also diminish the quiet, relaxing experience most users seek on paths. Motorized wheelchairs are an exception to this rule, and should be permitted to access shared use paths. In cases where mopeds or other similar motorized users are permitted and are expected to use the pathway, providing additional width and improved sight lines may reduce conflicts. Signs that emphasize appropriate user etiquette may also be useful.

Bicycling and equestrian use have successfully been integrated on many pathways in the United States. However, care should be taken in designing these facilities to reduce potential conflicts between users. Bicyclists are often unaware of the need for slower speeds and additional clearance around horses. Horses can be startled easily and may act unpredictably if they perceive approaching bicyclists as a danger. Measures to mitigate bicyclist–equestrian conflicts include provision of separate bridle paths, maintenance of adequate sight lines so that bicyclists and equestrians are able to see each other well in advance, and signing that clarifies appropriate passing techniques and yielding responsibilities. Along paths with high- to moderate-use, the separate paved and unpaved treads should be divided by at least a 6-ft (1.8-m) wide vegetation buffer or barrier. Consideration can also be given to providing an elevation change between the treads (*15*). Where used, a separate, unpaved bridle path can often serve a dual purpose, as many joggers also prefer unpaved surfaces (see Figure 5-5).

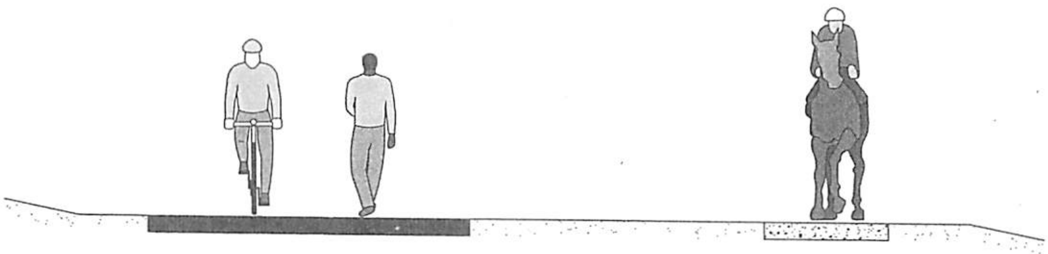

Figure 5-5. Shared Use Path with Separate Unpaved Equestrian/Jogger Path

5.2.4 Design Speed

Design speed is a selected speed used to determine various geometric features of the shared use path. Once the design speed is selected, all pertinent path features should be related to it to obtain a balanced design. In most situations, shared use paths should be designed for a speed that is at least as high as the preferred speed of the fastest common user. The speed a path user travels is dependent on several factors, including the physical condition of the user; the type and condition of the user's equipment; the purpose and length of the trip; the condition, location, and grade of the path; the prevailing wind speed and direction; and the number and types of other users on the path.

There is no single design speed that is recommended for all paths. When selecting an appropriate design speed for a specific path, planners and designers should consider several factors including the context of the path, the types of users expected, the terrain the path runs through, prevailing winds, the path surface, and other path characteristics. The following examples help to illustrate these factors:

- **Types of Users and Context.** An urban path with a variety of users and frequent conflicts and constraints may be designed for lower speeds than a rural path with few conflicts that is primarily used by recreational bicyclists (potentially including recumbent bicyclists, whose 85th percentile speed is 18 mph [29 km/h]).
- **Terrain.** A path in fairly hilly terrain should be designed for a higher speed.
- **Path Surface.** Bicyclists tend to ride slower on unpaved paths, so a lower design speed may be used.

In street and highway design, design speeds are generally selected in 5 mph or 10 km/h increments; which are based on the approximate 85th percentile speed range on various types of roadways of 20 mph (30 km/h) to 75 mph (120 km/h) or higher. On paths, the range of speeds is much smaller, ranging as low as 12 mph (19 km/h) to 30 mph (50 km/h). Therefore, design speeds for paths can be selected in 2 mph (3 km/h) increments. Design criteria for geometric features in this document are provided in 2 mph (3 km/h) increments for the slower end of the scale (design speeds between 12 mph [19 km/h] and 20 mph [32 km/h]). For design speeds above 20 mph (32 km/h), 5 mph (8 km/h) increments are used.

The following guidance and the aforementioned consideration of various factors should guide the selection of an appropriate design speed:

- For most paths in relatively flat areas (grades less than 2 percent), a design speed of 18 mph (30 km/h) is generally sufficient, except on inclines where higher speeds can occur. The design speed should not be lower, except in rare circumstances where the context and user types support a lower speed.
- In areas with hilly terrain and sustained steeper grades (6 percent or greater), the appropriate design speed should be selected based on the anticipated travel speeds of bicyclists going downhill. In all but the most extreme cases, 30 mph (48 km/h) is the maximum design speed that should be used.

Lower speeds can reduce the likelihood for crashes at approaches to crossings or conflict points by allowing the path user to better perceive the crossing situation or potential conflict. It is important to give the bicyclist adequate warning (either through signs or by maintaining adequate sight lines) prior to areas of the pathway where lower design speeds are employed. See Section 5.4.2 for guidance on warning signs.

Geometric design and traffic control devices can be used to reduce path users' speed. Speeds can be reduced by geometric features such as horizontal curvature. Effectiveness of speed control through design is limited if bicyclists can veer off a path to "straighten out" curves, and speed limit signs on paths may not be effective, as most bicyclists do not use speedometers.

5.2.5 Horizontal Alignment

The typical adult bicyclist is the design user for horizontal alignment. The minimum radius of horizontal curvature for bicyclists can be calculated using two different methods. One method uses "lean angle," and the other method uses superelevation and coefficient of friction. As detailed below, in general, the lean angle method should be used in design, although there are situations where the superelevation method is helpful.

Calculating Minimum Radius Using Lean Angle

Unlike an automobile, a bicyclist must lean while cornering to prevent falling outward due to forces associated with turning movements. Most bicyclists usually do not lean drastically; 20 degrees is considered the typical maximum lean angle for most users (*10*). Assuming an operator who sits straight in the seat, Table 5-1 shows an equation that can determine the minimum radius of curvature for any given lean angle and design speed.

Table 5-1. Minimum Radius of Curvature Based on Lean Angle

U.S. Customary		
$R = \frac{0.067V^2}{\tan\theta}$		
where:		
R	=	minimum radius of curvature (ft)
V	=	design speed (mph)
θ	=	lean angle from the vertical (degrees)

Metric		
$R = \frac{0.0079V^2}{\tan\theta}$		
where:		
R	=	minimum radius of curvature (m)
V	=	design speed (km/h)
θ	=	lean angle from the vertical (degrees)

As described in Section 5.1.1, shared use paths should meet accessibility guidelines, which restrict the steepness of cross slopes. One percent slopes are recommended on shared use paths where practical, because they are easier to navigate for people using wheelchairs. In most cases the lean angle formula should be used when determining the minimum radius of a horizontal curve, due to the need for relatively flat cross slopes and the fact that bicyclists lean when turning (regardless of their speed or the radius of their turn). The curve radius should be based upon various design speeds of 18 to 30 mph (29 to 48 km/h) and a desirable maximum lean angle of 20 degrees. Lower design speeds of 12 to 16 mph (19 to 26 km/h) may be appropriate under some circumstances (e.g., where environmental or physical constraints limit the geometrics). Minimum radii of curvature for a paved path can be selected from Table 5-2.

Table 5-2. Minimum Radii for Horizontal Curves on Paved, Shared Use Paths at 20-Degree Lean Angle

U.S. Customary		Metric	
Design Speed (mph)	Minimum Radius (ft)	Design Speed (km/h)	Minimum Radius (m)
12	27	19	8
14	36	23	11
16	47	26	15
18	60	29	18
20	74	32	22
25	115	40	35
30	166	48	50

Calculating Minimum Radius Using Superelevation

The second method of calculating minimum radius of curvature negotiable by a bicycle uses the design speed, the superelevation rate of the pathway surface, and the coefficient of friction between the bicycle tires and the surface, as shown in Table 5-3:

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Table 5-3. Minimum Radius of Curvature Based on Superelevation

U.S. Customary		
$$R=\frac{V^2}{15\left(\frac{e}{100}+f\right)}$$		
where:		
R	=	minimum radius of curvature (ft)
V	=	design speed (mph)
e	=	rate of bikeway superelevation (percent)
f	=	coefficient of friction

Metric		
$$R=\frac{V^2}{127\left(\frac{e}{100}+f\right)}$$		
where:		
R	=	minimum radius of curvature (m)
V	=	design speed (km/h)
e	=	rate of bikeway superelevation (percent)
f	=	coefficient of friction

The coefficient of friction depends upon speed, surface type 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 turning forces or perceived lack of surface traction 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 0.34 at 6 mph (10 km/h) to 0.21 at 30 mph (48 km/h). On unpaved surfaces, friction factors should be reduced by 50 percent to reduce the likelihood of crashes.

Calculating minimum radius based on superelevation may be useful on unpaved paths, where bicyclists may be hesitant to lean as much while cornering due to the perceived lack of traction. In these situations, the superelevation formula should be used with appropriate friction factors for unpaved surfaces. Calculating minimum radius based on superelevation may also be useful on paved paths intended for bicycle use only, allowing higher design speeds to be accommodated on relatively sharp curves with cross slopes (superelevation) up to 8 percent.

When a radius is smaller than that needed for an 18 mph (29 km/h) design speed, standard turn or curve warning signs (W1 series) should be installed in accordance with the MUTCD (*7*). Smaller radius curves are typically used when there are constrained site conditions, topographic challenges, or a desire to reduce path user speeds. The negative effects of sharper curves can also be partially offset by widening the pavement through the curves.

5.2.6 Cross Slope

As previously described, shared use paths must be accessible to people with disabilities. Shared use paths located adjacent to roadways essentially function as sidewalks, and therefore should follow PROWAG (*13*), which requires that cross slopes not exceed 2 percent. Until the specific regulations concerning shared use paths are completed (*14*), paths in independent rights-of-way should be designed according to *ANPRM on Shared Use Paths* (*12*), which also requires that cross slopes not exceed 2 percent. As described in the previous section, 1 percent cross slopes are recommended on shared use paths, to better accommodate people with disabilities and to provide enough slope to convey surface drainage in most situations. A cross-section that provides a center crown with no more than 1 percent in each direction may also be used.

Because this guide recommends a relatively flat cross slope of 1 percent, and because horizontal curvature can be based on a 20-degree lean angle, superelevation for horizontal curvature is not needed. Since superelevation is not needed for horizontal curvature, cross slopes can follow the direction of the existing terrain. This practice enables the designer to better accommodate surface drainage and lessen construction impacts.

If cross slopes steeper than 2 percent are needed, they should be sloped to the inside of horizontal curves regardless of drainage conditions. Steeper cross slopes (up to 5 percent) may occasionally be desirable on unpaved shared use paths to reduce the likelihood of puddles caused by surface irregularities and to allow increased superelevation to achieve smaller radii of curvature, as previously described in the subsection on horizontal alignment. In rare situations where a path is intended for bicycle use only (e.g., pedestrians are accommodated on a separate pathway) and does not need to meet accessibility guidelines, cross slopes between 5 and 8 percent can be used to allow for smaller minimum horizontal curve radii, as discussed above.

Cross slopes should be transitioned to connect to existing slopes, or to adjust to a reversal of predominant terrain slope or drainage, or to a horizontal curve in some situations. Cross slope transitions should be comfortable for the path user. A minimum transition length of 5 ft (1.5 m) for each 1 percent change in cross slope should be used.

5.2.7 Grade

The maximum grade of a shared use path adjacent to a roadway should be 5 percent, but the grade should generally match the grade of the adjacent roadway. Where a shared use path runs along a roadway with a grade that exceeds 5 percent, the sidepath grade may exceed 5 percent but must be less than or equal to the roadway grade. Grades on shared use paths in independent rights-of-way should be kept to a minimum, especially on long inclines. Grades steeper than 5 percent are undesirable because the ascents are difficult for many path users, and the descents cause some users to exceed the speeds at which they are competent or comfortable. In addition, because shared use paths are generally open to pedestrians, the allowable grades on paths are subject to the accessibility guidelines described in the *ANPRM on Shared Use Paths* (*12*). Grades on paths in independent rights-of-way should also be limited to 5 percent maximum. The ANPRM suggests that certain conditions such as physical constraints (existing terrain or infrastructure, notable natural features, etc.) or regulatory constraints (endangered species, the environment, etc.) may prevent full compliance with the 5 percent maximum grade. Refer to the U.S. Access Board website (www.access-board.gov) for up-to-date information regarding the accessibility provisions for shared-use paths covered by the Americans with Disabilities Act and the Architectural Barriers Act.

Options to mitigate excessive grades on shared use pathways include the following:

- Use higher design speeds for horizontal and vertical curvature, stopping sight distance, and other geometric features.
- When using a longer grade, consider an additional 4 to 6 ft (1.2 to 1.8 m) of width to permit slower bicyclists to dismount and walk uphill, and to provide more maneuvering space for fast downhill bicyclists.
- Install the hill warning sign for bicyclists (W7-5) and advisory speed plaque, if appropriate, per the MUTCD (*7*).

- Provide signing that alerts path users to the maximum percent of grade as shown in the MUTCD (7).
- Exceed minimum horizontal clearances, recovery area, and/or protective railings.
- If other designs are not practicable, use a series of short switchbacks to traverse the grade. If this is done, an extra 4 to 6 ft (1.2 to 1.8 m) of path width is recommended to provide maneuvering space.
- Provide resting intervals with flatter grades, to permit users to stop periodically and rest.

Grades steeper than 3 percent may not be practical for shared use paths with crushed stone or other unpaved surfaces for both bicycle handling and drainage erosion reasons. Typically, grades less than 0.5 percent should be avoided, because they are not efficient in conveying surface drainage. Where paths are built in very flat terrain, proposed path grades can be increased to provide a gradually rolling vertical profile that helps convey surface drainage to outlet locations.

5.2.8 Stopping Sight Distance

To provide path users with opportunities to see and react to unexpected conditions, shared use paths should be designed with adequate stopping sight distances. The distance needed to bring a path user to a fully controlled stop is a function of the user's perception and braking reaction times, the initial speed, the coefficient of friction between the wheels and the pavement, the braking ability of the user's equipment, and the grade. The coefficient of friction for the typical bicyclist is 0.32 for dry conditions. Figures 5-6 and 5-7 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 0.16 (Table 5-4), appropriate for wet conditions. Minimum stopping sight distance can also be calculated using the equation shown in Table 5-4.

Table 5-4. Minimum Stopping Sight Distance

U.S. Customary		
$S = \frac{V^2}{30(f \pm G)} + 3.67V$		
where:		
S	=	stopping sight distance (ft)
V	=	velocity (mph)
f	=	coefficient of friction (use 0.16 for a typical bike)
G	=	grade (ft/ft) (rise/run)

Metric		
$S = \frac{V^2}{254(f \pm G)} + \frac{V}{1.4}$		
where:		
S	=	stopping sight distance (m)
V	=	velocity (km/h)
f	=	coefficient of friction (use 0.16 for a typical bike)
G	=	grade (m/m) (rise/run)

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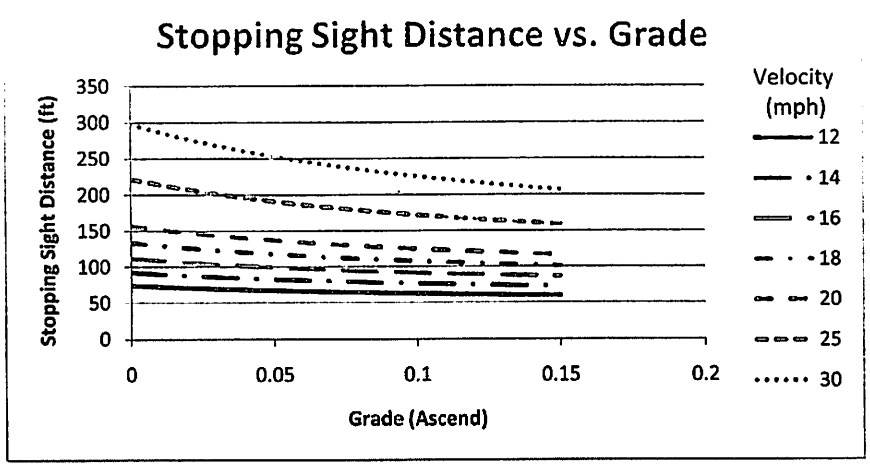


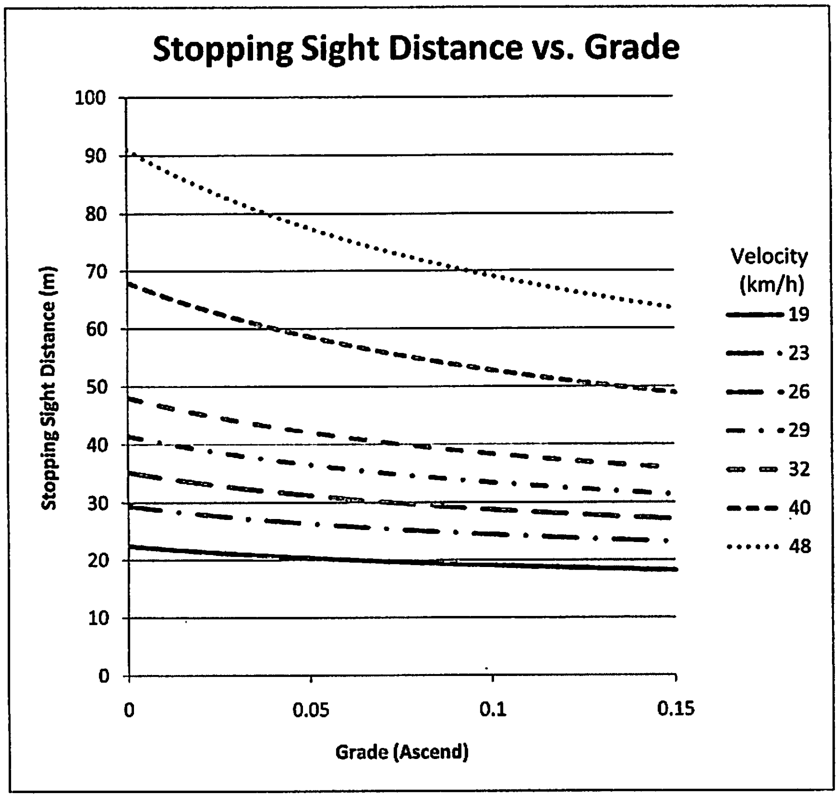
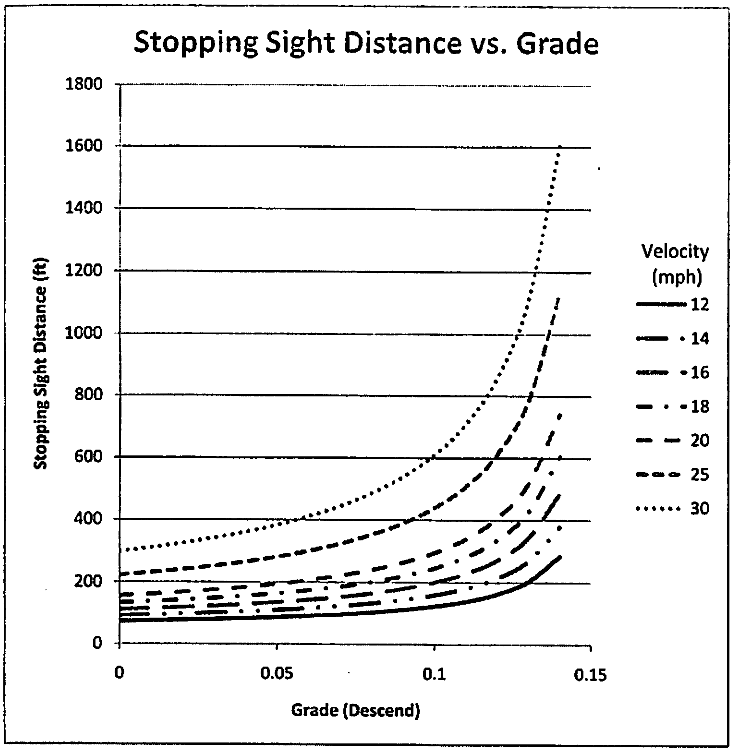


Figure 5-6. Minimum Stopping Sight Distance vs. Grades for Various Design Speeds—Ascending Climbing Grade



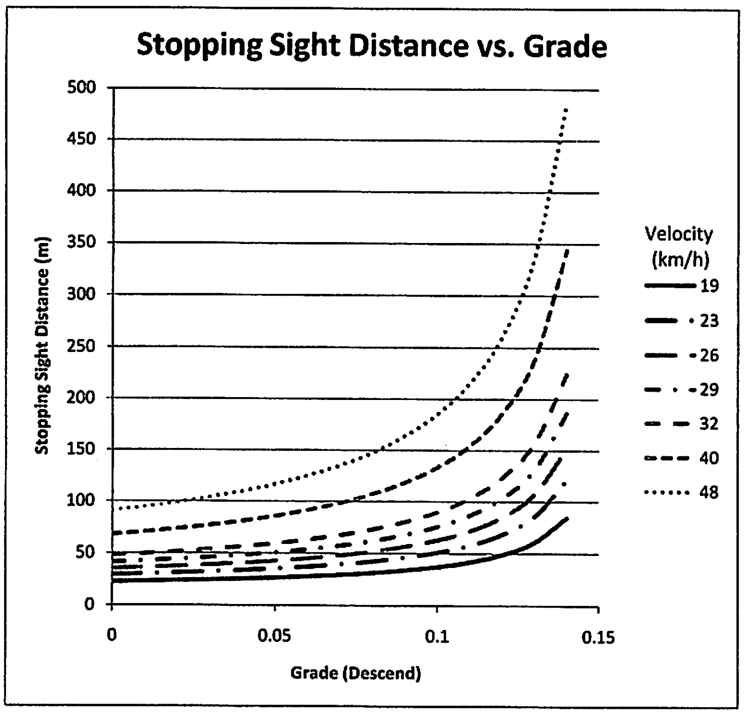


Figure 5-7. Minimum Stopping Sight Distance vs. Grades for Various Design Speeds—Descending Climbing Grade

Research indicates that, under dry conditions, the coefficient of friction of various other path users range from 0.20 for inline skaters to 0.30 for recumbent bicyclists. If users with lower coefficients of friction such as inline skaters or recumbent bicyclists are expected to make up a relatively large percentage of path users, stopping sight distances should be increased. For two-way shared use paths, the sight distance in the descending direction, that is, where "G" is defined as negative, will control the design.

Figure 5-8 is used to select the minimum length of vertical curve needed to provide minimum stopping sight distance at various speeds on crest vertical curves. The eye height of the typical adult bicyclist is assumed to be 4.5 ft (1.4 m), and the object height is assumed to be 0 in. (0 mm) to recognize that impediments to bicycle travel exist at pavement level. The minimum length of vertical curve can also be calculated using the following equation as shown in Table 5-5.

Table 5-5. Length of Crest Vertical Curve to Provide Sight Distance

U.S. Customary		
$S<L \quad L=2S-\frac{200\left(\sqrt{h_1}+\sqrt{h_2}\right)^2}{A}$ $S<L \quad L=2S-\frac{AS^2}{100\left(\sqrt{2h_1}+\sqrt{2h_2}\right)^2}$		
where:		
L	=	minimum length of vertical curve (ft)
A	=	algebraic grade difference (percent)
S	=	stopping sight distance (ft)
h_1	=	eye height (4.5 ft for a typical bicyclist)
h_2	=	object height (0 ft)

Metric		
$S<L \quad L=2S-\frac{200\left(\sqrt{h_1}+\sqrt{h_2}\right)^2}{A}$ $S<L \quad L=2S-\frac{AS^2}{100\left(\sqrt{2h_1}+\sqrt{2h_2}\right)^2}$		
where:		
L	=	minimum length of vertical curve (m)
A	=	algebraic grade difference (percent)
S	=	stopping sight distance (m)
h_1	=	eye height (1.4 m for a typical bicyclist)
h_2	=	object height (0 m)

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U.S. Customary

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	170	210	267	323	384	451	523	600
7				31	71	111	151	191	231	311	376	448	526	610	700
8			8	48	88	128	168	208	248	356	430	512	601	697	800
9			20	60	100	140	180	220	260	400	484	576	676	784	900
10			30	70	110	150	190	230	270	444	538	640	751	871	1000
11			38	78	118	158	198	238	278	489	592	704	826	958	1100
12		5	45	85	125	165	205	245	285	533	645	768	901	1045	1200
13		11	51	91	131	171	211	251	291	578	699	832	976	1132	1300
14		16	56	96	136	176	216	256	296	622	753	896	1052	1220	1400
15		20	60	100	140	180	220	260	300	667	807	960	1127	1307	1500
16		24	64	104	144	184	224	264	304	711	860	1024	1202	1394	1600
17		27	67	107	147	187	227	267	307	756	914	1088	1277	1481	1700
18		30	70	110	150	190	230	270	310	800	968	1152	1352	1568	1800
19		33	73	113	153	193	233	273	313	844	1022	1216	1427	1655	1900
20		35	75	115	155	195	235	275	315	889	1076	1280	1502	1742	2000
21		37	77	117	157	197	237	277	317	933	1129	1344	1577	1829	2100
22		39	79	119	159	199	239	279	319	978	1183	1408	1652	1916	2200
23		41	81	121	161	201	241	281	321	1022	1237	1472	1728	2004	2300
24	3	43	83	123	163	203	243	283	323	1067	1291	1536	1803	2091	2400
25	4	44	84	124	164	204	244	284	324	1111	1344	1600	1878	2178	2500

Shaded area represents S = L
Minimum length of vertical curve = 3 ft

Figure 5-8. Minimum Length of Crest Vertical Curve Based on Stopping Sight Distance

Metric

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						0	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	332	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

Shaded area represents S = L
Minimum length of vertical curve = 1 m

Figure 5-8. Minimum Length of Crest Vertical Curve Based on Stopping Sight Distance (continued)

Other path users such as child bicyclists, hand bicyclists, recumbent bicyclists, and others have lower eye heights than a typical adult bicyclist. Eye heights are approximately 2.6 ft (0.85 m) for hand bicyclists and 3.9 ft (1.2 m) for recumbent bicyclists. When compared to the eye heights of typical bicyclists, these lower eye heights limit sight distance over crest vertical curves. However, since most hand bicyclists and child bicyclists travel slower than typical adult bicyclists, their needs are met by using the values in Figure 5-8. Recumbent bicyclists generally travel faster than typical upright bicyclists, so if they are expected to make up a relatively large percentage of path users, crest vertical curve lengths should be increased accordingly (operating characteristics of recumbent bicyclists are found in Chapter 3).

Figures 5-9, 5-10, and Table 5-6 indicate the minimum clearance that should be used for line-of-sight obstructions for horizontal curves. The lateral clearance (horizontal sight line offset or HSO) is obtained by using the table in Figure 5-9 with the stopping sight distance (Figure 5-6) and the proposed horizontal radius of curvature.

Path users typically travel side-by-side on shared use paths. On narrow paths, bicyclists have a tendency to ride near the middle of the path. For these reasons, and because of the higher likelihood for crashes on curves, lateral clearances on horizontal curves should be calculated based on the sum of the stopping sight distances for path users traveling in opposite directions around the curve. Where this is not practical, consideration should be given to widening the path through the curve, installing a yellow center line stripe, installing turn or curve warning signs (W1 series) in accordance with the MUTCD (7), or a combination of these alternatives. See Sections 5.4.1 and 5.4.2 for more information about center line pavement markings and signs.

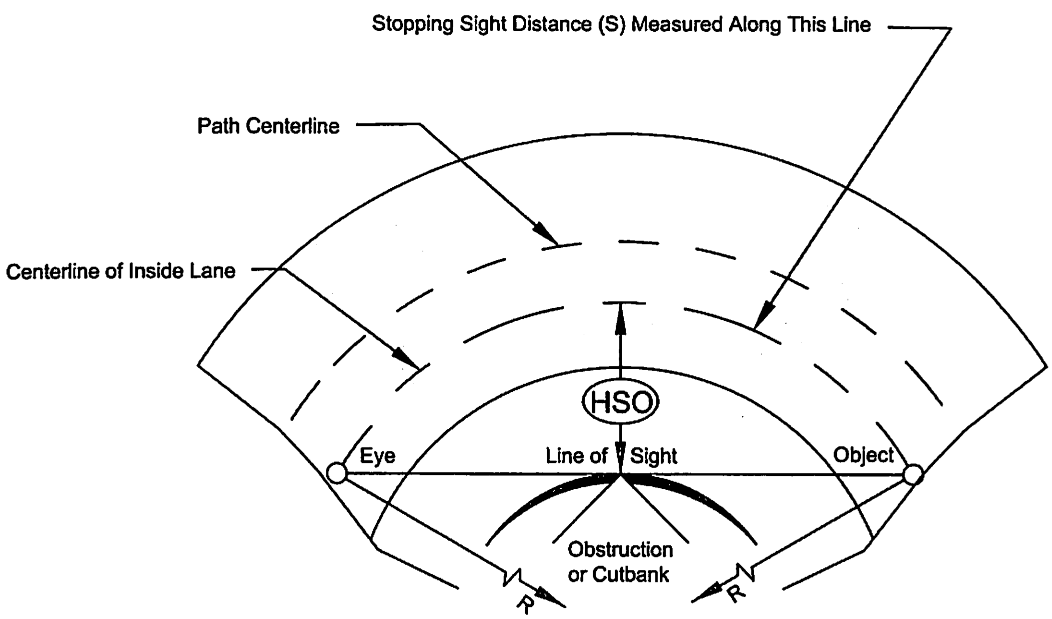

Figure 5-9. Diagram Illustrating Components for Determining Horizontal Sight Distance

Table 5-6. Horizontal Sight Distance

U.S. Customary		
$HSO = R\left[1-\cos\left(\frac{28.65S}{R}\right)\right]$ $HSO = \frac{R}{28.65}\left[1-\cos^{-1}\left(\frac{R-HSO}{R}\right)\right]$		
where:		
S	=	stopping sight distance (ft)
R	=	radius of centerline of lane (ft)
HSO	=	horizontal sightline offset, distance from centerline of lane to obstruction (ft)
Note: Angle is expressed in degrees; line of sight is 2.3 ft above centerline of inside lane at point of obstruction.		

Metric		
$HSO = R\left[1-\cos\left(\frac{28.65S}{R}\right)\right]$ $HSO = \frac{R}{28.65}\left[1-\cos^{-1}\left(\frac{R-HSO}{R}\right)\right]$		
where:		
S	=	stopping sight distance (m)
R	=	radius of centerline of lane (m)
HSO	=	horizontal sightline offset, distance from centerline of lane to obstruction (m)
Note: Angle is expressed in degrees; line of sight is 0.7 m above centerline of inside lane at point of obstruction.		

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U.S. Customary

S = Stopping Sight Distance (ft)															
R (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

Metric

S = Stopping Sight Distance (m)																			
R (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	11.0	14.0											
20	0.6	1.4	2.4	3.8	5.4	7.2	9.2	11.0	14.0	16.0	19.0								
25	0.5	1.1	2.0	3.1	4.4	5.9	7.6	9.5	11.0	14.0	16.0	18.0	21.0	23.0					
50	0.3	0.6	1.0	1.6	2.2	3.0	3.9	5.0	6.1	7.4	8.7	10.0	12.0	13.0	15.0	17.0	19.0	21.0	23.0
75	0.2	0.4	0.7	1.0	1.5	2.0	2.7	3.4	4.1	5.0	5.9	6.9	8.0	9.2	10.0	12.0	13.0	15.0	16.0
100	0.1	0.3	0.5	0.8	1.1	1.5	2.0	2.5	3.1	3.8	4.5	5.2	6.1	7.0	7.9	8.9	10.0	11.0	12.0
125	0.1	0.2	0.4	0.6	0.9	1.2	1.6	2.0	2.5	3.0	3.6	4.2	4.9	5.6	6.3	7.2	8.0	8.9	9.9
150		0.2	0.3	0.5	0.7	1.0	1.3	1.7	2.1	2.5	3.0	3.5	4.1	4.7	5.3	6.0	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	3.0	3.5	4.0	4.6	5.1	5.8	6.4	7.1
200		0.1	0.3	0.4	0.6	0.8	1.0	1.3	1.6	1.9	2.2	2.6	3.1	3.5	4.0	4.5	5.0	5.6	6.2
225		0.1	0.2	0.3	0.5	0.7	0.9	1.1	1.4	1.7	2.0	2.3	2.7	3.1	3.5	4.0	4.5	5.0	5.5
250		0.1	0.2	0.3	0.5	0.6	0.8	1.0	1.2	1.5	1.8	2.1	2.4	2.8	3.2	3.6	4.0	4.5	5.0
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	1.0	1.3	1.5	1.8	2.0	2.3	2.7	3.0	3.4	3.8	4.2

Figure 5-10. Minimum Lateral Clearance (Horizontal Sightline Offset or HSO) for Horizontal Curves

5.2.9 Surface Structure

Hard, all-weather pavement surfaces are generally preferred over those of crushed aggregate, sand, clay, or stabilized earth. Since unpaved surfaces provide a lower level of service, it may cause bicyclists to more easily lose traction (particularly bicycles with narrower, higher-pressure tires), and may need more maintenance. On unpaved surfaces, bicyclists and other wheeled users must use a greater effort to travel at a given speed when compared to a paved surface. Some users, such as inline skaters, are unable to use unpaved paths. In areas that experience frequent or even occasional flooding or drainage problems, or in areas of moderate or steep terrain, unpaved surfaces will often erode and are not recommended. Additionally, unpaved paths are difficult to plow for use during the winter.

Unpaved surfaces may be appropriate on rural paths, where the intended use of the path is primarily recreational, or as a temporary measure to open a path before funding is available for paving. Unpaved pathways should be constructed of materials that are firm and stable. Possible surfaces for unpaved paths include crushed stone, stabilized earth, and limestone screenings, depending upon local availability.

Asphalt or Portland cement concrete provides good quality, all-weather pavement structures. Advantages of Portland cement concrete include longer service life, reduced susceptibility to cracking and deformation from roots and weeds, and a more consistent riding surface after years of use and exposure to the elements. On Portland cement concrete pavements, transverse joints can be cut with a saw to provide a smooth ride. A disadvantage of Portland cement concrete pavements is that pavement markings (such as centerlines) can have a lower contrast against the concrete surface; markings typically have a higher contrast on an asphalt surface, particularly at night.

Advantages of asphalt include a smooth rolled surface when new, and lower construction costs than with concrete. Asphalt surfaces are softer and are therefore preferred by runners and walkers over concrete. However, asphalt pavement is less durable (typical life expectancy is 15–20 years) and needs more interim maintenance.

Because of wide variations in soils, loads, materials, and construction practices, and varying costs of pavement materials, it is not practical to recommend typical structural sections that will be applicable nationwide. However, the total pavement depth should typically be a minimum of 6 in. (150 mm), inclusive of the surface course (asphalt or Portland cement concrete) and the base course (typically an aggregate rock base). Any pavement section should be placed over a compacted subgrade.

Designing and selecting pavement sections for shared use paths is similar to designing and selecting highway pavement sections. A soils investigation should be conducted to determine the load-carrying capabilities of the native soil, or former railroad bed (if ballast has been removed), and the need for any special treatments. A soils investigation should also be conducted to determine whether subsurface drainage may be applicable. In colder climates, the effects of freeze-thaw cycles should be anticipated. Geotextiles and other similar materials should be considered where subsurface conditions warrant, such as in locations with swelling clay subgrade. Experience in roadway pavement design, 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, porous pavement, and recycled asphalt.

While loads on shared use paths will be substantially less than roadways, paths should be designed to sustain wheel loads of occasional emergency, patrol, maintenance, and other motor vehicles that are expected to use or cross the path. When motor vehicles are driven on shared use paths, their wheels often will be at, or very near, the edges of the path. This can cause edge damage that, in turn, will reduce the effective operating width of the path. The path should, therefore, be constructed of sufficient width to accommodate the vehicles, and adequate edge support should be provided. Edge support can be provided by means of stabilized shoulders, flush or raised concrete curbing, or additional pavement width or thickness. The use of flush concrete curbing has other long-term maintenance benefits, such as reducing the potential for encroachment of vegetation onto the path surface. If raised curbs are used, one foot of additional path width should be provided, as users will shy away from the curb, resulting in a narrower effective path width.

It is important to construct and maintain a smooth riding surface on shared use paths. Pavements should be machine laid; soil sterilizers should be used where needed to prevent vegetation from erupting through the pavement. On Portland cement concrete pavements, the transverse joints needed to control cracking should be saw cut, rather than tooled, to provide a smoother 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.

Utility covers (i.e., manholes) and bicycle-compatible drainage grates should be flush with the surface of the pavement on all sides. Preferably, manhole covers and drainage grates would be located to the side of the paths so when work needs to be performed, the path would not need to be closed. Railroad crossings should be smooth and be designed at an angle between 60 and 90 degrees to the direction of travel in order to minimize the possibility of falls. Refer to Chapter 4 for design treatments that can be used to improve railroad crossings.

Where a shared use path crosses an unpaved road or driveway, the road or driveway should be paved a minimum of 20 ft (6 m) on each side of the crossing to reduce the amount of gravel scattered onto or along the path by motor vehicles. The pavement structure at the crossing should be adequate to sustain the expected loading at that location.

5.2.10 Bridges and Underpasses

A bridge or underpass may be needed to provide continuity to a shared use path. The "receiving" clear width on the end of a bridge (from inside of rail or barrier to inside of opposite rail or barrier) should allow 2 ft (0.6 m) of clearance on each side of the pathway, as recommended in Section 5.2.1, but under constrained conditions may taper to the pathway width.

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 or bicyclists who have stopped on the bridge (e.g., to admire the view).

Access by emergency, patrol, and maintenance vehicles should be considered in establishing design clearances of structures on shared use paths. Similarly, vertical clearance may be dictated by occasional authorized motor vehicles using the path. A minimum vertical clearance of 10 ft (3.0 m) is desirable for adequate vertical shy distance.

At transitions and approaches from paths to bridge decks, the height of the path's surface should match the height of the bridge deck surface so as to provide a smooth transition between pathway and bridge deck. Bridge deck lips, formed by differences between pathway and bridge deck heights, should be avoided because they can cause tire blowouts, bent wheels, crashes, and injuries. These lips can be eliminated by placing a transitional layer of asphalt between the path surface and the bridge deck.

Where grade separation is desired between a path and a roadway or railroad, designers sometimes have the choice between constructing a bridge over the roadway or railroad, and constructing a tunnel or underpass under the roadway or railroad. The adjacent topography typically is the greatest factor in determining which option is best; however, bridges are preferred to underpasses because they have security advantages and are less likely to have drainage problems.

When a bridge or underpass is built over a public right-of-way (such as a road), a connection is often needed between the path and roadway; as this represents a potential access point for pedestrians and bicyclists. This often involves significant ramping or other means to provide an accessible connection between the two.

Protective railings, fences, or barriers on either side of a shared use path on a stand-alone structure should be a minimum of 42 in. (1.05 m) high. There are some locations where a 48-in. (1.2 m) high railing should be considered in order to prevent bicyclists from falling over the railing during a crash. This includes bridges or bridge approaches where high-speed, steep-angle (25 degrees or greater) impacts between a bicyclist and the railing may occur, such as at a curve at the foot of a long, descending grade where the curve radius is less than that appropriate for the design speed or anticipated speed.

Openings between horizontal or vertical members on railings should be small enough that a 6 in. (150 mm) sphere cannot pass through them in the lower 27 in. (0.7 m). For the portion of railing that is higher than 27 in. (0.7 m), openings may be spaced such that an 8 in. (200 mm) sphere cannot pass through them. This is done to prevent children from falling through the openings. Where a bicyclist's handlebar may come into contact with a railing or barrier, a smooth, wide rub-rail may be installed at a height of about 36 in. (0.9 m) to 44 in. (1.1 m), to reduce the likelihood that a bicyclist's handlebar will be caught by the railing (see Figure 5-11).

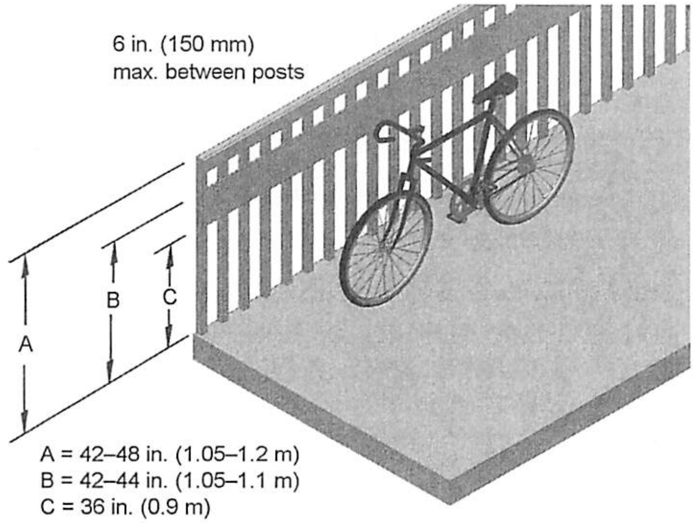

Figure 5-11. Bridge Railing

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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 that bicycle-compatible expansion joints are used, and that decking materials are not slippery when wet. There are often opportunities to retrofit path structures to existing highway or railroad bridges. Using an existing bridge can result in significant cost savings and provide path continuity over large rivers and other obstacles. These retrofits can be accomplished in several ways, including cantilevering the path onto an existing bridge, or by placing the path within the substructure of the existing bridge, as shown in Figure 5-12.

Figure 5-12. Example of Bridge Structures (Photo courtesy of Jennifer Toole of Toole Design Group.)

In many situations, there is a desire to retrofit a path under a bridge along a river or waterway to provide a grade-separated crossing of a major road or railroad. Special treatments may be needed in these circumstances. These paths are often located within a floodplain, so path pavement and subgrade treatments may need to be enhanced. In extreme cases, paths can be built below the normal water level, such that the water would need to be retained and a pumping system would need to be provided for the path. The structural design of bridges for shared use paths (e.g., railings) should be designed in accordance with the AASHTO *LRFD Bridge Design Specifications* (*1*) and the *Guide Specifications for Design of Pedestrian Bridges* (*3*). The technical provisions in this manual either meet or exceed those recommended in the current versions of these respective specifications.

5.2.11 Drainage

The minimum recommended pavement cross slope of 1 percent usually provides adequate drainage. Sloping in one direction instead of crowning is preferred and usually simplifies drainage and surface construction. An even 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.

Depending on site conditions, typically paths with cross slope in the direction of the existing terrain will provide sheet flow of surface runoff and avoid the need for channelizing flow in ditches, cross culverts, and closed pipe systems. However, where a shared use path is constructed on the side of a slope that has considerable runoff, or other conditions that result in relatively high runoff, a ditch of suitable dimensions should be placed on the uphill side to intercept the slope's drainage. Such ditches should be designed so that the potential for injury to errant bicyclists is limited. Where needed, catch basins with drains should be provided to carry the intercepted water under the path. Bicycle-compatible drainage grates and manhole covers should be located to the side of the pathway.

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Paths that are located in low-lying areas may need attention to other drainage issues in the vicinity that have not been previously addressed so that the path drains properly, and that retention areas located away from the pathway are provided.

To prevent erosion in the area adjacent to the shared use path, consideration should be given to preserving a hardy, natural ground cover. In addition, pathway design should meet applicable storm water management regulations. In an effort to improve water quality and manage the quantity of runoff, low-impact development techniques such as bio-retention swales should be considered. Other erosion and sediment control measures should be employed as needed, including seeding, mulching, and sodding of adjacent slopes, swales, and other erodible areas.

5.2.12 Lighting

Fixed-source lighting can improve visibility along paths and at intersections at night or under other dark conditions. Lighting can also greatly improve riders' ability to detect surface disconformities under such conditions, even when their bicycles are properly equipped with headlamps. Provision of lighting should be considered where nighttime usage is not prohibited, and especially on paths that provide convenient connections to transit stops and stations, schools, universities, shopping, and employment areas.

Where nighttime use is permitted, pathway lighting is recommended at path–roadway intersections. If nighttime use is prohibited, lighting at crosswalks should still be considered if the pathway connects to existing sidewalks, because the crossing is in the public right-of-way and may be used at night even if the pathway is not. Lighting should also be considered in locations where personal security is an issue.

Pedestrian-scale lighting is preferred to tall, highway-style lamps. Pedestrian-scale lighting is characterized by shorter light poles (standards about 15 ft [4.6 m] high), lower levels of illumination (except at crossings), closer spacing of standards (to avoid dark zones between luminaires), and high pressure sodium vapor or metal halide lamps. Metal halide lamps produce better color rendition ("white light") than sodium vapor lamps and can facilitate user recognition in areas with high volumes of night use. Depending on the location, average maintained horizontal illumination levels of 0.5 to 2-foot candles (5 to 22 lux) should be considered. For personal safety, higher lighting levels may be needed in some locations.

Placement of light poles should provide the recommended horizontal and vertical clearances from the pathway. Light fixtures should be chosen to reduce the loss of light and may need to comply with local "dark sky" guidelines and regulations. The use of solar-powered lighting can be considered; however, care should be taken that the installation provides adequate light. Solar-powered lighting is often inadequate in locations with significant tree canopy, or in northern regions where it sometimes fails to provide enough illumination during winter months.

If a pathway is used infrequently at night, lighting can be provided at certain hours only, based on an engineering study of pathway usage; for example, up to 11:00 p.m. and starting at 6:00 a.m. These conditions should be made known to path users with a sign at path entrances. Where lighting is not provided, or only provided during certain hours, reflective edge lines should be provided as described in Section 5.4.1.

Lighting should be provided in pathway tunnels and underpasses. At night, lighting in tunnels is important to provide security. Daytime lighting of tunnels and underpasses is often needed, and should be designed in a manner similar to the design of lighting in roadway tunnels. This includes brighter lighting during the day than at night, due to the fact that users' eyes cannot make fast adjustments to changing light conditions. On long tunnels it is appropriate to use varying light intensities through the tunnel, with higher levels of illumination near the entrances and lower levels in the middle. Refer to the *Roadway Lighting Design Guide* (*5*) for more information about designing appropriate lighting in tunnels and underpasses.

5.3 SHARED USE PATH–ROADWAY INTERSECTION DESIGN

The design of intersections between shared use paths and roadways has a significant impact on users' comfort and mobility. Intersection design should not only address cross-traffic movements, but should also address turning movements of riders entering and exiting the path. Due to potential conflicts at these junctions, careful design should be used for predictable and orderly operation between shared use path traffic and other traffic.

Regardless of whether a pathway crosses a roadway at an existing intersection between two roadways, or at a new "mid-block" location, the principles that apply to design for pedestrians at crossings (controlled and uncontrolled) are also applicable to pathway–intersection design. There are a wide range of design features that have the likelihood to reduce pedestrian and bicyclist crashes at such intersections. This guide provides a general overview of crossing measures; other sources, such as AASHTO's *Guide for the Planning, Design, and Operation of Pedestrian Facilities* (*2*), should be consulted for more detail.

Shared use path crossings come in many configurations with many variables: the number of roadway lanes to be crossed; divided or undivided roadways, number of approach legs; the speeds and volumes of traffic; and traffic controls that range from uncontrolled to yield-, stop-, or signal-controlled. Each intersection is unique and needs engineering judgment to determine an appropriate intersection treatment.

Due to the mixed nature of shared use path traffic, the practitioner should keep in mind the speed variability of each travel mode and its resulting effect on design values when considering design treatments for path–roadway intersections. The fastest vehicle should be considered for approach speeds (typically the bicyclist and motor vehicle) as these modes are the most likely to surprise cross traffic at the intersection. By contrast, for departures from a stopped condition, the characteristics of slower path users (typically pedestrians) should be taken into account due to their greater exposure to cross traffic. Intersections between pathways and roadways should be designed to be accessible to all users, as stated in Section 5.1.1.

5.3.1 Shared Use Path Crossing Types

Shared use path crossings can be broadly categorized as mid-block, sidepath, or grade-separated crossings. A crossing is considered mid-block if it is located outside of the functional area of any adjacent intersection. In some respects, a mid-block shared use path crossing can be considered as a four-leg intersection. A sidepath crossing occurs within the functional area of an intersection of two or more roadways (see Figure 5-13). Sidepath crossings are typically parallel to at least one roadway. Sidepath intersections have unique operational challenges that are similar to those of parallel frontage roadways. Section 5.2.2 covers these operational issues in detail.

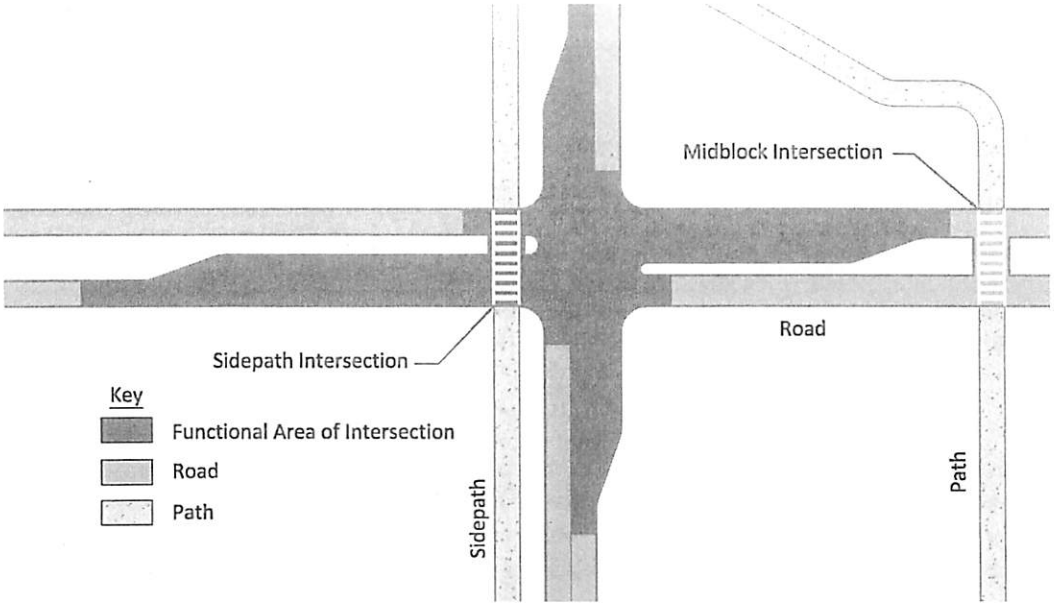

Figure 5-13. Mid-Block and Sidepath Crossings Relative to Intersection Functional Area

In some locations, roadway or path traffic conditions may warrant consideration of a grade-separated crossing consisting of either a bridge over the roadway or an underpass beneath the roadway. An analysis should be made to assess the demand for and viability of a grade-separated crossing. See Section 5.2.10 and the discussion of grade-separated crossings in the AASHTO *Guide for the Planning, Design, and Operation of Pedestrian Facilities* (*2*).

5.3.2 Design of Mid-Block Crossings

The task of designing a mid-block crossing between a pathway and a roadway involves a number of variables, including anticipated mix and volume of path users, the speed and volume of motor vehicle traffic on the roadway being crossed, the configuration of the road, the amount of sight distance that can be achieved at the crossing location, and other factors. Geometric design features and traffic controls should be used in combination to effectively accommodate all users.

Geometric Design Issues at Crossings

The design approach for the intersection of a shared use path with a roadway is similar to the design approach used for the intersection of two roadways in the following ways:

- The intersection should be conspicuous to both road users and path users.
- Sight lines should be maintained to meet the needs of the traffic control provided.
- Intersections and approaches should be on relatively flat grades.
- Intersections should be as close to a right angle as practical, given the existing conditions.

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- The least traffic control that is effective should be selected.
- Intersections should be sufficiently spaced to be outside the functional area of adjacent intersections (see Figure 5-13).

It is preferable for mid-block path crossings to intersect the roadway at an angle as close to perpendicular as practical, so as to minimize the exposure of crossing path users and maximize sight lines. A crossing skewed at 30 degrees is twice as long as a perpendicular crossing, doubling the exposure of path users to approaching motor vehicles, and increasing delays for motorists who must wait for path users to cross. Retrofitting skewed path crossings can reduce the roadway exposure for path users. Figure 5-14 depicts a path realignment to achieve a 90-degree crossing. A minimum 60-degree crossing angle may be acceptable to minimize right-of-way needs (*12*).

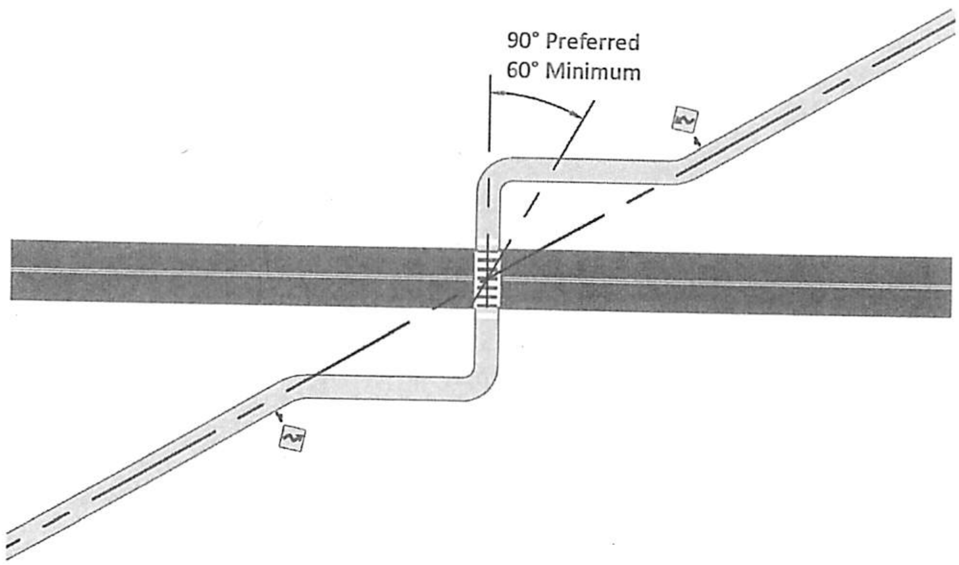

Figure 5-14. Crossing Angle

Special Issues with Assignment of Right of Way

Shared use paths are unique in terms of the assignment of the right of way, due to the legal responsibility of drivers to yield to (or stop for) pedestrians in crosswalks. Most state codes also stipulate that a pedestrian may not suddenly leave any curb (or refuge area) and walk or run into the path of a vehicle that is so close that it is impossible for the driver to yield. The result is a mutual yielding responsibility among motor vehicle drivers and pedestrians, depending upon the timing of their arrival at an intersection. Some states extend the rights and responsibilities of pedestrians at crosswalks to bicyclists as well, while other states do not. When designing intersections of shared use paths, designers should understand the laws within their state regarding assignment of right of way for pedestrians and bicyclists (and other path users).

When assigning right of way, the speed differential between bicyclists and pedestrians on the pathway should also be taken into account. Bicyclists approach the intersection at a far greater speed than pedestrians, and they desire to maintain their speed as much as practical. The result may be the need to remind bicyclists of their responsibility to yield or stop, while not confusing the issue of who has the legal right of way at mid-block crossings.

Given these complexities, the most prudent approach when determining the appropriate design and control measures at mid-block pathway intersections is to first determine what measures might likely reduce pedestrian crashes or improve access (as described below), as it may be determined through this process that a pedestrian signal or beacon is needed. If a signal or a beacon is not needed, the next step is to determine clear sight triangles on the major and minor approaches, so as to evaluate applicability of yield control on the minor approach. Engineering judgment should be applied.

Determining Appropriate Crossing Measures

Pedestrians amount to a substantial share of users on most paths and experience the greatest amount of exposure at intersections. Uncontrolled pathway crossings should be designed to accommodate pedestrians, while also taking into consideration measures tailored to the operational characteristics of bicyclists and other path users.

High-visibility marked crosswalks are recommended at uncontrolled path–roadway intersections. On roadways with low traffic volumes and speeds where sight distances are adequate, the marked crosswalk should be sufficient to accommodate pedestrians effectively. It is recommended that a minimum of 20 pedestrian crossings (or 15 or more elderly and/or child pedestrians) per peak hour exist at a location before placing a high priority on installing a marked crosswalk alone. Additional crossing measures (such as reducing traffic speeds, shortening crossing distance, enhancing driver awareness of the crossing, and/or providing active warning of crosswalk user presence) are recommended at uncontrolled locations where the speed limit exceeds 40 mph (64 km/h) and either:

- The roadway has four or more lanes of travel without a raised crossing island and an ADT of 12,000 vehicles per day or greater; or
- The roadway has four or more lanes of travel with a raised crossing island (either existing or planned) and an ADT of 15,000 vehicles per day or greater (*17*).

Use of marked crosswalks should be consistent with guidance provided in the MUTCD (*7*).

Determining Priority Assignment

In conventional roadway intersection design, right of way is assigned to the higher volume and/or higher speed approach. In the case of a path–roadway intersection, user volumes on the path should be considered. While in many cases roadways will have greater volumes, user volumes on popular paths sometimes exceed traffic volumes on minor crossed streets. In such situations, total user delay may be minimized if roadway traffic yields to path traffic, and given bicyclists' reluctance to lose momentum, such an operating pattern often develops spontaneously. In such situations, "YIELD" or "STOP" control is more appropriately applied on the roadway approaches (given an analysis of speeds, sight distances, and so forth as described below).

Changes in user volumes over time should also be considered. New shared use paths are often built in segments, resulting in low initial volumes. In that case, assignment of priority to roadway traffic is usually appropriate. However, path volumes may increase over time, raising the need to re-examine priority assignment. Traffic flows at path–roadway intersections should be reviewed occasionally to confirm that the priority assignment remains appropriate.

Use of Stop Signs

Application of intersection controls ("YIELD" signs, "STOP" signs, or traffic signals) should follow the principle of providing the least amount of restriction that is effective. Installing unwarranted or unrealistically restrictive controls on path approaches in an attempt to "protect" path users can result in path users disregarding the signs and other traffic control devices at the intersection. This can lead to a loss of respect for traffic control at more critical locations.

A common misconception is that the routine installation of stop control for the pathway is an effective treatment for preventing crashes at path–roadway intersections. Poor bicyclist compliance with "STOP" signs at path–roadway intersections is well documented. Bicyclists tend to operate as though there are "YIELD" signs at these locations: they slow down as they approach the intersection, look for oncoming traffic, and proceed with the crossing if it is safe to do so. "YIELD" control (either for vehicular traffic on the roadway or for users on the pathway) can therefore be an effective solution at some mid-block crossings, as it encourages caution without being overly restrictive.

Evaluating Sight Distance to Select Type of Control

Intersection sight distance (sight triangles) is a fundamental component in selecting the appropriate control at a mid-block path–roadway intersection. As described above, the least restrictive control that is effective should be used. As noted in the horizontal sight distance equation (Table 5-6), the line of sight is considered to be 2.3 ft (0.7 m) above the roadway or path surface. Roadway approach sight distance and departure sight triangles should be calculated in accordance with procedures detailed in AASHTO's *A Policy on Geometric Design of Highways and Streets* (*4*), as motor vehicles will control the design criteria.

Generally, pathway approach sight distance should be calculated utilizing the fastest typical path user, which in most cases is the adult two-wheeled bicyclist. Under certain conditions it may be desirable to use a different design user (and therefore a different approach speed) if they are more prevalent and represent a faster value. Ideally, approach sight triangles provide an unobstructed view of the entire intersection and a sufficient amount of the intersecting facility to anticipate and avoid a potential collision with crossing traffic, regardless of the traffic control. Approaches to uncontrolled and yield-controlled intersections should provide the recommended approach sight triangle, or else a more restrictive control should be considered.

Approach sight triangles depend on the design speeds of both the path and the roadway. If yield control is to be used for either the roadway approach or the path approach, it is desirable that available sight distance be adequate for a traveler on the yield-controlled approach to slow, stop, and to avoid a traveler on the other approach. The roadway leg of the sight triangle is based on bicyclists' ability to reach and cross the roadway if they do not see a potentially conflicting vehicle approaching on the roadway, and have just passed the point where they can execute a stop without entering the intersection (see Figure 5-15 and Table 5-7). See Table 5-4 and Figures 5-6 and 5-7 for bicyclist stopping sight distance. Similar to the roadway approach, the path leg of the sight triangle is based on motorists' ability to reach and cross the junction if they do not see a potentially conflicting path user approaching, and have passed the point where they can execute a stop without entering the intersection. The length along the path leg of each approach is given in Table 5-8. If this yield sight triangle is not available, a more restrictive control may be appropriate.

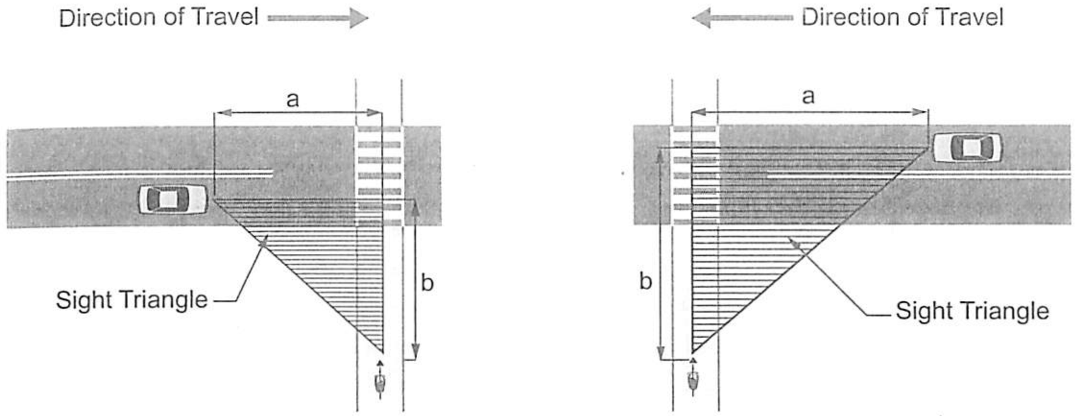

Figure 5-15. Yield Sight Triangles

Table 5-7. Length of Roadway Leg of Sight Triangle

U.S. Customary		
$t_a = \frac{S}{1.47V_{path}}$ $t_g = t_a + \frac{w + L_a}{1.47V_{path}}$ $a = 1.47V_{road}t_g$		
where:		
t_g	=	travel time to reach and clear the road (s)
a	=	length of leg sight triangle along the roadway approach (ft)
t_a	=	travel time to reach the road from the decision point for a path user that doesn't stop (s)
w	=	width of the intersection to be crossed (ft)
L_a	=	typical bicycle length = 6 ft (see Chapter 3 for other design users)
V_{path}	=	design speed of the path (mph)
V_{road}	=	design speed of the road (mph)
S	=	stopping sight distance for the path user traveling at design speed (ft)

Metric		
$t_a = \frac{S}{0.278V_{path}}$ $t_g = t_a + \frac{w + L_a}{0.278V_{path}}$ $a = 0.278V_{road}t_g$		
where:		
t_g	=	travel time to reach and clear the road (s)
a	=	length of leg sight triangle along the roadway approach (m)
t_a	=	travel time to reach the road from the decision point for a path user that doesn't stop (s)
w	=	width of the intersection to be crossed (m)
L_a	=	typical bicycle length = 1.8 m (see Chapter 3 for other design users)
V_{path}	=	design speed of the path (km/h)
V_{road}	=	design speed of the road (km/h)
S	=	stopping sight distance for the path user traveling at design speed (m)

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Table 5-8. Length of Path Leg of Sight Triangle

U.S. Customary		
$t_a = \frac{1.47V_e - 1.47V_b}{a_i}$ $t_g = t_a + \frac{w + L_a}{0.88V_{road}}$ $b = 1.47V_{path}t_g$		
where:		
t_g	=	travel time to reach and clear the path (s)
b	=	length of leg sight triangle along the path approach (ft)
t_a	=	travel time to reach the path from the decision point for a motorist that doesn't stop (s). For road approach grades that exceed 3 percent, value should be adjusted in accordance with AASHTO's *A Policy on Geometric Design of Highways and Streets* (5)
V_e	=	speed at which the motorist would enter the intersection after decelerating (mph) (assumed 0.60 × road design speed)
V_b	=	speed at which braking by the motorist begins (mph) (same as road design speed)
a_i	=	motorist deceleration rate (ft/s²) in intersection approach when braking to a stop not initiated (assume -5.0 ft/s²)
w	=	width of the intersection to be crossed (ft)
L_a	=	length of the design vehicle (ft)
V_{path}	=	design speed of the path (mph)
V_{road}	=	design speed of the road (mph)

Metric		
$t_a = \frac{0.278V_e - 0.278V_b}{a_i}$ $t_g = t_a + \frac{w + L_a}{0.167V_{road}}$ $b = 0.278V_{path}t_g$		
where:		
t_g	=	travel time to reach and clear the path (s)
b	=	length of leg sight triangle along the path approach (m)
t_a	=	travel time to reach the path from the decision point for a motorist that doesn't stop (s). For road approach grades that exceed 3 percent, value should be adjusted in accordance with AASHTO's *A Policy on Geometric Design of Highways and Streets* (5)
V_e	=	speed at which the motorist would enter the intersection after decelerating (km/h) (assumed 0.60 × road design speed)
V_b	=	speed at which braking by the motorist begins (km/h) (same as road design speed)
a_i	=	motorist deceleration rate (m/s²)in intersection approach when braking to a stop not initiated (assume -1.5 m/s²)
w	=	width of the intersection to be crossed (m)
L_a	=	length of the design vehicle (m)
V_{path}	=	design speed of the path km/h)
V_{road}	=	design speed of the road km/h)

Note: This table accounts for reduced motor vehicle speeds per standard practice in AASHTO's *A Policy on Geometric Design of Highways and Streets* (5).

Determining sufficient stop- and signal-controlled approach sight distance is simpler than yield-controlled. Regardless of which approach has stop-control or whether the intersection is signal-controlled, the roadway and path approaches to an intersection should always provide enough stopping sight distance to obey the control, and execute a stop before entering the intersection.

Departure sight distance for the path should be based on the slowest user who will have the most exposure to crossing traffic. This is typically the pedestrian. However, because path crossings function as legal crosswalks for pedestrians (and in some states for bicyclists), a key sight distance consideration is stopping sight distance for the roadway approach to provide adequate distance for the motor vehicle to stop if the path user is either already in the crosswalk, or is just beginning to enter it. Ideally, departure sight distance provides stopped pathway users with enough sight distance of the intersecting roadway to judge adequate gaps in oncoming traffic to cross the road. This type of departure sight distance is desirable for yield- and stop-controlled path approaches. Under certain conditions it may be desirable to use a different design user (and therefore different departure speed) if they are more prevalent and represent a slower value. Regardless of intersection sight triangle lengths, roadway and path approaches to an intersection should provide sufficient stopping sight distance so that motorists and bicyclists can avoid obstacles or potential conflicts within the intersection.

At an intersection of a shared use path with a walkway, a clear sight triangle extending at least 15 ft (4.6 m) along the walkway should be provided (see Figure 5-16). The clear sight line will enable pedestrians approaching the pathway to see and react to oncoming path traffic to avoid potential conflicts at the path-walkway intersection. If a shared use path intersects another shared use path, sight triangles should be provided similar to a yield condition at a path–roadway intersection. However, both legs of the sight triangle should be based on the stopping sight distance of the paths. Use the equation in Table 5-7 for both legs of the sight triangle.

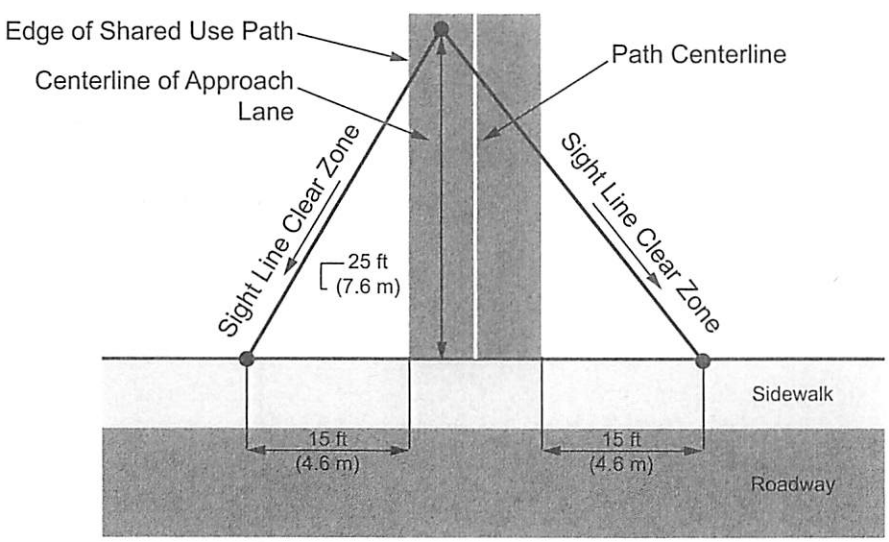

Figure 5-16. Minimum Path-Walkway Sight Triangle

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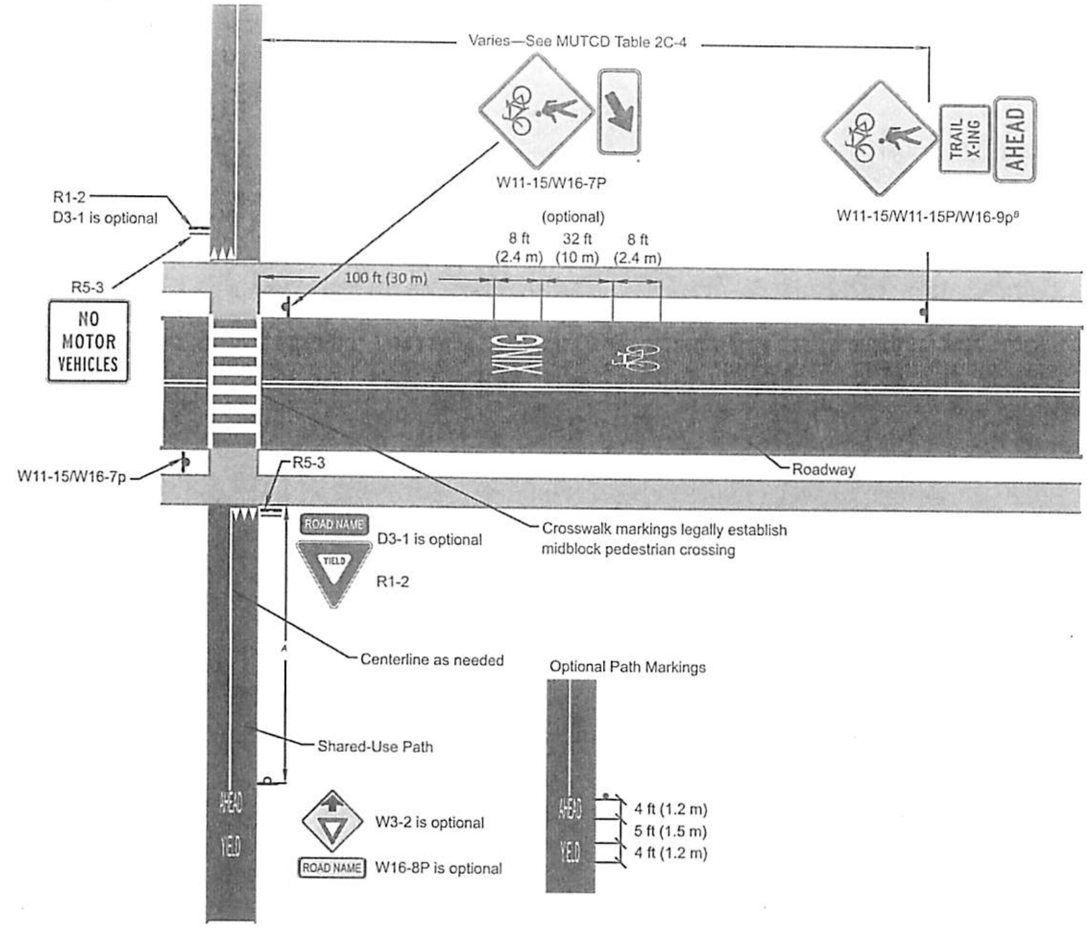
Mid-Block Signalized Intersections

If traffic and roadway characteristics make crossing difficult for the path user, the need for a signal or active warning device (such as a beacon) should be considered based on traffic volumes, speed, number of lanes, and availability of a refuge. Guidance on the need for a signal and other traffic control devices is provided in the MUTCD (*7*) and in other sources such as FHWA's *Safety Effects of Marked Versus Unmarked Crosswalks at Uncontrolled Locations: Final Report and Recommended Guidelines* (*18*). Path user volumes may be used to determine the need for a signal and/or other active warning devices. In some situations when considering path user volume, it may be appropriate to assess whether the path users have access to another appropriate crossing location. More information on signals at path–roadway intersections is provided in Section 5.4.3.

5.3.3 Examples of Mid-Block Intersection Controls

Figures 5-17, 5-18, 5-19, and 5-20 illustrate various examples of mid-block control treatments. They show typical pavement marking and sign crossing treatments. These diagrams are illustrative and are not intended to show all signs and markings that may be necessary or advisable, or all types of design treatments that are possible at these locations. Each graphic assumes the appropriate minimum sight distances that are provided for the roadway and the path.



Notes:

[A] Advance warning signs and solid centerline striping should be placed at the required stopping sight distance from the roadway edge, but not less than 50 ft (15 m).

[B] W11 series sign is required, supplemental plaques are optional.

Figure 5-17. Example of Mid-Block Path–Roadway Intersection—Path Is Yield Controlled for Bicyclists

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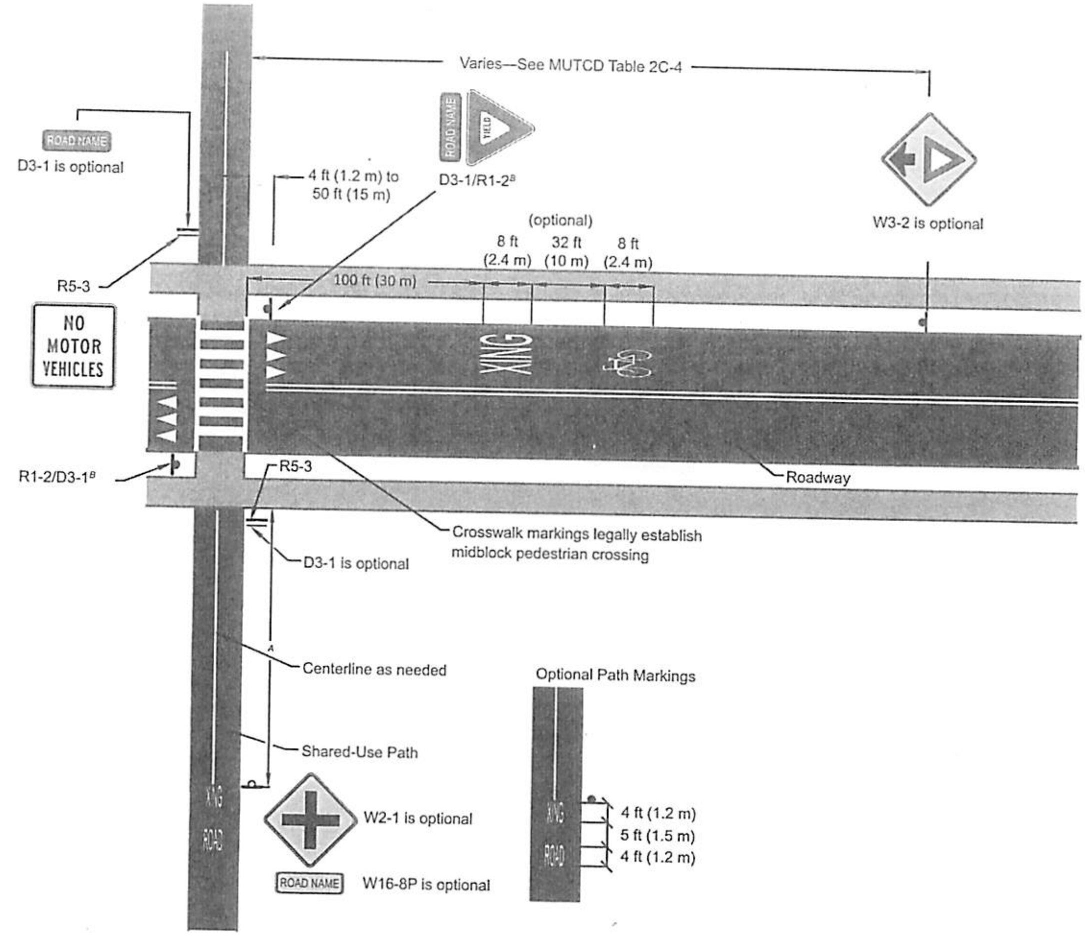

Notes:

[A] Advance warning signs and solid centerline striping should be placed at the required stopping sight distance from the roadway edge, but not less than 50 ft (15 m).

[B] D3-1 sign is optional, R1-2 sign is required. At multilane road crossings, the R1-5 series (Yield Here To/Stop Here for Pedestrians signs and markings, placed in advance of the crosswalk to reduce muliple-threat crashes) may be a more appropriate solution.

Figure 5-18. Example Mid-Block Path–Roadway Intersection—Roadway Is Yield Controlled

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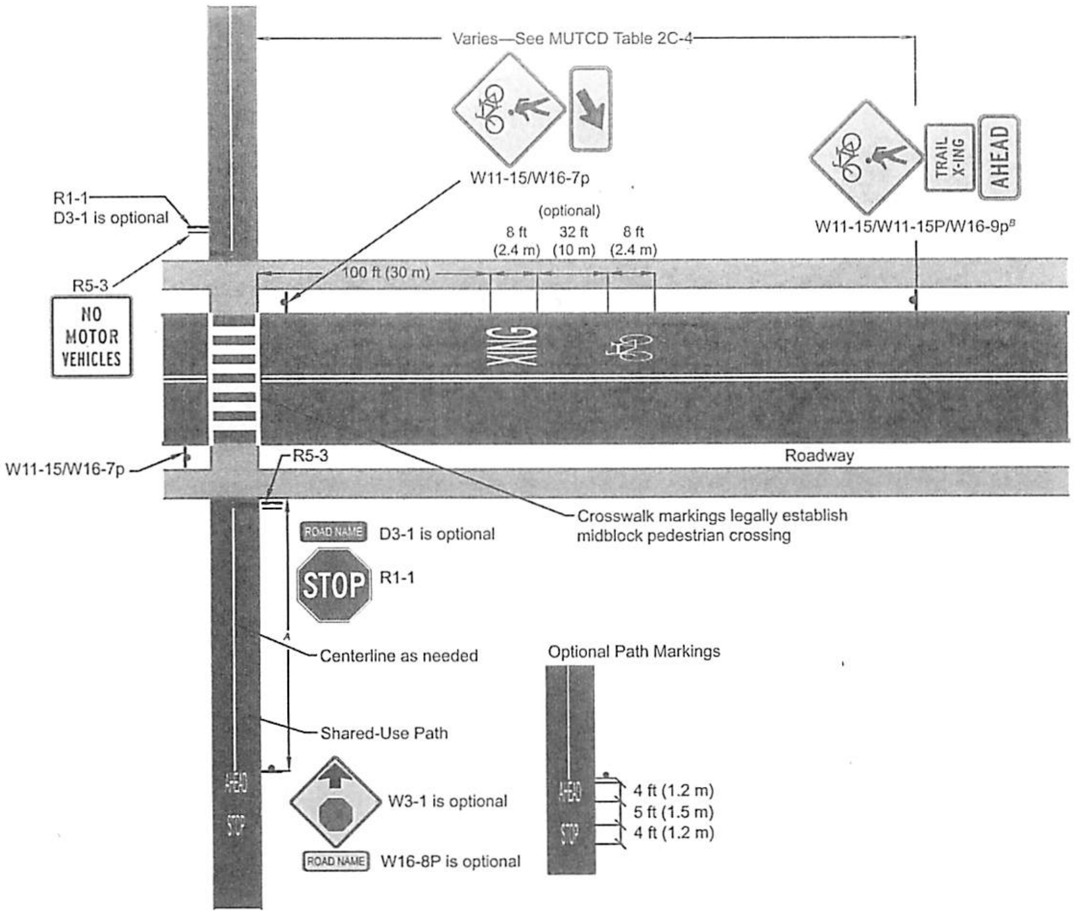
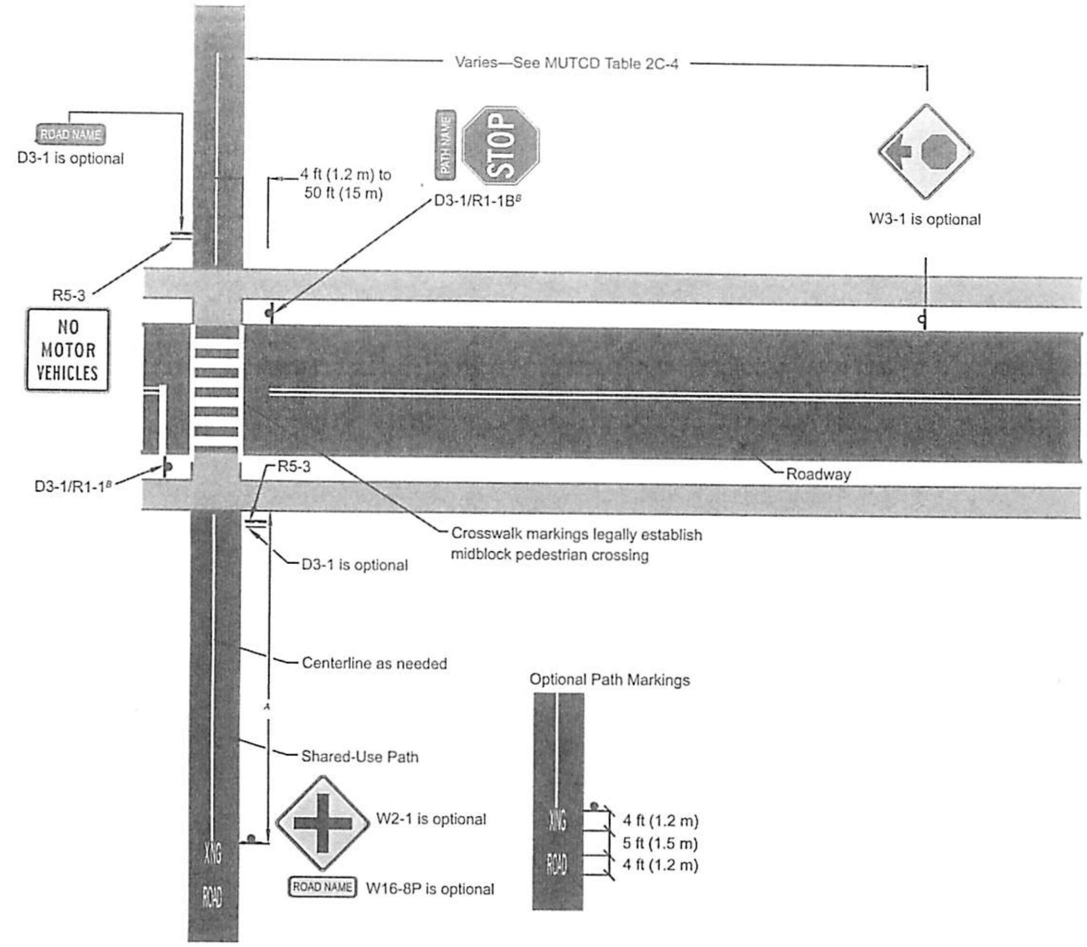


Notes:

[A] Advance warning signs and solid centerline striping should be placed at the required stopping sight distance from the roadway edge, but not less than 50 ft (15 m).

[B] W11 series sign is required, supplemental plaques are optional.

Figure 5-19. Example of Mid-Block Path–Roadway Intersection—Path is Stop Controlled for Bicyclists



Notes:

[A] Advance warning signs and solid centerline striping should be placed at the required stopping sight distance from the roadway edge, but not less than 50 ft (15 m).

[B] D3-1 sign is optional, R1-2 sign is required. At multilane road crossings, the R1-5 series (Yield Here To/Stop Here for Pedestrians signs and markings, placed in advance of the crosswalk to reduce muliple-threat crashes) may be a more appropriate solution.

Figure 5-20. Example Mid-Block Path–Roadway Intersection—Roadway is Stop Controlled

5.3.4 Sidepath Intersection Design Considerations

This section presents several design measures that may be considered when designing sidepath intersections. Depending upon motor vehicle and pathway user speeds, the width and character of the adjacent roadway, the amount of separation between the pathway and the roadway, and the characteristics of conflict points, sidepath travel may involve lesser or greater likelihood of motor vehicle collisions for bicyclists than roadway travel. This section concludes with additional details on the operational challenges of sidepath intersections, building upon the challenges described in Section 5.2.2.

The first and most important step in the design of any sidepath is to objectively assess whether the location is a candidate for a two-way sidepath. Guidance on this issue is given in Section 5.2.2. At-grade intersections of roadways and driveways with sidepaths, especially those with two-way sidepaths, have inherent conflicts that may result in bicycle–motor vehicle crashes. When approaching an intersection, drivers focus their attention in certain specific directions, depending on the planned maneuver through the intersection. If planning to turn left from the parallel roadway, drivers focus their attention ahead to watch for a gap in oncoming traffic and to the left to watch for potentially conflicting traffic on the side road. When turning right from the parallel roadway, drivers focus their attention ahead and to the right, as this is the direction from which they expect conflicting traffic. When turning onto the parallel roadway (or crossing the parallel roadway) from a side road or a driveway, drivers almost exclusively focus on traffic approaching from the left, in order to look for a gap and to avoid conflicting traffic. Figure 5-4 illustrates the typical scanning behavior of drivers when turning or approaching an intersection or driveway near a sidepath.

Sidepaths, especially two-way sidepaths, insert path users into intersections at locations that do not match with the ingrained scanning behaviors of motorists, which can in effect create virtual "blind spots," even in locations with no actual restrictions on sight distance or visibility. For example, a driver turning left from the parallel roadway across the sidepath might do a very conscientious job of looking for potentially conflicting traffic from the parallel road and crossroad, but completely miss a path user approaching from behind and to the driver's left, a location from which a driver is not conditioned or trained to expect conflicting traffic. It is nearly impossible for a driver turning left from the parallel roadway across the sidepath to accurately monitor the presence, location, or speed of sidepath traffic approaching from behind and to the left without compromising the ability to look for potential conflicts from other directions. Similar mismatches between scanning behavior of roadway traffic and arrival locations of sidepath traffic can be found with right turns from the parallel roadway and movements from the crossing roadway. On multilane streets with higher speed limits, the situation can be more challenging, due to narrowing field of vision, shorter reaction times, and the screening effect of other traffic in adjacent lanes.

Sidepath users typically take their right of way cues from either the pedestrian signalization or the signals controlling the parallel roadway. Path users typically enter the intersection when the parallel roadway has a green indication. Some path users, mainly pedestrians, observe the pedestrian signal and enter under the walk phase, but bicyclists often continue to enter and cross the intersection well into the "DONT WALK" phase. Conflicts between roadway traffic and sidepath users can be complicated by the perception among some path users that turning and crossing drivers will yield to sidepath traffic when the path user has the right of way (e.g., when given a green signal or "WALK" signal) and the potentially conflicting vehicle is visible to the path user; however, due to scanning patterns, the vehicle driver may not look in the direction of the path user. Conventional signalization may not be effective in mitigating these conflicts.

Assuming that the location has been determined to be a candidate for a two-way sidepath, pathway width and separation from roadway at intersections and driveways should be determined with respect to roadway speeds and number of lanes. Motorists on multilane roadways with higher speeds are more distracted by driving conditions, and are less likely to notice the presence of bicyclists on the sidepath during turning movements. On roads with speed limits of 50 mph (80 km/h) or greater, increasing the separation from roadway is recommended to improve path user comfort and potentially reduce crashes. At lower speeds, greater separation does not reduce crashes; therefore the sidepath should be located in close proximity to the parallel roadway at intersections, so motorists turning off the roadway can better detect sidepath riders (*11*).

Three countermeasures that may reduce crash frequency and severity at driveways and intersections are: (1) reduce the speeds of both path users and motorists at conflict points; (2) increase the predictability of sidepath and road user behavior; and (3) limit the amount of exposure at these conflict points as much as practical.

While the design measures described here are not necessarily supported by research that shows their implementation will reduce crashes, they are rational measures that may improve the quality of bicycle facilities. These design measures include the following:

- Reduce the density of driveways and the incidence of less predictable driveway movements through access management. For example, combine driveways of adjacent properties, reduce driveway width to the minimum needed to accommodate ingress and egress volumes, and prevent left turns into driveways by allowing only right-in, right-out movements. However, if the access management instead serves to concentrate the traffic at a single driveway or intersection, then the conflicts may be displaced from the old location to the new location.

- Design intersections to reduce driver speeds and heighten awareness of path users. Strategies include tighter corner radii, avoidance of high-speed, free-flowing movements (such as ramp-style turns), providing median refuge islands, maintaining adequate sight distances between intersecting users, and other measures to reduce motor vehicle speeds at intersections. The use of additional standard signs and markings, or the use of enhanced or unconventional signs and markings, may not have a notable effect on driver or path user behavior.

- Design driveways to reduce driver speeds and heighten awareness of path users. Strategies can include tighter corner radii; maintaining adequate sight distances; and keeping the path surface continuous across the driveway entrance, so that it is clear that motorists are crossing an area where the path user has the right of way, among other measures. The use of additional standard signs and markings, or the use of enhanced or unconventional signs and markings, may not have a notable effect on driver or path user behavior.

- Consider design measures on approaches to intersections and driveways that encourage lower speeds for pathway approaches. There are a variety of measures that jurisdictions have used to encourage lower speeds; however, it is important that these measures not limit visibility or create conflicts for pathway users, or cause the pathway to become inaccessible. This is another reason why in many cases it is important to accommodate bicycles on the roadway as well as the sidepath, so that bicyclists who prefer to travel at faster speeds may do so on the roadway.

- Employ measures on the parallel roadway (appropriate to the roadway function) to reduce speeds. These may include, among others, installation of raised medians, reduction of the number of travel lanes, and provision of on-street parking (configured so as to avoid restriction of sight lines at driveways).

- Design intersection crossings to facilitate bicycle access to and from the road or driveway that is being crossed, as this location represents an entry and exit point to the pathway.

- Keep approaches to intersections and major driveways clear of obstructions due to parked vehicles, shrubs, and signs on public or private property. Consider adding stop bars or yield markings for vehicles pulling up to the sidepath intersection.

At signalized intersections, the pathway should be integrated into the controls of the intersection following the same principles as a pedestrian crossing. Care should be taken to avoid turning movements that will conflict with the "green" signal for the pathway. Some design measures may include:

- Institute fully-protected left- and right-turn movements from the parallel street across the sidepath. This may help to mitigate some crash types; however, this may have significant effects on intersection operation and capacity, especially when implementing protected-only right-turns.

- Prohibit right turns on red from the crossing roadway. This may help to mitigate conflicts, but may need targeted enforcement to maintain effectiveness if drivers do not perceive a need for this restriction.

- Provide a leading pedestrian interval, and provide an exclusive pedestrian phase where there are high volumes of path users.

Pedestrian countdown signal heads and accessible push buttons should be provided along with high visibility crosswalks, crossing islands at wide intersections, and sufficient space for queuing bicyclists, if high volumes of pathway users are expected.

As described above, in locations where the sidepath parallels a high-speed roadway and crosses a minor road, it is advisable to move the crossing away from the intersection to a mid-block location. By moving the crossing away from the intersection, motorists are able to exit the high speed roadway first, and then turn their attention to the pathway crossing.

5.3.5 Other Intersection Treatments

Curb Ramps and Aprons

The opening of a shared use path at the roadway should be at least the same width as the shared use path itself. If a curb ramp is provided, the ramp should be the full width of the path, not including any side flares if utilized. The approach should provide a smooth and accessible transition between the path and the roadway. The ramp should be designed in accordance with the proposed PROWAG (*13*). Detectable warnings should be placed across the full width of the ramp. A 5-ft (1.5-m) radius or flare may be considered to facilitate turns for bicyclists. Unpaved shared use paths should be provided with paved aprons extending a minimum of 20 ft (6 m) from paved road surfaces.

Path Widening at Intersections

For locations where queuing at an intersection results in crowding at the roadway edge, consideration can be given to widening the path approach. This can increase the crossing capacity and help reduce conflicts at path entrances.

Shared Use Path Chicanes

Chicanes (i.e., horizontal curvature) can be designed to reduce path users' approach speeds at intersections where users must stop or yield, or where sight distance is limited. Care should be taken to end chicanes far enough in advance of the intersection to allow the user to focus on the curves in the pathway first, then the approaching intersection (rather than both at the same time). A solid centerline stripe is recommended at chicanes to reduce the instances of bicyclists "cutting the corners" of the curves. Chicanes should not be designed for speeds less than 8 mph (13 km/h).

Restricting Motor Vehicle Traffic

Unauthorized use of pathways by motor vehicles occurs occasionally. In general, this is a greater issue on pathways that extend through independent rights-of-way that are not visible from adjacent roads and properties. Per the MUTCD (*7*), the R5-3, "No Motor Vehicles" sign can be used to reinforce the rules.

The routine use of bollards and other similar barriers to restrict motor vehicle traffic is not recommended. Bollards should not be used unless there is a documented history of unauthorized intrusion by motor vehicles. Barriers such as bollards, fences, or other similar devices create permanent obstacles to path users. Bollards on pathways may be struck by bicyclists and other path users and can cause serious injury. Approaching riders may shield even a conspicuous bollard from a following rider's view until a point where the rider lacks sufficient time to react.

Furthermore, physical barriers are often ineffective at the job they were intended for—keeping out motorized traffic. People who are determined to use the path illegally will often find a way around the physical barrier, damaging path structures and adjacent vegetation. Barrier features can also slow access for emergency responders. A three-step approach may be used to prevent unauthorized motor vehicle entry to shared use paths:

1. Post signs identifying the entry as a shared use path and regulatory signs prohibiting motor vehicle entry. For example, the R5-3, "No Motor Vehicles" sign may be placed near where roads and shared use paths cross and at other path entry locations.
2. Design the path entry location so that it does not look like a vehicle access and make intentional access by unauthorized users difficult. A preferred method of restricting entry of motor vehicles is to split the entry way into two sections separated by low landscaping. Each section should be half the nominal path width; for example a 10-ft (3-m) path should be split into two 5-ft (1.5-m) sections. Emergency vehicles can still enter, if needed, by straddling the landscaping. Alternatively, it may be more appropriate to designate emergency vehicle access via protected access drives that can be secured. The approach to the split should be delineated with solid line pavement markings to guide the path user around the split.
3. Assess whether signing and path entry design prevents or reduces unauthorized traffic to tolerable levels. If motor vehicle incursion is isolated to a specific location, consider targeted surveillance and enforcement. If unauthorized use persists, assess whether the problems posed by unauthorized vehicle entry exceed the risks and access issues posed by barriers. Where the need for bollards or other vertical barriers in the pathway can be justified despite their risks and access issues, measures should be taken to make them as compatible as possible with the needs of bicyclists and other path users (*6*):

- Bollards should be marked with a retroreflectorized material on both sides or with appropriate object markers, per Section 9B.26 of the MUTCD (7).
- Bollards should permit passage, without dismounting, for adult tricycles, bicycles towing trailers, and tandem bicycles. Bollards should not restrict access for people with disabilities. All users legally permitted to use the facility should be accommodated; failure to do so increases the likelihood that pathway users will collide with the bollards.
- Bollard placement should provide adequate sight distance to allow users to adjust their speed to avoid hitting them.
- Bollards should be a minimum height of 40 in. (1.0 m) and minimum diameter of 4 in. (100 mm). Some jurisdictions have used taller bollards that can be seen above users in order to reinforce their visibility.
- Striping an envelope around the approach to the post is recommended as shown in Figure 5-21 to guide path users around the object.
- One strategy is to use flexible delineators, which may reduce unauthorized vehicle access without causing the injuries that are common with rigid bollards.
- Bollards should only be installed in locations where vehicles cannot easily bypass the bollard. Use of one bollard in the center of the path is preferred. When more than one post is used, an odd number of posts spaced at 6 ft (1.8 m) is desirable. However, two posts are not recommended, as they direct opposing path users towards the middle, creating conflict and the possibility of a head-on collision. Wider spacing can allow entry to motor vehicles, while narrower spacing might prevent entry by adult tricycles, wheelchair users, and bicycles with trailers.
- Bollards should be set back from the roadway edge a minimum of 30 ft (10 m). Bollards set back from the intersection allow path users to navigate around the bollard before approaching the roadway.
- Hardware installed in the ground to hold a bollard or post should be flush with the surface to avoid creating an additional obstacle.
- Lockable, removable (or reclining) bollards allow entrance by authorized vehicles.

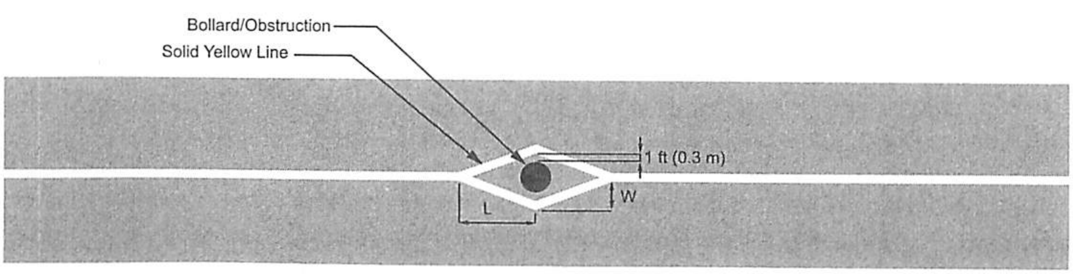


Figure 5-21. Bollard Approach Markings

Crossing Islands

Raised medians are associated with significantly lower pedestrian crash rates at multilane crossings. Although crossing islands (or medians) can be helpful on most road types, they are of particular benefit at path–roadway intersections in which one or more of the following apply: (1) high volumes of roadway traffic and/or speeds create difficult crossing conditions for path users; (2) roadway width is excessive given the available crossing time; or (3) the roadway cross section is three or more lanes in width. In addition to reducing the likelihood for bicycle crashes, crossing islands benefit children, the elderly, the disabled, and others who travel slowly.

Crossing islands should be large enough to accommodate platoons of users, including groups of pedestrians and/or bicyclists, 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 perpendicularly across the island or via a diagonal or offset storage bay (see example in Figure 5-22). The diagonal storage area has the added benefit of directing attention towards oncoming traffic, and should therefore be angled towards the direction from which traffic is approaching. Crossing islands should be designed in accordance with the proposed *Public Rights-of-Way Accessibility Guidelines* (PROWAG) (*13*). The minimum width of the storage area (shown as dimension "Y" in Figure 5-22) should be 6 ft (1.8 m); however, 10 ft (3 m) is preferred in order to accommodate a bicycle with a trailer.

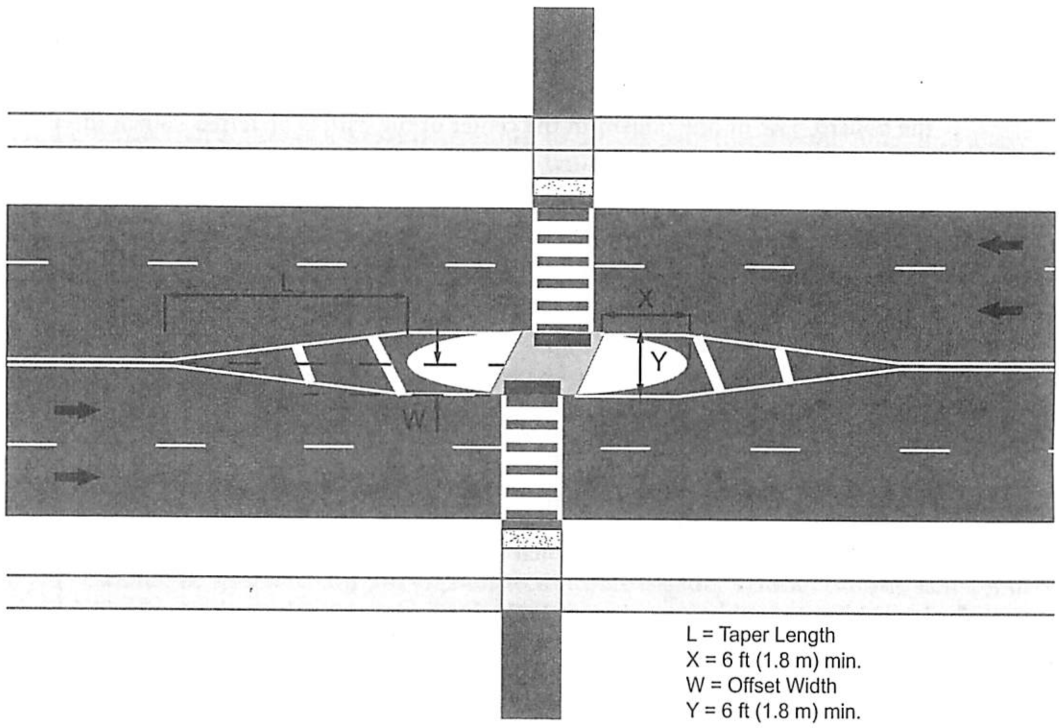


Figure 5-22. Crossing Island (see Table 5-9 to compute taper length)

Table 5-9. Taper Length

U.S. Customary		
$L = \frac{WV^2}{60}$, where $V < 45$ mph $L = WV$, where $V \geq 45$ mph		
where:		
L	=	taper length (ft)
W	=	offset width (ft)
V	=	approach speed (mph)

Metric		
$L = \frac{WV^2}{155}$, where $V < 70$ km/h $L = 0.62\,WV$, where $V \geq 70$ km/h		
where:		
L	=	taper length (m)
W	=	offset width (m)
V	=	approach speed (km/h)

5.3.6 Additional Bicycle Crossing Considerations

Transition Zones

Where a shared use path crosses or terminates at an existing road, it is important to integrate the path into the existing system of on-road bicycle facilities to accommodate bicyclists and into sidewalks to accommodate pedestrians and other path users. Care should be taken to properly design the terminus to transition the traffic into an effective merging or diverging situation. Appropriate signing is needed to warn and direct both bicyclists and motorists at such transition areas. Each roadway crossing is also an access point, and should therefore be designed to facilitate movements of path users who either enter the path from the road, or plan to exit the path and use the roadway.

Traffic Calming for Intersections

At crossing locations where the speed of approaching roadway traffic is a concern, traffic calming measures may be helpful. These can include locations where roadway users are expected to yield to path users and sidepath crossings where road users turn across the path. Slower motorist approach speeds can improve the ability of path users to judge gaps, improve motorists' preparedness to yield to path users at the crossing, and reduce the severity of injuries in the event of a collision.

Traffic calming measures that may be appropriate include a raised intersection or raised crosswalk, chicanes, curb extensions, speed cushions, crossing islands, and curb radius reduction at corners. Traffic calming measures at path–roadway intersections should not be designed in a way that makes path access inconvenient or difficult for bicyclists on the roadway who may wish to enter the path, or vice versa.

Shared Use Paths Through Interchanges

Where a shared use path is parallel to a roadway that intersects with a freeway, separation and continuity of the path should be provided. Users should not need to exit the path, ride on roadways and/or sidewalks through the interchange, and then resume riding on a path.

At higher volume interchanges, a path may need grade-separated crossings to enable users to cross free-flow exit and entrance ramps with reasonable convenience and reduced likelihood for crashes. An engineering analysis should be done to determine if grade separation is needed. Away from ramps, paths can often be carried (with appropriate roadway separation or barrier) on the same structure that carries the parallel roadway through the interchange. See Section 5.2.10 for guidance on the design of structures.

5.4 PAVEMENT MARKINGS, SIGNS, AND SIGNALS

The MUTCD (7) regulates the design and use of all traffic control devices. Part 9 of the MUTCD presents standards and guidance for the design and use of signs, pavement markings, and signals that may be used to regulate, warn, and guide bicyclists on roadways and pathways. Other parts of the MUTCD also include information relevant to shared use path operation and should be consulted as needed. Path users should never be given conflicting traffic control messages (e.g., use of a "STOP" sign at a signalized intersection), leaving it unclear as to which device should be followed.

5.4.1 Pavement Markings

Pavement markings can provide important guidance and information for path and roadway users. Pavement markings should be retroreflective. They should not be slippery or rise more than 0.16 in. (4 mm) above the pavement.

Marked Crosswalks

Marked crosswalks are recommended at intersections between shared use paths and roadways. They delineate the crossing location and can help alert roadway users to the potential conflict ahead. At a mid-block location, no legally recognized crosswalk for pedestrians is present if no crosswalk is marked. As noted in Section 5.3.2 some states extend the rights and responsibilities of pedestrians at crosswalks to bicyclists, while other states do not; therefore, it is important for designers to understand the laws within their state regarding assignment of right of way for pedestrians and bicyclists (and other path users).

Where crosswalks are marked at shared use path crossings, the use of high visibility (i.e., ladder or zebra) markings is recommended as these are more visible to approaching roadway users. More information on the installation of crosswalks at path–roadway intersections is provided in Section 5.3.2.

Centerline Striping

A 4 to 6 in. (100 to 150 mm) wide, yellow centerline stripe may be used to separate opposite directions of travel where passing is inadvisable. This stripe should be dotted where there is adequate passing sight distance, and solid in locations where passing by path users should be discouraged. This may be particularly beneficial in the following circumstances: (1) for pathways with heavy user volumes; (2) on curves with restricted sight distance, or design speeds less than 14 mph (24 km/h); and (3) on unlit paths where night-time riding is not prohibited. The use of the broken centerline stripe may not be appropriate in parks or natural settings. However, on paths where a centerline is not provided along the entire length of the path, appropriate locations for a solid centerline stripe should still be considered where described above.

A solid yellow centerline stripe may be used on the approach to intersections to discourage passing on the approach and departure of an intersection. If used, the centerline should be striped solid up to the stopping sight distance from edge of sidewalk (or roadway, if no sidewalk is present). A consistent approach to intersection striping can help to increase awareness of intersections.

Edgeline Striping

Edgeline striping may be considered for use on shared use paths under several situations. The use of 4 to 6 in. (100 to 150 mm) wide, white edge lines may be beneficial on shared use paths where nighttime use is not prohibited. The use of white edge lines may be considered at approaches to intersections to alert path users of changing conditions, and if the pathway design includes a separate area for pedestrian travel, it should be separated from the bicycle traveled way by a normal white line. Refer to Section 5.2.1 for more information on segregation of traffic.

Approach Markings for Obstructions

Obstructions should not be located in the clear width of a path. Where an obstruction on the traveled portion occurs (for example, in situations where bollards are used), channelizing lines of appropriate color (yellow for centerline, otherwise white) should be used to guide path users around it. An example of a centerline treatment is given in Figure 5-21. For obstructions located on the edge of the path, an obstruction marking (see Figure 4-30) should be used. Approach markings should be tapered from the approach end of the obstruction to a point at least 1 ft (0.3 m) from the obstruction (See Table 4-1 to determine taper length).

Pavement Markings to Supplement Intersection Control

Stop and yield lines may be used to indicate the point at which a path user should stop or yield at a traffic control device. Design of stop and yield lines is described in Chapter 3B of the MUTCD (*7*). Stop or yield lines may be placed across the entire width of the path. If used, the stop or yield line should be placed a minimum of 2 ft (0.6 m) behind the nearest sidewalk or edge of roadway if a sidewalk is not present.

Supplemental Pavement Markings on Approaches

Advance pavement markings may be used on roadway or path approaches at crossings where the crossing is unexpected or where there is a history of crashes, conflicts, or complaints. If a supplemental word marking (such as "HWY XING") is used, its leading edge should be located at or near the point where the approaching user passes the intersection warning sign or advance traffic control warning sign that the marking supplements. Additional markings may be placed closer to the crossing if needed, but should be at least 50 ft (15 m) from the crossing. Advance pavement markings may be placed across the entire width of the path or within the approach lane. Pavement markings should not replace the appropriate signs. Pavement markings may be words or symbols as described in Part 3 of the MUTCD (*7*).

Advance Stop or Yield Lines

Advance stop lines or yield lines may be used on multilane roadway approaches to a path crossing where the path is given priority. The applicability of either a stop line or a yield line is governed by state law. Figure 5-23 shows an application of advanced yield lines, and Figures 5-18 and 5-20 illustrate the use of both applications where the path is given priority. Advance stop and yield lines reduce the likelihood for a multiple-threat crash between the path user and a vehicle. The advance stop or yield line provides a clearer field of vision between path users who are crossing the road and approaching vehicles in both lanes. These treatments have shown promising results (*16*), (*17*).

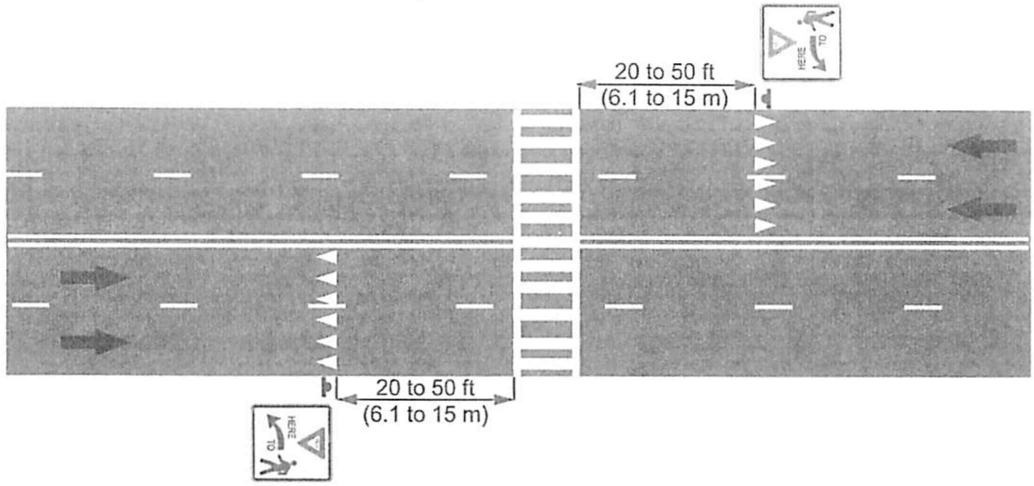


Figure 5-23. Advance Yield Signs and Markings

5.4.2 Signs

All signs should be retroreflective and conform to the color, legend, and shape requirements described in the MUTCD. (*7*) Signs used along a path may be reduced in size per Table 9B-1 of the MUTCD. Signs utilized along a roadway which are visible to motorists should not be reduced in size and should conform to the sizes established in the MUTCD.

Regulatory signs notify pathway (and roadway) users of location-specific regulations. Such a sign is installed at or near the location where the regulation applies. Regulatory signs are generally rectangular with white backgrounds and black text and symbols.

Warning signs are utilized to notify road and pathway users of unexpected conditions that might need a reduction of speed or other action. A warning sign should be used, for example, where pathway width is reduced in a short section because of a constraint. However, warning signs should be used sparingly; use perceived as excessive or unnecessary can result in disrespect for other important signs.

Warning signs are diamond shaped with black symbols and text. Permanent warning signs for bicycle facilities should be yellow or fluorescent yellow-green (temporary warning signs should be orange). In general, a uniform application of warning signs of the same color should be used.

For advance warning sign placements on shared use paths, the sign should be placed to allow adequate perception-response time. The location of the sign should be based on the stopping sight distance needed by the fastest expected path user; however, in no instance should the sign be located closer than 100 ft (30 m) from the location warranting the advance warning. Warning signs should not be placed too far in advance of the condition, such that path users tend to forget the warning because of other distractions.

The purpose of guide and wayfinding signs is to inform path users of intersecting routes, direct them to important destinations, and generally to give information that will help them along their way in the most simple and direct manner. Guide signs are rectangular with green backgrounds and white text.

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Shared Use Path Crossing Warning Sign Assembly

Roadway users may be warned of a shared use path crossing by utilizing a combined bicycle-pedestrian warning sign (W11-15), as shown in Figure 5-24, or a bicycle warning sign (W11-1). On a roadway approach to a path crossing, placement of an intersection or advance traffic control warning sign should be at (or close to) the distance recommended for the approach speed in Table 2C-4 of the MUTCD (*7*). See Figures 5-17 through 5-20.

The assembly consists of a W11-15 or a W11-1 accompanied by a W16-7p (downward arrow) plaque mounted below the warning sign. This sign should not be installed at the crossing if the roadway traffic is yield-, stop-, or signal-controlled. The W16-8P (path name) plaque may be mounted on the sign assembly (below the W11-15 or W11-1 sign) to notify approaching roadway users of the name of the shared use path being crossed.

Figure 5-24. Advance Warning Assembly Example

At path crossings that experience frequent conflicts between motorists and path users, or on multilane roadways where a sign on the right-hand side of the roadway may not be visible to all travel lanes, an additional path crossing warning sign assembly should be installed on the opposite side of the road, or on the refuge island, if there is one.

The combined bicycle-pedestrian warning sign (W11-15) or bicycle warning sign (W11-1) may be used in advance of shared use path crossings of roadways. Again, this warning sign should not be used in advance of locations where the roadway is stop-, yield-, or signal-controlled. Advance warning sign assemblies may be supplemented with a W16-9p (AHEAD) plaque or W16-2P (XX FEET) plaque located below the W11-15P sign.

Traffic Control Regulatory Signs

"YIELD" and "STOP" signs are used to assign priority at controlled but unsignalized path–roadway intersections. The choice of traffic control (if any) should be made with reference to the priority assignment guidance provided in Section 5.3.2 and in the MUTCD. The design and use of the signs is described in sections 2B and 9B of the MUTCD (*7*).

Intersection and Advance Traffic Control Warning Signs

Advance traffic control warning signs announce the presence of a traffic control of the indicated type ("YIELD," "STOP," or signal) where the control itself is not visible for a sufficient distance on an approach for users to respond to the device. An intersection warning sign may be used in advance of an intersection to indicate the presence of the intersection and the possibility of turning or entering traffic.

On a shared use path approach, placement of an advance warning sign should be at a distance at least as great as the stopping sight distance of the fastest expected path user in advance of the location to which the sign applies. In no case should the advance placement distance be less than 50 ft (15 m). See Figures 5-17 through 5-20.

An intersection or advance traffic control warning sign may carry a W16-8P (road or path name) plaque to identify the intersecting road or path, as appropriate for the approach. An advisory speed (W13-1) plaque may be added to the bottom of the sign assembly to advise the approaching user to the proper traveling speed for the available sight lines or geometric conditions.

Guide Signs

Road name/path name signs (D3-1 and W16-8P) should be placed at all path–roadway crossings. This helps path users track their locations. At mid-block crossings, the D3-1 sign may be installed on the same post with a regulatory sign.

Guide signs to indicate directions, destinations, distances, route numbers, and names of crossing streets should be used in the same manner as on roadways and as described in Section 4.11.

Reference location signs (also called mile markers) assist path users in estimating their progress, provide a means for identifying the location of emergency incidents, and are beneficial during maintenance activities. Section 9B.24 of the MUTCD provides guidance for the use of reference location signs.

Where used, wayfinding signs for shared use paths should be implemented according to the principles discussed in Section 4.11. Mode-specific guide signs (D11-1a, D11-2, D11-3, and D11-4) may be used to guide different types of users to the traveled way that is intended for their respective modes (see Figure 5-25). If used, the signs should be installed at the point where the separate pathways diverge (see Section 9B.25 of the MUTCD) (*7*).

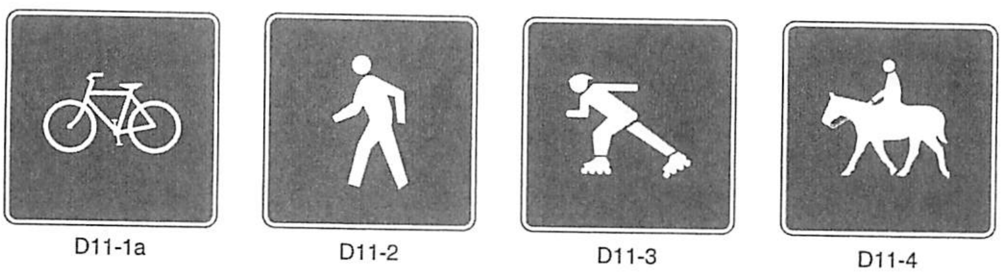

Figure 5-25. Mode-Specific Guide Signs

5.4.3 Signalized and Active Warning Crossings

As discussed earlier in this chapter, it may be appropriate to provide active warning or a traffic signal at some shared use path crossings of roadways. Guidance on the need for a signal and other traffic control devices is provided in the MUTCD (*7*) and in other sources such as FHWA's *Safety Effects of Marked Versus Unmarked Crosswalks at Uncontrolled Locations: Final Report and Recommended Guidelines* (*18*). Path user volumes may be used to determine the need for a signal and/or other active warning devices, and in some situations when considering path user volume, it may be appropriate to assess whether the path users have access to another appropriate crossing location.

Signalized shared use path crossings should be operated so the slowest user type likely to use the path will be accommodated. This will typically be the pedestrian. For manually operated signal actuation, the push button should be located in a position that is accessible from the path and in accordance with the proposed PROWAG (*13*). Bicyclists should not have to dismount to activate the signal. Part 9 of the MUTCD provides a variety of signs that are appropriate for these locations.

Another method of signal actuation is to provide automated detection (such as an inductive loop in the pavement); however, if the detection device is such that it does not detect pedestrians and other path users, it should be supplemented with a pushbutton. At signalized intersections on divided roadways, a push button should also be located in the median for those path users who may be trapped in the refuge area. Further discussion of signal design considerations is in Chapter 4. Path crossing warning sign assemblies (W11-15) should not be used at a signal-controlled shared use path–roadway intersection.

In locations where motor vehicle traffic delay is a concern, a pedestrian hybrid beacon (popularly known as a HAWK (High-intensity Activated Cross WalK) may be considered, in accordance with MUTCD (*7*). This signal is activated with a pushbutton. It controls traffic on the roadway by using a combination of red and yellow signal lenses, while the path approach is controlled by pedestrian signals.

A warning beacon is another type of crossing device that can be considered. A flashing warning beacon is a signal that displays flashing yellow indications to an approach. It is typically a single light, but can be installed in other combinations. A common application is to add a flashing amber signal to the top of a standard warning sign to bring attention to a shared use path crossing. The flashing signal may also be used on overhead signs at crosswalks. Flashing beacons are more effective if they only flash when path users are present, rather than flashing continuously—and therefore should be actuated by path users. However, flashing beacons have shown little or no effectiveness in many crosswalk or crossing situations.

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