4.12 OTHER ROADWAY DESIGN CONSIDERATIONS

4.12.1 Railroad Grade Crossings

Railroad tracks that cross roads or shared use paths on a diagonal can cause steering difficulties for bicyclists. Depending on the angle of the crossing, the width and depth of the flangeway opening, and pavement unevenness, a bicycle wheel may be turned from its course. The height of the track relative to the road is also important. If the track is too low, a bicycle wheel can be "pinched" or deformed, increasing the likelihood of a flat tire, wheel damage, or loss of control by the bicyclist. By improving track placement, surface quality, and flangeway opening width, the angle may be less critical. The following is a more detailed discussion of these issues.

Crossing Angle

The bikeways shown in Figures 4-28 and 4-29 are short independent alignments that continue bike lanes immediately adjacent at either end and, therefore, need not be considered as shared use paths. The likelihood of a fall is kept to a minimum where the roadway or shared use path crosses the tracks at 90 degrees. The preferable skew angle between the centerline of the tracks and the bikeway is between 60 and 90 degrees, so bicyclists can avoid catching their wheels in the flange and losing their balance (see Figures 4-28 and 4-29).

Efforts to create a right-angle crossing at a severe skew can have unintended consequences, as the reversing curves needed for a right-angle approach can create other concerns for bicyclists. It is often best to widen the roadway, shoulder, or bike lane to allow bicyclists to choose the path that suits their needs the best. On extremely skewed crossings (30 degrees or less), it may be impracticable to widen the shoulders enough to allow for 90 degree crossing; widening to allow 60 degree crossing or better is often sufficient. It may also be helpful to post a W10-1 or W10-12 warning sign at these locations.

Crossing Surfaces

The four most common materials used at railroad crossings are concrete, rubber, asphalt, and timber. Concrete performs best, even under wet conditions, as it provides the smoothest ride. Rubber crossings are quite rideable when new, but they are slippery when wet and degrade over time. Asphalt is smooth when first laid, but can heave over time and needs maintenance to prevent a buildup next to the tracks. Timber wears down rapidly and is slippery when wet.

Bikeway Width

The minimum width for a shoulder bikeway as shown in Figure 4-28 should be 6 ft (1.8 m).

Flange Opening

The flangeway opening between the rail and the roadway surface can catch a bicycle wheel, causing the rider to fall. Flange width should be minimized when practical. Light rail and trolley lines need only a narrow flange, whereas heavy rail needs a wider flange. There are flangeway filler products that can be used on heavy rail lines with occasional low-speed rail traffic, such as on spur lines. These rubber fillers are depressed by the rail wheels as they ride over the filler; the filler rises again after the train has passed by to keep the flangeway opening limited. Design and traffic control for bicycle facilities at railroad grade crossings should be coordinated with the responsible railroad company.

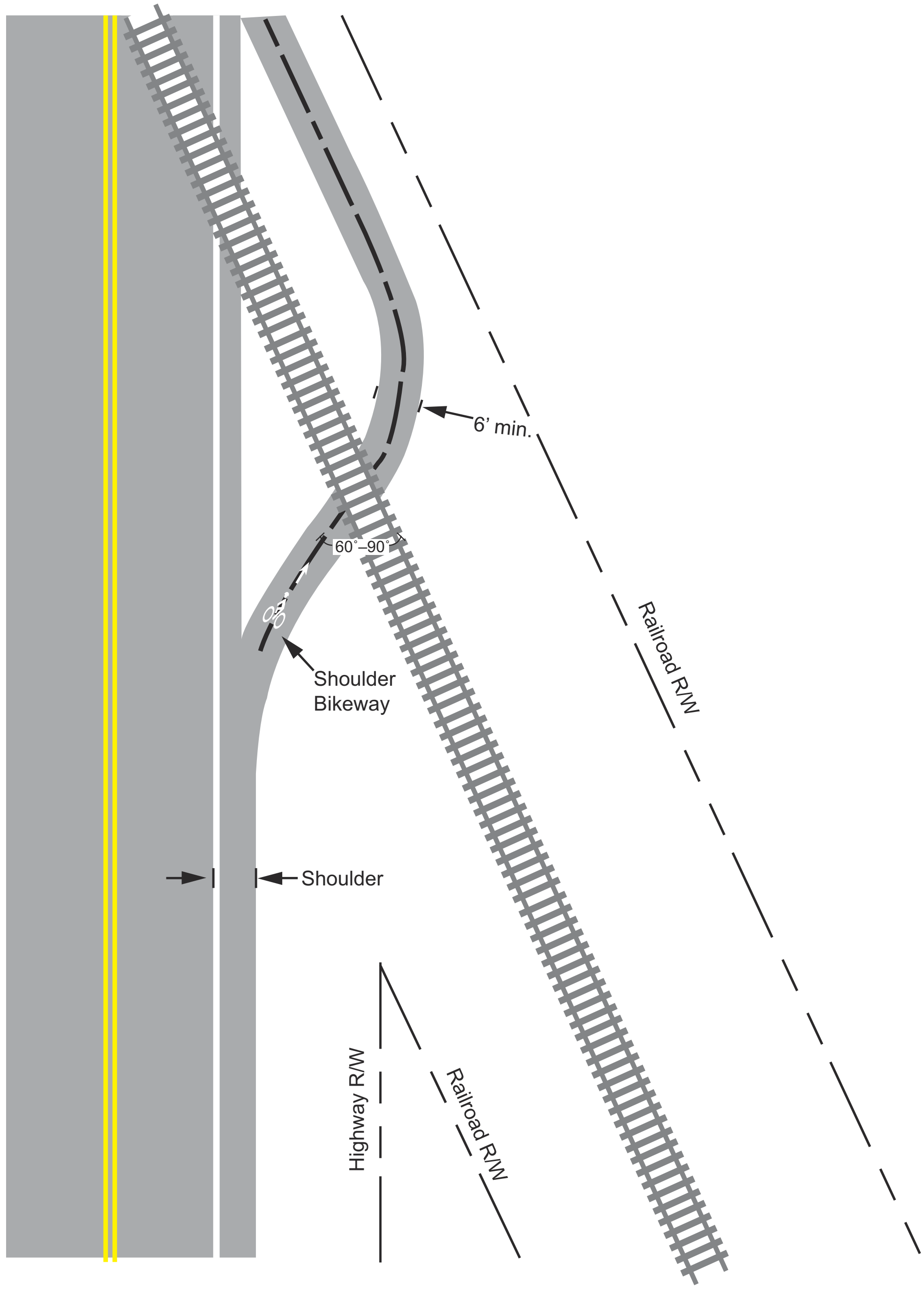


Figure 4-28. Correction for Skewed Railroad Grade Crossing—Separate Pathway

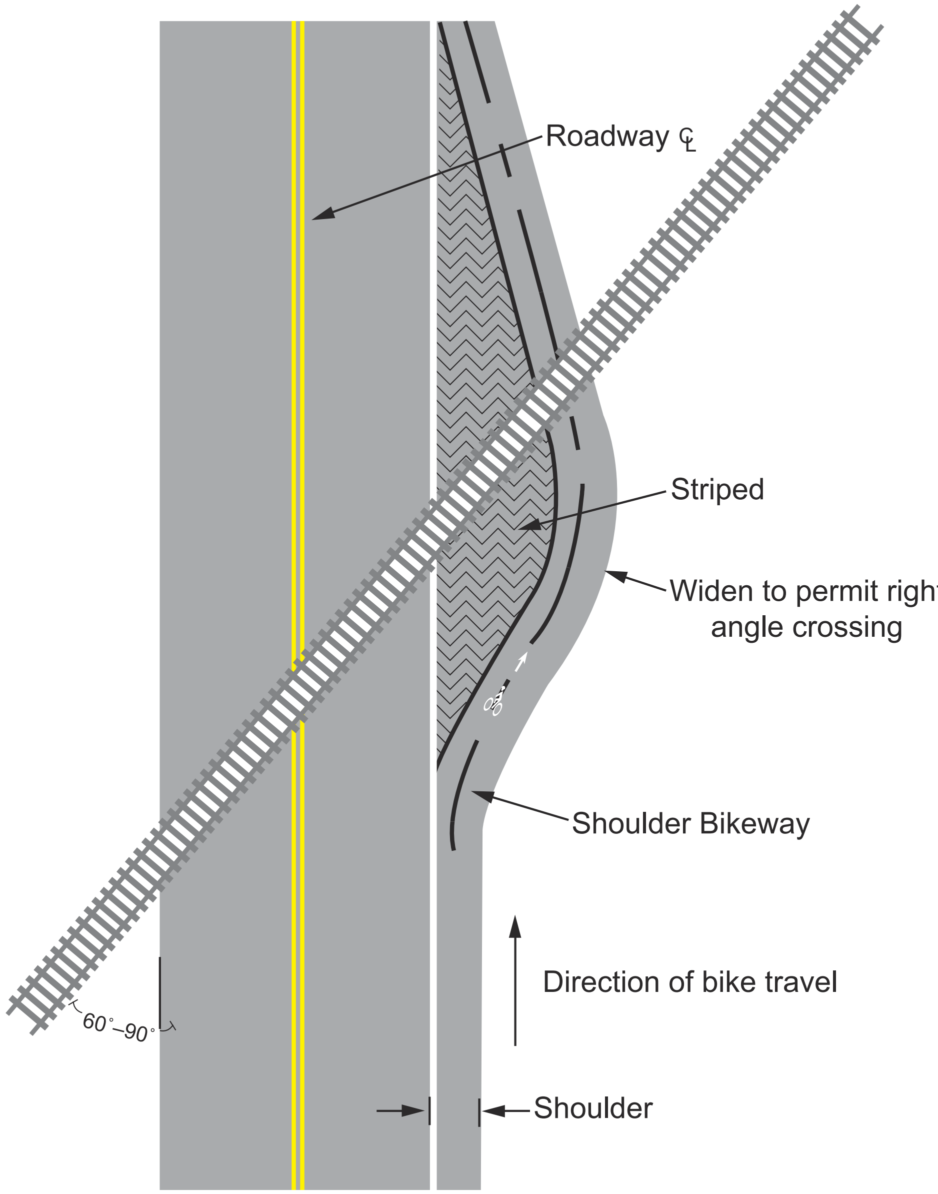
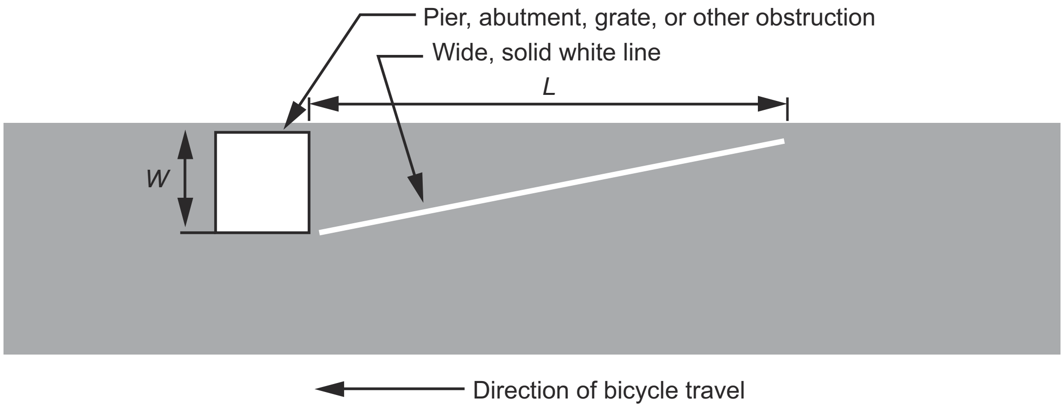


Figure 4-29. Correction for Skewed Railroad Grade Crossing—Widened Shoulder

4.12.2. Obstruction Markings

Barriers and obstructions, such as abutments, piers, rough grates, and other features constricting a bikeway should be clearly marked to gain the attention of approaching bicyclists. This treatment should be used only where the obstruction is unavoidable, and should not substitute for good bikeway design; removing the obstruction is preferred. An example of an obstruction marking is shown in Figure 4-30. Table 4-1 provides the equation for determining the taper length based on MUTCD criteria (*3*). Table 3-2 presents typical bicycle approach speeds for use in this equation. Signs, reflectors, diagonal yellow markings, or other treatments from MUTCD Part 9 (*3*) may also be appropriate to alert bicyclists to potential obstructions.



For metric units:
$L = 0.62WS$, where S is bicycle approach speed in kilometers per hour

For English units:
$L = WS$, where S is bicycle approach speed in miles per hour

Figure 4-30. Obstruction Marking

Table 4-1. Formula for Determining Taper Length for Obstruction Markings

U.S. Customary		
$L = WS$		
where:		
L	=	taper length (ft)
W	=	offset width (ft)
S	=	bicycle approach speed (mph)

Metric		
$L = 0.62WS$		
where:		
L	=	taper length (m)
W	=	offset width (m)
S	=	bicycle approach speed (km/h)

Note: An additional 1 ft (0.3 m) of offset should be provided for a raised obstruction.

4.12.3 Bridges, Viaducts, and Tunnels

Bridges, viaducts, and tunnels should accommodate bicycles. As a general exception, these structures do not need to accommodate bicycles on roadways where bicycle access is prohibited. However, there are numerous examples of limited access highway bridges that cross major barriers (such as wide waterways) that incorporate a shared use path for bicyclists and pedestrians.

The type of bicycle accommodation should be determined in consideration of the road function, length of the bridge or tunnel (i.e., potential need for disabled vehicle storage), and the design of the approach roadway. The absence of a bicycle accommodation on the approach roadway should not prevent the accommodation of bicyclists on the bridge or tunnel. Shoulder improvements associated with bridge projects (approach shoulders) should include bicycle accommodations, such as paved shoulders or bike lanes.

The most common types of bicycle facilities that are provided on bridges and inside tunnels are bike lanes in urban and suburban areas, and shoulders in rural locations. In most cases (except for those cited below), the bicycle facility will be separated from the pedestrian facility (sidewalk).

In cases where a bridge on a controlled access freeway affects a non-controlled access roadway (e.g., an overpass/underpass that serves as existing surface roadway), the project should include appropriate access for bicycles on the non-limited access roadway, including such elements as bike lanes, paved shoulders, and bicycle crossings at associated ramps.

In locations where bicyclists will operate in close proximity to bridge railings or barriers, the railing or barrier should be a minimum of 42 in. (1.05 m) high. On bridges where bicycle speeds are likely to be high (such as on a downgrade), and where a bicyclist could impact a barrier at a 25 degree angle or greater (such as on a curve), a higher 48-in. (1.2-m) railing may be considered. Where a barrier is less than 42 in. (1.2 m) high, an aluminum rail with posts is usually mounted on top of the barrier. If the shoulder is sufficiently wide so that a bicyclist does not operate in close proximity to the rail, lower rail heights are acceptable.

Long Bridges

Long bridges often have higher motor vehicle speeds than their approach roadways. On bridges with a continuous span over 0.5 mi (0.8 km) in length and design speeds that exceed 45 mph (70 km/h), consideration should be given to providing a shared use path separated from traffic with a concrete barrier, preferably on both sides of the bridge. The provision of a pathway on one side tends to result in wrong-way travel on the departures when bicyclists continue on the same side of the road for some distance. If a pathway is only provided on one side, crossing provisions (grade separated, where needed) should be provided on each end of the bridge to allow bicyclists traveling against the flow of traffic to cross over to the other side of the roadway and proceed in a legal manner. See Section 5.2.10 for information on the appropriate widths of bridges and underpasses.

Retrofits to Existing Bridges and Tunnels

At existing bridges and viaducts, there are often sudden changes in roadway geometry that can significantly reduce travel lane widths and negatively affect bicyclists' comfort for the length of the bridge span.

The preferred solution is to continue to enable bicyclist operation (riding with traffic) on the bridge or viaduct with shoulders or bike lanes by narrowing travel lanes where practical. Where the deck of a bridge is too narrow to accommodate shoulder widths useful for bicyclists, it may be feasible to widen a sidewalk to a shared use path width, e.g., by reducing travel lane widths or installing a cantilever structure. In both cases, the weight increase must be compatible with the structural sufficiency of the bridge. A ramp between the roadway and the sidewalk is needed at either end of the bridge.

Retrofit options for tunnels include widening an existing sidewalk, or eliminating a narrow sidewalk. The latter may not be practical where the sidewalk functions as a barrier curb to discourage large vehicles from traveling too close to the side, or where it is intended for emergency access or egress. In narrow tunnels where bicyclists share travel lanes with motor vehicles, one option is to provide a warning sign and beacon at the tunnel entrance that can be activated by bicyclists. The beacon should be designed to flash for the length of time that it will take for a typical bicyclist to travel through the tunnel, to signal to a motorist that a bicyclist is present. Alternatively, a regulatory R4-11 sign ("BICYCLES MAY USE FULL LANE") may be provided without a beacon.

Adequate lighting is particularly important in these locations so that motorists can see and react to bicyclists using the tunnel.

The installation of shared-lane markings informs bicyclists of where they should position themselves within the shared lane and may be serve to remind motorists of the possible presence of bicycle on bridges or in tunnels.

4.12.4 Traffic Signals

Traffic signals assign right of way to various traffic movements at intersections. Traditionally, signal design has been determined by the operating characteristics of motor vehicles. Bicyclists typically use the same travelled way and signal displays as motorists. Bicyclists, however, have significantly different operating characteristics; and it is, therefore, advisable to adjust signal operations for bicyclists. Although non-motorized users of various types may cross at an intersection, this section addresses only the needs of bicyclists.

Signal Considerations for Bicyclists

The differences in operating characteristics of bicyclists have an impact on some signal design elements. Important factors to consider are the speeds and behaviors of bicyclists. Experienced bicyclists on higher classification roadways (major streets) are typically comfortable entering intersections in the mid-to-late green due to longer greens available for major thoroughfares. However, bicyclists on cross streets tend to slow down approaching the intersection even when approaching on a green, in order to start at the beginning of green. Most bicyclists tend to stop at the onset of yellow in the traffic signal. Youth bicyclists often use crosswalks and pedestrian push buttons to cross; therefore, these facilities should be accessible to bicyclists who may wish to proceed through the intersection in this manner. These behaviors and preferences have an impact on the selection of signal timing parameters suitable for bicyclists. It is, therefore, important to evaluate bicyclist needs at a traffic signal by considering the scenarios of a stopped bicycle and a rolling bicycle.

The signal parameters that should be modified to accommodate bicyclists, when appropriate, are the minimum green interval, all-red interval, and extension time:

- Minimum green is intended to effectively clear a vehicle through the intersection from a stopped position. Bicycles need a longer minimum green than automobiles. Some controllers have a bicycle minimum green parameter which can be used with appropriate detection to service bicyclists.
- The all-red interval is used to provide time for crossing automobiles and bicyclists to approach or pass beyond the far side of an intersection.
- Extension time or passage time is the time a detected automobile or bicyclist needs to extend the green indication to provide enough time to clear the intersection before a green indication is displayed to conflicting traffic.

The yellow interval is based on the approach speed of the automobiles and is usually between 3 and 6 seconds in duration. Generally, yellow change intervals calculated for automobiles using commonly accepted formulas are adequate for bicycles.

In some instances, it may be appropriate to indicate that a signal head is intended for the exclusive use of bicyclists. A sign can be added near the signal head that states “BICYCLE SIGNAL”.

This may be appropriate where bicyclists share a signal phase with pedestrians or have their own phase. It may also be appropriate at some path crossings of roadways.

Stopped Bicyclist

When an approach receives a green indication, a stopped bicyclist needs enough time to react, accelerate, and cross the intersection before traffic on the crossing roadway enters the intersection on its green. This is referred to as standing bicycle crossing time, and is used to determine the bicycle minimum green (BMG) time. Intersection crossing time for a bicyclist who starts from a stop and attains crossing speed *V* within the intersection is shown in Table 4-2.

Table 4-2. Standing Bicycle Crossing Time

U.S. Customary		
$BCT_{standing} = PRT + \frac{V}{2a} + \frac{(W+L)}{V}$		
where:		
$BCT_{standing}$	=	bicycle crossing time (s)
W	=	intersection width (ft)
L	=	typical bicycle length = 6 ft (see Chapter 3 for other design users)
V	=	attained bicycle crossing speed (ft/s)
PRT	=	perception reaction time = 1s
a	=	bicycle acceleration (1.5 ft/s^2)

Metric		
$BCT_{standing} = PRT + \frac{V}{2a} + \frac{(W+L)}{V}$		
where:		
$BCT_{standing}$	=	bicycle crossing time (s)
W	=	intersection width (m)
L	=	typical bicycle length = 1.8 m (see Chapter 3 for other design users)
V	=	attained bicycle crossing speed (m/s)
PRT	=	perception reaction time = 1s
a	=	bicycle acceleration (0.5 m/s^2)

Most bicyclists can accelerate at a rate of at least 1.5 ft/s^2 (0.5 m/s^2) and can obtain a speed of at least 10 mph (14.7 ft/s) [16 km/h (4.5 m/s)]. Youth bicyclists often have slower reaction times and need additional time to get started and accelerate. Extended crossing times should be considered where young riders are expected (e.g., near schools).

Bicyclists who begin crossing an intersection from a standing start on a new green take more time to cross than rolling bicyclists who enter on green, since they have to accelerate. This time is usually more critical for bicyclists on minor road approaches, since minor-road crossing distance is ordinarily greater than major-road crossing distance. Bicycle minimum green is determined using the bicycle crossing time for standing bicycles and clearance time as shown in Table 4-3.

Some controllers have a built-in feature to specify and program a bicycle minimum green. If appropriate bicycle detection exists, and a bicycle is detected stopped at the intersection, the controller will provide the bicycle minimum green instead of the normal minimum green. If this type of controller is not used, and if the minimum green needed for local bicyclists is greater than what would otherwise be used, minimum green time should be increased. However, as with all calculated signal timing, field observations should be undertaken prior to making any adjustments.

Table 4-3. Bicycle Minimum Green Time Using Standing Bicycle Crossing Time

U.S. Customary		
$BMG = BCT_{standing} - Y - R_{clear}$ $BMG = PRT + \frac{V}{2a} + \frac{W+L}{V} - Y - R_{clear}$		
where:		
BMG	=	bicycle minimum green time (s)
$BCT_{standing}$	=	bicycle crossing time (s)
Y	=	yellow change interval (s)
R_{clear}	=	all-red (s)
W	=	intersection width (ft)
L	=	typical bicycle length = 6 ft (see Chapter 3 for other design users)
V	=	bicycle speed crossing an intersection (ft/s)
PRT	=	perception reaction time = 1s
a	=	bicycle acceleration (1.5 ft/s^2)

Metric		
$BMG = BCT_{standing} - Y - R_{clear}$ $BMG = PRT + \frac{V}{2a} + \frac{W+L}{V} - Y - R_{clear}$		
where:		
BMG	=	bicycle minimum green time (s)
$BCT_{standing}$	=	bicycle crossing time (s)
Y	=	yellow change interval (s)
R_{clear}	=	all-red (s)
W	=	intersection width (m)
L	=	typical bicycle length = 1.8 m (see Chapter 3 for other design users)
V	=	bicycle speed crossing an intersection (m/s)
PRT	=	perception reaction time = 1s
a	=	bicycle acceleration (0.5 m/s^2)

Rolling Bicyclist

Rolling bicycle crossing time determines the adequacy of any red clearance interval and any extension time, if provided. Although a small percentage of adult bicyclists travel at speeds below 10 mph (14.7 ft/s) [16 km/h (4.5 m/s)], most bicyclists momentarily can and do achieve higher speeds. Under typical conditions, the speed (V) can be assumed to be at least this great. If the approach is on an appreciable upgrade or downgrade, a modified value may be appropriate.

When estimating whether adequate time is available for a rolling bicycle to cross the intersection at the end of a green indication, the braking distance and the width of the intersection should be considered. Towards the end of a green indication, beyond a certain point on the approach to the intersection, the bicyclist can neither stop comfortably prior to the intersection nor clear the intersection if clearance time is inadequate. A bicyclist needs some distance to brake and stop comfortably. This distance depends on the bicyclist's speed, perception reaction time, and deceleration rates. The equation for rolling bicycle crossing time considering braking distance is shown in Table 4-4.

Table 4-4. Rolling Bicycle Crossing Time Considering Braking Distance

U.S. Customary		
$BCT_{rolling} = \frac{BD + W + L}{V}$ $BD = PRT \times V + \frac{V^2}{2a}$		
where:		
$BCT_{rolling}$	=	bicycle crossing time (s)
W	=	intersection width (ft)
L	=	typical bicycle length = 6 ft (see Chapter 3 for other design users)
V	=	bicycle speed crossing an intersection (ft/s)
BD	=	breaking distance (ft)
PRT	=	perception reaction time = 1s
a	=	deceleration rate for wet pavement = 5 ft/s^2

Metric		
$BCT_{rolling} = \frac{BD + W + L}{V}$ $BD = PRT \times V + \frac{V^2}{2a}$		
where:		
$BCT_{rolling}$	=	bicycle crossing time (s)
W	=	intersection width (m)
L	=	typical bicycle length = 1.8 (see Chapter 3 for other design users)
V	=	bicycle speed crossing an intersection (m/s)
BD	=	breaking distance (m)
PRT	=	perception reaction time = 1s
a	=	deceleration rate for wet pavement = 1.5 m/s^2

A signal should provide sufficient time for a rolling bicyclist who enters at the end of the green interval to clear the intersection before traffic on a crossing approach receives a green indication. The time available for bicyclists to cross the intersection is composed of the yellow change interval, all-red interval, and any extension time, if provided. (Extension time is time added to the duration of a signal phase based on the volume of traffic detected.) As previously stated, the yellow interval is based on the approach speeds of automobiles, and therefore should not be adjusted in order to accommodate bicycles. However, it may be feasible to increase the all-red interval. The time should be increased, where appropriate, up to the longest interval used in local practice. Table 4-5 shows the equation used to determine the all-red interval and extension time needed for the rolling bicycle crossing time.

If time for bicycle crossing is inadequate with maximum red clearance time, use of adaptive signal timing for bicycles may be helpful. This technique extends green time when a bicycle approaching late on green is detected. Traffic engineers typically use extension time and call features within traffic signal controllers; however, the extension setting can also be applied within a specific detector. An extension setting for a phase within a traffic signal controller will extend the green time for vehicles that actuate any detector that feeds the respective phase. However, an extension setting applied within a specific detector will extend the green time only for actuations on that detector. Therefore, when using an exclusive bicycle detector, it is recommended to use the extend feature in the bicycle detector settings instead of the extension settings in the traffic signal controller.

Loop detectors cannot distinguish between bicycles and motor vehicles. Therefore, in locations utilizing loop detectors and extension time, a bike lane is typically needed on the approach in order to provide a location where bicycles (and not automobiles) are detected. In the absence of bike lanes, it may still be feasible to use video detection to distinguish approaching bicyclists. The braking distance mentioned earlier can also be used to help determine the location of the bicycle detector so that adequate distance is provided for a bicyclist to stop prior to the intersection if they do not reach the detector just before the end of the green interval. Detection for bicycles at signals is discussed in the following section.

Table 4-5. All-Red and Extension Time Using Rolling Bicycle Crossing Time

U.S. Customary			Metric		
$BCT_{rolling} \leq T_{extension} + Y + R_{clear}$			$BCT_{rolling} \leq T_{extension} + Y + R_{clear}$		
where:			where:		
$BCT_{rolling}$	=	bicycle crossing time (s)	$BCT_{rolling}$	=	bicycle crossing time (s)
$T_{extension}$	=	extension time (s)	$T_{extension}$	=	extension time (s)
Y	=	yellow change interval (s)	Y	=	yellow change interval (s)
R_{clear}	=	all-red (s)	R_{clear}	=	all-red (s)

4.12.5 Detection for Bicycles at Traffic Signals

Actuated traffic signals should detect bicycles; otherwise, a bicyclist may be unable to call a green signal and may be forced to break the law by violating a red signal. Various technologies are available for detecting bicycles, including inductive loops, microwave, video, magnetometers, and pushbuttons.

Inductive Loops

The metal rims of a bicycle intercept the horizontal magnetic field above an inductive loop. Diagonal quadrupole inductive loops, such as illustrated in Figure 4-31 have some horizontal magnetic field everywhere within the loop and thus are suitable for detecting bicycles. Other types of inductive loops, such as the conventional quadrupole loop illustrated in Figure 4-32, have a horizontal magnetic field only above the loop slots and are thus generally unsuitable for bicycle detection, particularly at new installations. For existing installations of conventional loops, the MUTCD contains a bicycle detector symbol (see Figure 4-33) as a way of showing bicyclists the location of the loop slot. This pavement marking can be supplemented by a R10-22 sign (see Figure 4-34) to reinforce the message to the bicyclist.

A diagonal quadrupole loop can be used on shared use paths and bike lanes, as well as in travel lanes on roadways. A diagonal quadrupole loop is particularly effective at rejecting vehicles in the adjacent travel lane, allowing the use of a higher sensitivity setting on the detector amplifier.