CHAPTER 14

BICYCLE FACILITIES

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GENERAL OVERVIEW

Fundamentals of Bicycle Operation

Bicyclists can and are expected to operate on all streets, roadways, and highways, except those highways upon which they are legally prohibited. Current U.S. Department of Transportation policy states bicycling should be given the same priority as other modes of transportation, and accommodations for bicyclists should be incorporated into transportation projects.[1] Bicyclists also use off-street facilities, such as shared-use paths and trails, to supplement the mobility offered by the roadway system.

Bicyclists are not "wheeled pedestrians." Although human-powered, the operating characteristics of bicycles have much more in common with other vehicles than with pedestrians. Even at low speeds, bicyclists cannot turn and stop instantly, but have defined turning radii and stopping distances included in design guidelines listed elsewhere in this chapter.

Terminology

Care should be taken to use correct terms when referring to types of bicycle facilities. It is common for members of the public and some professionals, including journalists, to refer to all bicycle facilities as "bike paths" or "bike lanes" even though the former refers to separated, two-way, shared-use pathways, and the latter refers to one-way facilities within the roadway. Such mislabeling can confuse members of the transportation community and the general public, and could possibly cause the recommendation or development of an incorrect type of facility. As shown in Table 14-1, "Bikeway" is the preferred generic term for any on- or off-street bicycle travelway, whether for exclusive or shared use.

TABLE 14-1. Bicycle Facility Terminology

Term	Definition
Bicycle Facility	Generic term for any transportation improvement for bicycling, including bikeway but also destination improvements such as bicycle parking
Bikeway	Generic term for any on- or off-street travelway specifically designated for bicycle travel
Shared-Use Path, Shared-Use Pathway	Travelway for non-motorized traffic, typically two-way, aligned on an independent right-of-way or separated from the roadway by a landscape buffer or physical barrier
Bicycle Lane, Bike Lane	Preferential lane for one-way bicycle travel on the roadway in the same direction as motor traffic on that side of the road
Buffered Bicycle Lane, Buffered Bike Lane	Bicycle lane separated from adjacent travel lane by a striped or delineated area
Bicycle Boulevard	A type of shared roadway specifically enhanced for bicycle travel
Shared Lane	Roadway lane shared by all wheeled travel modes including bicycles
Shared Roadway	Roadway shared by all wheeled travel modes including bicycles

SOURCE: John Ciccarelli.

This *Handbook* uses the following terms in Table 14-1 for bicycle facilities:

In some parts of the United States, the term "trail" (as in "bike trail" or "hike and bike trail") is used to describe a shared-used path. However, the term "trail" is often associated with non-engineered and unimproved facilities, such as narrow and steep mountain bike trails in mountains or outdoor areas. The term trail should not be used to define or describe a facility that can be better defined using a standard term as noted in Table 14-1.

Importance of Uniform Traffic Control

Regardless of the mode of travel, uniformity of traffic control is one of the basic principles of efficient traffic operation. Providing uniform and consistent traffic control for all users, whether motorized or non-motorized, enhances smooth traffic operation on roads, paths, and other transportation facilities. This commitment to uniformity is a guiding vision for the *Manual on Uniform Traffic Control Devices* (MUTCD), and Part 9 of the 2009 MUTCD ensures bicyclists are treated in a manner befitting their status as operators of vehicles.

Agencies have occasionally installed nonstandard signing on bikeways in a desire to give a unique or distinctive look to their facilities. This can create problems and confusion for road and path users if the signs are poorly designed, use unusual typefaces or layouts, or if the sign panels use shapes or colors that make it difficult for bicyclists to discern at a glance that the signs are official traffic control devices (TCDs) that apply to them. The use of nonstandard signing may also create serious problems if important regulatory and warning signs are not immediately recognizable, such as if the sign is placed in a decorative or geometric housing or border that obscures or disguises the sign's shape. The use of uniform signs, markings, and other devices as defined in Part 9 of the 2009 MUTCD can reduce confusion, reduce installation and maintenance costs, and increase safety and convenience for all users.

Local policies, standards, and guidelines should be developed and revised so as to comply with the MUTCD and recognized bicycle facility design references.

Advantages of Bicycle Facilities

Bicycle facilities are one of many ways to improve bicycle safety, access, mobility, and convenience. Bicycle facilities can assist in accommodating bicycle and motor vehicle traffic on roadways, or complement the roadway system to provide additional transportation opportunities. The creation of a network of interlinked facilities can encourage bicycling by creating a continuous guided route to destinations within an urban area, or from city to city. Where rivers, non-connecting streets, or other barriers to bicycle travel exist, facilities such as paths can close gaps and provide shorter travel times and distances for bicyclists. Off-street pathways on independent corridors can provide new recreational opportunities and transportation routes.

The provision and development of bicycle facilities have been cited as one feature that could encourage bicycle use by persons interested in riding, but not confident enough to share many roadways otherwise useful for bicycling. Some reports and studies have supported this in noting increased ridership and bicycle-mode share on roadways after facilities are installed. However, providing an inappropriate or poorly designed or constructed facility can create problems, as noted in the following section.

Limitations of Bicycle Facilities

Bicycle facilities do have limitations that may not be readily apparent. Most bicyclists are currently served, and will be served in the future, by the same roadway system that serves other users. Bicycle-specific facilities will never serve bicyclists' every possible destination or need.

Bicycle facilities are sometimes viewed by other road users as being the only legal or legitimate location for bicycle travel. Laws or ordinances that require a cyclist (with few exceptions) to use a bicycle facility where available may contribute to this misperception. This causes problems for bicyclists who choose not to use designated facilities (due to operational or safety concerns), or to make turns or access destinations not served by the facility.

Bicyclists should not be legally compelled to use paths or bike lanes when provided, any more than carpools should be restricted to carpool lanes, or buses to bus lanes. The Uniform Vehicle Code (UVC) contains no requirement bicyclists be restricted to facilities when they exist. It is highly recommended state and local laws be reviewed and updated to be consistent with the UVC in this regard, so as not to place undue burdens on safe bicycle operation.

Poorly designed bicycle facilities can actually be counterproductive to bicycle safety by:

- placing users where conflicts with other traffic may not be expected;
- encouraging unsafe or unlawful behavior such as riding against the flow of traffic; and
- failing to properly address the vehicular nature of bicycle travel.

Design References

The most notable and reputable design reference for bicycle facilities in the U.S. is the *Guide for the Development of Bicycle Facilities*, published by the American Association of State Highway and Transportation Officials (AASHTO). This document contains planning, design, maintenance, and operations information for bikeways, roadways, and other facilities used by bicyclists. AASHTO is expected to publish a revised edition of this guide in 2012.

Several states and cities have also adopted bicycle transportation plans, design guides, and facility development manuals. Contact your state department of transportation or local transportation agency for more information.

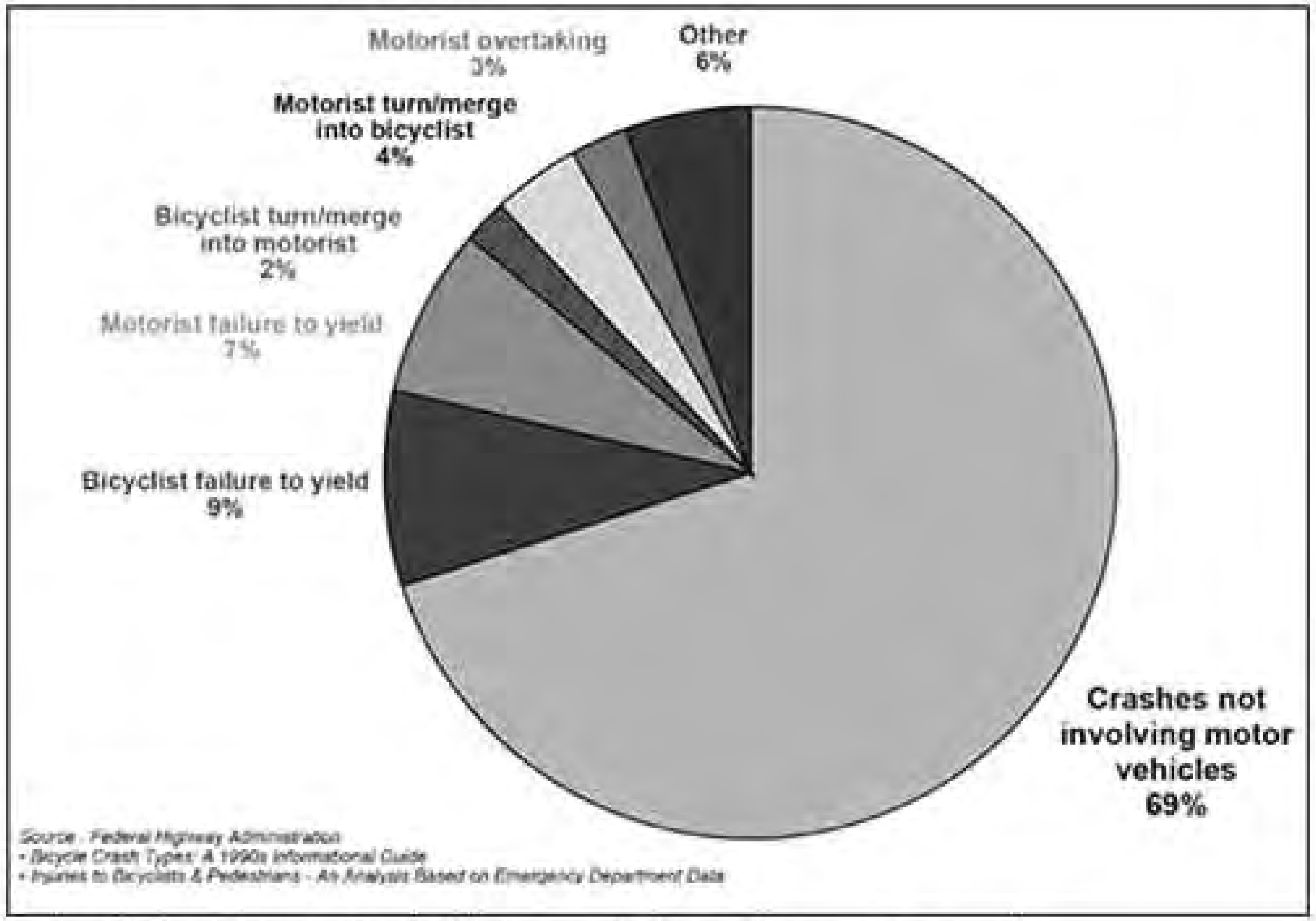
Recently, the National Association of City Transportation Officials (NACTO) has published an *Urban Bikeway Design Guide* on the NACTO website.[2] Several of the traffic control device treatments included in the NACTO document are approved for use in the MUTCD, but some treatments in the NACTO *Guide* are still considered experimental as of the writing of this *Handbook*, and use of those treatments will require approval by the Federal Highway Administration (FHWA) in accordance with Section 1A.10 of the 2009 MUTCD. Practitioners consulting the NACTO *Guide* should also review the MUTCD to determine whether TCDs in the proposed treatment are included in the MUTCD at the time the treatment's implementation is intended, and should also review other established design references, such as the AASHTO *Guide*, to determine if these other references contain information that might affect the decision to select a specific treatment. At the time of publication of this *Handbook*, FHWA maintains a website that provides the current MUTCD status of various treatments.[3]

Note that if there is a discrepancy between the current MUTCD and a bicycle facility design guide (including this one, in fact), the standards or guidance in the MUTCD supersede the direction or content in the design guide. No design guideline has the authority to overrule the MUTCD in defining standards and guidance for TCDs on bikeways and other facilities open to public travel.

Bicycle Crash Types

Studies have estimated that 70 percent or more of all bicycle crashes do not involve a motor vehicle.[4] Other studies have noted single-bicyclist falls comprise about half of all bicycle crashes.[5] This emphasizes the importance of providing a smooth and unobstructed area for bicycle travel whenever practical. Figure 14-1 presents a breakdown of total reported bicycle crashes by type, with bicycle-motor vehicle crashes broken down by sub-type.

FIGURE 14-1. Types of Bicycle Crashes as a Percentage of Total Reported Crashes



SOURCE: Richard Moeur, FHWA Reports *Bicycle Crash Types: A 1990s Informational Guide* and *Injuries to Bicyclists & Pedestrians—An Analysis of Emergency Department Data.*

Of the remaining percentage of bicycle crashes that involve a motor vehicle, between 50 and 70 percent occur at intersections or driveways.[6] Accommodating bicyclists in a manner consistent with other vehicular traffic can reduce the potential for crashes, since this fits well with the expectations and behaviors of other road users. This can be achieved through the use of on-street facilities such as shared roadways and bike lanes, and by not channelizing bicyclists onto sidewalks or into unexpected or inappropriate locations at intersections.

Of particular note is that overtaking-type collisions comprise a relatively small percentage of motor vehicle-bicycle collisions, and an even smaller percentage (approximately 3 percent) of total bicycle crashes. Yet there is a widespread perception that overtaking-type crashes are the primary threat to bicyclists due to the high frequency of overtaking maneuvers by motorists passing slower bicyclists, and the perception of a fast object approaching from a difficult-to-see direction for the bicyclist being a greater threat than other more-visible potential conflicts. It is very important for transportation professionals to recognize that in most circumstances the relative risk of overtaking-type crashes is small compared to the risk of crashes at intersections and driveways. Also, many popular proposals to reduce the chance of overtaking crashes, such as the use of parallel sidepaths, can greatly increase crash risks at intersections and driveways (see the section of this chapter dealing with "Problems with Adjacent Separated Paths"). It should be noted overtaking-type crashes do make up a disproportionately high percentage of fatal motor vehicle-bicycle crashes, especially in rural areas. However, such crashes frequently involve bicyclists with insufficient or no rear lighting or reflectorization, or involve impaired drivers or bicyclists.

In recent years, there has been a much greater awareness of the cyclist crash risk posed by suddenly opened driver-side vehicle doors. Historically, these crashes were not recorded in agency databases, since they did not involve a motor vehicle in transit. In addition, bicyclist education materials published in previous decades made the assumption a bicyclist could see and avoid an opening door at normal travel speeds. However, analyses of "dooring" crashes indicate a door can open into a bicyclist's path much faster than the bicyclist can react (typically in less than one-half second). There have been reports from some U.S. cities that these collisions comprise a relatively high percentage of injury crashes, with several fatalities reported. A later section of this chapter describes pavement marking treatments that can reduce the risk of these types of crashes by channelizing bicyclists away from the "door zone," i.e., the area occupied by the opening vehicle door.

FHWA and the National Highway Traffic Safety Administration (NHTSA) have developed a Pedestrian and Bicycle Crash Analysis Tool,[7] which can be used to analyze reported bicycle-motor vehicle crashes to develop reports and recommended countermeasures. Contact FHWA for more information.

Legal Issues

Since before the invention of the automobile, courts have recognized bicyclists have the right to use public roads and highways in reasonable safety, and that operating agencies owe bicyclists due care in designing, operating, and maintaining all roadways not specifically prohibited to bicycle travel.

The UVC, which has historically served as the nationally recommended model for state traffic laws, and a number of state vehicle codes, specifically defines bicyclists as vehicles. Other states, although they may not specifically define bicyclists as vehicles, recognize bicyclists have the same rights and responsibilities as other vehicle operators.

Bicycle facilities, whatever the type, should not encourage bicyclists to operate in a manner inconsistent with standard traffic laws and traffic flow, as this will likely result in operational and safety problems at the locations where this occurs, and can encourage and reinforce behavior types linked to significantly increased risk of conflicts and crashes.

Unfortunately, some members of the public see bicyclists as "pedestrians on wheels," and believe pedestrian-oriented rules and laws should apply to bicyclists. One very notable example is the persistent belief bicyclists should ride on the left-hand side of the roadway, against the flow of traffic, in a manner similar to pedestrians on roadways without sidewalks or shoulders. This behavior is associated with greatly elevated risk of many common crashes, and traffic control devices may be employed to try to change this behavior (see details elsewhere in this chapter).

Bikeways and Liability. Federal and state laws, regulations, and policies encourage the development and establishment of bikeways. However, a recurring concern of agencies and landowners is how the designation of a bicycle facility might affect the liability or risk management exposure of the facility operator.

Immunity and exposure to tort liability for public agencies and public and private landowners can vary greatly from state to state.[8] Some agencies have strong immunity under tort claims and recreational use laws in their state. It should be noted recreational use statutes can apply to facilities used by non-recreational traffic, such as a pathway used by commuting bicyclists. In addition, some states have statutory caps on damage claims made against public agencies. However, in other states, laws and legal precedents can create a legal climate where agencies face limited or no immunity for decisions or actions, and unlimited exposure to claims.

Some decisions made by agencies in the course of their duties are considered discretionary, and may be exempt from tort claims. Examples may include a decision to designate a travel way as a bikeway, or to install or remove signs, markings, and other devices in accordance with the MUTCD and local policies. Documentation of discretionary decisions noting how agency discretion was exercised may be advisable in helping defend against future claims. Other agency actions are classified as operational and ministerial, and might not be covered by immunity. Examples may include maintenance of existing installed signs, markings, and other devices.

Many claims by bicyclists against agencies or landowners arise out of allegations the agency or landowner had notice of a hazardous condition and failed to either correct the condition or provide adequate warning of it. Bicyclists are more susceptible than other road users to some roadway surface conditions, such as open gaps or slots in drainage grates, longitudinal cracks in the pavement surface, or uneven pavement edges. In some states, courts have held agencies liable for such hazards; but in other states agencies have maintained immunity on the basis of tort claim or recreational use statutes. Note designation of the facility as a bikeway may have little bearing on claims of this type, as an agency may be responsible for these conditions on all roadways and pathways open to bicycle travel. A recent research digest published by the Transportation Research Board on this topic[9] notes an extremely low incidence of reported cases where a tort claim was filed based on whether an agency designated a particular facility as a bikeway.

An agency can reduce its liability exposure by creating a program of documenting road and path surface conditions and maintenance activities, and by proactively addressing damaged or missing traffic control devices or roadway or pathway surface imperfections.

Bicycle Facility Type and Roadway Traffic

The speed and volume of motor vehicle traffic can be important factors in selecting what type of bicycle facility to install in a specific location, but judgment should be used in determining what weight should be given to these factors. In general, bicyclists prefer to operate near slower rather than faster traffic, and prefer to ride on facilities with lower traffic volumes. But often times, the destinations bicyclists want to reach are most accessible from higher-volume or higher-speed roadways. Also, some high-speed and high-volume roadways can provide a high quality of service to bicyclists, especially if a shoulder or other added roadway width is provided. Traffic volume and speed should not be used as justifications for not providing bicyclist accommodation along a roadway.

At the time of this writing, there has not been a large amount of robust or detailed research in regard to the types of bicycle accommodations on roadways best suited to various traffic speed and volume conditions in the United States. Some guidelines and aggregations of local practice have been published, but these are not based on observed research data, but on conjecture and rule of thumb. There is also a tension in setting guidelines between minimizing crash rates or creating perceived comfort for bicyclists, with optimizing one goal possibly working against another, e.g., a separate sidepath may be perceived as most comfortable by less-confident bicyclists, but may have very high crash rates at intersections.[10]

There are a variety of design guidelines developed outside the United States that use traffic volume and speed as primary determinants in the selection of facility type. Caution should be exercised in the use of non-U.S. design guidance, because driver behavior and condition, roadway characteristics, and traffic laws and regulations are typically significantly different than in the U.S. For example, some European design guides call for the installation of segregated pathways when traffic volumes and speeds exceed certain values. In the U.S., such paths can be problematic at intersections, and can actually increase crash frequency due to differences in ingrained scanning and operating behavior at intersections between European and U.S. drivers.

TABLE 14-2. Bicycle Facility Type by Roadway Speed, Volume, and Classification (U.S. Practice)

		Motor vehicle speeds		
		Low	High	Freeways & Expressways
Traffic volumes	Low	Shared roadway	Shared roadway Shoulders	Shoulders
	High	Shared roadway Bike lanes	Shoulders Bike lanes	Shoulders Separate path

SOURCE: Richard Moeur.

Characteristics of Bicyclists

Physical Parameters. There are many different types of non-motorized wheeled conveyances encompassed by the operational and legal definition of "bicycle."[11] These include, but are not limited to:

- conventional bicycles;
- tandem and multiple-rider bicycles;
- adult tricycles;
- recumbent bicycles and tricycles;
- hand-powered cycles; and
- bicycles with trailers (either one-wheeled or two-wheeled).

A typical bicycle and its rider have a total physical width of about 30 inches (750 mm). However, due to the need for bicyclists to adjust their travel paths to remain balanced and to avoid obstructions, additional width is needed for effective operation. Recent design guidance recommends a minimum operating width of 4 ft. (1.2 m) in each direction for bicyclists,[12] which will provide minimal adequate width for use by most tricycles and trailers. The recommended width for single-lane bicycle facilities is least 5 ft. (1.5 m) in each direction, to allow for lateral movement to avoid obstructions. If there is a curb, barrier, or other fixed object bordering or immediately adjacent to the bike-way, bicyclists will typically adjust their travel path to place some "shy distance" between their vehicle and the fixed object, and additional width may be useful or needed to accommodate this shift in travel location.

The height of bicyclists varies with age, stature, and bicycle type. A minimum clearance of 8 ft. (2.4 m) should provide clearance for all reasonably foreseeable bicycle users, and will provide adequate clearance for typically used maintenance vehicles. This minimum clearance is also reflected in Figure 9B-1 of the 2009 MUTCD.

Operating and Design Speed. Typical operating speeds for bicyclists can vary significantly from a 15th percentile speed of 8 mph (13 km/h) for hand-cyclists to an 85th percentile speed of 18 mph (29 km/h) for recumbent bicyclists on level terrain.[13] Bicycle facilities may occasionally be used by electric-assist bicycles that can operate at speeds near 18 to 20 mph (29 to 32 km/h) for extended periods. If not prohibited (and enforced), bicycle facilities may also be used by motorized bicycles or mopeds capable of speeds of 25 mph (40 km/h). However, most design guides recommend using 18 to 20 mph (29 to 32 km/h) as a guideline for design speed on level terrain, with higher design speeds up to 30 mph (50 km/h) used on descending grades.

Turning and Stopping. As noted earlier, bicycles, like any other wheeled vehicle, have turning radii and stopping distances that are dependent on operating speeds. The most recent edition of the AASHTO *Guide for the Development of Bicycle Facilities* contains formulas and nomographs for determining turning and stopping distances for typical bicyclists.

Trip Classification

Bicycling trip purposes are as varied as bicycling itself. In general, and for the sake of this chapter, bicycle trips can be classified into two major types, recreational and for transportation.

Recreational trips can be broadly defined as riding for pleasure. The destination may be important, but it is not the primary objective. Exercise, touring, and fun rides with family and friends all fall under this category. Recreational bicycling is done on all types of facilities, but some facilities, such as shared-use paths in parks and along waterways, see much of their rider volume due to recreational trips.

Transportation or utility bicycling is defined as that serving specific destinations; e.g., trips to work, school, stores, offices, etc. The destination could even be of a recreational nature (e.g., sporting, entertainment, etc.), but in these cases the bicyclist simply seeks to use the bicycle as a means to get to the recreational activity, not necessarily as recreation itself. The primary objective of these trips is to reach a destination quickly with minimum effort, with few interruptions, and without unnecessary detours or delays. Major streets frequently offer the best service in terms of minimum distances or delays, but may be intimidating to less-experienced bicyclists if wide shared lanes or bike lanes are not present.

These trip purposes do not necessarily define the personal traits of the bicyclist, or the type of traffic control devices required. An understanding of the differences in bicyclists' purposes for riding can be an important element in designing a network of facilities that is responsive to the needs of users.

Traffic Control Devices vs. Education

Bicycle facilities are expected to accommodate a wide assortment of users of different ages, skills, and education levels. In an ideal world, it would be wonderful to have a uniform set of bicyclists fully trained and skilled in operating on a wide variety of facilities. We must recognize, though, that many of the bicyclists currently using our transportation network are not uniformly well trained, nor are they always comfortable in using the same facilities as other road users. While this may indeed describe the current situation, this does not mean we should assume all users will never be trained, or give up on the considerable benefits of education.

Bicycle facilities cannot compensate for lack of proper bicyclist education, or somehow grant an inexperienced rider the set of knowledge and skills needed for safe operation on transportation facilities.

Bicyclist education programs, such as the Smart Cycling program of the League of American Bicyclists[14] and the Cycling Savvy education program,[15] have proven effective in reducing crash and conflict rates. These programs teach youth and adult bicyclists the principles of vehicular operation and proper techniques for bicycling in the presence of other traffic. Some of these programs also have motorist education modules, to inform and make motorists aware of the presence, rights, and responsibilities of both motorists and bicyclists.

A reduction in crash rates is also correlated with increased experience.[16] However, this is not a satisfactory substitute for instructional programs, given that many bicyclists may continue unsafe riding patterns in the absence of proper instruction, or may not ride enough to gain the necessary experience.

Enforcement of traffic laws is also a very important part of bicycle safety. Bicyclists who violate traffic laws by riding against traffic and disobeying STOP signs, signals, and other TCDs comprise a high percentage of total motor vehicle-bicycle crashes.[17] This is not surprising, since such right-of-way violations place bicyclists at far greater risk from turning and crossing motor vehicle traffic. Also, motorists who disobey traffic laws and traffic control devices endanger bicyclists, and enforcement efforts should be targeted against these violators as well.

Bicycle Parking

The provision of convenient and secure parking is an important element in encouraging bicycle travel. Surveys indicate one of the greatest impediments to bicycle use for work, shopping, and other trips is the lack of useful parking at these destinations.

Bicyclists strongly prefer to park at or near the entry points to their destinations, so it is advisable to provide parking at these locations. If parking cannot be provided, then Bicycle Parking (D4-3) signs can be used to direct bicyclists from entry points to designated or provided parking areas. Bicycle Parking signs can be combined with other guide signs if needed to provide detailed information on parking and other amenities.

More information on providing secure and convenient bicycle parking may be found in other references, such as the *Bicycle Parking Guidelines* published by the Association of Pedestrian and Bicycle Professionals.

SIGNING FOR BICYCLISTS

Design Issues

Sign Effectiveness. This cannot be overly emphasized: *The presence of a sign does not ensure compliance with that sign.* There are countless examples of signs that were installed under the direction of capable and responsible professionals with the best of intentions, and conform fully with all guidelines regarding size, shape, color, and placement—and yet have no effect at all, or worse, create the impression conditions are improved when in fact they are not. Practitioners should recognize there are situations where signs, markings, and other devices may be ineffective or counterproductive. These situations may include:

- using traffic control devices to try to change or counteract ingrained and conditioned behavior.

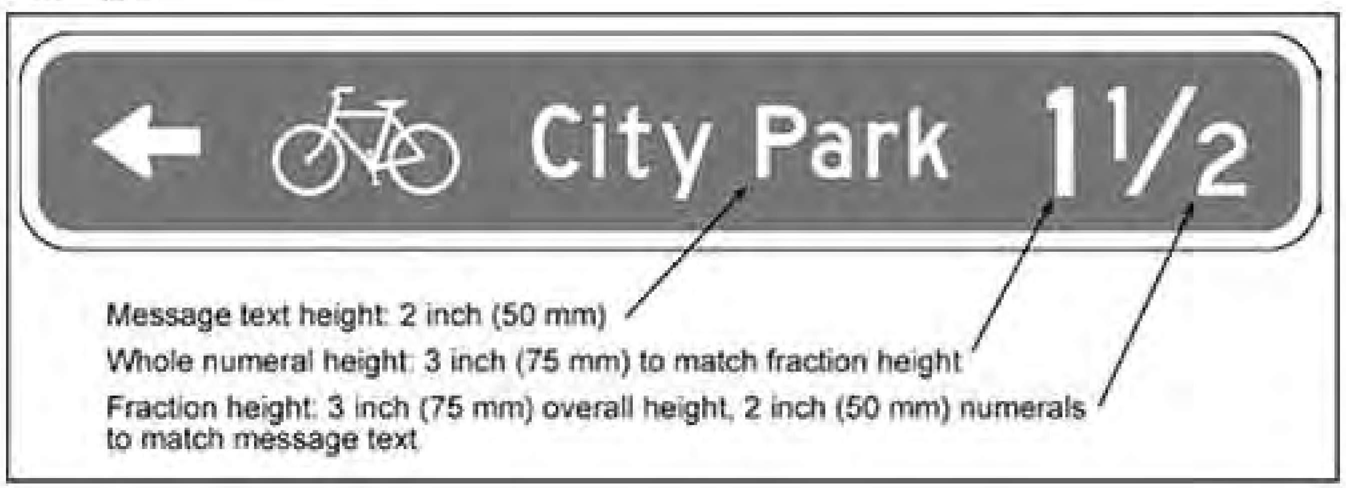
  Example: A STOP sign is installed on a pathway where it crosses a local street with low traffic volume and good sight distance. Based on observed experience, nearly all bicyclists using the path will scan for cross traffic, then proceed without coming to a full stop. In these locations, it would be more consistent with appropriate observed behavior to use a YIELD sign on the path. It may even be appropriate to place YIELD control on the local street in accordance with Section 9B.03 of the 2009 MUTCD—see the section of this chapter dealing with "Path Signing."
- using traffic control devices to direct road users to perform unexpected actions.

  Example: A two-way separated path crosses a roadway immediately adjacent to (or as part of) a roadway intersection. At these locations, experience has shown the likelihood of serious conflicts between path users and turning and crossing motor vehicle traffic. There may be consideration given to installing signs on the intersection approaches warning of these potential conflicts. However, warning signs of this type are very ineffective in inducing drivers to look for potential conflicts from unexpected directions—and, as noted above, can create the impression that safety is ensured due to the presence of these conspicuous warning signs.

Letter, Numeral, and Symbol Size. All signs intended to warn, regulate, or guide motor vehicle traffic and bicyclists should conform to the design guidelines in Part 2 of the 2009 MUTCD. As previously noted in this chapter, 18 to 20 mph (29 to 32 km/h) are typical values used for design and operating speeds on bikeways in level terrain. The majority of signs in Part 9 of the MUTCD designed and directed specifically for bicyclist warning, guidance, and regulation use a minimum letter height of 2 in. (50 mm), which is one-third the height used on equivalent signs on conventional roadways, and corresponds roughly to the ratio of maximum design speeds for these types of facilities. If an agency is designing signs intended solely for bicyclists and pedestrians, 2 in. (50 mm) minimum letter heights are strongly recommended to maintain legibility at typical bicyclist speeds. Larger text may be used for emphasis or for increased legibility. Signs intended for bicyclists and motor vehicle traffic should use larger panels, text, and symbols in accordance with Part 2 of the 2009 MUTCD.

Numerals used on signs on bikeways are typically the same height as the corresponding messages; i.e., 2 in. (50 mm) for bicycle-specific signs. In the case of a distance to a destination that is a fraction of a whole mile, it is typically best to use a fraction instead of a decimal mileage, as the small decimal point could be missed in a glance reading of the sign. Numerals within fractions use the same height as the corresponding message, but the total height of the fraction, including the solidus (slash), is 150 percent of the height of the corresponding message, as required by Section 2A.13 of the 2009 MUTCD. It is inadvisable to use smaller numerals in the fraction in order to make the total fraction height the same height as the corresponding message text, as it greatly reduces the legibility distance of the fractional part of the sign message. In signs with fractions, 50 percent larger whole numerals may be used to match the height of the fraction, and to keep the fraction from looking disproportionately large compared to the entire distance message. (See Figure 14-2.)

FIGURE 14-2. Example of Fractions on a Bicycle Guide Sign



SOURCE: Richard Moeur.

Sign Layout. Whenever it is reasonably possible and appropriate, standard signs, as shown in the MUTCD, should be used on all categories of bikeways. This is especially important for regulatory and warning signs. See the section of this chapter dealing with "Types of Signing" for more details on the use of these signs on bikeways.

If a situation does arise where a standard sign in the MUTCD will not function effectively, agencies may design a special sign to suit the condition. However, any special sign must conform to MUTCD standards and guidance on sign color, layout, shape, and placement.

When designing a special sign, remember these sign layout guidelines:

- Bicyclists and other road users operate in an environment where they do not have the ability to focus on a sign for a long period of time. Signs should be designed to convey information quickly and accurately at a single glance.
- Keep legend to a minimum, but do not minimize legend to the point where the sign message is unclear, cryptic, or possibly misunderstood.
- Size the panel to the legend, maintaining appropriate spacings between lines, between symbols, dividers, and other features, and from the legend to the outside border.
- When parsing legends, remember it lakes longer to read multiple lines than a single longer line. In some cases, however, the shape of the sign panel may control the parsing and placement of sign legends.
- Be aware not all readers will understand and interpret a sign in the same manner as the designer. Each road user brings their own set of knowledge, understandings, assumptions, and experience to the vehicle operation task, and a sign message that seems intuitively obvious to the designer may be interpreted in a completely different manner by others. It is a very good idea to either formally or informally circulate sign design concepts to others for review, especially to those who might have different backgrounds and experiences than the designer.
- If a sign design becomes too complex for reading at a single glance, consider splitting the message (if feasible) onto multiple signs spaced at an appropriate distance, or simplifying the message.
- If the sign contains non-critical information, such as supplemental information about an area or park hours, then consider installing the sign at a location where bicyclists are likely to stop for a period of time, such as at a turnout that might have picnic tables or water fountains. Do not install such signs on the main travel path of a bicycle facility, as cyclists will either not read them or may stop in the traveled way to read them, either of which can create operational problems and conflicts. Do not install these signs at or near intersections, as they may distract from more-critical detection and navigation tasks, and may block sight lines.

On all types of signs, standard FHWA-approved symbols should be used whenever possible, and these symbols should be used only in the manner and context permitted by the MUTCD. If for some reason no standard symbol will work, and a word legend will not work in lieu of a symbol, then consult Section 1A.10 of the 2009 MUTCD for the steps to follow in obtaining experimental approval from FHWA for evaluating a nonstandard symbol.

If considering designing or using a nonstandard symbol for experimental use in accordance with Section 1A.10 of the 2009 MUTCD, the following guidelines are strongly recommended:[18]

- Operators of bicycles and motor vehicles are in an environment where many urgent tasks and pieces of information are competing for their attention. Drivers are operating complicated equipment, often at considerable speed, and bicyclists must balance, steer, pedal, and navigate while paying attention to signs and other items in their surroundings.
- Symbols (or groups of symbols) must be accurately detected, interpreted, and understood at a single glance, along with all other sign content.
- A symbol should convey a clear and unambiguous message.
- Symbols (and other sign features such as text) should be sized for adequate detection and reading time by the intended road user. Symbols intended for motorized and bicycle traffic should be large enough to be read at motor vehicle speeds.
- A symbol or pictograph should be simple, without detail or embellishments that cannot be readily discerned by a distracted moving observer; but should not be so abstract it fails to be recognized or convey the intended message.
- A symbol should be relevant to its context in the roadway or pathway environment.
- A symbol should be consistent with and function within the existing system of symbols used on U.S. signs.

Not all concepts can be accurately represented in a symbol or set of symbols (at least not in a legible manner in a roadway environment):

- Spatial orientation of elements on a sign panel affects comprehension—viewers will read meanings or messages into how or where a symbol or symbols are placed on a sign, even if such messages were not intended by the sign designer.
- A symbol or pictograph should be reviewed to verify unintended messages are not sent by symbols or combinations of symbols or designs, which could create a potentially confusing or misleading message. For example, a pine tree in a pictograph could be interpreted by some viewers as an arrow.
- Conspicuity may assist in sign detection, but will likely not have much effect on sign legibility. And some treatments that increase conspicuity may actually decrease legibility by distracting from more-critical elements on the sign.

Types of Signing

Bikeways, just like any other vehicular transportation facility, use a variety of signs to convey important warning, regulatory, and guidance messages. Each category encompasses different varieties of signs that convey specific information to bicyclists and other road and path users. For example, guide signs include wayfinding, destination and distance, route information and trailblazing, location reference, and other types of informational signs.

Signs should be placed in a manner that optimizes visibility and potential effectiveness. However, it is inadvisable to mix different types of signs—such as a regulatory and a warning sign—on a single post; this can result in conveying an ambiguous or confusing message, or not allow adequate time for proper interpretation and response to each sign message. Specific exceptions are permitted where appropriate when a sign combination assists in providing useful information in context, such as placing a street name sign above a STOP or YIELD sign at an intersection. It is also inadvisable to install too many signs on one post or in one location for these same reasons.

Regulatory Signs. As noted in the MUTCD, regulatory signs inform road or path users of selected traffic laws or regulations and indicate the applicability of any legal requirements. Regulatory signs should be installed at or near where the regulations apply, and should clearly indicate the requirements imposed by the regulations. Like any other sign, regulatory signs should be designed and installed to provide adequate visibility and legibility in order to obtain compliance.

In most cases, it is not effective to post signs that simply confirm general regulations. Such signing tends to increase sign clutter and may result in more-critical signs being overlooked. However, in situations where road or path users may be unaware of a law or regulation, and this lack of awareness may result in operational problems, it may be appropriate to place signs reminding of the law or rule. One example is the BICYCLES MAY USE FULL LANE (R4-11) sign, discussed in greater detail elsewhere in this chapter.

In locations where wrong-way bicycle travel is a problem, Bicycle WRONG WAY (R5-1b) and RIDE WITH TRAFFIC (R9-3cP) signs have been used. Wrong-way travel by bicyclists is a major cause of conflicts and collisions, and should be discouraged at every opportunity. These signs may be mounted back-to-back with other signs to minimize visibility to other traffic (see Figure 14-3).

FIGURE 14-3. Example of Bicycle Wrong Way Signing (Tucson, Arizona)

SOURCE: Richard Moeur.

More information on specific uses of regulatory signs, such as STOP or YIELD signs on pathways, may be found in the specific sections on those facility types elsewhere in this chapter.

Warning Signs. If a bicycle facility is designed and constructed in accordance with recognized guidelines, with good sight distance at intersections, adequate width, and appropriate geometric elements, the need for warning signs is minimized. But given constraints in right of way, alignment, intersection location and sight distance, and road user conditioning and expectations, there may be situations where the use of warning signs may be appropriate. However, warning signs should not be overused, such as installing warning signs at every intersection along a bikeway. (See Figure 14-4.)

FIGURE 14-4. Overuse of Warning Signs

SOURCE: Richard Moeur.

All warning signs used on bicycle facilities should conform to the specifications for color, shape, placement, and mounting height in the MUTCD. Most warning signs on bikeways should use a diamond-shaped panel, unless a different design is specified (such as for a Large Arrow [(W1-6] sign), or the design of the sign makes it impractical to use a diamond-shape panel. The color of warning signs for permanent, temporary, pedestrian, and school conditions and locations should conform to Table 2A-5 of the 2009 MUTCD.

Recommended advance placement distances for warning signs on bikeways shared by motor vehicle traffic (such as a shared roadway or bike lane) are given in Table 2C-4 of the 2009 MUTCD. There is no table corresponding to Table 2C-4 for advance placement distance for warning signs on shared-use paths, so engineering judgment should be used to determine the optimum location, taking into account design and operating speed, and adequate sight distance.

There are roadway conditions that can cause problems for bicyclists, such as diagonal railroad tracks or areas with surfaces that may provide poor traction for bicycle tires, such as metal plates or grates. In these locations, a Bicycle Surface Condition (W8-10) sign should be used based on engineering judgment and other factors, such as analyses of crash reports. A supplemental plaque describing the specific condition may be used in conjunction with the W8-10 sign.

More information on the use of warning signs on specific facility types may be found in the specific sections on those facility types elsewhere in this chapter.

Guide and Information Signs. D1 series signs, either with or without bicycle symbols, can be used independently on paths to provide useful destination and guidance information for bicyclists. These destinations may be local in nature, including popular cultural or recreational sites such as parks, trails, or museums, or provide guidance to more desirable routes to employment or commercial destinations.

Other types of guide signs, such as traveler services (D9 series) signs as seen in Chapter 2I of the 2009 MUTCD and recreational and cultural interest (RS series) signs as seen in Chapter 2M in the 2009 MUTCD, may also be used to provide guidance to services and activities along a bikeway.

A later section in this chapter contains information on the use of reference location (milepost) signs on shared-use paths.

Note the 2009 MUTCD now requires the use of mixed-case (upper and lower case) lettering for all place names, street names, and other destinations on guide and information signs.

Wayfinding and Trailblazing. When using any type of sign for guidance, it is important to provide the following information at the appropriate locations:

- advance notice of a turn, change in alignment, or decision point;
- directional guidance to relevant destinations;
- confirmation the selected route is correct; and
- reassurance the traveler is following the correct route to the desired destination.

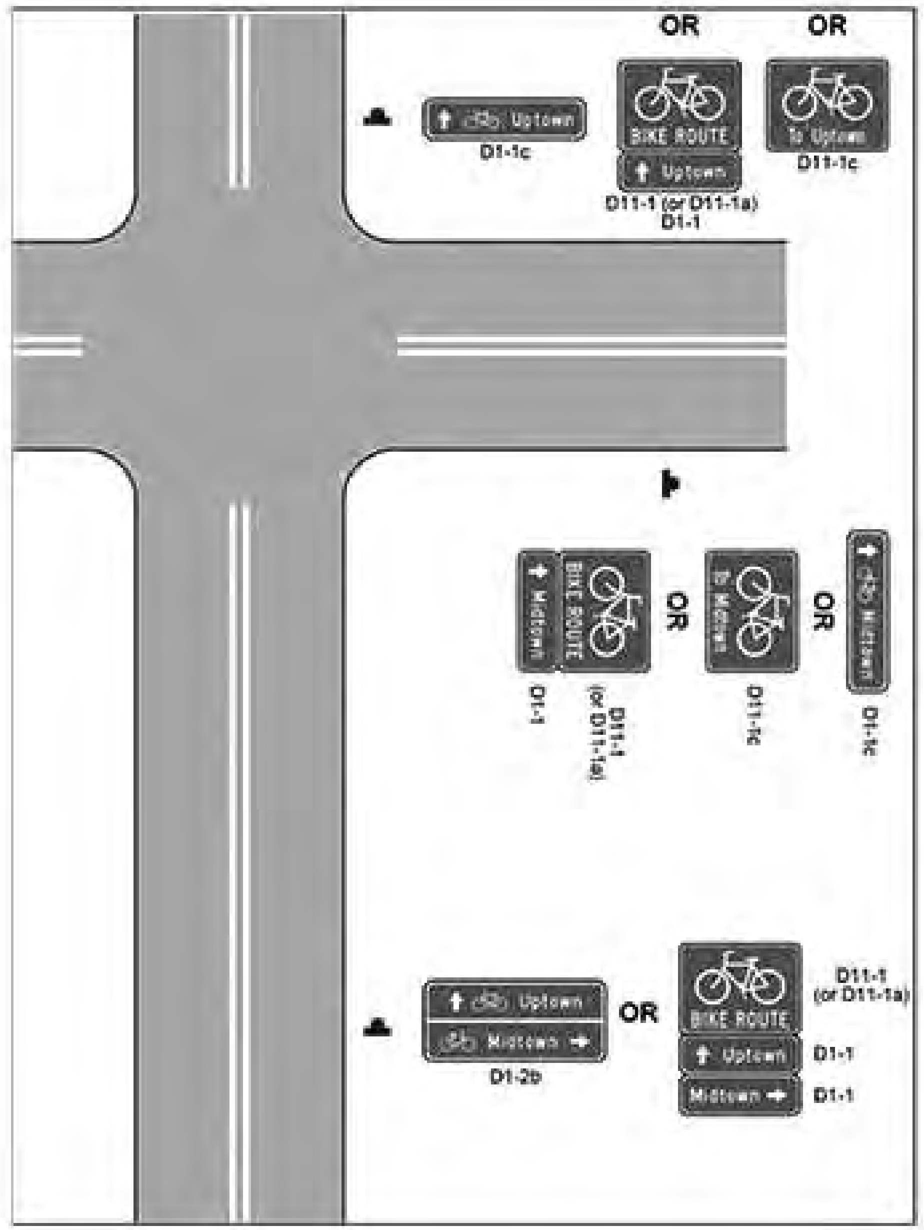
The use of wayfinding and guide signs with destination and distance messages can significantly improve the ability of bicyclists to navigate urban, suburban, and rural roadway and pathway environments by providing useful information on routing, travel distance, and destinations.

Note Figure 9B-4 of the 2009 MUTCD adds several new types of guide signs for bicyclists, among them:

- Bicycle-specific D1 series destination and distance signs: scaled-down versions of standard D1 signs, with a bicycle symbol added to clearly denote the information on the sign is intended for bicyclists. These are used in a manner similar to D1 series signs in Figure 2D-7 of the 2009 MUTCD, with the ability to display up to three different directions and/or destinations on a single panel.
- D11-1c routing signs: an adaptation of the long-established D11-1 sign, which takes the "content-challenged" BIKE ROUTE message and replaces it with more specific destination or route guidance.
- D11-1a, D11-2, D11-3, and D11-4 mode-specific guide signs, which can be combined with other guide signs to provide guidance information.

Figure 14-5 depicts these different types of signs as used as guide and wayfinding signs for bicycle travel.

FIGURE 14-5. Example of Guide Signs on an On-Street Bikeway



SOURCE: Richard Moeur.

All of these types of signs can be used to convey the following information:

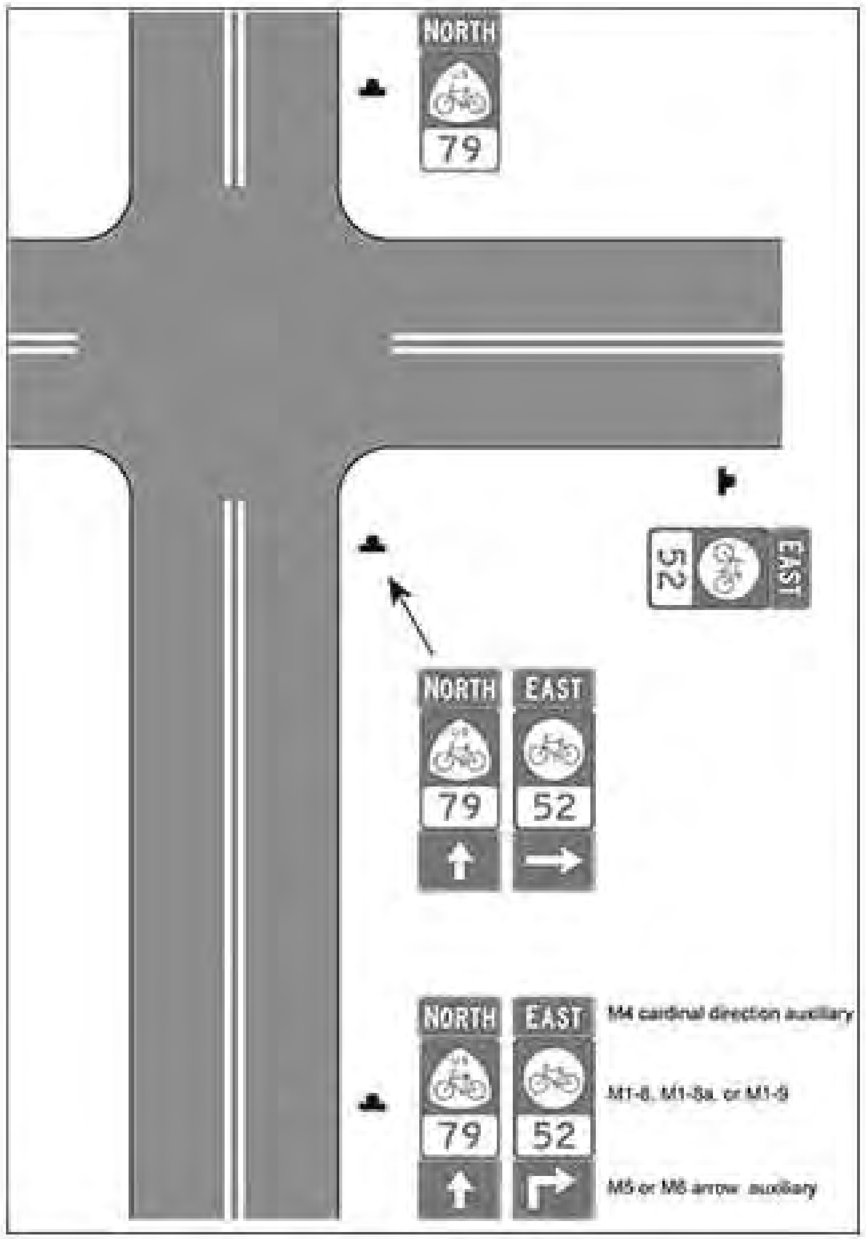
- directions and distances to destinations;
- trailblazing along a preferred bicycle route;
- guidance on how to join or follow a route that provides an alternate route avoiding a busy highway or around a geographic barrier; or
- confirmation and reassurance to confirm a designated route continues, such as on a departure from an intersection.

Bicycle-specific destination and wayfinding signs may optionally include estimated travel times to destinations, in addition to listing the distances. When calculating these times, it may be a good practice to use a conservative travel speed such as 10 mph (16 km/h), and take into account delays induced by signalization or other factors. If including travel times on a bicycle guide sign, display the travel time in a text size similar to that used for distances, typically using a 2 in. (50 mm) minimum letter height.

Bicycle Route Signing. BIKE ROUTE (D11-1) signs are the signs most frequently used to designate shared roadways as bikeways. However, these signs provide little route guidance information, other than to simply state the facility is a designated route for bicycles. D11-1 signs should not be used alone, but in conjunction with bicycle-specific D1 series guide signs as shown in Chapter 9B of the 2009 MUTCD. Figure 14-5 shows one example of the use of D11-1 or D1 series signs on an on-street bikeway, while Figure 9B-5 of the 2009 MUTCD shows an example of bike route signs for an off-street bikeway.

Designated/Numbered Routes. Numbered Local Bicycle Route (M1-8 and M1-8a) signs can be used to establish a system of numbered routes on pathways or on-road facilities. These signs may be used for popular touring routes, to identify routes in a system of bikeways in urban areas, or to provide a bypass or alternate route for a parallel highway sharing the same number. The M1-8a retains the shape, color, and standard bike symbol and numerals of the M1-8, but allows the inclusion of a distinctive local or regional pictograph at the top of the oval. M5 and M6 series auxiliaries in appropriate sizes should be used with M1-8, M1-8a, and M1-9 signs as needed for trailblazing and route guidance. Figure 14-6 shows an example of this type of signing.

FIGURE 14-6. Example of Numbered Bicycle Route Signs



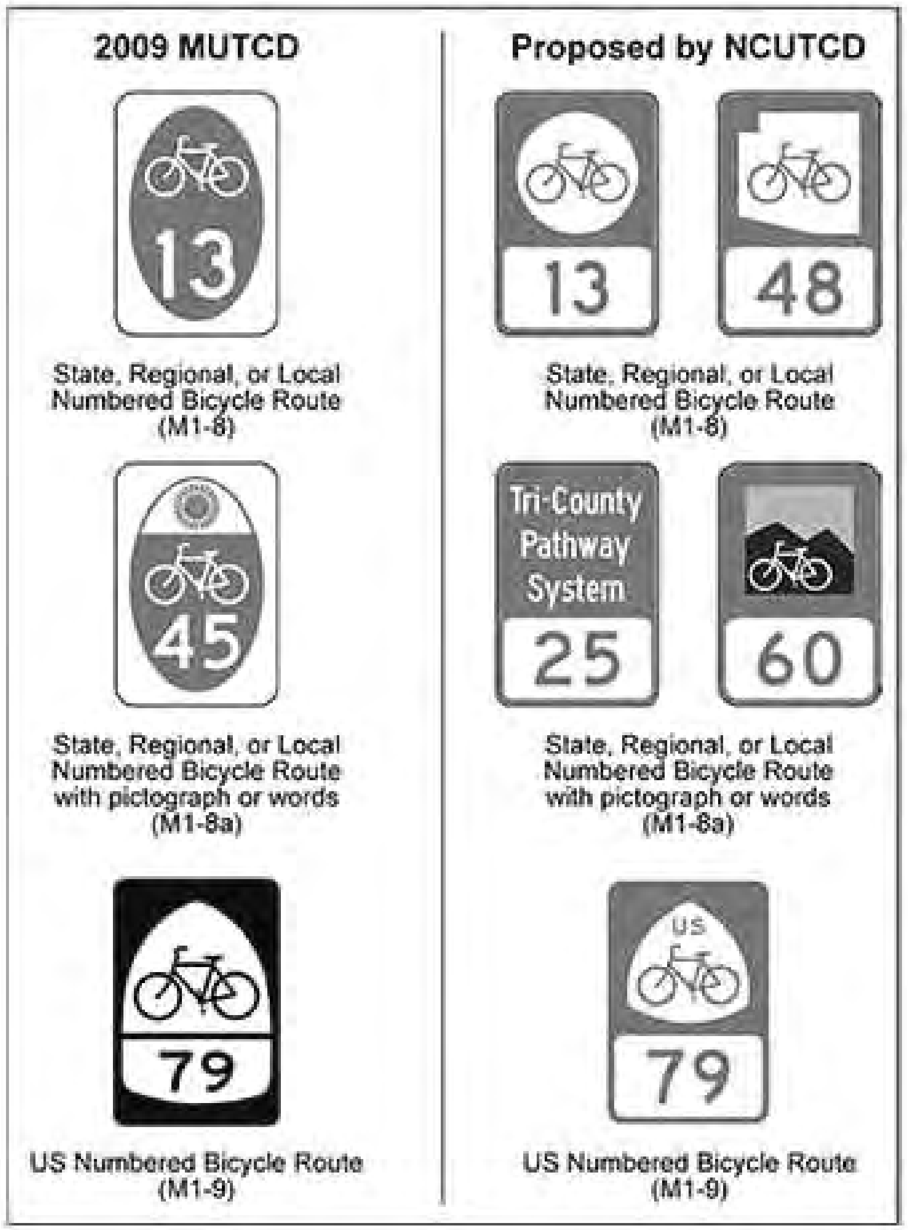
SOURCE: Richard Moeur.

If developing a pictograph for use on an M1-8a, consult the recommendations on symbol and pictograph design in the section on "Design Issues" in this chapter.

The National Committee on Uniform Traffic Control Devices (NCUTCD) has submitted a formal proposal to FHWA to revise the design of the M1-8 and M1-8a signs to eliminate the oval layout in favor of a rectangular design with the route designation at the bottom of the sign panel, which should allow for greater clarity and flexibility for state, regional, or local routes while maintaining a generally uniform design and presentation.

However, until the revised design is accepted into the, agencies wanting to use this new design should follow the process defined for Interim Approval or experimentation in Section 1A.10 of the 2009 MUTCD. Figure 14-7 shows the current and proposed designs of the M1-8 and M1-8a.

FIGURE 14-7. Existing and Proposed Signs for Numbered Bicycle Routes



SOURCE: Richard Moeur.

The U.S. Numbered Bicycle Route (M1-9) sign is the bicycle facility counterpart to the U.S. Numbered Route (M1-4) sign. It is similar to the U.S. Route sign in that its use is administered by AASHTO, and is intended for use on specifically numbered routes that extend for long distances through two or more states as identified in the AASHTO *U.S. Bicycle Route Corridor Plan.*[19]

The process for assigning a route number to a U.S. Bicycle Route is similar to that used when establishing a U.S. numbered highway route, and uses similar forms and procedures. Note AASHTO will only accept U.S. Bicycle Route numbering requests from state departments of transportation, and all affected states must submit their documentation in a coordinated manner. Information regarding the proposed route, including maps, termini, and pavement widths and conditions should be noted on the application forms.

NCUTCD has also submitted a formal proposal to FHWA to revise the design of the M1-9 U.S. Bicycle Route sign to improve its legibility and identifiability as a national-level route sign, and to make it more consistent with other route signs. However, until the revised M1-9 design is accepted into the MUTCD, agencies wanting to use this new design should follow the process defined for Interim Approval or experimentation in Section 1A.10 of the 2009 MUTCD. Figure 14-7 shows the current and proposed designs of the M1-9.

Non-Numbered Routes. Agencies and organizations have used designations other than numbers or letters to designate continuous routes. These usually take the form of systems of named routes, with names displayed on guide, wayfinding, and trailblazing signs along each route in a manner similar to numbered routes. These routes can be local or regional in nature, such as a City Circle Trail, or can extend through multiple states, such as the East Coast Greenway. If this type of system is used, it is advisable to use a consistent presentation of the route name in a manner that is clear and easy for travelers to follow, and does not distract from guidance or other messages.

Other Sign Types. Other types of signs may be used on bicycle facilities, such as temporary traffic control signs. Temporary traffic control on facilities shared with motorized traffic should conform to Part 6 of the 2009 MUTCD. On shared-use pathways, temporary traffic control should conform to the general principles and concepts of Part 6 of the 2009 MUTCD. Although the MUTCD does not include any bicycle-specific Typical Applications (TAs) at this time, NCUTCD and FHWA are developing TAs for bikeway traffic control for future MUTCD editions. In the meantime, existing TAs found in Chapter 6H of the 2009 MUTCD can be adapted for pathway work zones. For advance sign placement and tapers, a design speed of 20 mph (32 km/h) should be adequate for most expected conditions; higher speeds may be considered for pathways on downgrades.

Maintenance

Although signs, posts, and mounting systems are typically designed for long service lives, periodic maintenance may still be necessary. Signs are vulnerable to damage from graffiti and vandalism, especially in urban areas or on low-volume facilities. On pathways, signs are typically mounted closer to the ground, which may make them more susceptible to damage, vandalism, or graffiti. On pathways with lower user volumes (day, night, or both) or areas that cannot be readily seen from occupied areas, there may be a problem with sign theft. Missing signs (especially warning signs) could place an agency in an adverse tort liability situation if a crash occurs at that location. Given the significant increase in raw commodity prices in recent years, theft of recyclable metallic items from lightly traveled or unattended pathways has become a notable problem. Agencies can use non-recyclable sign panel materials, such as wood or plastic/aluminum composite, to reduce the scrap value of these signs, but these materials may be more susceptible to vandalism or damage.

Signs for bicycle travel on roadways are typically inspected at the same frequency and maintained in the same manner as other signs on that roadway. On pathways, it may be advisable to set up a regular pattern of day and night sign inspections to ensure all signs (and other devices) are present, visible, and in good condition. If performing a night inspection on a shared-use path, it may be advisable to use a bicycle equipped with a headlight that meets the specifications listed in state law to verify signs are adequately visible under nighttime conditions.

The 2009 MUTCD now requires agencies to develop management methods to ensure signs under their jurisdiction maintain adequate retroreflectivity for the signs' service life. See Section 2A.08 of the 2009 MUTCD for more information. Although Section 2A.08 specifically excludes bikeway signs intended for exclusive use of bicyclists or pedestrians from the minimum retroreflectivity requirements, it still may be advisable for an agency to inspect, maintain, and replace these signs as needed to minimize life-cycle costs and litigation risks.

MARKINGS FOR BICYCLISTS

Pavement markings are employed to reinforce and supplement signing and to communicate with the road user.

TABLE 14-3. Travel Areas Framework

	Travel Area	Description	Examples of bicycle-motor vehicle conflicts	Marking example (Bike Lanes)
BLOCK	B1-Corner	Corner immediately after intersection	Motorists turning into corner property driveways. Motorists entering from cross street	Solid line begins. First bike lane arrow and legend
BLOCK	B2-Mid-block	Away from intersections	Close passing	Solid line
BLOCK	B3-Transition	Approaching intersection; users shift laterally to line up for storage area	Crossing or weaving	Optional dashed line(s)
BLOCK	B4-Storage	Final approach. Users should have completed lateral shifts	Through bicyclist staying too far right risks right-turn cutoff ("hook") by motorist behind	If right-turn-only lane, there may be a through bike lane to its left. If not RTOL, dashed line
INTERSECTION	I1-Entry	Entering intersection, before through and right- turn movements have diverged	"Right hook" of through bicyclist by right-turning motorist	Optional dashed extension line(s)
INTERSECTION	I2-Middle	Within intersection, after through/right diverge, before cross street right-turn overlap	Bicyclist turning left on a wide arc may be at risk if there is a simultaneous opposing left turn	Optional dashed extension line(s)
INTERSECTION	I3-Exiting	Within intersection, where cross street right turns overlap and some through motorists are preparing to turn into corner driveway	Motorist turning right from cross street fails to yield to through bicyclist	Optional dashed extension line(s)

SOURCE: John Ciccarelli.

Markings may be particularly effective for bicyclists, as they are generally placed within the bicyclist's cone of vision.

"Travel Areas" Framework for Understanding Bikeway Markings

Most markings, including bikeway markings, are context-specific. Some are applicable where no intersection is nearby, others on approaches to intersections, still others within intersections. To understand the rationale for and placement of bikeway markings, particularly longitudinal markings, it is useful to think of roadway users passing through seven sequential "travel areas" as they traverse blocks and intersections. (Here "block" means a roadway segment outside of an intersection, which in rural areas may cover a considerable distance.)

The Travel Areas framework helps in understanding bicycle-motor vehicle conflicts and how bikeway marking practices can help or hinder bicyclists in avoiding or deterring these conflicts. Table 14-3 defines the framework and uses Bike Lane markings as an example of how one type of bikeway marking changes through sequential areas.

This framework will be referred to in subsequent discussions of specific bikeway markings (e.g., section on Shared Lane Markings).

Design Issues

In most cases, markings for bicycle facilities are similar to markings for roadways and other transportation facilities, using the same colors, designs, and materials. One significant difference is markings intended specifically to guide, warn, or control bicycle traffic are scaled down in size from comparable markings used for general traffic control. For example, word markings used on shared-use paths use the same letterforms as standard markings, but scaled down 50 percent to 60 percent in keeping with the lower operating speeds of bicyclists (and the often narrower travelways used for bicycle facilities). A marking letter height of 44 to 48 in. (1.1 to 1.2 m) is typically used on shared-use paths and bike lanes, and arrows are typically 50 percent of the standard roadway size in accordance with Section 9C.03 of the 2009 MUTCD. Transverse markings, such as stop lines, should be at least 8 to 12 in. (200 to 300 mm) in width.

Scaled-down versions of yield lines as defined in Section 3B.16 of the 2009 MUTCD may be used on pathways where appropriate. Symbols used on bike lanes and pathways are typically 6 ft. (1.8 m) in length, although smaller symbols have occasionally been used in bike lanes where clear pavement width is a concern.

Although bicycle-specific letter and symbol markings are smaller than comparable symbols used on roadways, the need for elongation to compensate for viewing angles is still very important. A bicyclist viewing a symbol from a distance will see it at a low viewing angle with respect to the pavement surface, similar to the view motorists get of roadway markings. To compensate for this, markings should be significantly elongated in the direction of viewing so they exhibit "normal" proportions when viewed by road or path users at a distance, even if this results in the markings looking "stretched" from directly above. Using non-elongated markings will result in the markings looking compressed or non-readable at a distance, greatly reducing detection and reading time.

When possible, use only standard FHWA-approved symbols for markings, and use them only in manners and contexts permitted by the MUTCD. If for some reason no standard symbol will work, and a word legend will not work in lieu of a symbol, consult Section 1A.10 of the 2009 MUTCD for the steps to follow in obtaining experimental approval from FHWA for evaluating a nonstandard symbol. If an agency is considering the use of a nonstandard pavement marking symbol, the design factors listed for sign symbols in the section on "Design Issues" in this chapter should be consulted.

When applying markings to a light-colored surface, such as a Portland cement concrete roadway or pathway, it may sometimes be advisable to use a contrast marking material in conjunction with the standard marking material as permitted in Section 3A.05 of the 2009 MUTCD.

Materials

Bicycle facilities are typically marked using the same materials as used for other pavement markings, such as paint, thermoplastic, epoxy, tape, and methyl methacrylate. Bicycle tires may skid on markings when wet, so care should be taken to minimize the use of marking materials in locations requiring higher traction, such as stopping areas and curves (see section on slip resistance below).

Proper preparation of pavement surfaces can assist in improving marking durability. The surface should be clean and dry, and application temperatures should be within the marking manufacturer's recommended specifications. On new Portland cement concrete surfaces, any curing compound should be removed prior to application, and primers and sealers should be used if recommended by the manufacturer. (Also see Chapter 9 of this *Handbook* for more information on pavement markings.)

Slip Resistance. There is a significant concern regarding the effect of certain types of pavement markings on the wet-weather traction of bicycles. Bicycle tires have a very small area in contact with the ground at any given time, typically on the order of only one square in. (625 square mm) per wheel. Due to this, bicycles are especially sensitive to surface friction changes on pavement surfaces.

There are proprietary marking materials that offer very good wet skid resistance for bicyclists and pedestrians, and are available in a wide variety of colors, shapes, and symbols. However, these proprietary materials may have a higher cost as compared to other pavement marking materials.

Some agencies have reported increasing the quantity of glass beads on the surface of pavement markings substantially improves wet-weather traction for bicyclists and pedestrians. Including high-traction additives such as sand, reinforcing fibers, or other similar additives within and on top of pavement marking materials also can improve traction for bicyclists.

Retroreflectivity. All pavement markings used on facilities used by both motorized and nonmotorized traffic, such as streets and highways, must be retroreflective. Markings on facilities used at night, such as shared-use paths, should be retroreflective. The UVC and all state laws require bicyclists operating at night to use a white front headlight, and a retro-reflective marking which will be much more visible at night than a non-reflective marking, especially in areas with little or no ambient lighting. Using a non-reflective marking on a facility open at night in areas with low ambient light could cause risk management problems, as a crash at night on such a facility could raise issues as to marking effectiveness.

The typical method used for providing marking retroreflectivity is incorporating glass beads into the marking material, and optionally spraying an additional layer of glass beads on the marking surface immediately after application and prior to curing. If sprayed or loose glass beads are used, it may be advisable to sweep the surface prior to reopening the facility to bicycle traffic, as any unbonded beads may contribute to loss of traction, even on an otherwise high-friction surface.

At the time of writing of this *Handbook*, FHWA had not yet established final values for minimum retroreflectivity for markings on roadways, and has indicated the minimum retroreflectivity values may be waived for markings on facilities used solely by non-motorized users, such as shared-use paths. However, as noted above, it is advisable to provide retroreflective markings if a facility is open to bicycle travel at night.

Maintenance of Markings

Although pavement marking materials will typically last for a long time on bicycle facilities, maintenance will still be necessary. Bike lanes in areas with high volumes of turning motor vehicle traffic may see damage or obliteration of markings at a much faster rate than in areas with little movement across the markings. Pavement wear and damage can also greatly affect marking durability. Markings on roads and paths may also be subject to vandalism and graffiti.

It may be advisable for operators of bicycle facilities to periodically inspect bikeway markings during day and night conditions and note any areas that might need maintenance or replacement. If performing a night inspection on a shared-use path, it may be advisable to use a bicycle equipped with a headlight that meets the specifications listed in state law to verify markings are adequately visible.

Colored Pavements

Contrasting green-colored pavement has been used in certain limited North American locations within marked bicycle lanes to denote the possible presence of bicyclists, in shared lanes to denote a preferred position and appropriate travel path for bicyclists, and in extensions of bicycle lanes through intersections and other traffic conflict areas such as merge areas where turning vehicles must cross a through bike lane.

An Interim Approval issued by FHWA in April 2011 permits the use of green-colored pavement. However, the scope of this Interim Approval only encompasses the use of green-colored pavement in a bicycle lane or conflict area, and not in "bike boxes" or shared lanes. The use of this treatment under the scope of the Interim Approval requires written authorization from FHWA in accordance with Section 1A.10 of the 2009 MUTCD. This approval can be requested and granted for a specific location, or for an entire jurisdictional area. For the use of green-colored pavement outside the scope of the Interim Approval, such as in a travel lane shared with other traffic, experimental approval from FHWA in accordance with Section 1A.10 of the 2009 MUTCD is required.

Within the scope of the current Interim Approval, green-colored pavement can be installed for the entire length of the bike lane, or for only a portion or portions of the bike lane, or as a rectangular background behind standard MUTCD symbol and word markings. If used in conjunction with a pair of dotted lines, such as when extending a bike lane across an intersection, the green-colored marking can match the dotted line pattern, filling in the area connecting the opposing dotted line segments. However, the green-colored pavement should not replace or be used in lieu of the white lines defined in the MUTCD, as the bike lane would then no longer comply with the Standards in Chapter 9C of the 2009 MUTCD.

Surveys conducted in conjunction with the installation of colored pavements indicate bicyclists have a strong belief the addition of colored pavement will significantly improve traffic safety and operation, and reduce conflicts. This has been touted as an advantage of this treatment by advocates, as it may encourage an increased mode shift toward bicycle travel. However, the observed results of experimentation with colored pavements on bikeways have shown, overall, a neutral effect, with no truly significant improvements in operation or behavior attributable to the addition of color, but conversely showing no significant degradation of behavior or operation after addition of color.

Some jurisdictions have used colors other than green for bicycle facility pavements. Section 3A.05 of the 2009 MUTCD defines approved colors for specific uses; using colored markings for a purpose other than specified creates a violation of the Standards in Part 3. FHWA strongly encourages that, if a color is used for a pavement on a bicycle facility, green be used for conformance with the Interim Approval and to ensure uniformity. FHWA has published color specifications for green-colored pavement to also encourage uniformity of application.

Colored pavement should never be used to encourage violation of typical right-of-way rules at intersections, as experimental data shows very limited effectiveness in this treatment's ability to make meaningful changes in conflict or crash rates (again, presence of a device does not equal effectiveness). The effectiveness of green-colored pavement may be maximized if the treatment is used only where road users should already be expected to yield to bicyclists due to other visual and geometric cues, such as roadway alignment, lane continuity, and road user conditioning and expectation.

It may be a good idea for green-colored pavement to be retroreflective, unless sufficient ambient illumination allows the coloring to be adequately visible at night. Otherwise, any advantage to the colorization disappears when the colored region is indistinguishable from the rest of the paved area.

Colored pavements may require additional maintenance, as some treatments can wear away quickly with vehicle traffic. The use of durable materials can increase useful service life, but can incur substantially increased initial installation costs. Consideration should also be given to selecting marking materials that will minimize loss of traction for bicyclists.

DEVICES FOR SHARED ROADWAYS

Shared roadways make up the overwhelming majority of mileage of road systems in the United States and elsewhere. They include urban and rural highways, and arterial, collector, and residential streets.

On all roadways open to bicycle travel, agencies should set and maintain traffic signal equipment to detect bicyclists, and consider adjustments to signal timing as appropriate to accommodate bicyclists. See a later section in this chapter dealing with "Traffic Signals and Bicycles" for more information.

Difference Between a Shared Roadway and a Regular Roadway

Most bicycle travel in the U.S. occurs on streets and highways without bikeway designations. In some cases, an existing street system may be fully adequate for bicycle travel, and additional signing and marking may not be necessary. In other cases, some roads may not be under heavy demand by bicyclists, and it may not be appropriate to designate them as bikeways regardless of conditions.

A shared roadway is specifically defined as a roadway open to both bicycle and motor vehicle travel. All roadways that are not prohibited to bicycle travel will be used by bicyclists, and are therefore shared roadways. However, not all such roads are equal in their ability to accommodate bicyclists safely and efficiently.

By signing shared roadways as designated bicycle facilities, the agency is indicating to bicyclists these roads offer particular advantages for bicycle travel as compared to alternative routes. They provide continuity to other bicycle facilities or destinations, or designate preferred routes through high-demand corridors. However, once a facility is so designated, there will be an expectation from users the agency has verified these roads are suitable as shared roadways, and will be maintained in a manner consistent with bicyclists' needs.

Some features that can improve bicycle accommodation on shared roadways include:

- wide curb lanes—14 ft. (4.3 m) or greater;
- motor vehicle travel speeds generally below 40 mph (60 km/h);
- lower traffic volumes—below 10,000 annual average daily traffic depending on configuration; and
- lower percentages of heavy trucks and commercial vehicles.

Note a roadway may still perform adequately as a shared roadway even if it does not meet all of the above criteria. Also, high traffic volumes or speeds should not be used as a rationale for not providing for bicycles—bicyclists will still be out there choosing to (and most likely needing to) use that road.

If operating speeds on a roadway are higher than desired, changing speed limits or making other simple traffic control device-based modifications may not be effective in changing travel speeds. To effect meaningful changes in travel speeds, the character of the roadway as perceived by the motorist must be changed. Changes of this type can include:

- changes in density and offset of roadside objects such as trees or buildings;
- adding engineered vertical or horizontal deflections;
- varying the physical width of the roadway; and
- timing an interconnected traffic signal system to encourage traffic to operate at a desirable speed.

See ITE's *Urban Street Geometric Design Handbook* and the ITE Recommended Practice *Designing Walkable Urban Thoroughfares: A Context Sensitive Approach* for more information.

Wide Shared Lane or Bike Lane?

Research studies[20] have indicated wide shared lanes (defined as travel lanes with a continuous usable width of 14 ft. [4.3 m] or greater) and bike lanes both function well to accommodate bicyclists in terms of crash and conflict rates and efficiency, and wide shared lanes and bike lanes can be used to improve conditions for bicyclists. However, stated preference surveys of bicyclists indicate bike lanes are preferred by bicyclists, apparently due to the idea such designated and marked facilities establish a bicyclist's place on the roadway. Studies have also indicated sidewalk bicycling can place bicyclists in severe and more unexpected conflict with pedestrians and motor vehicles at intersections or driveways.[21] The use of sidewalks by bicyclists may be reduced when bike lanes are present.

There is also a belief that bike lanes are safer than wide curb lanes, but research has been inconclusive; some studies show some safety benefits from bike lanes, while others find little difference in overall safety.

On shared roadways where bike lanes may not be appropriate, such as in locations where overall roadway width does not allow for placement of a bike lane, or where there are numerous intersections, driveways, or on-street parking spaces, shared lane markings may be appropriate. See a later section of this chapter for more information on shared lane markings.

Research over the past two decades on the perceived comfort level of bicyclists on roadways has created models of "bicyclist level of service," which take factors such as traffic volume, operating speed, lane width, surface condition, and presence or absence of a usable shoulder, bike lane, or wide lane to predict use and comfort level of "average" bicyclists on that roadway. This has been incorporated into the 2010 edition of the *Highway Capacity Manual*. However, a significant limitation of these models is, currently, there is not an accurate method of determining the effect of intersections on this perceived quality of service, and a cross-section that gives a high score assuming few or no intersections may create problems in locations with a high number of intersections and driveways.

Bicycle Use of Shared Roadways

Rural Highways. Rural highways are used by bicyclists for intercity and recreational travel. In most cases, these roadways will not be designated as bikeways, unless they are part of a system of signed or numbered routes.

In general, roadways that carry low volumes of traffic can provide an enjoyable and comfortable bicycling experience, with no need for bike lanes or any other special accommodations or devices. For example, a narrow and curving rural road with low traffic volumes can be a very suitable and popular bicycling route, and may be preferable for some bicyclists compared to a high-speed, high-volume highway with good geometrics and shoulders—as long as the road serves as a convenient through route to the desired destinations. Outside urban areas, these types of roads may comprise a high percentage of popular or designated bicycle routes, and may be appropriate for designation as a local, state-level, or U.S. Bicycle Route. However, there are often situations where a higher-volume or higher-speed highway serves as the most convenient or efficient route between destinations, and bicycle travel can and should be expected, even if roadway or lane widths and conditions are not optimal for bicycle travel.

On rural highways, paved shoulders with a clear width of 4 ft. (1.2 m) or greater, or a combined width of the right lane and shoulder of 14 ft. (4.3 m) or greater, can greatly improve the convenience and perceived comfort of motor vehicle and bicycle travel along such routes. See a later section of this chapter for more information on shoulder use by bicyclists on rural highways.

Rumble strips can create problems for bicyclists on rural highway shoulders. See a later section of this chapter dealing with "Devices for Shoulder Bikeways" for discussions of rumble strips and their impact on bicyclists.

Arterial Streets. Bicyclists frequently use arterial streets, since these streets link most primary destinations for all traffic, including bicyclists. In fact, due to land development and traffic engineering practices of the past few decades, in many locations travel between neighborhoods is possible only on arterial streets.

If the operating speed of the street is faster than typical travel by bicyclists, there are likely to be frequent overtaking maneuvers by faster motor vehicles around slower bicyclists. As discussed earlier in the chapter, crashes involving overtaking vehicles striking bicyclists are uncommon in urban areas, so even though there may be some disruption of traffic flow the operation of bicyclists in mixed-flow traffic on arterials is not necessarily a safety risk.

Many arterial streets have high volumes of traffic, or high operating speeds. Provision of shared lanes wider than 14 ft. (4.3 m), bike lanes, or paved shoulders on these routes can significantly increase convenience for both bicyclists and motorists. Wide shared lanes, bike lanes, or shoulders may also decrease sidewalk use by bicyclists, which can reduce many common types of crashes and conflicts.

Lane widths can affect operation of bicyclists and other traffic. This can also be affected by the prevalence of laws in many states where a specific minimum offset distance between an overtaking motor vehicle and a bicycle (typically 3 ft. or 0.9 m) is defined by statute. On streets where the curbside travel lane is 14 ft. (4.3 m) or wider from the lane line to the edge of pavement (not including gutter pan), faster traffic can overtake bicyclists within the same lane while maintaining adequate separation between the motor vehicle and the bicyclist. In locations where the curbside lane width is less than 11 ft. (3.3 m), bicyclists and motor vehicles will usually occupy the same lane width, as the lane is perceived as being insufficiently wide for side-by-side passing. In locations where the lane width is between 11 and 14 ft. (3.3 and 4.3 m), the perception of "sharable" width may be ambiguous, and bicyclists may ride to the extreme right of the travel lane to politely accommodate faster traffic.

This can create two operational and safety problems. First, the bicyclist may be riding in the gutter pan, next to a vertical curb, or near posts and other roadside objects, creating the risk of a fixed-object crash. Second, this can create the misleading impression the remaining unoccupied travel lane width is adequate for an overtaking maneuver, resulting in too-close passing inconsistent with good operating procedure or law, and may result in a sideswipe-type crash if the motorist misjudges separation distance.[22] In locations with 11 to 14 ft. (3.3 to 4.3 m) lanes, it may be advisable, based on engineering judgment, to install additional devices, such as shared lane markings and BICYCLES MAY USE FULL LANE (R4-11) signs, or if practicable, reallocate lane widths to reduce the ambiguity.

In congested urban areas, lane widths of 17 ft. (5.2 m) or wider may see side-by-side motor vehicle travel in the same lane, which may create operational problems for bicyclists and other road users.

Some communities have designated collector streets that parallel major arterials as bike routes, as bicyclists may prefer to use those lower-volume roadways instead of the arterial.[23] However, bicyclists may be reluctant to divert a significant distance to a parallel route. If a parallel route is designated, it may be advisable to provide trailblazing signing for bicyclists to and from the parallel route and the arterial (so bicyclists on the arterial are aware of the parallel route), and for bicyclists on the parallel route to reach and access destinations on the arterial.

Collector/Residential Streets. Collector streets and local residential streets typically have lower volumes and speeds than arterial streets, and can be quite suitable for all types of bicyclists. However, these streets may not offer the same level of convenience as arterial streets due to lack of continuity and geographic restrictions. In most cases no special traffic control devices are needed on residential streets, except for guide and route signing if the street is part of a route network, or has been designated as a "bicycle boulevard" (see below). On minor collector streets with low volumes and wider lanes, no devices may be needed. If traffic volumes are higher or lanes are narrower, the use of shared lane markings or bike lanes may be considered if appropriate.

Bicycle Boulevards. Another type of shared roadway that is specifically enhanced for bicycle travel is the bicycle boulevard. This is a residential or collector street (or segments of streets comprising a continuous route) which has been modified to provide enhanced through right-of-way and travel speeds for bicyclists, and provide access to local residences and businesses, but discourage through traffic by motor vehicles. This is typically accomplished by requiring motor vehicles to leave the street at certain locations while permitting bicyclists to continue unimpeded.

Many local streets already have some of these characteristics, but a bicycle boulevard is engineered through the use of geometric treatments and traffic control devices to provide:

- continuity;
- operating speeds that are very compatible with bicycle travel; and
- access across obstacles to through travel, such as high-volume streets and geographic barriers such as railroad lines or canals.

Bicycle boulevards are typically developed to connect two or more destinations with high bicyclist demand, such as a transit or rail station, college or school campus, residential area, or commercial center. Bicycle boulevards can also be sited parallel to a high-volume or high-speed street or highway in order to provide a more comfortable or enjoyable travel path for bicyclists along the corridor. If so, frequent connections between the bicycle boulevard and the parallel major street(s) should be provided to allow access to destinations along that street. Note that if bicyclists view the major street as being more convenient, they may choose to use the higher-volume street instead of the designated facility.

Geometric design elements used on bicycle boulevards include:

- islands at intersections to direct motor vehicle traffic to turn at intersections, while permitting bicyclists to continue along the route;
- curb extensions;
- median refuges at crossings of major streets;
- roundabouts (if appropriate and adequate right of way is available);
- speed humps, speed tables, and other traffic calming features; or
- shared-use paths (in short segments), which may be used to provide connections between discontinuous segments of shared roadway, such as at a dead-end or across a waterway.

Specific design details of bicycle boulevards can be seen in the new edition of the AASHTO *Guide For Bicycle Facilities*.

Traffic control devices which may be used in bicycle boulevards include:

- bicycle route signing, used to provide continuous routing guidance along the bicycle boulevard. This can be a numbered and/or named route, using M1-8, M1-8a, D11-1, D11-1a, or other guide signs. Bicycle-specific guide signs as shown in Figure 9B-4 of the 2009 MUTCD may be used to provide or supplement route guidance. If using nonstandard signs, use standard sign colors and follow the design guidelines in the section of this chapter dealing with "Signing for Bicyclists."
- adjusted traffic control priority. Along the bicycle boulevard traffic controls should be adjusted to provide uninterrupted travel for bicyclists between major streets. This is typically accomplished by using either no regulatory control at minor intersections, or by using two-way STOP or YIELD control on the crossing street to give priority to the bicycle boulevard.
- use of shared lane markings along bicycle boulevards where appropriate. Symbol, word, and arrow markings may also be used to provide information and guidance along the route. However, standard bike lane symbols should not be used on a shared roadway.
- use of standard turn lane pavement markings and signing at mandatory turn lanes for motor traffic.
- sometime-use of bike lanes, where the bicycle boulevard is routed on higher-volume streets.
- use of crosswalk markings at collector and arterial streets to denote a crossing for pedestrian and bicycle travel.
- use, if warranted, of active devices such as pedestrian hybrid beacons or signalization. at crossings of higher-volume or higher-speed streets, See a later section of this chapter dealing with "Traffic Signals and Bicycles" for more information on the use of signals or beacons at these locations.

Wide Lanes

A wide shared lane can provide sufficient space for motor vehicles to pass bicyclists without needing to change lanes and without encouraging bicyclists to ride farther right than is reasonably practicable. A lane width of 14 ft. (4.3 m) is generally considered the minimum for such a shared lane. Note this lane width typically does not include space not usable by bicyclists, such as a gutter pan. In congested urban areas where parking is prohibited, a wide shared lane should not exceed 17 ft. (5.2 m) in width; such a lane may be misused by motorists as an additional travel or passing lane.

Bicycle quality-of-service assessments note wide lanes, even where there is ample width for overtaking, typically score lower and see lower bicyclist volumes than a bike lane or paved shoulder, even where the overall width is similar. This has been corroborated by anecdotal observations by traffic professionals: Where a wide lane was converted into a narrow lane plus shoulder or bike lane, rider volumes were reported to increase. However, there are situations where a wide lane is preferable to a bike lane or shoulder from an operations viewpoint, especially in locations with close spacings or high numbers of driveways or intersections, where channelization of bicyclists could exacerbate conflicts with turning traffic. In these locations, the use of shared lane markings may be beneficial in suggesting appropriate bicycle travel paths and encouraging bicyclists to use the roadway.

Narrow Lanes

In locations where the outside travel lane is less than 14 ft. (4.3 m), there is insufficient lateral room for a bicyclist and a motor vehicle to travel side by side in the same lane with adequate separation distance between the two vehicles. In this situation, the "as far right as practicable" requirement, found in section 11-1205(a) of the UVC and the traffic laws of most states, is waived, and bicyclists are legally permitted to position themselves laterally on the roadway in a manner that discourages too-close passing or being squeezed to the curb or roadway edge by passing traffic. However, many bicyclists and other road users may not be aware of the details of this law, and may incorrectly assume they must always stay to the far right of the roadway.

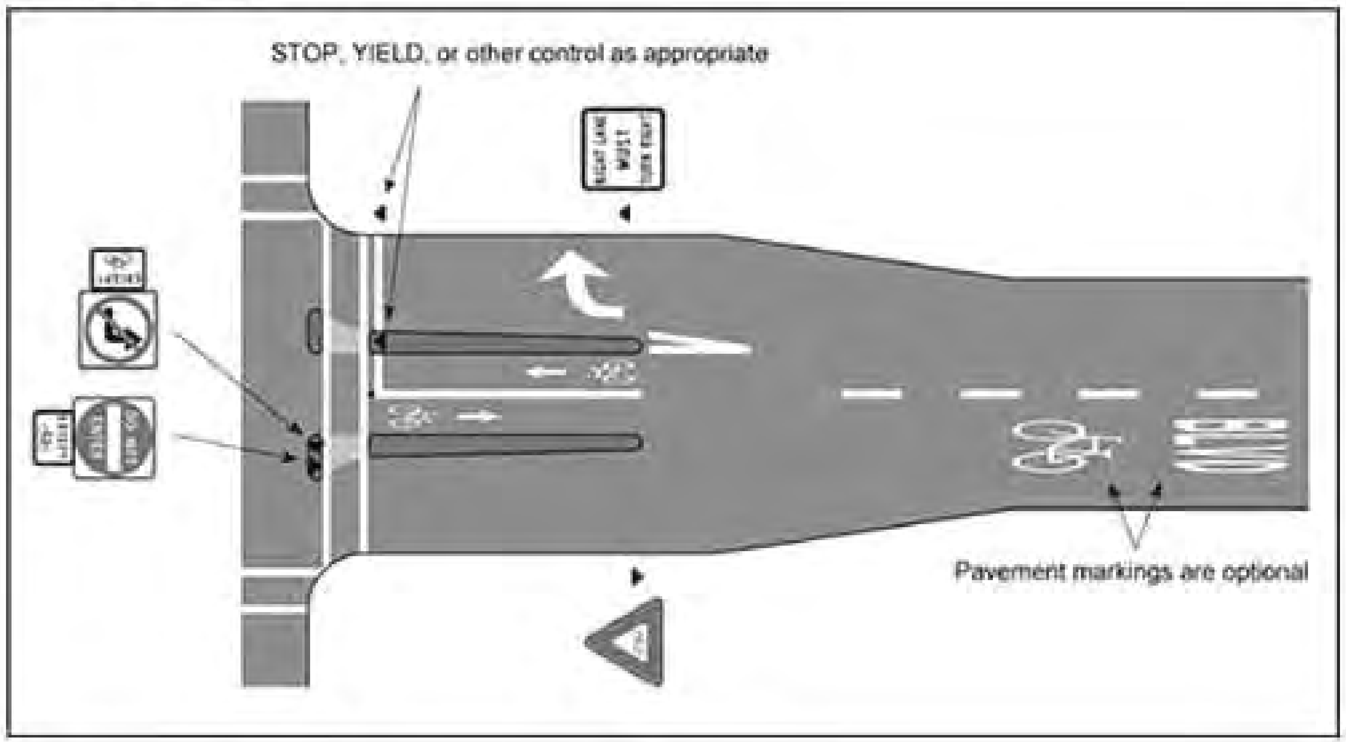
If the roadway has low traffic volumes, or has lower travel speeds and multiple lanes in each direction, there may not be any notable issues with bicyclist use of narrow travel lanes, and the road or street may serve bicyclists well. However, on roadways with higher traffic speeds and volumes, less-confident bicyclists may not be comfortable in using the full width of a standard narrower-width travel lane, even when it is lawful and in their best interest. In these locations, these bicyclists may choose to instead ride on the sidewalk or an unpaved shoulder, which can greatly increase their risk of intersection, pedestrian, and fixed-object collisions.

In locations with narrow travel lanes where operational problems (such as high incidences of sidewalk riding) have been observed, the use of shared lane markings or BICYCLES MAY USE FULL LANE (R4-11) signs may be beneficial in encouraging appropriate and legal use of the lane by bicyclists.

Shared Lane Markings

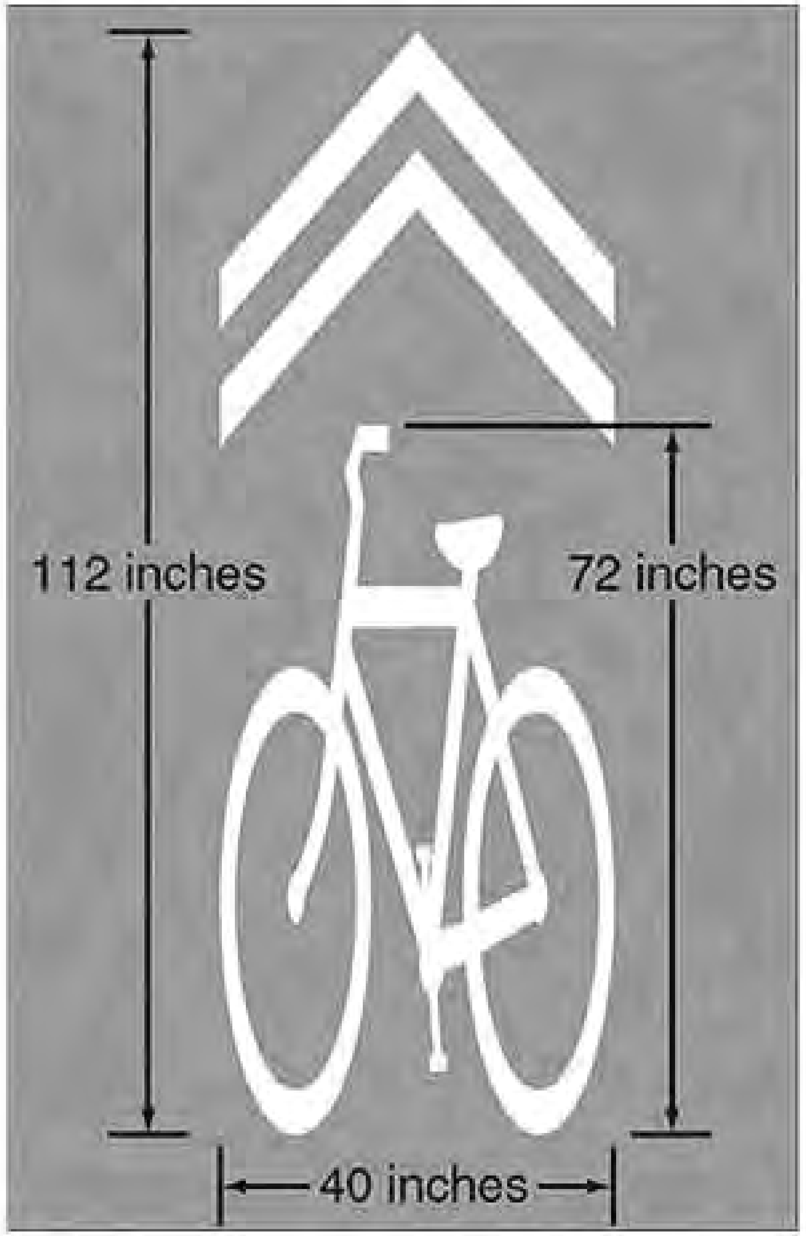
The Shared Lane Marking was added to the 2009 MUTCD, and is discussed in Section 9C.07 and depicted in Figure 9C-9. Its width of 40 in. (1.0 m) is the same as the bicycle plus rider width in AASHTO's *Guide for the Development of Bicycle Facilities*. Due to the design of earlier versions of this marking it is widely known as a "sharrow"; however, this *Handbook* will refer to these markings by the MUTCD's term "Shared Lane Marking" or the abbreviation "SLM" (illustrated in Figure 14-9).

FIGURE 14-8. Example of Bicycle Boulevard Signing and Marking



SOURCE: Richard Moeur.

FIGURE 14-9. Shared Lane Marking



SOURCE: MUTCD 2009, Figure 9C-9.

Prohibited Uses: Bicycle Lanes and Shoulders. The 2009 MUTCD says the "Shared Lane Marking shall not be used on shoulders or in designated bicycle lanes." Bicycle lane markings as shown in MUTCD Figure 9C-3 are a mandatory Standard, and no other markings (including SLMs) are allowed to substitute for standard symbols in bike lanes.

Motor vehicles are generally prohibited from driving on shoulders except for breakdowns and enforcement actions. However, many state vehicle codes allow shoulder travel by bicyclists in the same direction as adjacent traffic. Although shoulders are not lanes, bicycle-permitted shoulders are somewhat similar to bicycle lanes in that only bicycle travel is allowed, with the above-noted exceptions. See the section of this chapter dealing with "Devices for Shoulder Bikeways."

Prohibited Uses: Roadways With Speed Limits Above 35 mph (55 km/h). The 2009 MUTCD says the "Shared Lane Marking should not be placed on roadways that have a speed limit above 35 mph." Above 35 mph (55 km/h), the differential (closing) speed between a following motorist and a bicycle traveling at 15 mph (24 km/h) exceeds 20 mph (32 km/h), allowing less time and distance for smooth deceleration and overtaking maneuvers by motorists. However, many highways with higher speed limits are open to bicyclists, and many of these do not have shoulders suitable for bicycle travel. As such, some bicyclists will use the full width of a narrow lane on such highways to deter unsafe passing, especially if confident of their conspicuity to motorists approaching from behind.

Spacing. The 2009 MUTCD says, "If used, the Shared Lane Marking should be placed immediately after an intersection and spaced at intervals of not greater than 250 feet thereafter." To reduce wear on the first marking after an intersection or major driveway, consider locating the marking beyond the right turn sweep of the cross street or driveway. The maximum spacing of 250 ft. (76 m) is intended to ensure bicyclists and motorists can usually see the next marking. A spacing of less than 250 ft. (76 m) should be considered where a crest vertical curve limits visibility of the pavement ahead. Much closer spacing may be useful when a curved sequence of SLMs is used to guide bicyclists through a conflict area that requires turning, such as an angled railroad track crossing (see section on Angled Railroad Crossings).

Lateral Positioning Principles. The 2009 MUTCD states the Shared Lane Marking may be used to:

- assist bicyclists with lateral positioning in a shared lane with on-street parallel parking in order to reduce the chance of a bicyclist striking the open door of a parked vehicle;
- assist bicyclists with lateral positioning in lanes that are too narrow for a motor vehicle and a bicycle to travel side by side within the same traffic lane;
- alert road users of the lateral location bicyclists are likely to occupy within the traveled way;
- encourage safe passing of bicyclists by motorists; and
- reduce the incidence of wrong-way bicycling.

The common purpose noted for the SLM is to assist bicyclists with lateral positioning to improve operation and safety. As does any road user familiar with roadway hazards and traffic flow, a safety-conscious bicyclist is likely to choose a lateral position that is neither too close to the right edge nor too far left. Riding too far toward the right edge exposes the bicyclist to several hazards and conflicts:

- debris along the roadway edge;
- longitudinal discontinuities at gutter joints;
- the opening doors of parallel parked cars;
- parking space exiting maneuvers, including parallel, diagonal, and perpendicular;
- right turn movements from the left side (a.k.a. right hooks or right-turn cutoffs) wherever right turns are made (at cross streets, alleys and driveways); and
- passing on the left with inadequate lateral clearance where there is insufficient lane width at that point or just ahead.

Riding too far to the left may encourage passing on the bicyclist's right side where that would be inappropriate or unsafe. These same considerations apply in mirror-image fashion when a bicyclist uses the left-most lane of a one-way street, as allowed by many state traffic laws.

TABLE 14-4. Suggested Shared Lane Marking Offset Where On-Street Parking Is Prohibited

Lane Width (no parking)	Curb offset to center of SLM centered in lane
14.0 ft. (4.3 m)	7.0 ft. (2.1 m)
13.5 ft. (4.1 m)	6.75 ft. (2.1 m)
13.0 ft. (4.0 m)	6.5 ft. (2.0 m)
12.5 ft. (3.8 m)	6.25 ft. (1.9 m)
12.0 ft. (3.6 m)	6.0 ft. (1.8 m)
11.5 ft. (3.5 m)	5.75 ft. (1.8 m)
11.0 ft. (3.3 m)	5.5 ft. (1.7 m)
10.5 ft. (3.2 m)	5.25 ft. (1.6 m)
10.0 ft. (3.0 m)	5.0 ft. (1.5 m)

SOURCE: John Ciccarelli.

All these hazards and conflicts apply outside of intersections; the last two also apply within intersections. Within intersections, the use of Shared Lane Markings to provide lateral position guidance for through bicyclists may be useful, especially where there is substantial right-turn volume on entry, substantial merging right-turn volume from the cross street when leaving the intersection, and/or corner property driveways just beyond the intersection. At large intersections with simultaneous opposing left-turn movements, Shared Lane Markings may be useful for guiding left-turning bicyclists to stay well within their turning movement's sweep to avoid oncoming left turners while deterring passing by following motorists. Use of the SLMs within intersections is discussed in the section on intersection continuation.

The discussion in this section uses the "Travel Areas" framework and terminology defined earlier to describe the contexts where SLMs are applied: Mid-Block (away from intersections), Transition and Storage (approaching intersections), and Intersection (including Continuation).

Mid-Block Without Parking. The 2009 MUTCD says, "If used on a street without on-street parking that has an outside travel lane that is less than 14 feet wide, the centers of the Shared Lane Markings should be at least 4 feet from the face of the curb, or from the edge of the pavement where there is no curb."

Four feet (1.2 m) is considered to provide sufficient clearance from the right edge to avoid most debris and also hazards such as open-bar drain grates and longitudinal ridges along gutter joints. However, when the lane is too narrow to share, aligning the markings at this minimum offset may not deter unsafe passing on the left. Close passing can intimidate bicyclists into riding too far to the right, and motorists executing a close pass sometimes move back to the right too early if oncoming traffic appears.

The bicyclist's lateral position should clearly indicate to following motorists whether passing is encouraged. To support this, some agencies increase the minimum right-side offset of the Shared Lane Marking when used in narrow lanes; for example, Florida DOT uses 5.5 ft. (1.7 m) for lanes narrower than 13 ft. (4.0 m). Another approach is to center the marking in a lane that is too narrow to share. This clearly indicates a bicyclist is allowed full use of a narrow lane, and is likely to produce more consistent overtaking behavior, encouraging full lane changes into the adjacent travel lane on a multi-lane street, or crossing the centerline when an adequate gap is obtained on a street with only one lane in the bicyclist's travel direction. The offsets in Table 14-4 are required to center the marking in a narrow outside lane.

Mid-Block With Parallel Parking. As it does for the no-parking context, 2009 MUTCD establishes a minimum right-side offset for the Shared Lane Marking when used with parallel parking, but does not provide guidance for aligning the marking farther to the left based on usable lane width.

Regarding the right-side minimum offset, the MUTCD says, "If used in a shared lane with on-street parallel parking, Shared Lane Markings should be placed so that the centers of the markings are at least 11 feet from the face of the curb, or from the edge of pavement where there is no curb." The rationale is to guide the bicyclist to avoid the zone where the street-side doors of parked cars may open. The 11 ft. (3.3 m) minimum is based in part on the key experimental study documented in "San Francisco's Shared Lane Pavement Markings: Improving Bicycle Safety."[24] Field observations found an 85th percentile value of 9.5 ft. (2.9 m). The 11 ft. (3.3 m) minimum was computed by adding a 6 in. (150 mm) shy distance to the bicycle's handlebar end, and half the width of a common 24 in. (0.6 m) handlebar of an upright or "mountain" type bicycle.

However, the 11 ft. (3.3 m) minimum is inadequate. For the following reasons, a minimum of 13 ft. (3.9 m) should be considered in locations adjacent to parallel parking:

TABLE 14-5. Suggested Shared Lane Marking Offset Adjacent to On-Street Parallel Parking

Physical lane width (parallel parking)	Usable lane width (subtracting 11 ft. (3.3 m) unsafe riding area)	Curb offset to center of SLM centered in usable lane width
24.5 ft. (7.5 m)	13.5 ft. (4.1 m)	17.75 ft. (5.4 m)
24.0 ft. (7.3 m)	13.0 ft. (4.0 m)	17.5 ft. (5.3 m)
23.5 ft. (7.2 m)	12.5 ft. (3.8 m)	17.25 ft. (5.3 m)
23.0 ft. (7.0 m)	12.0 ft. (3.6 m)	17.0 ft. (5.2 m)
22.5 ft. (6.9 m)	11.5 ft. (3.5 m)	16.75 ft. (5.1 m)
22.0 ft. (6.7 m)	11.0 ft. (3.3 m)	16.5 ft. (5.0 m)
21.5 ft. (6.6 m)	10.5 ft. (3.2 m)	16.25 ft. (5.0 m)
21.0 ft. (6.4 m)	10.0 ft. (3.0 m)	16.0 ft. (4.9 m)
20.5 ft. (6.3 m)	9.5 ft. (2.9 m)	15.75 ft. (4.8 m)
20.0 ft. (6.1 m)	9.0 ft. (2.7 m)	15.5 ft. (4.7 m)
19.5 ft. (5.9 m)	8.5 ft. (2.6 m)	15.25 ft. (4.7 m)
19.0 ft. (5.8 m)	8.0 ft. (2.4 m)	15.0 ft. (4.6 m)
18.5 ft. (5.6 m)	7.5 ft. (2.3 m)	14.75 ft. (4.5 m)
18.0 ft. (5.5 m)	7.0 ft. (2.1 m)	14.5 ft. (4.4 m)

SOURCE: John Ciccarelli.

- The 85th percentile technique is typically used for setting speed limits, but exceeding the speed limit by a modest amount does not usually cause a fatality or serious injury, whereas a door strike can result in serious injury due to the bicyclist being thrown into adjacent traffic—even if only the handlebar end hits the door. In the context of door extent, an 85th percentile value of 9.5 ft. (2.9 m) means roughly one in six car doors extend farther than this when opened. This means on a single block with 18 parallel parking spaces, the doors of three vehicles could possibly exceed this distance if opened. At the least, a higher percentile value should arguably be used as a basis for a minimum marking offset.
- The combined vehicle width and door extent of large SUVs and certain other two-door vehicles can be nearly 10 ft. (3.0 m). One common example is a popular, current-model SUV that is 6.6 ft. (2.0 m) wide with a 3 ft. (0.9 m) door extent. Many narrower vehicles, especially two-door coupes, also have rather long doors. Adding a 1 ft. (0.3 m) space from the curb gives 10.6 ft. (3.2 m). Adding a 6 in. (150 mm) shy distance and 20 in. (0.4 m) Shared Lane Marking half-width would place the marking's center at 12.6 ft. (3.8 m) from curb face.

- At a typical on-street bicyclist speed of 15 mph (24 km/h), providing only 6 in. (150 mm) of shy distance may not be adequate to avoid a collision, given normal variances in a bicyclist's travel path.
- The 40 in. (1.0 m) width of the Shared Lane Marking is based on the minimum essential operating space of a bicycle plus rider depicted in Figure 1 of the 1999 edition of the AASHTO *Guide for the Development of Bicycle Facilities*. However, that same section states, "[w]here motor traffic volumes, motor vehicle or bicyclist speed, and the mix of bus and truck traffic increase, a more comfortable operating space of 1.5 m (5 ft.) or more is desirable."
- Centering the marking at 11 ft. (3.3 m) from curb face or pavement edge places it in the right wheel track for motor vehicles, which can substantially decrease its service life. Aligning the marking 13 ft. (4.3 m) or greater from curb face or pavement edge generally places it to the left of the right wheel track.

However, one intended function of the Shared Lane Marking is to deter passing on the left with inadequate clearance where there is insufficient lane width at that point or just ahead. If the usable lane width (after subtracting the unsafe door zone and door shy distance) is less than 14 ft. (4.3 m), a Shared Lane Marking positioned at the right-side minimum may not deter unsafe passing. Table 14-5 lists the curb offset for centering the SLM within the usable lane width, based on an unusable width of 11 ft. (3.3 m).

Mid-Block With Diagonal and Perpendicular Parking.

The MUTCD provides curb/edge offset minimums only for the no parking and parallel parking conditions. It does not prohibit the use of the Shared Lane Marking along diagonal or perpendicular parking. In such areas the marking should be placed far enough from the curb to provide ample time for a bicyclist to respond to a back-out maneuver by decelerating or maneuvering into a line of travel further from the parked cars. The concept of effective (safe operating) lane width applies here too, and if the effective lane width is under 14 ft. (4.3 m) the marking should be centered within the effective lane width.

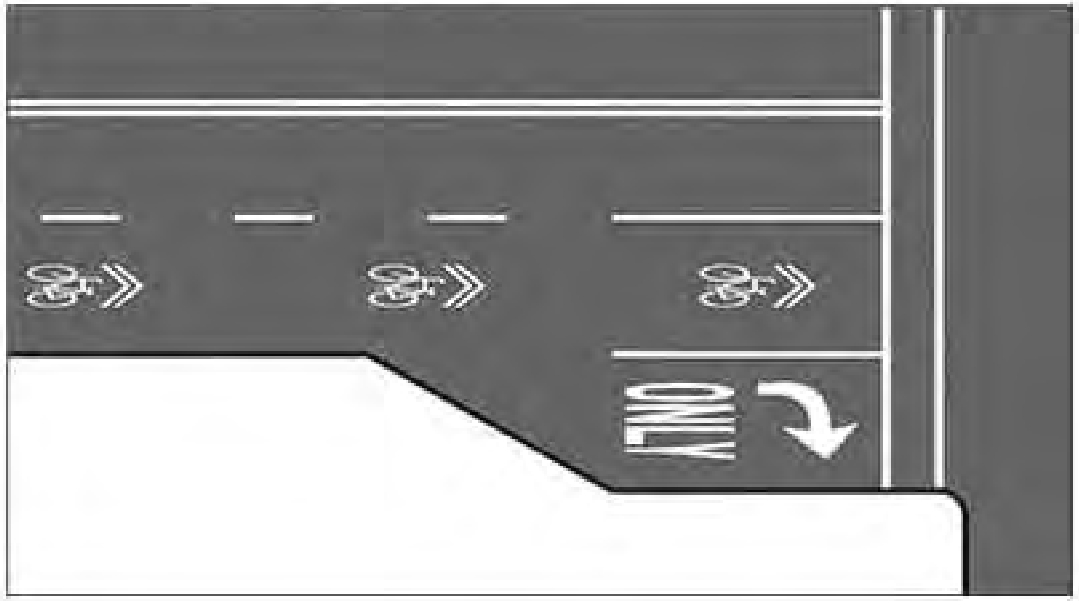
Reverse-angle parking, also known as back-in diagonal parking, is considered safer for bicyclists than head-in diagonal parking because motorists pull forward to exit and can see approaching bicyclists over the hoods of parked vehicles to their left. See a later section of this chapter on "Bike Lanes and Parking" for a related discussion of Bike Lanes and Reverse-Angle Parking.

Intersections. Shared Lane Markings can provide useful guidance and information for bicyclists and motorists approaching, traversing, and departing intersections. The 2009 MUTCD does not provide guidance for these contexts other than the minimum curb offsets discussed earlier.

Approaching Intersections. Shared Lane Markings can be useful within the transition and storage zones on an intersection approach. As discussed later in this section, the transition zone is where roadway users move laterally, if necessary, to prepare to enter the storage lane or space for their intended through or turning movement. The storage zone is the final approach to the intersection; lateral movements should have occurred in the transition zone.

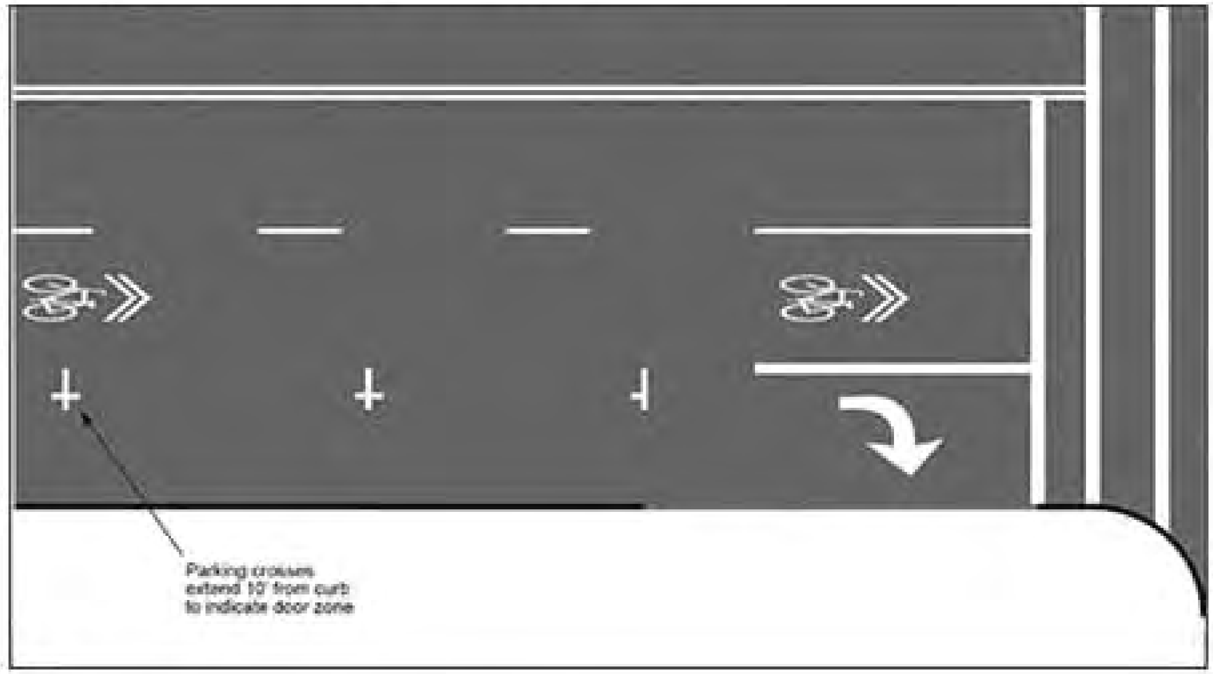
SLMs can be useful in several situations where through bicyclists approach intersections (Figures 14-10 through 14-13):

FIGURE 14-10. Example of Shared Lane Markings at a Right Turn Only Lane



SOURCE: John Ciccarelli.

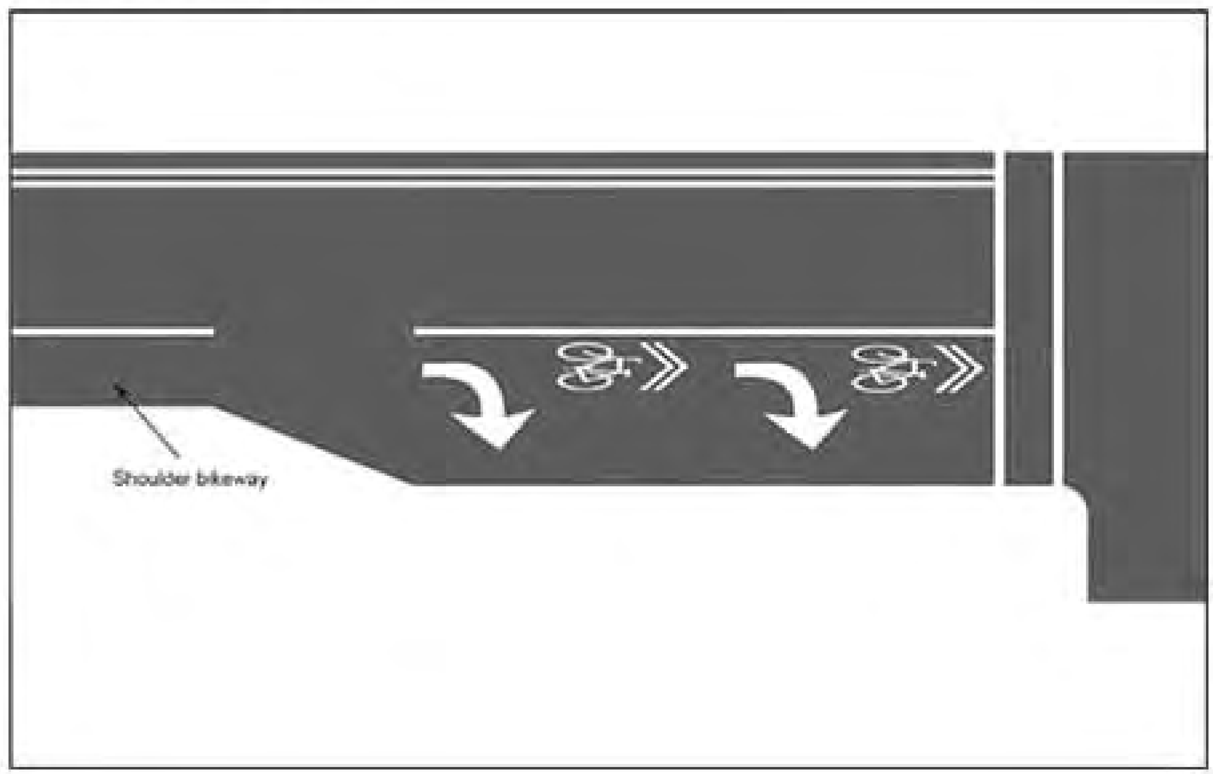
FIGURE 14-11. Example of Shared Lane Markings at a Parking Lane Into a Right Turn Only Lane



SOURCE: John Ciccarelli.

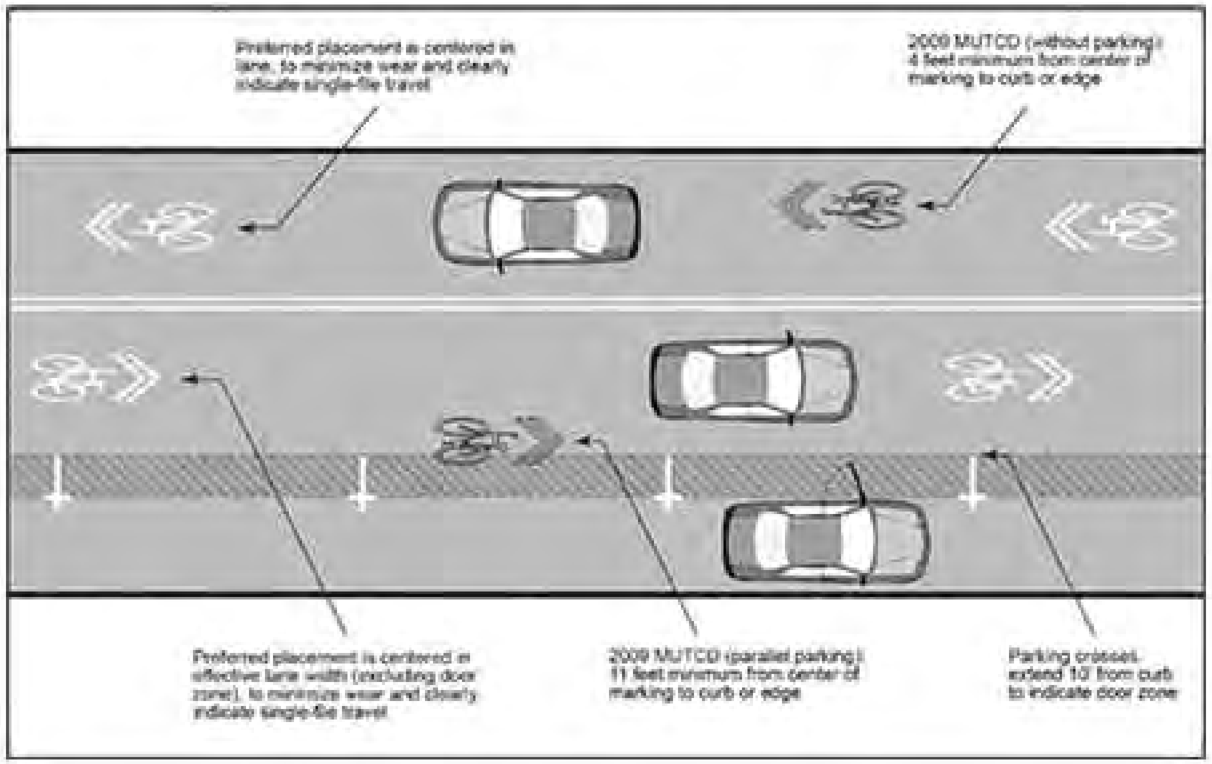
- approaches without a right turn only lane, where the mid-block segment has no bike lane;
- approaches without a right turn only lane, where the mid-block segment has a bike lane;

FIGURE 14-12. Example of Shared Lane Markings in a Right Turn Only Lane



SOURCE: John Ciccarelli.

FIGURE 14-13. Example of Shared Lane Markings on a Street With and Without On-street Parking



SOURCE: John Ciccarelli.

- a through bicycle lane located to the left of a right turn only lane; and
- a through lane to the left of a right turn only lane with no dedicated through bike lane.

In all of these scenarios the objective for use of markings is to guide bicyclists to a storage/entry line of travel that deters or eliminates the possibility of motorist right turns from the bicyclist's left side (a.k.a. Right Hook and Right Turn Cutoff). Where a bicycle waiting area is defined in the storage zone, whether as an exclusive bicycle lane or a "combination" bicycle lane overlaid on the inside edge of a right turn lane, SLMs (if used) should guide the through bicyclist toward that area. Where there is no delineated bicycle waiting area, the storage zone serves both the through and right turn movements, and SLMs should guide the through bicyclist into a line of travel that occupies enough of the lane or area to deter the right turn conflict.

1. *No Right Turn Only Lane, No Mid-Block Bike Lane.* Most simple intersection approaches have neither a right turn only lane nor a mid-block bike lane. Placing an SLM in a right-turn-deterring position several feet before the crosswalk or stop line can encourage bicyclists to not continue into the intersection along the curb, a behavior that facilitates right-hook conflicts. At simple intersections with longer transition and storage zones, several additional SLMs can lead bicyclists to the conflict-deterring line of travel.

2. *No Right Turn Only Lane, Mid-Block Bike Lane.* Many simple intersection approaches have bicycle lanes but no right turn only lane. MUTCD practice has been to continue the bicycle lane line up to the crosswalk or stop line. At intersections where right turns are permitted, the bicycle lane line is typically dotted for some distance in the transition and storage zones to inform through bicyclists of the right turn conflict and to remind right-turning motorists to merge toward the outside edge in states where that is required. However, continuing the bicycle lane line through the transition and storage zones at the same curb offset as used in the mid-block zone—even if the line is dotted—guides bicyclists unaware of the right turn conflict squarely into a curbside storage/entry position that does not deter it.

   In this situation, it may improve safety to replace the bicycle lane line in the storage area with one or more SLMs aligned at a curb offset chosen to deter the right turn conflict. Bicycle guidance markings in the transition area could be omitted, or SLMs could guide through bicyclists from the end of the mid-block bike lane to the right-turn-deterring storage position.

   When deciding whether to place SLMs in the transition zone, one consideration is the lateral shift, if any, between the bicyclist's curb offset in the mid-block bike lane relative to the bicyclist's line of travel in the storage zone ahead. If a substantial lateral shift is required in the transition zone, some agencies prefer to omit bicyclist guidance there to encourage bicyclists to scan for gaps and move left at a location depending on traffic at that moment. If, however, the bicyclist's line of travel through the transition zone is either straight ahead or requires only a small lateral shift, placing SLMs thorough the transition zone mainly informs motorists that bicyclists will be continuing forward to the storage area. One situation requiring only a small lateral shift is when the mid-block bicycle lane is to the left of parallel parking.

3. *Through bicycle lane to the left of right turn only lane.* At an intersection with one or more exclusive right turn only lanes and with no through-and-right option lane to their left, a through bicycle lane can be placed in the storage zone without conflict because the through bicyclists are properly positioned on the "slow" side of the through lane(s). Although this configuration is typically used when the mid-block zone has a bicycle lane, the MUTCD does not prohibit the use of a storage zone bicycle lane where there is no bicycle lane at mid-block.

In this situation, if there is a mid-block bicycle lane and its curb offset is equal or similar to the storage zone bicycle lane ahead, bicyclists require little or no lateral shift within the transition zone, and a dashed bicycle lane is typically used to guide bicyclists through the transition zone. If, however, a substantial lateral shift is required between a mid-block curbside bicycle lane and a storage zone bicycle lane placed to the left of one or more right turn only lanes, placing Shared Lane Markings through the transition zone instead of a dotted bicycle lane may encourage bicyclists to scan and not to assume the dotted lines ensure their safety while shifting to the left.

If the mid-block zone has no bicycle lane, Shared Lane Markings through the transition zone can guide through bicyclists from their mid-block line of travel (which depends on the effective lane width there) to the storage zone bicycle lane.

4. *Through lane to the left of a right turn only lane with no dedicated through bike lane.* At an intersection with a through-only lane to the left of one or more exclusive right turn only lanes, but without sufficient total width to create a through bike lane, SLMs in the storage zone can help to encourage through bicyclists to avoid conflicts with right-turning traffic, and SLMs in the transition zone can guide through bicyclists to this lateral position.

The most straightforward SLM placement in the storage zone is in the right-most through lane, centered in the lane if it is too narrow to share, or in a right-side sharing position if the lane is wide enough to share, i.e., 14 ft. (4.3 m) or greater.

An alternative placement is along the left portion of the left-most right turn only lane. This could be considered when motor vehicle speed or volume in the right-most through lane deters bicyclists from merging into that lane through the storage zone, or when the bicyclist is approaching a developed right turn lane from a shoulder bikeway—a common situation on rural highways.

The use of the SLM in this context is allowed by FHWA per the agency's MUTCD adoption status web-page for bicycle and pedestrian traffic control devices (www.fhwa.dot.gov/environment/bikeped/mutcd_bike.htm). As of December 2011 that webpage has the following entry:

Description of Bicycle Facilities	Status in the FHWA's *Manual on Uniform Traffic Control Devices* (MUTCD)	Are FHWA Experiments in Progress?
Shared bike lanes and right turn lanes	Can be implemented at present time if Shared Lane Markings are used, but currently is experimental if any other pavement markings are used	Yes

Because this treatment guides through bicyclists to the left of right-turning traffic and to the right of other (potentially faster) through traffic, it conforms to the basic principle of "destination positioning" on an intersection approach. However, some states might need to change their traffic laws to allow a bicyclist to proceed straight into an intersection from a right turn lane, if they implement this treatment.

NOTE: In 1998, an FHWA study conducted in Eugene, Oregon evaluated a dashed through bicycle lane overlaid on the left side of a right turn only lane ("Combined Bicycle Lane/Right Turn Lane").[25] The report indicated the treatment functioned well at the study intersection. The treatment appeared in the 1995 *Oregon Bicycle and Pedestrian Plan* but the Oregon Traffic Control Devices Committee subsequently declined to approve it for inclusion in the Oregon Supplement to the MUTCD. This treatment is not compliant with the 2009 MUTCD if the bicyclist and right-turning motorist must share the same space. As of December 2011 an FHWA-sanctioned experiment was in progress.

Traversing Intersections. Shared Lane Markings can be useful to provide guidance for bicyclists continuing through intersections, to minimize conflicts specific to entering, traversing, and leaving the intersection (in the Travel Areas framework, the "Entry," "Middle," and "Exiting" areas) and also to prepare for conditions just beyond the intersection (the "Block: Corner" travel area in the framework).

The MUTCD does not currently address the use of Shared Lane Markings within intersections, but does not prohibit this application. As with the markings' use outside intersections, the objectives are to alert road users of the lateral location bicyclists are likely to occupy, and to encourage bicyclists to use a line of travel that minimizes conflicts and deters unsafe passing.

Section 3B.08 of the 2009 MUTCD allows the use of ed-geline, lane line, and centerline extensions through intersections and interchanges "[w]here highway design or reduced visibility conditions make it desirable to provide control or to guide vehicles through an intersection or interchange, such as at offset, skewed, complex, or multi-legged intersections, on curved roadways, where multiple turn lanes are used, or where offset left turn lanes might cause driver confusion…." Dotted lines are typically used, with solid lines permitted "[w]here greater restriction is required."

Within intersections, the use of Shared Lane Markings to provide lateral position guidance for through bicyclists may be valuable especially where there is substantial right-turn volume on entry and/or corner property driveways just beyond the intersection (see section on Intersection Departure below). In these situations a bicyclist's line of travel, roughly centered within the prolongation of the right-most through lane through the intersection, can deter right turn movements from their left side (a.k.a. right hooks or right-turn cutoffs).

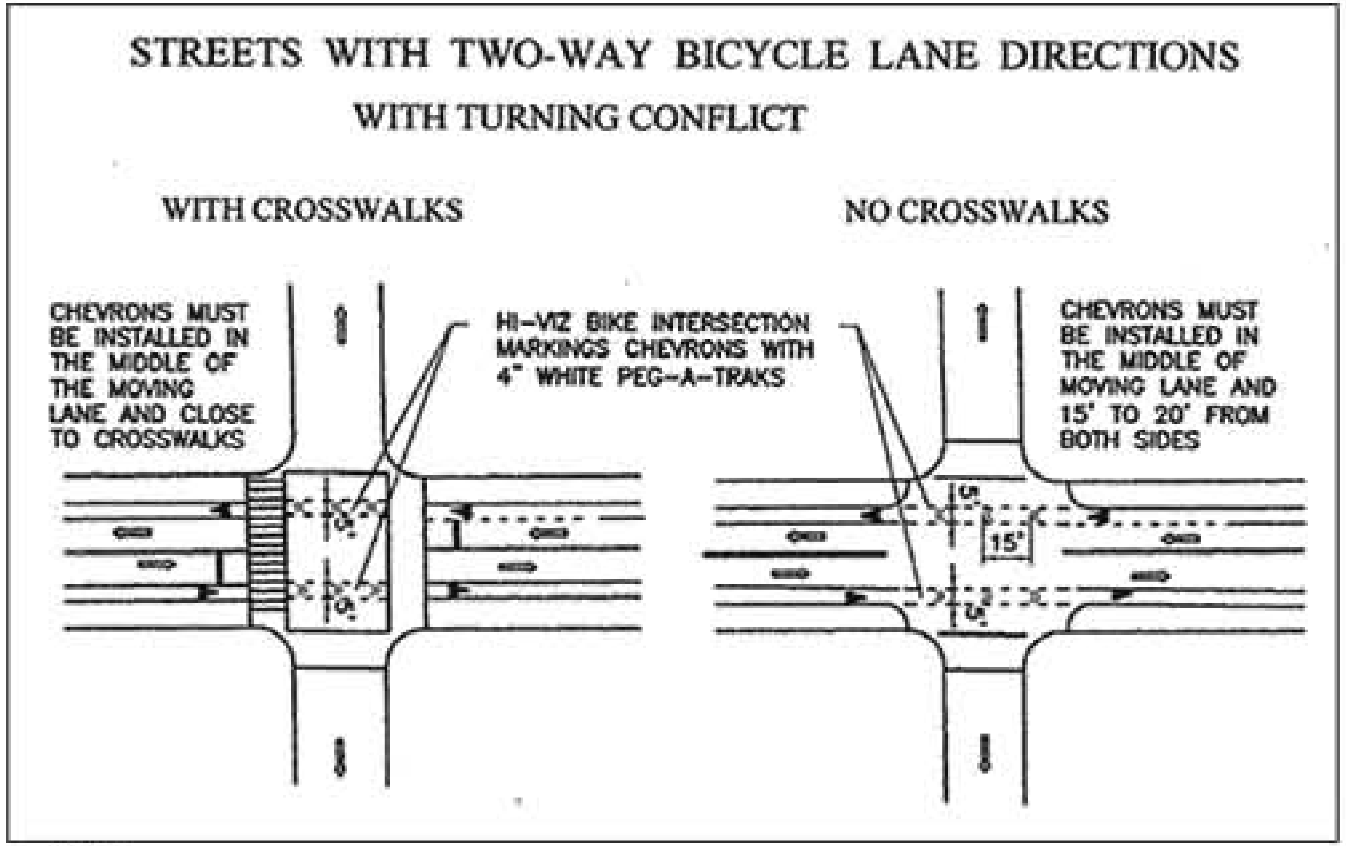
Often the physical or effective width of the outer through lane on the intersection approach and/or just beyond the intersection is too narrow for safe passing. Even if the intersection's curb returns provide a wider usable through lane prolongation through the intersection, a bicyclist must prepare to deter passing immediately after leaving the intersection. Bicyclist safety is enhanced by following a line of travel within the intersection that sets up the lateral position needed upon leaving the intersection.

Some inexperienced bicyclists also ride through intersections in the marked crosswalk of the cross street, in the mistaken belief riding in this marked area enhances their visibility and reduces their risk. In reality, riding through the crosswalk places the bicyclist squarely within the right turn conflict areas when entering and leaving the intersection. The use of bicycle continuation markings such as Shared Lane Markings may tend to reduce crosswalk-riding behavior and thus improve safety. This has not been tested by research.

At large intersections with simultaneous opposing left turn movements, Shared Lane Markings may be useful for guiding left-turning bicyclists to stay well within their turning movement's sweep to avoid oncoming left turners while deterring passing by following motorists.

The New York City Department of Transportation (NYC-DOT) uses dotted lines, optionally with the SLM chevron, to guide bicyclists through intersections (shown in Figure 14-14). Treatments are selected based on turning conflict volume.[26]

FIGURE 14-14. NYCDOT Highway Design Typical Markings



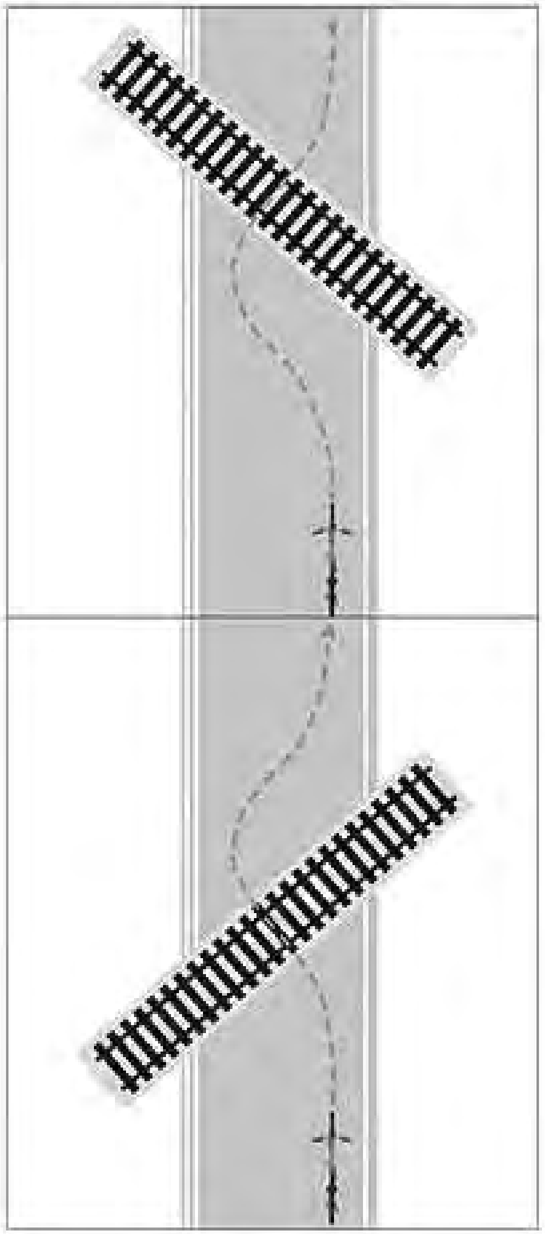
SOURCE: New York City Deparment of Transportation, excerpt from Drawing TBI-1.

Leaving Intersections. High-activity retail uses such as coffee shops, convenience stores, and gas stations are often located at intersection corners to attract motorist customers. These corner land uses often have one or more driveways near the corner. Many through motorists traversing an intersection will turn right into these driveways immediately upon leaving the intersection, creating right turn conflicts with through bicyclists who traverse the intersection on a parallel line of travel to their right, or who return to the curb immediately upon leaving the intersection. A curbside bicycle lane that begins just after the intersection can exacerbate this conflict.

Placing Shared Lane Markings in a right-turn-deterring position through this corner property right turn conflict area may encourage through bicyclists to ride away from the curb and deter the conflicting turns. Placing SLMs within the intersection on a line of travel that sets up such a deterring position beyond the intersection may also be valuable—see Intersection Continuation above.

Angled Railroad Crossings. Railroad tracks angled substantially from the transverse direction can guide a bicycle's front wheel either by causing it to slip along the metal rail or by trapping it in the flangeway gap, causing a sudden fall from which it is almost impossible to recover. As shown in Figure 14-15, angled tracks may be oriented "near-right to far-left" or "near-left to far-right." In the first case the bicyclist must occupy the lane before crossing to deter passing while crossing. In the second case the bicyclist will occupy the lane after crossing.

FIGURE 14-15. Recommended Bicyclist Travel Path Crossing Angled Railroad Tracks



SOURCE: John Ciccarelli.

At either type of angled crossing, Shared Lane Markings can be used to guide bicyclists to cross the tracks at a more perpendicular angle than the roadway alignment. At a "near-right to far-left" angled crossing, Shared Lane Markings can be used to guide bicyclists to approach in a lateral position that deters passing. At a "near-left to far-right" angled crossing Shared Lane Markings can be used to inform roadway users bicyclists will occupy the lane after crossing.

Shared Lane Markings used to guide bicyclists through such maneuvers should be closely spaced to make the turning movements apparent. The alignment of markings should reflect actual bicycle movements and speeds while executing the maneuvers. Figure 14-16 shows a nonstandard treatment using Shared Lane Marking elements. At this writing such usage would be experimental.

FIGURE 14-16. Elements of Shared Lane Markings at Angled Rail Crossing (Seattle, Washington)

SOURCE: Stephen M. Ciccarelli.

Where right of way is available, agencies should consider widening the shoulder in the vicinity of the railroad crossing to eliminate the need for bicyclists to move leftward into the lane before or after the crossing. If this is done, bicyclist guidance is usually provided by curving the edgeline or bike lane if one is provided.

Transitions and Continuity. As cross sections change along a roadway where Shared Lane Markings are used, the line or curve described by successive markings should indicate a reasonable bicyclist line of travel, without abrupt jumps in lateral offset, as for example where parallel parking begins and ends. Exceptions to this general principle include SLMs used to guide bicyclists through curving maneuvers, such as required to cross angled railroad tracks as discussed above.

Obstruction and Drainage Grate Markings

Drainage openings in the roadway surface, especially ones using bar-type grates with openings parallel to the curb, can be problematic for bicyclists. Some grates have spaces between the bars or gaps between the frame and body of the grate that are wider than bicycle tires. These grates can cause a bicycle's front wheel to suddenly drop into the grate or be diverted from the bicycle's travel path, causing a severe crash. Other surface imperfections, such as slots between pavement slabs wide enough to allow a bicycle wheel to drop in and be trapped, or sudden vertical bumps from utility covers or plates, can also cause crashes.

The optimal solution to the problem of drainage grates and other similar roadway imperfections is to remove or modify them so they are no longer within the travel path of bicyclists, or no longer allow a wheel to drop in or be diverted. Many standard parallel-bar grates can be replaced with curb inlets, or with grates that will not allow bicycle wheels to drop in, yet still offer good hydraulic efficiency. If a grate or other obstruction cannot be replaced or modified, pavement markings as described and shown in Section 9C.06 and Figure 9C-8 of the 2009 MUTCD may be used.

Signing of Shared Roadways

In general, no special signing is needed for bicycle travel on shared roadways, unless the agency chooses to identify the roadway as a designated bikeway by installing bike route signs or route signs. As on all other roads, bicyclists will be guided and governed by the same traffic control devices as other road users. However, it may be beneficial to provide additional bicycle-specific route guidance as described in an earlier section of this chapter. Other signs that may be useful on shared roadways are Bicycle Wrong Way sign assemblies facing wrong-way traffic and shared lane markings. W11-1 Bicycle Warning signs should not generally be used in conjunction with on-street bicycle facilities, since travel along such bikeways does not typically present any special hazards.

Share The Road Signs. In 1997, FHWA added the Share the Road sign assembly to the MUTCD. This is comprised of a W11 series mode warning sign with a SHARE THE ROAD (W16-1P) plaque immediately below the W11 sign.

This was intended to serve a variety of modes, including farm equipment, horse-drawn conveyances, and bicyclists, and to convey a message of cooperative use of the street, road, or highway.

However, since its introduction, there have been significant problems reported with the application and the results of the SHARE THE ROAD sign assembly. In some areas, agencies did not use a standard W11-1 bicycle symbol sign, but instead used signs with multiple symbols, most frequently a combination of an end-on motor vehicle and bicycle (neither of which are FHWA-approved symbols for this application) traveling side by side. This has been interpreted by road users as indicating bicyclists must always ride to the right of motorized traffic, even in areas where lane or roadway widths are too narrow for side-by-side operation. In other areas, agencies combined a number of travel mode symbols on a single sign panel, which resulted in much greater difficulty in discerning each symbol and the combination of symbols at roadway speeds, and also resulted in viewers interpreting the symbols in unexpected ways; i.e., reading relative positions of the symbols as being a significant part of the sign message. Agencies that followed the MUTCD guidelines and used a standard W11-1 sign as part of the SHARE THE ROAD assembly received reports of problems in that "share" is interpreted differently by different classes of users. For example, in a narrow travel lane, bicyclists occupying the center of the travel lane are, in their interpretation "sharing" correctly, as they are using the same roadway as other traffic in a cooperative manner. However, some motorists interpreted "share" as meaning slower bicyclists have an obligation to move out of the way of faster traffic, because otherwise the bicyclists aren't "sharing"—they are hogging the available roadway width.

Due to numerous reported problems with the SHARE THE ROAD sign assembly, other devices that can deliver a much more specific message to road users on lane use have been developed, including the shared lane marking and the Bicycles MAY USE FULL LANE (R4-11) sign (see below).

Bicycles MAY USE FULL LANE (R4-11) Sign. Section 11-1205(a) of the UVC and the traffic laws of nearly all states note slower-moving bicyclists should stay to the far right of the roadway, but create a specific exemption to this rule where the width of a roadway or travel lane does not allow for operation of a bicycle and motor vehicle side by side with adequate lateral separation. Unfortunately, many road users are not aware of this important exception written into the law. To help in these locations, the Bicycles MAY USE FULL LANE (R4-11) sign has been added to the MUTCD. This sign may be used where appropriate to convey to road users a clear message bicyclists may legally choose to use as much of the lane width as needed for safe and convenient operation, and are not compelled to stay to the far right.

FIGURE 14-17. Example of Bicycle MAY USE FULL LANE (R4-11) Sign (Tampa, Florida)

SOURCE: Jennifer Bartlett, Sprinkle Consulting.

The R4-11 sign is not a cure-all for operational issues arising from bicyclist operation in narrower lanes. In many cities, many or nearly all streets are potential candidates for this sign, and any attempt to post all potential locations would result in significant sign clutter. Therefore, judgment should be used in determining the most effective use of this sign. One method is to base use of the sign on lane width and volume of bicycle traffic, with criteria set by the agency, as appropriate. Another method is to install the signs where reports have been confirmed of conflicts or operational issues between bicyclists and other road users in locations with narrower lanes.

Although the Bicycles MAY USE FULL LANE sign and shared lane markings are used in similar locations and convey a generally similar message, the two devices are distinct and separate parts of a well-prepared traffic engineer's toolbox. The two devices can be used together, but this is not required. The R4-11 sign does not convey as specific a lateral positioning message as a shared lane marking, but may have a lower operational and life-cycle cost. The R4-11 sign may be used on roadways with a wide range of travel speeds.

And the R4-11 sign can also be used in locations where it is infeasible or inappropriate to install shared lane markings.

Other Signs. Other signs as noted in previous sections of this chapter may be used on shared roadways as appropriate based on engineering judgment and MUTCD Standards and Guidance.

DEVICES FOR SHOULDER BIKEWAYS

Shoulder Use by Bicyclists

Most state traffic codes permit, but do not require, bicyclists to use shoulders. Bicyclists can reasonably be expected to use shoulders when provided, but only if such shoulders are suitable for bicycle travel. There are a number of situations where shoulder use may be advantageous, such as on high-speed highways, roads with heavy truck traffic, and rural roadways with numerous curves or limited sight distance. Shoulders may not be appropriate for bicycle travel in locations with numerous intersections and right turn lanes, or on roadways with shoulders that have a usable width too narrow for bicycle travel. Shoulders also tend to accumulate debris that can be inconvenient or problematic for bicycle travel, so it is advisable to periodically sweep or clean shoulders frequently used by bicyclists, or are in locations where shoulder use may be required by law or administrative resolution, such as on freeways or expressways.

Bicycle Operation on Rural Highways

Bicyclists use all roadways legally open to bicycles, including rural highways. Often a rural highway is the only practical route between towns. The following issues are relevant to bicycle operation on rural highways issues, with implications for traffic control devices.

Operating Width. Paved shoulders with a clear width greater than 4 ft. (1.2 m), or a combined width of the right lane and shoulder (if no rumble strips are present) of 14 ft. (4.3 m) or greater, can greatly improve the convenience and perceived comfort of motor vehicle and bicycle travel on rural highways. However, roadways with low traffic volumes can serve bicycle travel acceptably even if shoulder width is less than 4 ft. (1.2 m). On higher-volume roadways, shoulder widths of 1.5 to 3.5 ft. (0.5 to 1.1 m) can create a perception the shoulder is sufficiently wide for use by bicyclists, when in fact the shoulder is actually too narrow for effective or continuous use by bicyclists. At these locations, it may be advisable to adjust lane and shoulder widths to reduce ambiguity.

On significant grades with limited total right-of-way width, providing extra width in the ascending direction should be prioritized. This is analogous to providing a climbing lane for trucks and slow motor traffic. Bicyclists descending significant grades can achieve moderate to high speeds and require the full outside lane width for control.

On long stretches of highway without comfortable width for passing of bicyclists, periodically providing shoulder width can enable bicyclists to pull aside and let waiting motorists pass.

Sight Distance. Rural highways often have high posted speed limits, resulting in high closing speeds between motorists and bicyclists. Adequate sight distance at crest vertical curves and horizontal curves—especially rightward curves—is important for safety. Provision of shoulders wide enough for comfortable bicycle use can reduce conflicts in areas of limited sight distance and on ascents.

Wind Effects. Large vehicles such as truck trailers and recreational vehicles push air to the sides at the front and draw it in at the rear of the vehicle. These "wind blast" effects are especially pronounced at high speeds, and can cause a closely passed bicyclist to lose control. In addition, bicyclists operating in significant crosswinds lean aside into the wind and can be toppled when a passing large vehicle's wind effects add to or subtract from the crosswind. Large vehicle wind blast effects decrease rapidly with lateral separation, so extra shoulder width is useful for reducing the effect of wind blast in areas that experience significant crosswinds.

Centerline Issues. Two-lane rural highways often have long stretches of double-yellow (no-passing) centerline. Some of these segments have little or no shoulder usable by bicyclists. Motorists will often pass bicyclists on these segments regardless of the centerline passing prohibition. Some states do permit crossing a double-yellow centerline to pass bicyclists on a two-lane highway when there is a gap in oncoming traffic.

Center line rumble strips (CLRS), intended to reduce the incidence of head-on collisions, have the side effect of deterring passing of bicyclists by motorists. The presence of CLRSs may increase conflicts between motorists and bicyclists on two-lane roadways with insufficient width for passing. See a later section of this chapter for discussion of rumble strips.

Shoulder Issues. Shoulder rumble strips, intended to reduce the incidence of run-off-road crashes, reduce the shoulder operating width available for bicycles. Best practices exist for the design and use of shoulder rumble strips; see a later section of this chapter for discussion of rumble strips.

Conventional shoulder striping provides incorrect guidance to bicyclists and motorists in several situations, including deceleration/exit lanes, acceleration/merge lanes, and exit diverges. Modified shoulder striping that incorporates useful features of bicycle lane striping addresses these issues.

Bicycle Operation on Freeways and Expressways

In some instances, a freeway or expressway may be the only available means of travel between destinations. A number of agencies permit bicycle travel on the shoulders of freeways or expressways under their jurisdiction. Such freeway or expressway shoulders would not normally be marked as bikeways, unless they comprise part of a larger system of bikeways, and meet suitability criteria set by the operating agency.

Traffic safety studies[27] have shown a remarkably low number of bicycle-motor vehicle crashes on freeways, in spite of the high motor vehicle speeds encountered. Much of this can be attributed to the elimination of the turning, crossing, and opposite-direction conflicts found on ordinary streets. While wind blast effects from high-speed trucks can be considerable, most freeway or expressway shoulders offer sufficient width to permit bicyclists to avoid severe wind blast.

Freeways or expressways open to bicycle travel typically have the following characteristics:

- continuous paved shoulder widths greater than five feet (1.5 m), excluding rumble strips;
- expansion joints and drainage grates traversable by bicyclists;
- relatively infrequent on-ramps and off-ramps, with good sight distance; and
- lower truck volumes.

However, even if all the preceding conditions cannot be fully satisfied, if no other route is available that offers reasonable safety and convenience for bicyclists, bicycle access to the freeway or expressway may be considered until such time as improvements—such as wider shoulders, improved grates and joints, or an acceptable parallel facility—can be provided.

TABLE 14-6. Shoulder Striping vs. Bike Lane Striping

Context	Striped Shoulder	Bicycle Lane
a) Cross street without right turn only lane	Curves around corner, to indicate edge or shoulder of cross street	Continues straight toward intersection
b) Cross street with right turn only lane		Dropped or dashed across transition zone. Placed to left of right turn lane(s) in storage zone
c) Exit diverge	Curves into exit, to indicate edge	Interrupted or dashed across exit
d) Merge area	Stays to right of merge area	Dropped or dashed across area
e) Right turn/deceleration lane	Stays to right of lane. Roadway right turn area is to the left of shoulder bicycle through area	Stays to left of right-turn lane(s). All through traffic is to the left of all right-turning traffic
f) Acceleration/merge lane	Stays to right of lane	Stays to left of lane. Often dashed across merge area

SOURCE: John Ciccarelli.

It may be better in some cases to permit bicyclists to merge across ramps and continue on the freeway or expressway mainline instead of requiring the bicyclist to exit and re-enter at each ramp. While there is some element of risk inherent in crossing high-speed ramps, this must be balanced against the induced delay and exposure to crossing and turning traffic that would occur at each cross street if the bicyclist is required to exit and cross the intersecting roadway at grade.

R5-7, R5-10a, and R5-10b signs are typically used for prohibiting bicycle access to freeway ramps. When bicycle access is permitted but pedestrians are prohibited, an R9-3 sign may be used in lieu of bicycle prohibition signs. Where bicyclists are directed off a freeway at an off-ramp, a BICYCLES MUST EXIT or similar sign should be used ahead of the ramp, with an R5-6 bicycle prohibition sign placed past the ramp.

An example of a statewide policy for bicycle access to freeways or expressways might read as follows:[28]

> *"Bicycles are permitted by law to operate on all State highways, including freeways and expressways, except where excluded by administrative regulation and the posting of signs to give notice of a prohibition. It is, therefore, intended that bicycles shall not be prohibited from controlled-access highways except under those conditions where alternate routes are available and where such alternate routes are considered comparable or better in terms of convenience and safety. It is not practical to establish specific criteria or absolute values to determine alternate routes. Each case shall be judged on its own. Factors that may be considered in evaluating the situation include, but are not limited to, traffic volumes, roadway geometrics, pavement surface conditions, travel times and distances, and potential for conflicts."*

Shoulder Striping vs. Bike Lane Striping

Striped shoulders of sufficient rideable width are similar to bike lanes in that they provide a bicycle-exclusive travel space. However, the original function of an edgeline is to indicate the right edge of the motor vehicle travel area, not to also indicate the left edge of a shoulder bicycle travel area. As such, conventional (edgeline-based) shoulder striping differs from bicycle lane striping in safety-significant ways in several contexts listed in Table 14-6. Conventional shoulder striping provides correct right-side guidance to users of the outside lane, but incorrect guidance to bicyclists operating on the shoulder to the right of the line.

Modified edgeline details for these situations can incorporate many of the bicycle guidance advantages of bicycle lanes while continuing to provide correct right-side guidance to motorists. Note the MUTCD prohibits the use of bike lane word and symbol markings on shoulders.

Rumble Strips

On many rural highways, milled-in rumble strips have been installed to give motor vehicle drivers tactile feedback and warning if their vehicle is departing the travel lane and straying onto the shoulder. Research has indicated these rumble strips can greatly decrease the incidence of run-off-road crashes. However, milled-in rumble strips can create severe operational difficulties for bicyclists. A bicycle riding in a milled-in rumble strip pattern will be subject to significant vertical oscillations that can quickly lead to loss of control and a severe fall-type crash. Even "bicycle-tolerable" rumble depths and patterns can be very uncomfortable for bicycle travel.

If longitudinal milled-in rumble strips are installed on the shoulders of rural highways open to bicycle travel, these rumble strips should use a design that does not create problems for bicyclists. Rumble strips should not be placed on roadway shoulders unless 4 ft. (1.2 m) of clear shoulder width can be maintained outside the rumble strip area. In addition, placing short gaps in the rumble strip pattern of 10 to 12 ft. (3.0 to 3.6 m) in length every 40 to 60 ft. (12 to 18 m) allows bicyclists to enter and leave the shoulder as necessary without having to enter the rumble strip pattern.[29]

Reports from transportation agencies seem to indicate many rumble strip-related crashes involving bicyclists occur at locations where a rumble strip pattern begins on an otherwise clear shoulder, and bicyclists are not aware of the rumble pattern until they enter it. There have been proposals for signs and markings to notify bicyclists of the beginning of a rumble strip pattern, but no standard treatment has been devised or is included in the MUTCD. One suggested treatment that may show some promise is the use of a transverse pavement marking pattern 100 to 200 ft. (30 to 60 m) in advance of the rumble strip that mimics the groove pattern; however, this has not been evaluated for effectiveness.

In areas which do not see notable amounts of snow plow activity, pavement markings with a raised profile have been used to create a tactile lane departure warning without the operational issues of milled-in rumble strips. Some of these designs, such as ones that use a "corrugated" marking surface, may not create problems for bicyclists, especially if periodic gaps of standard or lower-profile markings are provided. However, markings that use a periodic and abrupt raised profile, or the use of raised pavement markers as a rumble strip, may cause problems for bicyclists, including the possibility of loss-of-control crashes due to the front wheel being jolted out from under the rider's path.

DEVICES FOR BIKE LANES

Bike lanes are roadway travel lanes set out for the preferential use of bicyclists, in much the same manner as a preferential lane for buses, high-occupancy vehicles (HOV), or other special vehicle types. Bike lanes are used when there is a desire to specifically delineate roadway space for bicycle travel. For example, where there may be insufficient space for comfortable bicycling on existing streets, bike lanes could be installed by adjusting travel lane widths and parking accommodations. Bike lanes may also improve traffic flow by channelizing overtaking traffic past slower-moving bicyclists, and by reducing uncertainty by motorists in passing bicyclists. Bike lanes can allow bicyclists to conveniently pass slower traffic in congested locations. Bike lanes may also decrease the incidence of sidewalk riding in a roadway corridor. On high-volume or higher-speed streets, bike lanes may offer greater benefits, whereas on low-volume, low-speed streets, there may be little benefit in establishing bike lanes.

Bike lane lines define a preferential, but not necessarily exclusive, travel path for bicyclists on the roadway. Depending on state and local laws, other traffic may enter bike lanes for turning or merging, for emergency stopping and parking similar to a shoulder, or for accessing on-street parking. Agencies may install combination right-turn-plus-bike lanes, which may be continuous along the right-hand side of the roadway, and may also be used by buses.

Bike lanes, like any other designated bicycle facility, should be part of a consistent and continuous network of accommodations that serve the travel needs of bicyclists. Also, bike lanes should not be confused with off-roadway facilities such as sidepaths—if it is not on the roadway, it is not a bike lane. In most states, there is no law compelling bicyclists to stay in a bike lane at all times, just as there are no laws compelling carpools to stay in HOV lanes or buses to stay in bus lanes.

In general, bike lanes should be laid out to follow normal and legal travel patterns of bicyclists along roadways and at intersections, and will place the through bicyclist in the proper position on the roadway for convenient operation and to minimize the potential for conflicts with turning traffic.

Bike lanes do have some disadvantages. The following are among them.

- In warmer climates, asphalt concrete pavements may develop raised ridges along cracks in areas not subject to frequent automotive traffic. These cracks are uncomfortable for bicyclists, and may possibly cause bicyclists to fall.
- Bike lanes may encourage some inexperienced cyclists to turn left from the bike lane, placing them in conflict with other traffic.
- If not swept frequently, bike lanes may accumulate sand, gravel, and other debris. (See Figure 14-18.)

FIGURE 14-18. Debris Blocking a Bike Lane

SOURCE: Richard Moeur.

On arterial streets with frontage or service roads, it may be better to place the bike lane along the main roadway, and not along the frontage or service road. Although the main roadway may have higher operating speeds, it will also typically have relatively fewer turning and crossing movements, which are a far greater relative risk to cyclists than relatively infrequent overtaking-type crashes. Also, placing the bike lane on the main roadway will make bicycle traffic more visible to vehicles turning left or right off that main roadway.

Bike lanes should always be single-direction facilities. Two-way bike lanes violate normal rules of the road and road user expectations, and will cause serious conflicts at intersections and driveways. Additional marking and signing at these locations may not be effective in reducing these conflicts, since signing has historically been ineffective in contradicting or modifying ingrained driver behavior. Also, wrong-way bicycling is linked to significantly higher bicycle crash rates. Arrows as shown in Figure 9C-3 of the 2009 MUTCD and on many of the figures in this chapter are recommended for use on bike lanes to reinforce the directionality of the facility.

With very few exceptions, bike lanes should be placed adjacent to the right-hand side of the roadway. Bike lanes should never be placed on sidewalks.

On a two-way street, if bike lanes are provided they should be placed on both sides of the street. A bike lane placed on only one side of a street is very likely to be used in two directions, as bicyclists may perceive it as the only safe or legal place to ride on that street in either direction, encouraging wrong-way travel and increasing crash risks. One limited exception to this rule may be employed on a two-way roadway with a steep grade. In locations with steep grades, bicyclists will likely be riding very slowly in the uphill direction, but much faster in the downhill direction. It may be advantageous in these locations to stripe a bike lane in the uphill direction to accommodate slow cyclists, and install shared lane markings in the downhill direction to encourage bicyclists to use more roadway space at higher speeds in order to avoid parked vehicles and other obstacles.

On a one-way street, a bike lane is usually placed to the right-hand side of the roadway. An exception can be made where there are high volumes of right-turning traffic, or significant volumes of trucks or transit vehicles in the right-hand travel lane, or significant destinations of interest to bicyclists on the left-hand side of the one-way street. In these circumstances, it may be preferable to place the bike lane to the left-hand side of the one-way street, with all lane line markings mirrored as appropriate. On one-way streets, it may be appropriate to use additional directional arrows and Bicycle Wrong Way sign assemblies facing wrong-way traffic to discourage wrong-way travel in the bike lane.

Where there are "couplets" of adjacent parallel one-way streets, it is recommended bike lanes be installed on both streets to provide facilities in both directions. If there is a high incidence of wrong-way bicycling in the bike lanes on these streets, it may be a good idea to use Bicycle Wrong Way signs along with regulatory signs facing wrong-way traffic, directing bicyclists to use the correct-direction street in the couplet.

Due to the absence of the "sweeping action" of regular motor vehicle traffic, bike lanes and shoulders may collect gravel and other debris, such as the lane shown in Figure 14-18. A regular program of cleaning and sweeping bike lanes is desirable to keep the facilities clear and open to bicycle travel, and to reduce risk exposure and liability to the operating agency.

Bike Lane Signing

Unlike signs for other types of preferential lanes, there is not a requirement to place Bike Lane regulatory signs where bike lanes are present. If used, regulatory, warning, and other signs for bike lanes should be placed at the same height and offset as for all other signs on roadways open to motorized traffic, as shown in Part 2 of the 2009 MUTCD. The sign heights and offsets shown in Figure 9B-1 of the 2009 MUTCD are for shared-use paths, and are not applicable to roadways since the signs will need to be seen by all road users, not only bicyclists. All signs installed along bike lanes shall be retroreflective or internally illuminated.

Bike Lane signs may be placed to define the bike lane at the far side of intersections and periodically along longer segments of roadways, generally at the same spacing and locations as the bike lane markings. Bike Lane Ahead signing should be used in advance of the beginning of a bike lane. This sign should not be used at temporary interruptions of bike lanes at intersections or similar locations. End Bike Lane signing should be used to mark the end of a bike lane. Again, this sign should not be used at temporary interruptions of bike lanes. See Figure 9C-6 of the 2009 MUTCD for examples of the use of bike lane signing.

Bike Route signs are typically not used in conjunction with bike lane signs. A section of bikeway that is signed as a bike lane does not need to include D11-1 Bike Route signs, because the bike lane sign serves the same purpose (a bike lane is by definition a bike route), and is the correct sign specific to the facility. However, modified D11 series signs and bicycle-specific D1 signs providing detailed destination signing may be useful for bicyclist guidance in conjunction with bike lanes. M1-8, M1-8a, and M1-9 bicycle route number markers may also be used with bike lanes to establish a continuous numbered route.

Other regulatory signs may be used along bike lanes. The BEGIN RIGHT TURN LANE YIELD TO BIKES (R4-4) sign may be used at the beginning of an exclusive right turn lane added to the right of the bike lane. Bicycle Wrong Way (R5-1b) and RIDE WITH TRAFFIC (R9-3cP) signs may be placed back-to-back with other signs to discourage wrong-way bicycle travel. Where a parking lane is not provided, No Parking Bike Lane (R7-9) signs should be installed periodically along bike lanes. In locations where bike lanes are temporarily interrupted, Bicycles MAY USE FULLLANE (R4-11) signs may be used to remind bicyclists and other road users bicyclists may use the lanes as appropriate to continue their travel.

As is the case with shared roadways, bicycle-specific warning signs are generally not used with bike lanes. Exceptions to this may be the use of signing to denote locations of surface conditions such as railroad tracks or slippery pavement of special concern to bicyclists.

Bike Lane Markings

Bike lanes should be marked in a manner that makes them clearly distinct from shoulders or other travel lanes in accordance with the MUTCD. See an earlier section of this chapter regarding marking materials and their effects on bicyclists.

Longitudinal Markings. A normal width solid white line is generally used to delineate the bike lane from other travel lanes. Curbs, posts, raised pavement markers, or other raised devices should not be used to delineate a bike lane from other travel lanes, as these devices create a fixed-object collision risk that is much more likely to cause a crash than the risk of intrusion by motor vehicles. Bike lanes should not be continuously striped across marked crosswalks.

Bike lanes should have a minimum of 4 ft. (1.2 m) of clear pavement width, excluding gutter pans, longitudinal joints, and other obstructions. A width of 5 ft. (1.5 m) or greater is desirable, especially in locations with curbs at the roadway edge.[30] On roadways with higher motor vehicle speeds, a width of 6 ft. (1.8 m) or greater can make the bike lane more comfortable for use by less-confident riders. In congested urban areas, bike lane widths greater than 8 ft. (2.4 m) may see encroachment by motor vehicle traffic, unless bicycle volumes are high or effective enforcement programs are employed.

Where the outside edge of the bike lane is unclear or indistinct, such as locations without curbs, a normal width solid white line may be installed to mark the outside edge of the bike lane. Bike lanes adjacent to on-street parking are discussed in a later section of this chapter.

Symbol and Word Markings. First things first: If a facility is intended to be a designated bike lane, it must have bike lane symbols or word markings conforming to the MUTCD. Otherwise, it's indistinguishable from a marked shoulder.

Symbol and word markings are used within the bike lane to define its status as a preferential lane. These symbols and word markings should be placed after each intersection and along longer segments of roadways without intersections at periodic intervals of ¼ to ½ mile (400 to 800 m). Bike lane symbol and arrow markings may be used more frequently in areas where there is on-street parking or where additional emphasis may be appropriate. However, it may be advisable to avoid placing markings or symbols in locations where turning vehicles might cause premature wear or damage to the markings. Observing the travel paths of turning vehicles and then adjusting the locations of markings to avoid these locations may significantly improve service life.

Figures 9C-1 and 9C-4 through 9C-6 of the 2009 MUTCD show typical bike lane applications. Symbol markings used in bike lanes should conform to Figure 9C-3 of the 2009 MUTCD. Word markings in bike lanes should conform to the elongated designs shown in the MUTCD and *Standard Highway Signs* book, with the size reduced as appropriate to fit the facility.

The diamond symbol used for other types of preferential lanes should not be used in lanes used exclusively by bicyclists, due to confusion with HOV facilities and the erroneous interpretation of the diamond as a two-way arrow. The 2000 MUTCD established a compliance date of January 17, 2007 for replacement of all existing diamond markings in bike lanes with standard bike lane markings, so any existing diamond markings in bike lanes should be replaced with correct bike lane symbols or obliterated at the earliest practical opportunity.

Bike Lanes and Parking

Bike lanes are frequently installed adjacent to on-street parking. This section will discuss how the width, placement, and other features of bike lanes may be modified when each type of on-street parking is used.

It is inadvisable to place bike lanes between parked vehicles and the curb. These have sometimes been called "protected" bike lanes; that is a misnomer: This treatment offers no added protection from the most common types of urban bicycle crashes (and may in fact increase some risks). Placing bike lanes between parked vehicles and the curb creates a situation where bicyclists cannot be seen by motorists along the parallel roadway (and vice versa), which can create severe conflicts at intersections and driveways that may not be mitigated by traffic control devices. Placing bike lanes between parked vehicles and the curb also prevents bicyclists from making left turns except in a pedestrian manner. If a buffer between the parking lane and bike lane is missing, bicyclists may be at risk of striking opening doors on the passenger side of vehicles, or striking the passengers as they cross the bike lane to reach the sidewalk. This type of design can also create maintenance problems: The bike lane may accumulate debris that cannot easily be cleaned, and there may be conflicts with pedestrians who may perceive the bike lane as an extension of the sidewalk or pedestrian area, due to its placement away from the roadway.

Bike Lanes and Parallel Parking. Where bike lanes are adjacent to on-street parking, the parking lane width should be adjusted to take into account the space occupied by opening vehicle doors. At typical bicycle travel speeds, it is very difficult for bicyclists to predict or evade doors opened in their path. When allocating space between a parking lane and bike lane, it may be best to use a wider parking lane and a narrower bike lane, in order to channelize bicyclists farther from opening vehicle doors. This may seem counter-intuitive, as bicyclists, drivers, and others may perceive moving traffic in the adjacent travel lane poses a greater risk to bicyclists than stationary vehicles. However, same-direction crashes between vehicles in the travel lane and cyclists in the bike lane are typically rare,[31] whereas crashes between bicyclists and opening vehicle doors are much more likely.

If roadway width permits, it is better to place the bike lane completely outside the range of car doors, or at least 3 to 5 ft. (0.9 to 1.5 m) beyond the left side of parked vehicles. This can be accomplished by:

- using a parking lane width of 9 ft. (2.7 m) or greater next to the right of a standard-width bike lane;
- using a combination parking-plus-bike-lane width of 13 ft. (3.9 m) or greater with bike lane symbols offset to the far left near the lane line; or
- placing a buffer between a typical-width parking lane and a bike lane (see discussion on buffers between bike lanes and on-street parking below).

Bike Lanes and Angle Parking. If standard "head-in" diagonal parking is used along a roadway, bike lanes should be discontinued in the area, as drivers may not be able to see bicyclists in the bike lane when backing out of parking spaces. In these locations, it may be better to consider a conversion to back-in angle parking or other type of on-street parking, remove parking, or use shared lane markings placed near to the center of the right-most travel lane adjacent to the diagonal parking area to maximize the visibility of bicyclists traveling along the alignment of the markings.

FIGURE 14-19. Buffer Between Bike Lane and On-Street Parking

SOURCE: Richard Moeur.

Bike Lanes and Reverse-Angle Parking. Reverse-angle or "back-in" parking has been used successfully in areas with diagonal on-street parking to mitigate operational problems. Benefits include easier loading and unloading of vehicles, placement of passengers closer to the curb, greatly improved visibility when merging back into the roadway, and no risk of "dooring"-type crashes. Although reverse-angle diagonal parking does require a more-complicated entry movement than head-in angle parking, this can be more easily managed by the driver and other traffic. Note the diagonal parking spaces should be of sufficient length to accommodate nearly all reasonably expected motor vehicles, as a vehicle encroaching into the bike lane or roadway can create operational problems.

In locations with reverse-angle parking, bike lanes can be continued along the roadway adjacent to the spaces, preferably using a bike lane width that optimizes visibility to drivers pulling out of parking spaces.

Bike Lanes and Perpendicular Parking. It is very seldom bike lanes are installed adjacent to perpendicular on-street parking. This may occasionally occur in parking lots and similar areas. The concerns are similar to those with standard angle parking, with drivers backing up across the bike lane with limited visibility. In these locations, it may be advisable to use shared lane markings instead of bike lanes, to modify the parking to reverse-angle parking, or to remove the perpendicular parking.

Buffer between Bike Lane and On-Street Parking. As noted earlier in this chapter, crashes involving bicyclists and opening vehicle doors can cause severe injury. One countermeasure that has been employed to reduce the likelihood of this type of crash is to place a buffer zone between the parking lane and bike lane. This has been accomplished using longitudinal markings, transverse markings, or a combination of the two.

The outside edge of the buffer zone should be placed at the typical edge of the parking lane, and the inside edge of the buffer zone placed where at least 95 percent of opening vehicle doors will remain within the buffer area—creating a buffer area 2 to 3 ft. (0.6 to 0.9 m) in width, depending on parking lane width. A normal-width white longitudinal marking may be used to delineate the edges of the buffer area, or diagonal or transverse markings may be used. In general, longitudinal markings will have a higher material cost, but will be easier to install and maintain using long-line striping equipment. If no transverse markings are used, it may be advisable to install additional standard bike lane symbols and arrows in the bike lane, to emphasize the non-buffer area is where bicyclists are encouraged to travel.

In some locations, agencies have used elongated transverse parking stall space markings that extend into the bike lane the same width doors are expected to encroach. These markings, described informally as "parking Ts" or "parking crosses," have been reported to have a positive effect on bicyclists by encouraging travel farther from parked vehicles, but there is not much detailed data confirming this. In these locations, bike lane symbols and legends are placed farther to the left side of the bike lane to also encourage travel farther from parked vehicles.

Buffer between Bike Lane and Travel Lanes. A buffer may be installed between travel lanes and adjacent bike lanes. Chapter 3D of the 2009 MUTCD contains information on marking details for buffer-separated preferential lanes. Section 9C.04 of the 2009 MUTCD recommends bike lanes not be separated from other traffic by posts or raised pavement markers, and notes raised devices may create a potential of a fixed-object collision. Such obstacles can create a significantly greater crash risk to bicyclists than the potential threat from adjacent vehicles, since the frequency of falls and fixed-object crashes due to adjacent obstructions is significantly higher than the typical frequency of overtaking-type crashes. Also, while overtaking crashes can be quite severe, fixed-object crashes can be equally injurious. A collision with such devices typically diverts the bicycle's front wheel, causing the bicyclist to fall across the obstacle and possibly into the path of other traffic. Obstacles can also cause overtaking-type crashes by toppling the bicyclist into the path of other vehicles. Raised devices or obstacles can restrict the ability of bicyclists to make movements in entering and leaving the bike lane when necessary, and may likely encourage left turns by bicyclists across the path of through traffic at intersections by not permitting merging movements to a left turn lane position prior to the intersection. Finally, using raised devices may encourage wrong-way bicycle travel in the bike lane. Wrong-way bicycling is a violation of the UVC and state laws, and can increase the risk of intersection-related crashes by 300 percent or more, according to published studies.[32]

Motor vehicle operators in adjacent travel lanes may not be expecting higher-speed bicycle travel on the far side of a buffer area, even if signing and markings are used to denote bicycle use. This violation of driver expectations can be a significant cause of intersection- and driveway-related bicycle crashes, especially those involving vehicles turning left or right off the roadway. At approaches to intersections and high-volume driveways, eliminating the buffer and channelizing the bike lane in a conventional manner may reduce these conflicts.

Bike lanes should not be placed to the right of parking lanes, since this would place through bicyclists in severe conflict with pedestrians exiting and entering parked vehicles, and can greatly reduce the visibility of bicyclists approaching intersections and driveways by being out of the field of vision of turning and crossing traffic (see discussion at the beginning of this section).

Bike lanes separated by physical barriers, raised devices, or wider buffers have a greater tendency to accumulate debris and other hazards due to the lack of the "sweeping action" of motorized traffic. This can result in slippery surface conditions which, if not promptly removed by maintenance forces, are another source of potential liability. This may necessitate enhanced maintenance requirements to keep the facility usable and clear. It should be noted if the remaining clear width of the bike lane does not allow standard street cleaning equipment to access or travel along the area behind the raised devices, maintenance may become much more expensive and difficult for the agency, due to the need to use hand labor or specialized equipment.

Bike Lanes and Intersections

As noted in the section on bicycle crashes, most motor vehicle-bicycle crashes on roadways occur at intersections or driveways. Special attention should be given to proper design and channelization of bike lanes at intersections to allow for smooth and consistent traffic flow and to minimize unexpected conflicts.

Bike lanes may complicate both bicycle and motor vehicle turning movements at intersections. Bike lanes encourage bicyclists to keep to the right and other road users to keep to the left, which may create problems at intersections. Some bicyclists may initiate left turns from the right-side bike lane, placing them in conflict with vehicles proceeding straight through the intersection. Some motorists will begin right turns from the travel lane to the left of the bike lane, placing through bicyclists in conflict with right turning vehicles, contrary to the established rules of the road. Also, bike lanes can encourage bicyclists to overtake stopped vehicles on the right, where drivers will not be expecting overtaking maneuvers. Intersections with free-flow turn lanes or ramps can further complicate intersections where bike lanes are present.

Bike lane alignment at an intersection should encourage through bicyclists traversing the intersection to use a travel path that is direct, efficient, and parallel to other through traffic. There may be situations where this is not always practical, such as where the right travel lane becomes a right turn only lane, or where an optional turn lane is placed next to an exclusive turn lane. Recommended treatments for these specific situations are discussed later in this chapter.

When the roadway and travel lane widths do not permit a full-width bike lane to be continued to the intersection, the bike lane should be discontinued prior to the intersection at a point where the bicyclist can merge with through traffic in the right lane. Do not continue a bike lane to the intersection if minimum bike lane widths cannot be maintained. If a continuous travel path for bicyclists is desired, one option is to place markings and signs that permit through bicyclists to use the left side of the right turn only lane. This is discussed in more detail later in this section.

Do not use markings to channelize bicyclists onto sidewalks at intersections. Road users will not be expecting bicyclists to enter intersections from the sidewalk, and bicyclists on the sidewalk will be much less visible to turning and crossing traffic. There is also a risk of crashes due to bicyclists colliding with pedestrians on the sidewalk. If a crash involving a bicyclist occurs, and the traffic control devices at that location directed, recommended, or required bicyclists to use the sidewalk, this could place the operating agency in an adverse situation in terms of exposure to tort liability.

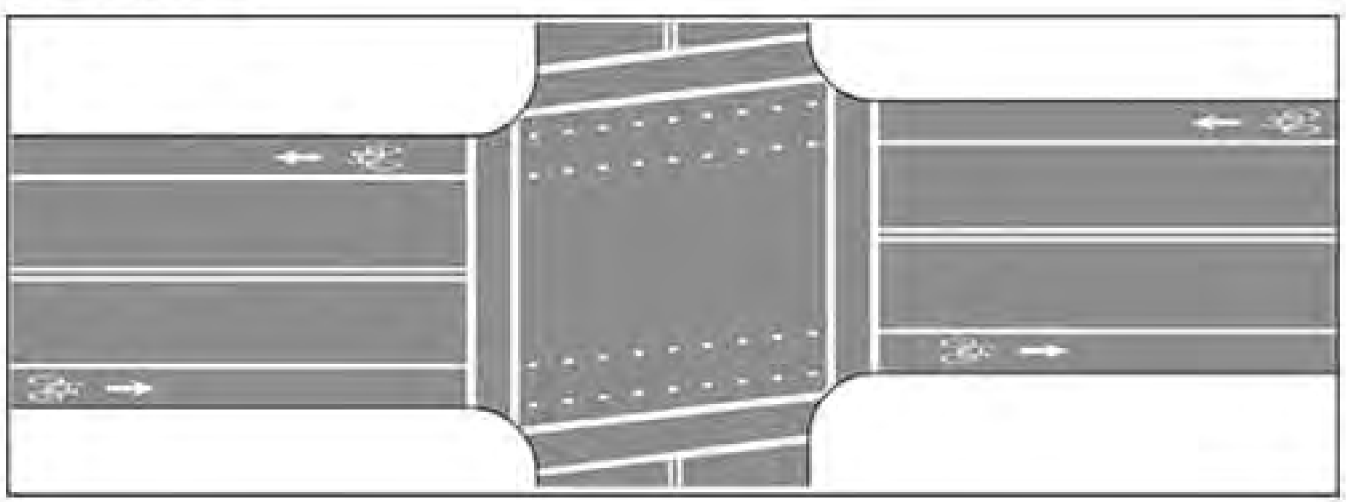
Where the travel path for bicyclists through an intersection may not be obvious, dotted lines may be used within the intersection to delineate the desired travel path for bicyclists, such as at offset intersections.

Signal timing and detection should be checked and adjusted as needed to ensure bicyclists entering the intersection are detected and receive adequate green time without excessive delay. See a later section of this chapter dealing with "Traffic Signals and Bicycles" for more information.

Solid, Dotted, or Dropped? In most states, vehicle laws call for right-turning traffic to make their turns from the far right edge of the roadway. However, in locations where a dedicated right turn lane has not been provided, the presence of a bike lane may discourage drivers from merging all the way to the right, and instead make their turn across the bike lane. This could create a severe conflict with bicyclists traveling straight at that location. In fact, this type of crash, commonly called a "right hook," is the leading cause of crashes for bicyclists operating legally on roadways. Although some bicyclists may be uncomfortable with the idea of a motor vehicle merging into "their" area, such a movement can minimize the possibility of crossing travel paths at the intersection and can greatly reduce ambiguity as to who will proceed first upon entering the intersection.

There are three different marking patterns that have been used in advance of intersections: (1) continuing the solid bike lane line all the way to the curb return of the intersection, (2) changing the solid line to a dotted normal-width line 50 to 200 ft. (15 to 60 m) in advance of the intersection, or (3) omitting or "dropping" the bike lane line entirely for a distance of 50 to 200 ft. (15 to 60 m) in advance of the intersection (see Figures 14-20 and 14-21). The dotted-line option is illustrated in Figure 9C-6 of the 2009 MUTCD, and the solid and dropped options are illustrated in other design guides.

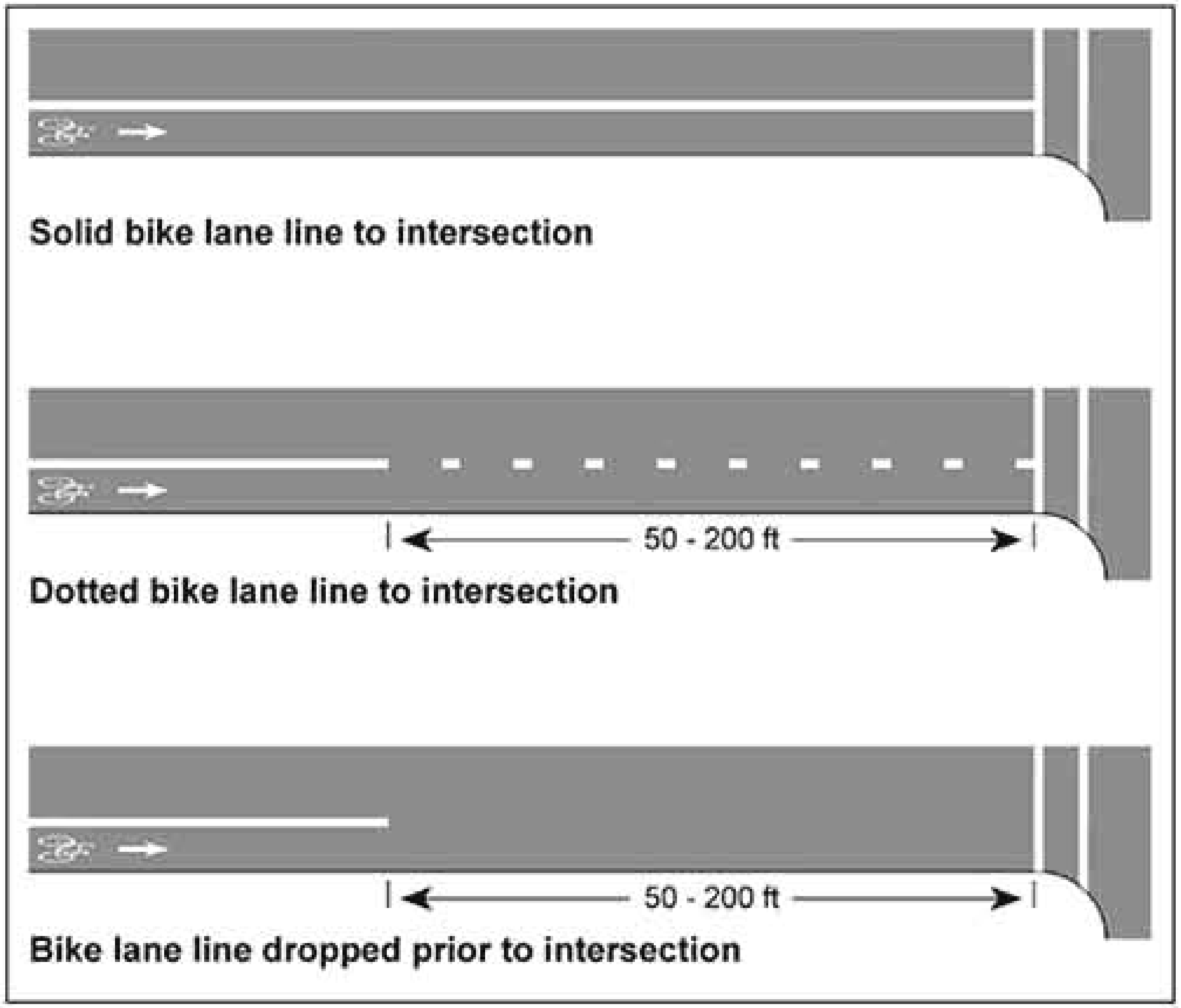
FIGURE 14-20. Continuation of Bike Lane Lines into Intersection



SOURCE: Richard Moeur.

There has been quite a bit of discussion in the bicycle transportation community about which of these options is preferable at certain types of intersections, with some practitioners making strong arguments in favor of one or more treatments. Although all three types of markings have been in use for almost four decades, there has never been any formal research study to determine which of them is most effective at a specific type of intersection and, at the time of writing of this *Handbook*, proposals to perform this research have not received funding. Therefore, no detailed guidance can be given as to exactly which marking style is "best," and engineering judgment should be used to select an option that may be "best" for a specific situation.

FIGURE 14-21. Bike Lane Line Alternatives at Intersection Approaches



SOURCE: Richard Moeur.

TABLE 14-7. Advantages and Disadvantages of Bike Lane Marking Patterns at Intersections

Marking Pattern	Advantages	Disadvantages
Solid Bike Lane Line to Intersection	• Creates a continuous path for bicycle travel along the roadway, interrupted only by intersections • Can be more "comfortable" for less-confident bicyclists • May reduce sidewalk riding at intersections • May be required by law in some states (check state & local laws)	• Can induce conflicts and crashes from right-turning motor vehicles turning across the path of through bicyclists • May need increased maintenance as markings wear near intersections
Dotted Bike Lane Line in Advance of Intersection	• Intended to allow right-turning motorists to merge into the bike lane before turning right • May reduce drivers turning across the path of through bicyclists in the bike lane • May reduce sidewalk riding by providing a "continuous" route	• May not actually induce drivers to merge to far right • Dotted marking may be a maintenance issue
Discontinued ("Dropped") Bike Lane in Advance of Intersection	• May be more likely to encourage right-turning motorists to merge to the far right than solid or dotted markings • Low maintenance • No legal ambiguity	• May not be "comfortable" for less-confident bicyclists • May see higher rates of sidewalk riding

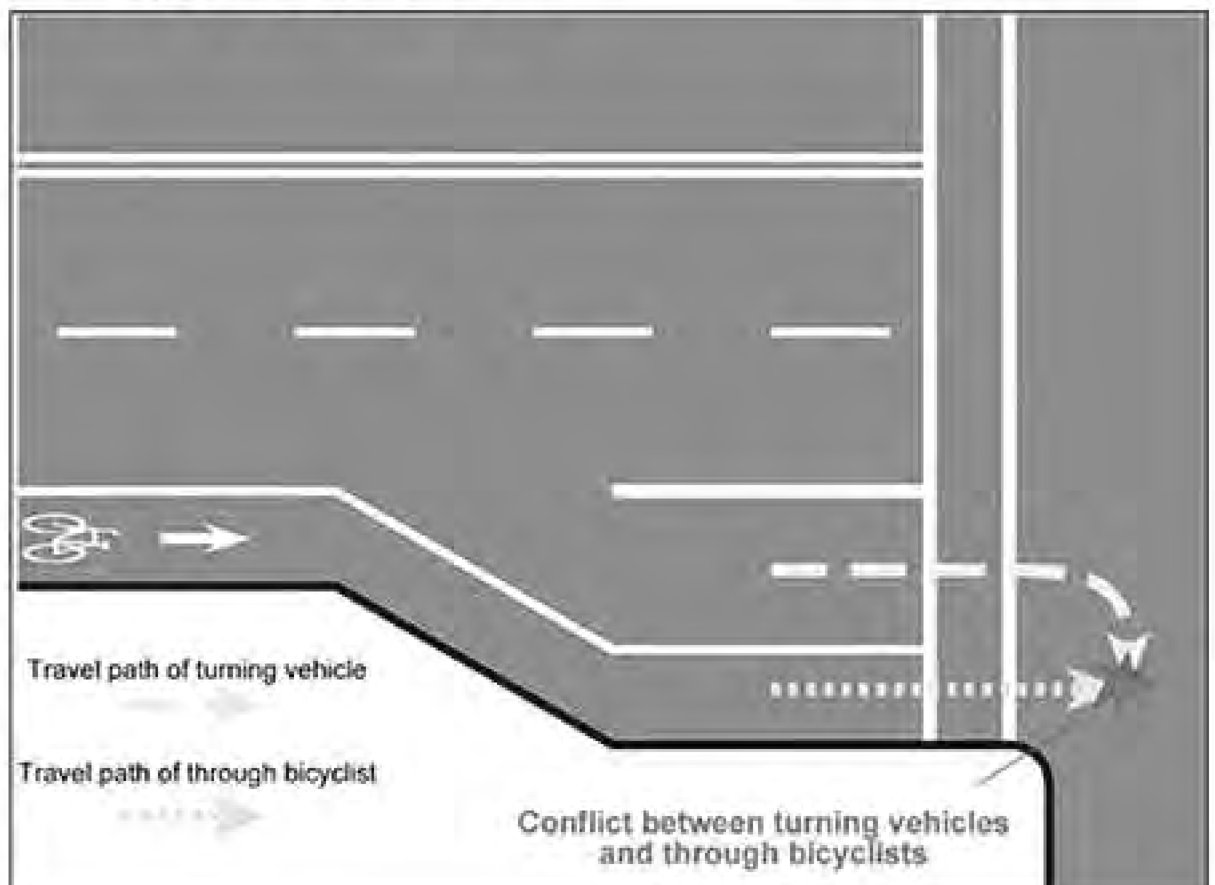
SOURCE: Richard Moeur.

In general practice, at major intersections with high volumes of turning movements the bike lane line is dotted or dropped. At minor intersections or driveways with low turning volumes, the bike lane line is continued solid to the intersection. At intermediate intersections, a variety of treatments have been employed. But practitioners are advised to use engineering judgment to determine the appropriate treatment at each location—and hope to have some research-based recommendations in the future.

Bike Lanes and Right Turn Lanes. At locations where there is a single exclusive right turn lane, the bike lane is placed between the right-most through lane and the right turn lane, as illustrated in Figures 9C-1, 9C-4, and 9C-5 of the 2009 MUTCD. This bike lane should be a minimum of 4 ft. (1.2 m) in width, but a wider lane up to 6 ft. (1.8 m) may be used to accommodate higher volumes of bicyclists where intersection width permits. The solid bike lane line is either dropped or changed to a dotted line at the upstream end of the right turn lane taper, and continues to where the through bike lane resumes, along the length and to the left of the right turn lane. This treatment does require drivers entering the turn lane to weave across the travel path of through bicyclists, but this weaving movement is performed in an area where there is typically an ample amount of sight distance, and more than sufficient longitudinal space to allow motorists to see, react, and yield to bicyclists. A BEGIN RIGHT TURN LANE YIELD TO BIKES (R4-4) sign may be placed to remind motorists entering the right turn lane to yield to bicyclists. Optionally, a broken line may also be placed at the right edge of the bike lane from the upstream end of the right turn lane to the upstream end of the solid turn lane stripe. Symbol and straight arrow markings may also be placed in the bike lane next to the turn lane to identify the roadway space and reinforce the message that only through bicyclists should occupy that lane.

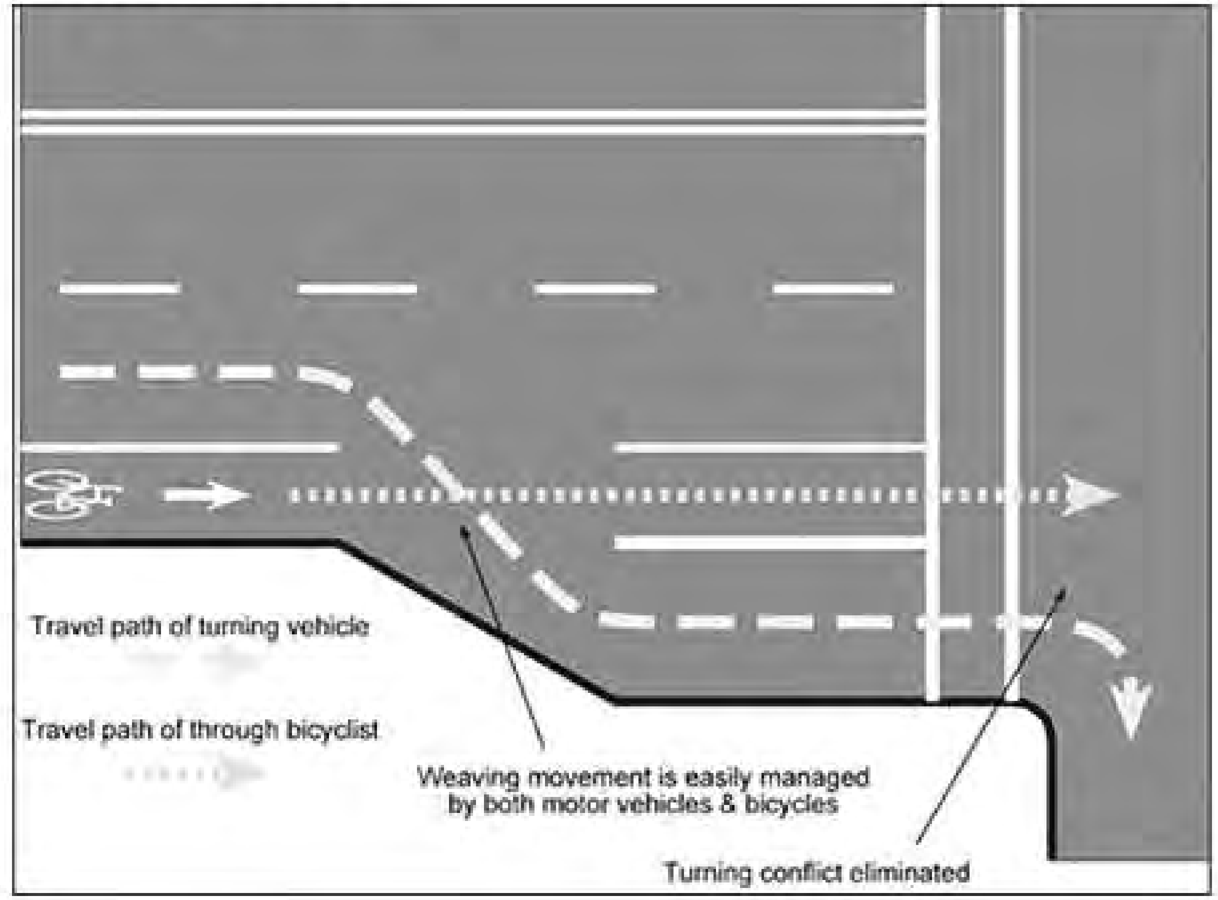
Through bike lanes should never be striped to the right of exclusive right turn lanes, as a bicyclist continuing straight through an intersection from the right of a right turn lane is inconsistent with normal traffic behavior and violates the expectations of motorists using the intersection. While it may seem through bicyclists are more exposed if there is motorized traffic on both sides, traffic in these lanes will be moving parallel to the bicyclist, not across the bicyclist's path, and this should not create a greater risk to the bicyclist (see Figures 14-22 and 14-23). Bike lanes should also not be placed to the right of exclusive bus or bus/right turn lanes, but note some cities have had operational success in designating the entire lane as a combination bus-plus-bike-plus-right-turn lane.

FIGURE 14-22. Problems With Placement of Bike Lane to the Right of a Right Turn Lane



SOURCE: Richard Moeur.

FIGURE 14-23. Correct Placement of Bike Lane to the Left of a Right Turn Lane



SOURCE: Richard Moeur.

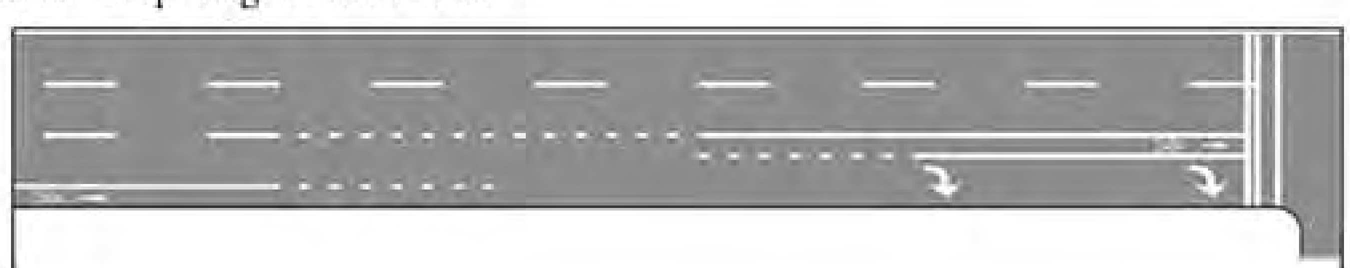
Where there is a painted island separating the right turn lane from other travel lanes, if the bike lane is routed to the left of this island, adjacent to other through travel lanes, it will reduce debris buildup in the bike lane. This treatment should also reduce the possibility of other drivers erroneously assuming bicyclists in the bike lane are turning right.

Right turn only lanes for bicyclists are not typically used, as bicyclists are usually comfortable sharing right turn lanes with other traffic. If an agency does see a need for a right turn only bike lane, such as at a T-intersection or where there are exceptionally high volumes of right-turning bicyclists, the lane should be placed to the right of the exclusive right turn lane, but arrows should be placed in the lane to clearly note the lane is not intended for through bicycle travel.

Lanes that become exclusive right turn lanes are often called "trap" or "drop" right turn lanes. Through bicyclists should merge across the right lane in order to continue along the roadway. In these locations, it is typically impractical to define a single path for bicyclists to follow while merging across the lane, due to variations in travel speeds and traffic flow, unless there are high bicycle volumes and very low volumes of right-turning traffic. Note R4-4 signs should not be used, as in this case the bicyclists are the road users needing to yield to traffic continuing in the lane. Figure 14-24 shows a recommended treatment for marking of bike lanes at these locations.

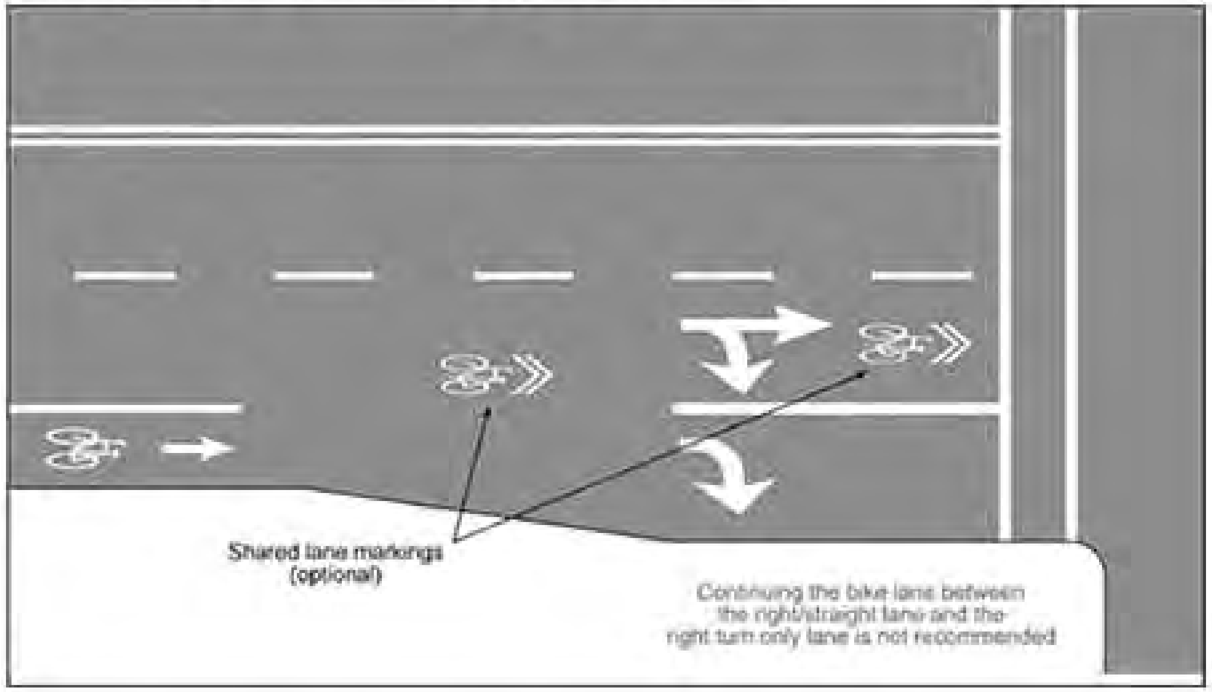
Intersections with multiple right turn lanes or straight/right optional lanes next to exclusive right turn lanes pose a problem for through bike lane designs. In these locations, bicyclists must merge across multiple lanes in order to continue along the through roadway. Roadways with bike lanes should avoid the use of this turn lane configuration. As noted in the MUTCD, if a straight/right option lane is placed next to an exclusive right turn lane where a bike lane feeds into the intersection approach, a capacity analysis should be performed to determine if the extra turn lane is truly necessary.

FIGURE 14-24. Recommended Bike Lane Treatment at "Trap" Right Turn Lanes



SOURCE: Richard Moeur.

FIGURE 14-25. Intersection Approach with Straight/ Right Option and Mandatory Right Turn Lane



SOURCE: Richard Moeur.

At an intersection with a straight or right turn option lane and a right turn only lane, it is best to not provide any specific bike lane channelization, as any location for a bike lane will place bicyclists in potential conflict with turning traffic. One possible option is to place shared lane markings leading to the center of the straight/right option lane. Figure 14-25 depicts a signing and marking treatment for locations with multiple turn lanes.

Left Turn Lanes. Exclusive left turn lanes very seldom have any interaction with bike lanes, as most bike lanes are placed on the right-hand side of the roadway. One exception is on a one-way street where a bike lane is placed on the left-hand side of the street; in this case, the treatment is the same as at right turn lanes on conventional roadways, only with the left/right directions reversed.

When considering installation of a left turn lane for bicyclists, it is important to recognize the two ways bicyclists make left turns at intersections. Some bicyclists negotiate across traffic lanes when approaching the intersection to use the left-most through lane or left turn lane, then turn in the same manner as other roadway traffic. However, some may not be fully comfortable with making vehicular-style left turns, and will make a two-stage left turn by either riding a course similar to that followed by pedestrians, or by dismounting and walking in the pedestrian crosswalk. Bike lanes or other traffic control devices should not prohibit or discourage either of these types of turns. Where there are numerous left-turning bicyclists, or where a left turn movement may legally be performed only by bicyclists, such as at the entrance to a pathway or bicycle boulevard, a bike left turn lane as shown in Figure 9C-1 of the 2009 MUTCD may be used.

Bike Lanes and Intersection Departures. Section 9C.04 of the 2009 MUTCD states "If used, bicycle lane word, symbol, and/or arrow markings… should be placed at the beginning of a bicycle lane…." However, the MUTCD does not require a bike lane begin or resume immediately after an intersection's far crosswalk.

There are two reasons why it may be advantageous not to begin or resume bicycle lane markings immediately after an intersection:

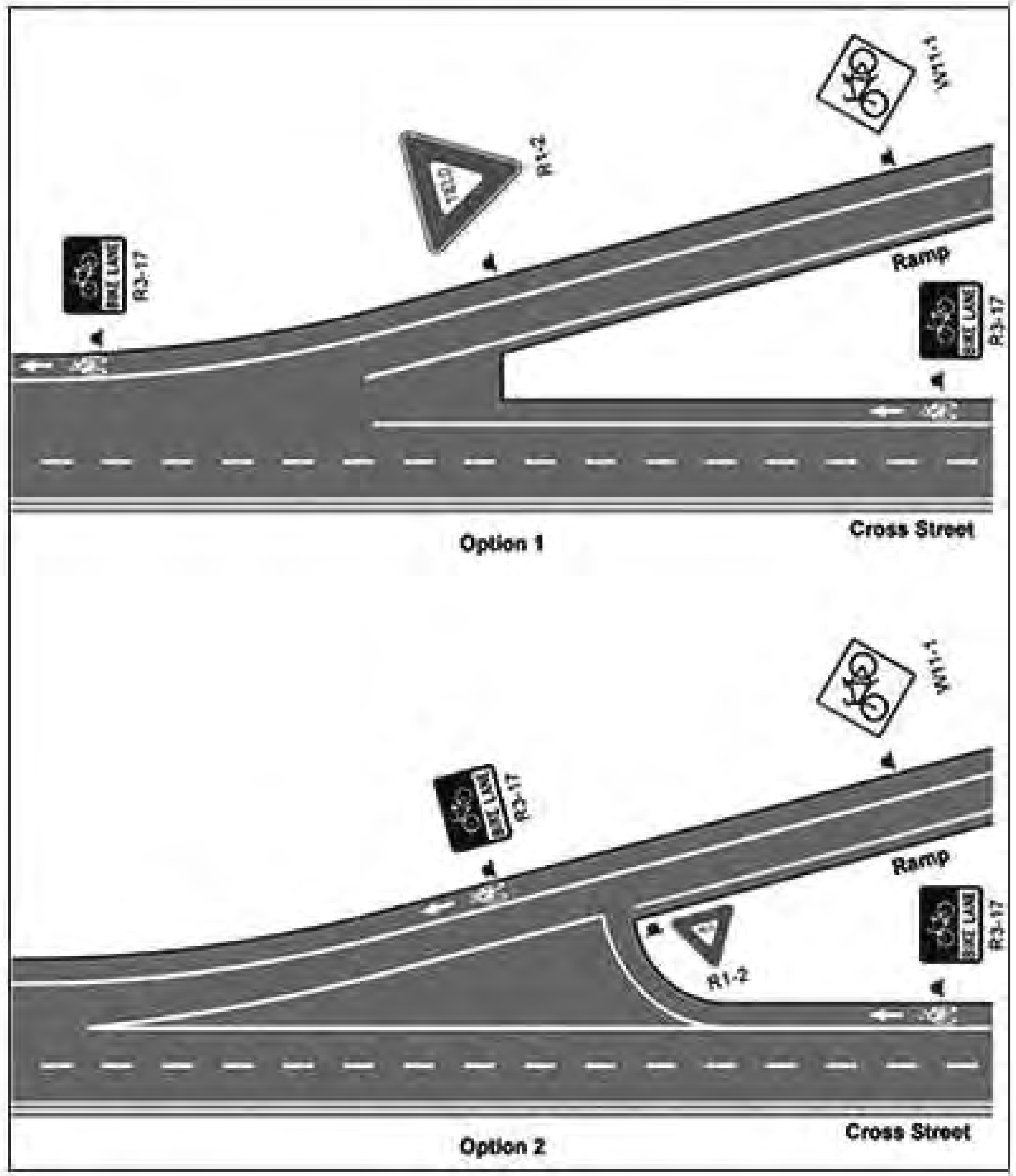
- to avoid wear from vehicle right turns from the cross street; and
- at high-activity corner properties, to delay guiding through bicyclists toward the curb until beyond the driveway conflict(s).

In some corner conflict situations the use of Shared Lane Markings for some distance after departing the intersection may be considered to guide bicyclists on a line of travel that deters turning conflicts.

Acceleration Lanes and Bike Lanes. The presence of an acceleration lane can complicate the placement of a bike lane, in that drivers using the acceleration lane are often focused on merging into the traffic stream, and may not be looking for bicycle traffic. Options for placement of bike lanes where acceleration lanes are present include:

- Short acceleration lane, 200 ft. (60 m) or less: In this condition, a user of the acceleration lane will merge into the traffic stream while traveling at a lower speed. The bike lane can be placed to the left of the acceleration lane, in a manner similar to how a bike lane is typically placed to the left of an exclusive right turn lane.
- Longer acceleration lane, greater than 200 ft. (60 m): In this condition, a vehicle using the acceleration lane may be traveling at a higher speed near the downstream end of the acceleration lane while preparing to merge into the traffic stream. It may be advisable to place the bike lane to the right of the acceleration lane, in a manner similar to a typical shoulder; this eliminates any potential higher-speed weaving conflict. However, this can complicate the geometric alignment of the bike lane at the intersection crossing by introducing a diagonal shift in the bike lane alignment. (Note: Do not place the bike lane to the right of an exclusive turn lane to "fix" the alignment problem!) Shared Lane Markings may also be used in lieu of a bike lane in an acceleration lane of this type.
- Continuous acceleration/deceleration lane: Where a continuous acceleration/deceleration lane is installed, placing the bike lane to the left of the continuous lane can reduce the risk of crashes between turning traffic and through bicyclists.

FIGURE 14-26. Bike Lane Crossing of Interchange Entrance Ramp



SOURCE: Richard Moeur.

Bike Lanes at Freeway Interchanges

The MUTCD has no specific guidance regarding bike lanes at freeway interchanges. However, many traffic control issues at freeway interchanges arise from the practice of creating "uninterrupted-flow" connections between the freeway and the intersecting roadway, such as loop ramps or channelized turn lanes. It may be best to instead use roadway geometric design prnciples that encourage an appropriate transition from free-flow freeway travel to interrupted mixed-mode travel on arterial streets, such as designing ramps that encourage slower speeds approaching intersections. However, these design details are beyond the scope of this *Handbook*.

On arterial streets at interchanges with exclusive turn lanes (either single lane or multiple lane) serving the ramp from the arterial street to the freeway, the bike lane should be channelized to the left of the exclusive turn lanes in the conventional manner as depicted in the MUTCD and in figures elsewhere in this chapter.

In some locations, such as where a bike lane is placed along an expressway, there may be high-speed free-flow ramps merging onto the roadway across the bike lane. Two possible methods for delineating the bike lane where a ramp merges onto a roadway are depicted in Figure 14-26. If the ramp volume is relatively low and there are frequent gaps in ramp traffic sufficient to allow a bicyclist to traverse the merge area directly, the treatment depicted in Option 1 may provide the least delay to bicyclists. If the ramp has higher traffic volumes or fewer available gaps, Option 2 may be advisable, as this provides the shortest crossing distance across the ramp for bicyclists. At locations where acceleration lanes are placed to receive free-flow ramp traffic, the guidance on acceleration lanes in the previous section should be consulted.

Bike Lanes at Roundabouts

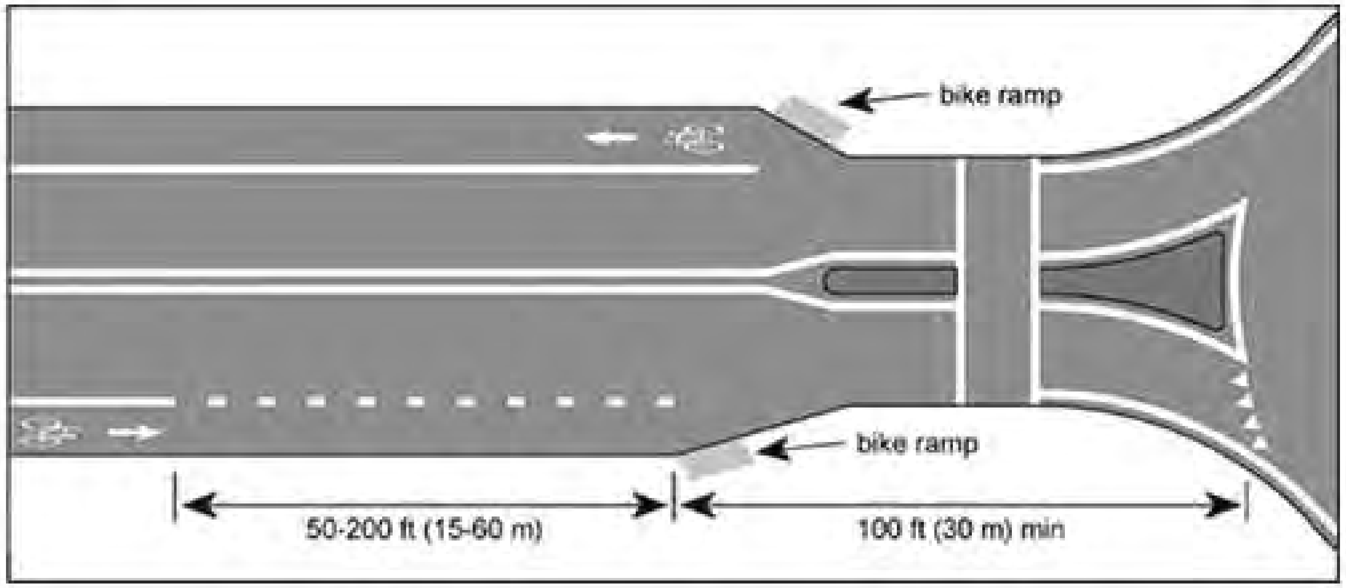
A roundabout is a type of intersection with three distinct operating characteristics:

- a generally circular or oval shape for the circulating roadway;

• yield control on entry (the circulating roadway is given priority); and
• geometric design features (deflection on entry, radii) that encourage appropriate speeds.

A properly designed roundabout can significantly reduce the number and frequency of severe angle collisions at an intersection by eliminating high-speed angle conflicts. However, roundabouts can complicate travel for bicyclists. Roundabouts are typically designed for entry and operating speeds of approximately 20 mph (32 km/h). This creates a situation where expected travel speed differentials between bicyclists and other users are not large, and bicyclists, if they choose to do so, can traverse the roundabout in the circulating roadway without difficulty.

FIGURE 14-27. Bike Lane Approaching a Roundabout[34]



SOURCE: Richard Moeur.

Section 9C.04 of the 2009 MUTCD prohibits the marking of a bike lane on the circular roadway of a roundabout. Placing a bike lane within a roundabout channelizes through bicyclists to the right of high volumes of exiting traffic, which creates severe operating problems, conflicts, and crashes.

There are two primary methods bicyclists use to traverse roundabouts:

• bicyclists can merge from the bike lane into the traffic stream in advance of the roundabout, enter and traverse the roundabout in the circulatory roadway, and rejoin the bike lane after departing the roundabout; or
• bicyclists can merge from the bike lane onto the sidewalk in advance of the roundabout, traverse the roundabout as a pedestrian, and rejoin the bike lane after departing the roundabout.

The combination of geometric features and traffic control devices should provide bicyclists the choice of either method, but should not require bicyclists to always merge either onto the sidewalk or into the roadway. Section 9C.04 of the 2009 MUTCD states bike lane markings should be discontinued a minimum of 100 ft. (30 m) in advance of the roundabout. The bike lane line may be changed to a dotted line for a distance of 50 to 200 ft. (15 to 60 m) in advance of the discontinuation, as this may encourage bicyclists to merge into the travel lane at an earlier location if gaps in the traffic stream permit. The most recent design guidance for roundabouts recommends a ramp be provided in advance of the roundabout (typically in the vicinity where the bike lane ends) to allow bicyclists the option to merge onto a sidewalk and traverse the roundabout as a pedestrian, and recommends another ramp be provided on the roundabout departure to allow bicyclists on the sidewalk to rejoin the bike lane.[33]

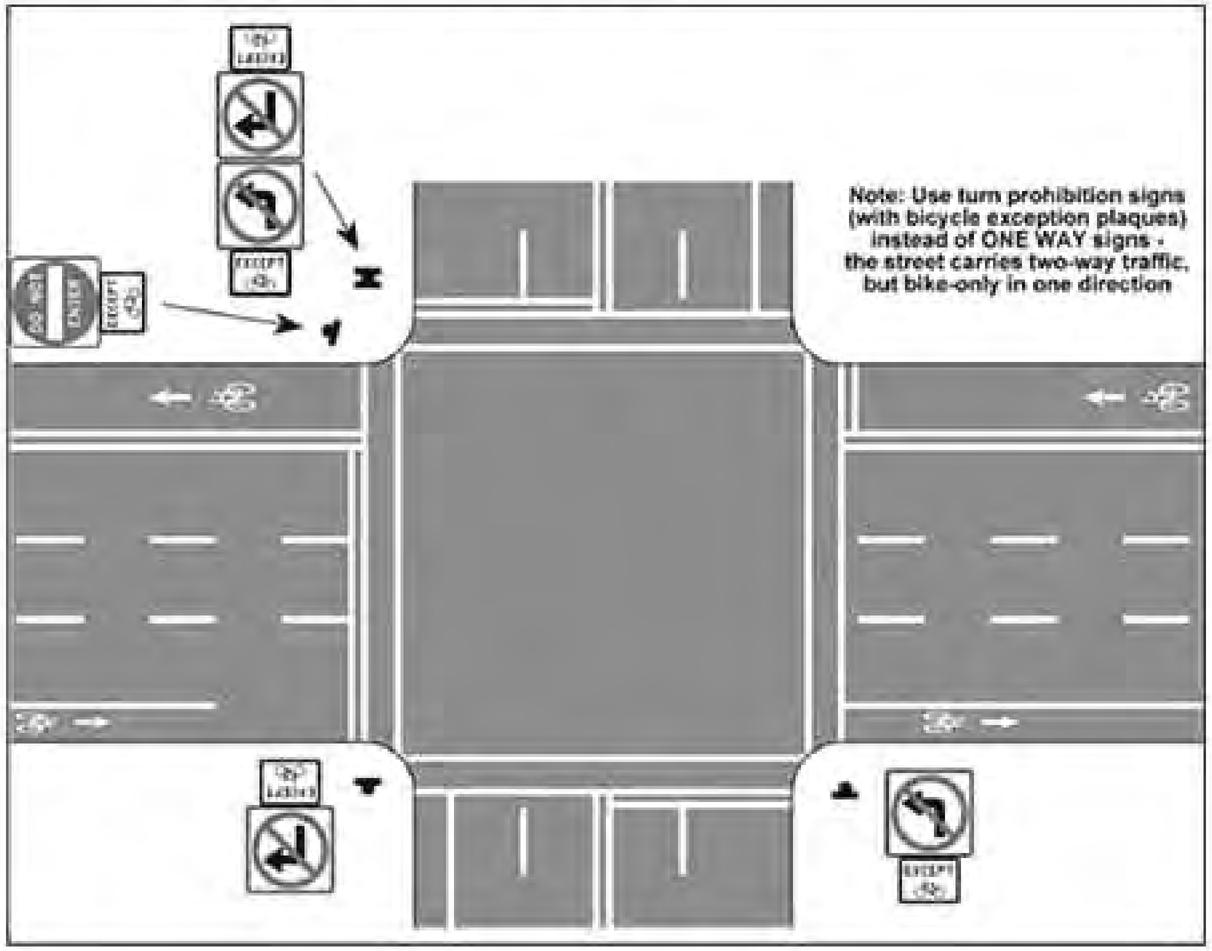
Markings, signing, and other traffic control devices should not be used to compel, coerce, recommend, require, or suggest bicyclists exit and ride on the sidewalk at roundabouts. If a bicyclist were to crash while using the sidewalk (as a result of striking a pedestrian, fixed object, or other bicyclist) or were struck by a vehicle in the crosswalk, and it could be shown devices either removed the option for a bicyclist to merge onto the roadway, or coerced or encouraged sidewalk use, the bicyclist may have a successful cause of legal action against the agency, since it can be argued the devices removed or negatively affected the bicyclist's discretion in choosing travel paths.

Contraflow Bike Lanes

On one-way streets where there is not a parallel adjacent through street in the opposite direction, it may be desirable to install a bike lane in the direction opposite that of other traffic. This in effect changes the street to a two-way street, except one direction is solely for bicycle travel. This is called a "contraflow bike lane," and can be especially useful if the roadway serves as a direct connection to destinations of interest to bicyclists, or where the roadway provides a better quality of service by offering fewer delays, less-steep grades, or other advantages.

The contraflow bike lane is placed on the correct side of the roadway for a lane in its direction, i.e., the right-hand side of the road for direction that it travels, which would place it to the left of the primary traffic flow direction. A bike lane should also be provided in the primary direction in the normal location for such a lane, or the contraflow lane is likely to see two-way bicycle travel, which can lead to conflicts and crashes. The contraflow bike lane is typically separated from the other direction of travel with a yellow centerline. This is typically a double yellow centerline, but can be a broken yellow centerline if appropriate. In some cases, a raised median may be used to separate the contraflow bike lane, in much the same way raised medians are used to separate opposite-direction traffic on conventional streets. If this is done, consideration should be given to adjusting the width of the contraflow bike lane to allow for convenient access by maintenance and emergency equipment.

FIGURE 14-28. Example of Regulatory Signing at an Intersection With a Contraflow Bike Lane



SOURCE: Richard Moeur.

On-street motor vehicle parking should not be provided on the same side of the street as the contraflow bike lane. Vehicles accessing this parking would be required to cross the contraflow bike lane, and conflicts or crashes could occur due to sight distance limitations and driver expectations.

At intersections of contraflow bike lanes with streets, alleys, and driveways, do not use ONE WAY signs, as there is two-way traffic on that street (with one direction being bicycle-only). Instead, use turn prohibition signs and DO NOT ENTER (R5-1) signs, with black on white EXCEPT BICYCLES plaques mounted below these regulatory signs. See Figure 14-28 for an example of this type of regulatory signing at an intersection with a contraflow bike lane.

At signalized intersections, street name signs, signal indications, and other devices must be provided to serve bicyclists using the contraflow bike lane. Bicycle-specific signals should not be necessary, as other traffic should not be able to see the signal faces serving the contraflow bike lane.

Bike Lanes at Rail Crossings

At railroad crossings where the tracks cross perpendicular to traffic flow (or close to perpendicular), no special treatment is needed for bike lanes. The bike lanes may be continued up to the crossing, and resumed immediately after the crossing. Railroad tracks that cross at a shallow angle to the direction of traffic (see Figure 14-15) can cause problems by diverting a bicycle's front wheel, either by causing it to slip along the metal rail or by trapping it in the flange-way gap. This causes a sudden fall from which it is almost impossible to recover. If a bike lane is striped continuously across a railroad crossing of this type, bicyclists may be likely to cross the tracks at a shallow angle, which increases the risk of a slip-type or trapping-type crash.

Where right of way is available, agencies can widen the shoulder just before and after the crossing to accommodate a more-perpendicular crossing of the tracks. An example of this may be seen in Chapter 4 of the AASHTO *Guide for Bicycle Facilities*. If the bike lane is realigned on a widened shoulder to create a perpendicular crossing, the width of the bike lane should be maintained, and curves or turns should be designed with appropriate radii in accordance with the most recent edition of the AASHTO *Guide for Bicycle Facilities*.

If space is not available for realigning the bike lane to create a perpendicular crossing, Shared Lane Markings may be used to guide bicyclists to cross angled railroad tracks, as depicted earlier in this chapter.

The use of Skewed Crossing (W10-12) warning signs may be considered at locations where railroad tracks cross at a shallow angle. See Section 8B.25 of the 2009 MUTCD for more information.

DEVICES FOR SHARED-USE PATHS

Shared-use paths are bikeways that are physically separate from roadways or other vehicular transportation facilities. They are often on independent alignments through parks or other open spaces, or parallel to rivers, canals, utility corridors, or freeways. Shared-use paths are engineered facilities, unlike an unimproved trail, and have either a paved surface (typically asphalt concrete or Portland cement concrete) or an improved surface made of treated base, decomposed rock, or other surface suitable for bicycle travel.

These pathways have accumulated a variety of names—"bike paths," "greenways," "trails," "multi-use paths," etc. The accepted term "shared-use path" found in the MUTCD and other references should be used, as it best describes the simultaneously shared use of these facilities by a variety of modes, including bicyclists, pedestrians, skaters, strollers, and others.

Path Design

The operating characteristics of bicyclists have been discussed earlier in this chapter. However, it is important to recall bicyclists operate in a vehicular manner, whether on roads or on paths. Bicyclists also will tend to travel faster than other path users—as much as five times faster than pedestrians on average. This creates the potential for numerous overtaking and oncoming maneuvers or conflicts.

Path Users

Pedestrians will be present on nearly all shared-use paths, even if the path is specifically designated or signed as a "bike path." Pedestrians on paths may be using wheelchairs, or traveling with strollers, carts, or wagons, which can take up to 3 to 4 ft. (0.9 to 1.2 m) of lateral space on the path. Pedestrians on shared-use paths may be accompanied by pets, which take up additional lateral space and also can exhibit unpredictable behavior.

In general, pedestrians on shared-use paths will be using these paths for recreation or exercise. However, this perception of the path as a recreational facility may mean these pedestrians may not be devoting their full attention to other path users, especially higher-speed users such as bicyclists and skaters. This may result in unpleasant conflicts and the potential for crashes. Young children walking or bicycling on paths may also behave in an unpredictable manner. They may stop or slow suddenly, may weave back and forth across the pathway, or may dart suddenly across the path.

Skaters are frequent users of shared-use paths. Skaters can achieve the same speeds as bicyclists, but less-experienced skaters cannot brake or stop as quickly as bicyclists. Also, skaters occupy a much wider travel path than bicyclists, typically up to 5 ft. (1.5 m) wide, due to their need to push laterally with their legs to maintain movement.

Design Issues

Shared-use paths should have a minimum width of 10 ft. (3.0 m), typically operating with one unmarked or marked lane in each direction occupying half the travel way. A wider path may be considered to allow for wider lanes to accommodate convenient maneuvering and overtaking where there are significant volumes of bicyclists, pedestrians, and other path users.

It is not appropriate in most cases to build separate one-way paths 5 to 6 ft. (1.5 to 1.8 m) in width. Experience has shown these paths will still frequently be used for two-way traffic, even when regulatory signs are in place. Also, the narrower paved width does not allow for safe and convenient passing of other path users, especially of stopped pedestrians.

Traffic flow on paths may be improved by including areas where path users can stop, rest, congregate, and socialize. This may reduce the frequency of pedestrians and other path users stopping in the traveled way of the path.

Problems with Adjacent Separated Paths (Sidepaths)

It is frequently assumed a separated parallel pathway along an arterial street or highway will provide a facility for bicyclists that is superior to the provision of on-street accommodations. While a parallel path may be aesthetically appealing, and may serve pedestrians well, the use of sidewalks or parallel separated paths for bicycle accommodation creates the following problems:

- These paths will operate as sidewalks, and will be used in both directions, despite signing to the contrary. Bicyclists coming from the right will not be noticed by drivers emerging from or entering cross streets and driveways. See Figure 14-29, Figure 14-30, and Figure 14-31 for diagrams that show these potential conflicts.
- Travel in the direction opposite the flow of traffic is particularly hazardous during hours of darkness, because bicyclists may be blinded by oncoming motor vehicle headlamps.
- At intersections, drivers will not be looking for bicyclists, who will be traveling much faster than pedestrians, to enter the crosswalk area.
- At approaches to intersections, parked vehicles interfere with the visibility of bicyclists to road users. Also, at driveways sight distances on sidewalks and sidepaths are often impaired by buildings, property fences, vegetation, and other obstructions.
- Stopped cross street motor vehicle traffic or vehicles exiting side streets or driveways may block the sidepath or sidewalk.
- These paths are typically not safe for higher-speed use. Due to the speed differential, conflicts between bicyclists and pedestrians are common. Fixed objects such as parking meters, utility poles, sign posts, bus shelters and benches, trees, hydrants, and cross-sloped sidewalk ramps also pose a hazard to bicyclists.
- The development of extremely wide sidewalks or sidepaths does not necessarily add to the safety of bicycle travel, as wide sidewalks and paths will encourage higher-speed bicycle use, magnifying the potential for conflicts at intersections and driveways, and conflicts with pedestrians and fixed objects.

- Many bicyclists will use the roadway instead of the sidewalk or sidepath because they have found the highway to be safer, more convenient, or better maintained. Bicyclists using the roadway are often subjected to harassment by motorists, who feel in all cases bicyclists should be on the sidepath or sidewalk instead.
- On sidewalks, there is the potential for bicyclists to accidentally ride off the curb, possibly causing a fall or collision with traffic on the roadway. While pathways may reduce the possibility of such collisions by using the recommended 5 ft. (1.5 m) separation between the path and the roadway, such pathways will still be vulnerable to most of the other problems listed here.
- Experience has shown the use of STOP or YIELD signs on sidewalks and pathways to reduce conflicts at driveways and cross streets has little or no benefit. Bicyclists will not comply with unreasonable restrictions on their right of way, especially if the adjacent roadway has no such limitations. This may also breed disrespect for other traffic control devices that are far more important for traffic safety.

One exception to this recommendation against sidewalk use is in the case of a sidewalk on a long bridge on a high-speed roadway without shoulders—in this infrequent case, bicycle use of the sidewalk may be considered.

This does not mean bicyclists will never use sidewalks. In residential areas, sidewalk riding may be done by young children who may not have sufficient experience to ride on streets. With lower bicycle speeds and lower motor vehicle speeds, potential conflicts are somewhat lessened—but still exist. However, it is inappropriate to sign or designate these facilities as bikeways, and signing or other traffic control devices should not encourage the use of such facilities.

FIGURE 14-29. Sidepath Intersection Conflicts—Left Turn from Parallel Street

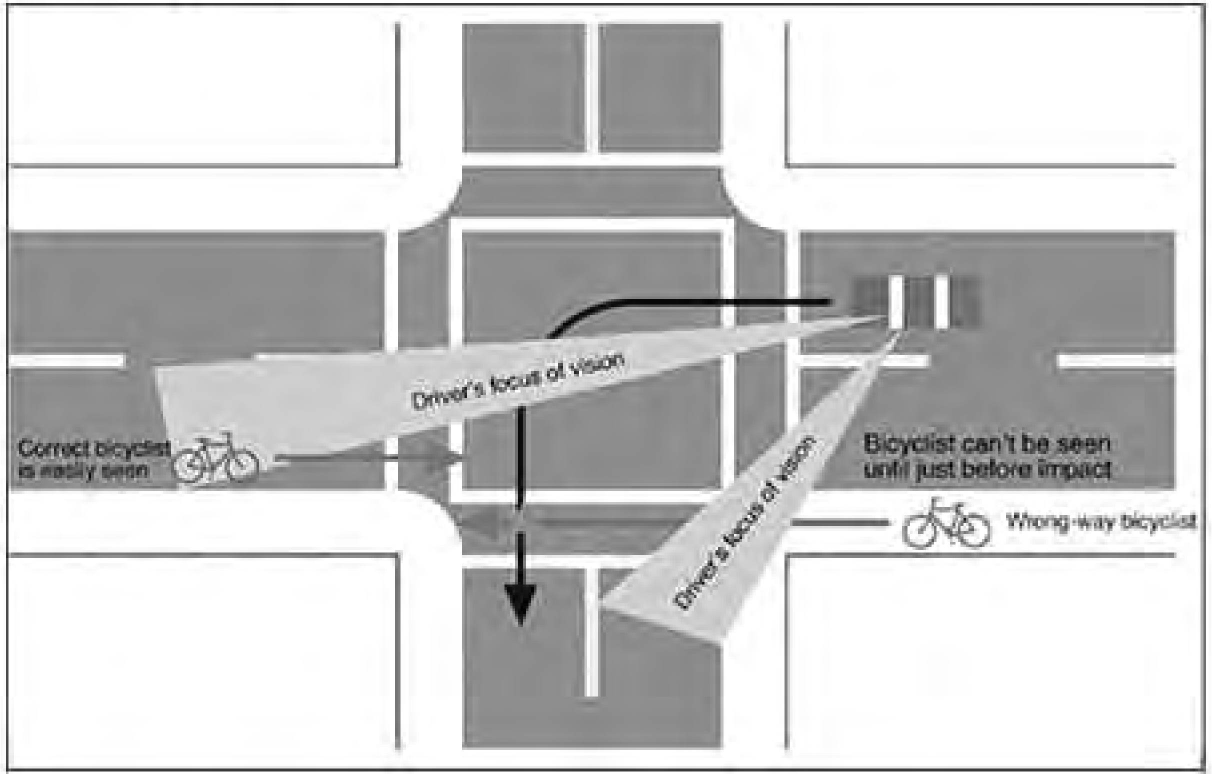


FIGURE 14-30. Sidepath Intersection Conflicts—Right Turn from Cross Street

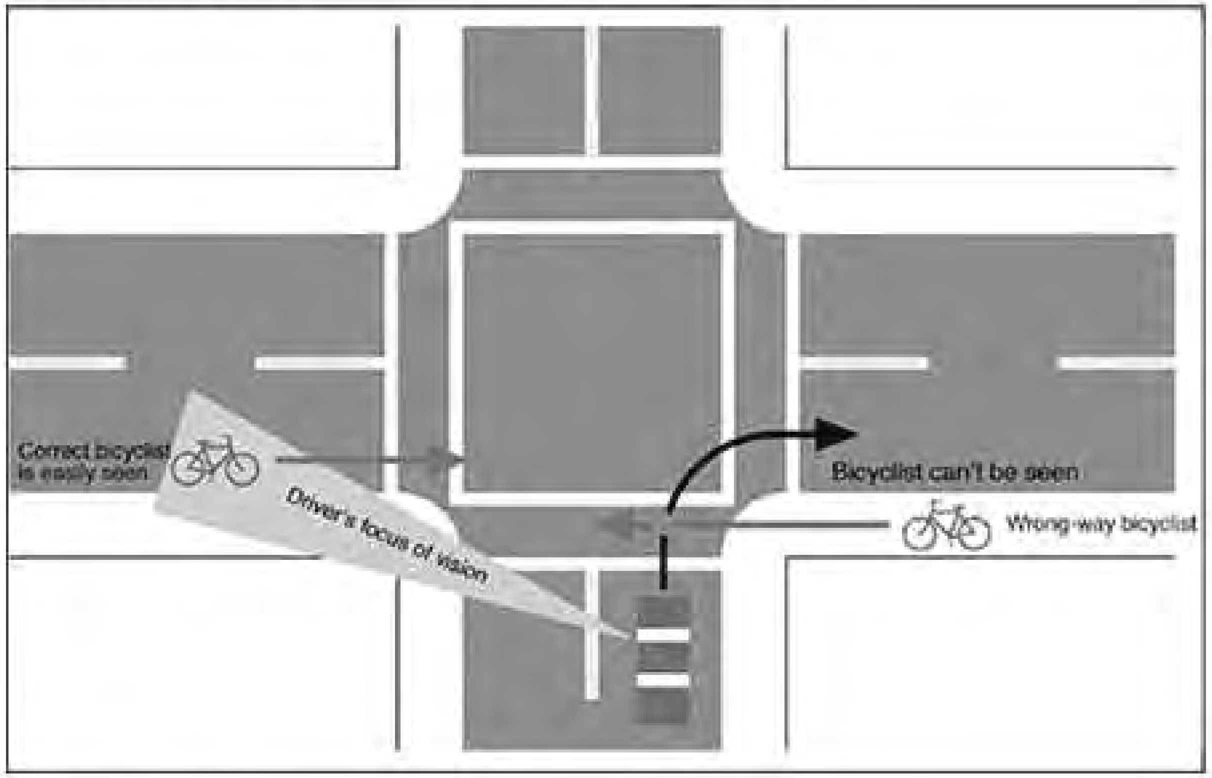
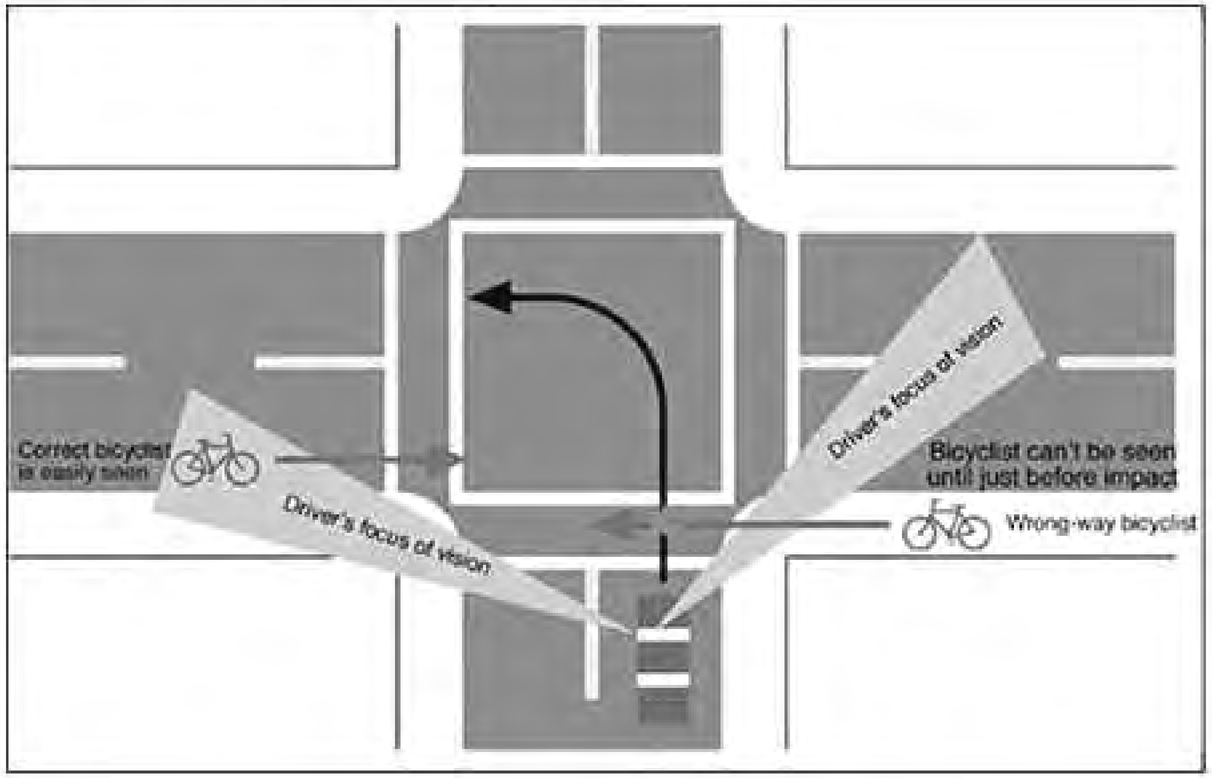


FIGURE 14-31. Sidepath Intersection Conflicts—Left Turn from Cross Street



SOURCE FOR ALL: Richard Moeur.

The AASHTO *Guide for Development of Bicycle Facilities* contains a section dealing specifically with the details of pathway design.

Ineffectiveness of Devices vs. Intersection Conflicts. Decades of observations of roadway behavior in the United States have confirmed drivers of motor vehicles will almost always act in a predictable manner at intersections. Drivers have developed patterns of visual scanning that work best to inform them of potentially conflicting traffic movements, and the design and operation of the roadway system serve to reinforce this behavior with experience.

Figure 14-29, Figure 14-30, and Figure 14-31 show the locations where drivers focus their vision and attention when preparing to make common turning movements. These figures also clearly show the travel paths of bicyclists on sidepaths do not match up well with the conditioned and ingrained scanning patterns, which can create serious conflicts and crashes when a bicyclist "suddenly" appears in the driver's field of vision and path of travel.

Note that sight distance, as commonly defined in traffic engineering references, does not typically come into play at these locations. In many cases, these locations do not have obvious sight obstructions, and a potentially conflicting bicyclist could be seen from some distance. Instead, the more critical issue is that the driver has been conditioned by traffic behavior and simple self-preservation to not look in those directions, even if the sight distance is clear (see Chapter 2 of this *Handbook* for a discussion of Human Factors).

The approach speed of bicyclists is another critical factor. A bicyclist traveling at 15 mph (24 km/h) can cover over 100 ft. (30 m) in only 5 sec. Even if a driver were to be very conscientious and look in the directions from which conflicting bicycle traffic might be approaching on a sidepath every 10 sec. or so, a bicyclist could cover over 200 ft. (60 m) in that 10 sec. of time—going from nearly unseen to directly into the driver's path. As discussed in the first section of this chapter, bicyclists have notably different operating characteristics than pedestrians, and cannot stop or turn instantly or see conflicting movements in the periphery of their vision.

Signs, markings, and other static devices have sometimes been installed in attempts to alert road users a sidepath crossing is present, or to induce drivers to scan in directions from which unexpected users, such as bicyclists on sidepaths, might be approaching. However, the behavioral conditioning is typically so strong that static devices have no meaningful effect.

For example, some agencies have installed warning signs for sidepaths based on the design of W10-2 to W10-4 signs used to warn of railroad crossings on parallel streets adjacent to the roadway, with a bicycle pathway symbol substituted for the railroad track. However, there has never been a rigorous study to determine whether these types of signs have any meaningful effect on driver behavior at these locations. The signs are likely not to be effective for the following reasons:

- bicyclists are much smaller than trains, and bicyclists do not have extremely bright headlights and deafeningly loud horns;
- the busiest at-grade rail crossings in the United States typically see approximately 150 train crossings per day; even a relatively quiet pathway will likely have a greater number of users; and
- if there is any significant train and motor traffic volume at a railroad grade crossing, the crossing is equipped with actuated flashing lights and gate arms; sidepath crossings have neither of these.

Agencies have also used enhanced-visibility crosswalks or colored markings in the crossing area to attempt to make crossing or turning traffic "aware" of the presence of the sidepath and of potentially conflicting traffic. Again, there are no studies that have shown any effectiveness or meaningful behavior changes under U.S. conditions, and these types of markings have not been fully effective in Europe, where paths of this type are more common. It should also be noted the Interim Approval issued by FHWA for green-colored pavement in bike lanes does not extend to this application.

If signs, markings, or other devices of these types are installed, they will likely create an impression with path users, road users, and public agencies that the presence of the devices "solves" the problem with the sidepath—when in fact behavior patterns are in all likelihood unchanged. This creates a situation where safety can actually be decreased due to the disconnect between perceived and actual effectiveness.

The use of active traffic control devices such as signalization of sidepath movements may be more effective in mitigating conflicts; however, this could require signalization of all conflicting traffic movements, including signals for the pathway and protected-only turning movements across the pathway, similar to how rail or light rail corridors adjacent to parallel streets in cities are frequently addressed. This also assumes bicyclists would comply with pathway signalization, which may not be a valid assumption based on observations in similar locations. The use of other active devices such as passively actuated rectangular rapid-flash beacons (RRFBs) to alert drivers of potentially conflicting movements has been proposed, but at the time of writing of this *Handbook*, no experiments have been attempted or evaluated to determine if this would be effective in reducing conflicts.

Path Signing

Sign Size and Visibility. Sign sizes on shared-use paths are smaller than the signs used on other transportation facilities, in accordance with the lower operating speeds for the traffic on them. However, all signs maintain the same shape, color, retroreflectivity, and other characteristics of the larger signs found on roadways. See Table 9B-1 of the 2009 MUTCD for sign sizes for use on paths. Do not use path-size signs on facilities open to motorized traffic. On any facility open to motor vehicle traffic, sign sizes must conform to the minimum sizes listed in Part 2 of the 2009 MUTCD.

See Figure 9B-1 of the 2009 MUTCD for minimum mounting heights and lateral offsets for signs on shared-use paths. Using the dimensions depicted in Figure 9B-1 provides good visibility for bicycle traffic, while providing adequate offset. Overhead signs should be a minimum of 8 ft. (2.4 m) above pathways in order to provide sufficient clearance for bicyclists, maintenance vehicles, and other potential path users, such as equestrians.

The key concept in using Figure 9B-1 most effectively is to imagine a "box," which is 8 ft. (2.4 m) tall and 2 ft. (0.6 m) wider than the traveled way of the path on each side; keep all encroaching fixed objects, including signs, completely out of that box. For example, in locations where there is little or no lateral distance between the traveled way and an adjacent continuous retaining wall or fence, a sign panel mounted at the typical 4 ft. (1.2 m) minimum height may encroach into the traveled way. In these cases, it is best to mount the sign at an 8 ft. (2.4 m) mounting height to ensure clearance, even though the sign might not typically be considered an overhead sign.

Regulatory Signs. STOP and YIELD controls may pose problems for bicyclists. Bicyclists, due to their desire to maintain momentum, are often reluctant to stop or slow unnecessarily. Unfortunately, STOP and YIELD sign violations are a major cause of bicycle-motor vehicle collisions. Therefore, pathway intersections should be designed in a manner that minimizes the need for bicyclists to stop. See the section later in this chapter for the use of STOP and YIELD control at path-roadway intersections.

Where motor vehicle traffic is prohibited, the R5-3 NO MOTOR VEHICLES sign may be used. However, this should be supplemented with pathway design features that discourage motor vehicle intrusion. Bollards, posts, poles, or other physical obstructions placed within the traveled way of a path create a persistent fixed-object crash risk to path users. Even if the post or bollard is marked, delineated, or reflectorized, there is still a risk of a crash due to striking the end of a handlebar while passing or to another path user obscuring the view of the obstacle until it is too late to avoid a crash, such as when one bicyclist is closely following another. In addition, they may be ineffective against many common types of intrusion, as many motorized vehicles and devices such as motorcycles and narrower ATVs can maneuver around or between bollards. Placing bollards too close together can restrict adult tricycles or bicycles with trailers from accessing a path. FHWA advises against the use of bollards or similar obstructions unless there is documented evidence the risk of crashes or injury from motor vehicle intrusion outweighs the persistent crash risk of the bollard itself.[35]

Some treatments that may lessen the likelihood of intrusion by unauthorized vehicles without the use of posts or bollards include:

- designing the pathway entrance so it does not resemble or is not mistaken for a roadway or driveway; or
- splitting the path into two smaller paths a minimum of 5 ft. (1.5 m) wide in the vicinity of the entrance, using a flush median with landscaping.

R9-5 signs may be used at locations where the crossing of a street by bicyclists is controlled by pedestrian signal indications, such as at the intersection of a shared-use path with a street. Where it is not intended for bicyclists to be controlled by pedestrian signal indications, such as when the pathway is controlled exclusively by a standard signal indication, the R10-24 or R10-26 sign may be used.

The R9-6 sign may be used where a bicyclist is required to cross or share a facility used by pedestrians and the bicyclist is required to yield to pedestrians. On paths with heavy volumes of bicycle and pedestrian traffic, it may be desirable to define specific areas on the path for each mode of travel using markings or other forms of separation. The R9-7 sign is used in these locations to define the proper travel paths for each mode of travel.

The R9-5, R9-6, and R9-7 signs should not be used to encourage bicycle travel on sidewalks. As noted earlier, sidewalks are a less safe and convenient location for bicycle travel. In these cases, it is recommended bicyclists be accommodated on the roadway using a shared roadway or bike lane.

It is typically not advisable to install regulatory signs requesting bicyclists dismount and walk their bicycles, especially in locations where the pathway width is restricted or sight distance is limited. When people are walking bicycles, they are occupying nearly twice as much pathway width as they would be if they were riding, and are hampered in maneuverability due to the requirement to push and steer the bicycle while walking. Signs of this type typically see a very low compliance rate, and a moving bicyclist unexpectedly encountering a person walking a bike could result in a serious crash.

Some agencies have installed speed limit (R2-1) signs on pathways to try to manage bicyclist speeds, typically where there is a documented history of conflicts between different user modes. However, the signs alone may not be effective in changing travel speeds, as most bicycles are not equipped with speedometers, and some bicyclists may not be able to accurately judge or monitor their speed.

Other regulatory signs from Chapter 2B of the 2009 MUTCD may be used on paths as needed. Sign sizes for paths should be appropriately reduced from the standard roadway size, but should not be smaller than comparable sizes listed in Table 9B-1 of the 2009 MUTCD.

Warning Signs. Turn and Curve warning signs (W1-1 through W1-7) are used in advance of locations where changes in path alignment may not be readily apparent, or where horizontal alignment does not meet accepted design criteria. Intersection warning signs (W2-1 through W2-5) are used in advance of locations where intersecting facilities may introduce unexpected entering and crossing traffic, or where there is limited sight distance approaching the intersection. The use of W2 series signs is not limited solely to roadway intersections; intersections of paths with other paths may benefit from the use of these signs.

W8-10 Bicycle Surface Condition signs may be used in locations where pathway pavement may occasionally be slippery due to water, locations that may accumulate debris or loose sand that cannot be addressed by maintenance, or physical features that may inherently be slippery at times such as metal bridge decks, steel plates, expansion joints, or diagonal railroad tracks. Supplemental plaques (W8-10P) may be used with the W8-10 to specifically define the condition of concern.

BUMP (W8-1), DIP (W8-2), and PAVEMENT ENDS (W8-3) signs may also be used on shared-use paths. When these conditions do occur, it is more appropriate to use the standard warning sign than a W8-10 with plaque.

On approaches to railroad crossings of paths, Railroad Advance Warning (W10-1) and Railroad Crossbuck (R15-1) signs should be installed as shown in Chapter 8D of the 2009 MUTCD (note this information was moved to Part 8 in the 2009 edition of the 2009 MUTCD). If the crossing is at an angle, a Skewed Crossing (W10-12) sign may also be used. It may also be advisable to adjust the alignment of the path such that approaching trains will be visible in front of path users, but such alignment changes should not be hazardous in and of themselves, i.e., involve hairpin curves or physical barrier, which cannot be easily spotted or navigated.

W7 series hill and grade signs may be used on pathways where a downgrade can affect bicyclist operation, such as a long downgrade or an underpass with a short, yet steep, grade. In many cases, the hill may be self-evident, and no signs may be needed. But if a grade is not fully visible due to changes in horizontal alignment, or becomes steeper in a location that might not be expected, hill signing may be beneficial. Hill signing is not typically necessary at upgrades.

Other warning signs from Part 2C of the 2009 MUTCD may be used on paths as needed. As noted above, sign sizes for paths should be appropriately reduced from the standard roadway size, but should not be smaller than comparable sizes listed in Table 9B-1 of the 2009 MUTCD. As a general rule, most standard diamond-shape warning signs adapted for use on paths should have a standard size of 18 in. x 18 in. (450 x 450 mm) as measured along the sign edge.

FIGURE 14-32. Advance Warning Sign for Path-Roadway Intersection

SOURCE: Richard Moeur.

There is no table corresponding to Table 2C-4 of the 2009 MUTCD for advance placement distance for warning signs on shared-use paths, so engineering judgment should be used to determine the optimum location, taking into account design and operating speed, and adequate sight distance. On most shared-use paths with a design or operating speed of 15 to 20 mph (24 to 32 km/h), a minimum advance placement distance of 100 ft. (30 m) is appropriate. On paths with higher design or operating speeds, longer distances may be used. However, warning signs should not be placed too far in advance, as path users may forget about the warning due to distractions, especially in busy operating environments.

Guide Signs. Guide and route signing as shown in Chapter 9B of the 2009 MUTCD and discussed earlier in this chapter should be used where appropriate to implement a comprehensive system of signing providing route guidance, distance, and destination information to path users. For example, guide signs on paths can show directions and distances to towns, parks, population centers, landmarks, and other destinations of interest to bicycle travelers. Numbered or designated routes can provide a continuous travel path for cyclists to a variety of destinations at the local, regional, statewide, or national level.

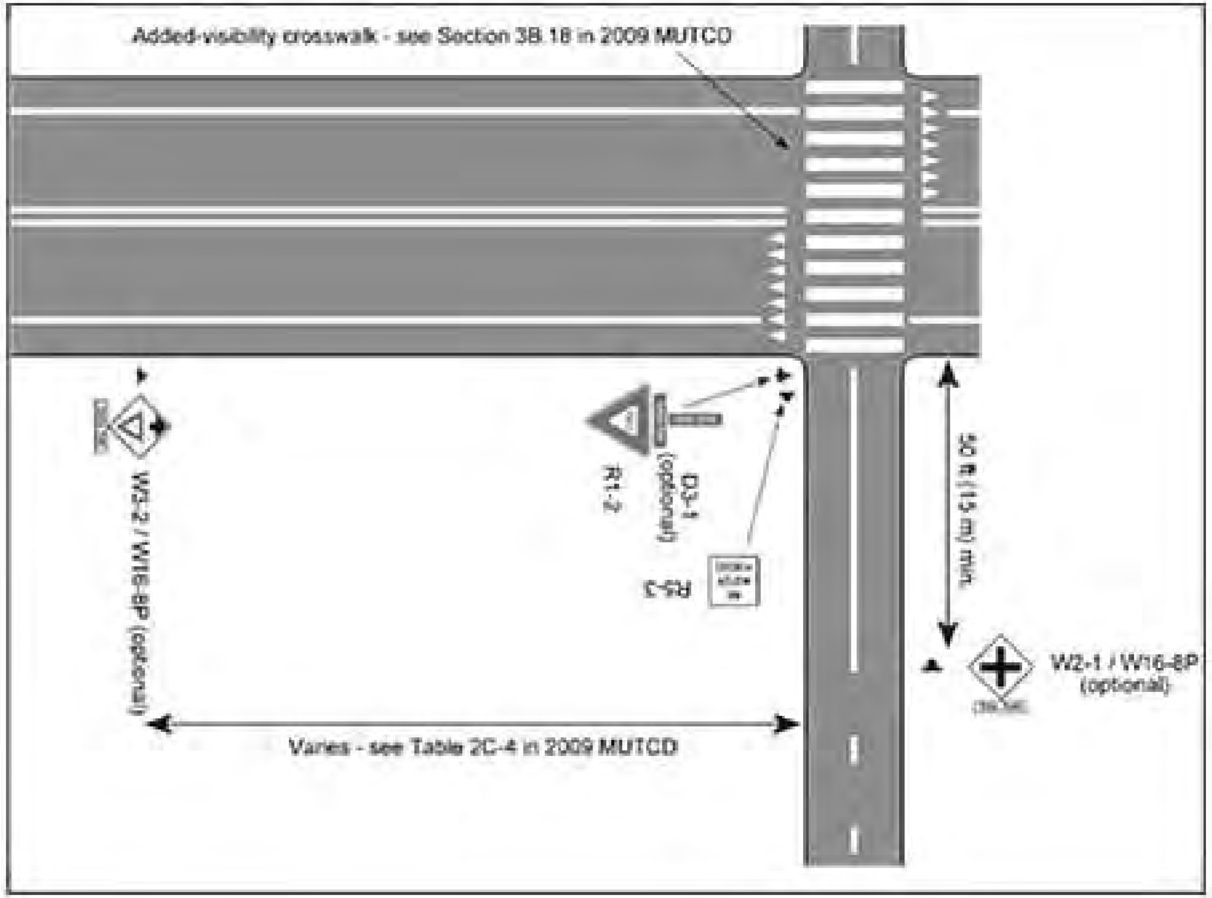
The 2009 MUTCD now incorporates bicycle-sized versions of D10 series reference location (milepost) signs that are very suitable for use along shared-use paths. These can be very useful for providing information to path users on distance traveled and distances to destinations. They can also be very useful for maintenance and operation of the path by providing detailed location information for path features, and for emergency response to incidents along a path by facilitating detailed location information which may not be available through conventional means, especially to path users not familiar with the area. Due to the lower speeds of path users, it may be a good idea to use intermediate reference location signs at shorter spacings. An agency could use these at 0.2 mile (.3 k) intervals staggered such that the signs on the increasing-direction side are placed at even decimal miles (0.2, 0.4, etc.) and signs on the decreasing-direction side are placed at odd decimal miles (0.1, 0.3, etc.). This would have the effect of providing location information at a 0.1 mile (160 m) spacing but at reduced cost.

Path-Intersection Signs. At intersections of roadways and shared-use paths in locations that are not at or adjacent to roadway-roadway intersections, signing should follow the general example of Figure 9B-7 of the 2009 MUTCD. Bicycle Warning (W11-1) or Combined Bicycle/Pedestrian (W11-15) signs may be used on the roadway approaches in advance of locations where crossings by bicyclists and other path users may not be expected by drivers. (See Figure 14-32.) However, warning signs should not be overused, such as installing warning signs at every intersection along a pathway, such as seen in Figure 14-4.

Other W11 series signs, signs that combine symbols, or multiple W11 warning signs for different modes in a single location should not be used, due to the possibility of drivers misunderstanding nonstandard or multiple symbols, and the potential for diluting the warning message by overloading the driver with too many symbols or sign types.

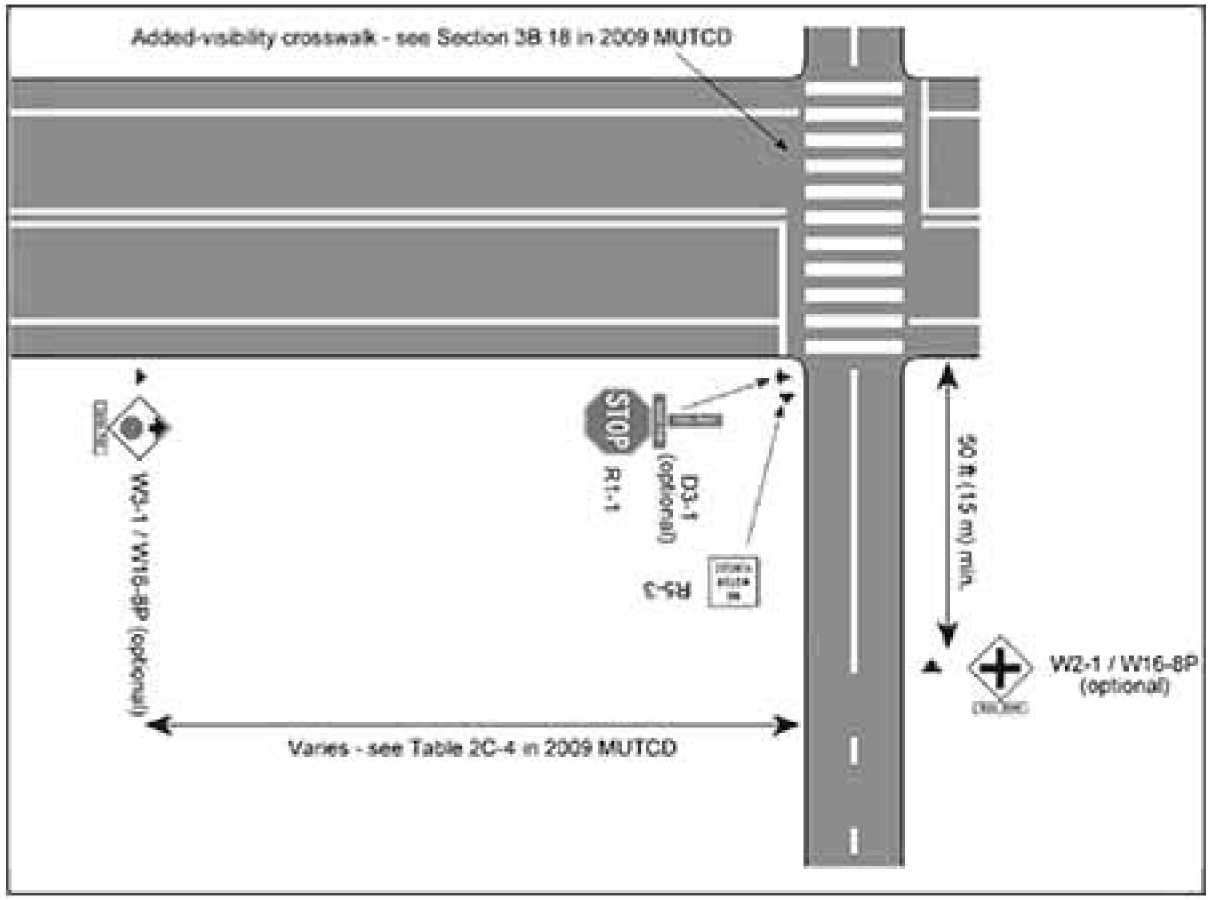
At path-roadway intersections, priority should not automatically be assigned to the roadway. A number of factors should be considered in determining priority, including volume and type of users on the path, volume of traffic on the intersecting roadway, available sight distance, and other factors. At an intersection between a high-volume path and a low-volume street, it may be most efficient to have the roadway yield to the pathway, or stop for the pathway if sight distance does not allow for yield control. In addition, routinely placing stop or yield control on the pathway will typically not prevent crashes and conflicts at path-roadway intersections, as bicyclist compliance with inappropriate stop controls at path-roadway intersections is poor.

FIGURE 14-33. Path-roadway Intersection—YIELD Control For Roadway



SOURCE: Richard Moeur.

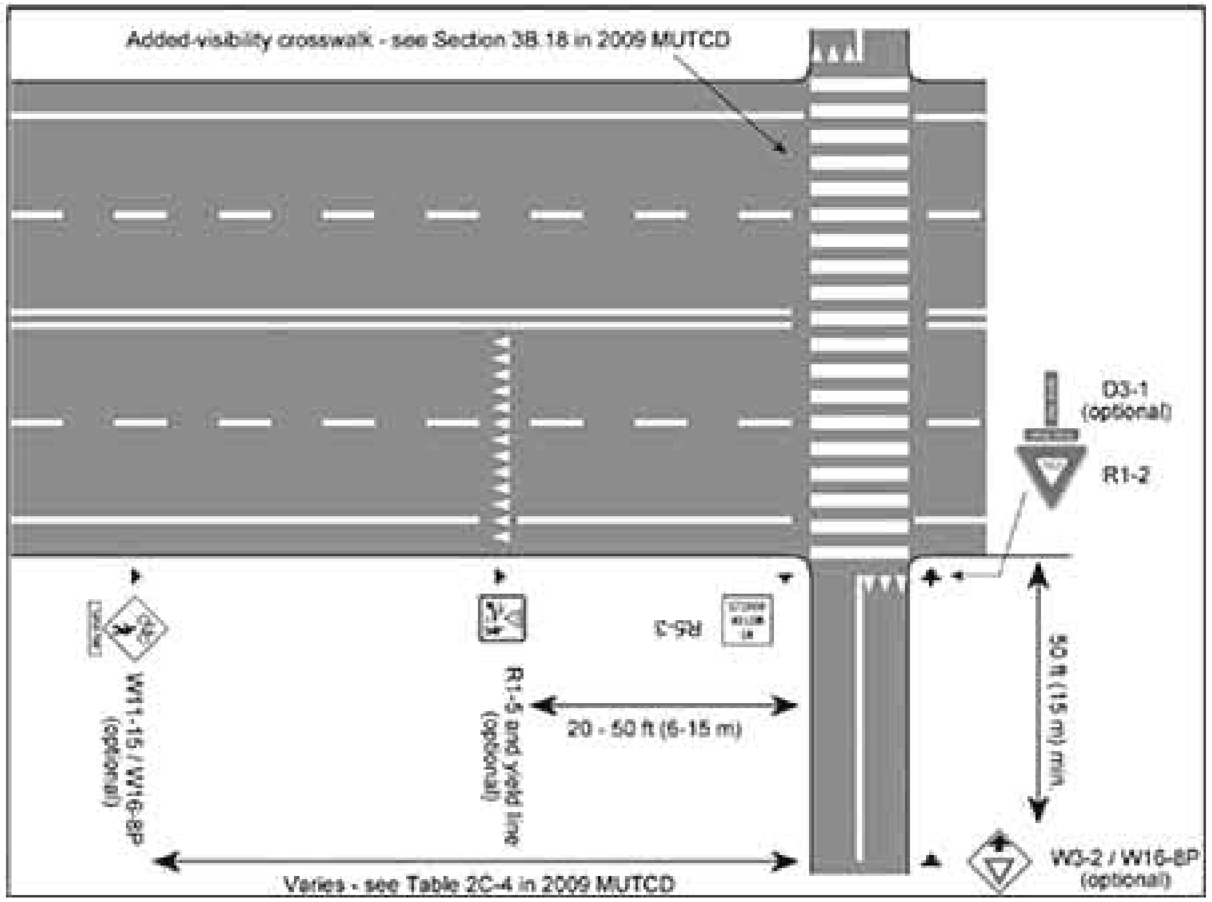
FIGURE 14-34. Path-roadway Intersection—STOP Control For Roadway



SOURCE: Richard Moeur.

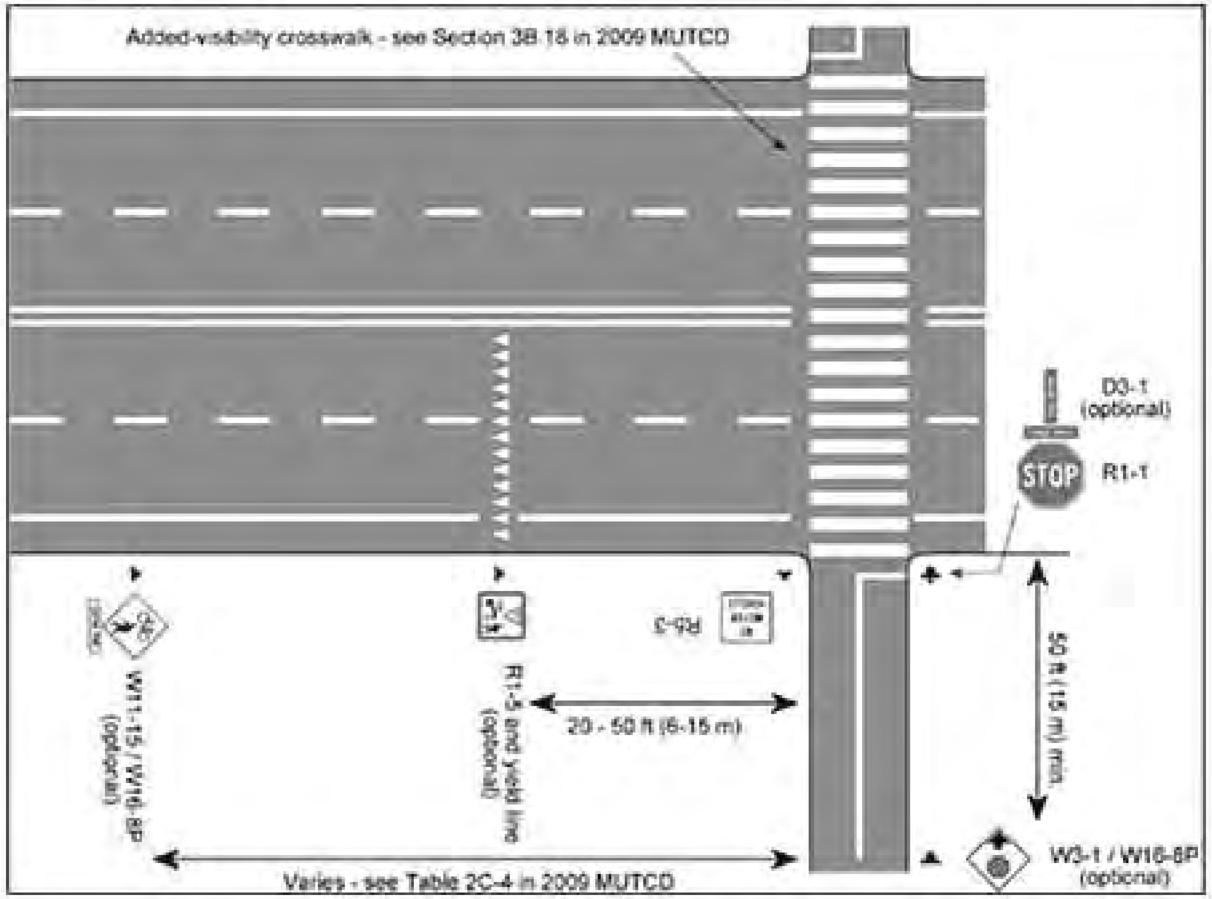
Observation has noted that bicyclists often treat STOP signs as YIELD signs at these locations, slowing, scanning for conflicting traffic, and then proceeding if no conflicting traffic is detected. This can serve to induce a pattern of behavior that can result in operational problems at locations where unexpected conflicts do actually warrant a full stop prior to entering the intersection. Yield control (either for the roadway or pathway) can be an effective and efficient treatment as it encourages appropriate scanning behavior without unneeded restriction (or routine disobedience).

FIGURE 14-35. Path-roadway Intersection—YIELD Control For Pathway



SOURCE: Richard Moeur.

FIGURE 14-36. Path-roadway Intersection—STOP Control For Pathway



SOURCE: Richard Moeur.

The determination of intersection sight distance is a basic step in determining the appropriate level of control at a path-roadway intersection. The detailed procedures and calculations for determining sight distance, however, are beyond the scope of this *Handbook*. Readers are directed to the most recent edition of the AASHTO *Policy on Geometric Design of Highways and Streets* for determining approach sight distance for roadways, and the most recent edition of the AASHTO *Guide for the Development of Bicycle Facilities* for determining approach sight distance for pathways.

Once the path-roadway intersection has been evaluated and a decision made on type of control, Figures 14-33 through 14-36 may be consulted for examples of signing and marking for each type of control. These figures are general in nature, and other devices may also be useful or recommended depending on conditions.

It can be very useful to place street name signs at path-roadway intersections to inform path users of intersecting streets, and also to inform bicyclists and others on the roadway of the presence and name of the path. These signs can be mounted above STOP or YIELD signs at the intersection, or placed in advance of the intersection.

Marking of Paths

Markings are used on shared-use paths for a variety of purposes. Markings can warn of obstructions and obstacles, advise users of two-way travel and locations where passing is permitted or prohibited, and provide guidance, especially at night.

Marking Materials. As noted elsewhere in this chapter, marking materials used on paths should possess high skid resistance and wet-weather traction where practicable. Epoxy, thermoplastic, and other high-durability marking materials may be used on paths that encounter heavy use or frequent snowplowing, while standard traffic paints may perform quite well on paths that are not heavily trafficked or plowed. Markings on shared-use paths shall be retroreflective. See the earlier section of this chapter, "Markings for Bicyclists," for more information.

Centerline Marking. Centerline marking may be a useful channelizing device for shared-use paths, and may also provide pathway alignment guidance information in areas with curvilinear alignments or numerous intersecting sidewalks or paths. In addition, centerline markings are useful in locations with restricted sight distances, as they may help in channelizing opposing traffic flows and reduce the potential for head-on conflicts. Centerline markings may be continuous along the length of a pathway, or installed only in specific locations where engineering judgment indicates a centerline may be beneficial.

Opposing traffic flows should always be channelized in the standard manner for North American traffic, i.e., with oncoming traffic to the far left, and same-direction traffic to the right. Exceptions to this practice may be confusing to bicyclists and other path users who are conditioned through years of experience to keeping to the right, and may result in severe conflicts and collisions.

Centerline marking that separates opposing directions of pathway traffic shall be yellow. Standards for centerline markings on paths may be found in Section 9C.03 and Figure 9C-2 of the 2009 MUTCD. The two patterns used are a normal-width single broken line with a 3 ft. (0.9 m) stripe and a 9 ft. (2.7 m) gap, and a normal-width single solid line. In most locations, the broken line should be used, as there will typically be adequate sight distance for passing maneuvers. Solid centerline markings may be used where there are restrictions in sight distance, or where added emphasis for staying on the correct side of the pathway may be useful, such as approaching a sharp curve or intersection, or entering an underpass or tunnel. However, solid centerline markings should not be overused; this can create disrespect for solid markings which could result in poor behavior at locations where solid markings are used to denote a more-critical operational problem.

Edgeline Marking. Edgeline markings may be useful channelizing devices on shared-use paths in specific locations. In a manner similar to edgelines on roadways, edgeline markings on pathways can provide useful alignment guidance, such as where approaching intersections on paths that have significant travel volume at night, or where the alignment of the path may be unclear, such as traversing an open paved area or plaza. Edgeline markings may also be used to designate a specific area for pedestrian travel (see additional information below). Edgeline markings on paths should be a normal-width solid white line.

Intersection Marking. On pathway approaches to intersections, markings such as stop lines and word legends may be used as appropriate based on engineering judgment. See Figure 9B-7 of the 2009 MUTCD for one example.

Crosswalks should be considered at shared-use path crossings in accordance with Section 3B.18 of the 2009 MUTCD, since pedestrians are expected to use shared-use paths, and may be served best by a marked crosswalk. However, in a number of jurisdictions, bicyclists are legally forbidden from using crosswalks, or must use crosswalks in a pedestrian manner, i.e., by traveling at pedestrian speeds or by dismounting and walking. In these locations, it may be desirable to include a dashed or unmarked crossing area for bicyclists outside the crosswalk.

However, the presence of a crosswalk is no guarantee drivers will yield to path users crossing the roadway, even if a high-visibility crosswalk is used. Where a path crosses a two-lane roadway with an operating speed of 40 mph (64 km/h) or less, a marked crosswalk with standard warning signs may perform acceptably. The use of a high-visibility crosswalk marking pattern can improve visibility of the crosswalk and increase detection time by drivers on the roadway.[36] On streets with two or more lanes in each direction, a raised median with a refuge area may be beneficial in allowing path users to make a two-stage crossing. Where a path intersects with a higher-volume street with multiple lanes in each direction, drivers may be unlikely to yield to path users unless some type of active traffic control device is used.[37] See a later section of this chapter for more information on the use of signals or other active devices on bikeways.

A common type of crash at path-roadway intersections or crosswalks is the "multiple-threat" crash, where a driver in one lane yields to a crossing path user, but in doing so obstructs of the view of the crossing path user from traffic in adjacent lanes, who then may fail to yield and collide with the crossing path user as he or she enters the travel path of the non-yielding vehicle. To mitigate this type of crash, a stop line or yield line along with R1-5 series signs may be placed 20 to 50 ft. (6 to 15 m) upstream of the crosswalk in accordance with Section 3B.16 of the 2009 MUTCD, and as depicted in Figure 3B-17 of the 2009 MUTCD.

Symbol and Word Markings. Symbol and word markings may be used on shared-use paths to denote areas intended for bicyclist and pedestrian travel, to denote directionality where centerline markings are used, and to advise of other conditions and situations, such as in advance of an intersection or railroad crossing.

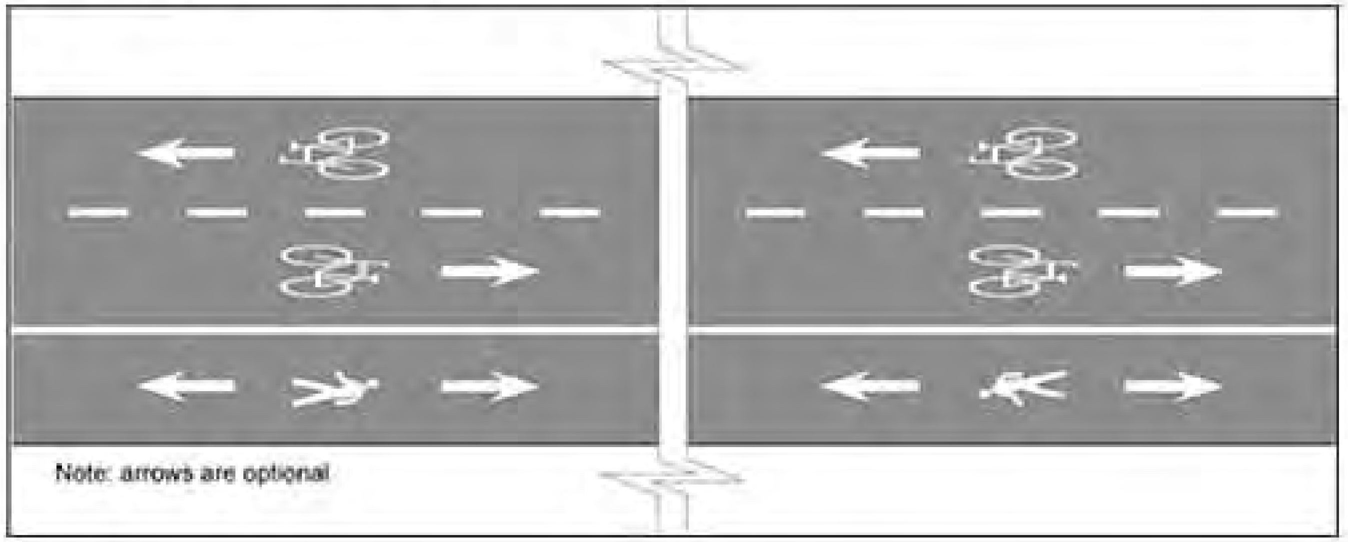
Bicycle symbol and arrow markings used on shared-used paths typically conform to bicycle symbols and arrows in Figure 9C-3 of the 2009 MUTCD. Word markings in bike lanes should conform to the elongated designs shown in the MUTCD and *Standard Highway Signs* book, with the size reduced as appropriate to fit the facility. See the earlier section of this chapter dealing with "Markings for Bicyclists" for more information on design details for markings on bikeways.

Marking for Pedestrian/Bicycle Channelization. On pathways with high bicycle and pedestrian volumes, and where pathway width is adequate to do so, typically 14 ft. (4.3 m) or greater, a separate pedestrian area may be marked on the pathway to one side (see Figure 14-37). This should be delineated with a single solid white edgeline. R9-7 signs and symbol and word markings may also be used to clarify that the marked area is for two-way pedestrian use. However, experience has indicated such channelization may not have a high degree of compliance without enforcement.

Where a pedestrian area is provided, the remaining part of the pathway width intended for bicycles and other wheeled users should be sufficiently wide for two-way travel. A pathway should not be divided in a manner such that the space for wheeled users is only wide enough for one-way travel. Centerline markings on the non-pedestrian part of the pathway, along with bicycle symbols and directional arrows, may be useful in clearly denoting expected travel paths for different types of users.

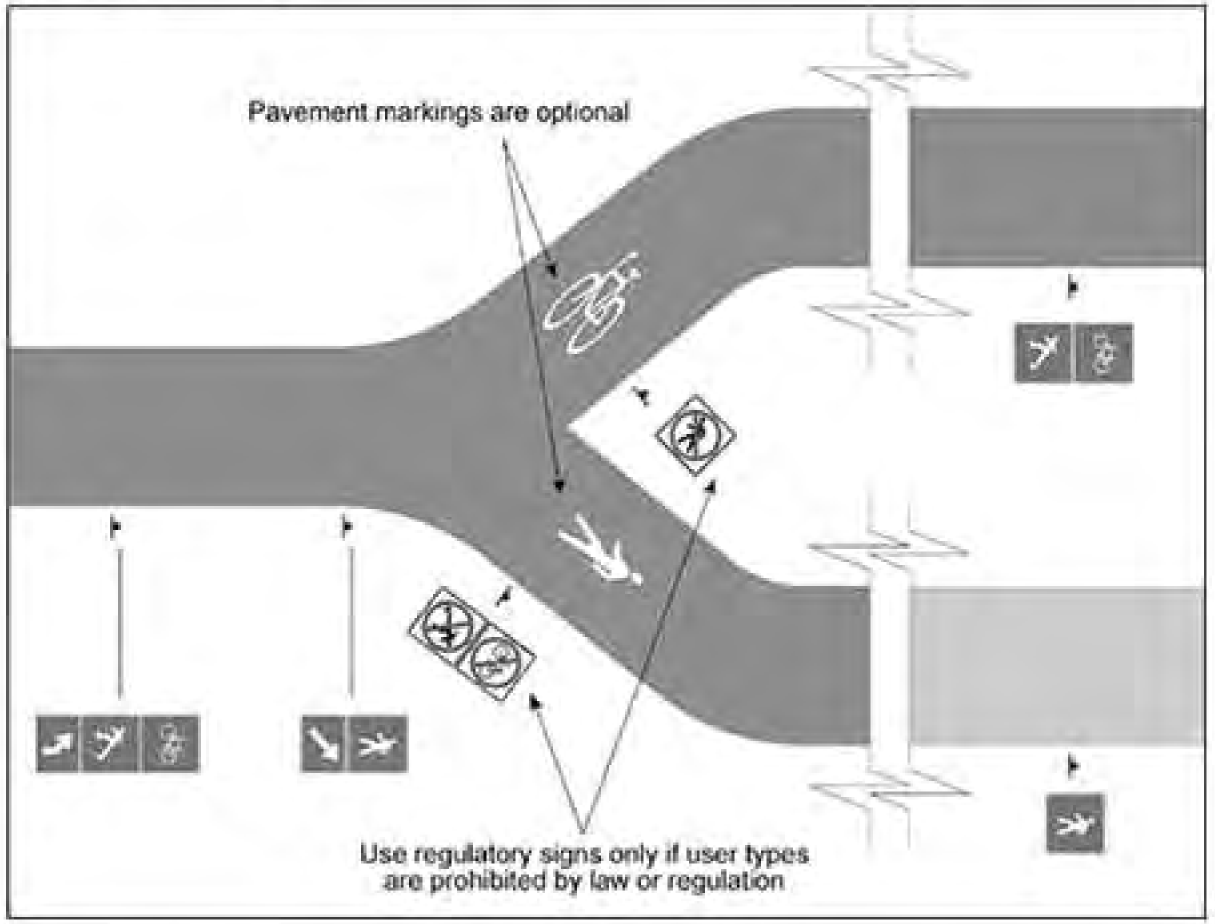
Engineering judgment should be used in determining which side of the pathway is appropriate for the pedestrian area. On a path traveling along a lake or other scenic area, the pedestrian area is typically placed on the side closest to the scenic area, as this is the side to which pedestrians are most likely to be attracted.

FIGURE 14-37. Example of Markings for a Pedestrian Area on a Shared-Use Path



SOURCE: Richard Moeur.

FIGURE 14-38. Example of Mode-Specific Signing for Separate Pathways



SOURCE: Richard Moeur.

In some areas, the provision of physically separate paths for pedestrian and bicycle (and other wheeled-user) travel may be advisable (see Figure 14-38). Where these paths connect, merge, or diverge from one another, word and symbol markings may be used to clarify which user types are expected or intended to use each path. Mode-specific signs (D11-1a through D11-4) and mode prohibition signs (R5-6, R9-3, R9-13, R9-14) may also be used to convey information on mode use and prohibition.

Obstruction Markings. There may be obstructions within the traveled way of a shared-use path that may create crash risks for bicyclists. These obstructions should be marked with standard object markers or retroreflectorized material to make them conspicuous to bicyclists.

As noted earlier, posts, bollards, and other fixed objects are sometimes placed in the traveled way of shared-use paths, ostensibly to prohibit motor vehicle intrusion. These obstructions should not be used unless the risk of intrusion by a motor vehicle outweighs the crash risk presented by the presence of the obstruction. Other design treatments, such as short landscaped medians at intersections with roadways, may be more effective and less inconvenient to bicycle travel, and will likely have lower crash risks.

If posts or bollards must be used, these posts should either have retroreflectorized material or object markers installed as stated in Section 9B.26 of the 2009 MUTCD, and pavement marking as shown in Figure 9C-8 of the 2009 MUTCD should be used. If used, posts or bollards should divide the width of a path into an even number of lanes, since the directionality of a center area is undefined, and increases the likelihood of head-on collisions. Centerline striping may be helpful on the approaches to posts or bollards to indicate the direction in which traffic is to travel in each lane.

Markings at Path-Railroad Crossings. Where a pathway on an independent alignment crosses a railroad, markings are typically used in advance of the crossing and at the crossing location. Chapter 8D of the 2009 MUTCD discusses traffic control devices at path-railroad crossings, and Figure 8D-1 depicts examples of signing and markings at a path-railroad crossing. If a swing gate is used at a path-railroad crossing, it should be retroreflectorized or marked with object markers.

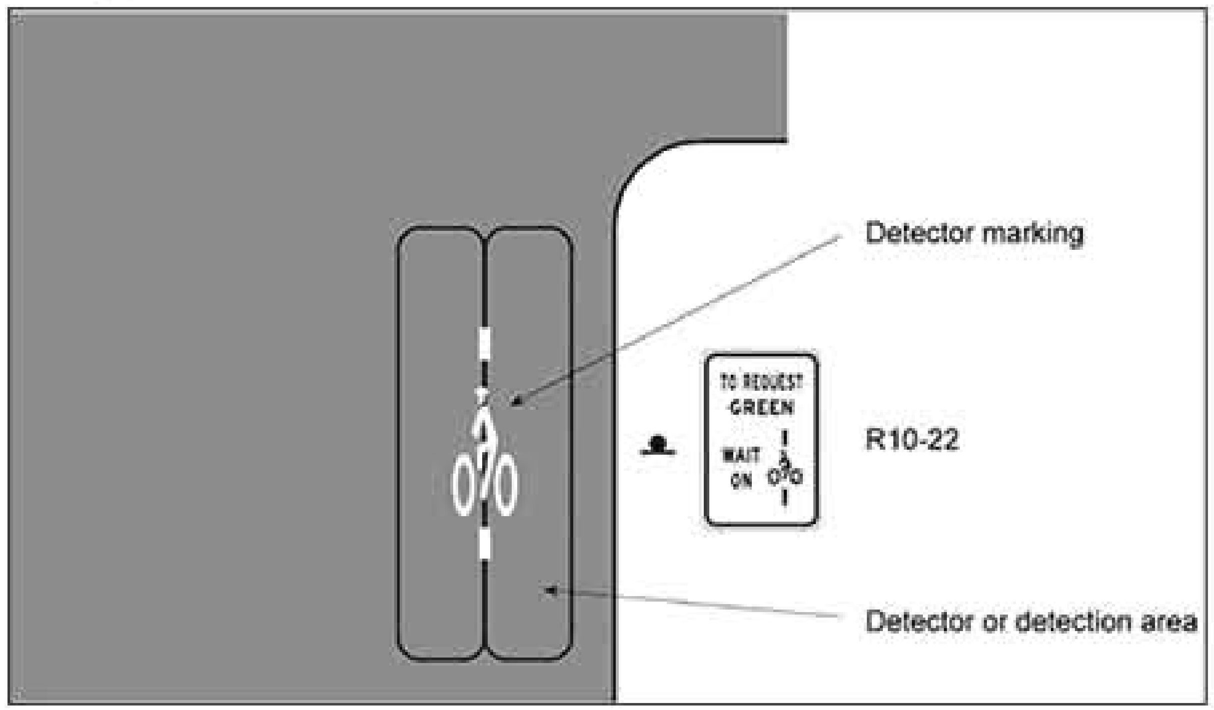
Other Devices

Other traffic control devices may be used on shared-use pathways, such as conventional traffic signals, pedestrian hybrid beacons (PHBs), or RRFBs. For more information on the use of signals on bikeways, see the following section of this chapter.

TRAFFIC SIGNALS AND BICYCLES

Bicyclists, like all other road users, are affected by traffic signals. In many cases, bicyclists use traffic signals in the same manner as other vehicles. Less-confident bicyclists and child bicyclists may use signals in a pedestrian manner, walking or riding in crosswalks. But in either case, there are some circumstances in which special care should be taken to properly address the needs of bicyclists at signalized intersections.

FIGURE 14-39. Example of Detector Marking Symbol and Sign



SOURCE: Richard Moeur.

Bicycle Detection

Detection at traffic signals is of critical importance for bicyclists. For example, if a bicyclist operating in a normal, lawful manner approached a fully or semi-actuated signal, and could not be detected by the existing intersection equipment, that bicyclist may never receive a green indication or be properly served by that intersection. In these cases, it could be argued the intersection is malfunctioning. In any case, the frustration and delay due to the signal's failure to detect and change may tempt the bicyclist to disobey the signal—which will cause operational and safety problems, especially if it becomes a habit. Section 9D.02 of the 2009 MUTCD requires agencies to review and adjust signal actuation on bikeways to consider the needs of bicyclists.

There are two major types of bicycle detection—active and passive.

Active detection requires the bicyclist to perform a specific action in order to be detected at a signal. The most frequently used method of active detection is to place a pedestrian-type pushbutton adjacent to the facility, near the travel path of the bicyclist. However, this requires bicyclists to divert their travel path to the button location, then to stop and push the button, often times while having to lean over to do so. This can leave bicyclists in an incorrect position at the intersection approach, such as to the right of right-turning vehicles. Also, a pushbutton at the right curb will be of no use to a bicyclist choosing to legally use the left turn lane at an intersection approach. Therefore, this type of detection should be limited to shared-use path approaches to signalized crossings, or similar situations where the location of the pushbutton will not require the bicyclist to perform inconvenient maneuvers, or maneuvers that could violate laws or the expectations of other road users.

Passive detection is defined as a method of detecting bicycles without requiring the cyclist to perform any special action. The most commonly used method of passive detection uses electrified loops that are buried in the pavement, but other systems of detection—such as video, microwave, ultrasonic, or passive acoustic sensors—have also been used. Any type of detection that detects only large or noisy vehicles may not provide acceptable detection of bicyclists.

Loop detectors work by sensing changes in inductance caused by the passage of metallic objects above them, such as a motor vehicle chassis or a bicycle's frame and wheels. Some types of loop patterns, such as the quadrupole (figure-eight) pattern, can be tuned to provide more than adequate sensitivity at the center of the loop to detect bicycles, without also erroneously detecting vehicles in adjacent lanes. Other types of loops may not be as easily tuned to sense the presence of bicycles without also sensing motor vehicles in adjacent lanes, and it may be inadvisable to use these in locations where bicyclists are anticipated.

Passive detectors of any type should be placed such that their area of maximum sensitivity is in the anticipated travel path of bicyclists, and detectors should be tuned and adjusted to sense bicycles without any special effort on behalf of the bicyclist. If this cannot be achieved, then detectors should be adjusted so they will at least detect a bicycle that is directly within the area of maximum sensitivity of the detector, or signs and markings may be used as noted below to direct a bicyclist to occupy a location where the probability of detection is maximized.

Signs and Markings to Facilitate Detection. In locations where existing passive detection devices might not reliably detect a bicyclist unless the bicycle stops at a specific location, signing and markings may be used to show the location of the point of maximum detectability for a bicycle. An example of how the detector marking symbol and accompanying sign defined in the MUTCD may be used is seen in Figure 14-39. Another feature that may reassure bicyclists they have been successfully detected is to use some sort of detection confirmation signal that will not be confused with signal indications, but changes or illuminates to show detection has occurred.

Traffic Signals on Bikeways

There are many common situations where signalization may be warranted on a bikeway facility. On shared roadways and bike lanes, the volume and speed of the motor vehicle traffic on the roadway (and of intersecting roadways) will be the primary factors considered when evaluating warrants for signalization at an intersection.

Where shared-use paths intersect higher-volume streets with multiple lanes in each direction, or where a bicycle boulevard crosses a street with multiple lanes in each direction, drivers may be less likely to yield to path users unless some type of active traffic control device is used.[38] If warranted and justified, a conventional traffic signal can be used to control traffic at an intersection of a shared-use path and a roadway, or where a bicycle boulevard intersects a cross street.

If the intersecting facility is a shared-use path, standard pedestrian signals may be used alone to control the path movement, or a combination of standard signal faces (to control bicyclists) and pedestrian signals may be used. If the intersecting facility is a bicycle boulevard, standard pedestrian signals may be used to control the boulevard crossing, or a combination of bicycle-specific signalization and pedestrian signals may be used. Using a conventional signal face on a bicycle boulevard at a signalized intersection where motor-ized traffic is required to turn could be potentially confusing, especially if the mandatory vehicular turning movement is controlled by a STOP or YIELD sign.

Alternatives to Signalization. If an active traffic control device is desirable at either a path-roadway intersection or where a bicycle boulevard crosses an intersecting roadway, and a traffic control signal is not warranted or is not an optimal solution due to interruption of progression or other factors, other active devices may be considered. If warranted, a pedestrian hybrid beacon (PHB) as defined in Chapter 4F of the 2009 MUTCD may be a desirable option, as these devices typically see nearly 100 percent compliance when the red indication is displayed to the cross street, and reduce delay and interruption of traffic flow on the intersecting roadway as compared to conventional signalization. If a signal or PHB is not warranted, the use of RRFBs is currently permitted by an Interim Approval issued by FHWA. RRFBs are considerably less expensive than signals or PHBs, but exhibit lower rates of yielding to crossing traffic. Agencies considering the use of RRFBs should review the conditions for Interim Approval found on the FHWA MUTCD website at mutcd.fhwa.dot.gov.

Agencies have used flashing conventional beacons at crosswalks and path-roadway intersections in an attempt to warn roadway users of crossing traffic, but these may not be as effective as RRFBs or other treatments.[39]

Visibility of Signal Indications. Signal indications facing roadways, pathways, and other bicycle facilities must be visible to all legal road users, including bicyclists. Section 9D.02 of the 2009 MUTCD explicitly states visibility-limited signal faces shall be adjusted so bicyclists for whom the indications are intended can see the signal indications, or separate standard signal faces be provided.

Phase Change Intervals to Accommodate Bicyclists

Section 9D.02 of the 2009 MUTCD requires agencies to review and adjust signal timing on bikeways to consider the needs of bicyclists. Bicyclists typically cross intersections under the same signal phases as other traffic. The greatest risk to bicyclists is during phase change intervals. Signal timing at intersections should provide adequate time for bicyclists who enter the intersection legally at the end of the green phase to complete their crossing before conflicting traffic receives a green indication. Also, signals should provide a total crossing time (minimum green plus phase change intervals) long enough to allow bicyclists to fully exit the intersection if they start up at the beginning of a green.

Calculation of Bicycle Clearance Time—Bicyclist Rolling Entry (at End of Green). A signal should provide adequate time for a bicyclist entering an intersection at the end of the green interval to clear the path of any conflicting movements prior to the crossing traffic receiving their green indication. This time is comprised of the yellow change interval, a red clearance interval, and any green extension time (if provided). The yellow change interval is determined in accordance with recommended practices based on motor vehicle speed. This interval should not typically be modified to accommodate bicyclists, as it could result in unpredictable effects on motor vehicle traffic. Therefore, the red clearance interval can be adjusted to provide any additional time for bicyclist clearance. However, the red clearance interval should not be excessively long; this could impact intersection capacity and progression, and could encourage drivers to enter the intersection after the end of the yellow change interval.

The following formula[40] may be used to determine the crossing time for bicyclists making a rolling entry into an intersection during the green interval:

$$BCT_R = \frac{t \times V + \frac{V^2}{2a} + W + L}{V} = t + \frac{V}{2a} + \frac{(W+L)}{V}$$

where

BCT_R = Bicycle crossing time—rolling entry (sec.)

t = Perception-reaction time, typically 1 sec.

V = Bicycle speed in intersection (ft./sec. or m/sec.), typically 14.7 ft./sec. (10 mph) or 4.5 m/sec. (16 km/h) (can be greater)

a = Bicycle deceleration rate—wet pavement (ft./sec.^{2}), typically 5 ft./sec.^{2} or 1.5 m/sec.^{2}

W = Intersection width (ft. or m)

L = Bicycle length (ft. or m), typically 6 ft. or 2 m

The value of BCT_R from this equation may then be used to determine the bicycle clearance time:

$BCT_R \leq e + Y + AR$

where

BCT_R = Bicycle crossing time—rolling start (sec.)

e = Extension time (sec.)

Y = Yellow change interval (s), typically 3 to 6 sec.

AR = Red clearance interval (s), typically 0 to 6 sec.

If the calculated bicycle crossing time exceeds the maximum allowable values for yellow change plus red clearance, it may be helpful to use some type of adaptive signal timing triggered by bicycle detection. A bicycle-specific detector can be installed on the intersection approach to notify the controller to extend the green time when a bicyclist is detected.

However, this may only be feasible where either a detector can be placed in a bike lane on the approach, or using specific detection programming using video or microware detection, so as to minimize false detector actuations caused by other traffic.

Calculation of Bicycle Clearance Time—Bicyclist Standing Start (At Beginning of Green). At the beginning of a green signal interval, a bicyclist stopped at the approach should be given sufficient clearance time to react, accelerate, and travel across the intersection to clear the path of any conflicting movements prior to the crossing traffic receiving their green indication. This time is comprised of the green interval, any green extension time (if provided), the yellow change interval, and red clearance interval.

The following formula may be used to determine the crossing time for bicyclists making a standing-start entry into an intersection at the beginning of the green interval:

$$BCT_S = t + \frac{V}{2a} + \frac{(W+L)}{V}$$

where

BCT_S = Bicycle crossing time—standing start (sec.)

t = Perception-reaction time, typically 1 sec.

V = Bicycle speed in intersection (ft./sec. or m/s), typically 14.7 ft./sec. (10 mph) or 4.5 m/s (16 km/h) (can be greater)

a = Bicycle acceleration rate (ft./sec.^{2} or m/sec.^{2}), typically 1.5 ft./sec.^{2} or 0.5 m/sec.^{2}

W = Intersection width (ft. or m)

L = Bicycle length (ft. or m), typically 6 ft. or 2 m

This equation is mathematically correct for cross street widths where a bicyclist can reach full cruising speed (66 ft. or 20 m) using the typical values for acceleration and cruising speed listed above, but slightly conservative and reasonably close (within about 0.2 seconds) for street widths where bicyclists do not reach full cruising speed prior to completing their crossing.

The value of BCTS from this equation may then be used to determine the minimum green interval for that approach:

TABLE 14-8. Bicycle Clearance Time Based on Intersection Width

Intersection Width		Bicycle Clearance Time	
		Standing Start	Rolling Start
(feet)	(meters)	(seconds)	(seconds)
40	12.2	9.0	5.6
45	13.7	9.4	5.9
50	15.2	9.7	6.3
55	16.8	10.0	6.6
60	18.3	10.4	7.0
65	19.8	10.7	7.3
70	21.3	11.1	7.6
75	22.9	11.4	8.0
80	24.4	11.8	8.3
85	25.9	12.1	8.7
90	27.4	12.4	9.0
95	29.0	12.8	9.3
100	30.5	13.1	9.7
105	32.0	13.5	10.0
110	33.5	13.8	10.4
115	35.1	14.1	10.7
120	36.6	14.5	11.0
125	38.1	14.8	11.4
130	39.6	15.2	11.7
135	41.1	15.5	12.1
140	42.7	15.8	12.4

Default values used to develop table:
Perception-reaction time: 1 sec.
Bicyclist speed: 14.7 ft./sec. (10 mph) (4.5 m/sec.) (16 km/h)
Acceleration rate: 1.5 ft./sec.2 (0.5 m/sec.2)
Deceleration rate (wet): 5 ft./sec.2 (1.5 m/sec.2)
Bicycle length: 6 ft. (2 m)

SOURCE: Richard Moeur.

$$BMG = BCT_S - Y - AR$$

where

BMG = Bicycle minimum green time (sec.)
BCT_S = Bicycle crossing time—standing start (sec.)

Y = Yellow change interval (sec.), typically 3 to 6 sec.
AR = Red clearance interval (sec.), typically 0 to 6 sec.

Using the default values listed above for acceleration, deceleration, perception-reaction time, bicyclist speed, and other factors, Table 14-8 indicates clearance times based on intersection width.

Note lower acceleration rates and additional perception-reaction time may be considered for use in locations where younger bicyclists may be frequently expected, such as near schools. The values for bicyclist speed and acceleration may be adjusted based on grades or observations of bicyclists at the intersection. As with any adjustment to signal timing, field observations, verification, and adjustment may be required.

"Challenging" Intersections

A single-point diamond interchange (SPDI) is a type of interchange where all ramp movements take place in a single intersection, unlike standard diamond interchanges that use two separate intersections. Due to the geometrics of this type of intersection, the stop lines on the cross street can be up to 300 ft. (90 m) apart, creating a situation where bicyclists may be potentially exposed to cross traffic for an extended period. At SPDIs, it may be beneficial to arrange the signal phasing such that bicyclist exposure can be minimized, by first servicing the cross street, then releasing the left-turn movements from the cross street, and then releasing the left-turn movements from the ramps to the cross street. It may also be advisable to evaluate the yellow change and red clearance intervals to determine if bicyclists might still be in the intersection when conflicting movements are released, especially if the signal operation allows phases to be skipped if no vehicles are present.

Other intersections, such as ones with multiple left turn lanes, more than three through lanes in each direction, or with an acute angle between the intersecting roadways, can also cause problems for entering and crossing bicyclists. These intersections may also have long distances between stop lines, sometimes well over 150 ft. (45 m). As noted in the discussion of bicycle clearance times, such distances between stop lines can cause significant problems for bicyclists entering and crossing these intersections, even taking into account their longer yellow change and red clearance intervals. If the cross street is a bikeway, the signal timing shall take into account for the needs of bicyclists, as specified in Section 9D.02 of the 2009 MUTCD.

FIGURE 14-40. Bicycle-Specific Traffic Signal (Tucson, AZ)

SOURCE: Richard Moeur.

A new type of interchange is the "diverging diamond," where the traffic movements on the cross street are "crossed over" in the vicinity of the interchange to provide for higher-volume movements to and from the ramps and the left lane of the cross street. If the bike lane, shoulder, or other on-road facility is channelized in the conventional manner, it will be adjacent to the median within the interchange; however, this is actually an advantage, as it places the bicyclists on the opposite side from the turning movements at the interchange. It is inadvisable to direct bicyclists to the outside of the travel lanes in these interchanges; this will require crossing several ramps, some of which may have free-flow operation.

Bicycle-Specific Traffic Signals

Bicycle traffic signal faces resemble standard traffic signal faces, with the distinguishing feature being the bicycle signal displays the outline of a bicycle instead of the standard ball or arrow indication. Bicycle traffic signals are not currently included or recognized in the MUTCD, and bicycle traffic signals should currently only be used within the structure of an approved experiment in accordance with Section 1A.10 of the 2009 MUTCD.

Uses of Bicycle Traffic Signals. Bicycle traffic signals have been used in other countries to regulate bicycle movements at intersections that contain legs with separated parallel bicycle pathways or mandatory bike lanes. This is typically due to the fact these parallel facilities can see complicated traffic flow patterns at intersections.

Bicycle traffic signals have been used in locations in the United States in a limited manner in the following situations:

- at intersections of shared-use paths with roadways to control bicycle traffic on the path;
- at intersections of bicycle boulevards with roadways to control bicycle traffic continuing on the bicycle boulevard across the roadway without confusing motor vehicle traffic on the bicycle boulevard;
- at intersections with multiple turn lanes adjacent to a bike lane; and
- on parallel adjacent sidepaths at signalized intersections to control bicycle traffic on the sidepath during conflicting traffic movements.

The typical phasing for bicycle traffic signals is to hold bicycle traffic for the majority of the signal cycle as conflicting movements receive their phases, and then to release the bicycle traffic either during a "bike-only" phase or a phase when parallel traffic is given a green indication but all motor vehicle turning movements across the path of bicyclists are restricted. This reduces the potential for bicycle-motor vehicle conflicts at the intersection, but typically results in a rather short green indication for bicycle travel, with bicyclists expected to stop and wait for the remainder of the cycle. If the signal cycle and movements are simplified, such as at an intersection where a one-way street with a parallel one-way sidepath intersects a cross street, then the bicycle movement can receive a large proportion of the parallel street green time—but will still be restricted when turning movements are released across the sidepath. Figure 14-40 shows a bicycle traffic signal used at a bicycle boulevard crossing of an intersecting major street.

Concerns with Bicycle Traffic Signals. In order to establish a green phase solely for bicycle traffic, green time must be reduced for all other phases in the cycle, which reduces the capacity of the intersection for all users. Also, bicycle traffic must be stopped on all other phases except the bicycle-specific phase. This greatly increases intersection delay to bicyclists who could otherwise proceed at the same time as other traffic in the same direction. This may lead to disobedience of the signal by bicyclists who refuse to accept the added delay, especially if a parallel roadway movement is seen to receive a much higher percentage of green time.

A recent study in Denver, Colorado noted that if a bicycle signal was timed to give a green signal to bicyclists that coincided with already-established patterns of crossing movements, relatively good signal compliance was observed. However, if the signal timing for the bicycle movement was not consistent with established crossing patterns, observed compliance with the signal was significantly decreased.[41]

There are concerns the use of bicycle signalization could promote non-uniformity of traffic control. Bicyclists could be expected to operate in a significantly different manner at intersections controlled by these signals. Where bicycle traffic signals are present, bicyclists may be expected to turn left from the right-hand side of the roadway to the left of through traffic. If bicyclists turn in the same manner at intersections not controlled by bicycle signalization, serious conflicts would be likely to occur.

Future of Bicycle Traffic Signals. There may be specific applications where bicycle-specific signalization may show systemic benefits, such as at bicycle boulevard crossings of intersecting roadways. The National Committee on Uniform Traffic Control Devices is developing preliminary standards and guidelines for the implementation of bicycle signals, but this process is still in its early stages. Bicycle signals may be included in future editions of the MUTCD, but this is dependent on the acquisition of additional data from approved experiments to evaluate effectiveness of and compliance with bicycle signals in these applications. California has included bicycle traffic signals in their state-specific MUTCD Supplement for several years, and in 2011 Oregon passed a law authorizing the use of bicycle traffic signals in that state.

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