CITY OF WILLARD, MO

ACTIVE TRANSPORTATION DESIGN REFERENCE GUIDE

2026

City of Willard MISSOURI

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DESIGN GUIDELINES OVERVIEW

Active transportation infrastructure can take various forms, including bicycle lanes, shared-use paths, sidewalks, trails, and greenways. The core objective of this guidance is to offer the City of Willard residents a transportation network that is safe, well-connected, accessible, comfortable, and convenient. To achieve this, the guidance emphasizes the importance of implementing quality designs that work in harmony with other plans, policies, and standards set by the City of Willard. This guidance document focuses on three specific types of facilities. They are shared-use facilities and separated bicycle and pedestrian facilities. This document acknowledges that each active transportation project may have unique aspects, necessitating design adjustments or deviations from the standard guidelines. Therefore, it advocates for the application of context-sensitive solutions and professional engineering judgment in such cases. This design guidance establishes high expectations for the design and construction of active transportation infrastructure. These guidelines represent a compilation of recommendations from various state and national resources and are not intended to be a replacement for these documents. This document is a “quick reference guide” which is not intended to be an exhaustive list of all design considerations and details, and guidance shall not be considered a legal standard. Designers and the city should always consult the manuals and guidance outlined in the publications listed herein when finalizing and applying designs for any project.

Willard currently uses the Ozark Transportation Organization (OTO) design standards for their street design. Some of these design standards accommodate sidewalks and bike lanes, but there are no standards for shared-use paths, sidepaths, or bicycle boulevards. Guidance for these facilities in Willard is provided in this document along with additional guidance for sidewalks. These standard recommendations are found on pages 12-13, 37-38, and 54.

The design guidance summations included in these guidelines are included in color-coded boxes. These summations do not constitute the full guidance of any particularly-referenced publication. For more guidance, we recommend obtaining the full volumes of the reference for use in your planning process. [1]

These design guidelines were developed using research and guidance provided by multiple state and national sources including, but not limited to, the Federal Highway Administration (FHWA), the American Association of State Highway and Transportation Officials (AASHTO), and the National Association of City Transportation Officials (NACTO). The collective work and publications developed by these respected entities are cited throughout the design guidelines. The publications cited in this document may vary in their recommendations regarding minimum design standards.

The following publications have been utilized in the development of these guidelines:

- AASHTO-Guide for the Development of Bicycle Facilities (2024)
- AASHTO-Guide for the Planning, Design, and Operations of Pedestrian Facilities (2021)
- FHWA-Small Town and Rural Multimodal Networks (2016)
- FHWA-Bikeway Selection Guide (2019)
- FHWA-Traffic Calming ePrimer
- FHWA-Separated Bike Lane Planning and Design Guide (2015)
- Manual on Uniform Traffic Control Devices for Streets and Highways (MUTCD)- 11th edition (2023)
- Minnesota Department of Transportation-Bicycle Facility Design Manual (2020)
- NACTO-Urban Bikeway Design Guide (2025)
- NACTO-Urban Street Design Guide (2013)

[1] Publications cited in this document may be referenced or purchased at the following sites:

American Association of State Highway and Transportation Officials (AASHTO). "Guide for the Development of Bicycle Facilities." (2024): https://aashtojournal.transportation.org/aashto-releases-5th-edition-of-comprehensive-bicycle-guide/.

American Association of State Highway and Transportation Officials (AASHTO). "Guide for the Planning, Design, and Operations of Pedestrian Facilities, 2nd ed." (2021): https://store.transportation.org/Item/PublicationDetail?ID=4651.

Federal Highway Administration (FHWA). "Bikeway Selection Guide." (2019): https://highways.dot.gov/safety/pedestrian-bicyclist/bikeway-selection-guide.

Federal Highway Administration (FHWA). "Manual on Uniform Traffic Control Devices for Streets and Highway (MUTCHD) 11th Edition." (2023): https://mutcd.fhwa.dot.gov/kno_11th_Edition.htm.

Federal Highway Administration (FHWA). "Small Town and Rural Multimodal Networks." (2016): https://www.transportation.gov/grants/dot-navigator/small-town-and-rural-multimodal-networks.

Federal Highway Administration (FHWA). "Separated Bike Lane Planning and Design Guide." (2015): https://highways.dot.gov/safety/pedestrian-bicyclist/safety-tools/pg-69-71-separated-bike-lane-planning-and-design-guide.

Federal Highway Administration (FHWA). "Traffic Calming ePrimer." (2026): https://highways.dot.gov/safety/speed-management/traffic-calming-eprimer

Minnesota Department of Transportation (MnDOT). "Bicycle Facility Design Manual." (2024): https://www.dot.state.mn.us/bike/bicycle-facility-design-manual.html.

National Association of City Transportation Officials (NACTO). "Urban Street Design Guide." (2013): https://nacto.org/publication/urban-street-design-guide/.

National Association of City Transportation Officials (NACTO). "Urban Bikeway Design Guide." (2025): https://nacto.org/publication/urban-bikeway-design-guide/.

DESIGNING FOR VULNERABLE ROAD USERS

Section 11122(a)(2) states the definition of vulnerable road user is provided in 23 U.S. Code (U.S.C.) 148(a)(15), as follows:

"A nonmotorist-
a. with a fatality analysis reporting system [FARS] person attribute code that is included in the definition of the term "number of non-motorized fatalities" in section 490.205 of title 23, Code of Federal Regulations (or successor regulations); or

b. described in the term "number of non-motorized serious injuries" in that section.

This definition includes people walking, bicycling, using mobility aids (such as wheelchairs), or using most micromobility devices (whether motorized or not), but does not include motorcyclists. Throughout this plan, the phrase "people walking, biking, or rolling" is used to generally refer to vulnerable road users."

SHARED-USE FACILITIES

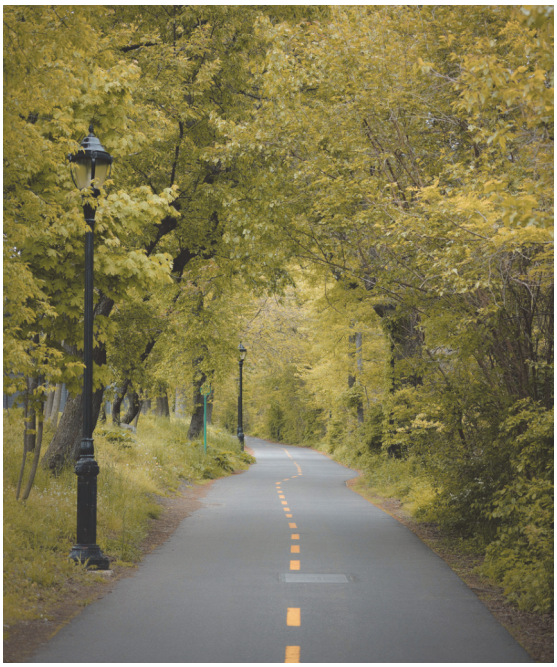
Shared-use facilities allow for and accommodate different types of users and are focused on creating safe and comfortable connections for bicycle riders, pedestrians, and people using mobility devices such as wheelchairs and electric mobility scooters. The design guidelines focus on the following types of shared-use facilities:

1 Shared-Use Paved Paths

Shared-use paved paths are pathways dedicated to pedestrians and bicycle riders, separated from motor vehicles and roadways, and often found in parklands accommodating both pedestrians and cyclists.

2 Sidepaths

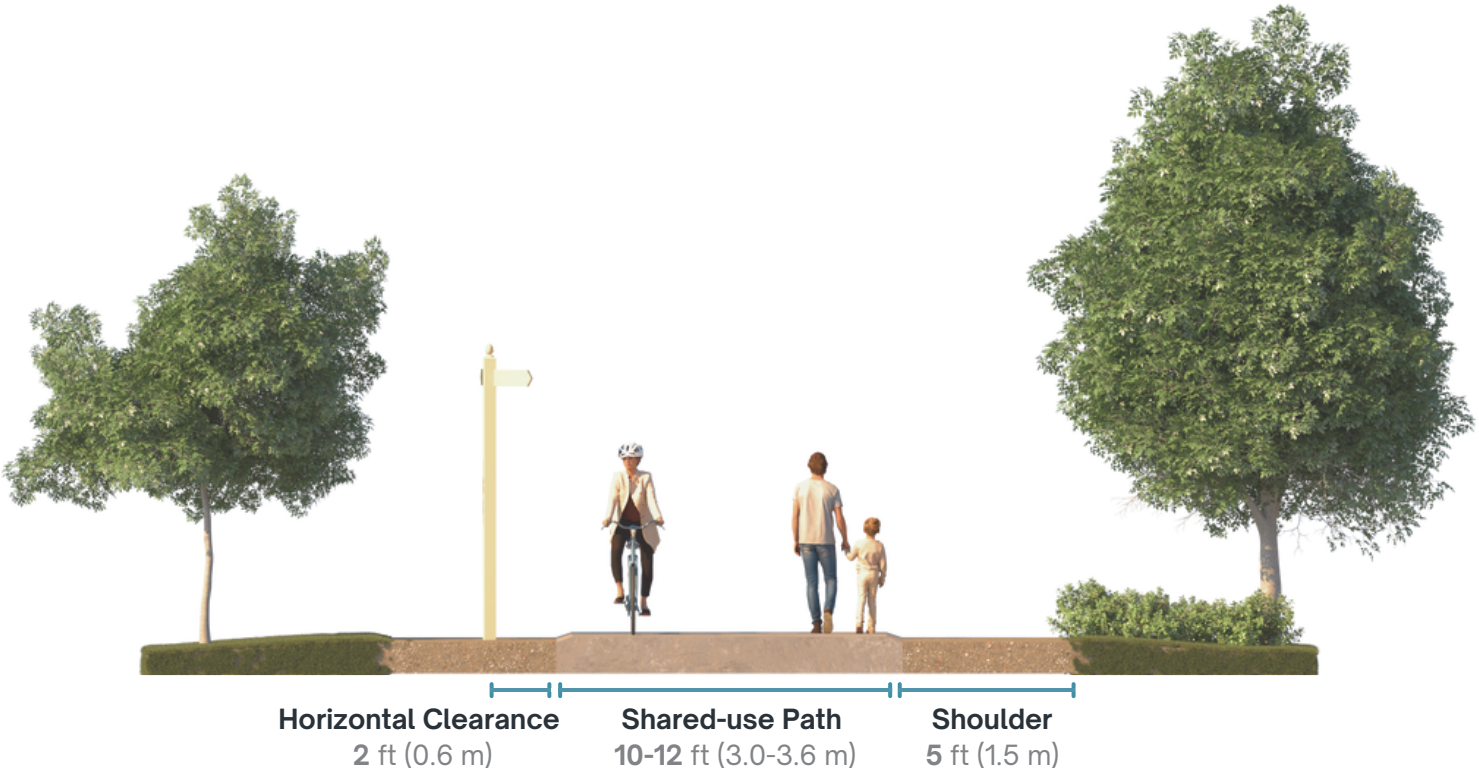
Sidepaths are shared-use paved paths running parallel to a road, separated from motor vehicles by a barrier or buffer, and are for use by pedestrians and cyclists.



See pages 63-73 for design guidance for elements of pathway design and pages 75-79 for intersection and crossing design guidance specifically for pathways.

1 Shared-use Paved Paths

Shared-use paved paths can provide a travel network for non-motorized users to get to different places and make connections not along roadways. In addition to connecting different destinations, off-road shared-use paved paths can provide access to natural areas or for recreation.

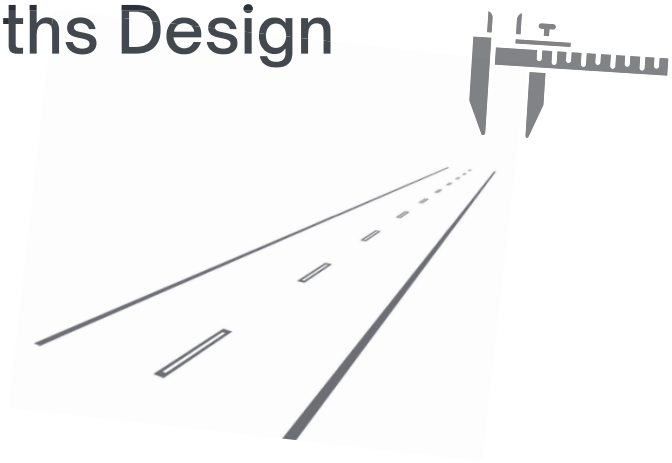


Typical Applications

- In natural areas and parks
- Shortcuts between cities or neighborhoods
- For recreation and transportation
- Surfaces can be concrete, asphalt, or other hard surfaces

Shared-Use Paved Paths Design

greenways/trails/paths



DESIGN GUIDANCE

AASHTO

GBF 6

Facility Widths

- A 10 ft wide path is the general minimum path width for two-directional shared use paths (6.4.3)
- An 11 ft width is the recommended minimum width to safely allow users to travel side-by-side (to allow for socializing when walking) and provide space for traffic traveling the opposite direction (6.4.3).
- FHWA provides the *Shared Use Path Level of Service Calculator* (SUP LOS), which can be used when determining appropriate widths (6.4.2).
- Paths less than the recommended width (8 ft minimum) should only be considered for low-traffic situations or short lengths where required because of physical constraints (6.4.3).
- Wider paths (over 12 ft) are useful:
  - to accommodate maintenance vehicles
  - on steep grades to allow for comfortable passing
  - through curves to provide more operating space
  - in heavy use situations with high concentrations of different user types
  - on regionally significant corridors (6.4.3).

Other Recommendations

- A 5 ft shoulder (2 ft minimum for short distances) should be maintained on each side of the path and kept clear of obstructions. Signs and vertical elements should be at least 2' from the path (6.6.1).

NACTO

UBDG 3.4

- Recommended width is between 11 ft (8 ft minimum) for low bicycle volume and 20 ft (15 ft minimum) for high bicycle volume. Minimum widths should only be used intermittently in constrained conditions along the path.
- The area alongside the path should be flush with the path and a lateral clearance of 2 ft (1 ft minimum when constrained) should be provided that is clear of obstructions.
- Separation of users improves safety and comfort when there is a high volume of pedestrians or bicycles and/or when the path is a main transportation corridor for bicycles.
- Highlight path crossings and prioritize the safe travel of path user over motorists.
- Striping (centerline and edge) and symbols on the pathway are optional
- Lighting is needed on all paths.

MUTCD

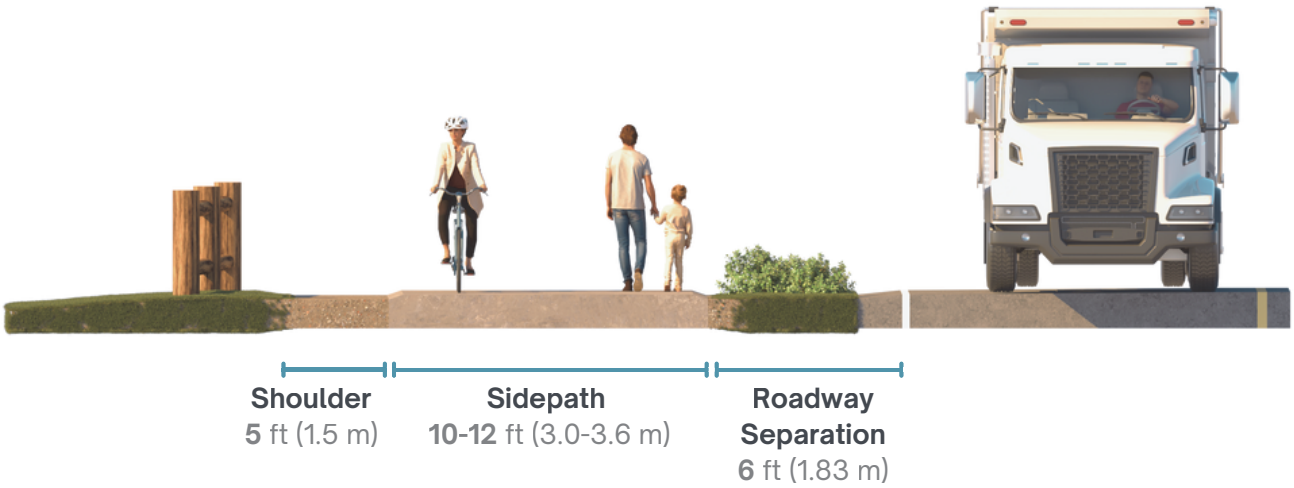
9E.13

- A solid center line may be used to separate two directions of travel where passing to the left of the line is not permitted

2 Sidepaths

Shared-use paved paths along roadways are often referred to as sidepaths. They are used by non-motorized users (bicyclists, pedestrians, joggers, wheelchairs, etc.) and provide a physically separated travel area from motorized traffic. The increased separation between motorized and non-motorized traffic provides a more comfortable experience for a wider variety of users. In areas of high speed and high traffic volume, increasing the space between the roadway and the sidepath is recommended to maintain a high comfort level for users. Crosswalk enhancements are also recommended with increased speed and traffic volume.

Another consideration in using sidepaths is reducing the risk of collisions, especially at intersections and driveways. This can be done by reducing the number of driveways, encouraging low-speed approaches at crossings, maintaining visibility to all users, and designing to increase awareness of all users. These designs may include elements like small roadway turning radii, using crosswalk markings through the pathway's crossing, raised crossings, and stop or yield markings on the roadway to discourage encroachment.



Typical Applications

- Total traffic lanes - 3 or more
- Along high-volume or high-speed roadways where increased separation is desired
- Where there is room in the right-of-way to accommodate
- Where volumes of pedestrians and bicyclists are relatively low
- Fill gaps in the network between other low-stress routes

Sidepath Design

DESIGN GUIDANCE

AASHTO

GBF 6 & 7

Facility Widths

- A 10 ft wide path is the general minimum path width for two-directional shared use paths (6.4.3)
- An 11 ft width is the recommended minimum width to safely allow users to travel side-by-side (to allow for socializing when walking) and provide space for traffic traveling the opposite direction (6.4.3).
- FHWA provides the *Shared Use Path Level of Service Calculator* (SUP LOS), which can be used when determining appropriate widths (6.4.2).
- Paths less than the recommended width (8 ft minimum) should only be considered for low-traffic situations or short lengths where required because of physical constraints (6.4.3).
- Wider paths (over 12 ft) are useful:
  - to accommodate maintenance vehicles
  - on steep grades to allow for comfortable passing
  - through curves to provide more operating space
  - in heavy use situations with high concentrations of different user types
  - on regionally significant corridors (6.4.3).

Other Recommendations

- A 5 ft shoulder (2 ft minimum for short distances) should be maintained on each side of the path and kept clear of obstructions. Signs and vertical elements should be at least 2' from the path (6.6.1).
- Pedestrians and bicyclists may be separated to improve comfort and safety (6.4.4)
- The recommended width of the street buffer is at least 6 ft measured from the white edge line or curb when no edge line is provided to the side path. Wider buffers are recommended when speeds are 35 mph or more or when approaching intersections or driveways. Vertical elements can be considered when the desired street buffer width is not available (7.4.1)

NACTO

UBDG 3.4

- Recommended width is between 11 ft (8 ft minimum) for low bicycle volume and 20 ft (15 ft minimum) for high bicycle volume. Minimum widths should only be used intermittently in constrained conditions along the path.
- The area alongside the path should be flush with the path and a lateral clearance of 2 ft (1 ft minimum when constrained) should be provided that is clear of obstructions.
- Separation of users improves safety and comfort when there is a high volume of pedestrians or bicycles and/or when the path is a main transportation corridor for bicycles.
- Highlight path crossings and prioritize the safe travel of path user over motorists.
- Striping (centerline and edge) and symbols on the pathway are optional
- Lighting is needed on all paths.

MUTCD

9E.13

- A solid center line may be used to separate two directions of travel where passing to the left of the line is not permitted

Laneshift Design Note:
When in public right-of-way and functioning as a sidewalk, sidepaths should be designed in accordance with PROWAG. Although the maximum slope of a shared-use path should be 5%, the grade should also generally match the grade of the adjacent roadway. When the roadway grade exceeds 5%, the shared-use path may match or be less than the roadway grade.

Shared-Use Facilities

Recommendations for Willard

1 Shared-Use Paved Paths

Shared-use paved paths can be located along roadways or in properties that are not adjacent to a street. These standards are for paved paths that are not adjacent to a roadway, but may cross roadways as needed.

Feature	Standard	Considerations
Width	12 feet Minimum	-
Location	In locations that are not inside the street right of way	-
Crossings	Evaluate safety and comfort at crossings (mid-block and intersections)	Some measures include: • RRFB or HAWK • Curb extensions • Raised crosswalks • Pedestrian refuge islands

2 Sidepaths

The current Ozark Transportation Organization (OTO) design standards do not include sidepaths in their current roadway designs. Many of the roadways include sidewalks, which can be modified to provide a sidepath by widening at least one of the sidewalks to 12 feet wide instead of the recommended OTO design standard sidewalk width. Additional right of way may be required on streets where sidepaths are planned to allow for the additional width that sidepaths (12 feet) have compared to sidewalks (6 feet).

Feature	Standard	Considerations
Width of Sidepath	12 feet Minimum	Additional ROW may be required to accommodate a 12' sidepath instead of a standard sidewalk.
Buffer width between roadway and sidepath	6 feet Minimum	The current OTO standard already provides a vegetative buffer between the roadway and the sidewalk, but doesn't specify the width. Additional width should be considered on high-speed roadways (over 35 MPH).
Location	Minimum of one side of the street	A sidepath should be on at least one side of the street. The Active Transportation Network Plan can be referenced to determine which side of the street has been recommended for sidepaths.
Crossings	Evaluate safety and comfort at crossings (mid-block and intersections)	Some measures include: • RRFB or HAWK • Curb extensions • Raised crosswalks • Pedestrian refuge islands

BICYCLE FACILITIES

Well-designed bicycle facilities not only encourage more cycling but also help individuals operate their bikes legally and predictably. This design guidance focuses on the following bicycle facilities, as outlined below:

1 Physically Separated Facilities

Separated Bike Lanes:
Separated bike lanes have horizontal and vertical separation from motor vehicles, distinct from pedestrian areas, enabling one-way or two-way travel.

2 Visually Separated Facilities

Conventional Bike Lanes:
Bike lanes designate an exclusive space for bicyclists through the use of pavement markings and signage. The bike lane is located adjacent to motor vehicle travel lanes and flows in the same direction as motor vehicle traffic. Bike lanes are typically on the right side of the street, between the adjacent travel lane and curb, road edge, or parking lane.

Buffered Bike Lanes:
Buffered bike lanes are conventional bicycle lanes paired with a designated buffer space separating the bicycle lane from the adjacent motor vehicle travel lane and/or parking lane.

Paved Shoulders:
Paved shoulders refer to extra pavement wide enough for bicycle use, located outside the travel lane and separated from motor vehicles by the roadway's edge line.

3 Mixed Traffic Facilities

Shared roadways are present in various settings, allowing cyclists to ride legally, including local neighborhood streets, urban streets, and suburban and rural highways. These roadways offer cyclists minimal to no physical separation from motor vehicles and are best suited for low-volume, low-speed roads. Shared roadways form the basis for many bicycle boulevards, but function as designated bicycle facilities only when properly designed.

Bicycle Boulevards:
Bicycle boulevards are streets with low motorized traffic volumes and speeds, designated and designed to prioritize bicycle travel. Bicycle Boulevards use signs, pavement markings, and speed and volume management measures to discourage through trips by motor vehicles and create safe, convenient bicycle crossings of busy arterial streets.

See pages 63-73 for design guidance for elements of bike lane design and pages 80-85 for intersection and crossing design guidance specifically for bike lanes.

1 Physically Separated Facilities

Separated Bike Lane

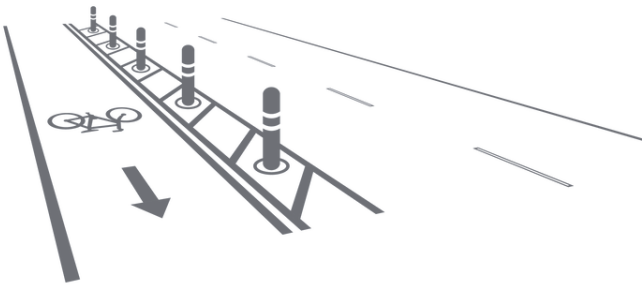
A separated bike lane (SBL) is an exclusive bike facility that combines the user experience of a separated path with the on-street infrastructure of a conventional bike lane. SBLs have different forms, but all share common elements—they provide space that is intended to be exclusively or primarily used for bicycles and are separated from motor vehicle travel lanes, parking lanes, and sidewalks. In situations where on-street parking is allowed, SBLs are located on the curbside of the parking (in contrast to bike lanes). SBLs may be one-way or two-way and may be at the street, sidewalk, or intermediate level. NACTO refers to separated bike lanes as protected bike lanes.

At sidewalk level, a curb or median separates them from motor traffic, while a buffer and/or different pavement colors/textures separate the SBL track from the sidewalk. If at street level, they can be separated from motor traffic by raised medians, on-street parking, or bollards. By separating people on bikes from motor traffic, SBL can offer a higher level of security than bike lanes and are attractive to a wider spectrum of the public.

Typical Applications

The separated bike lane zone offers a clear operating area for bicyclists. Because of the physical separation between the bike lane and the adjacent travel lanes, the design may be more sensitive to debris accumulation, maintenance access, and operating space impacts than conventional on-street bike lanes.

Separated or Protected Bike Lane Design



DESIGN GUIDANCE

AASHTO

GBF 7

Facility Widths

- The type of curb adjacent to the bike lane may require an additional shy distance, or small buffer of space, when considering lane widths (7.3.3 & 7.3.4).
- Bike lanes should be wide enough to accommodate anticipated bicycle volumes (7.3.4).
- The preferred minimum width of a one-way separated bike lane is 7.5 ft. This width allows for side-by-side riding or passing (7.3.4).
- The absolute minimum bike lane width is 5.5 ft without considering shy distance. At this width, bicyclists will not be able to pass slower users until there is a break in the facility and an opportunity to overtake (7.3.4).
- Two-way separated bike lanes should have a preferred minimum combined width of at least 11 ft, not including shy distances, to accommodate occasional passing (7.3.4). Given this total width, clear signs and markings should be provided so that the separated bike lane is not mistaken for an additional motor vehicle travel lane (7.9.6).

Additional Recommendations

- Determining on-way versus two-way operation requires analysis factors such as safety, connectivity, ease of access, available right-or-way, public feedback, curbside uses, intersection operations, feasibility, and other factors (7.2.3).
- Changes in bike lane elevation and horizontal alignment should be smooth and infrequent (7.2)
- The recommended width of a street buffer for separated bike lanes is at least 6 ft measured from the white edge line (7.4.1)
- Wider buffers are recommended on multilane roads with speeds greater than or equal to 35 mph and when approaching features such as transit or accessible on-street parking (7.4.1)
- A buffer of 4 ft minimum eliminates door zone conflicts. The buffer can be reduced to 2 ft but it will result in an overlap of door zone and bike lane (7.4.1)
- Smaller buffers can be used when vertical elements provide separation (7.4.1).
- Buffers are not needed in constrained conditions of streets with speeds 30 mph or less and flexible delineator posts on the white edge line (7.4.1)

NACTO

UBDG 3.3

Facility Widths

- Design for future volumes as the protection on this facility attract more users.
- Rideable width is the useable width of the bikeway. It doesn't include unrideable areas, gutter pans, and shy distances. It may extend into parts of the buffer that are rideable.
- Preferred rideable width of one-way protected bike lane is 8 to 12.5 ft (minimum is 6.5 to 7 ft).
- Preferred minimum rideable width of two-way protected bike lane is 13 ft (absolute min. of 8 ft).
- Consider maintenance vehicle access in determining width of the facility

Additional Recommendations

- Only recommended on street facility for All Ages & Abilities for streets with:
  - speeds of 25 mph or more
  - multiple travel lanes in each direction
  - vehicle volumes over 6,000 vehicles per day
- Include visibility zones approaching driveways and intersections and consider geometric changes to slow vehicular turns across protected bike lanes
- Bike lane symbols or work markings should be at the beginning of a bike lane, after major driveways, at intersections, and at least every 500 ft.
- Green surface treatment can be used to increase the conspicuity of bike lanes and crossings.
- Bike lane signs may be used at the start of a bike lane and can be used to supplement pavement markings along the bike lane.
- Avoid merging or mixing bike lanes and vehicular traffic at intersections.
- Two-way protected bike lanes require specific attention at intersections.
- Yellow dotted centerlines should be used along two-way bike lanes.
- Consider a modified two-way sign at T-intersections or major driveways to alert drivers to look both directions for bicycle traffic.

MUTCD

9E.07

- Buffer space shall be marked with solid longitudinal lines.
- BIKE LANE (R3-17) signs should be used to distinguish the bicycle lane

Laneshift Design Note:
A clear-through area of 10 ft (3.0 m) is beneficial for allowing snow plows and street sweepers to access the area.

1 Pedestrian Separation/Sidewalk Buffer:

Separation from pedestrians is particularly important when a separated bike lane is located immediately adjacent and is at the same level as a sidewalk.

- Design and construct separated bike lanes that are clearly distinct from the sidewalk. This is accomplished using a curb, separation buffer space (often landscaped), different pavement or other surface treatments, or detectable tactile guidance strips (AASHTO GBF 7.5). NACTO recommends the sidewalk buffer be a 2 ft area clearly not meant for pedestrians, and if that isn't available using tactile warning delineators along the sidewalk

2 Roadway Separation/Street Buffer:

The roadway separation is the vertical element between the bike lane and the adjacent roadway. The width of the separation will vary depending on the separation type. Street buffer guidance can be found in section 7.4 of AASHTO GBF and section 3.3.2 of NACTO UBDG.

- AASHTO recommends a street buffer of 6 ft wide to allow space for typical street design elements but also outlines instances that it can be wider or narrower (AASHTO GBF Section 7.4).
- A separation width of 3 ft (0.9 m) allows for various separation methods and provides space adjacent to a parking lane to accommodate door swing and passenger unloading.
- Constrained raised bike lanes can use a 1-2 ft street buffer with a 5-6 ft bike lane (NACTO UBDG 3.3).
- A minimum width roadway separation of 1 ft (0.3 m) may be possible with a mountable or vertical curb face.

Types of Roadway Separation for Separated Bike Lanes

Vertical elements are needed in the street buffer zone. They can be continuous (including poured medians or vehicle parking) intermittent (including flexible delineator posts, rigid bollards, parking stops, or planters) and provide a separation between bicycle and vehicular traffic. Buffer zones can also contain a mix of different separation types, such as flexible delineator posts in between parking stops.

Most retrofit projects use intermittent vertical elements, which can be designed to work with the existing drainage pattern of the roadway.

The type of vertical barrier used can also provide a visual cue to drivers that the roadway has a different character where they should drive more cautiously and at slower speeds.

NACTO recommends that more robust separation should be used where vehicles are more likely to enter the bike lanes, such as at intersections or on retail corridors.

Option 1: Flexible Delineator Posts/Rigid Bollards

AASHTO (GBF 7.4.2.4):

- Meet MUTCD requirements and specifications
- Require closer spacing
- For high-speed environments.

NACTO (UBDG 3.3):

- Buffer typically 2 ft wide, but minimum of 3 ft when speeds are over 25 mph.
- Space 10 to 40 ft apart, but space closer where high curbside demand or at intersections.

Option 2: Parking Stops

AASHTO (GBF 7.4.2.5):

- May need to be supplemented with flexible delineator posts to increase visibility.
- Require pavement markings to delineate the buffer zone.
- May not be appropriate for speeds over 35 mph.
- Should be secured to roadway.

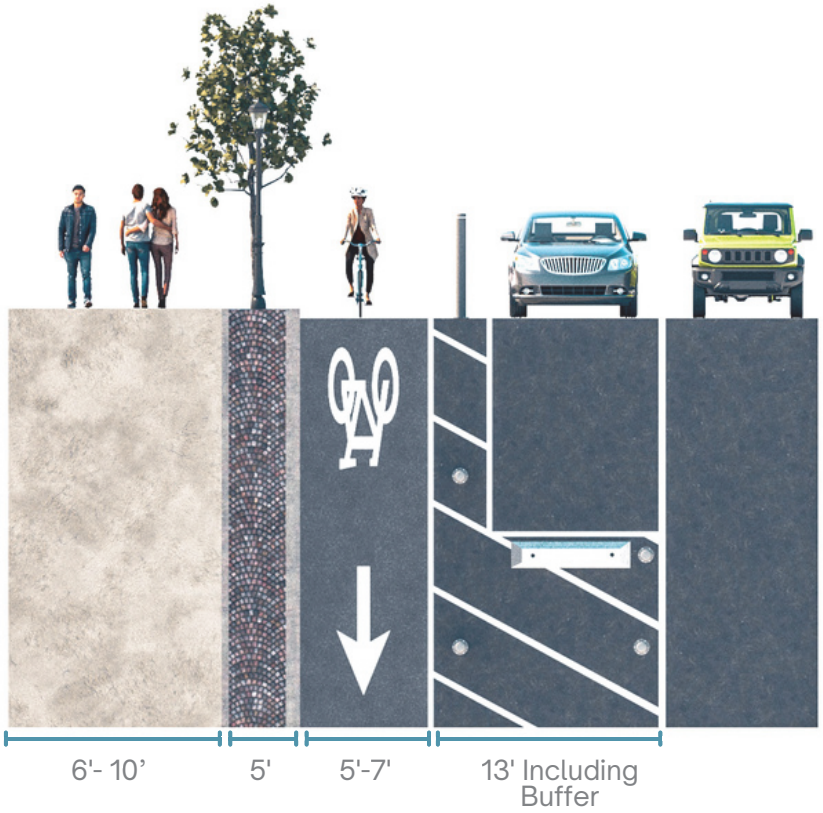
NACTO (UBDG 3.3):

- Buffer typically 2 to 3 ft wide, but minimum of 3 ft when speeds are over 25 mph.
- Spacing is typically 5 to 20 ft apart.

Option 3: Planters

AASHTO (GBF 7.4.2.6):

- Require pavement markings to delineate the buffer zone.
- Should not obstruct sight-lines.
- Can effectively reduce motorist operating speeds.



Option 4: On-Street Parking

AASHTO (GBF 7.4.2.3):

- Require pavement markings to delineate the buffer zone.
- Additional vertical element should be used where parking demand is low.
- Door zone of 4 ft (2 ft minimum) should be provided.

NACTO (UBDG 3.3):

- Buffer width should be a minimum of 3 ft to accommodate the full swing of a vehicle door.
- Vertical elements can be installed 0.5 to 1 ft from the parking line.
- Parking lanes may be reduced to 7 ft wide to allow more space for the bikeway.

Option 5: Poured/Constructed Median

NACTO (UBDG 3.3):

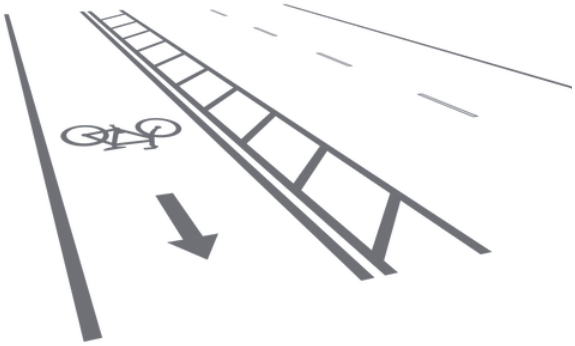
- Buffer width should be a minimum of 3 to 4 ft.
- Vertical elements or object markers should be used incorporated into the median at intersections to improve visibility.
- Need to consider drainage in the design to reduce water in the bikeway.

2 Visually Separated Facilities

Unlike physically separated facilities, visually separated facilities have no physical barrier between adjacent vehicle travel lanes and bike lanes. The paint is the delineator between bike lanes and vehicle travel lanes for visually separated facilities.

These facilities should be kept clear of debris and obstructions and should be a smooth rideable surface. Also, considerations regarding intersections, loading zones, on-street parking, and transit stops apply to these facilities as with physically separated bicycle facilities.

Buffered Bike Lane Design



Buffered bike lanes are conventional bike lanes paired with a designated buffer space separating the bicycle lane from the adjacent motor vehicle lane and/or parking lane. As per MUTCD chapter 9, buffered bike lanes are required to have the bicycle lane symbol or word and/or chevron and arrow. This defines the lane to be used solely for bicyclists. A buffer is not required between the bike lane and parking, and a solid line may be used to separate them. However, if there is additional road width, a buffer between the parking and bike lane may be considered to reduce door zone conflicts or to narrow vehicle travel lanes to encourage slower vehicle speeds. The lane markings should be dashed in areas where traffic is meant to cross the bicycle lane.

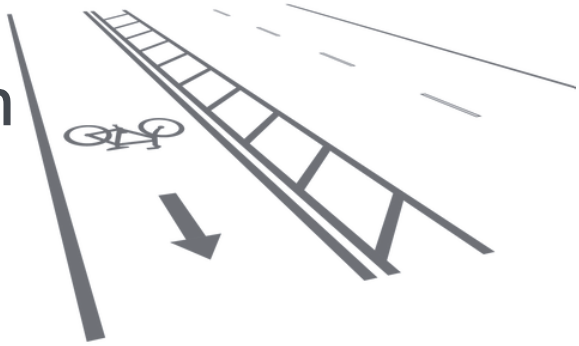
Buffered Bike Lane
without Parking

Typical Buffer Width: 3'

NACTO Buffer Minimum: 18"

MUTCD Recommendation:
If the buffer space is less than 2', NO chevron or diagonal striping may be applied. If the buffer space is 2'-3', chevron or diagonal marking SHOULD be used. If the buffer is greater than 3', then chevron or diagonal marking MUST be applied.

Buffered Bike Lane Design



DESIGN GUIDANCE

AASHTO

GBF 9

Facility Widths

- Gutters may be included in the bike lane width when the cross slope is less than 2%, they aren't narrow, they are smooth and rideable, and they don't present a crash hazard (9.4.1.2).
- Bike lane widths are measured by (9.4.1.2):
  - face of curb or edge of pavement to the center of the bike lane line.
- center of parking lane line to center of bike lane line.
- When bicycle lane widths are more than 7 ft it may look like a travel lane to motorists, so separated bike lanes or buffered bike lanes should be considered (9.4.1.3).
- Bike lane widths vary between 4 ft and 11 ft but depend on many factors. A minimum of 6.5 ft is needed for occasional passing and 8 ft or more is needed for side-by-side riding (9.4.1.3).
- Wider bike lanes and/or buffer lanes are beneficial when there are (9.4.1.3 & 9.5):
  - high traffic volumes and/or speeds
  - over 5 percent heavy vehicles
  - bike lanes adjacent to railings or barriers (require additional shy space)
  - speeds over 30 mph or 6,000 vehicles per day
  - high parking turnover

Additional Recommendations

- State laws and local ordinances vary on what motorist activity is allowed in bike lanes (9.4).
- Bike lanes are not designed to allow bicycle users to leave and enter them as needed (9.4).
- Require cleaning to keep clear of debris and should be a smooth rideable surface (9.4.1).
- Door zones for bike lanes next to bike lanes are important considerations (9.6).
- May be beneficial to use separated bike lanes at transit stops (9.7).
- Bicycle routes through intersections or driveways should be continuous and legible to all users (9.12).
- See section 9.12 for additional intersection design guidance.
- Buffers are desirable on streets with a posted speed >30 mph and >6,000 vehicles per day (9.5).

NACTO

UBDG 3.2

Facility Widths

- Preferred width is 6 to 7 ft to accommodate passing and riding side by side (4 ft minimum width).
- Bike lanes wider than 7 ft should have at least a 2 ft buffer and a protected bike lane should be considered to prevent use of the bike lane for parking or vehicular travel.
- Lanes narrower than 6 ft may not accommodate cargo bikes or larger devices.
- Two-way bike lanes should be 13 ft wide (9 ft minimum for short segments).

Additional Recommendations

- One way buffered bike lanes can be used on roadways with the following conditions:
  - vehicle speeds of less than or equal to 25 mph
  - single lane in each direction
  - less than or equal to 12,000 vehicles per day (for All Ages & Abilities: less than or equal to 6,000 vehicles per day and less than or equal to 600 vehicles in the peak hour)
  - low curbside demand
  - heavy vehicles are rare
  - lane blockages are unlikely
- Two-way buffered bike lanes can be used when streets are 25 mph or less and have 6,000 vehicles per day or less.
- Consider adding vertical elements of separation or traffic-calming measures
- Provide parking buffers of 3 ft for the door zone.
- Bike lanes along the curbside generally have 2 to 4 ft buffers between them and traffic.
- Bike lane words or markings should be used at the start of the bike lane, intersections, major driveways, and at least every 500 ft along the bike lane.
- Green surface treatments can be used the full length of the bike lane or at intersections and driveways.
- The buffer between the bike lane and vehicular traffic is marked by a solid white stripe on each side of the buffer edges. Diagonals or chevrons should be used in the buffer space if wider than 2 ft.
- Bike lane and no parking signs can be used along blocks as needed.
- Roadways should be designed in a way to limit speed (narrow lanes, raised crosswalks, medians, roundabouts, etc.)
- Avoid merging or mixing bike lanes and vehicular traffic at intersections and use dotted bike lane lines to continue them through intersections.

MUTCD

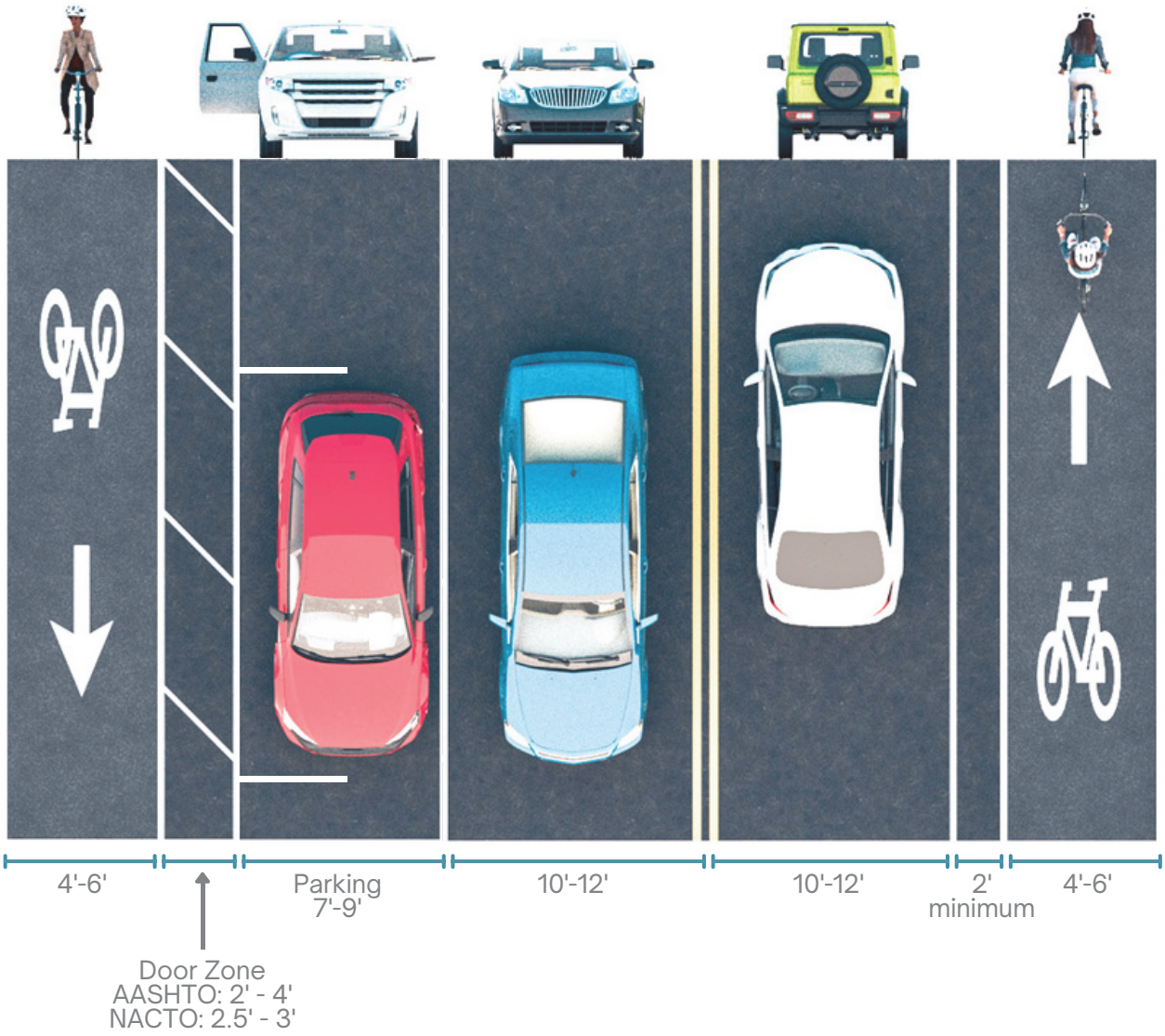
9E.06

- Buffer space shall be marked with solid white lines on both edges.

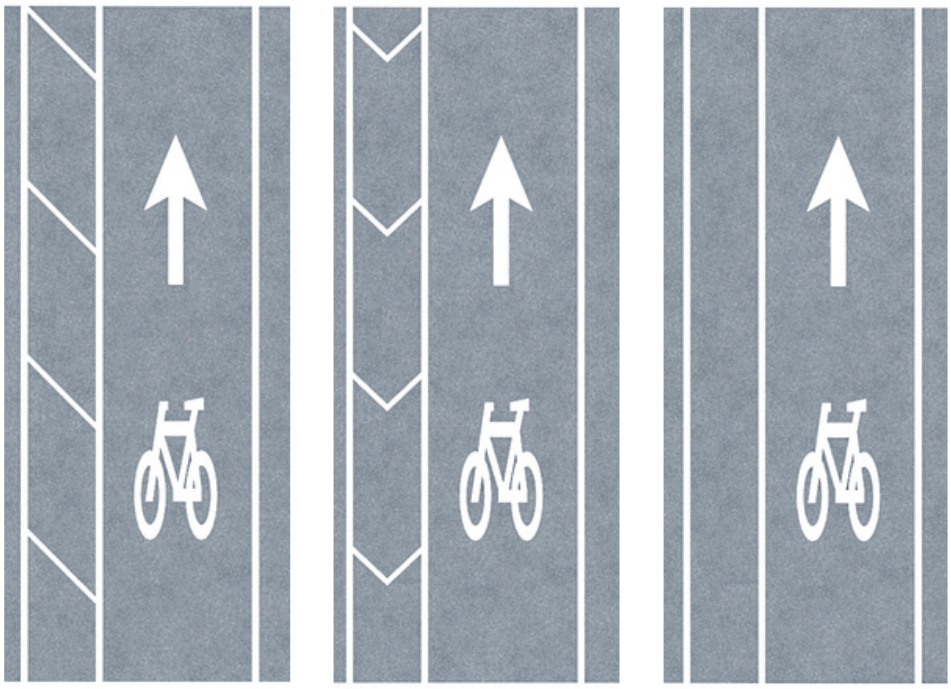
See pages 70-71 for design guidance for pavement markings for buffered bike lanes.

See page 64 for design guidance on bi-directional bikeways.

Visually Separated Bicycle Facility with Parking

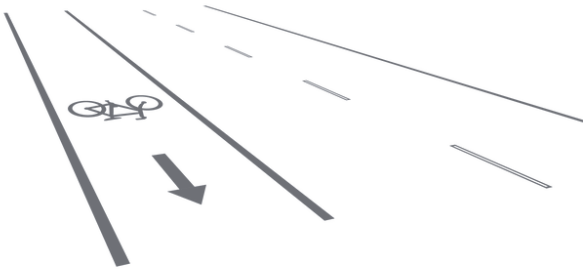


Preferred Buffer Types

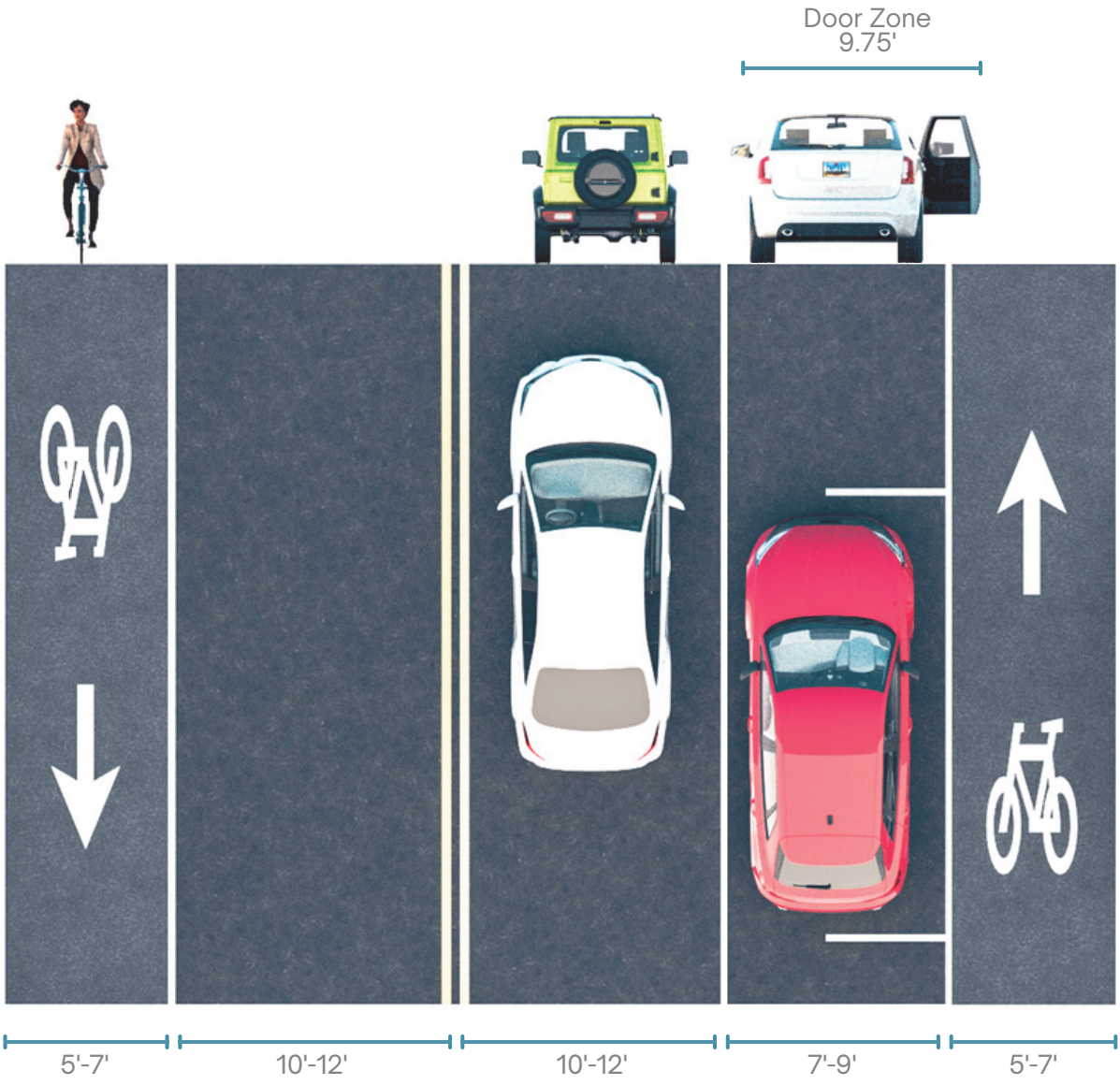


Guidance on buffer markings is provided in AASHTO GBF 9.5, NACTO UBDG 3.2.4., and MUTCD 9E.06.

Conventional/Constrained Bike Lane Design

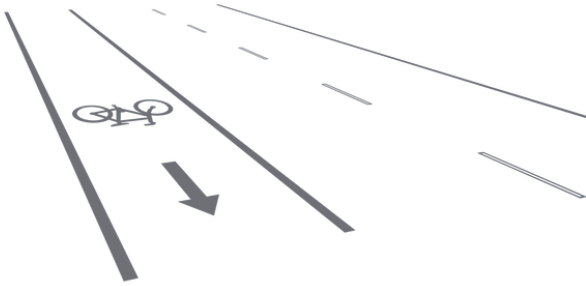


Conventional bike lanes provide an exclusive space for bicyclists on the roadway. These facilities can be located adjacent to both directions of vehicular traffic. Vehicular traffic is not allowed to travel in dedicated bike lanes unless temporarily to access parking, entering & exiting alleyways or driveways. Stopping, standing, and parking within a dedicated bike lane is prohibited.



- On streets with high traffic volume, regular truck traffic, high parking turnover, or speed limit > 30 mph, consider treatments that provide wider bike lanes or greater separation between bicycles and motor traffic.

Conventional/Constrained Bike Lane Design



DESIGN GUIDANCE

AASHTO

GBF 9

Facility Widths

- Gutters may be included in the bike lane width when the cross slope is less than 2%, they aren't narrow, they are smooth and rideable, and they don't present a crash hazard (9.4.1.2).
- Bike lane widths are measured by (9.4.1.2):
  - face of curb or edge of pavement to the center of the bike lane line.
  - center of parking lane line to center of bike lane line.
- When bicycle lane widths are more than 7 ft it may look like a travel lane to motorists, so separated bike lanes or buffered bike lanes should be considered (9.4.1.3).
- Bike lane widths vary between 4 ft and 11 ft but depend on many factors. A minimum of 6.5 ft is needed for occasional passing and 8 ft or more is needed for side-by-side riding (9.4.1.3).
- Wider bike lanes are beneficial when there are (9.4.1.3):
  - high traffic volumes and/or speeds
  - over 5 percent heavy vehicles
  - bike lanes adjacent to railings or barriers (require additional shy space)
  - speeds over 30 mph or 6,000 vehicles per day
  - high parking turnover

Additional Recommendations

- State laws and local ordinances vary on what motorist activity is allowed in bike lanes (9.4).
- Bike lanes are not designed to allow bicycle users to leave and enter them as needed (9.4).
- Require cleaning to keep clear of debris and should be a smooth rideable surface (9.4.1).
- Door zones next to bike lanes are important considerations (9.6).
- May be beneficial to use separated bike lanes at transit stops (9.7).
- Bicycle routes through intersections or driveways should be continuous and legible to all users (9.12).
- See section 9.12 for additional intersection design guidance.

NACTO

UBDG 3.2

Facility Widths

- Preferred width is 6 to 7 ft to accommodate passing and riding side by side (4 ft minimum width).
- Bike lanes wider than 7 ft should have at least a 2 ft buffer and a protected bike lane should be considered to prevent use of the bike lane for parking or vehicular travel.
- Lanes narrower than 6 ft may not accommodate cargo bikes or larger devices.
- Two-way bike lanes should be 13 ft wide (9 ft minimum for short segments).

Additional Recommendations

- One way buffered bike lanes can be used on roadways with the following conditions:
  - vehicle speeds of less than or equal to 25 mph
  - single lane in each direction
  - less than or equal to 12,000 vehicles per day (for All Ages & Abilities: less than or equal to 6,000 vehicles per day and less than or equal to 600 vehicles in the peak hour)
  - low curbside demand
  - heavy vehicles are rare
  - lane blockages are unlikely
- Two-way buffered bike lanes can be used when streets are 25 mph or less and have 6,000 vehicles per day or less.
- Consider adding vertical elements of separation or traffic-calming measures
- Provide parking buffers of 3 ft for the door zone.
- Bike lanes along the curbside generally have 2 to 4 ft buffers between them and traffic.
- Bike lane words or markings should be used at the start of the bike lane, intersections, major driveways, and at least every 500 ft along the bike lane.
- Green surface treatments can be used the full length of the bike lane or at intersections and driveways.
- The buffer between the bike lane and vehicular traffic is marked by a solid white stripe on each side of the buffer edges. Diagonals or chevrons should be used in the buffer space if wider than 2 ft.
- Bike lane and no parking signs can be used along blocks as needed.
- Roadways should be designed in a way to limit speed (narrow lanes, raised crosswalks, medians, roundabouts, etc.)
- Avoid merging or mixing bike lanes and vehicular traffic at intersections and use dotted bike lane lines to continue them through intersections.

MUTCD

9E.01

- Longitudinal pavement markings and bike lane symbols or word markings shall be used to define bike lanes.
- An established bike lane cannot also be an established shoulder.

See pages 70-71 for design guidance for pavement markings specifically for conventional bike lanes.

See page 64 for design guidance on bi-directional bikeways.

3 Mixed Traffic Facilities

Bicycle Boulevard/Shared Lanes/Shared Roadways

Bicycle boulevards are streets with low motorized traffic volumes and speeds, designated and designed to prioritize bicycle travel. Bicycle Boulevards use signs, pavement markings, and speed and volume management measures to discourage through trips by motor vehicles and create safe, convenient bicycle crossings of busy arterial streets.

Low-traffic residential streets can be designated for bicycle use. Optimal street dynamics and design elements include but are not limited to the following:

- Traffic calming measures such as speed bumps, chicanes, or roundabouts.
- Bicycle-friendly intersections with features like bike boxes and signage.
- Neighborhood connectivity to provide direct routes to key destinations.
- Grid-patterned streets are well-suited as they provide alternative routes for vehicular traffic and minimize turns.
- Regular maintenance and enforcement to ensure compliance with traffic calming measures.

Well-designed bicycle facilities and implemented traffic calming measures to maintain low vehicle volumes and speeds have the potential to create an all ages and all abilities facility for bicycle riders. These traffic calming measures also improve safety for pedestrian movement. For additional information on traffic calming measures, see the section on Traffic Calming on pages 55-60.

Bike Boulevards/Shared Lanes/ Shared Roadways

DESIGN GUIDANCE

AASHTO

GBF 8 & 9

Recommendations

- Bike boulevards are preferable on roads with volumes of < 1,000 vehicles per day (3,000 vehicles per day maximum) and at or below 15 mph (25 mph maximum) (8.2.1).
- Traffic calming and traffic management treatments are key on bicycle boulevards (8.1). According to AASHTO, three key principles define bicycle boulevards:
  - manage vehicular volumes and speeds, which may require traffic calming (methods in section 8.4) or diversion strategies (methods in section 8.5) (8.2.1)
  - prioritized right-of-way at local street crossings that minimize the need for bicyclists to stop (8.2.2)
  - safe and convenient crossings at major streets that accommodate the slowest user (methods in sections 8.6 and 8.7). Additional crossing measures may be needed in crossings where there is not a traffic signal (8.2.3)
- Wayfinding signage and shared lane markings (sharrows) may be used to identify the bicycle boulevard route. Sharrows are generally placed in the center of the travel lane (8.3.1).
- BICYCLES MAY USE FULL LANE (R4-11) signs can be used where motorists may need to wait behind bicyclists or change lanes to pass at a safe distance (8.3.1.3).
- Speeds should be posted when they are lower along bicycle boulevards than the citywide local street speed limit. Advisory speed signs should also be posted as required with traffic calming design measures (8.3.2).
- Shared roadways are more compatible with good quality pavement without hazards, good sight distances, appropriate timing for signals at intersections, and roadway design that encourages lower speeds or lower traffic volumes (9.3).
- Traffic calming measures are most effective when used every 200 ft to 400 ft (8.4).
- Wide curb lanes are not recommended as a strategy for improving passing of bicyclists (9.3.2).

NACTO

UBDG 3.2

Recommendations

- Bike boulevards are appropriate for streets with speeds of less than 20 mph (25 mph maximum), have a single lane in the same direction, have up to 2,000 vehicles per day (3,000 vehicles per day maximum and 500 vehicles per day for All Ages & Abilities), and less than 150 vehicles in the peak hour (50 vehicles in peak hour for All Ages & Abilities).
- Travel in each direction for bicycles should be allowed.
- Shared lane markings should be placed in the center of the lane. They should be within 50 ft of the approach and receiving side of all intersections as well as every 100 ft to 250 ft midblock. When the bike boulevard route changes direction in an intersection, shared lane marking can be placed close together to help bicyclists navigate turns and identify the route.
- Traffic calming should be used to improve comfort levels by managing speeds and volumes of motorists.
- Centerlines should not be used mid-block and are optional at intersections.
- Additional design treatments to organize the roadway should be considered when two-way roads have 24 ft or more of roadway travel width and one-way roads have 15 ft or more of roadway travel width.
- When the roadway is too narrow to allow vehicles to pass bicyclists, speeds should be limited to 10-20 mph.
- Wayfinding signs should be used consistently through the city and can be identified with BIKE ROUTE (D11-1) signs.
- BICYCLES ALLOWED USE OF FULL LANE (R9-20) signs may be used.
- Intersections should prioritize bicycle traffic and maximize safety through geometric changes, traffic control devices, and/or bike lane protection.
- Contraflow bike lanes should be used on one-way streets to permit bicycle travel in both directions.

MUTCD

9E.09, 9E.10

- Shared lane markings shall not have green-colored pavement applied as a background

Bicycle Facilities

Recommendations for Willard

1 & 2 Physically & Visually Separated Facilities

The Proposed Trails and Connectivity Plan does not include bike lanes, however bike lanes are listed in the OTO standards. The bike lanes identified in the OTO standards are 4' wide and do not include a buffer. If the City of Willard determines to implement bike lanes at some point in the future, wider bike lanes and and the inclusion of buffers should be considered based on the vehicle speeds and volumes of the roadways. Additionally, vertical separation should be used on roadways with higher speeds and volumes. Accommodating this additional space for wider bike lanes and buffers could require a wider roadway and/or narrower vehicular travel lanes.

3 Mixed Traffic Facilities

The current OTO standards do not include bicycle boulevards in any facility design. Bicycle boulevards are used on roadways with low traffic volumes and speeds. Collector streets and arterials often have traffic speeds and volumes that are too great for safe and comfortable bicycle boulevards. As such, they are typically incorporated into local neighborhood streets. OTO does not have a street standard for local neighborhood streets.

Feature	Standard	Considerations
Speed of vehicular traffic	Maximum of 25 MPH	Traffic calming measures can be installed as needed to reduce vehicular speeds along bicycle boulevards.
Sharrows on roadway	Placed along route in the center of the travel lane at a maximum distance of 250 feet	Sharrows can be placed in intersections to show which direction the bicycle route is traveling.
Signage	Used to designate bicycle boulevard routes	Bike route signage is especially important for bicycle riders when the route changes, such as when it turns onto another roadway.
Intersection prioritization and protection	Evaluate comfort and safety at each intersection and implement measures as needed	Some measures include: • minimized stop signs along the bike route • Curb extensions • Raised crosswalks • Bike crossing islands

PEDESTRIAN FACILITIES

See page 54 for design guidance for pedestrian facilities specific to the City of Willard.

1 Sidewalks

Sidewalks are an essential element in a community as they are often the most readily accessible and cost-effective way to connect residents to destinations within the city.

2 Pedestrian Crossings

A walkable environment includes safe and frequent crossings. We will explore some aspects that should or can be included.

Pedestrian Refuge/Crossing Islands
Pedestrian islands reduce the exposure time for pedestrians or bicyclists at intersections and can also allow users to cross one direction of traffic at a time.

Marked Crossings
High-visibility marked crossings can be utilized at intersections or other locations where pedestrian traffic is anticipated to improve yielding behavior by drivers.

Curb Ramps
Curb ramps provide accessible pedestrian access between sidewalks and the street where there is a curb face or change in elevation.

3 Pedestrian Crossing Signals:

Pedestrian crossings and signals are crucial components of urban infrastructure designed to enhance the safety and convenience for pedestrians. Signals can be utilized at intersections or mid-block to warn motorists and bring additional attention to pedestrians. Signalized intersections are used frequently in cities nationwide; however, in the design guidance, two signals will be explored in greater detail.

Rectangular Rapid Flashing Beacon
RRFBs are manually or passively activated warning beacons alerting drivers to yield.

High-Intensity Activated Crosswalk Beacon (HAWK) or Pedestrian Hybrid Beacon (PHB)
HAWKs are hybrid signals that stop traffic on high-volume roadways.

4 Additional Pedestrian Safety Countermeasures

Curb Extensions
Curb extensions are an element that can physically narrow the roadway and create safer and shorter crossings for pedestrians.

Crosswalk Visibility Enhancements
Low visibility creates an unsafe environment at crossings.

Leading Pedestrian Interval (LPI)
LPIs give pedestrians advance time to enter crossings before the signal changes for motorists.

Most modes of transportation begin and end with a walk or roll. Well-designed and strategically placed sidewalks, pedestrian crossings, and signals can increase safety and comfort for the largest user group of any active transportation network. While sidewalks, pedestrian crossings, and signals are focused on moving pedestrians safely and comfortably, they also serve bicycle riders in most cases. Missouri laws state that bicycles are permitted to ride on the sidewalk in non-business districts and are required to yield to pedestrians. In Missouri bicycles are considered vehicles and people riding a bicycle have the same rights, duties, and responsibilities as vehicle drivers. However, at shared-use path crossings motorists are expected to stop whenever a person walking, running, or bicycling is using the crossing area.

1 Sidewalks

Sidewalk Considerations

Sidewalk widths will vary based on available ROW, street widths, and adjoining uses. Sidewalk widths should be based on the anticipated use and the surrounding amenities and uses. For example, a downtown sidewalk should have a greater width than a sidewalk located along a typical residential street. High-volume sidewalks will require additional width to allow for passing in various directions compared to lower-volume sidewalks.

1 Frontage Area
The area from the front door to the right of way but can also adjoin or abut buildings, front porches, stoops, lawns, or other landscaped areas. In downtown environments, this area can include outdoor retail signage, seating, awnings, or other intrusions within the right of way.

3 Amenity Area
This area is typically between the pedestrian area and the street. It is usually occupied by streetlights, signal boxes, benches, trash receptacles, trees or other landscaping, bike racks, and various stormwater control measures. These areas can create snow storage areas from cleared streets or sidewalks.

2 Pedestrian Area
This area typically comprises a sidewalk or shared-use path. It is the portion of the right of way meant for pedestrians to travel actively. The width should be set to accommodate the volume of pedestrian activities, which should include the passing of people both alone and in groups and the use of wheelchairs, strollers, or wagons.

Pedestrian Refuge/Crossing Islands

Crossing islands provide pedestrians with a refuge when using multistage crossings. These are typically found at mid-block crossings where pedestrians must cross the street away from an intersection. These can also be found in roundabouts, right turn lanes, or even in downtown areas where the crossing is unusually long or misaligned. Crossing islands have various designs and warrant an engineered solution. As traffic speed or the number of traffic lanes that must be crossed increases, crossings feel less safe for pedestrians entering the intersection. Pedestrian islands can be used to reduce the exposure time for pedestrians or bicyclists at intersections and can also allow pedestrians to cross one direction of traffic at a time. The FHWA has published considerations for pedestrian islands. These include that they should be considered in curbed sections of multilane roadways with a significant mix of pedestrian and vehicular traffic, where traffic volumes are over 9,000 vehicles per day and travel speeds are 35 mph or greater. Other design considerations include being at least 4 feet (preferably 8 feet) in width and an adequate length to accommodate the anticipated number of pedestrians waiting for traffic gaps before crossing.

Typical Applications

- In areas where vehicle speeds and volumes make pedestrian crossings prohibitive.
- Typically applied where three lanes of traffic or more diminish pedestrians' feelings of safety and comfort.

Design Guidance

Crossing Island Requirements:

- Should be in crossings that are 50 feet or more.
- Pedestrian refuge islands should be at least 6' in width, however, 8-10' feet is preferred.
- Mid-block crossings should have a “Z” configuration that forces pedestrians to face oncoming vehicular traffic.
- Raised concrete islands or some form of vehicular barrier is required to protect anyone using the crossing island. Vegetation and aesthetic treatments can be used if it doesn’t obscure visibility.
- Where a 6-foot wide median cannot be attained, a narrower raised median is still preferable to nothing. The minimum protected width is 6 feet, based on the length of a bicycle or a person pushing a stroller. The refuge is ideally 40 feet long.

Marked Crossings

Typical Applications

Marked crossings are not always necessary at intersections on streets with low volumes and speeds. However, they should be considered near schools, transit stops, hospitals, major public buildings, and parks regardless of traffic volumes and speeds.

Judgment should be used on the applicability and design of crossings, but generally, marked crossings should be used on multi-lane roads (over 2 lanes) when speeds are higher than 20 mph or when there are high traffic volumes (such as over 3,000 ADT). It should be noted that marked crosswalks, alone, do not always achieve a high level of safety. Additional safety measures are often needed to create traffic calming and increase safety at crossings.

Design Guidance

All legs of signalized intersections should be marked unless there is a section where pedestrians are prohibited from crossing.
Crossings should be placed to accommodate pedestrian desire lines. They should be at intersections but may be needed mid-block in high-traffic areas to encourage crosswalk use.
Markings should be highly visible.

Curb Ramps

Curb ramps are required anywhere the pedestrian travel-way crosses a vehicular or rail travel-way. This is enforced by Federal, State, and Local laws that protect pedestrians, bicyclists, and individuals with mobility disabilities. Curb ramps come in various sizes and shapes based on roadway design, grades, and drainage. At a minimum, curb ramp landings are typically 5 feet by 5 feet, with a max cross slope in all directions of 2%. Ramp and landing widths should reflect the width of the sidewalk. Flares along the ramp are required when the surfaces adjacent to the ramp are traversable. A barrier curb is usually used when adjacent to landscape or other amenities that make the space un-walkable.

Design Guidance

Ramp Requirements:

- Max slope – 1 : 12 or 8.33%
- Max slope of side flares – 1 : 10 or 10%
- Max cross slope – 2%
- Truncated domes are required at all curb ramps. This is to alert those with visual impairments that they are coming up to the street edge.
- Avoid using radial curb ramps as this could cause an individual with visual impairments to navigate the street outside of the painted crosswalk.

3 Pedestrian Crossing Signals

There are several types of pedestrian crossing signals. The most familiar and common are located at signalized intersections. Two additional signals, RRFBs, and HAWKs, are also used at pedestrian crossings. Pedestrian Signals are typically located at signalized intersections and allow time for pedestrians to cross the street safely and in the direction of normal traffic flow. Signals can also be used to cross islands. The issue with signals is that some individuals will cross against the direction of the signal, which can cause crashes or disrupt normal traffic flow, which can cause vehicles to rear-end another vehicle. Signal guidance and requirements are found in the MUTCD 11th Edition Chapter 4I.

Typical Requirements

- A signal must be timed to allow sufficient time for crossing the street
- Signals must have an audible sound to notify those with visual impairments that it is safe to cross
- Delay left turn movements to allow pedestrians to clear the crossing
- Adequate signage is needed to inform pedestrians how to use the signal
- Signal timing is typically 3.5 feet per second as a measurement of travel time

Types of Pedestrian Signal Activation:

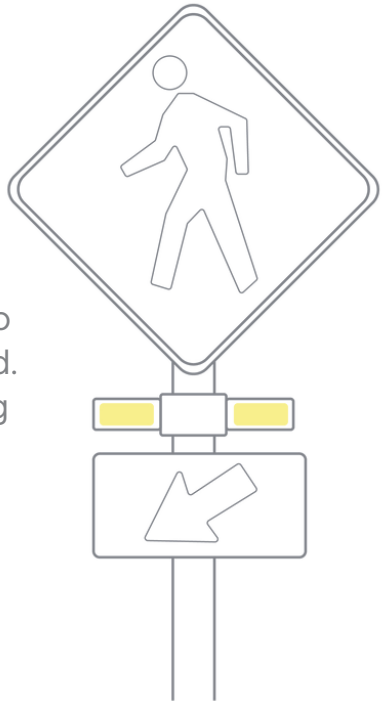
Option 1: Pedestrian Light Controlled

These crossings are controlled by pedestrian-operated signals. Pedestrians press a button to activate the traffic light, stopping vehicles and allowing pedestrians to cross. They are common in urban areas with significant pedestrian activity.

Option 2: Pedestrian User-Friendly Intelligent

These crossings use sensors to detect when pedestrians are waiting and when they have finished crossing. The lights adjust accordingly to ensure safe crossing times. They are typically found in urban areas, it is designed to be more responsive to pedestrian needs than pedestrian-actuated crossings.

Rectangular Rapid Flashing Beacon (RRFB)



RRFBs are warning beacons that can be installed at a crossing to alert drivers that a crosswalk is in use and that they need to yield. They are used in combination with the standard crossing warning signs and markings and can be used at mid-block crossings or intersections where a signal is not warranted. RRFBs can be activated manually or passively through detection.

Typical Applications

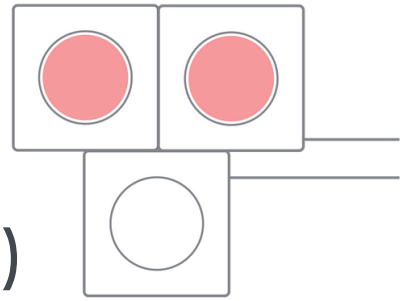
- Crosswalk visibility enhancements
- Pedestrian refuge island
- Advance STOP or YIELD markings and signs

Design Guidance

- Install RRFBs in the median rather than the far-side of the roadway if there is a pedestrian refuge or other type of median.
- Use solar-powered panels to eliminate the need for a power source.
- Reserve the use of RRFBs for locations with significant pedestrian safety issues, as over-use of RRFB treatments may diminish their effectiveness.
- A detailed study of actuation is recommended to provide a context-sensitive solution and avoid false signals, which could diminish effectiveness.
- See MUTCD 11th Edition Chapter 4L and Section 5.11.7 of AASHTO GBF for additional design requirements.

RRFB with Median and Pedestrian Refuge Island

High-Intensity Activated Crosswalk Beacon (HAWK) or Pedestrian Hybrid Beacon (PHB)



High-Intensity Activated Crosswalk Beacon (HAWK) is a hybrid signal that allows pedestrians and bicyclists to stop traffic from crossing high-volume roadways. This type of signal is usually located along long stretches of roadway where intersecting roads don't warrant a signal. The MUTCD recommends a minimum volume of pedestrians and bicyclists an hour for major arterial crossings or volumes exceeding 2,000 vehicles per hour. This type of crossing should be added for all crossings where other crossing controls have proven inadequate. Push button actuators should be placed conveniently for all users and abide by other ADA standards. Passive signal activations such as cameras, pavement loops/pucks, and infrared sensors may also be considered. See MUTCD 11th Edition Chapter 4J and Section 10.7 of AASHTO GBF for additional design requirements.

Typical Applications

- In general, HAWKs are used where it is difficult for pedestrians to cross a roadway, such as when gaps in traffic are insufficient or speed limits exceed 35 miles per hour.
- They are very effective at locations where three or more lanes will be crossed, or traffic volumes are above 9,000 annual average daily traffic.
- Installation of a HAWK must also include a marked crosswalk and pedestrian countdown signal.
- If a community is not already familiar with HAWKs, agencies should conduct appropriate education and outreach as part of implementation.

HAWK Crossing

Curb Extensions

Curb extensions narrow the roadway both visually and physically. They improve pedestrian visibility by aligning them with parking lanes and also create shorter and safer crossings for pedestrians. The narrowing of the roadway and decrease in the curb radii also encourages slower turning speeds.

Typical Applications

- In neighborhoods or low-speed streets where there are high numbers of pedestrians, and slower vehicle speeds are desired.
- Where on-street parking is present to increase pedestrian visibility.

Design Guidance

- Where curb extensions create drainage impacts, they can be designed as islands with a small 1 to 2-foot gap between the curbs or use a trench drain.
- Curb extensions should be at least as long as the width of the crosswalk.

Crosswalk Visibility Enhancements

Poor lighting conditions, obstructions such as parked cars, and horizontal or vertical roadway curvature can reduce visibility at crosswalks, contributing to safety issues. For multilane roadway crossings where vehicle volumes are in excess of 10,000 Average Annual Daily Traffic (AADT), a marked crosswalk alone is typically not sufficient. Under such conditions, more substantial crossing improvements could prevent an increase in pedestrian crash potential. According to FHWA, the following enhancements can be made to improve crosswalk visibility.

High-Visibility Crosswalks:

UP TO **40**% REDUCTION IN **PEDESTRIAN** CRASHES

High-visibility crosswalks use patterns (i.e., bar pairs, continental, ladder) that are visible to both the driver and pedestrian from farther away compared to traditional transverse line crosswalks. They should be considered at all midblock pedestrian crossings and uncontrolled intersections. Agencies should use materials such as inlay or thermoplastic tape instead of paint or brick for highly reflective crosswalk markings.

Improved Lighting:

UP TO **42**% REDUCTION IN **PEDESTRIAN** CRASHES

Crosswalk lighting should aim to illuminate with positive contrast to make it easier for a driver to identify the pedestrian visually. This involves carefully placing the luminaires in forward locations to avoid a silhouette effect of the pedestrian.

Enhanced Signing and Pavement Markings:

UP TO **25**% REDUCTION IN **PEDESTRIAN** CRASHES

On multilane roadways, agencies can use “YIELD HERE TO PEDESTRIANS” or “STOP HERE FOR PEDESTIANS” signs 20 to 50 feet in advance of a marked crosswalk to indicate where a driver should stop or yield to pedestrians, depending on State law. To supplement the signing, agencies can also install a STOP or YIELD bar (commonly referred to as ”shark’s teeth”) pavement markings.
In-street signings, such as ”STOP Here for Pedestrians“ or ”YIELD Here to Pedestrians, “ may be appropriate on roads with two- or three-lane roads where speed limits are 30 miles per hour or less.

Sources:
1. The Relative Effectiveness of Pedestrian Safety Countermeasures at Urban Intersections - Lessons from a New York City Experience (2012)
2. Handbook of Road Safety Measures (2004)
3. Development of Crash Modification Factors for Uncontrolled Pedestrian Crossing Treatments, FHWA (2017).

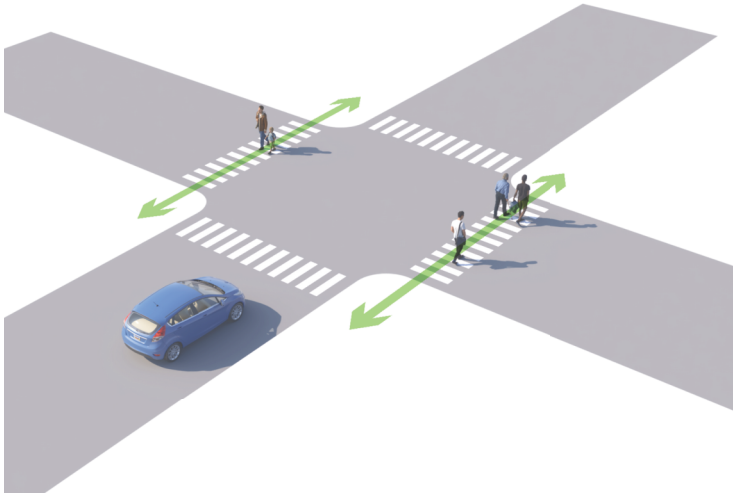
Leading Pedestrian Intervals

A leading pedestrian interval (LPI) allows pedestrians to enter the crosswalk at an intersection 3 to 7 seconds before vehicles are given a green indication. Pedestrians can better establish their presence in the crosswalk before vehicles have priority to turn right or left.

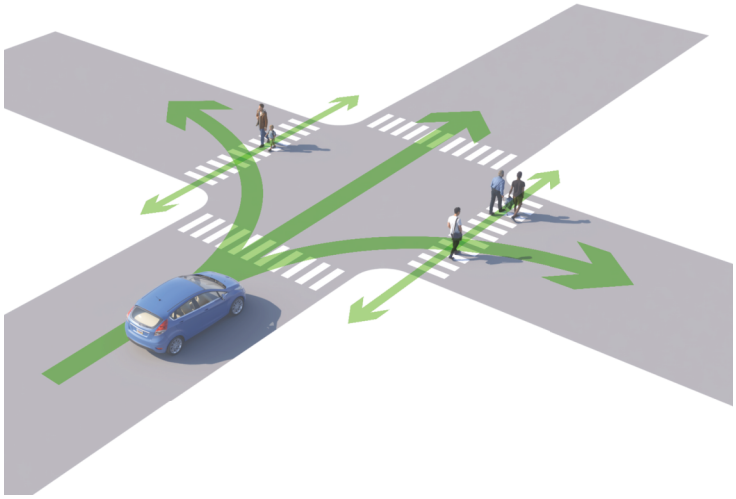
UP TO **13%** REDUCTION IN **PEDESTRIAN** CRASHES AT INTERSECTIONS

LPIs provide the following benefits:

- Increased visibility of crossing pedestrians.
- Reduced conflicts between pedestrians and vehicles.
- Increased likelihood of motorists yielding to pedestrians.
- Enhanced safety for pedestrians who may be slower to start into the intersection.



Phase 1 (First 3-7 seconds):
Pedestrians are given a minimum 3 to 7 second head start entering the intersection. This is the pedestrian-only phase.



Phase 2 (After 3-7 seconds):
Through and turning traffic is given the green light. Turning traffic yields to pedestrians already in the crosswalk.

Sources
1. Manual on Uniform Traffic Control Devices, Section 4I.06. FHWA (2023).
2. Safety Evaluation of Protected Left-Turn Phasing and Leading Pedestrian Intervals on Pedestrian Safety, FHWA (2018)

Pedestrian Facilities

Recommendations for Willard

1 Sidewalks

The current OTO standards include sidewalks in most facility designs. Sidewalks should also be included on all local streets.

Feature	Standard	Considerations
Width of sidewalk	6 feet Minimum	The current OTO standard gives a range of minimum sidewalk widths. The recommendation of this design guidance is to use a 6' minimum sidewalk width.
Buffer width between roadway and sidewalk	6 feet Minimum	The current OTO standard already provides a vegetative buffer between the roadway and the sidewalk but doesn't specify the width. Additional width should be considered on high-speed roadways (over 35 MPH).
Location	Both sides of the street or on one side of the street when a sidepath is on the other side of the street	-
Crossings	Evaluate safety and comfort at crossings (mid-block and intersections)	Some measures include: • RRFB or HAWK • Curb extensions • Raised crosswalks • Pedestrian refuge islands

TRAFFIC CALMING

1. Vertical Treatments
2. Horizontal Treatments
3. Routing Restriction
4. Travel Lane Width Reduction

According to FHWA and Institute of Transportation Engineers (ITE), “The primary purpose of traffic calming is to support the livability and vitality of residential and commercial areas through improvements in non-motorist safety, mobility, and comfort. These objectives are typically achieved by reducing vehicle speeds or volumes on a single street or a street network. Traffic calming measures consist of horizontal, vertical, lane narrowing, roadside, and other features that use self-enforcing physical or psycho-perception means to produce desired effects.”

Traffic calming measures are used to alter driver behavior in a way that improves safety for all users, and often focuses on improving conditions for non-motorized street users. These measures not only increase safety by reducing vehicle speed and/or volume, but they can create a sense of place for communities.

1 Vertical Traffic Calming Treatments

Vertical treatments force drivers to slow down by creating a change in the height of the roadway. Extensive planning, design, and public outreach are needed prior to traffic calming elements being placed on the street. Designers should strive to design context-sensitive and appropriate solutions. Examples of vertical treatments include:

- Speed Hump
- Speed Cushion
- Speed Table
- Offset Speed Table
- Raised Crosswalk
- Raised Intersection

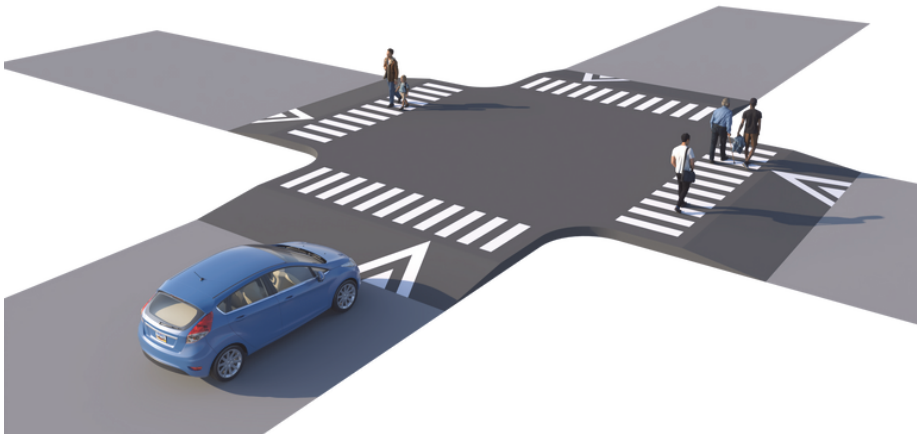
Typical Applications

Vertical speed control elements should be applied where the roadway's target speed cannot be achieved through the use of conventional traffic calming elements, such as medians, narrower roadways or lanes, curb extensions, enforcement, or lower speed limits.

Design Guidance

- Unless otherwise desired, vertical traffic calming should reduce a street's target speed to 20 mph or less (AASHTO GBF 8.4.3).
- Implementation may be carried out on a trial basis to gauge residents' support before finalizing the design. Temporary speed humps, tables, and cushions should be used with caution as they can diminish residents' opinions due to unappealing design and reduced functionality.
- Should allow bicycle riders and vehicle drivers to navigate with minimal discomfort at intended speeds and should be visible and marked when necessary.
- Additional guidance is found in Section 8.4.3 of AASHTO GBF and Section 3.1.2 of NACTO UBDG.

Raised Intersection



2 Horizontal Traffic Calming Treatments

Horizontal treatments create a horizontal shift or deflection in the roadway for drivers to navigate. This shift requires drivers to reduce their speed from what it would be if they were driving in a straight path. Extensive planning, design, and public outreach are needed before traffic calming elements are placed on the street. Designers should strive to design context-sensitive and appropriate solutions. Examples of horizontal treatment include:

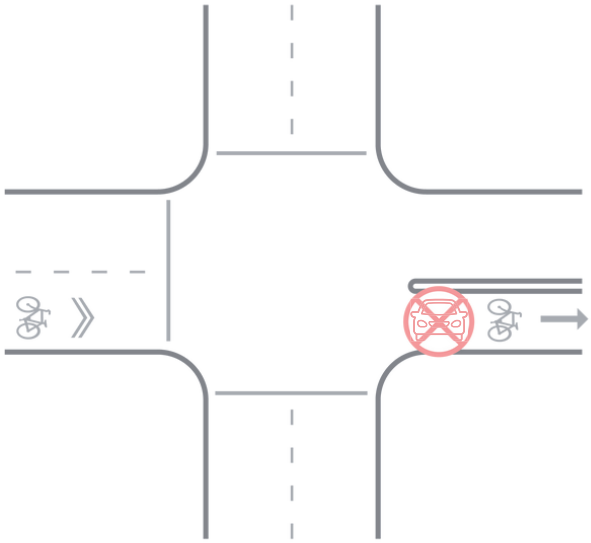
- Lateral Shift
- Chicane, Neckdown, or Pinch Point
- Realigned Intersection
- Traffic Circle
- Roundabout
- Mini-roundabout
- Curb extensions

Design Guidance

- When using horizontal speed management treatments, a minimum clear width of 12 feet for travel shall be maintained.
- Space for bicycles to bypass horizontal treatments should be considered when the average daily vehicle volumes are greater than 2,000 vehicles per day (AASHTO GBF 8.4.2).
- Additional guidance is found in Section 8.4.2 of AASHTO GBF and Section 3.1.2 of NACTO UBDG.

Mini Roundabout

3 Routing Restriction



Routing restrictions are intended to eliminate some portions of cut-through traffic by preventing particular vehicle movements. Some routing restrictions can be created using paint on the roadway, but they are most effective when raised curbs or other physical barriers exist. Extensive planning, design, and public outreach are needed before traffic calming elements are placed on the street. Designers should strive to design context-sensitive and appropriate solutions. Examples of routing restrictions include:

- Diagonal Diverter
- Full Closure
- Half Closure
- Median Barrier
- Forced Turn Island

Typical Applications:

- Urban and suburban settings along roadways and at intersections.
- Where it is desired to reduce vehicle traffic along a particular route and an alternative route is available to through vehicular traffic, while preserving local access as necessary.

Design Guidance

- Where emergency vehicle access is still needing to be maintained, there should be breakaway or lockable bollards or gates.
- A gap or channel in the physical restrictions can allow at-grade access for bicyclist movements.
- It is important to consider where diverted traffic will go and what effect that will have.
- Each type of routing restriction has its own design requirements and should be designed with engineering principles and judgment.
- Need to maintain access to residences and businesses and divert vehicular traffic on through trips to other routes.
- Additional guidance is found in Section 8.5 of AASHTO GBF and Section 3.1.2 of NACTO UBDG.

4 Travel Lane Width Reduction/ Creating Enclosure

Reducing travel lane widths is an effective traffic-calming measure that can help slow down vehicle speeds and enhance safety for all road users. Here's how narrower travel lanes contribute to traffic calming and slowing traffic:

Physical Impact on Traffic Flow

Reduced Speed:
Studies have shown that reducing lane widths from 12 feet to 10 or 11 feet can result in lower vehicle speeds. The reduced width discourages speeding and promotes a more controlled driving pace.

Traffic Calming Effect:
Narrower lanes can create a natural traffic-calming effect, slowing down vehicles without the need for additional physical barriers like speed bumps.

Safety Improvements

Shorter Crossing Distances for Pedestrians:
Reducing lane widths can shorten the distance pedestrians need to cross, decreasing their exposure to moving vehicles and enhancing their safety.

Increased Buffer Zones:
Narrowing travel lanes can create space for wider shoulders, bike lanes, or buffer zones between travel lanes and sidewalks, providing additional safety for cyclists and pedestrians.

Enhanced Visibility:
Slower speeds and narrower lanes improve drivers' ability to see and react to pedestrians, bicyclists, and other vehicles, reducing the likelihood of accidents.

Space Reallocation

Bike Lanes and Sidewalks:
The space saved from narrowing travel lanes can be reallocated to create dedicated bike lanes and wider sidewalks or sidepaths, promoting active transportation and improving safety for non-motorized users.

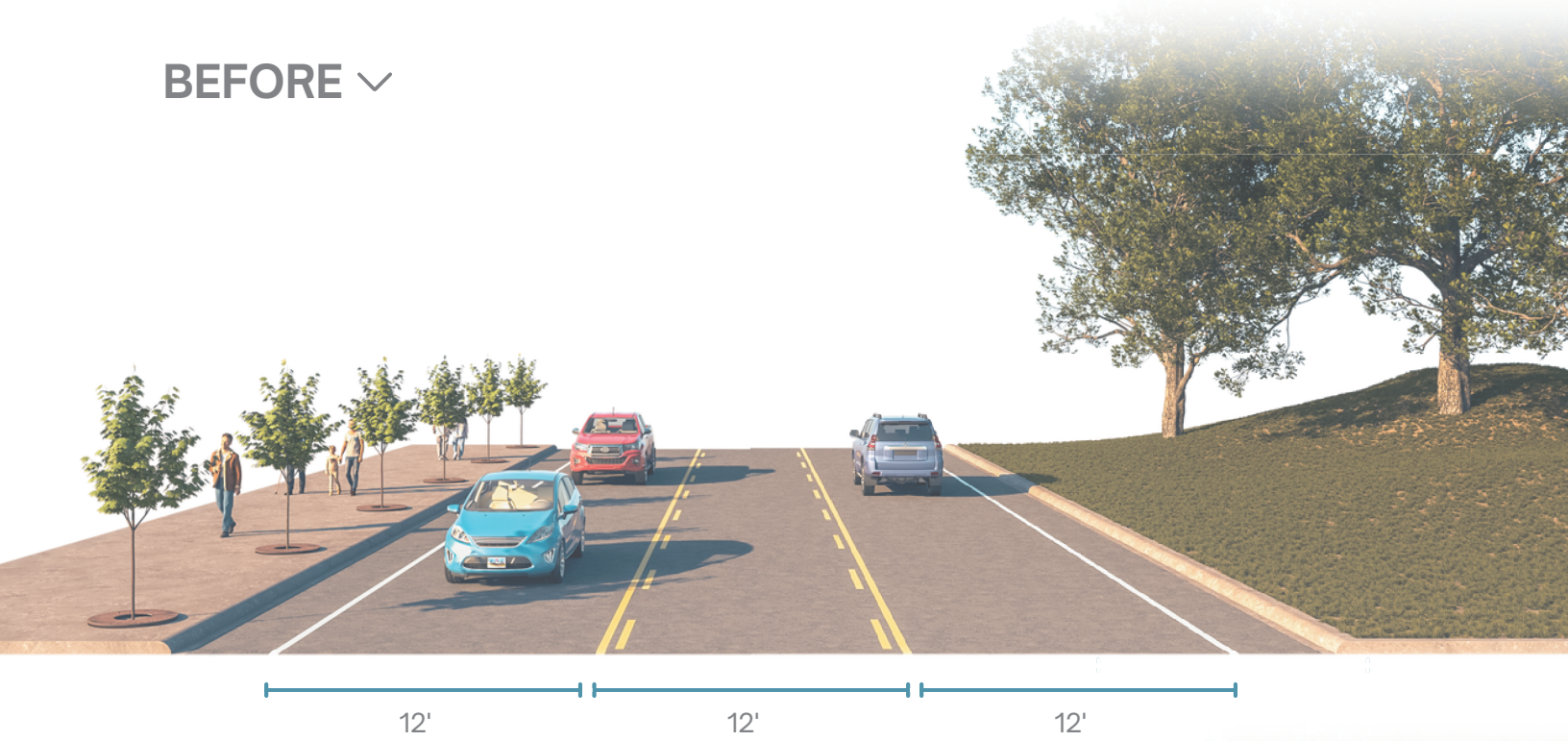
Landscaping and Buffer Zones:
Additional space can also be used for landscaping, street furniture, or buffer zones, enhancing the street's aesthetic appeal and providing physical barriers that further calm traffic.

Additional guidance is found in Section 8.4.1 of AASHTO GBF.

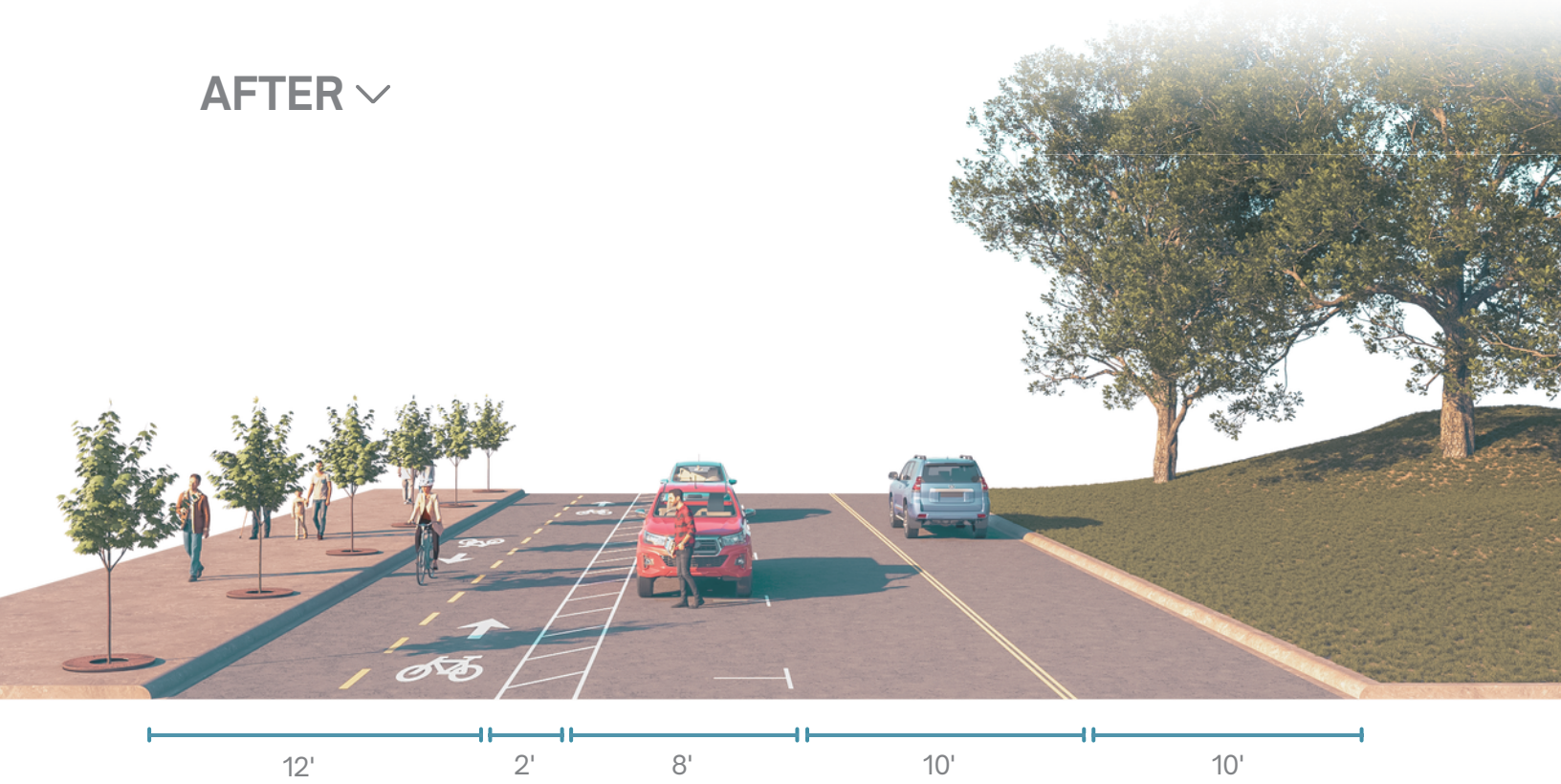
Design Guidance

- Reducing lane widths should involve careful attention to design and planning, coupled with extensive public engagement.

BEFORE



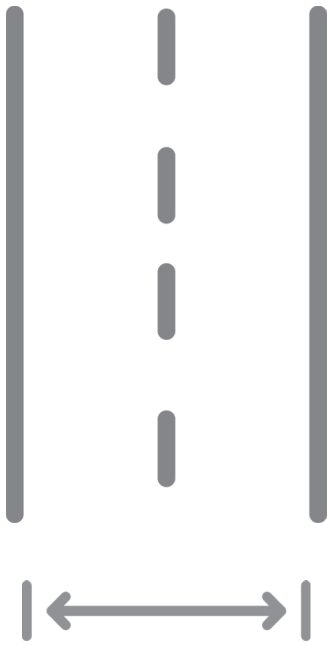
AFTER



EVALUATING SURPLUS RIGHT-OF-WAY

Opportunities exist to evaluate the right-of-way (ROW) along corridors or sections of roadway to evaluate their current usage and whether there is an opportunity to alter their current use to provide better facilities for vulnerable road users while still providing sufficient service levels for motorists. Road reconfigurations provide a method of utilizing existing right of way and roadway width to increase safety and can often include additional facilities for other modes of travel, such as dedicated transit lanes, widened and enhanced sidewalks, and bike lanes.

According to FHWA, a Road Diet repositions pavement markings to better meet the needs of all road users. A classic Road Diet converts a four-lane undivided roadway to a three-lane roadway, but many other reconfigurations are used by States and local jurisdictions. For example, a road diet could convert the roadway space from five to three lanes, two to three lanes, or various lanes of a three-lane roadway. An agency could even use a Road Diet on a one-way street.



Resources such as the Road Diet Information Guide (FHWA) navigate to the appropriate application and implementation of road diets. Many factors should be considered when planning and designing a road reconfiguration, including extensive public outreach and traffic studies and the potential positive and negative effects on all stakeholders, including businesses, neighborhoods, vulnerable road users, and motorists.

GENERAL DESIGN GUIDANCE

The following pages provide guidance on various aspects of paths and general bike and mixed-use facilities. Many recommendations for these design elements are found in Chapter 5 of AASHTO GBF. The following pages include information on:

- Transitions between facility types
- Bi-Directional Bikeways
- Side Slopes
- Fence/Barrier Guidance
- Cross Slopes
- Stopping Sight Distance
- Grade
- Options to Mitigate Excessive Grades
- Surfaces
- Accessibility
- Vertical Alignment
- Drainage
- Design Speed
- Horizontal Alignment
- Pavement Markings
  - Pavement Markings for Buffered Bike Lanes
  - Pavement Markings for Conventional/Constrained Bike Lanes
- Signage
- Signage and Wayfinding & General Trail Signage Information

Transitions Between Facility Types:
Bicycle networks are composed of a variety of facilities (i.e. sidepaths, bike lanes, mixed traffic facilities, etc.) and each transition between facility types is unique and requires careful planning and design. A good transition zone will clearly indicate what users are required to do and maximize their safety and comfort.

One key design element for the transition between sidepaths and street level facilities is the design of the bicycle ramp. AASHTO GBF provides design guidance in Section 5.10.7.

A physical separation, such as poured curbs and medians in conjunction with pavement markings (i.e. arrow showing travel direction with a bike rider marking) can be helpful in providing clear direction to bicycle riders in advance of and during transitions between facility types. These can also be helpful at intersections to improve comfort and safety of bicycle riders by preventing the accidental mixing of bicycles and vehicles at the intersection.

Section 7.10 of the AASHTO GBF provide guidance and examples for a variety of transition types in different contexts. This guidance covers where ideal transition points are as well as more complicated transitions such as two-way bike lanes to one-way bike lanes and vice versa.

NACTO Section 3.1.4 covers their guidance for bike transitions. The guidance in this section covers lateral shifts for bikeways as well as bike ramps and vertical grade transitions. Other guidance for transitions can be found in the sections for each bike facility type.

Bi-Directional Bikeways:
Bicycle network routes should allow and prioritize bicycle travel in each direction. Bi-directional travel is typically easily accomplished with paths, however on-street facilities may require additional planning and design.

On-street bi-directional travel may be accomplished in a variety of ways. Some examples include:

- Bike lanes on each side of the roadway
- Two-way bike lanes - typically protected bike lanes that accommodate travel in each direction
- Contraflow bike lane - often a bike lane on the left side of the street for the opposite direction of travel on a one-way street

Signage to notify motorists can be considered when bi-directional bike traffic is present. This may be particularly beneficial at driveways to notify drivers that bicycles may be approaching from either direction.

Additional design guidance for two-way contraflow bike lanes can be found in NACTO UBDG and AASHTO GBF.

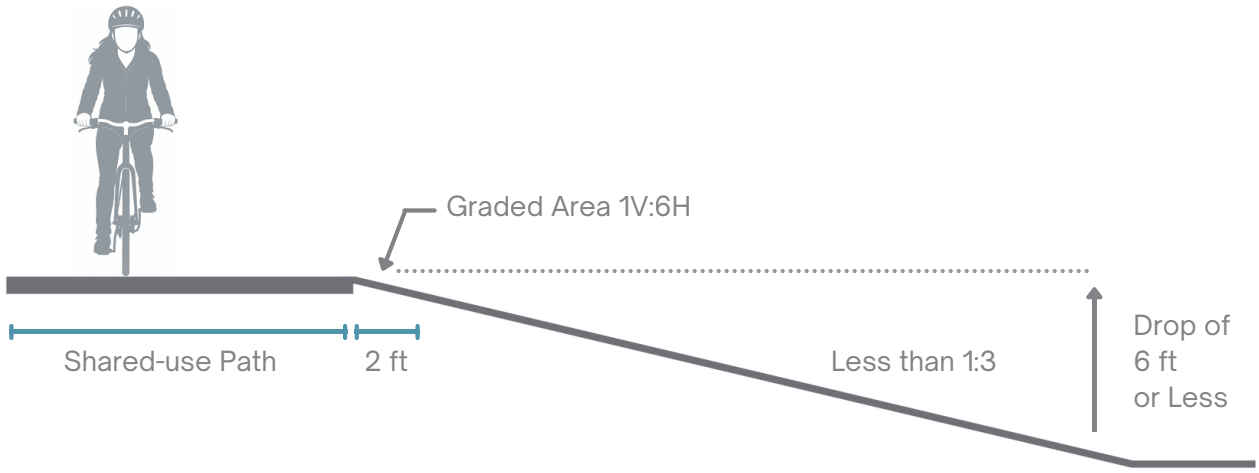
Side Slopes:
The shoulders of paths should be graded in a manner that provides a recoverable area for users who leave the path either intentionally or unintentionally. At a minimum, there should be a 2-foot-wide graded area with a maximum slope of 1V:6H. Ideally, the shoulder should be 5 feet wide, but the minimum 2 feet of clear shoulder at a maximum of 1V:6H slope should be maintained. See AASHTO GBF 6.6.1.1 for guidance.

In locations with a downhill slope greater than 1V:3H adjacent to the path, a wider shoulder (5 feet or more) with a 1V:6H slope should be considered before the top of the steeper slope. Conditions such as slope, the height of the drop, and conditions at the bottom of the drop should be considered in analyzing whether barriers such as fences, rails, or dense vegetation should be used to reduce risks to trail users.

A physical barrier or rails are recommended where a 5-foot wide recovery area cannot be maintained, and there are:

- slopes of 1V (vertical):3H (height) or steeper with a drop of 6 feet or greater,
- slopes of 1V:3H or steeper adjacent to a parallel body of water or other substantial obstacle,
- slopes of 1V:2H or steeper with a drop of 4 feet or greater, or
- slopes 1V:1H or steeper with a drop of 1 foot or greater.

Condition 1: Gentle side slope, no fence or additional graded area needed



Condition 2: Steep side slope, additional graded area provided

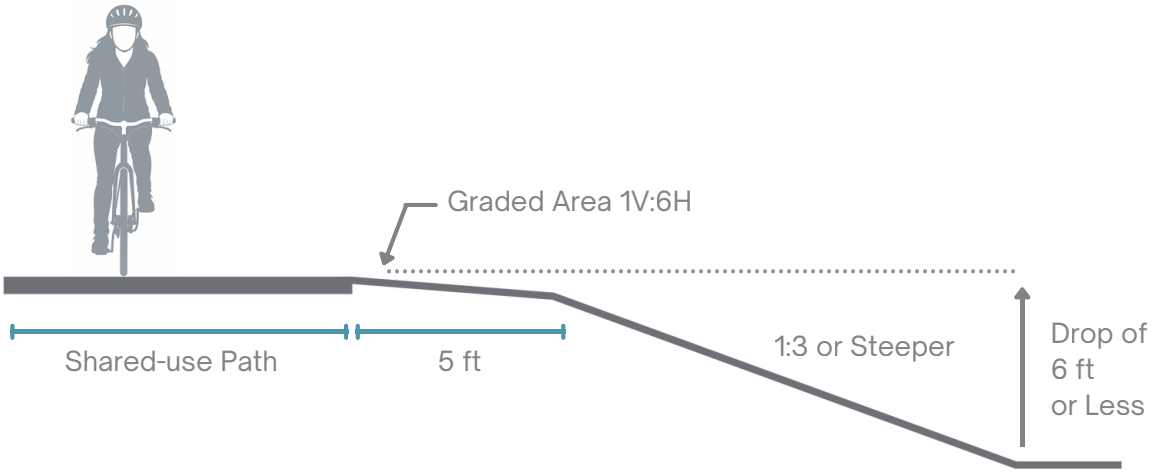


Image based off Bicycle Facility Design Manual, MNDOT

Fence/Barrier Guidance:

When barriers, such as fences, are used there should be a 2' clear area between the edge of the path and the barrier. Also, when fences or rails are adjacent to a path, rub rails should be used to prevent handlebars from getting caught. The images below also show some guidance for when fences or barriers are adjacent to slopes.

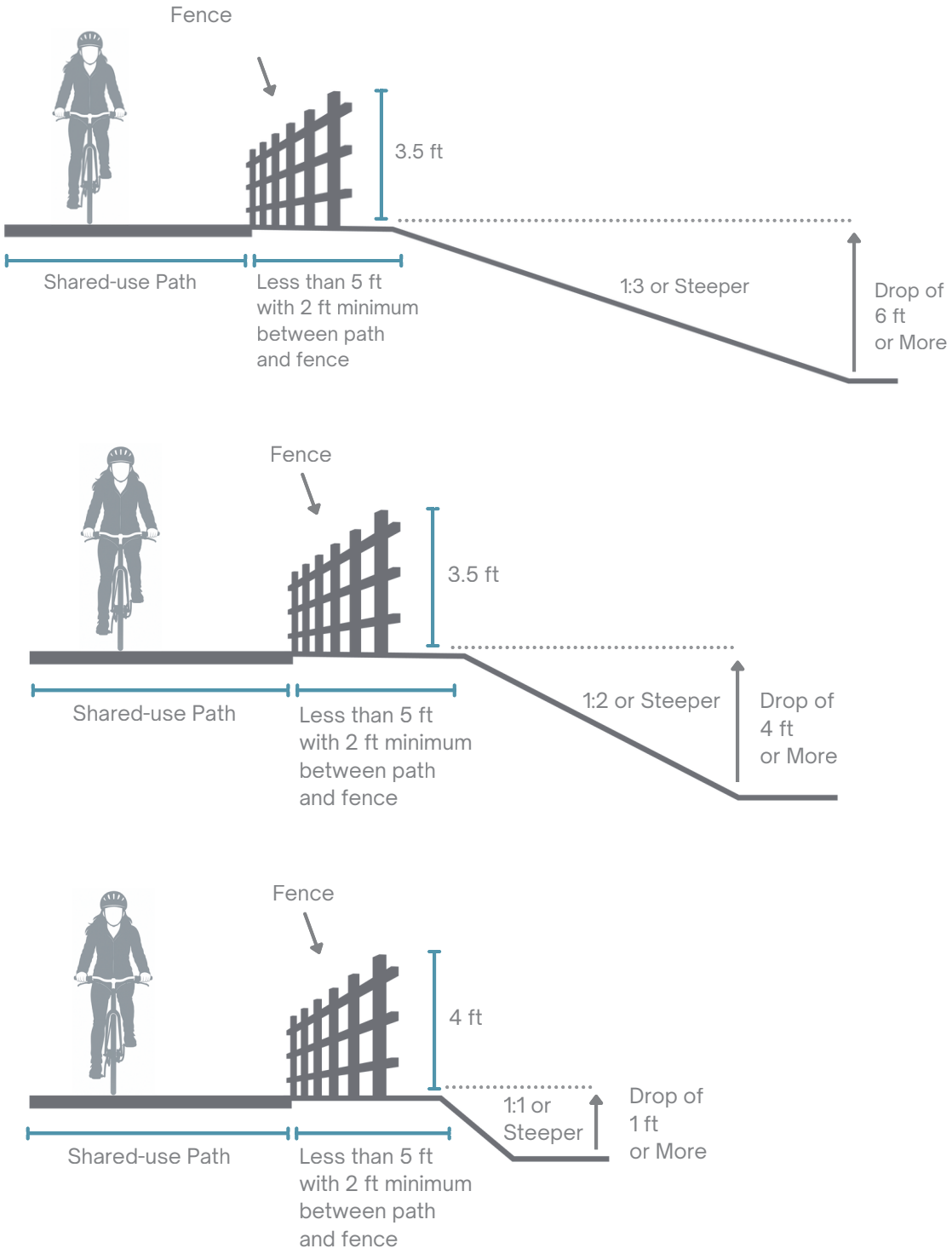


Image based off Bicycle Facility Design Manual, MNDOT

Cross Slopes:
The ideal cross slope for bike and pedestrian facilities is 1%-1.5%, as they are easier for people in wheelchairs to navigate while being able to convey drainage. Additionally, cross slopes should not exceed 2% to meet disability design requirements. See AASHTO GBF 5.6.3 for additional guidance.

Cross slopes should transition to connect to existing slopes to adjust to changes in slope or drainage, or sometimes to a horizontal curve. These transitions should be smooth and comfortable for users and have a minimum length of 5 feet per 1% change in cross slope.

Stopping Sight Distance:
Bicycle facility design should take into consideration stopping sight distance to ensure that there is time to react to unexpected conditions. Stopping sight distance calculations include variables such as reaction time, starting speed, the coefficient of friction between the path and the wheels, the grade of the path, and the braking ability of the user's equipment. Formulas for calculating stopping sight distance can be found in resources such as the 2024 AASHTO Bike Guide. Sight distance needs to be evaluated for vertical curves, as well as horizontal curves. In locations where there isn't adequate stopping sight distance for trail users, pavement markings such as a solid yellow center stripe indicating a "no passing" zone or curve warning signs should be considered. See AASHTO GBF 5.5 for additional guidance.

Grade:
Paths should have a maximum grade of 5%. Grades should be minimized on long stretches, as steep ascents and descents can be difficult and dangerous for many trail users. Pedestrian access standards must also be met with shared-use paved paths, which also limits maximum grades to 5%, except under certain circumstances which can be found on the U.S. Access Board website.

Grades of less than 0.5% should be avoided because they create challenges with stormwater conveyance. It is better to use small rolling hills that convey storm drainage to outlet locations.

The path material must also be considered, as grades steeper than 3% may be difficult for users when the path is unpaved.

Options to mitigate excessive grades include:
- When long grades must be used, provide an additional width of 4 to 6 feet to permit slower bicyclists to dismount and walk uphill and to provide more space for fast downhill riders.
- Use higher design speeds for horizontal and vertical alignments, stopping sight distance, and other geometric features.
- Install hill warning signs for bicyclists (W7-5 in the MUTCD) and alert users to the maximum percent grade on the downhill approach.
- Provide greater clearances on each side of the path and/or railings where appropriate.
- Provide resting areas and resting intervals with flatter grades.
- Use a series of short switchbacks with 4 to 6 feet of extra maneuvering space.
- Consider the use of advisory speed plaques.

See AASHTO GBF 6.6.4.1 for additional guidance.

Surfaces:
Paths can be either concrete or asphalt. Asphalt is the most common surface since it has the lowest initial cost. However, concrete paths have been proven to reduce maintenance costs over the long term and are more durable. When concrete is used, saw-cut concrete joints are recommended to improve users' experience.

Asphalt's advantages include that it has a lower initial construction cost, is softer and preferred by runners and walkers, and pavement markings are often more visible on asphalt over concrete due to a higher contrast.

A soil investigation should be performed and considered along with the expected loads (maintenance and emergency vehicle use should be considered) on the trail to determine the pavement section design for all paved paths.

Efforts should be made to ensure a smooth riding surface. When utility covers or drainage grates are required, they should be bicycle-compatible and flush with the pavement surface.

See AASHTO GBF 6.6.2 for additional guidance.

Accessibility:
Aspects such as the surface type, cross slope, and grade directly affect the accessibility of paths. Wheelchair users can most easily navigate hard surface paths with a cross slope of 1%. Slopes of paths should be 5% or less, and rest areas and rest intervals should be considered for long stretches of steep slopes.

Vertical Alignment:
The vertical alignment should provide users with a smooth and comfortable experience. It should also provide users with sight distances that allow them to pass other users safely. In flat areas, a gradually rolling vertical profile can help convey stormwater better than letting the area remain flat around the path.

See AASHTO GBF 6.6.4 for additional guidance.

Drainage:
Minimum cross slopes of 1 percent and longitudinal grades of 0.5% typically provide conditions for adequate drainage, and paths are typically sloped uniformly in one direction rather than crowning. The slope direction typically follows the natural terrain to avoid the need for channelized flow where possible. When needed, manhole covers and bicycle-compatible drainage grates should be located outside the bicycle/pedestrian facility.

See AASHTO GBF 6.6.6 for additional guidance.

Design Speed:
Design speeds should be selected and used for all pertinent features along a facility to provide continuity. Usually, the selected speed should be at least as high as the preferred speed of the fastest common user. This speed depends on many conditions, including the type of equipment being used, the purpose and length of the trip, the condition and grade of the path, wind conditions, and the number and type of other users. Design speeds for paths are typically reported in 2 mph increments and range from 12 mph to 30 mph. Most paths in flat areas have a design speed of 18 mph, but it varies depending on all the path conditions. In some areas, it may be desirable to lower speeds through geometric design, such as horizontal curves, to reduce the likelihood of crashes at conflict points.
See AASHTO GBF 6.5 for additional guidance.

Horizontal Alignment:
Most adult bicyclists lean while turning at corners to avoid falling. There are two methods for calculating the minimum radius of horizontal curvature for bicycles: using the “lean angle” or the superelevation method. These methods are outlined in resources such as the 2024 AASHTO Bike Guide. When the minimum radius of horizontal curvature cannot be achieved in the path design, warning signs or widened pavement through constrained corners can be used. See AASHTO GBF 6.6.3 for additional guidance.

Pavement Markings:
Pavement markings on bicycle and mixed use facilities can be used to indicate separation of lanes, provide guidance on assigned travel paths, and provide information in advance of turning and crossing maneuvers. They should be retroreflective and use materials that will minimize loss of traction under wet conditions.

On two-way facilities, a solid yellow centerline stripe may be used when passing is not advisable (due to sight distance concerns or heavy user volumes), and a broken yellow line may be used when passing is permitted.

In some areas of extremely heavy path volumes, pedestrians and wheeled users can be segregated using pavement markings. The markings and signage should clearly define what lane is used for bi-directional pedestrian use and also define lanes for each direction of bicycle traffic. The pedestrian only lane should be on the side of the path with a view when applicable. Bicycle specific marking requirements are found in Chapter 9E of the MUTCD 11th Edition and AASHTO GBF 6.6.9.

Additionally, pavement markings can be used at potential conflict points to prevent collisions between motorists and bicyclists/pedestrians. This can include stop bars at intersections as well as crosswalk markings across the intersection. It can also include markings on a path to warn users to yield and watch for vehicles.

Green pavement markings are often used for bicycle facilities and standards for their use can be found in Chapter 3H.06 of the MUTCD 11th Edition.

Pavement Markings for Buffered Bike Lanes:

- Bicycle lane word and/or symbol and arrow markings (MUTCD Figure 9E-1) shall be used to define the bike lane and designate that portion of the street for preferential use by bicyclists.
- The buffer shall be marked with 2 solid white lines. White lines on both edges of the buffer space indicate lanes where crossing is discouraged, though not prohibited (MUTCD 9E.06). For clarity, consider dashing the buffer boundary where cars are expected to cross at driveways.
- The buffer area shall have interior diagonal cross-hatching if it is between 2 ft and 4 ft wide or chevron markings if wider than 4 feet (AASHTO GBF 9.5).
- Consider separated bike lanes with vertical elements when space allows for buffers of 6 ft or more (AASHTO GBF 9.5).

Pavement Markings for Conventional/Constrained Bike Lanes

- Mark a bike lane line with a normal solid white line and a standard bike lane symbol marking (AASHTO GBF 9.4.2). The MUTCD 2023 Section 9E provides standards and guidance for applying these elements.
- Lane markings should remain solid and not dotted at the driveway crossing. The MUTCD does not recognize a driveway as an intersection (MUTCD 2023).
- Bicycle lane word and/or symbol and arrow markings (MUTCD Figure 9E-1) shall be used to define the bike lane and designate that portion of the street for preferential use by bicyclists. These markings shall be placed outside of the motor vehicle tread path at intersections, driveways, and merging areas in order to minimize wear from the motor vehicle path.
- A solid white lane line marking shall be used to separate motor vehicle travel lanes from the bike lane.
- A dotted lane line can be used in high conflict areas such as intersections where vehicles may be entering the bike lane and where transit vehicles will be frequently crossing the bike lane (AASHTO GBF 9.12.1).
- A through bike lane shall not be positioned to the right of a right-turn-only lane or to the left of a left turn-only lane (MUTCD 9E.02). A bike lane may be positioned to the right of a right-turn-only lane if split-phase signal timing is used (AASHTO GBF 9.12.3.7).
- Guidance for bike lane markings at intersections is provided in AASHTO GBF 9.12.
- Bike lane symbols should be placed within 50' of an intersection and then at intervals that are not more than every 250 feet in urban areas. Symbols may be needed more frequently depending on factors such as the frequency of driveways or turn lanes (AASHTO GBF 9.4.2).
- Bike lane symbols may be up to 1,000 feet apart in rural areas (AASHTO GBF 9.4.2).

Signage:
Signage can serve many purposes, and guidance for bike facility specific signage can be found in the 11th Edition of the MUTCD in Chapters 9B, 9C, and 9D.

Warning Signage:
Careful attention should be placed on warning signage. Warning signs can be used to notify of path narrowing, a crossing ahead, steep grades, etc. Guidance for warning signs can be found in Chapter 9C of the MUTCD 11th Edition.

Directional Signs:
Place directional signs at junctions and decision points to help users navigate the network. Use arrows or symbols to indicate where users should go to reach specific destinations or points of interest. Signs can also be used at mid-block crossings to notify users of what streets they are crossing as well as to notify drivers of the name of the trail they are crossing. Guidance for directional signage can be found in Chapter 9D of the MUTCD 11th Edition.

Signage and Wayfinding:
Knowing your location within an active transportation network is important for user security while enhancing the experience. An opportunity exists for the city to develop a comprehensive wayfinding and signage program for the active transportation network. A comprehensive wayfinding and signage plan can delve into the system's look, feel, and brand to create a unified approach to navigating on bike and foot. Essential elements of a wayfinding and signage plan are as follows:

Clear and Consistent Signage:
Ensure all signage is clear, easy to read, and consistent throughout the system. Use large fonts and high-contrast colors to make signs easily visible, even from a distance. Ensure that the signage has a consistent look and feel both in the physical structure of the sign and in the maps.

Distance Markers:
Install distance markers at regular intervals along routes to inform users of how far they have traveled and how far they have left to go. This information can be especially helpful for planning breaks and estimating travel time.

Emergency Information:
Include emergency contact information and instructions on what to do in case of an emergency on signage, especially for paths that aren't along roadways. This can include contact numbers for local emergency services, trail rules, and safety tips.

Trailhead Signage:
Provide clear signage at trailheads indicating the trail's name, difficulty level, length, and any important safety information. Trailhead signage should also include a map of the trail system with key landmarks and points of interest marked.

Trail Markers:
Install trail markers regularly along the trail to reassure users that they are on the right path. Depending on the terrain, these markers can be posts, blazes painted on trees, or other visible markers.

Trail Maps:
Provide trail maps at key locations such as trailheads, parking areas, and visitor centers. These maps should be easy to read and include information on trail difficulty, length, elevation gain, and points of interest.

Multilingual Signage:
If the trail system is frequented by users who speak different languages, consider providing multilingual signage to ensure that all users can understand important information.

Accessible Signage:
Ensure that signage is accessible to users with disabilities, including those who are visually impaired or have mobility impairments. Use braille, tactile markers, and wheelchair-accessible formats as needed.

Regular Maintenance and Updates:
Regularly inspect and maintain signage to ensure that it remains in good condition and continues to provide accurate information to users. Replace damaged or faded signs promptly to avoid confusion.

INTERSECTION DESIGN GUIDANCE

The following pages provide guidance on intersection design on bicycle and mixed-use facilities. The following information is provided:

Path Intersection and Crossing Design

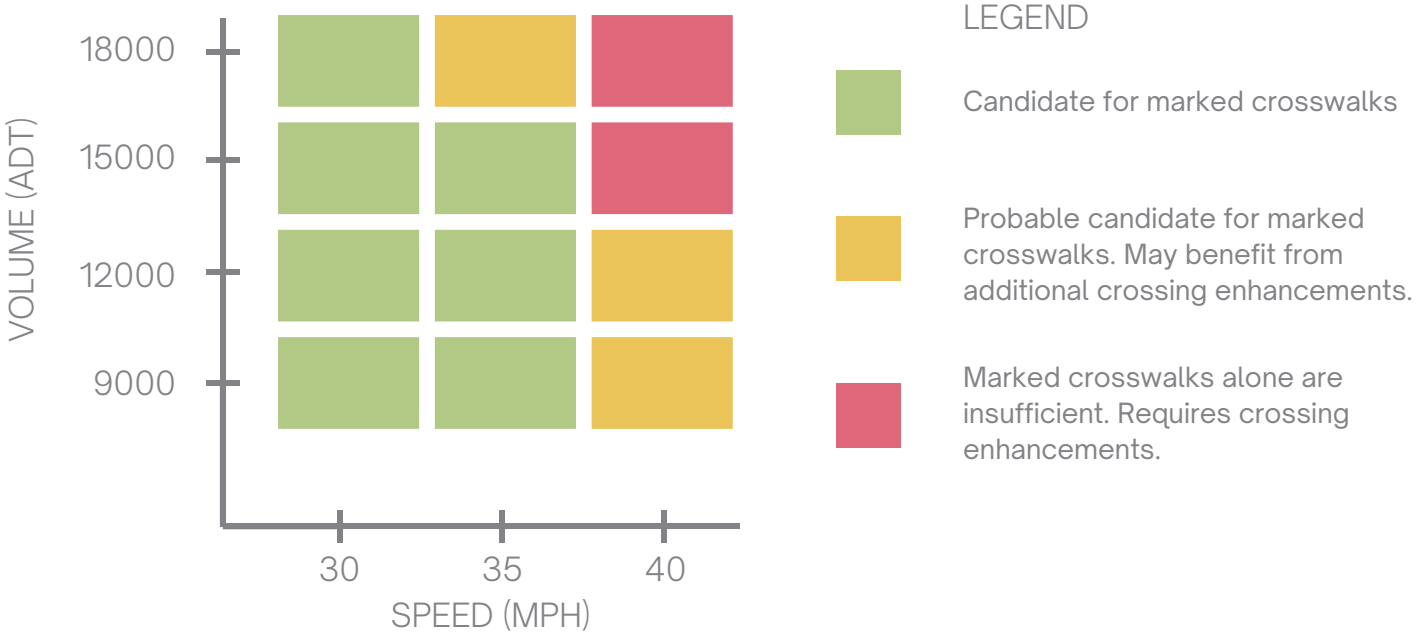
- Intersection Design
- Mid-Block Crossing Design
- Driveway Intersections
- Minor Intersection Crossings
- Managing Bicycle Speed at Crossings
- Crossing Accessablitity

Bike Lane Intersection and Crossing Design

- Protected Intersection
- Key Intersection Elements
- Intersection Crossing Markings
- One-way Separated Bike Lane Driveway Crossings
- Two-way Separated Bike Lane Driveway Crossings
- Mixing Zones

Path Intersection and Crossing Design

People of all ages and abilities use shared paths for activities like walking and cycling. These paths often intersect with roadways, posing user challenges at these points. Crossing designs should minimize path users' exposure to traffic and minimize the speed differential where travel movements intersect.
Intersection crossing criteria should be established based on the slowest users, which are typically pedestrians and child bicyclists. When paths intersect roadways away from designated crossings, conflicts can arise between path users and road users. It is crucial to apply sound design principles for these midblock intersections, similar to regular road intersections. Inappropriate treatments at these crossings can lead to users' non-compliance. For instance, using stop signs where visibility is good may not be effective, whereas yield signs could match user behavior better. Conflicts may also arise at angled intersections, affecting sightlines between path and road users. Ideally, intersections should be close to a 90-degree angle to ensure good visibility and stopping distances for everyone. By incorporating these design principles, conflicts at path and roadway intersections can be reduced or prevented effectively. See AASHTO GBF 6.7 for additional guidance.



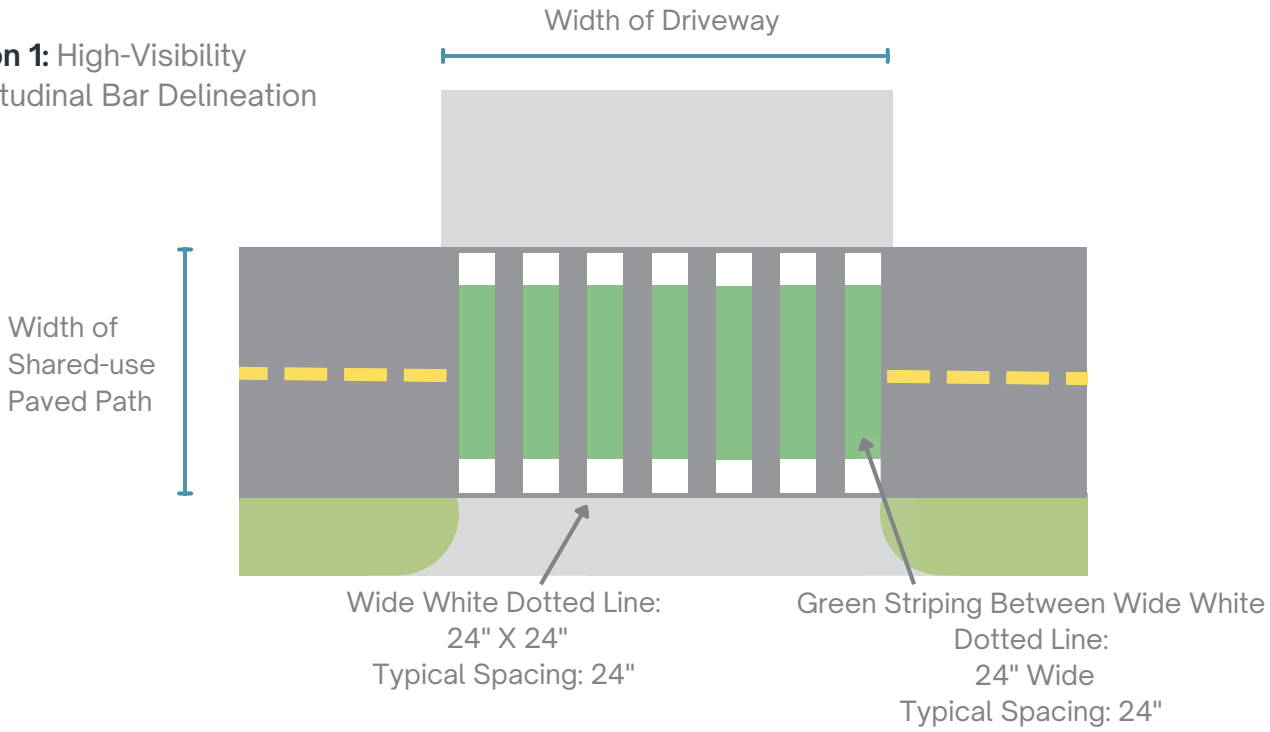
Source: Small Town and Rural Design Guide, FHWA

Intersection Design:
Intersection design for shared use paths requires careful attention to address potential conflicts. The design should be predictable and orderly to provide comfort and increase safety. Each intersection is unique and requires engineering judgment to determine the best treatment. Basic measures that can be used to reduce crash severity and frequency include reducing the speeds of path users and motorists, increasing the predictability of behavior, and limiting the amount of exposure at conflict points.

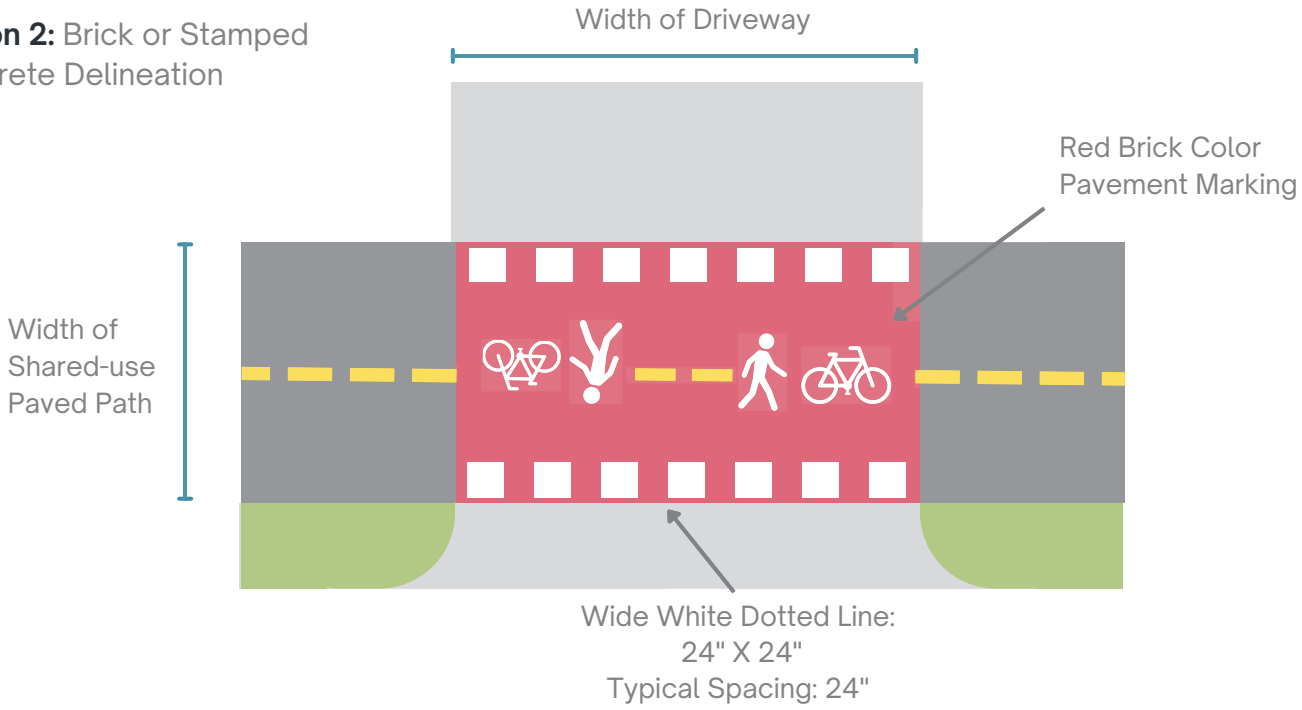
Mid-Block Crossing Design:
Mid-block crossings are similar to intersection design, and the same design principles apply. Many features can be considered, and some may be appropriate at different locations, but engineering judgment should be used to determine appropriate treatments based on the conditions at the crossing location. One principle that should be considered in the design is that it is safest at crossings for the path to be perpendicular to the roadway and provide the best lines of sight for path users and drivers.

Driveway Intersections for Paths:
Pathways with a low density of driveways are the ideal condition. However, shared-use paths frequently must cross driveways and some design options help bring drivers' attention to the path and its users. One option is to continue the path surface across the driveway so it is clear that the path users have the right of way. Signs and pavement markings can also be used, as well as small corner radii, to encourage reduced speeds.

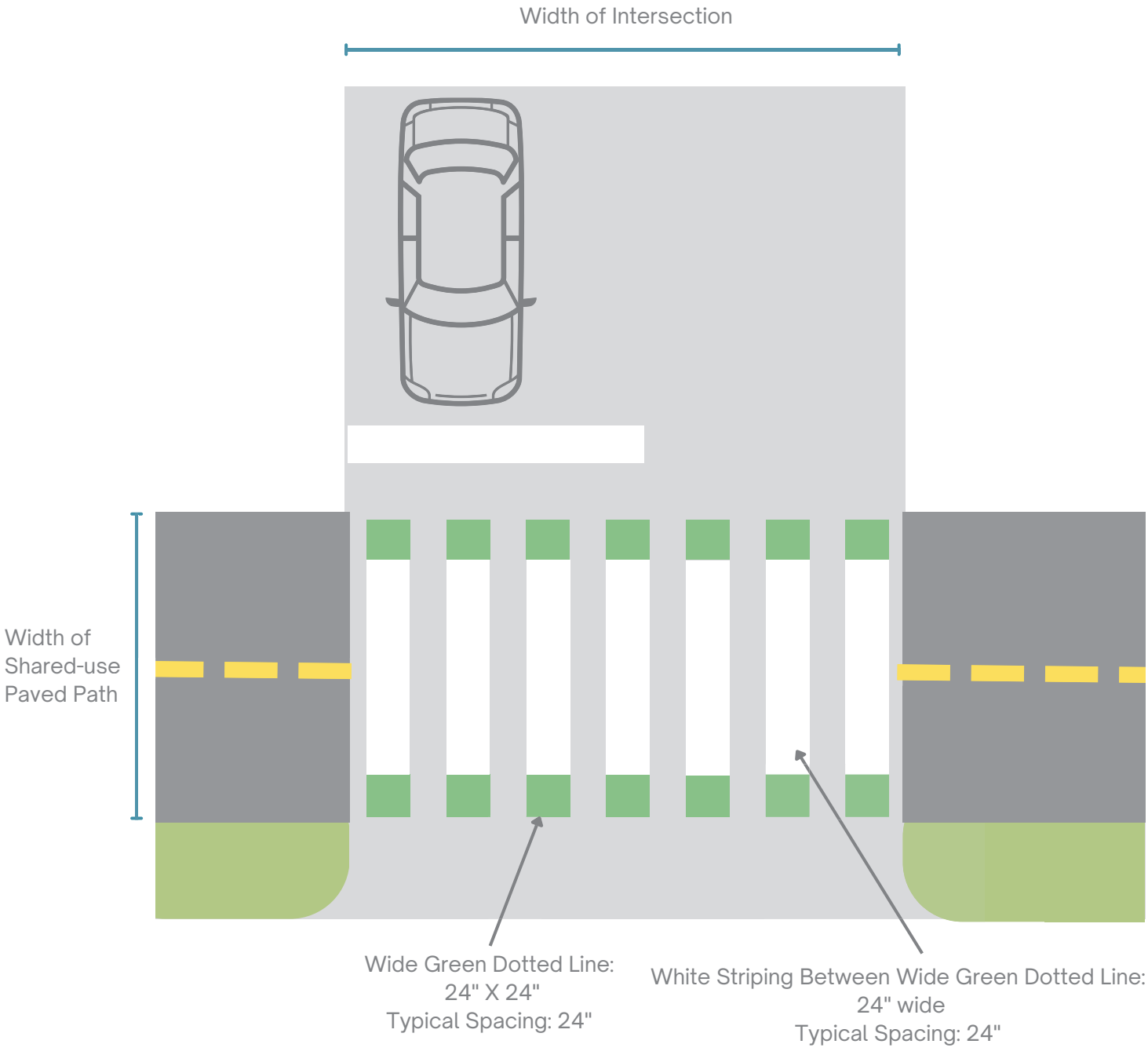
Option 1: High-Visibility Longitudinal Bar Delineation



Option 2: Brick or Stamped Concrete Delineation



Minor Intersection Crossings:
It is not always cost effective to continue shared-use paved paths over minor intersection crossings. In these cases, the intersection or road material can remain, and white high-visibility longitudinal bars are recommended to be painted in the crossing area to increase visibility for vehicle operators and vulnerable road users.



Managing Bicycle Speed at Crossings:
Design methods can be used to reduce shared path users' speeds at the approach of a street crossing. One such method is a chicane, which introduces horizontal curvature, to slow users before a crossing where they must yield, stop, or have limited sight distance. Chicanes should be placed in a location that allows users to navigate them and then be able to direct their attention to the intersection they are approaching.

Crossing Accessibility:
The transition between the shared use path and roadway should be smooth and accessible, and usable by individuals with disabilities. Ramps should be the full width of the side path and have detectable warning surfaces along the full width as well.

Bike Lanes Intersection and Crossing Design

Intersections and crossings are important considerations in designing safe and comfortable bike lanes. Due to vehicular traffic converging at intersections, strategic design is needed to mitigate risks. Ideally bike lanes and vehicular traffic will maintain their separation at intersections, but in constrained locations with low speeds “mixing zones”, or spaces where bicycle traffic is reintroduced to vehicular traffic, may be considered.

Protected Intersection:
Protected intersections use corner refuge islands, forward stop bars, and setback crossings to maintain the separation between cyclists and vehicles. These elements improve visibility and provide safe waiting areas for cyclists, making it easier for them to navigate the intersection. See AASHTO GBF 7.9.7 for additional guidance on protected intersections.

Key elements for intersection design are outlined in section 7.9 of AASHTO GBF and they include minimizing exposure to conflict and reducing speeds at potential conflict points. Another key factor is increasing visibility of the bicycle riders to motorists. These factors should be considered in intersection design, as well as minor intersection design and driveway crossings. Chapter 4 of NACTO UBDG also provides recommendations improving safety for intersection design.

Minimizing Exposure to Conflict

Pedestrian Islands

Islands reduce crossing distances and improve visibility by keeping the intersection clear. Wider islands support high volumes of people walking and biking, raising the intersection's capacity. In some cases, islands can reduce the signal time needed for pedestrians.

Bike Queue Area

People biking can wait ahead of the crosswalk for a green signal or a gap in traffic. This shortens crossing distances and accommodates the natural positioning of people biking. Bike detection is optional.

Corner Island

A corner island separates bikes from motor vehicles, prevents motor vehicles from encroaching on the bikeway, and creates a protected queuing area for people on bikes waiting to turn.

Motorist Waiting Zone

The space between the motor vehicle lane and the crossbike provides a place for motor vehicle drivers to wait before turning across the bike's path of travel.

Reducing Speeds

Compact Corners

Small turn radii force turning drivers to slow down. If there is no raised crossing, the corner radius is the primary method to reduce turn speed.

Raised Crossings

See "Increasing Visibility for more details

Increasing Visibility

Clear Sight Distance

A clear approach sightline gives drivers time to see and yield to people in the crossbike and gives people on bike or on foot time to see and react to turning cars.

No Stopping / No Standing Zone

Motor vehicle parking and stopping are prohibited on the approach to the intersection. This improves sight distance.

Bikeway Setback

The setback determines how much room will be available for drivers to wait and yield, and the angle at which they cross the bikeway. Larger setbacks provide better visibility and give people bicycling more time to notice and react to turning vehicles.

Markings

Markings provide conspicuity and directional guidance to bikes in the intersection. They are marked with dotted bicycle lane line extensions and may be supplemented with green color or bike symbols between these lines.

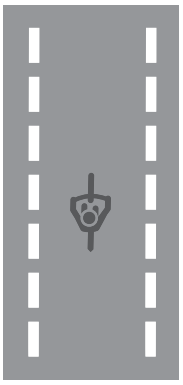
Raised Crossing

Raised crossings improve bicyclists' visibility and reduce the speed at which vehicles turn by bringing the vehicle crossing up to (or near) the sidewalk level. In addition, the raised crossing is a signal to turning cars that through-moving bikes and pedestrians have the right of way.

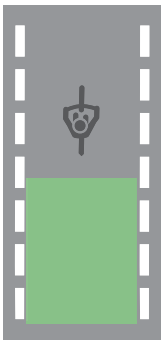
Intersection Crossing Markings:

Intersection crossing markings indicate the intended path of bicyclists. They guide bicyclists on a safe and direct path through intersections, including driveways and ramps. They provide a clear boundary between the paths of through bicyclists and either through or crossing motor vehicles in the adjacent lane. AASHTO GBF section 9.12 contains guidance for bicycle lanes at intersections and NACTO UBDG section 4.1.2 has guidance for crossings at intersections. MUTCD's standards for crosswalk markings are found in Chapter 3C and standards for bicycle specific crossings are found in Chapter 9E of the MUTCD 11th Edition. The following design elements should be considered based on existing intersection conditions:

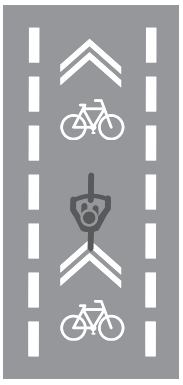
- Dotted lines should bind the bicycle space and should be white, skid-resistant, and retro-reflective (see MUTCD for requirements for dotted line extensions through intersections). Dotted lines should be used to delineate conflict areas within the bike lane and solid bicycle lane lines should be used immediately after the conflict area (AASHTO GBF 9.12.1).
- Colored pavement may be used for increased visibility within conflict areas or through the entire intersection (AASHTO GBF 9.12.1).
- Crossing lane width should match the position and width of the bike lane on each side of the intersection. Bike lanes should not be narrowed at street crossings.
- When two-way cycle tracks go through the intersection, markings should indicate the two-way traffic through the intersection.



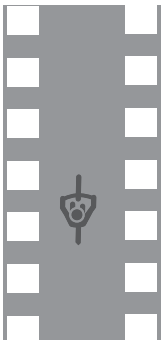
Dotted lines shall bind the bicycle crossing space. See MUTCD Sec. 38.08 for dotted line extensions through intersections. Stripping shall be a minimum of 6 inches adjacent to motor vehicle travel lanes and shall otherwise match the width and lateral positioning of leading bike lane striping, except when using wide white dotted line markings.



Colored pavement may be used for increased visibility within conflict areas or across entire intersections. Green colored pavement is experimental in the MUTCD.



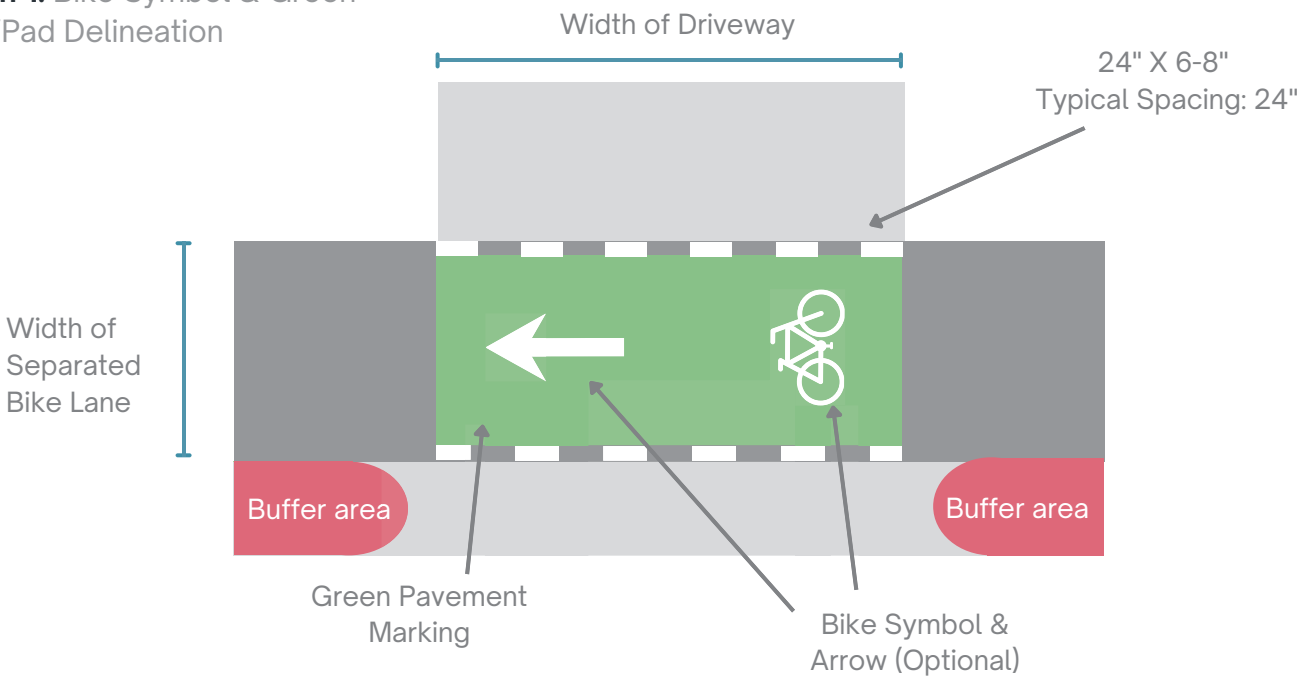
Shared lane markings (MUTCD Figure 9c-9) may be used for increased visibility within conflict areas or across entire intersections. Placement shall be in the middle of the moving lanes and close to crosswalks.



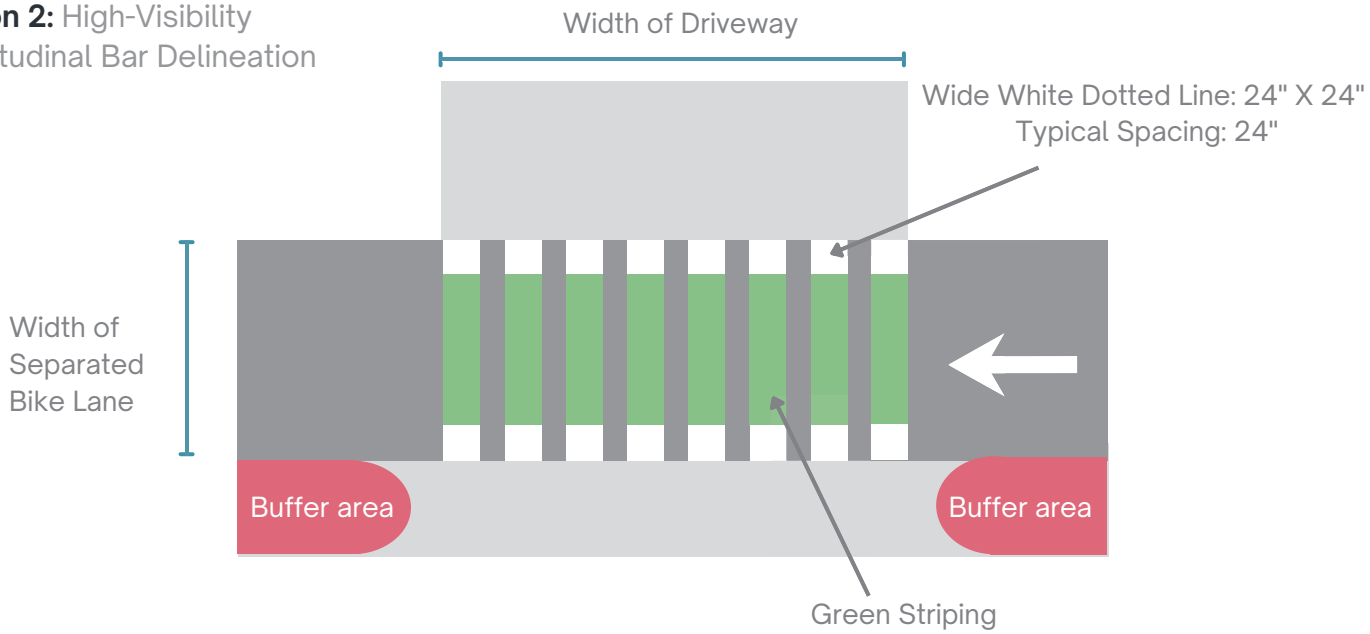
Wide dotted line markings (NACTO also refers to these as "Elephant's feet" markings) may be used as an alternative to dotted line extensions to increase visibility. If used, the markings should be 14-24 inches square, with equal distance spacing between markings. Markings should be positioned on the outside of the lane.

One-Way Separated Bike Lane Driveway Crossings:
Separated bike lanes (SBL) frequently cross driveways. Pavement markings and signage can help to increase visibility for bike riders in the SBL and help influence motorists to yield where applicable. The figures below show options for pavement markings which can help achieve these goals. Pavement markings can be applied as paint or as thermoplastic. Thermoplastic is a higher cost option however, it does have a longer useful life. Please reference MUTCD 11th edition and for full details and specifications for pavement markings (Chapter 9E.04) and regulatory signage Chapter 9B).

Option 1: Bike Symbol & Green Paint/Pad Delineation

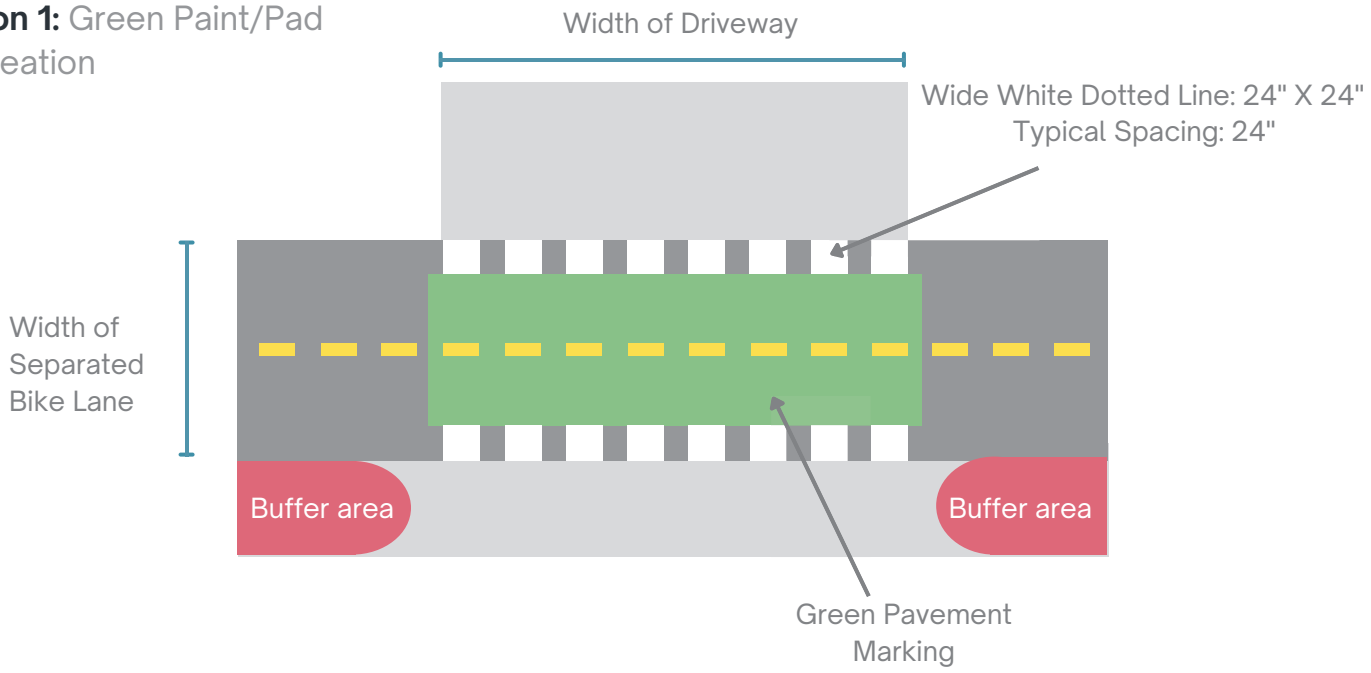


Option 2: High-Visibility Longitudinal Bar Delineation

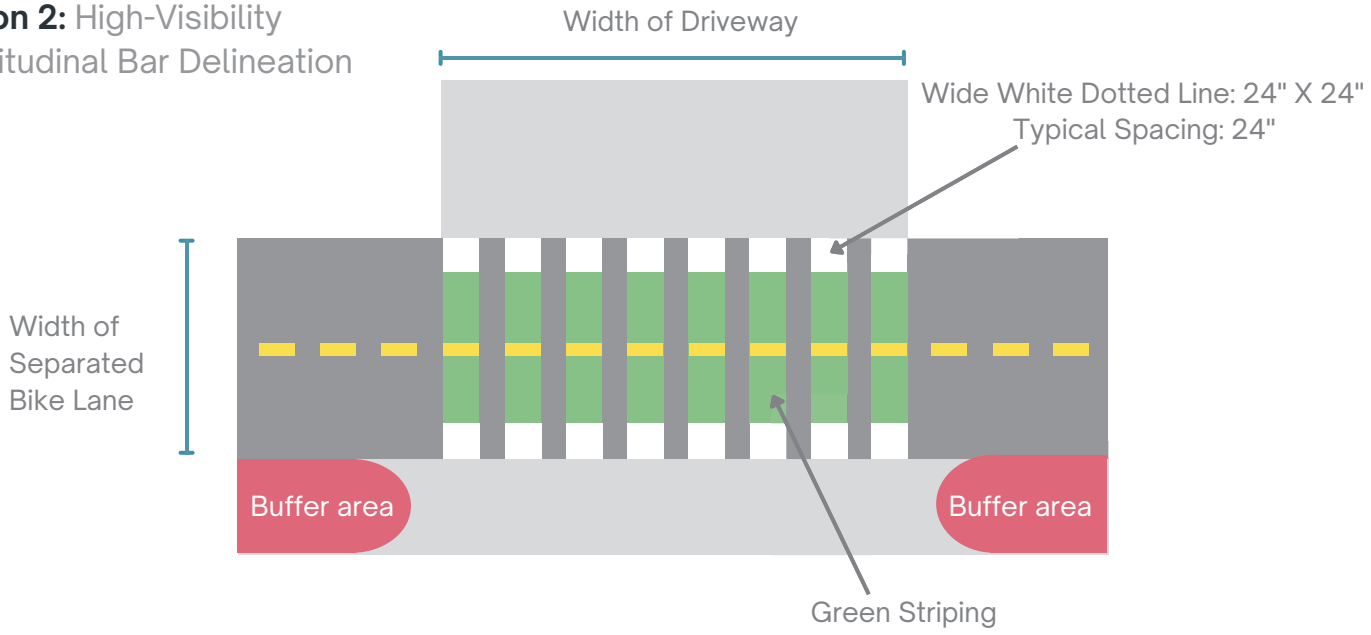


Two-Way Separated Bike Lane Driveway Crossings:
The figures below show options for pavement markings which can help achieve the goals outlined on the previous page but are for two-way separated bike lanes rather than one-way. Please reference MUTCD 11th edition and for full details and specifications for pavement markings (Chapter 9E.04) and regulatory signage Chapter 9B).

Option 1: Green Paint/Pad Delineation



Option 2: High-Visibility Longitudinal Bar Delineation



Mixing Zones:

Mixing zones are where a vehicular lane and bicycle lane cross paths and merge or switch lane placement. This typically occurs at intersections where the vehicular traffic has a dedicated right-turn lane. Mixing zones are only applicable on street segments with one-way separated bike lanes. Streets with speeds in excess of 35 mph may require deceleration lanes in advance of the mixing zone. See AASHTO GBF 7.9.9 for additional guidance on intersection design with mixing zones.

NACTO warns that mixing zones are not necessarily All Ages and Abilities bikeways as they don't provide the level of comfort needed for that designation. However, they are considered safer than having a bike lane in between travel lanes or dropping the bike lane altogether.

Mixing zones are recommended to be used only when:

- the bicycle lane is one-way in the same direction of traffic as motorists.
- speeds are 35 mph or less.
- it isn't possible to provide dedicated bicycle facilities at the intersection approach.

Mixing zones with a yielding area must have markings to indicate where motorists enter the shared space and shall yield. Shared lane markings and turn arrows must be provided where the mixing zone continues into the intersection and bicycles, and motorists continue to share space. Signage and markings should be used to inform users of the mixing zone and provide instructions for positioning in the lane. Standards for pavement markings at mixing zones can be found in Section 9E.02 and 9E.03 of the MUTCD 11th Edition.