BICYCLE FACILITY TYPES AND DESIGN RECOMMENDATIONS

4

Bicycle Facility Types and Design

This section serves as an introduction to the set of recommended facilities to be considered to enhance bicycle safety, connectivity, and accessibility in Mercer County. The types of facilities are both related to the existing conditions, strengths, and constraints discussed in chapter two, and reflective of established guidelines and design recommendations.

The designs and recommendations to be considered are derived from a series of design and policy manuals from both local and national contexts. These manuals aim to share standards, best practices, and strategies for design and construction of bicycle facilities. The following section outlines the guides referenced for development of these recommendations. It is important to note that many Mercer County Roads have limited right-of-way and without massive corridor improvement projects and takings, the County is mainly limited to existing road cartways & Right of Way. As such, staff will look at cost-effective benefits to the general public and utilize context-sensitive solutions for the roadway environment.

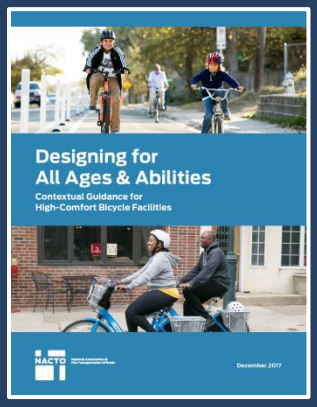
It is important to note that there is significant room for flexibility in highway and roadway design and the often used AASHTO Green Book is not a detailed design manual but a guidance document to be used by users to make better informed decisions. There is a significant range of roadway conditions within Mercer County so a “one size fits all” approach will not work. Context sensitive solutions must be used to reflect the location and community. As a result, a range of design reference and guidance documents will be used to design and implement bicycle facilities throughout the County. The following page refers to the most current and applicable reference documents for Mercer County staff.

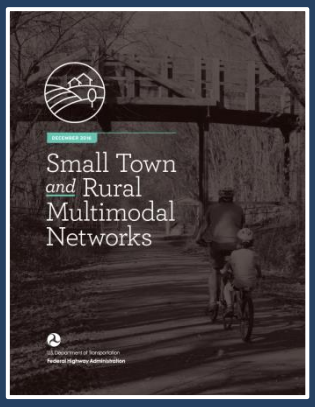
It is important to note that the County does however need to follow the Manual on Uniform Traffic Control Devices (MUTCD) to stay in standards conformance with FHWA and can only follow recommendations if in line with the MUTCD. The MUTCD is adopted by reference in accordance with Title 23, United States Code, Section 109(d) and Title 23, Code of Federal Regulations, Part 655.603, and is approved as the national standard for designing, applying, and planning traffic control devices. As the MUTCD and other federal guidance changes, these recommendations may change during the life of this plan.

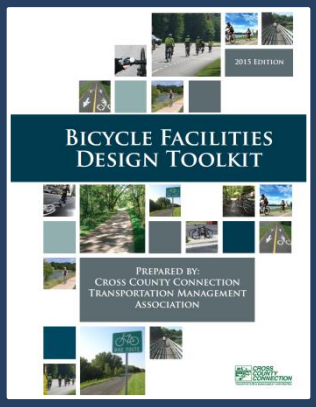
AASHTO GREEN BOOK NOTE:

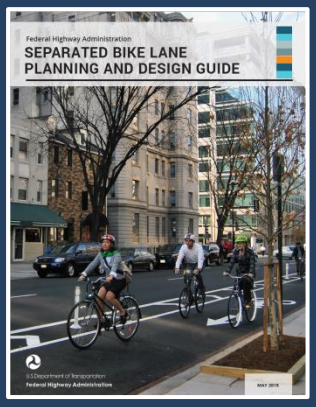
“The intent of this policy is to provide guidance to the designer by referencing a recommended range of values for critical dimensions. It is not intended to be a detailed design manual that could supersede the need for the application of sound principles by the knowledgeable design professional. Minimum values are either given or implied by the lower value in a given range of values. The larger values within the ranges will normally be used where the social, economic, and environmental (S.E.E.) impacts are not critical.”

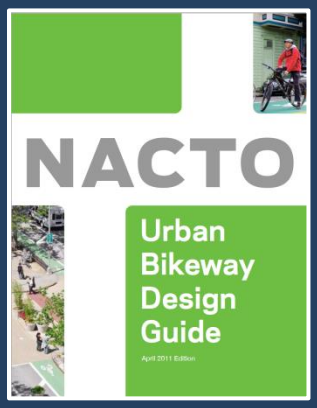
Reference and Guidance Documents

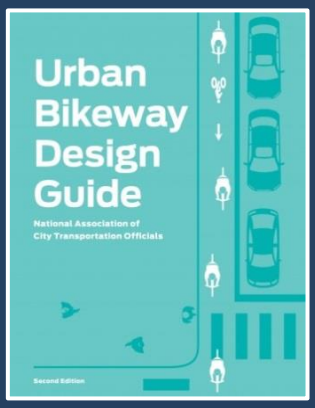


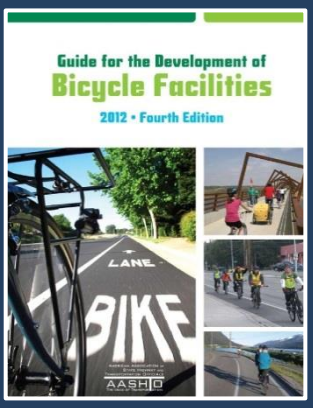


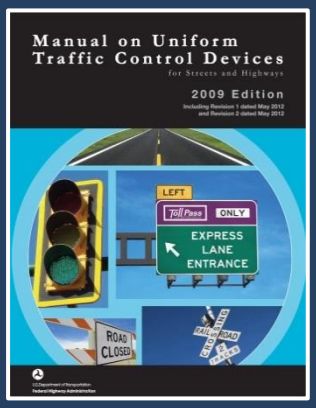


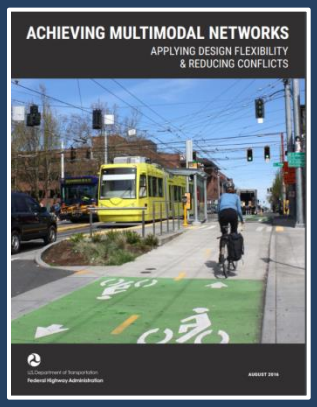


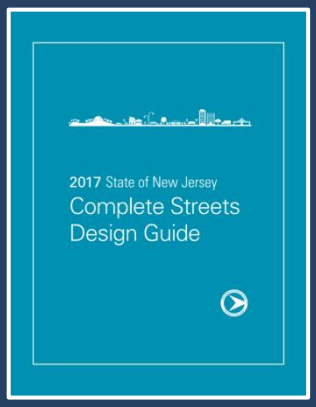


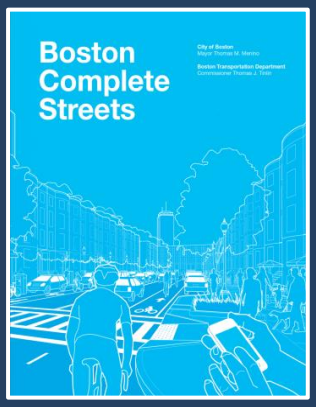


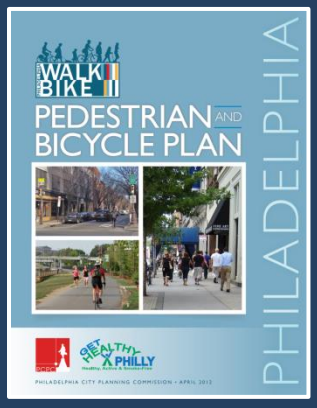


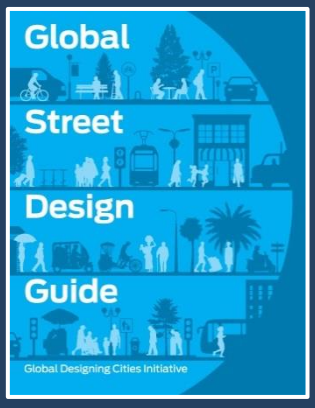


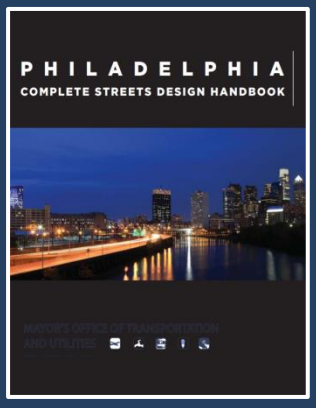












Bicycle Facilities To Be Considered

1. Sharrows and Shared Lane Markings
2. Bikable Paved Shoulders *(temporary or when cartway restricted)
3. Standard Bike Lanes
4. Buffered Bike Lanes (Painted and Rumble)
5. Two-Way Cycle Tracks & Hybrid Bike Lanes
6. Separated/ Protected Bike Lanes
7. Multi-Use Path and Shared-Use Paths
8. Through Lanes
9. Combines Bike Lane/ Turn Lanes
10. Intersection Crossings
    - Intersection Bike Box
    - Two-Stage Turn Queue Box
    - Protected Intersection
    - Signal Timing and Cycle Length
    - Leading Bike/ Pedestrian Interval
    - Signalized Turns
    - Bike Boxes and Two-Stage Bike Turn Boxes
11. Road Diet and Lane Diets
12. Driveway Design
13. Bikeway through Existing Bridge and Underpass/ Tunnel Considerations
14. Entrance/ Exit Ramp Designs
15. Midblock Crossings
16. Pavement Markings, Wayfinding, and Signage Standards (MUTCD)

Sharrow

A sharrow, or shared lane marking, is a street marking indicating that a lane should be used by both bicyclists and motor vehicles. The image, a bicycle below two wide directional arrows, identifies proper bicyclist positioning within the cartway. Sharrows can also be helpful tools for wayfinding and signaling directionality.

Benefits

> Does not require additional street space.

> Reduces bicyclists riding against motor vehicle traffic.

> Provide wayfinding and directionality guidance for bicyclists.

Considerations

> “May Use Full Lane” Signs encourage bicyclists to use the full lane to discourage unsafe within-lane passing

>Bike-and-chevron lane sharrow marking were approved for use within the US per the 2009 MUTCD.

> Frequency of sharrows should be increased when being used to fill gaps in other facilities, or in areas with high motor vehicle volume/speed.

> Placing sharrows in the center of a travel lane when possible will reduce marking wear from motor vehicle tires.

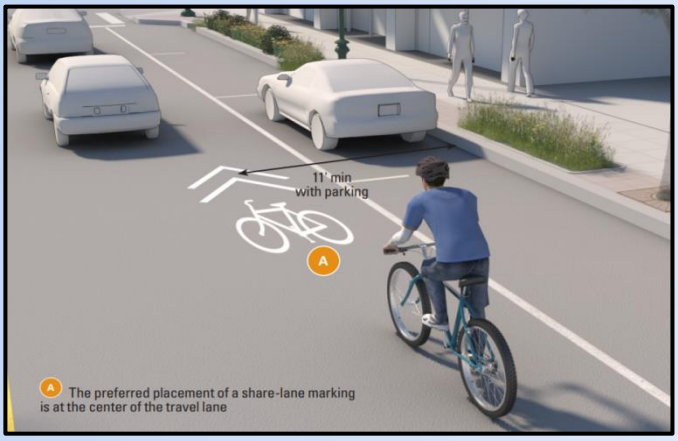
> The “door zone” should be avoided when determining lateral sharrow placement.

> In the absence of on-street parking, sharrows should be placed so as to avoid gutters, seams and other hazardous obstacles.

> The chevron orientation may be adjusted to serve wayfinding purposes.

> Color may be used to enhance the visibility of the sharrow.

Source: Town of Frisco, CO



Source: NJDOT Complete Streets Design Guide

Design Recommendations

-Sharrow spacing, high volume street: 50-100’

-Sharrow spacing, low volume street: 250’ or more

-Minimum distance from curb: 4’ (no parking)

-Shared Lane Marking (MUTCD 9C-9)

-MUTCD Sign Options: R4-11 > W11-1 & W16-1

Mercer County Bicycle Facility Selection Table

	USLIMITS2 Recommended Speed						
ADT	≤ 20	25	30	35	40	45	≥50
≤ 2,500	A B C D E F	A B C D E F	C D E F	C D E F	C D E F	D* E F	F
2,500–5,000	B C D E F	B C D E F	C D E F	C D E F	D* E F	D* E F	F
5,000–10,000	B C D E F	B C D E F	C D E F	C* D E F	D* E F	D* E F	F
10,000–15,000	C* D E F	C* D E F	C* D E F	C* D* E F	D* E F	D* E F	F
15,000-30,000	C* D E F	C* D E F	C* D E F	D* E F	E F	E* F	F
≥30,000	F	F	F	F	F	F	F

A: Shared Street/Bicycle Boulevard
B: Shared-lane Markings
C: Bicycle Lane
D: Buffered Bicycle Lane
E: Separated Bicycle Lane
F: Shared-use Path

C*: Bicycle Lane (After careful consideration)
D*: Buffered Bicycle Lane (After careful consideration)
E*: Separated Bicycle Lane (After careful consideration)

Bikable Paved Shoulder

Paved shoulders may be used as space for bicyclists and pedestrians to travel adjacent to a motor vehicle lane and provide motorists with an area to pull over in emergencies. In cases of incomplete bicycle networks, paved shoulders can serve as an unofficial connection until such connection can be made.

Benefits

> May not require additional street space.

> Reduces bicyclists riding against motor vehicle traffic.

> Provides wayfinding and directionality guidance for bicyclists.

Considerations

> Physical separation, such as rumble strips in the buffer area, can be used to alert drivers that they are encroaching on the bike lane and increase bicyclist comfort/safety.

> Bicyclist signage is not required, but could be used to signify a bicycle route.

> The solid shoulder line should be discontinued at intersections and major driveways. Dotted white lines may be used to extend the shoulder and signify bicycle travel space through these areas.

> Provide more than the minimum 4' shoulder width when possible to increase bicyclist and pedestrian comfort.

> Contrasting colors may be used to distinguish the shoulder from the motor vehicle lanes.

> Paved shoulders should be considered during routine roadway maintenance, reconstruction, and in new constructions.

Above: Children riding bikes in shoulder of Pond Road in Robbinsville, NJ.
Source: Jerry Foster

Source: Alta Planning + Design (CC-BY-SA)

Design Recommendations

-Paved shoulders can be considered as a precursor to dedicated bicycle facilities and marked routes

-Minimum shoulder width: 4' (wider shoulders and rumble strips should be considered on roads with higher speeds AADTs)

-If rumble strips included, place rumble strips to overlap with the roadway edge line

>Rumble lines should provide a 12' gap every 40'-60' to allow for bicycle access into and out of the shoulder

- *12 inch spacing center to center*
- *6-8 inches long perpendicular to roadway*
- *6 inches wide, measured parallel to roadway*
- *3/8 inch deep*

Standard Bicycle Lane

Standard bicycle lanes are delineated by solidly striped lines and can be marked with a combination of bicycle symbols, directional arrows, and words. Lanes are located between a vehicular travel lane and parking or the curb, directing bicyclists to move with traffic.

Benefits

> Further separates sidewalks, if present, from motor vehicle travel lanes.

> Provides a space exclusively for bicyclist travel.

> Establishes a level of predictability for bicycle and vehicle placement and behavior.

Considerations

> Markings for bike lanes should not be dotted when passing through a driveway crossing, as driveways are not considered intersections (MUTCD 2009, AASHTO Bike Guide 2012).

> When determining the width of bike lanes, one should take into account the presence of curb faces, guardrails, on-street parking, and other features.

> Larger bike lanes (~7') may enable parking or driving within the lane. In this case, consider adding a buffer zone to clarify.

> When the bike lane is adjacent to a guard rail or physical barrier, add two feet to the bike lane width.

> A distance of four inches should be used to separate a bike lane from a parking lane.

> Obstacles in the bicycle lane such as gutters, drainage inlets, and utility covers should be designed so as not to interfere with bicycle tires. These features should be oriented appropriately and level with the ground.

Above: Standard bike lane in West Windsor, NJ *Source: Jerry Foster*

Source: Chicago Department of Transportation

Design Recommendations

-Lane width: 4'-6'

-Cartway width: 28' min.

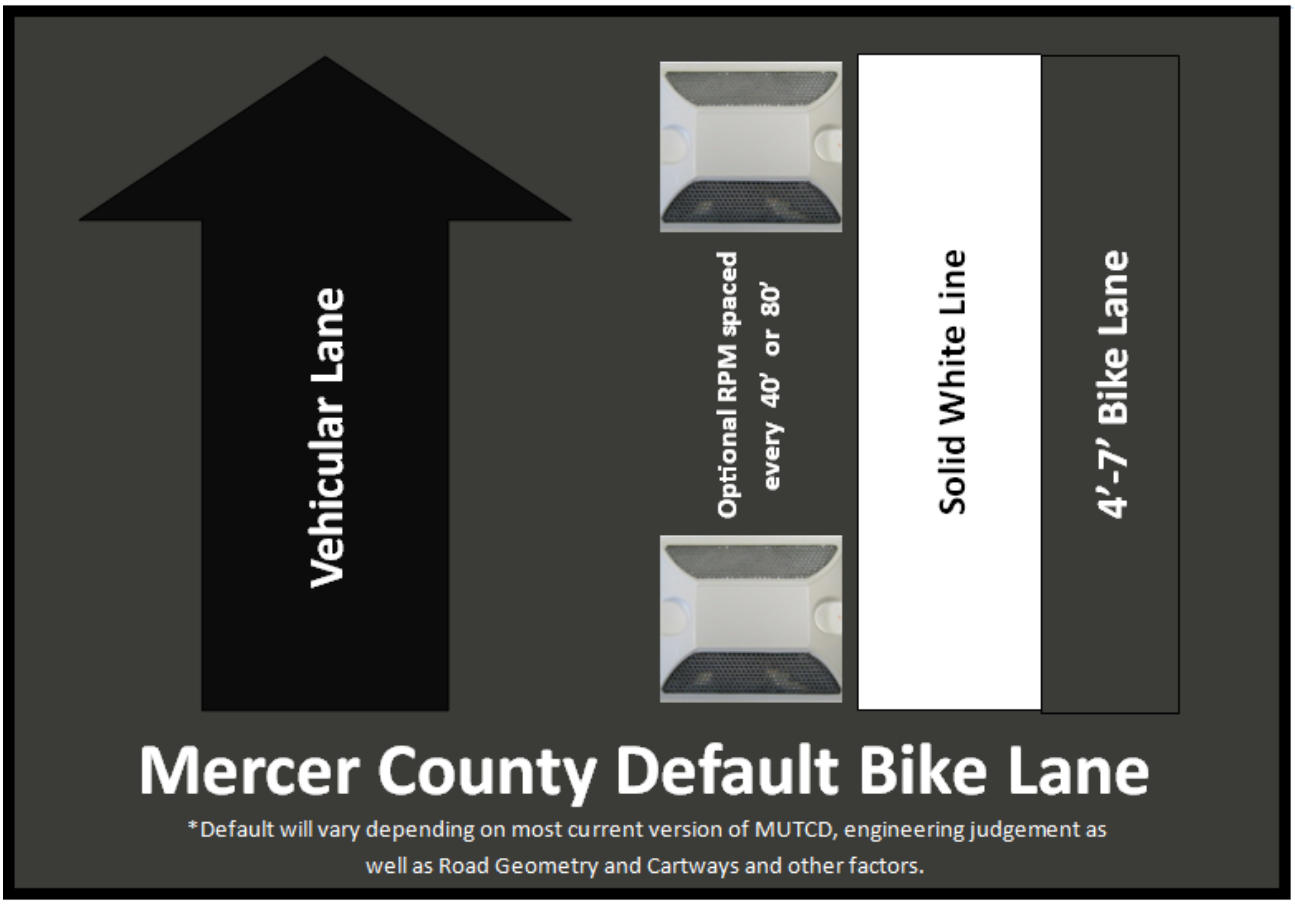
-Line width: 6"-8"

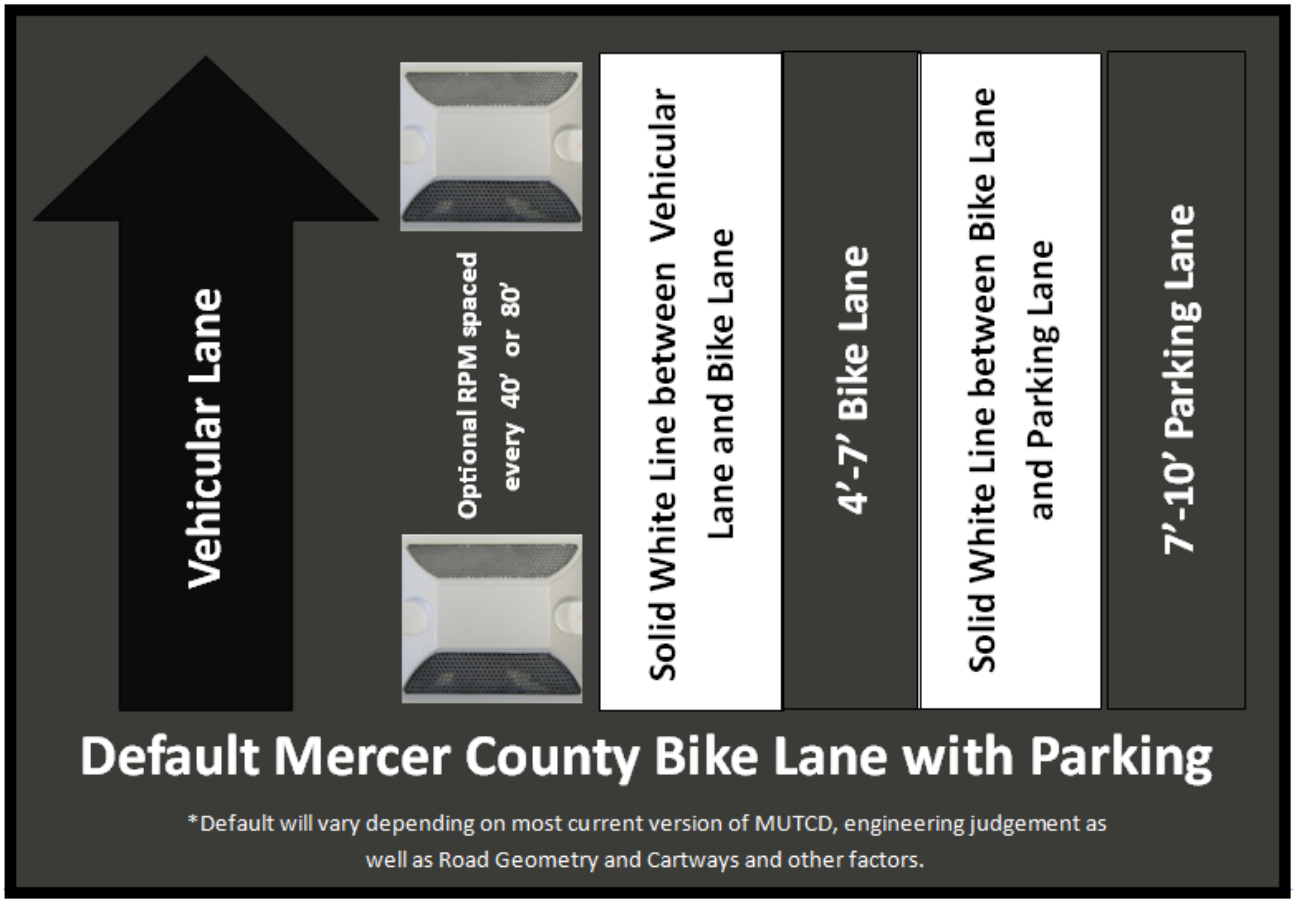
>Green paint can be an appropriate tool in areas where motor vehicles need to cross bike lanes, such as merging. (MUTCD Interim Approval)

Mercer County Bicycle Facility Selection Table

	USLIMITS2 Recommended Speed						
ADT	≤ 20	25	30	35	40	45	≥50
≤ 2,500	A B C D E F	A B C D E F	C D E F	C D E F	C D E F	D* E F	F
2,500–5,000	B C D E F	B C D E F	C D E F	C D E F	D* E F	D* E F	F
5,000–10,000	B C D E F	B C D E F	C D E F	C* D E F	D* E F	D* E F	F
10,000–15,000	C* D E F	C* D E F	C* D E F	C* D* E F	D* E F	D* E F	F
15,000-30,000	C* D E F	C* D E F	C* D E F	D* E F	E F	E* F	F
≥30,000	F	F	F	F	F	F	F

A: Shared Street/Bicycle Boulevard
B: Shared-lane Markings
C: Bicycle Lane
D: Buffered Bicycle Lane
E: Separated Bicycle Lane
F: Shared-use Path
C*: Bicycle Lane (After careful consideration)
D*: Buffered Bicycle Lane (After careful consideration)
E*: Separated Bicycle Lane (After careful consideration)


Vehicular Lane
Optional RPM spaced every 40' or 80'
Solid White Line
4'-7' Bike Lane
Mercer County Default Bike Lane
*Default will vary depending on most current version of MUTCD, engineering judgement as well as Road Geometry and Cartways and other factors.


Vehicular Lane
Optional RPM spaced every 40' or 80'
Solid White Line between Vehicular Lane and Bike Lane
4'-7' Bike Lane
Solid White Line between Bike Lane and Parking Lane
7'-10' Parking Lane
Default Mercer County Bike Lane with Parking
*Default will vary depending on most current version of MUTCD, engineering judgement as well as Road Geometry and Cartways and other factors.

Buffered Bicycle Lane

To increase separation between bikers and motor vehicle traffic, bicycle lanes may be enhanced with a buffer. Buffers can include visual separation, such as a painted area marked with longitudinal stripes, or physical separation such as rumble strips to alert drivers when they are entering the bike lane. Buffer treatments improve safety and bicyclist comfort on roadways with high traffic volumes and speed, as well as those with trucks or oversized vehicles.

Benefits

> Expands the benefits of a conventional bike lane by providing greater distance between bicyclists and motor vehicles compared to conventional bike lanes.

> Allows space for bicyclists to pass each other without having to enter the vehicle travel lane.

>Distinguishes larger bike lanes from travel or parking lanes.

> Can create separation between bicyclists and 'door zone'.

Considerations

> Physical separation, such as rumble strips in the buffer area, can be used to alert drivers that they are encroaching on the bike lane and increase bicyclist comfort/safety.

> A bike lane should be transitioned to a through bike lane when a right turn only lane approaches, placed to the left of the turn lane. If space does not permit, a shared bike lane/turn lane should be used.

> At intersections without a right turn only lane, buffer markings should become a conventional dashed line. Bike boxes may also be helpful in these scenarios.

>A 6"-8" solid white line may be painted to mark the separation from a motor vehicle travel lane.

Above: Buffered bike lane on Warren Street in the City of Trenton, NJ. Source: Jerry Foster

Above: Double White Line Buffered Bike Lanes on Scotch Road, Ewing.

Design Recommendations

-Lane width: 4'-6'

-Cartway width: 35' min

-Buffer width: 12" White Line or other buffer ≥18"

>Optional rumble lines should provide a 12' gap every 40'-60' to allow for bicycle access into and out of their lane.

-A buffered bike lane is allowed as per MUTCD guidelines for buffered preferential lanes (section 3D-01).

-Buffer width: 3 ft. min. for hatching within buffer

"When crosshatch markings are used in paved areas that separate traffic flows in the same general direction, they shall be white and they shall be shaped as chevron markings, with the point of each chevron facing toward approaching traffic…" (MUTCD section 3B.24)

Mercer County Bicycle Facility Selection Table

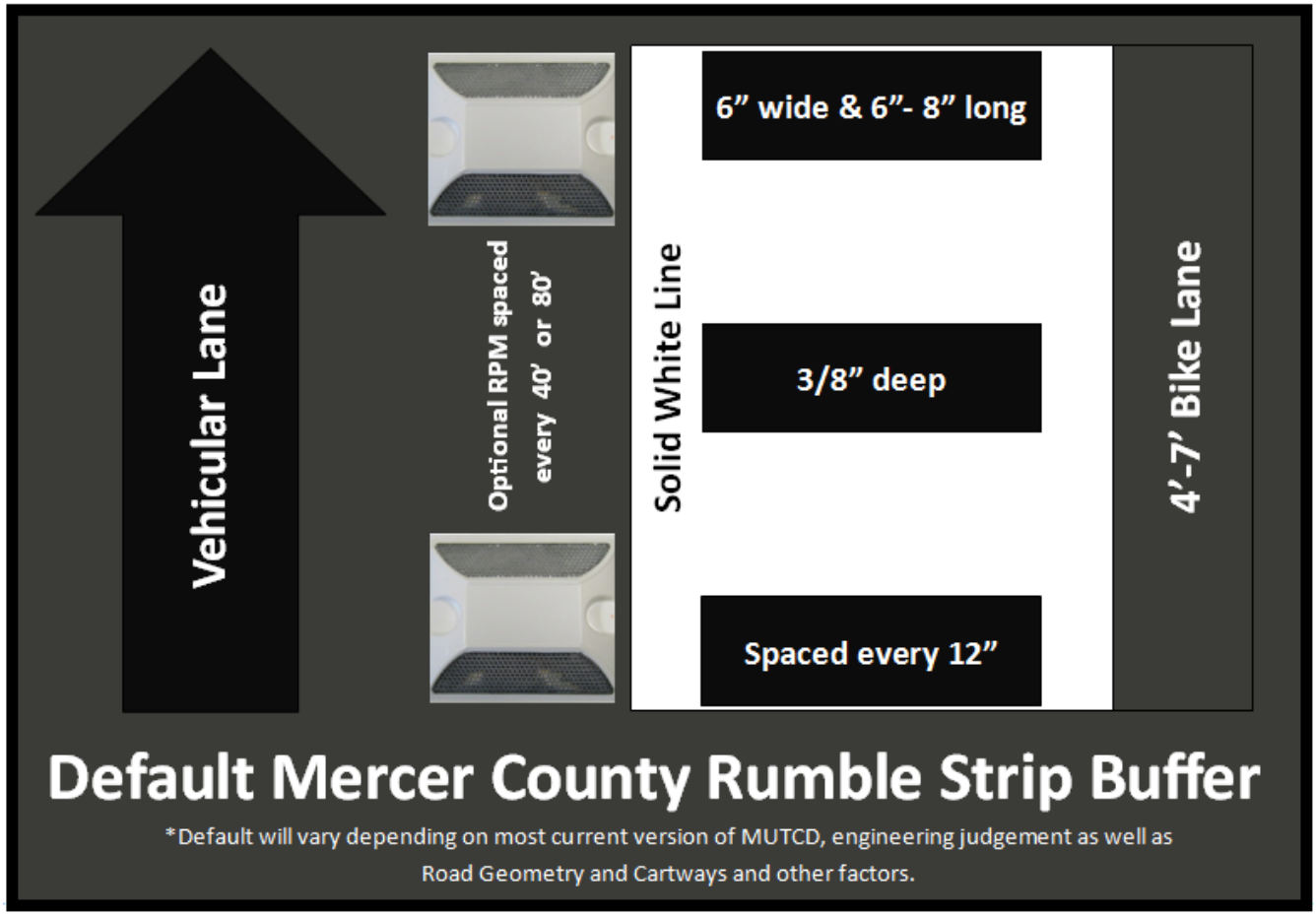
	USLIMITS2 Recommended Speed						
ADT	≤ 20	25	30	35	40	45	≥50
≤ 2,500	A B C D E F	A B C D E F	C D E F	C D E F	C D E F	D* E F	F
2,500–5,000	B C D E F	B C D E F	C D E F	C D E F	D* E F	D* E F	F
5,000–10,000	B C D E F	B C D E F	C D E F	C* D E F	D* E F	D* E F	F
10,000–15,000	C* D E F	C* D E F	C* D E F	C* D* E F	D* E F	D* E F	F
15,000-30,000	C* D E F	C* D E F	C* D E F	D* E F	E F	E* F	F
≥30,000	F	F	F	F	F	F	F

A: Shared Street/Bicycle Boulevard
B: Shared-lane Markings
C: Bicycle Lane
D: Buffered Bicycle Lane
E: Separated Bicycle Lane
F: Shared-use Path

C*: Bicycle Lane (After careful consideration)
D*: Buffered Bicycle Lane (After careful consideration)
E*: Separated Bicycle Lane (After careful consideration)

Default Mercer County Painted Buffer

*Default will vary depending on most current version of MUTCD, engineering judgement as well as Road Geometry and Cartways and other factors.



Default Mercer County Rumble Strip Buffer

*Default will vary depending on most current version of MUTCD, engineering judgement as well as Road Geometry and Cartways and other factors.

Separated Bicycle Lane

Separated bicycle lanes utilize a vertical buffer to distinguish the bicycle lane from motor vehicle traffic. Separated bicycle lanes differ from multi-use paths in that they are exclusively for bicyclists. They differ from conventional or buffered bike lanes in that they incorporate a vertical element as the buffer. Various treatments may be used as the vertical buffer, including: curbs, medians, on-street parking, landscaping, bollards, flexible delineators, and planters, depending on context and funding.

Benefits

> Provide a greater separation from motor vehicle traffic compared to buffered bike lanes.

> Appeals to more levels of bicyclists than conventional or visually buffered bike lanes.

> Bicyclist fear/risk of conflict with vehicles is eliminated, including crashes and “dooring”.

> Provide a more comfortable experience on high speed corridors than on-road shoulders.

Considerations

> Physically separated bicycle lanes can be one-way or two-way, as appropriate. Two-way separated bicycle lanes can be utilized to save space in the cartway.

> Solid white lines may be used to separate motor vehicle parking from the bicycle lane, diagonal crosshatching may be used to distinguish neutral areas.

> Increase the bicycle lane width when the gutter seam reaches more than 12 inches from the curb.

> Parking should not be allowed within 30 feet from an intersection to improve visibility when a lane is parking protected.

> To ease hazards at conflict areas, use color, yield lines and “Yield to Bikes” signage.

Source: Alta Planning + Design (CC-BY-SA)

Source: Dianne Yee, FHWA Separated Bike Lane Planning and Design Guide

Design Recommendations

-Lane width: 4’-6’

-Road width: 33’ min

-Buffer minimum: 1.5’ min; 3’ preferred

-Sight triangle from minor street crossings: 20’

-Sight triangle from driveway crossing: 10’

Mercer County Bicycle Facility Selection Table

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ADT	≤ 20	25	30	35	40	45	≥50
≤ 2,500	A B C D E F	A B C D E F	C D E F	C D E F	C D E F	D* E F	F
2,500–5,000	B C D E F	B C D E F	C D E F	C D E F	D* E F	D* E F	F
5,000–10,000	B C D E F	B C D E F	C D E F	C* D E F	D* E F	D* E F	F
10,000–15,000	C* D E F	C* D E F	C* D E F	C* D* E F	D* E F	D* E F	F
15,000-30,000	C* D E F	C* D E F	C* D E F	D* E F	E F	E* F	F
≥30,000	F	F	F	F	F	F	F

A: Shared Street/Bicycle Boulevard
B: Shared-lane Markings
C: Bicycle Lane
D: Buffered Bicycle Lane
E: Separated Bicycle Lane
F: Shared-use Path

C*: Bicycle Lane (After careful consideration)
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E*: Separated Bicycle Lane (After careful consideration)

Two-Way Cycle Track

Two-way cycle tracks are a physically separated set of bike lanes that allow bicycle movement in both directions on the same side of a street. Two-way cycle tracks tend to be good for bicyclists of all experience levels due to their physical separation from traffic, their ability to avoid the risk of being "doored" by a parked vehicle, and because they reduce indirect travel by allowing movement against the direction of one-way streets.

Benefits

>Provide dedicated and protected space to a cyclist, which improves their perceived feelings of safety.

> Reduces risk of dooring.

>Attractive to bicyclists with a range of ages and abilities.

Considerations

>Two way Cycle Tracks may be configured as:

- A protected cycle track at street level with a barrier such as a flexible delineator and/or with parking.
- Raised cycle tracks provide vertical separation from adjacent vehicular traffic.

>Function better on streets with fewer driveways and curb cuts and should be placed on the side of street with more desired destinations.

>Useful on streets with higher traffic volumes.

>Useful on higher stress streets with higher speeds and higher traffic volumes.

>Intersection controls should be oriented towards bicyclists going in both directions.

Above: Photo simulation of potential two-way cycle track on Lamberton Street in the City of Trenton. Source: NV5/ D&R Greenway Land Trust

Source: Dianne Yee, FHWA Separated Bike Lane Planning and Design Guide

Design Recommendations

-Minimum Track Width 8', Desired Width: 12'.

-When parking protected, 3' buffer is need between parked cars and cycle track.

-Dashed yellow centerline should be used to separate lanes.

-Approximately 10'-20' sight triangles are recommended at driveways and intersections. Parking should be prohibited near these driveways.

-Color, yield markings, and signage should be used to identify conflict zones.

-A "ONE WAY" sign (MUTCD R6-1, R6-2) should be provided if located on a one way street.

-A "DO NOT ENTER" with "EXCEPT BIKES" sign (MUTCD R5-1) sign should be provided.

Multi-Use Sidepath

A sidepath is a bidirectional shared use path located immediately adjacent and parallel to a roadway and provides a travel area separate from motorized traffic for bicyclists, pedestrians, skaters, wheelchair users, joggers, and other users. Sidepaths can offer a high-quality and low-stress experience for users of all ages and abilities using the network for transportation or recreation as compared to on-roadway facilities in heavy traffic environments

Benefits

>Encourages bicycling and walking in areas where high-volume and high-speed motor vehicle traffic would otherwise discourage it.

>Appropriate for walkers and bikers, as well as wheelchairs, roller blades, skateboards, etc.

> Provides a more appropriate facility for users of all ages and abilities than shoulders or mixed traffic facilities on roads with moderate or high traffic intensity.

>Very supportive of rural character when combined with vegetation.

Considerations

>Utilize medians and raised crossings at intersections to prioritize path travel and increase safety/comfort of path users.

>Widths and design details of sidepath elements may vary in response to the desire for increased user comfort and functionality, the available right-of-way, and the need to preserve natural resources.

>Landscaping can be used to further increase the separation between a path and the roadway, and add to the recreational appeal of the facility.

>When appropriate, sidepaths should transition to on-road facilities when the path ends.

Above: Penn Street Multi-Use Path in Philadelphia *Source: DRWC*

Above: Sidepath in Lawrence Township, NJ *Source: Jerry Foster*

Mercer County Bicycle Facility Selection Table

	USLIMITS2 Recommended Speed						
ADT	≤ 20	25	30	35	40	45	≥50
≤ 2,500	A B C D E F	A B C D E F	C D E F	C D E F	C D E F	D* E F	F
2,500–5,000	B C D E F	B C D E F	C D E F	C D E F	D* E F	D* E F	F
5,000–10,000	B C D E F	B C D E F	C D E F	C* D E F	D* E F	D* E F	F
10,000–15,000	C* D E F	C* D E F	C* D E F	C* D* E F	D* E F	D* E F	F
15,000-30,000	C* D E F	C* D E F	C* D E F	D* E F	E F	E* F	F
≥30,000	F	F	F	F	F	F	F

A: Shared Street/Bicycle Boulevard
B: Shared-lane Markings
C: Bicycle Lane
D: Buffered Bicycle Lane
E: Separated Bicycle Lane
F: Shared-use Path

C*: Bicycle Lane (After careful consideration)
D*: Buffered Bicycle Lane (After careful consideration)
E*: Separated Bicycle Lane (After careful consideration)

Multi-Use Sidepath

Design Recommendations

-Multi-Use sidepaths can be incorporated at any speed or volume of adjacent roadway.

-Intersections need to be carefully designed and other guides should be referenced for additional information.

-10' width is recommended in most situations and will be adequate for moderate to heavy use.

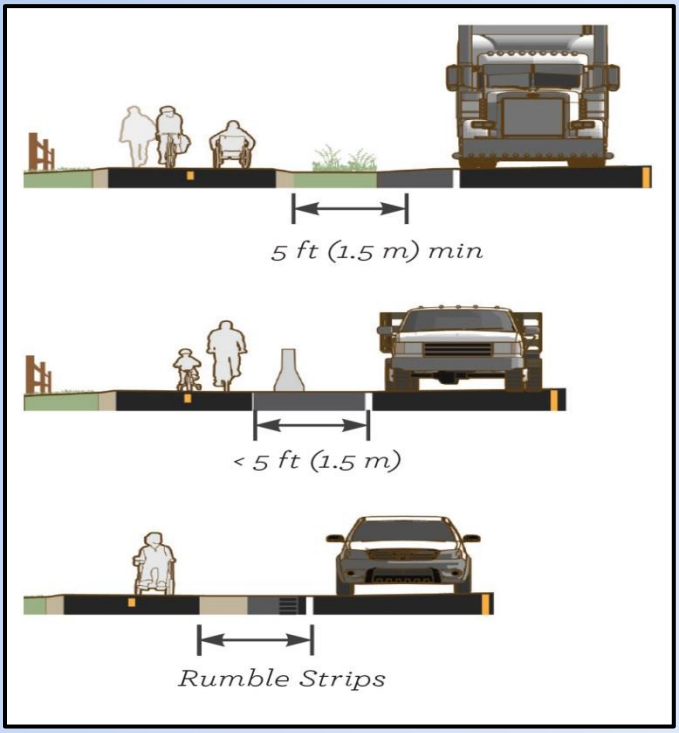
-A "BIKES YIELD TO PEDS" (R9-6) sign may be used at the entrances of path segments to remind bicyclists of the requirement to yield.

-A "RIGHT TURN YIELD TO PEDESTRIANS" sign (MUTCD R10-15) should be provided at road crossings with right turn intersections.

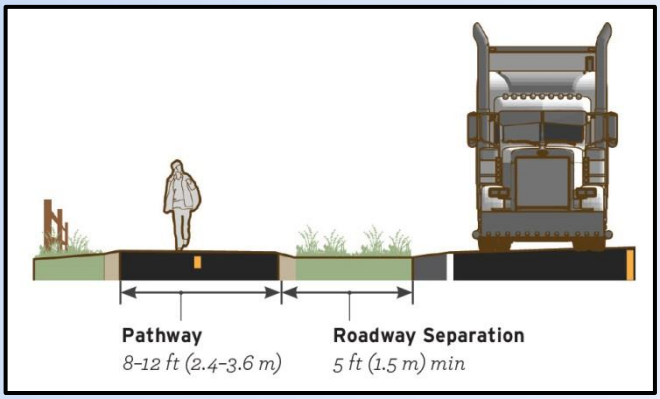
-Preferred minimum separation width is 6.5' and minimum separation distance is 5'

-Where a sidepath terminates, it may be necessary for path users to transition to a facility on the opposite side of the road.

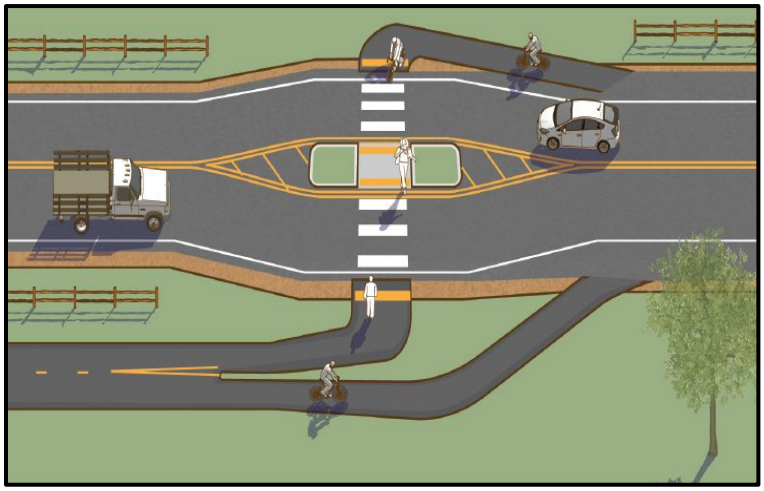
-Paths with a high volume of bidirectional traffic should include a centerline. When striping is required, use a 4 inch broken yellow center line stripe with 4 inch solid white edge lines. Solid center lines can be provided on tight or blind corners and on the approaches to roadway crossings.



Barriers can be used between the sidepath and the roadway where a 5' separation cannot be provided. In extremely constrained conditions for short distances, on-roadway rumble strips may be used as a form of separation. Source: FHWA Small Town and Rural Design Guide



Recommended Sidepath Dimensions To Be Considered (adjacent to roadway. Source: FHWA Small Town and Rural Design Guide)



Above: Sidepath Separation Distance at Road Crossings (left) and transition from a sidepath on one side to shoulders on each side of the road (right). Source: FHWA Small Town and Rural Design Guide

Multi-Use Sidepath Intersections and Crossings

Multi-Use Sidepaths require special attention at intersections and crossings, especially at mid-block crossings where motorists may be unaware of them. In the State of New Jersey, vehicles must yield the right of way to pedestrians at marked crosswalks and at intersections where stop signs or flashing red signals are in place. Pedestrians must yield the right-of-way to vehicles when crossing outside of a marked crosswalk or an unmarked crosswalk at an intersection with no stop sign. In many instances, multi-use paths will need to cross a County Highway away from a marked intersection.

Considerations

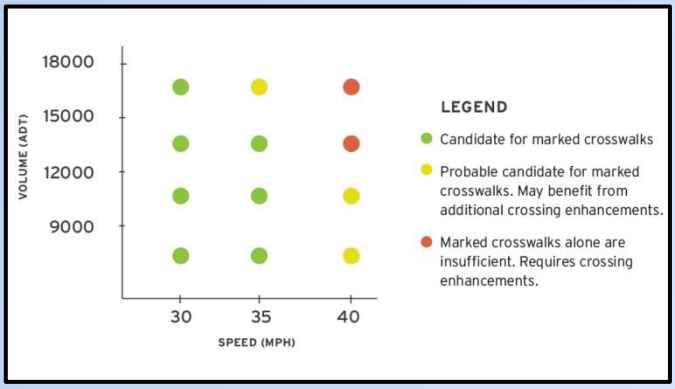
>Designs should consider the desire for natural directional flows, and the potential for conflicts with adjacent traffic. Use should be made of median islands and horizontal deflection of the roadway travel lanes to slow motor vehicle traffic and offer improved crossing conditions for path users.

>A basic marked shared use path crossing consists of a marked crosswalk, plus signs and other markings to slow or stop traffic.

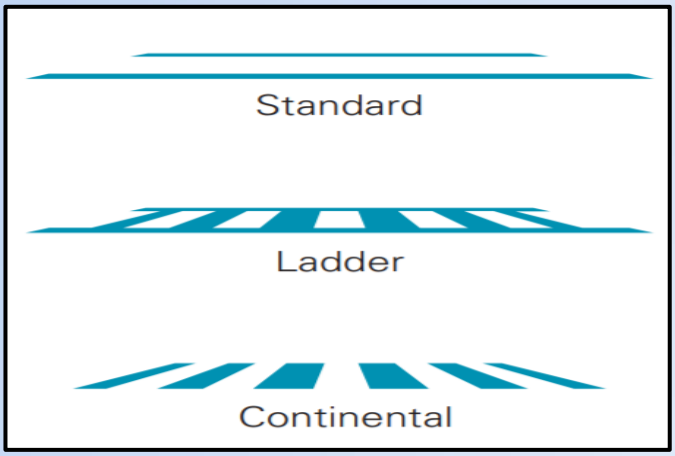
>High-visibility crosswalk markings are the preferred marking type at uncontrolled marked crossings. Transverse lines are “essentially not visible” when viewed from a standard approaching vehicle.

>At high-speed and high-volume intersections, it may be necessary to make full intersection improvements.

>Visual obstructions should be low to provide unobstructed sight of the crossing from the major street. Both motorists and path users should have a clear and unobstructed view of each other at intersections and driveways.



FHWA Safety Effects of Marked Crosswalks at Uncontrolled Locations 2005 recommends crossing enhancements on high-speed and high-volumes roadways where crosswalk markings alone are not a viable safety measure.
Source: FHWA

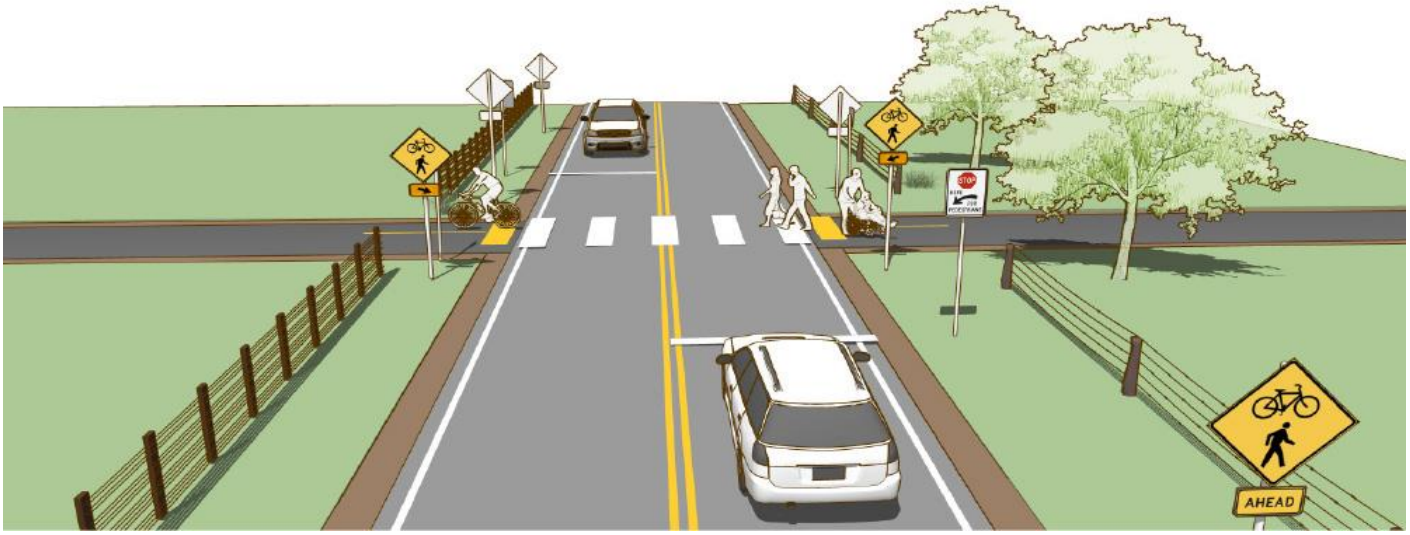


Standard crosswalk striping, shown at top, often has very poor visibility to motorists, particularly on higher speed roadways or where the striping has faded. Ladder or Continental striping is preferable in most situations because it significantly improves the visibility of the crossing to motorists and maintains this visibility better as it ages.
Source: NJDOT Complete Streets Design Guide

Source: Press of Atlantic City

Multi-Use Sidepath "Mid-Block" Crossings

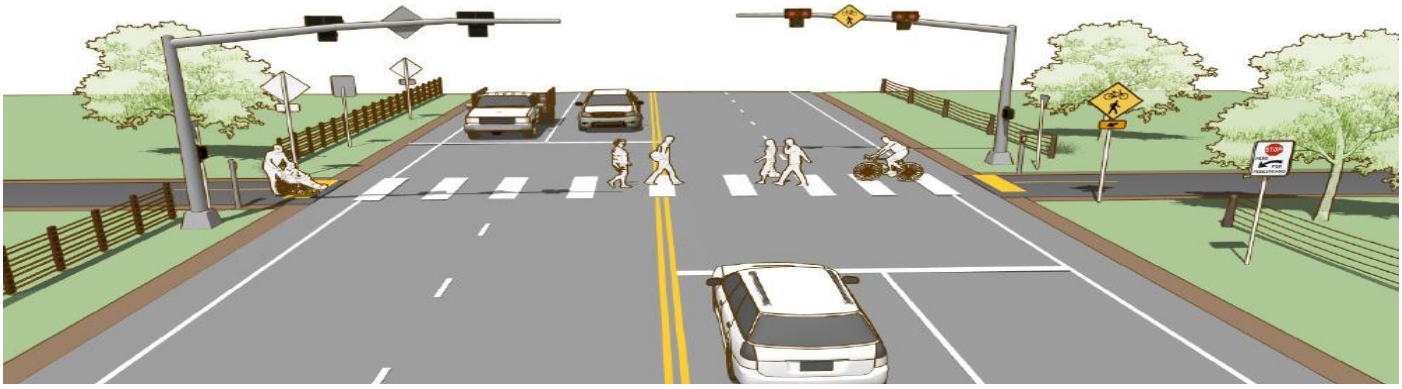
FHWA's report *Safety Effects of Marked Crosswalks at Uncontrolled Locations, 2005* recommends crossing enhancements on high-speed and high-volumes roadways where crosswalk markings alone are not a viable safety measure. There are several methods to create these safer crossings. For crossings on low-speed and low-volume roads, a simple marked crossing consisting of a marked crosswalk, signs and other marking to slow traffic, such as below. Crosswalk markings are necessary to establish a legal crosswalk at areas away from intersections. Crossing sign assemblies and advance crossing sign assemblies using W11-15 and W16-7P signs should be used to warn users of the crossing location and high-visibility crosswalk markings should be used.



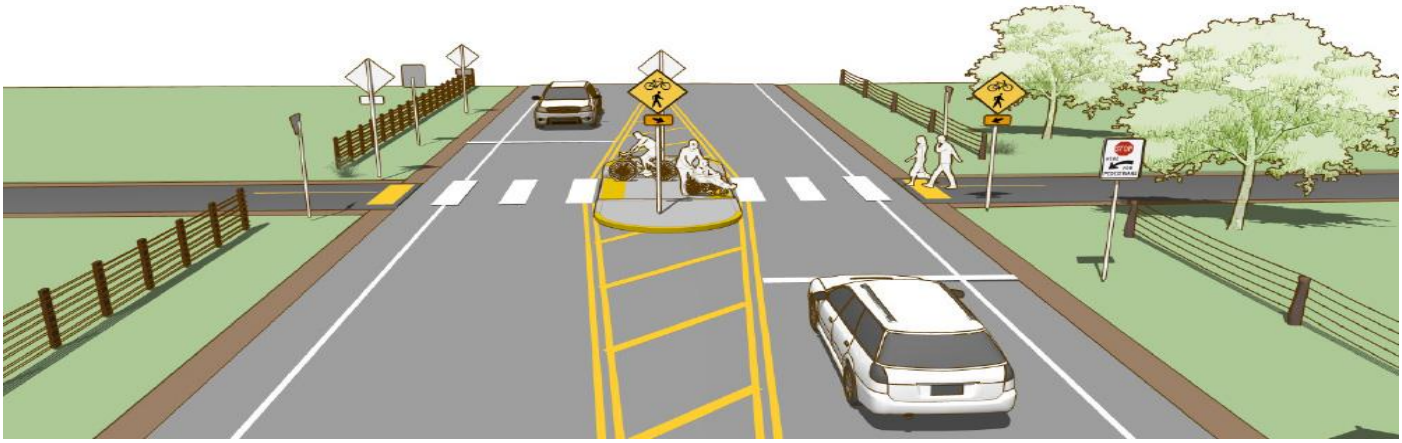
For higher-speed and higher-volume roads where greater visibility or traffic control is desired, a rectangular rapid flash beacon (RRFB) or pedestrian hybrid beacon (PHB) may be used. Where drivers fail to stop for pedestrians and compliance is low, RRFBs should also be incorporated. RRFBs are a yield enhancement device for use at uncontrolled crossings. They may be configured with solar power where it is the most cost-effective option. See an updated FHWA Interim Approval (March 2018) for guidance on the application of RRFBs. "State Law: Stop for Pedestrian" may also be placed to advise drivers of this requirement.

Multi-Use Sidepath “Mid-Block” Crossings

On treacherous and hard to cross multilane streets with high volumes and few gaps for crossing, a Pedestrian Hybrid Beacon (PHB) may be used to increase yielding rates. A pedestrian hybrid beacon, also known as a high intensity actuated crosswalk (HAWK), is a pedestrian actuated traffic control device for mid-block pedestrian crossing locations. They enable pedestrians to cross high-speed and high-volume roadways while traffic is stopped. As the name implies, it is essentially a hybrid between a RRFB and a full traffic signal. It provides planners and engineers with an intermediary option for locations that do not meet requirements for a traffic signal warrant, but where traffic conditions exceed the limitations of an RRFB. PHB’s provide a red signal indication to drivers, and create yielding rates similar to that of a conventional traffic signal. PHBs are particularly useful on undivided roadways with multiple lanes in any one direction. PHBs are an FHWA Proven Safety Countermeasure.



For many road segments, crossing islands or pedestrian refuge islands can be considered. These median islands are beneficial on roadways with high volumes and/or high speeds, and on roadways with three or more travel lanes. Median islands particularly benefit people who may travel slower, such as children, older adults, and people with disabilities. They enable pedestrians to make a crossing in two stages—crossing one direction of vehicular travel lanes, pausing at the island, and then completing the crossing. This reduces the exposure time of pedestrians to vehicular traffic. Crossing islands should be a minimum of 6 feet wide, with a preferred width of 8 to 10 feet, and a minimum of 6 feet long. They should also have a “nose” that extends beyond the crossing to protect pedestrians from turning vehicular traffic. Median islands are an FHWA Proven Safety Countermeasure which the FHWA identified as an effective, proven, tested and studied tool to promote safety.



Additional Design Considerations and Facilities

Through Lanes

A through bike lane uses dashed lines and/or colored lane to position bicyclists to the left of right turn lanes or to the right of left turn lanes and gets bicycles across dangerous or busy intersections.

Benefits

>Reduces conflict between turning motorists and cyclists going straight.

>Provides more predictable travel movements for all users.

>Alerts motorists to yield to merging traveling.

Design Recommendations

-Desired width of a through lane is 4'-6'.

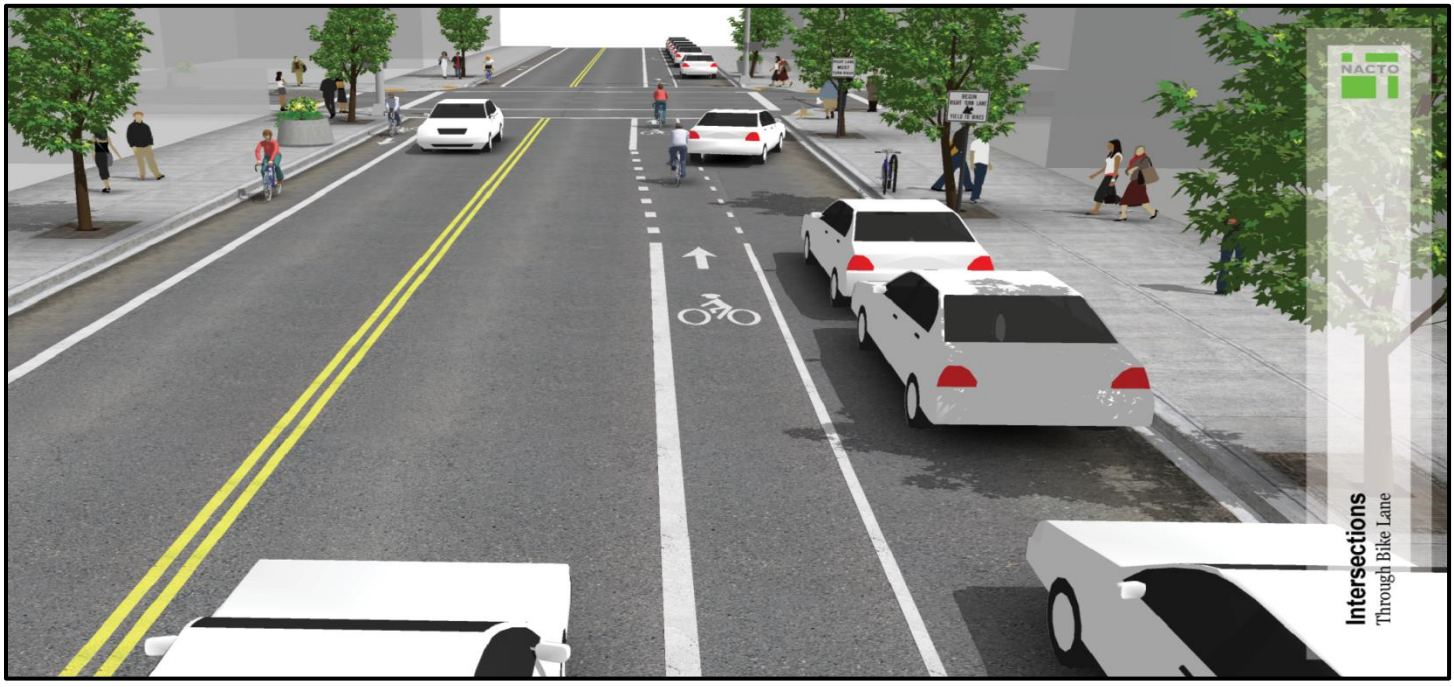
-Dotted white line should be 6'' wide and 2 'long with 6' gap between dashes.

-Dashed lines should begin a minimum of 50' before an intersection, 100' if on a high volume corridor.

-The through bike lane shall be placed to the left of the right-turn only lane.

Source: NACTO, Boulder, CO

Source: NACTO, Portland, OR



Source: NACTO, Urban Street Design Guide

Combined Right Turn / Bike Sharrow

A combined bike sharrow lane / turn lane uses signage and bike sharrow markings within a turn lane to suggest a route to delineate space for cyclists and to guide them through the intersection. Sharrow markers also provide a visual warning to vehicles to watch for cyclists.

Source: SF Municipal Transportation Authority

Source: NACTO

Benefits

>Helps to position and guide cyclists through intersections by aligning them to the left of right-turning vehicles and encourages motorists to yield to cyclists.

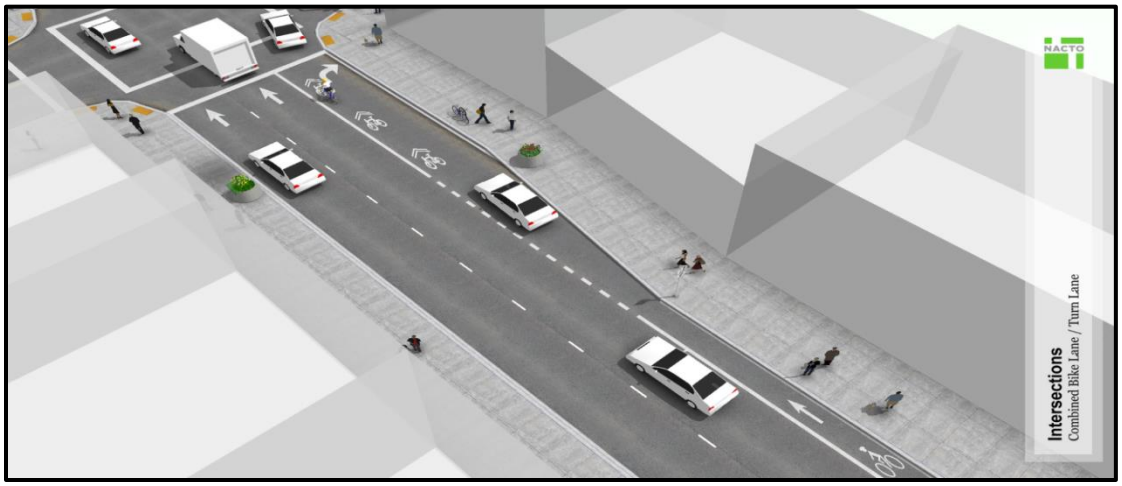
>Reduces risk of "right hook" collisions by keeping bikes left of vehicles making right turn. Cheapest alternative for streets with limited cartway.

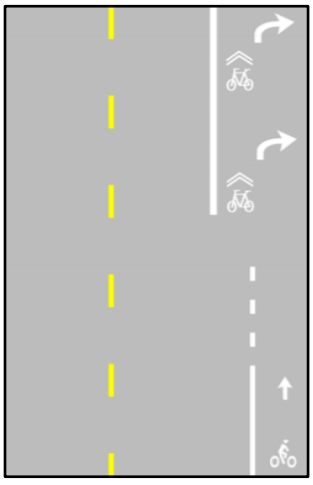
Design Recommendations

-Only MUTCD sharrow markings (with no alterations) shall be used to clarify bicyclist positioning within the combined lane. No bicycle lane markings or lines shall be used to attempt to create and establish a bike lane.

-Width of combined lane should be 9 feet minimum, 13 feet maximum. A full bicycle through lane can be accommodated if the vehicle right-turn only lane can be made 14 feet or wider.

-Chapter 5.3 of the NJDOT Roadway Design Manual: On land service highways states that where it is not practical to provide a shoulder adjacent to the outside lane (design exception required), the outside lane width shall be 15 feet to accommodate bicyclists. Where alternate bike access is provided, the outside lane width should be 1 foot wider than the adjacent through lane width. The designer should strive to accommodate the bicyclist and pedestrian on all projects.





Source: NACTO, Urban Street Design Guide (left); SF Municipal Transportation Agency (right)

Intersection Crossings

Intersection crossing markings help to guide bicyclists through intersections by providing clear and direct paths using arrows and dashes. These marking are also helpful in that they make bicyclists' paths more predictable for drivers, reinforcing that they have priority over turning vehicles and bringing attention to their presence.

Benefits

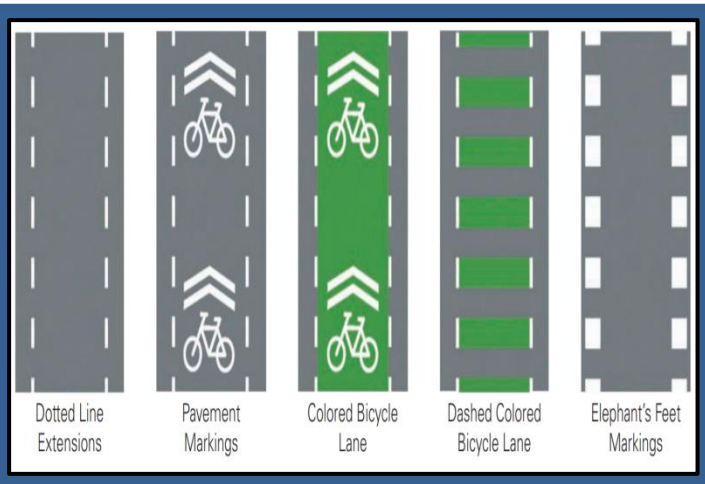
>Reduces conflict between turning motorists and cyclists going straight and Increases the visibility of bicyclists.

>Provides more predictable travel movements for all users.

>Guides bicyclists through the intersection in a straight and direct path.

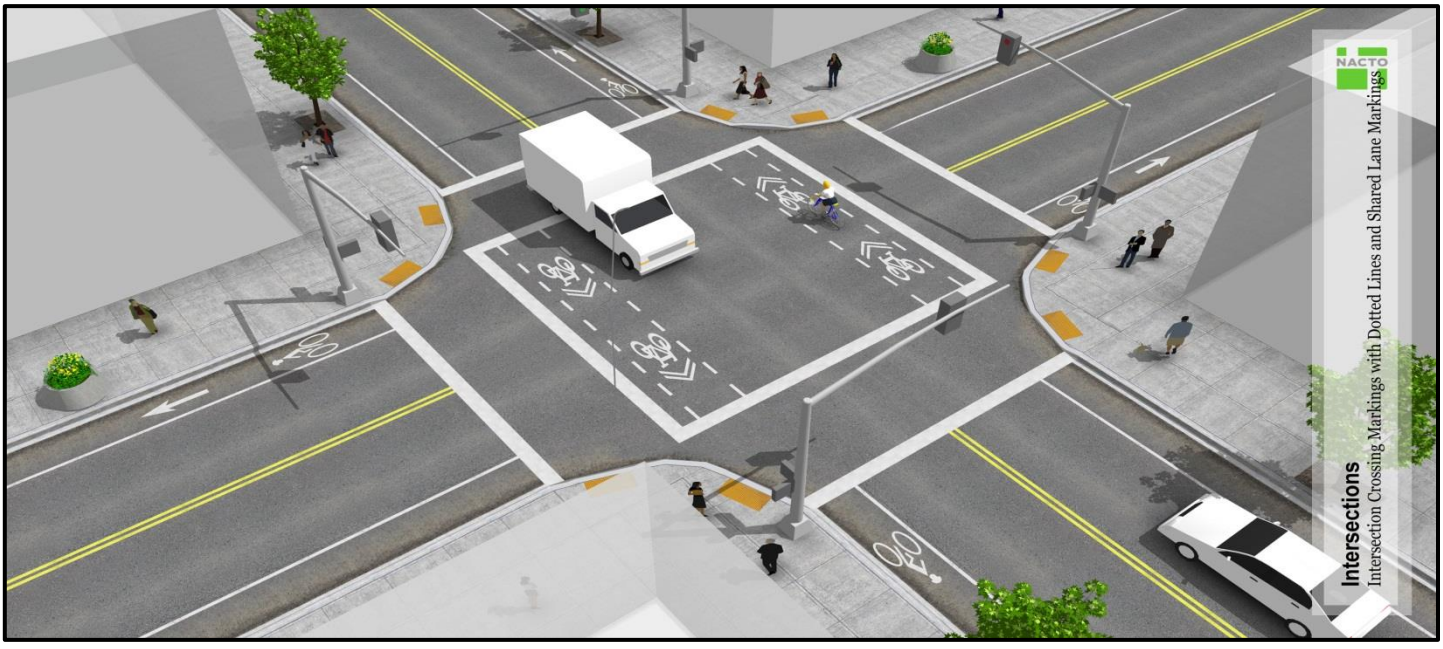
> Reinforces that through bicyclists have priority over turning vehicles or vehicles entering the roadway (from driveways or cross streets).

>Reduces bicyclist stress by delineating the bicycling zone.



Above: Types of possible markings *Source: NJDOT Complete Streets Guide*

Source: NACTO, Chicago, IL



Example of Intersection Markings *Source: NACTO, Urban Street Design*

Intersection Crossings

Design Recommendations

-Dotted lines shall bind the bicycle crossing space.

-Pavement markings extended into or continued through an intersection or interchange area shall be the same color and at least the same width as the line markings they extend.

-Striping width 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 elephant's feet markings.

-Dotted lines should be 2 foot lines with 2 to 6 foot spacing. Markings should be white, skid resistant and retro-reflective.

-Crossing lane width should match width and positioning of the leading bike lane.

-On crossings of two-way paths and cycle tracks, markings should indicate that there is two-way traffic either by marking the path center line through the intersection, or by marking bicycle silhouettes and / or chevrons in opposite directions in the two lanes. See Two-Way Cycle Tracks.

-Chevrons 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.

-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.

Above: Crossing of side street in Trenton, NJ *Source: Jerry Foster*

Source: NACTO, Urban Street Design Guide; NYC, NY

Source: NACTO, Urban Street Design Guide; Missoula, MT

Intersection Bike Box

A bike box is a designated area at the head of a traffic lane at a signalized intersection that provides bicyclists with a safe and visible way to get ahead of queuing traffic during the red signal phase.

Benefits

>Groups bicyclists together to clear an intersection quickly, minimizing impediment to transit or other traffic.

>Provides more predictable travel movements for all users.

>Helps prevent 'right-hook' conflicts with turning vehicles at the start of the green indication.

> Reduces signal delay for bicyclists.

>Facilitates bicyclist left turn positioning at intersections during red signal indication. This only applies to bike boxes that extend across the entire intersection.

>Facilitates the transition from a right-side bike lane to a left-side bike lane during red signal indication. This only applies to bike boxes that extend across the entire intersection.

Source: NJDOT Complete Streets Guide

Source: NACTO, Portland, OR

Source: NACTO, Urban Street Design Guide

Design Recommendations

-A box formed by transverse lines shall be used to hold queuing bicyclists, typically 10-16 feet deep. Deeper boxes show less encroachment by motor vehicles.

-Stop lines shall be used to indicate the point behind which motor vehicles are required to stop in compliance with a traffic control signal.

-Pavement markings shall be used and centered between the crosswalk line and the stop line to designate the space as a bike box. The marking may be a Bike Symbol (MUTCD 9C-3A) or Helmeted Bicyclist Symbol (MUTCD 9c-3B.)

-At intersections that currently permit right turns on red signal indications, a "No Turn on Red" sign shall be installed overhead to prevent vehicles from entering the Bike Box.

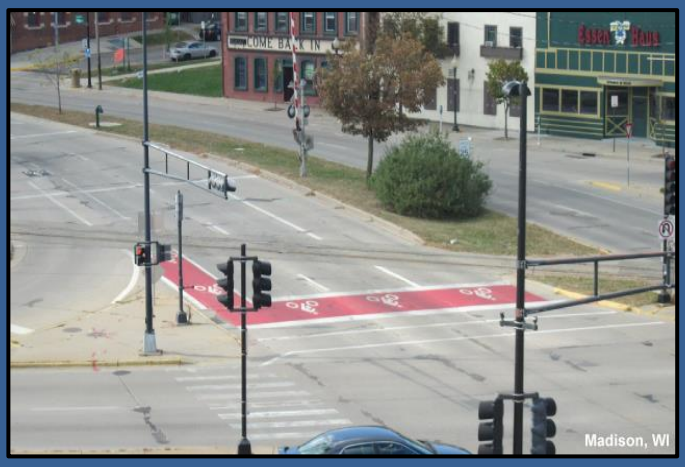
-A "Stop Here on Red" sign should be post-mounted at the stop line to reinforce observance of the stop line.

-Colored pavement should be used as a background color within the bike box to encourage compliance by motorists.

-An ingress lane should be used to define the bicycle space. Colored pavement may be used. When color is used, length shall be 25 to 50 feet to guarantee bicycle access to the box.

-An egress lane should be used to clearly define the potential area of conflict between motorists and bicyclists in the intersection when intersection is operating on a green signal indication.

-A "Yield to Bikes" sign should be post-mounted in advance of and in conjunction with an egress lane to reinforce that bicyclists have the right-of-way going through the intersection.



Source: NACTO, Madison, WI

Source: NACTO, Tucson, AZ

Source: NACTO, Austin, TX

Two-Stage Turn Queue Boxes

A two-stage bike turn box provides a more comfortable and safe way for bicyclists to cross multi-lane streets with high vehicle speeds or volumes. Similar to a jug-handle for motor vehicles, bicyclists complete a left turn by dividing it into two movements. Bicyclists first proceed through the intersection with traffic to a bike box on the far side of the intersection, where they position themselves in front of the traffic queue on the cross street. When the traffic signal turns green for the cross street, they cycle across the intersection with traffic, completing the left turn.

Benefits

>Improves bicyclist ability to safely and comfortably make left turns.

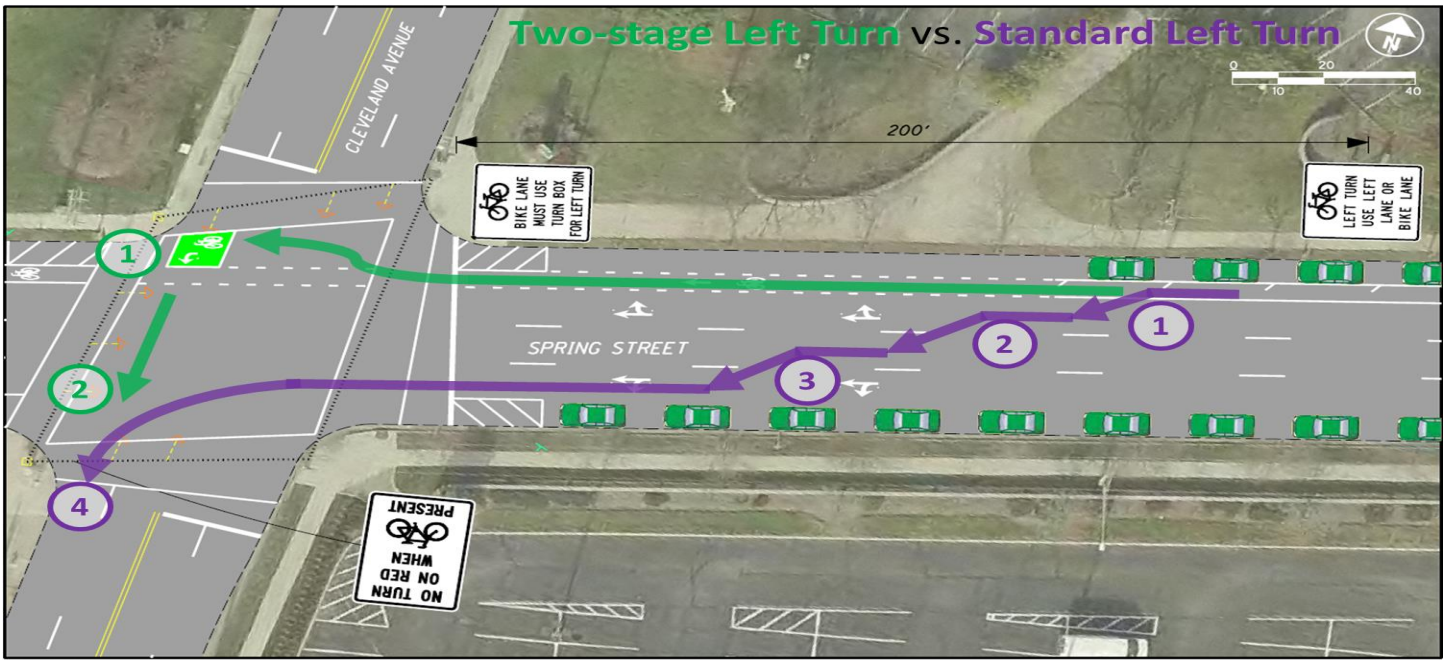
>Provides a formal queuing space for bicyclists making a two-stage turn.

>Reduces turning conflicts between bicyclists and motor vehicles.

>Prevents conflicts arising from bicyclists queuing in a bike lane or crosswalk.

Source: City of Columbus, Ohio

Source: NJDOT Complete Streets Guide



Source: City of Columbus, Ohio

Protected Intersection

A protected intersection extends the physical barrier of the protected bike lane into the intersection, creating a clear and safe, continuous path of travel for all modes. Protected intersections have four main design elements: a corner refuge island, a forward stop bar for cyclists, a setback bicycle and pedestrian crossing, and bicycle-friendly signal phasing. The corner refuge island is a physical barrier that protects people on bikes from cars making turns. After yielding to pedestrians, cyclists can either turn right safely or continue into the intersection past the crosswalk to the forward stop bar, where they can wait at a red light buffered from vehicles by the refuge island.

Source: Chicago Department of Transportation

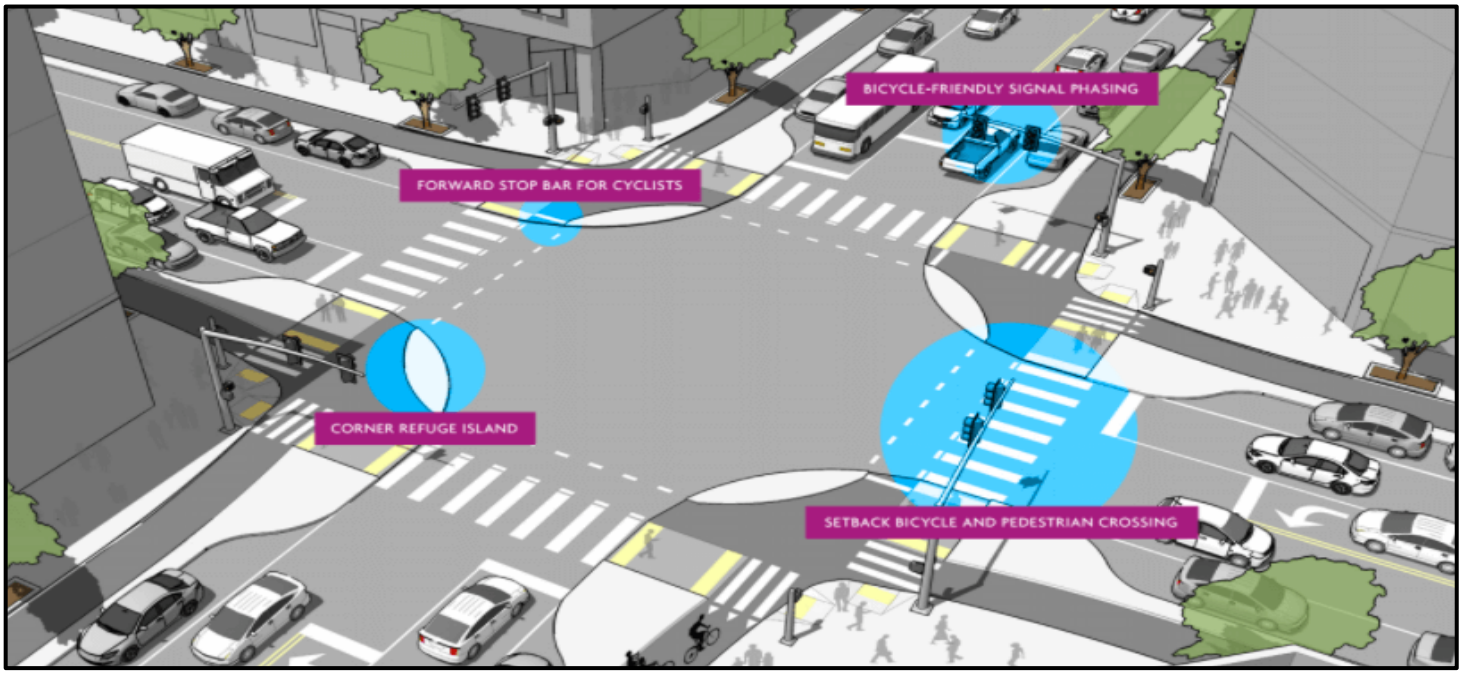
Source: Alta Planning, Salt Lake City

Benefits

>Improves bicyclist ability to safely and comfortably make left turns.

>Reduces turning conflicts between pedestrians, bicyclists and motor vehicles.

>Reduces crossing distances for bicyclists and pedestrians.



Source: Alta Planning

Lane Diets

A lane diet is a treatment that involves decreasing the size of lanes, rather than the number, to reduce vehicle speeds and encourage yielding. The size of the lane that is removed may be reallocated as a bicycle facility. According to the AASHTO Green Book, for rural and urban arterials, lane widths may vary from 10 to 12 feet. Ten feet is the recommended minimum width for travel lanes and turn lanes, while eleven feet is recommended for areas frequented by trucks and buses.

Benefits

>Narrower lanes typically result in lower speeds due to their effect on driver psychology, which can help to reduce the severity of crashes.

>Narrowed lanes help to create space for bicycle facilities.

>According to FHWA, there are "No significant safety or capacity differences between 10–foot and 12-foot wide travel lanes under most urban and suburban conditions."

Design Recommendations

-Lanes greater than 11 feet should not be used as they may cause unintended speeding and assume valuable right of way at the expense of other modes.

-Parking lane widths of 7–9 feet are generally recommended. Cities are encouraged to demarcate the parking lane to indicate to drivers how close they are to parked cars.

-For multi-lane roadways where transit or freight vehicles are present and require a wider travel lane, the wider lane should be the outside lane (curbside or next to parking).

Source: John Keating, Overland Park, Kansas

Source: NJDOT Complete Streets Design Guide

Road Diet

Generally, road diets involve reallocating roadway space by removing vehicle travel lanes from a roadway and using that space for other modes or uses. One of the most common conversions is moving from a four-lane road to one with two through lanes and a center two-way left-turn lane, an example of which is shown to the right. By reducing lanes, other features such as bicycle lanes, widened sidewalks, or landscaped boulevards can be added to the right-of-way, resulting in fewer vehicle conflicts and improved safety outcomes.

Benefits

> The space provided by removing a travel lane can be used to create bicycle lanes on both sides of the cartway.

> Bike lanes provide greater separation between motor vehicles and the sidewalk, creating a more comfortable pedestrian environment.

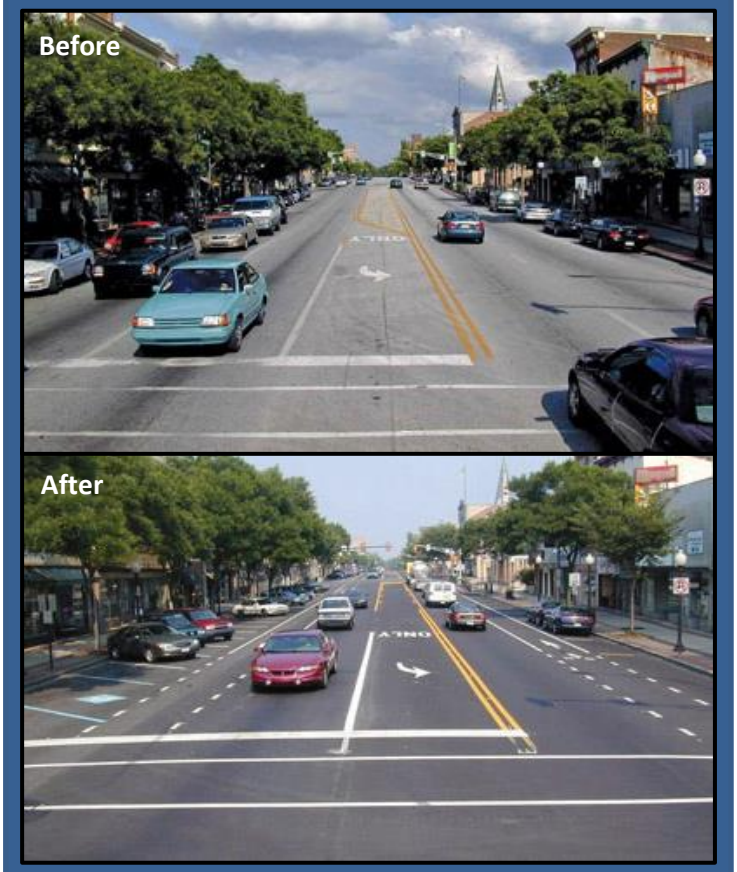
> Center turn lanes reduce crashes and conflicts with turning vehicles without reducing throughput. Center turn lanes have been shown to reduce crashes between 19% and 47%.

Design Recommendations

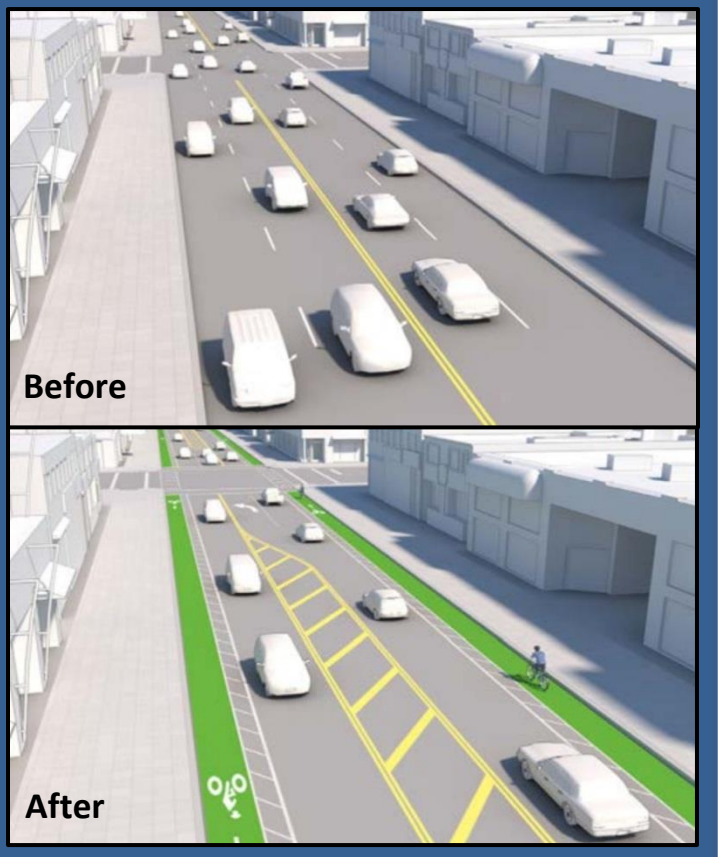
-Lane reductions on roadways with more than 20,000 AADT should be studied to assure that driveway access and signals are appropriate for higher volumes. Roadways with up to 25,000 AADT have successfully road dieted.

-Travel lane widths can be 10' to 12'.

-Width of center lane is 10' to 16' depending on types of vehicles using street.



Source: Michael Ronkin, Main Street, Pottstown, PA



Source: NJDOT Complete Streets Guide

Driveway Design

Driveways pose an often unforeseen danger to pedestrians and cyclists in that many are designed as intersections which promote high-speed turns and increase the likelihood that drivers will not stop for pedestrians or give cyclists the right of way.

Benefits

> Proper driveway design discourages high-speed turns and forces drivers to make slower turning movements. This allows drivers to better identify pedestrians and cyclists.

> Proper design is especially critical to safety for multi-use paths and facilities which include cyclists.

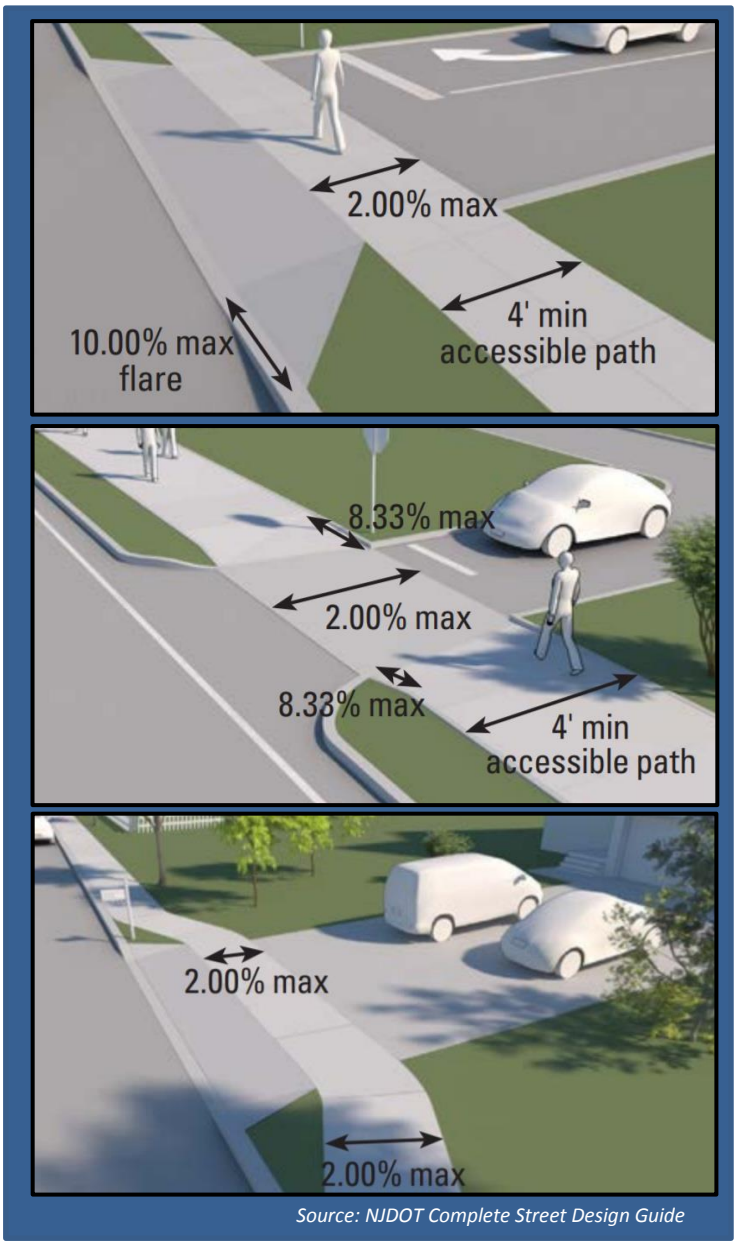
Design Recommendations

-According to ADAAG, driveways should be designed with the following guidance:

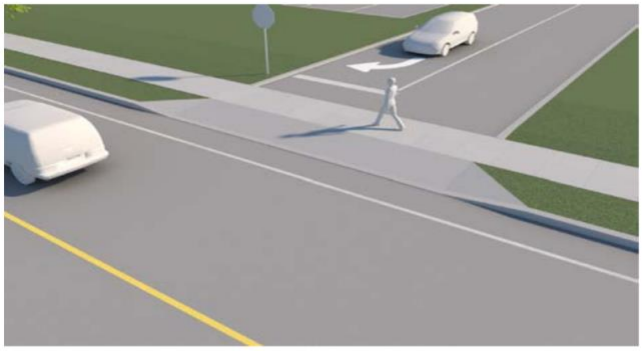
- *Cross slope should not exceed 2 percent.*
- *Changes in level or grade should be flush with a ¼-inch maximum gap in surface rise.*
- *The slope of the driveway apron flare should not exceed 10 percent.*
- *Sidewalk grade should not exceed 5 percent.*

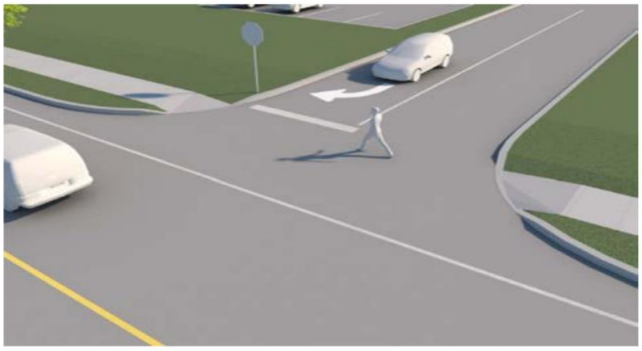
-Max grade differential between driveway apron and street shall be no more than 8%.

Where volumes are high, alternative B is preferred.



Source: NJDOT Complete Street Design Guide





Driveways should be designed for continuous and level pedestrian passage. Proper driveway design, such as in the above left, increases the visibility of pedestrians, encouraging drivers to stop. Driveways designed as intersections, such as in the above right, feature an interrupted crosswalk. This can reduce pedestrian visibility and increase the likelihood that drivers will not stop for pedestrians.

Source: NJDOT Complete Street Design Guide

Bikeways through an Existing Bridge

Bridges can be significant barriers to bicycle and pedestrian movement. Many bridges can be retrofitted to provide a bicycle/pedestrian crossing under the barrier by creating a crossing where there are no bicycle or pedestrian accommodations, or by upgrading the existing bicycle/pedestrian crossing.

Benefits

> Proper design allows for continuous bicycle facilities that are easy for cyclists or pedestrians to use.

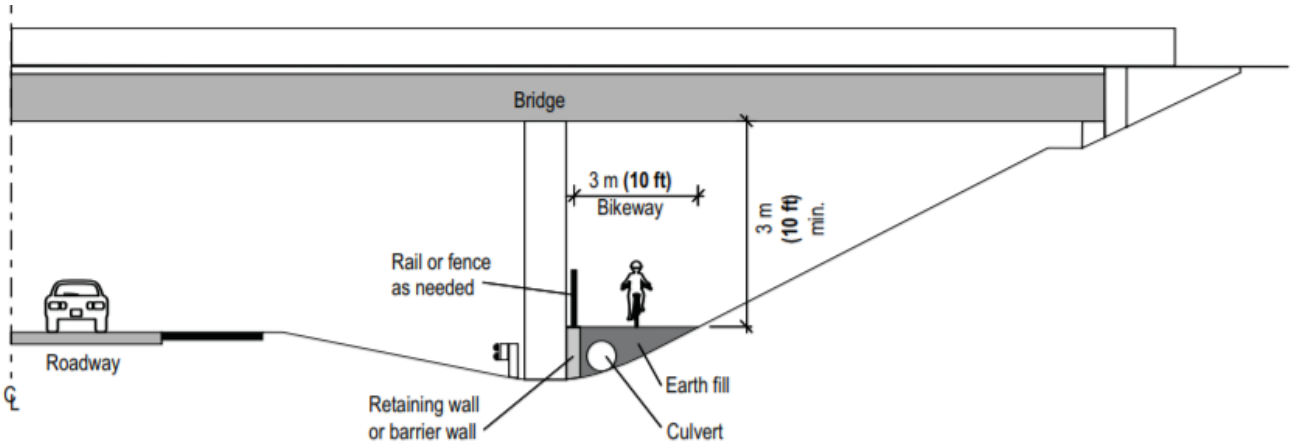
> Separating cyclists and pedestrians from vehicle traffic increases safety of all user groups.

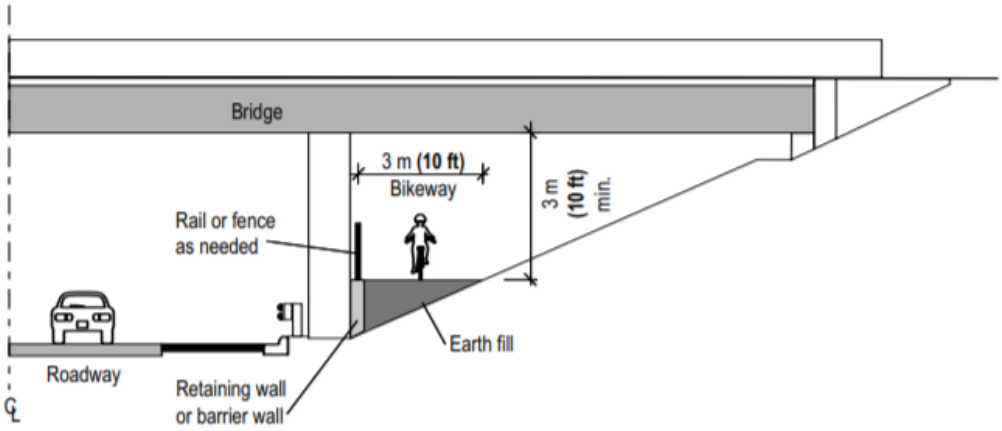
Design Recommendations

-It is preferred that bikeways have a width of 10 feet, but 8 feet may be allowable for short segments.

-Where access for emergency vehicles is necessary, vertical clearances shall be a minimum of 10 feet, otherwise vertical clearances over the bikeway shall be a minimum of 8 feet.

-Providing adequate drainage may also be a problem; providing a surface that does not become excessively slippery when wet is important. Proper drainage design is a key element to prevent wet silt deposits that are a common hazard for bicyclists using bridge underpasses.





Source: Minnesota Department of Transportation

Underpass and Tunnel Considerations

A bikeway underpass should be considered if there is no safe and direct on-street crossing, if the facility to be crossed is elevated, if an existing motor vehicle under-crossing is too narrow for a bicycle facility, and when the underpass would not require bicyclists to negotiate significant elevation changes. Underpass costs may be significantly lower than those for overpasses and encounter fewer constraints.

Benefits

>Underpasses are protected from weather and provide users from inclement weather. They also do not require snow removal or preventative application of deicing materials.

>Provides ability to reconnect divided neighborhoods and Provide critical connections within a municipality.

Design Recommendations

-Underpasses can be dark and intimidating to users and may pose safety concerns. Visibility through a tunnel and adequate lighting enhance users' perception of personal safety. For short underpasses or tunnels, modest lighting may all that is required. In many cases, lighting may be required on daily, 24-hour bases, especially for tunnels longer than 50 feet. All lighting should be recessed and vandal resistant.

-Underpasses are usually constructed of pre-cast concrete in a shape having the proper vertical/ horizontal clearances.

-Providing adequate drainage may also be a problem; providing a surface that does not become excessively slippery when wet is important. Proper drainage design is a key element to prevent wet silt deposits that are a common hazard for bicyclists using bridge underpasses.

-Underpasses need to be connected into Existing multi-use path networks with clear signage, adequate signage and ADA compatibility.

Above: Underpass in Northampton, Massachusetts
Below: Underpass in snowy winter of New Hampshire

Entrance Ramps/ Channelized Right-Turn Design

Some County arterials may contain high speed freeway-style channelized right-turn lane designs, which can create difficulties for bicyclists. The entrance lanes typically have intrinsic visibility problems because of low approach angles and feature high speed differentials between bicyclists and motor vehicles. Even with signage and striping improvements, free-flow ramps present significant challenges for pedestrians and bicyclists but getting bicycles across difficult to cross high-speed channelized turn lanes and entrance ramps is critical to the safety of cyclists.

Benefits

>Signage and striping provides a predictable environment to pedestrians, cyclists and vehicles.

Design Recommendations

-On low-speed entrance ramps (≤ 35 mph) the bike lane should travel straight through the merge area.

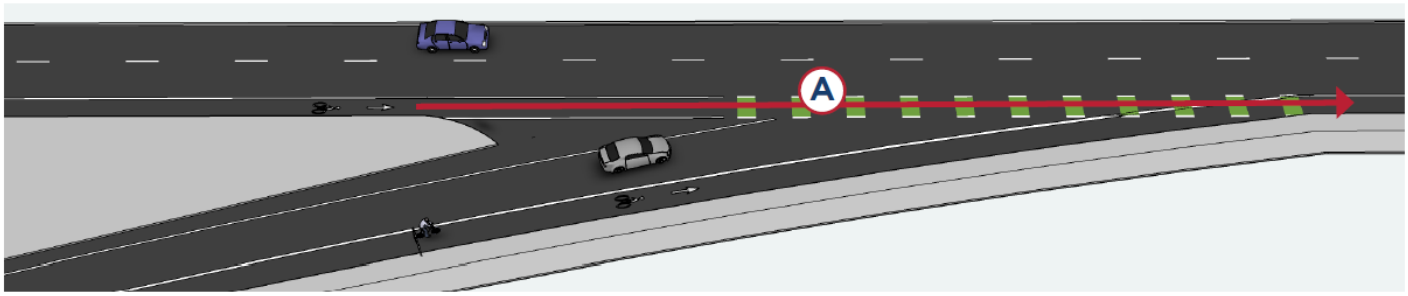
- Dashed lines, colored pavement and signs can be used to define bicyclist priority over merging traffic.

-At high-speed entrance ramps/ channelized right-turn lanes (≥ 40 mph), with dedicated receiving lanes, bicyclists should be encouraged to yield to merging traffic and cross when safe.

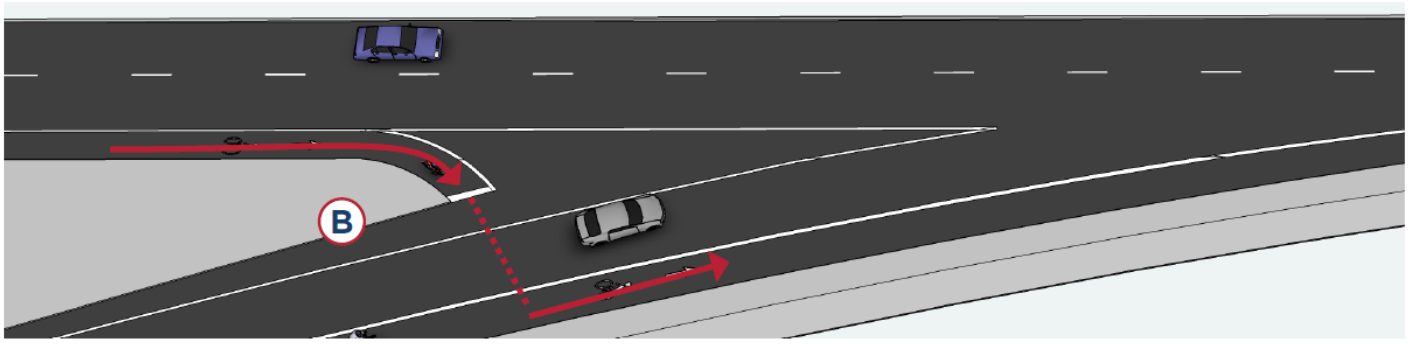
- Bike lane should be angled as close to a right angle as possible so as to increase the approach angle with entering traffic.

-The crossing should be positioned before the drivers' attention is focused on the upcoming merge.

Low Speed Entrance Ramp (Bicycle Priority)



High Speed Entrance Ramp (Motor Vehicle Priority)



Source: City of El Paso 2016 Bike Plan

Exit Ramps/ Channelized Right-Turn Design

Some County arterials may contain high speed freeway-style exit ramps and channelized right-turn lane designs, which can create difficulties for bicyclists. The entrance lanes typically have intrinsic visibility problems because of low approach angles and feature high speed differentials between bicyclists and motor vehicles. Even with signage and striping improvements, free-flow ramps present significant challenges for pedestrians and bicyclists but getting bicycles across difficult to cross high-speed channelized turn lanes and exit ramps is critical to the safety of cyclists.

Benefits

>Signage and striping provides a predictable environment to pedestrians, cyclists and vehicles.

Design Recommendations

-In constrained conditions, bicyclists may exit onto the sidewalk and complete the maneuver with pedestrians in the crosswalk.

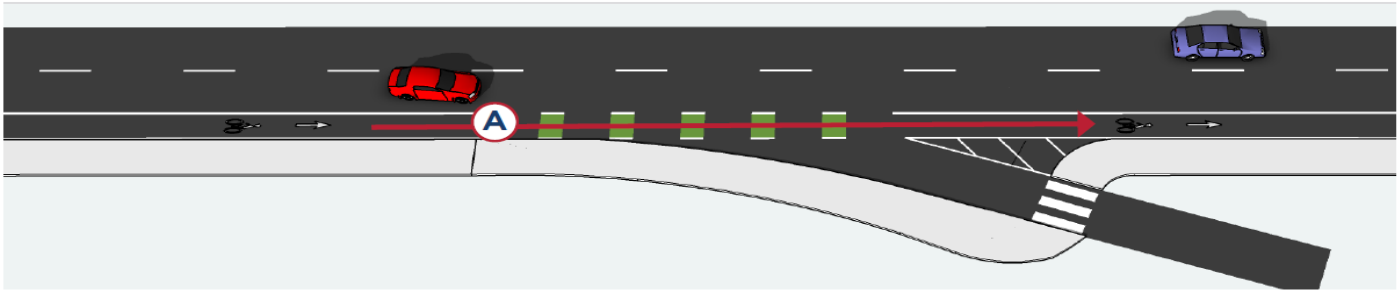
-On low-speed entrance ramps (≤ 40 mph) the bike lane should travel straight through the merge area.

- Dashed lines, colored pavement and signs can be used to define bicyclist priority over merging traffic.

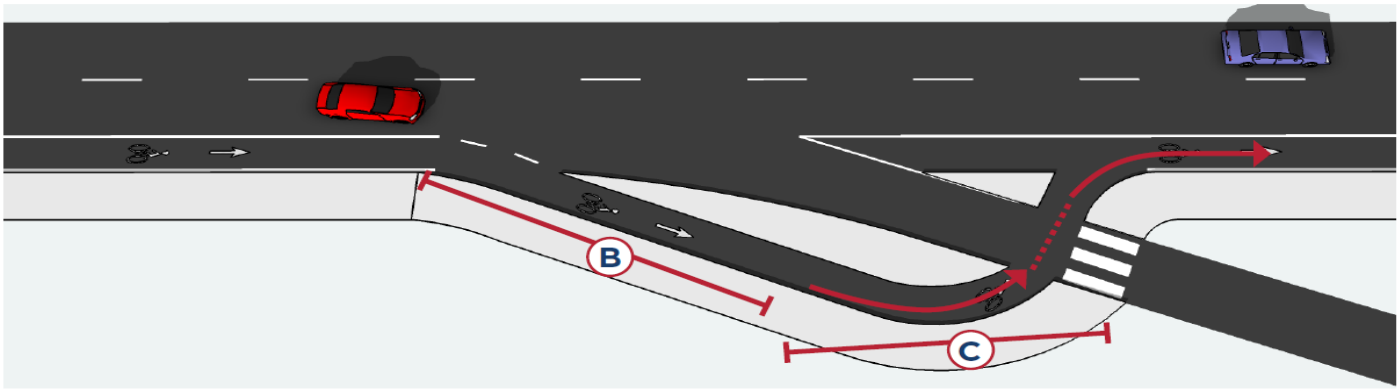
-On high-speed exit ramps (≥ 45 mph), use a jug handle turn to bring bicyclists to a visible location with exiting traffic.

- Design should include a *45 foot (35 foot minimum) taper from roadway.*
- Design should include a *45 foot (35 foot minimum) jughandle turn.*

Low Speed Exit Ramp (Bicycle Priority)



High Speed Exit Ramp (Motor Vehicle Priority)



Source: City of El Paso 2016 Bike Plan

Bicycle Facility Pavement Marking and Signage

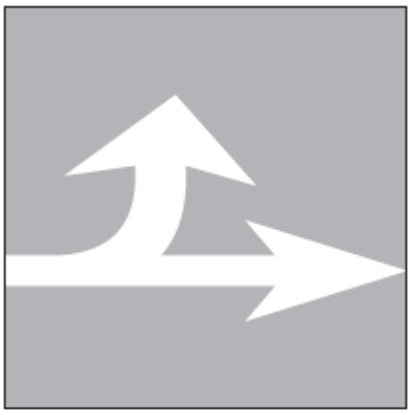
Signs and pavement markings supplement good design, create a predictable environment for motorists/ cyclists and reinforce appropriate behavior for all roadway users. This section provides a summary of the most commonly used signs and pavement markings related to separated bike lane installation.

Figure 9B-2. Regulatory Signs and Plaques for Bicycle Facilities

Figure 9B-3. Warning Signs and Plaques and Object Markers for Bicycle Facilities

★ A fluorescent yellow-green background color may be used for this sign or plaque. The background color of the plaque should match the color of the warning sign that it supplements.

MARKINGS GUIDANCE



Standard arrows for pavement markings (example shown)
MUTCD Fig. 3B-24

Bicycle pavement marking: bike symbol
MUTCD Fig. 9C-3

Bicycle pavement marking: helmeted bicyclist symbol
MUTCD Fig. 9C-3

Bicycle pavement marking: word legends
MUTCD Fig. 9C-3

Pavement marking
MUTCD Fig. 9C-5

Shared lane marking
MUTCD Fig. 9C-9

Bike detector pavement marking
MUTCD Fig. 9C-7

Recommended yield line pavement markings layout
MUTCD Fig. 3B-16

Figure 9C-3. Word, Symbol, and Arrow Pavement Markings for Bicycle Lanes

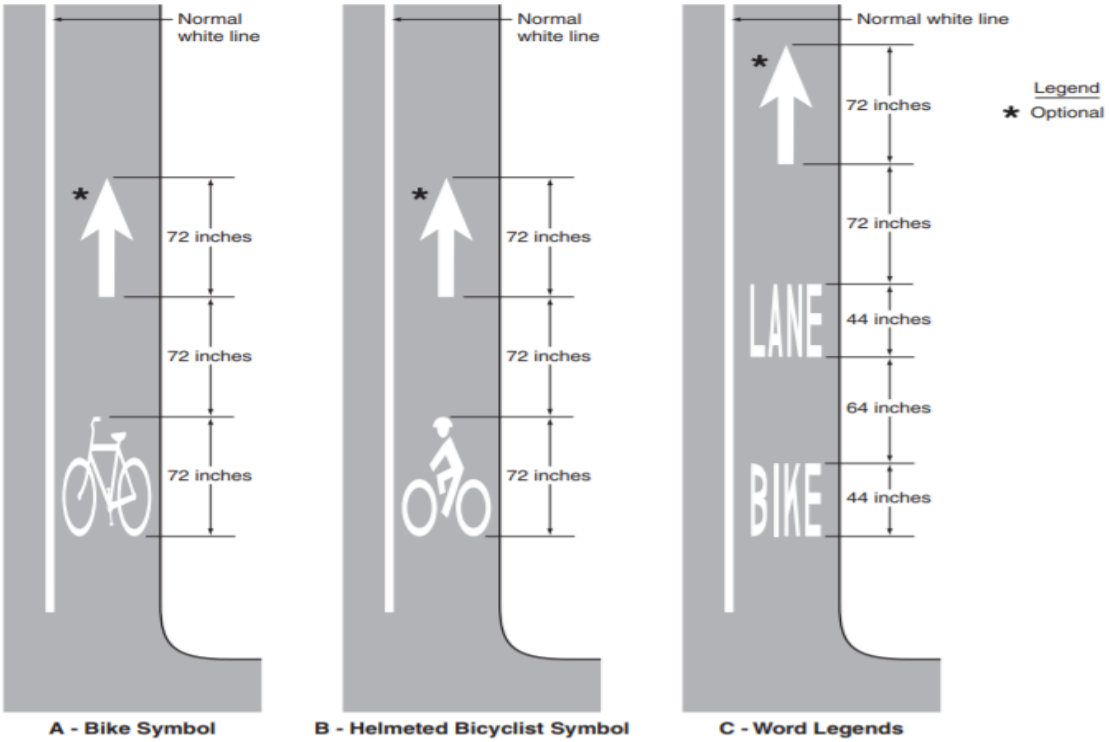


Figure 9C-4. Example of Bicycle Lane Treatment at a Right Turn Only Lane

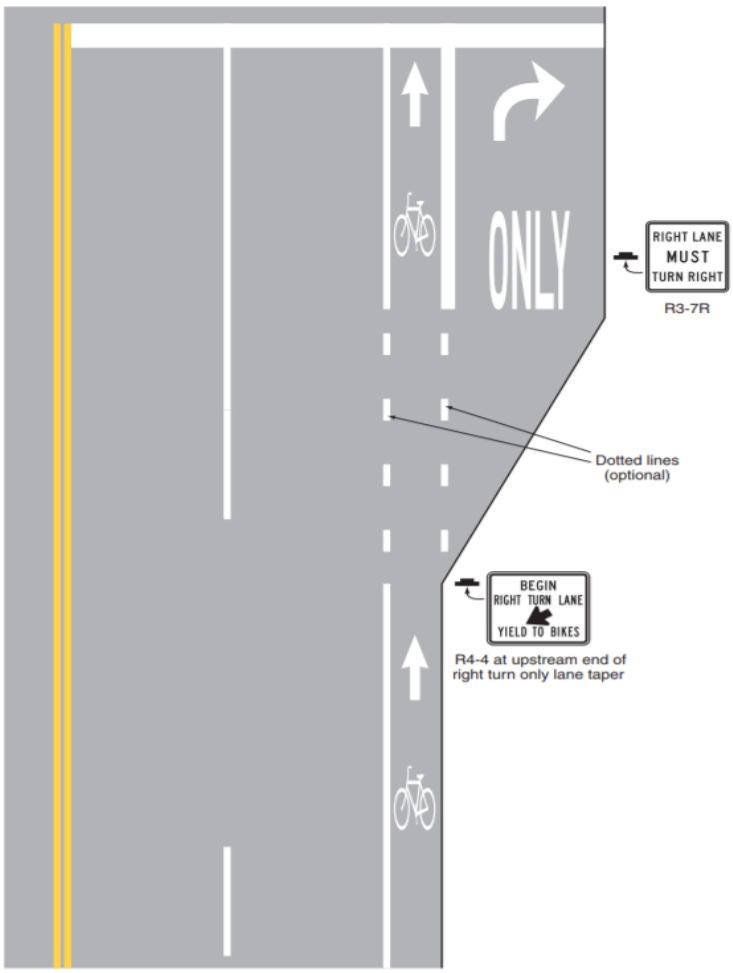


Figure 9C-1. Example of Intersection Pavement Markings—Designated Bicycle Lane with Left-Turn Area, Heavy Turn Volumes, Parking, One-Way Traffic, or Divided Highway

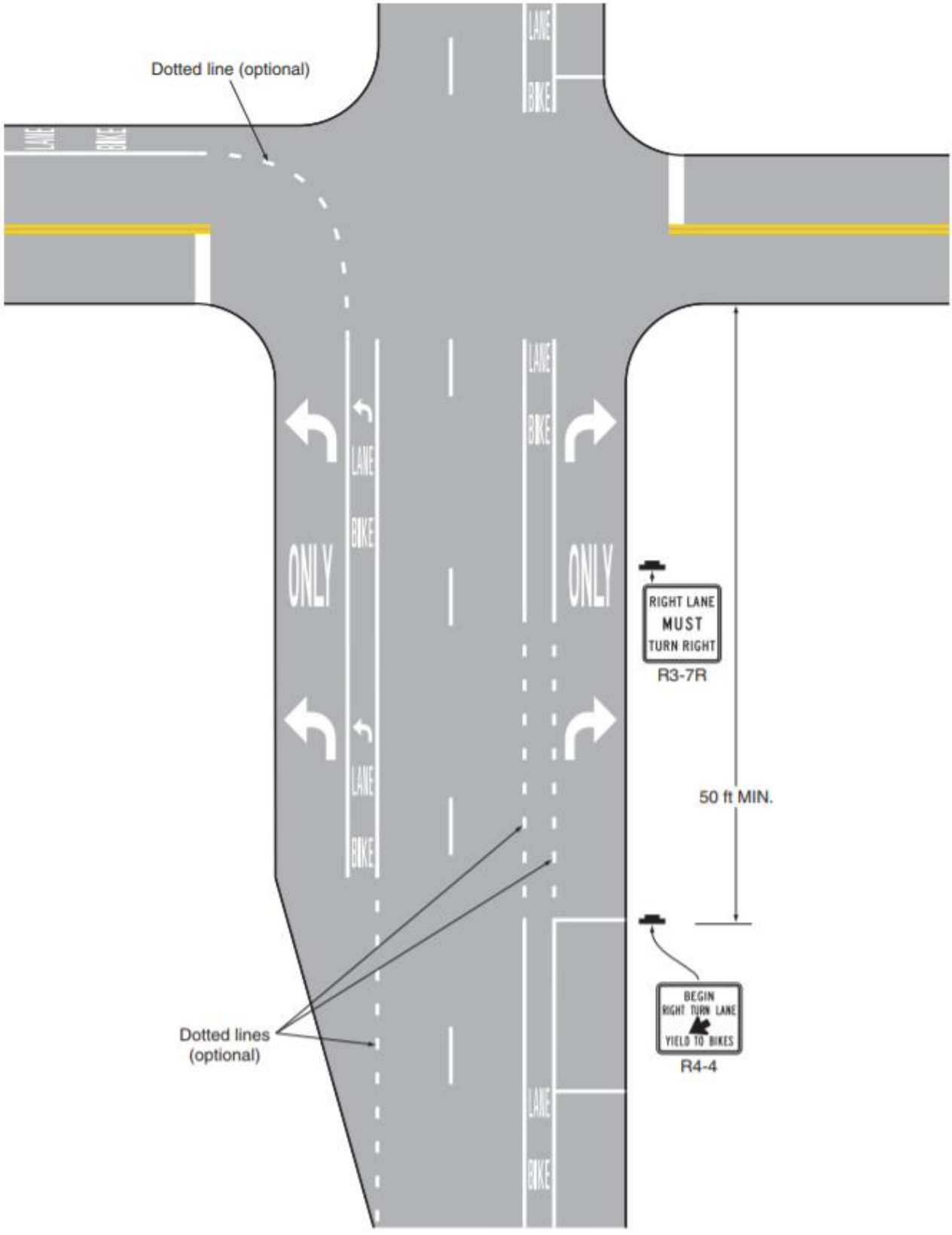
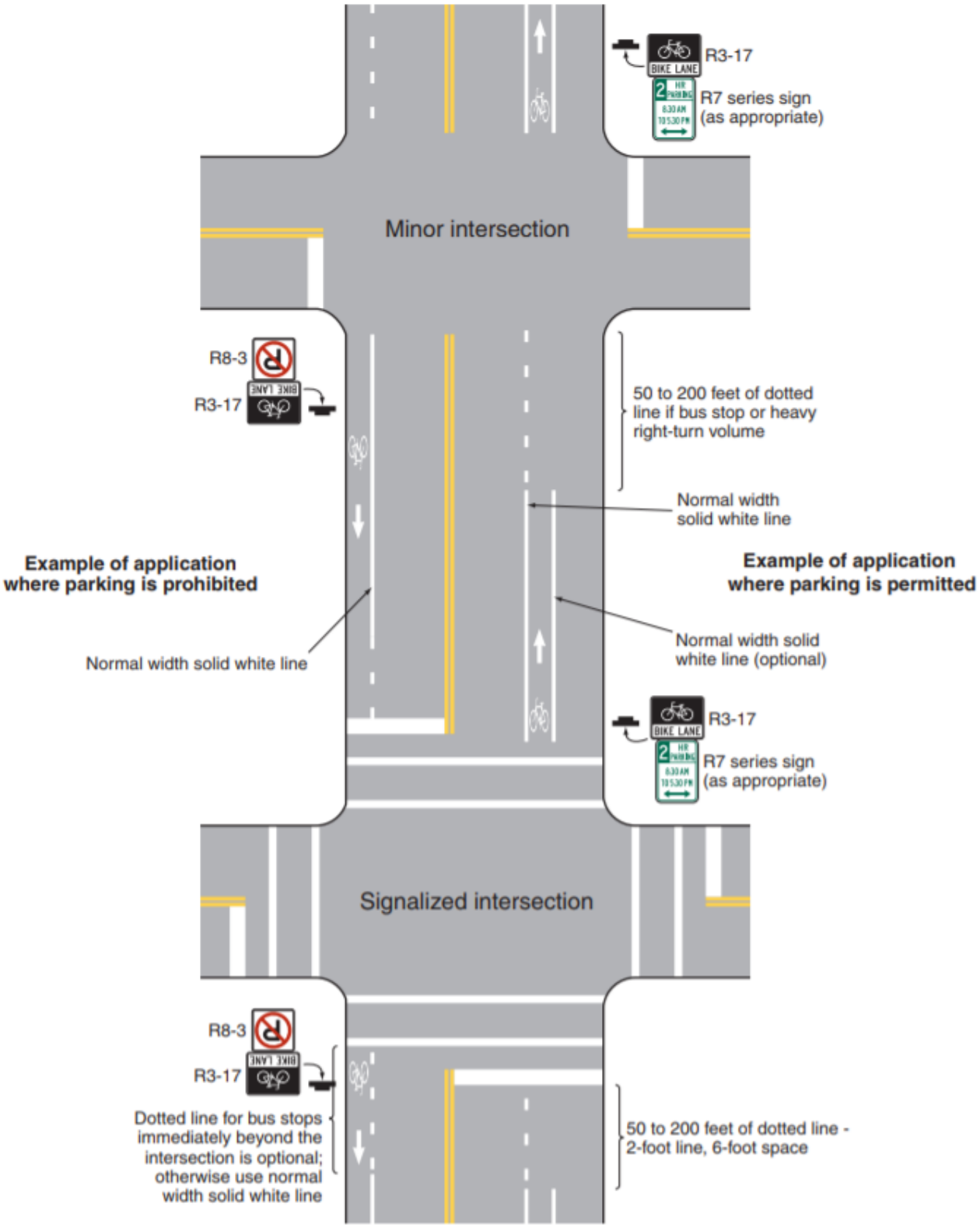


Figure 9C-6. Example of Pavement Markings for Bicycle Lanes on a Two-Way Street



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