APPENDIX E:

BICYCLE FACILITY DESIGN GUIDANCE

FACILITY DESIGN TOOLBOX

To ensure consistency throughout Lakewood's bicycle network, this appendix is intended to provide high-level guidance on the design of each proposed facility type in the project list (excluding overpass/underpass, as those vary so widely depending on the location context). Individual facility designs will be determined upon implementation on a route-by-route basis in alignment with Lakewood engineering standards and practices. For further guidance, please consult the manuals listed on page 88 at the end of this appendix.

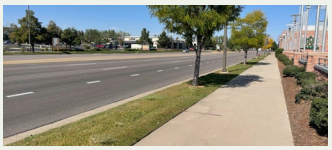
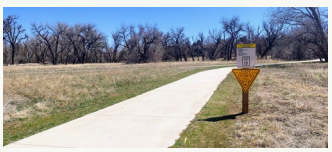
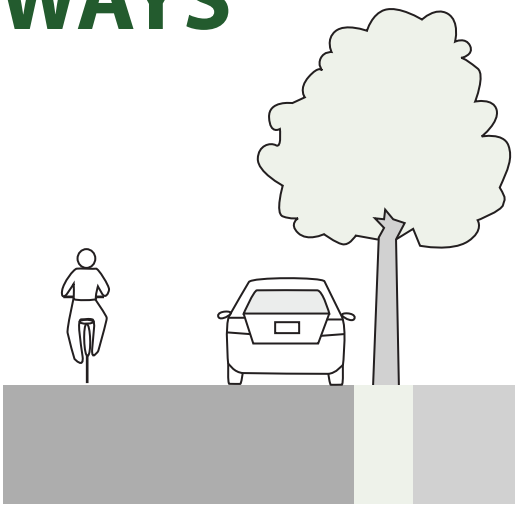
Facility Type	Typical Applications	Preferred Widths	Additional Considerations
Neighborhood Bikeway 	< 3,000 ADT < 25 mph	N/A	Traffic calming recommended where necessary to maintain target vehicle speeds
Bike Lane 	3,000 - 7,000 ADT 25 - 35 mph	5′ - 7′	Green conflict markings at major intersection approaches preferred
Buffered Bike Lane 	3,000 - 7,000 ADT 25 - 35 mph	5′ - 7′ bike lane 2′ - 4′ buffer	Green conflict markings at major intersection approaches preferred
Separated Bike Lane 	> 7,000 ADT 30 - 40 mph	5′ - 8′ bike lane 2′ - 4′ buffer	Green conflict markings at major intersection approaches required, dashed markings through intersection preferred, types of vertical elements may vary
Barrier Protected Bike Lane 	> 10,000 ADT > 40 mph	5′ - 8′ bike lane 2′ - 4′ buffer	Green conflict markings at major intersection approaches required, dashed markings through intersection preferred
Side path 	> 10,000 ADT > 40 mph	10′ - 12′	Detachment from roadway preferred, crosswalk markings required for major intersections and recommended for high-volume driveway or side street crossings
Shared Use Trail 	Parks, open spaces, greenbelts, cut-throughs	10′ - 14′	Enhanced crossing treatments (e.g. RRFBs, PHBs, grade-separated crossing) recommended for high-volume roadway crossings

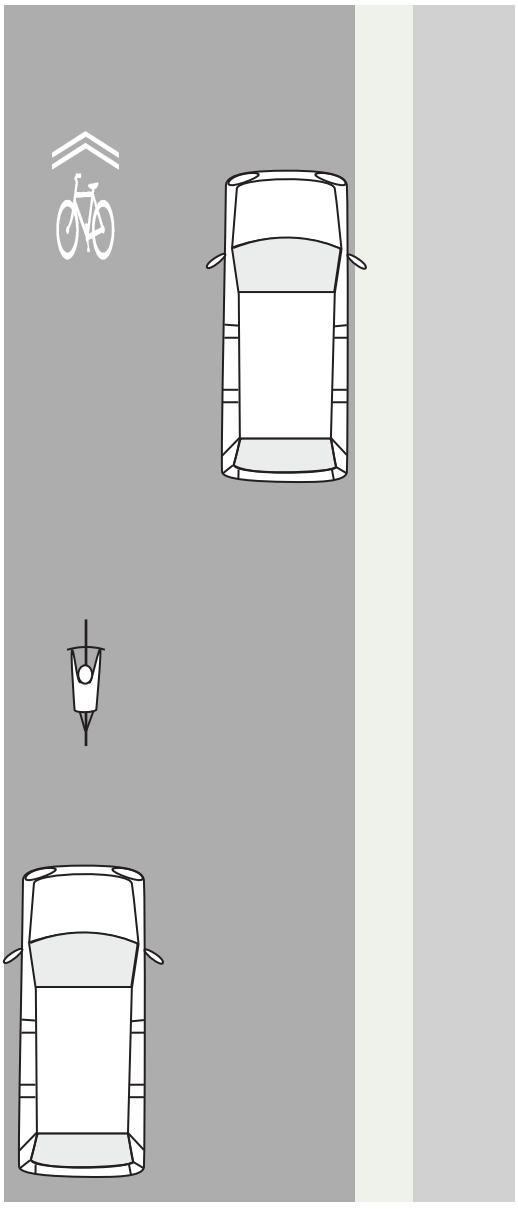
Table E-1: Overview of design guidance and considerations for each type of proposed bicycle facility, excluding overpass/underpass.

NEIGHBORHOOD BIKEWAYS

Neighborhood bikeways, also known as bicycle boulevards, are located on local streets with low vehicle volumes (<3,000 ADT) and speeds (<25 mph). A combination of signage and markings identify the street as a bikeway, and bicycle travel is a priority throughout the route including at intersections. Where necessary, traffic calming and volume management may be used to keep the route comfortable for bicyclists.

Figure E-1: Cedar Ave near Hoyt St is a proposed neighborhood bikeway with existing traffic calming, 2024.





Design Requirements

- Bike route signage (e.g. MUTCD D11-1) must identify the street as a recognized bikeway.
- Shared lane markings (sharrows) should be placed in the center of the travel lane to alert motorists that bicyclists may be occupying the lane.

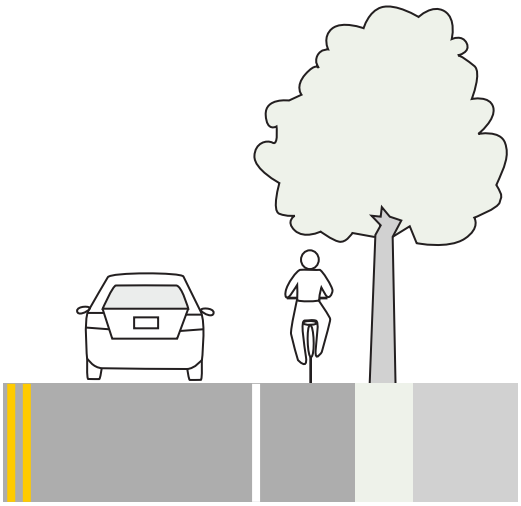
Additional Considerations

- Bicycle travel should be a priority at intersections with local street crossings, preferably reducing the need for bicyclists to stop as much as possible.
- Intersection treatments to increase bicycle comfort at major crossings should be implemented on a case-by-case basis. See pages 85-87 for example intersection treatments.
- Where vehicle volumes and speeds exceed the target range, traffic calming should be evaluated and implemented on a case-by-case basis.
- "Bicycles Allowed Use of Full Lane" (MUTCD R9-20) or "3 ft Min Clearance to Pass Bicycles" (MUTCD R4-19) may be used to supplement bike route signage.

BIKE LANES

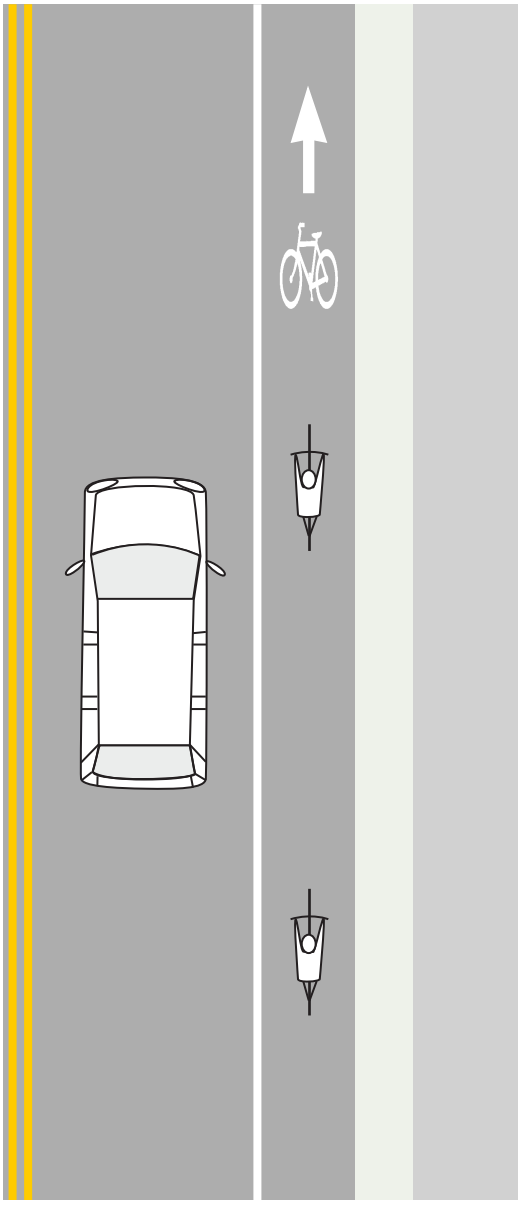
Standard bike lanes are an on-road facility exclusive to bicyclists, delineated by a single white painted stripe. They are typically located on roads with vehicle traffic between 3,000 - 7,000 ADT and speeds between 25 - 35 mph where the pavement is too constrained to accommodate a buffered bike lane.

Figure E-2: A standard bike lane on Garrison St near Addenbrooke Park in 2024 before it was upgraded to a separated bike lane.



Design Requirements

- Bike lanes must be a minimum of 5' wide from the center of the stripe to edge of asphalt (i.e. not including the gutter pan). A practical minimum width of 4' in addition to a 2' gutter pan is acceptable where a retrofit is too constrained to allow for the 5' minimum to edge of asphalt.
- Bike lane signage (MUTCD R3-17) and bicycle symbol markings (arrow optional) must be placed at the beginning of each block and alternate roughly every 400' throughout.



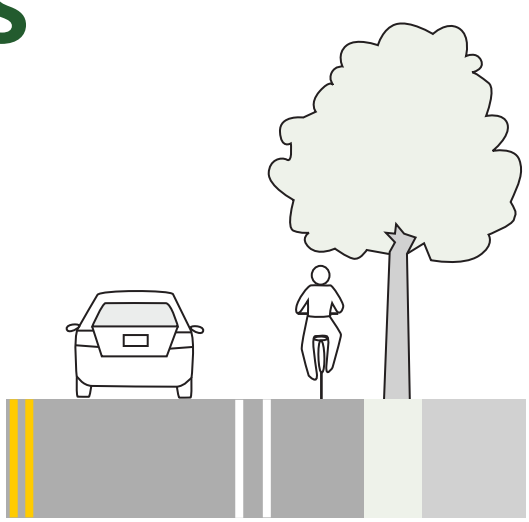
Additional Considerations

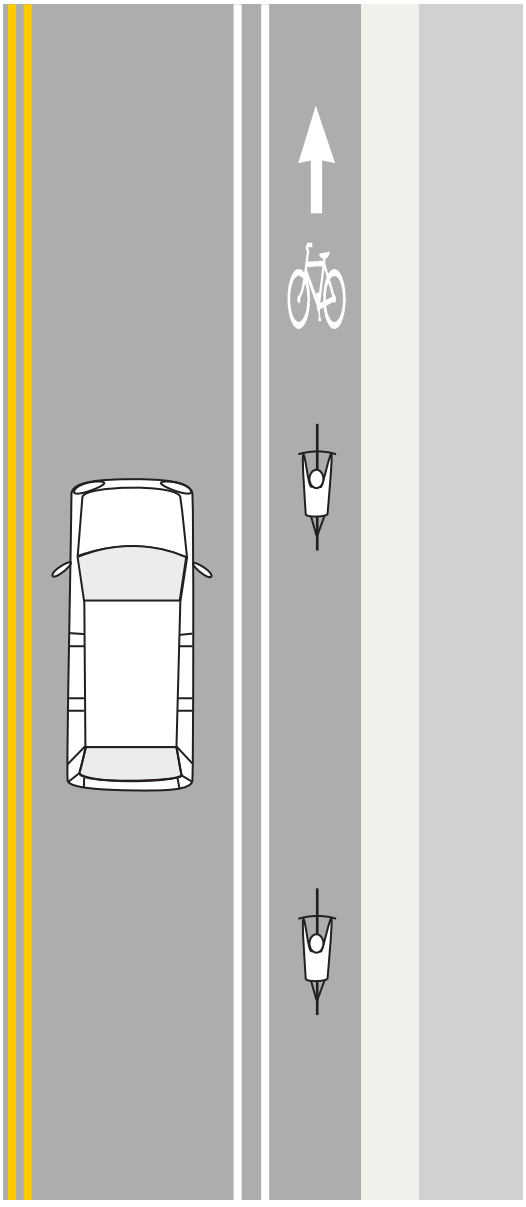
- Where more than 7' of width is available, a buffered bike lane is recommended over a standard bike lane to avoid confusion of the bike lane with a parking or travel lane.
- Green dashed conflict markings should be installed in areas where vehicle traffic is merging into or crossing the bike lane, such as intersection approaches with dedicated right turn lanes. See page 86 for examples.
- Dashed white lines may be installed to guide bike lanes through intersections where the alignment shifts across the intersection or could otherwise create confusion.

BUFFERED BIKE LANES

Buffered bike lanes are an on-road facility exclusive to bicyclists, delineated by a double white painted stripe with or without cross hatching. They are typically located on roads with vehicle traffic between 3,000 - 7,000 ADT and speeds between 25 - 35 mph, and are preferred over standard bike lanes wherever space allows.

Figure E-3: A buffered bike lane on Garrison St near Green Gables Park in 2023 before it was upgraded to a separated bike lane.





Design Requirements

- Bike lanes must be a minimum of 5' wide from the center of the stripe to edge of asphalt (i.e. not including the gutter pan). A practical minimum width of 4' in addition to a 2' gutter pan is acceptable where a retrofit is too constrained to allow for the 5' minimum to edge of asphalt.
- Buffers must be a minimum of 2' wide, but a practical minimum of 1.5' is acceptable where a retrofit is too constrained to allow for the 2' minimum.
- Where a buffer is wider than 2', diagonal cross hatch markings must be installed in the buffer zone.
- Bike lane signage (MUTCD R3-17) and bicycle symbol markings (arrow optional) must be placed at the beginning of each block and alternate roughly every 400' throughout.

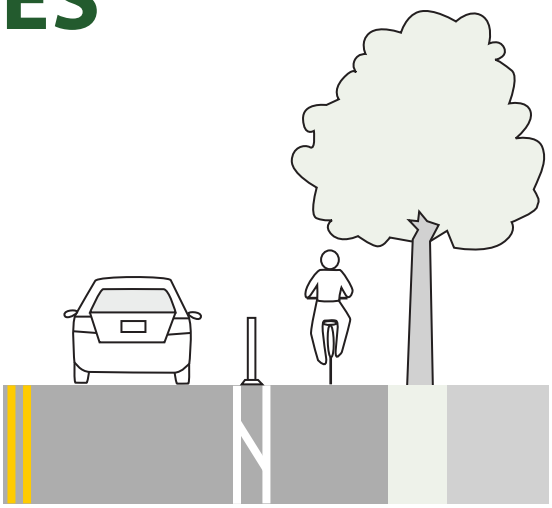
Additional Considerations

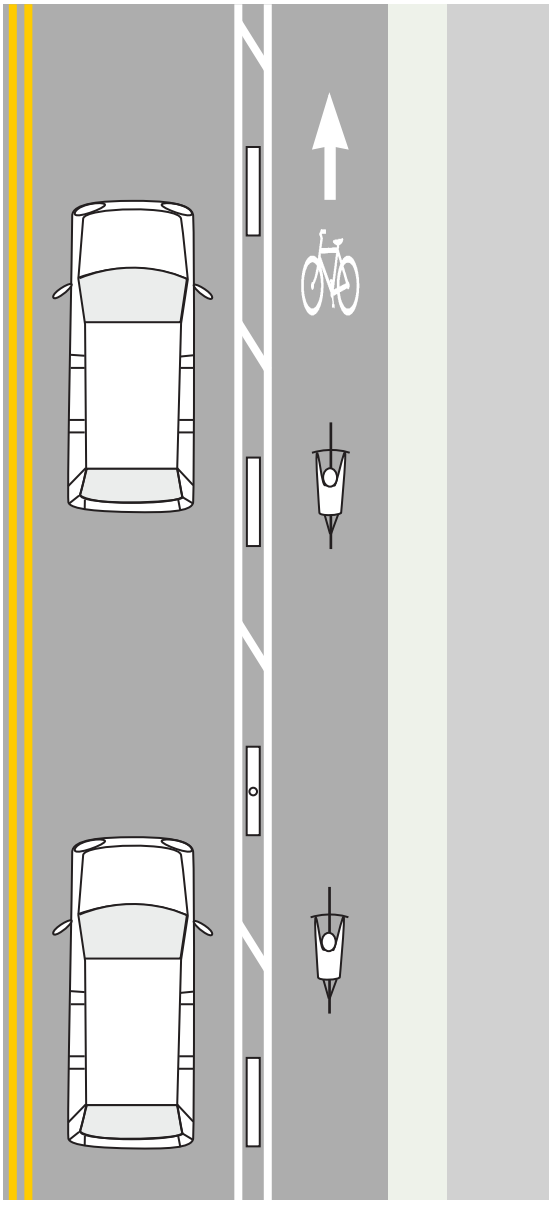
- Green dashed conflict markings should be installed in areas where vehicle traffic is merging into or crossing the bike lane, such as intersection approaches with dedicated right turn lanes. See page 86 for examples.
- Dashed white lines may be installed to guide buffered bike lanes through intersections where the alignment shifts across the intersection or could otherwise create confusion.

SEPARATED BIKE LANES

Separated bike lanes, also known as protected bike lanes or cycle tracks, are an on-road facility exclusive to bicyclists, delineated by a painted buffer and some type of vertical separation from vehicle traffic. They are recommended over standard bike lanes on roads with vehicle traffic above 7,000 ADT and speeds between 30 - 40 mph. Various elements may be used for vertical separation, examples of which can be found on page 81.

Figure E-4: Separated bike lanes constructed with plastic curbs and flexible delineator posts on Garrison St near Green Gables Park, 2024.





Design Requirements

- Bike lanes must be a minimum of 5' wide from the center of the stripe to edge of asphalt (i.e. not including the gutter pan), but 6'-8' is preferred to allow for passing. A practical minimum width of 4.5' in addition to a 2' gutter pan is acceptable where a retrofit is too constrained to allow for the 5' minimum to edge of asphalt.
- Buffers must be a minimum of 2' wide, but a practical minimum of 1.5' is acceptable where a retrofit is too constrained to allow for the 2' minimum.
- Where a buffer is 2' or wider, diagonal cross hatch markings must be installed in the buffer zone, unless the vertical separation element occupies the majority of the buffer.
- Bike lane signage (MUTCD R3-17) and bicycle symbol markings with an arrow must be placed at the beginning of each block and alternate roughly every 400' throughout.

Additional Considerations

- Green dashed conflict markings must be installed in areas where vehicle traffic is merging into or crossing the bike lane, such as intersection approaches with dedicated right turn lanes. See page 86 for examples.
- Dashed white lines with or without green pavement should be installed to guide separated bike lanes through intersections and driveways.

Vertical Elements

Separated bike lanes can be constructed with various types of vertical elements to separate the bike lane from vehicle traffic. Below are examples of the most common types of vertical elements used for separated bike lanes:

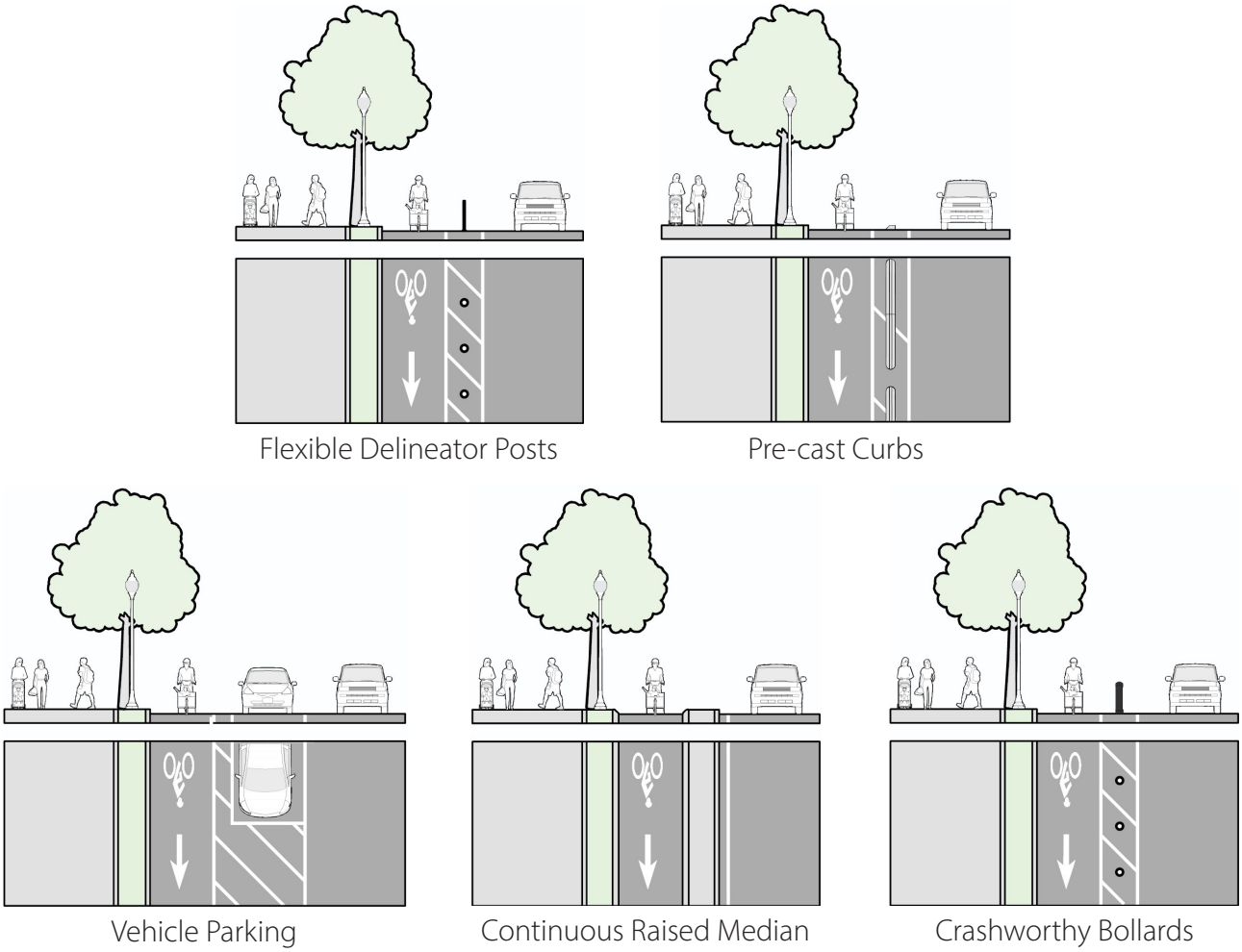


Figure E-5: Illustrations of various examples of vertical elements used for separated bike lanes, AASHTO Guide for the Development of Bicycle Facilities (2024). All AASHTO illustrations in this Plan used with permission.

The examples shown above are not exhaustive of all elements that may be used, and construction materials vary. In addition to the options above, a separated bike lane may also be raised to sidewalk level or an intermediate level between the sidewalk and the street as a form of vertical separation. The Bicycle Plan project list does not require any particular vertical element for proposed separated bike lanes, so separation devices will be determined on a route-by-route basis and may be changed or upgraded over time (see "Material Trade-Offs" on page 33). Two-way separated bike lanes are also not specifically recommended in the Bicycle Plan, but are an option that may be considered upon implementation if deemed contextually appropriate.

Barrier Protected Bike Lanes

For the purpose of this Plan, separated bike lanes with semi-continuous tall barriers (concrete or otherwise) are considered "barrier protected bike lanes" and are discussed separately on the next page.

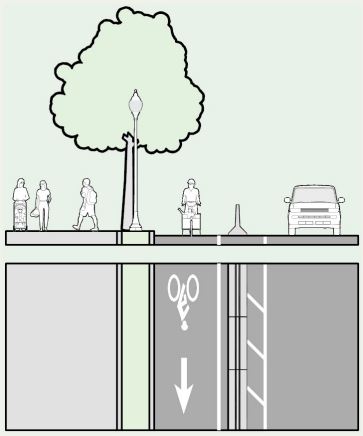
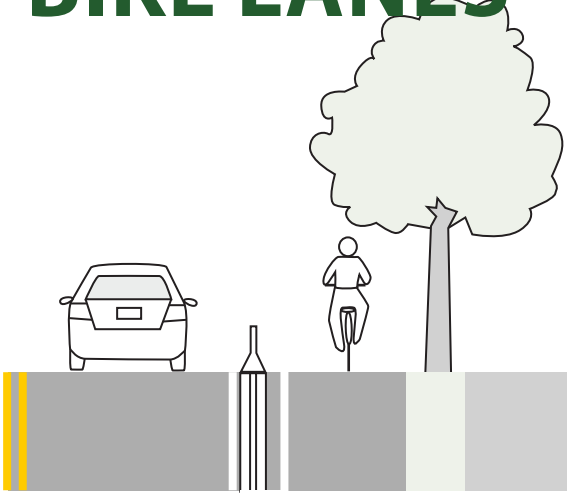


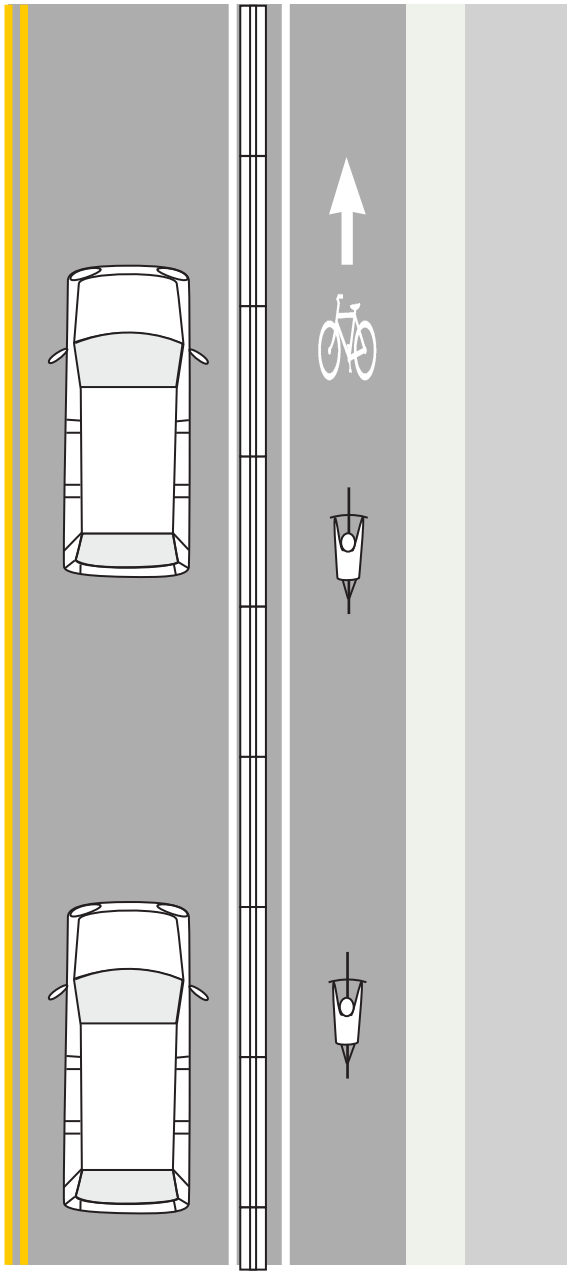
Figure E-6: Illustration of "Concrete Barriers", AASHTO Guide for the Development of Bike Facilities (2024).

BARRIER PROTECTED BIKE LANES

Barrier protected bike lanes are a specific type of separated bike lane (see page 80) with continuous curbing or barriers made of concrete or another durable material. Barrier protected bike lanes are recommended over other types of separated bike lanes on roads with vehicle traffic above 10,000 ADT and speeds above 40 mph as they offer greater physical protection from vehicle traffic.

Figure E-7: A concrete barrier protected bike lane with a painted mural on Baseline Rd in Boulder, 2023.





Design Requirements

- Bike lanes must be a minimum of 5' wide from the center of the stripe to edge of asphalt (i.e. not including the gutter pan), but 6'-8' is preferred to allow for passing. A practical minimum width of 4.5' in addition to a 2' gutter pan is acceptable where a retrofit is too constrained to allow for the 5' minimum to edge of asphalt.
- Buffers must be a minimum of 2' wide, but a practical minimum of 1.5' is acceptable where a retrofit is too constrained to allow for the 2' minimum.
- Bike lane signage (MUTCD R3-17) and bicycle symbol markings with an arrow must be placed at the beginning of each block and alternate roughly every 400' throughout.

Additional Considerations

- Green dashed conflict markings must be installed in areas where vehicle traffic is merging into or crossing the bike lane, such as intersection approaches with dedicated right turn lanes. See page 86 for examples.
- Dashed white lines with or without green pavement should be installed to guide bike lanes through intersections and driveways.
- Barriers should be shortened or discontinued on approaches to crossings if they restrict sight lines between bicyclists and motorists.

SIDE PATHS

Side paths are paved off-street paths that run adjacent to a roadway and accommodate two-way travel for bicyclists, pedestrians, and other non-motorized forms of travel. Side paths are recommended on roads with vehicle traffic above 10,000 ADT and speeds above 40 mph in areas where volumes of both pedestrians and bicyclists are moderate, or where an on-street barrier protected bike lane is not appropriate or feasible.

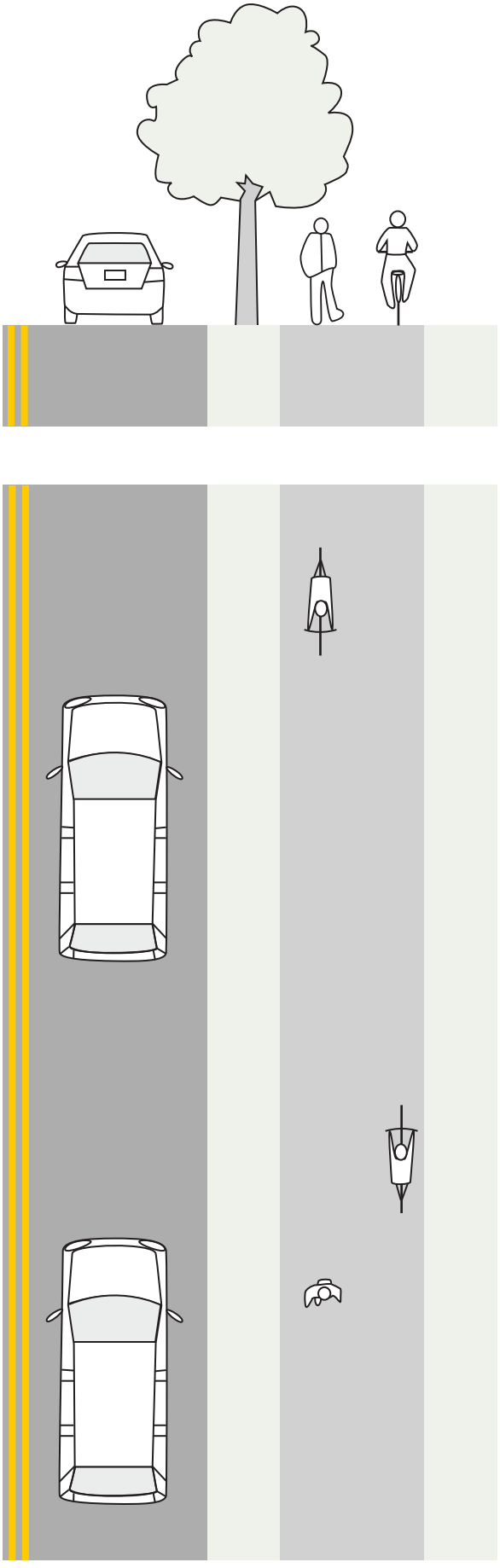
Figure E-8: A side path along Wadsworth Blvd near Virginia Ave, 2024.

Design Requirements

- Side paths must be a minimum of 10' wide to comfortably accommodate mixed use and safe passing. A practical minimum width of 8' is acceptable where a retrofit is too constrained to allow for the 10' minimum.
- Side paths must be detached a minimum of 6' from the roadway by a strip of landscaping or other contrasting material unless a retrofit is too constrained to allow for detachment.
- Crosswalk markings must be installed at major intersections to increase the visibility of path crossings.

Additional Considerations

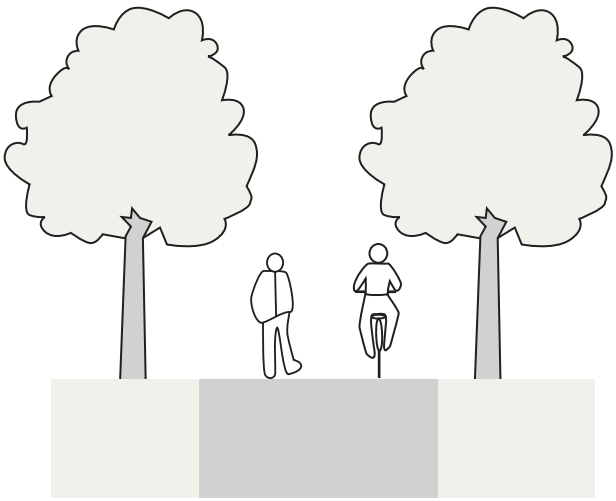
- Crosswalk markings are recommended across high-volume driveways and side streets to increase the visibility of path crossings.
- Raised crosswalks, pedestrian refuge islands, or other enhanced crossing treatments may be installed at high-volume intersections to further increase the safety and comfort of path crossings.
- Adjacent landscaping or other structures between a side path and a roadway should be shortened or discontinued on approaches to crossings if they restrict sight lines between bicyclists and motorists.

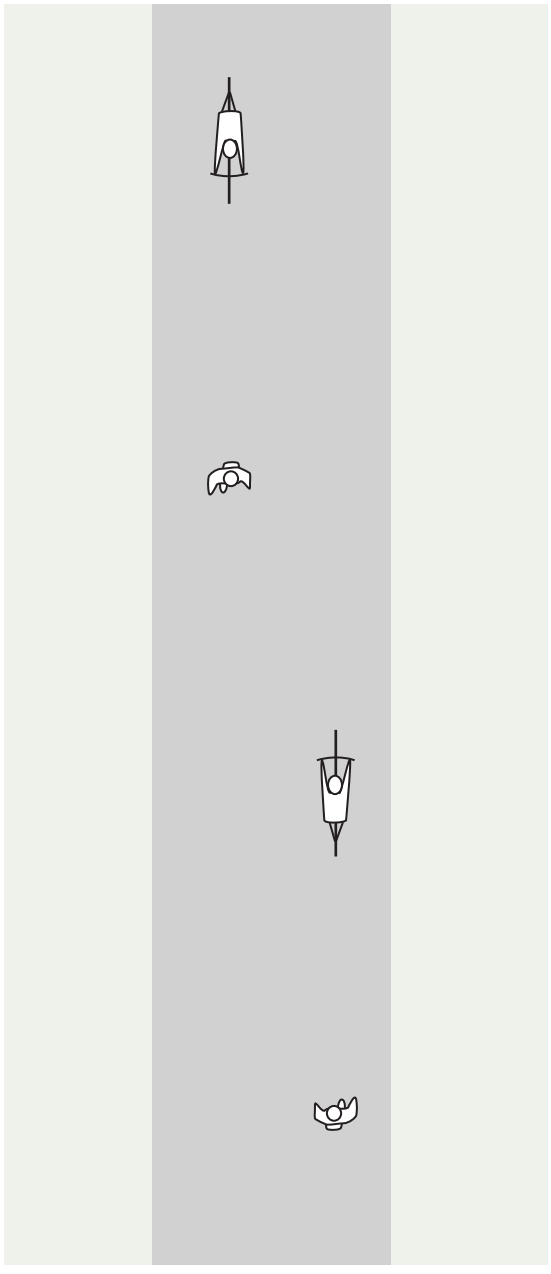


SHARED USE TRAILS

Shared use trails are paved off-street paths that accommodate two-way travel for bicyclists, pedestrians, and other non-motorized forms of travel. They are typically located in parks, along irrigation or rail corridors, and through greenbelts, but can also occur as cut-through paths to connect between roads or neighborhoods.

Figure E-9: A segment of the Bear Creek Trail near Stone House, 2024.





Design Requirements

- Shared use trails must be a minimum of 10' wide to comfortably accommodate mixed use and safe passing. A practical minimum width of 8' is acceptable where expected bicycle and pedestrian volumes are very low.
- Crosswalk markings should be installed at any street crossings to increase path visibility.

Additional Considerations

- A solid yellow painted centerline is recommended where passing is inadvisable or sight distance is restricted, such as at curves, steep grades, or crossing approaches.
- Signage, markings, or different paving materials may be used to separate bicyclists and pedestrians where high volumes of both are expected.
- Enhanced crossing treatments such as RRFBs, PHBs, and grade-separated crossings should be considered for high-volume roadway crossings.

INTERSECTION TREATMENTS

In addition to best practices for bicycle facility design, high-quality intersection treatments must be considered when developing a bicycle network suitable for people of all ages and abilities. While the following treatments are not an exhaustive list of all ways to move bicyclists through an intersection, they showcase a wide range of example designs available for consideration.

Pedestrian Refuge Islands

At unsignalized crossings or two-way stops, median refuge islands increase the comfort and safety of multi-lane crossings by allowing bicyclists to cross one direction of traffic at a time. They are particularly beneficial at crossings with high-volume and/or high-speed roadways, and could be an effective way to safely extend neighborhood bikeways across major roads without requiring a signal or other crossing enhancement.

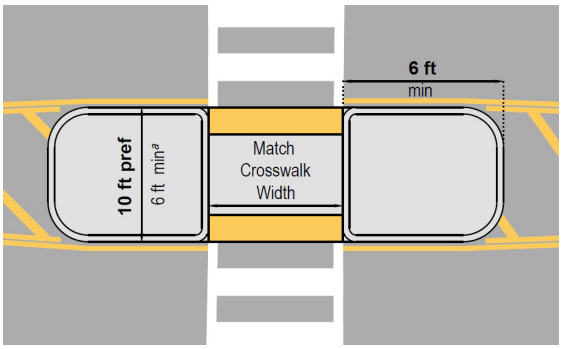


Figure E-10: Refuge island design example, AASHTO Guide for the Development of Bike Facilities (2024).

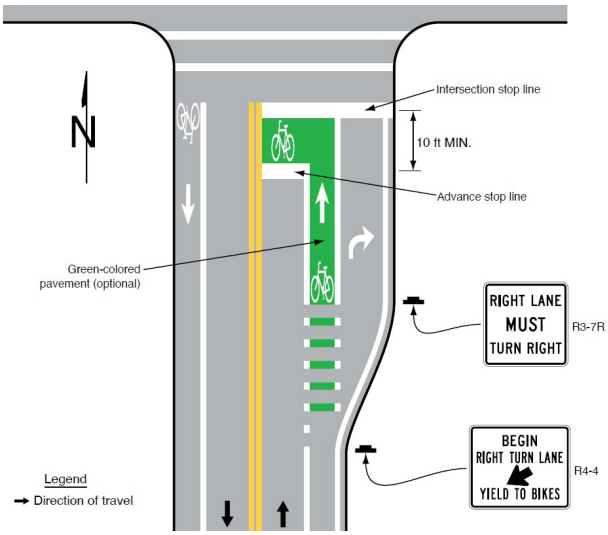


Figure E-11: Example of bike box design across one lane, MUTCD (2023).

Bike Boxes

At signalized intersections where a bike lane ends and transitions into a shared lane on the other side of the intersection, a bike box placed in front of the adjacent vehicle lane provides an opportunity for bicyclists to position themselves in front of queuing motorists. This allows bicyclists to travel through the intersection more visibly and align themselves with the receiving shared lane without having to merge with vehicle traffic in the intersection. Bike boxes may also be appropriate where there is a significant volume of left-turning bicyclists, or where bicycle volumes exceed the storage capacity of the approaching bike lane.

Two-Stage Turn Boxes

To avoid requiring left-turning bicyclists to weave across travel lanes and merge with vehicle traffic—a maneuver that is uncomfortable for most bicyclists—two-stage turn boxes allow bicyclists to safely execute a two-stage left turn by traversing an intersection within the bike lane, stopping in the turn box, reorienting themselves, and waiting for opposing traffic to clear before proceeding. They can be installed at signalized or unsignalized intersections. Some confident bicyclists avoid two-stage turns to reduce their waiting time at signalized intersections, so MUTCD D11-20 or R9-23 series signage should indicate whether use is optional or required.

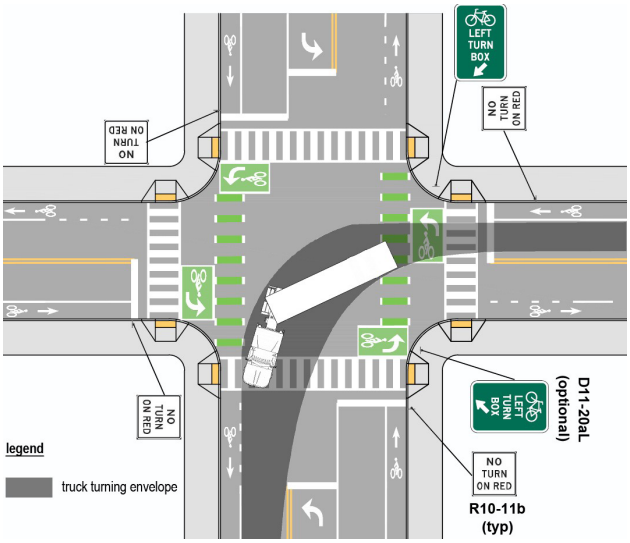


Figure E-12: Example intersection with two-state left turn boxes, AASHTO Guide for the Development of Bike Facilities (2024).

Mixing Zones

Where an intersection approach includes both a dedicated right-turn lane and an on-street bike facility, the bike facility should be shifted to the left of the right turn lane to avoid causing right hook crashes. This shift results in what is known as a mixing zone, or a defined merge point for a motorist to cross the bike facility and access the right turn lane. Mixing zones can exist in several forms depending on the intersection approach, including a shared lane transitioning to a bike lane (Figure E-13), a separated bike lane transitioning to a shared lane (Figure E-14), or a separated bike lane continuing through the intersection while a parking lane becomes a right-turn lane (Figure E-15). Regardless of the specific approach, mixing zones should be marked with MUTCD R4-4 signage and green dashes to clearly indicate where motorists are expected to yield to bicyclists. For separated bike lanes, any vertical separation elements on the approach to the mixing zone should be discontinued or spaced as necessary to maintain adequate sight distance between motorists and bicyclists.

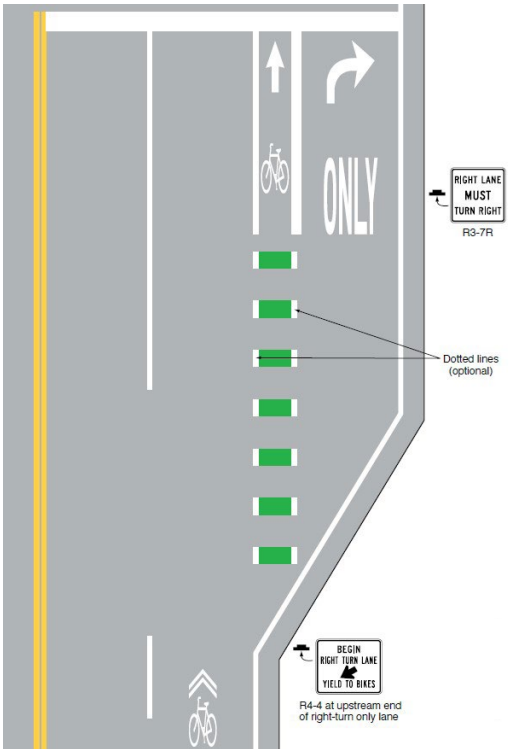


Figure E-13: Mixing zone approach for a shared lane to bike lane transition, MUTCD (2023).

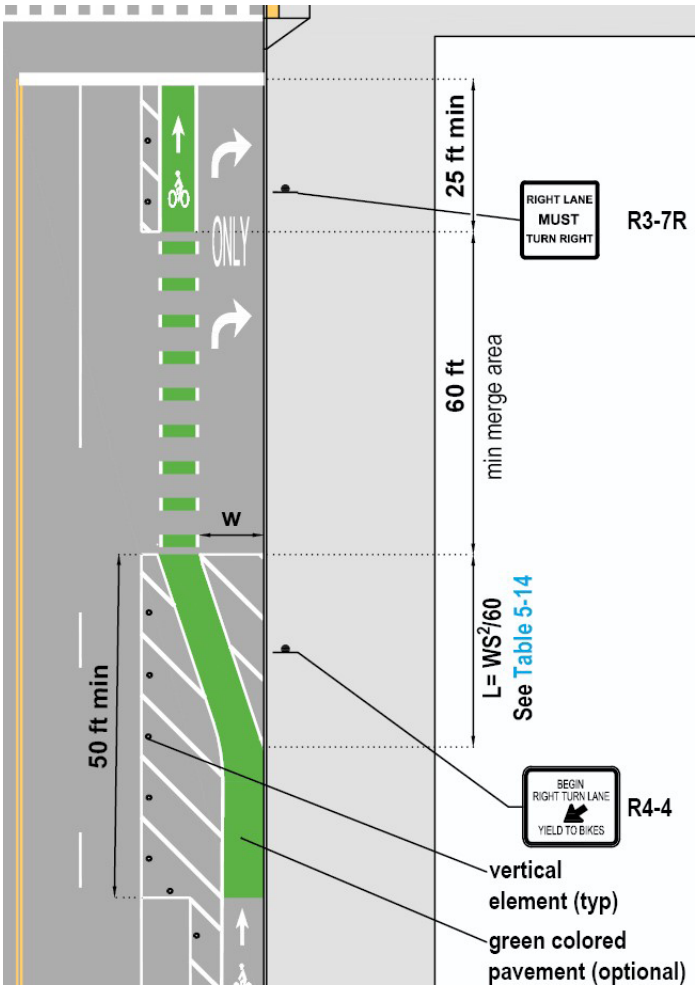


Figure E-14: Share lane mixing zone approach for a separated bike lane, AASHTO Guide for the Development of Bicycle Facilities (2024).

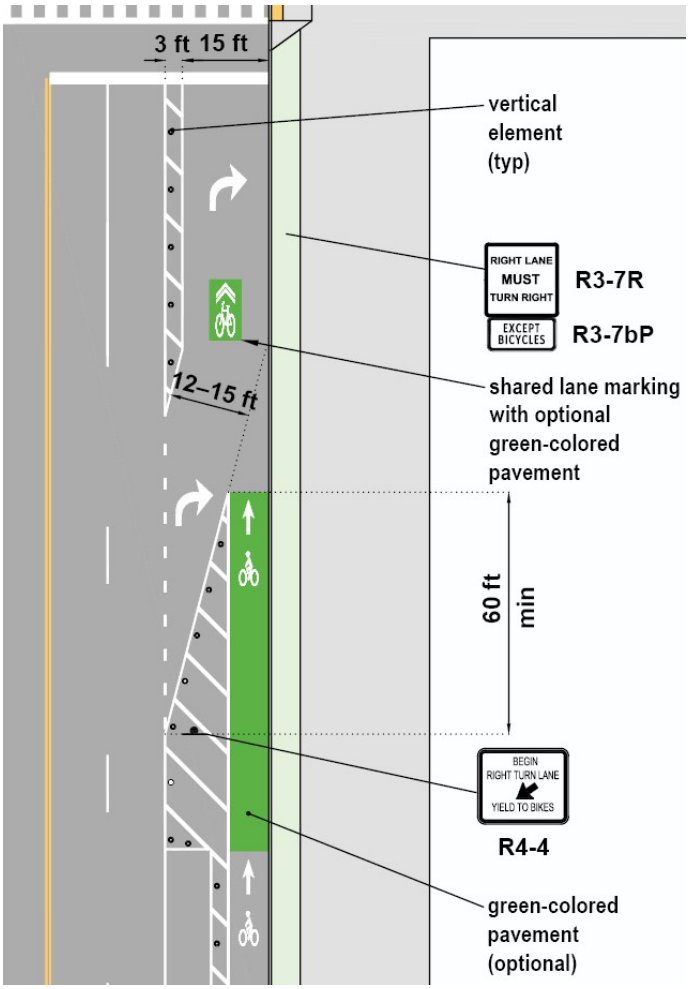


Figure E-15: Mixing zone approach for a separated bike lane, AASHTO Guide for the Development of Bicycle Facilities (2024).

Bend-In and Bend-Out Approaches

At intersections with a combined thru-right lane instead of a dedicated right-turn lane, the bike lane should continue running along the right-hand side of the vehicle lane(s). A forward stop line for the bike lane as shown in Figure E-16 is recommended (addition of green pavement optional) at signalized intersections to position bicyclists in front of turning motorists and increase the visibility of the bike lane. Where the approaching bike lane is buffered or separated, the bike lane may either be shifted toward or away from the adjacent vehicle lane, known as bend-in or bend-out deflection. Bend-in deflection (Figure E-16) improves the visibility of bicyclists to the adjacent motorists and minimizes turning conflicts, and is recommended where the right-of-way is too constrained to allow for a bend-out approach. Bend-out deflection (Figure E-17) shifts the bicyclist away from the adjacent vehicle lane, providing space for motorists to clearly see and yield to bicyclists after beginning a turn maneuver rather than requiring that all are done simultaneously. Where a bend-out approach is taken, a corner island is recommended to maintain the desired turn radius for motorists to clearly see approaching bicyclists before completing a turn. This bend-out deflection with a corner island is an important element of what is commonly known as a protected intersection.

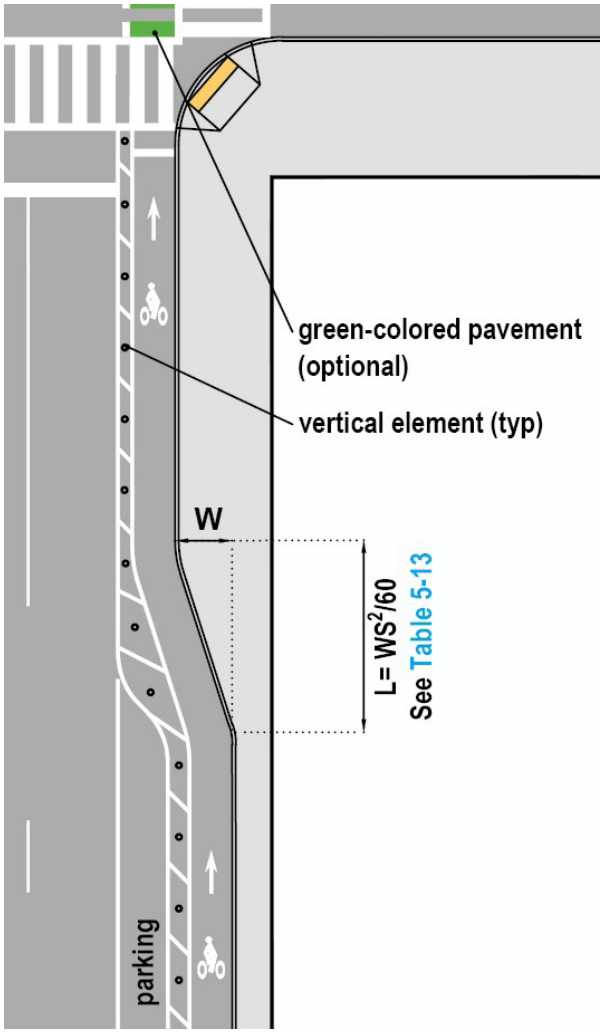


Figure E-16: Bend-in intersection approach for separated bike lanes, AASHTO Guide for the Development of Bicycle Facilities (2024).

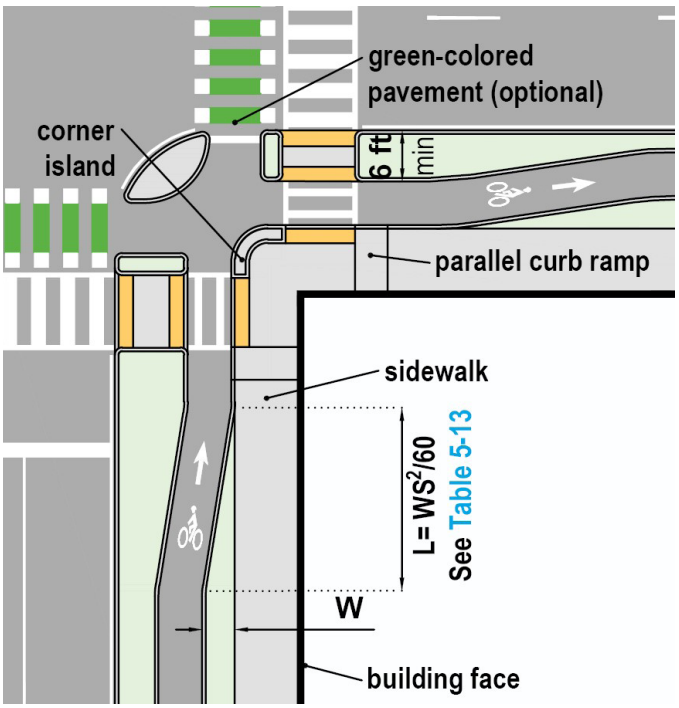


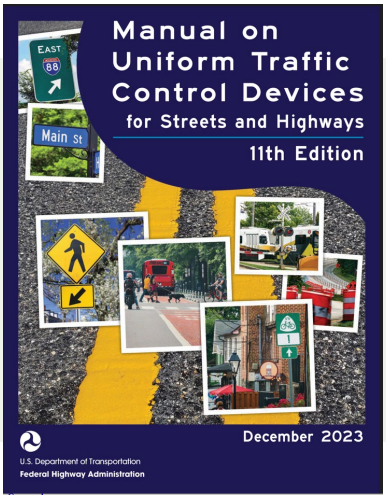
Figure E-17: Bend-out intersection approach for separated bike lanes. AASHTO Guide for the Development of Bicycle Facilities (2024).

Protected Intersections

A protected intersection is an intersection that fully separates motorists, bicyclists, and pedestrians as they travel through the intersection. Protected intersections essentially utilize bend-out deflection (Figure E-17) of the bike lane in all four directions, allowing motorists to more easily yield to bicyclists when turning and also providing space for bicyclists to queue ahead of vehicle traffic. Protected intersections are preferred over designs that require bicyclists to mix with vehicle traffic. Where existing public right-of-way is too constrained for a protected intersection, elements of the design such as a bend-out deflection with a corner island may still be implemented individually as space allows. Alternatively, modes may also be separated by bicycle signals with exclusive signal phasing where deemed appropriate.

ADDITIONAL GUIDANCE

While this appendix was informed by various written guides and examples, the three publications listed and summarized below were most heavily consulted to determine the high-level design recommendations for Lakewood's future bicycle network. It is recommended that anyone using this appendix to design and implement a proposed bicycle facility in Lakewood refers to the same guides or any updated versions for more information and additional best practices.

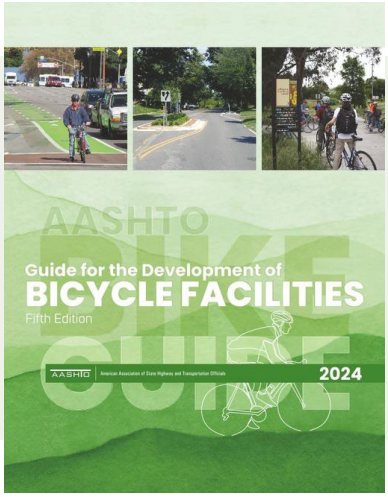


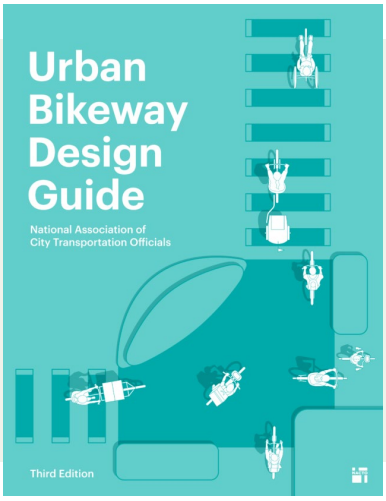
Manual on the Uniform Traffic Control Devices

The Federal Highway Administration's Manual on the Uniform Traffic Control Devices (MUTCD) establishes consistent criteria for the use of traffic control devices (e.g. signs and markings) on all roadways in the nation. It was recently updated in 2023, and now includes new standards and expanded guidance in Chapter 9 on the design of bicycle facilities.

Guide for the Development of Bicycle Facilities

The American Association of State Highway and Transportation Officials (AASHTO)'s recently updated Guide for the Development of Bicycle Facilities informed most of the recommendations in this Plan (see bikeway selection graph on page 26) and guidelines in this appendix. The guide includes design considerations for all proposed facility types and many treatments beyond those mentioned in the Bicycle Plan.





Urban Bikeway Design Guide

The January 2025 update of the National Association of City Transportation Officials (NACTO)'s Urban Bikeway Design Guide heavily emphasizes the importance of designing bikeways for people of all ages and abilities, and provides guidance and considerations beyond the acceptable standards in other guides (such as the MUTCD and AASHTO's guide) to further ensure that a bicycle network is safe and comfortable for all users.