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Director

DESIGN MEMO 6.01

To:	Designers, Contractors, and City Departments
Date:	January 10, 2023
Subject:	On-Street Bicycle Facilities
Category:	Pedestrian and Bicycle Facilities

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1 Purpose

This design memo provides design guidance for accommodating bicyclists on streets within the City of Columbus. Bicyclists have access and mobility needs as users of the transportation system and may use the street system as their primary means of access to jobs, services, and recreational activities. The guidance provided in this document is based on established practice supported by relevant research where available. The described designs reflect typical situations; however, local conditions may vary, and engineering judgment should be applied.

2 Applicability

The design of bike facilities should be evaluated early in the process for all new construction and alteration projects within the City of Columbus to ensure safe and comfortable facilities are provided where appropriate to continue the development of a comprehensive bike network throughout the city. Until further notice, this direction will be used for scoping, design, and construction of any bicycle facility being proposed and/or constructed within the City of Columbus right-of-way. This memo is also applicable to the provision of any design elements related to bicyclists that may exist outside of dedicated bicycle facilities within the right-of-way. Bicycle accommodations at a network level are identified and documented in the Columbus Bike Plan.

3 Definitions

Definitions of key terms in this memo are provided in City of Columbus Design Memo 1.00: Introduction.

4 Planning

Bicyclists should be expected on all roadways except where prohibited by law. A network of safe, comfortable, connected, and intuitive bikeways supports bicycling as a viable, convenient, and appealing mode of transportation for people of all ages and abilities. A well-designed and maintained bicycle network typically has higher rates of bicycling. A safe and connected network provides users with a comfortable place to ride over the course of their entire trip. In urban and suburban centers, where a large share of trips are shorter than three miles in length, there is opportunity for bicycling as a transportation mode to complement recreational bicycle activity.

Establishing a bicycle network should be considered at a city-wide level to understand network gaps and establish priorities. Active transportation plans, including the Columbus Bike Plan, Central Ohio Greenways Regional Trail Vision, and City of Columbus School Travel Plan, exist for the City of

Columbus and Central Ohio. Where a plan has identified that a roadway should include a bicycle facility, Sections 4.2 and 4.3 should be used to determine the appropriate bikeway based on the target user as defined in Section 4.1.

Arterial roadways without existing bicycle facilities should be evaluated for potential addition of on-street bicycle facilities, as appropriate to the context of the roadway, when being considered for resurfacing.

For existing roadways that have not been evaluated for bikeways as part of bikeway network planning, the following should be considered to determine if a bikeway should be provided:

- If the project is on a U.S., state, regional, or local bicycle route
- Where a project intersects or could extend an existing bikeway (e.g., bicycle boulevard, bike lane, separated bike lane, or shared use path)
- To replace existing high level of stress facilities, such as paved shoulders, standard bike lanes, etc. (level of stress ratings may be found in the Mid-Ohio Regional Planning Commission's online Columbus Metro Bike Map)
- Where there is a history of reported bicycle crashes that could be mitigated through the provision of a bikeway
- Where the project area has a high Active Transportation Need and/or Demand score (scores may be found in ODOT's online Transportation Information Mapping System – Active Transportation)
- On all new and widened bridges when any of the criteria listed above are met

When being considered for resurfacing, roadways without existing bicycle facilities should be evaluated for the addition of on-street bicycle facilities, regardless of whether the streets are identified in the bikeway plan.

4.1 Target User

The provision of low stress and connected multimodal networks often improves a user's safety and comfort and accommodates biking for a broader range of people. Often, when more people bicycle and walk, there is an increase in the safety of these user groups; this effect is commonly referred to as "safety in numbers." The presence of more bicyclists encourages motorists to look for these street users where they are prevalent.

Of adults who have stated an interest in bicycling, research has identified three types of potential and existing bicyclist profiles (see **Figure 1**). These bicyclist profiles consider a person's comfort level operating a bicycle with motorized traffic, bicycling skill and experience, age, and trip purpose. Bikeways designed for the Interested but Concerned Bicyclist will naturally accommodate the Somewhat Confident and Highly Confident users.

The target user for bikeways in the City of Columbus is the Interested but Concerned user. Designing for the widest range of users will best accommodate most users.

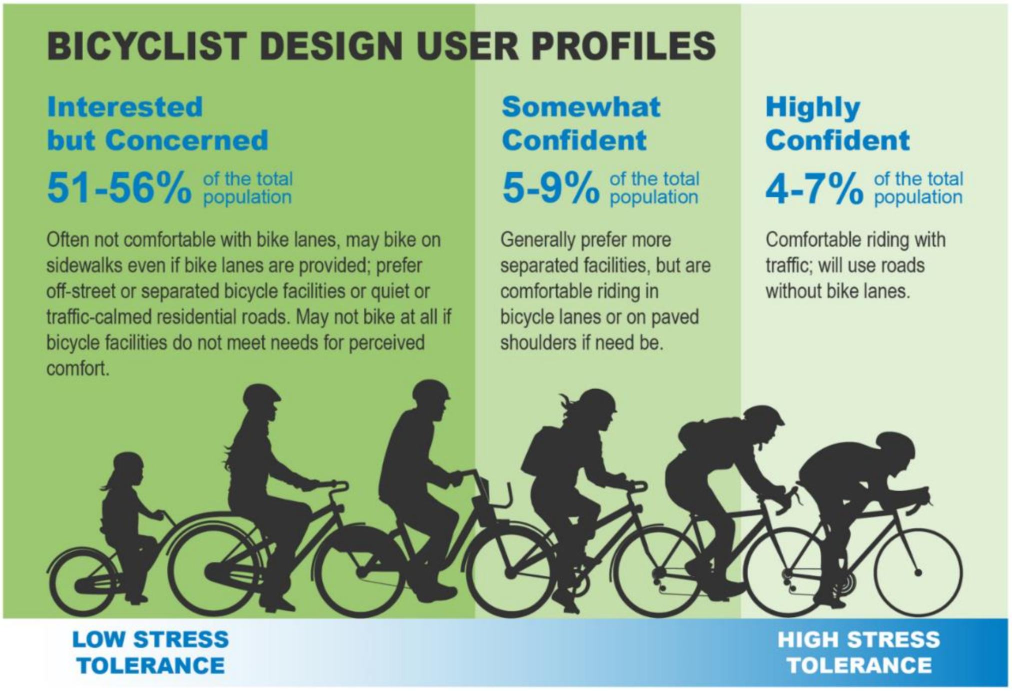


Figure 1: Bicycle Design User Profiles

4.2 Bikeway Selection Guidance

Proximity to motor vehicle traffic is a significant source of stress and discomfort for bicyclists. Crash and fatality risks sharply rise for vulnerable users when motor vehicle speeds exceed 25 mph. Further, as motorized traffic volumes increase above 6,000 vehicles/day, it becomes increasingly difficult for motorists and bicyclists to share roadway space.

Figure 2 shows the different types of bicycle facilities with varying levels of separation from traffic. **Figure 3** provides guidance for how motor vehicle volume and speed should be taken into consideration to determine a preferred bikeway type in the urban core, urban, and suburban contexts for the Interested but Concerned bicyclist. If the roadway in question cannot physically accommodate the preferred bikeway type, refer to Section 4.3.3.

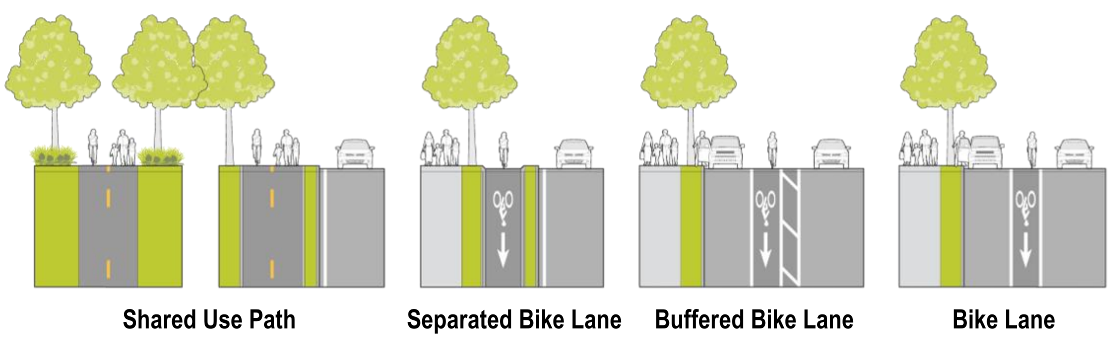


Figure 2: Types of Bicycle Facilities

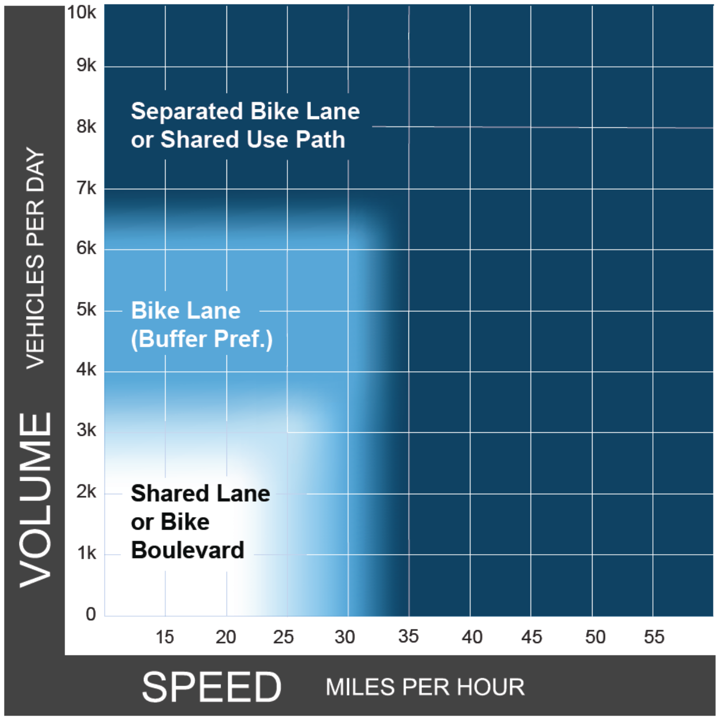


Figure 3: Preferred Bikeway Type for Interested but Concerned Bicyclists in Urban Core, Urban, and Suburban Context

4.3 Feasibility Assessment

Once the preferred bikeway type is identified, designers will need to assess its feasibility in the given project location with potential project constraints which could limit the ability to implement the preferred bikeway type. This assessment may involve determining whether additional separation between motorists and bicyclists is warranted or possible, identifying portions of the roadway to reallocate to achieve desired lane widths, selecting the “next best” bikeway, or selecting an alternative route for the bikeway.

Designers have an obligation to provide for the health, safety, and welfare of the public, which may require a careful evaluation of mobility and safety for each user. When evaluating safety trade-offs, options that reduce serious injuries and fatalities should be prioritized over options that may reduce property damage or minor injuries.

4.3.1 Conditions for Increasing Separation

There are a variety of conditions that may indicate the need for greater separation between motorists and bicyclists, which could increase the width of the bikeway or materials used in the buffer. Conditions where greater separation may be appropriate to accommodate the selected design user include the following:

- Heavier peak hour motor vehicle volumes (more than 8 to 12 percent of AADT)
- High percentages of heavy vehicles (trucks, buses, and heavy vehicles are more than 5 percent of traffic)
- Motor vehicle operating speeds exceeding posted speed limit
- Frequent parking turnover or heavy curbside activity

- High volumes of bicyclists (500 bicyclists per hour) or proximity to high bicycle-trip generating uses
- Presence of vulnerable populations (e.g. children, older adults)
- Network connectivity gaps
- Proximity to transit
- Frequent driveways

4.3.2 Options for Reallocating Roadway Space

For retrofit projects, it may be necessary to evaluate options that reallocate existing space. Strategies for reallocating roadway space to accommodate a bikeway include the following:

- Narrowing wider than necessary vehicular travel lanes, including medians/turn lanes
- Removing parking on one or both sides of street
- Converting angled parking to parallel parking
- Removing travel or turn lanes

4.3.3 Selecting the "Next Best" Bikeway Type or Parallel Routes

Impacts on ridership, comfort/stress, safety, and overall network connectivity should be considered when evaluating alternative bikeway designs or potential parallel routes to ensure the project will still meet the purpose identified at the outset. Trade-offs that should be considered when determining whether to select an alternative facility include the following:

- Reduced or suppressed ridership where the alternative bikeway does not meet the needs of the target design user.
- Additional trip length when bicyclists must use an alternative route. This length should not exceed 30 percent more than the original route and should not add excessive delay.
- Critical gaps in the network when projects fail to provide bicycle accommodations.
- Reduced safety where bicyclists must operate with relatively high motor vehicle speed and/or high-volume traffic in shared lanes.
- Reduced safety where bicyclists must operate in minimum width facilities with high conflicts (e.g., minimum width bike lanes adjacent to parking lanes or minimum width shared use paths with high volumes of pedestrians or bicyclists).
- Reduced safety where bicyclists improperly use facilities (e.g., bicycle the wrong way on shared lanes, sidewalk riding, etc.).
- Increased sidewalk bicycling where bicyclists are avoiding low-comfort/high-stress roadway conditions.

5 Design Guidance

The following section provides design guidance for accommodating bicyclists on roadways. Although this section refers to these facilities as bicycle facilities, designers should understand that these facilities are also used by people on scooters, skateboards, and other micromobility devices, all of which should be considered in the planning and design process. **Figure 4** depicts the types of accommodations discussed in this memo.

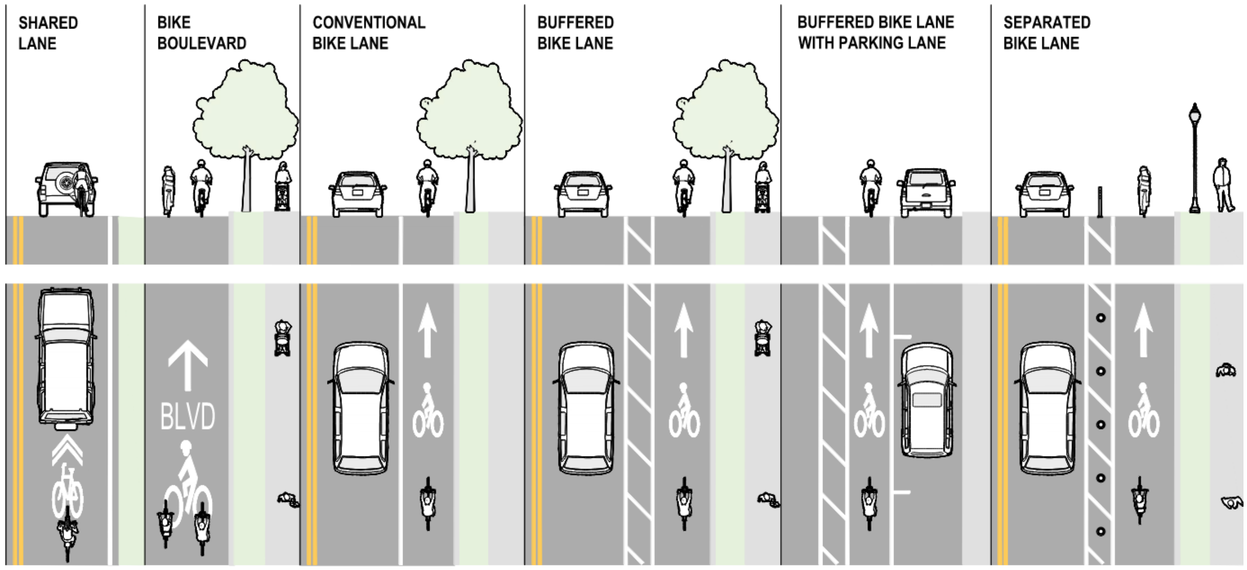


Figure 4: Accommodating Bicyclists on Roadways

5.1 Shared Lanes

Where dedicated bike facilities (e.g., bike lanes, buffered bike lanes, separated bike lanes, or shared use paths) are not provided, bicyclists and motorists must share travel lanes. Shared lanes may be identified with signage and markings or be left unmarked. Where it is desired to emphasize the presence of bicyclists on shared roadways, signage and markings shall be provided. Shared lanes should not be provided without first considering narrowing or removing travel lanes, parking lanes, and medians as necessary to provide an exclusive bicycle facility. Shared lanes are not recommended for roadways with speeds over 35 mph. Shared lanes are not considered bicycle facilities unless they are designed to operate as a bicycle boulevard.

The designs and dimensions for shared lanes differ by location, but attention to the following design features can make shared lanes more comfortable for bicyclists:

- Along the roadway, provide good pavement quality, roadway design that encourages slower motor vehicle operating speeds and lower traffic volumes, bicycle-compatible drainage grates and bridge expansion joints, and safe railroad crossings.
- At signalized intersections, provide appropriate signal timing and detection systems that respond to the presence of bicycles. See ODOT Multimodal Design Guide Section 8.4.4 for more information on signal timing for bicycles, including bicycle minimum green. See City of Columbus *Traffic Signal Design Manual* Section 9.3.11 for more information on bicycle detection.

- At uncontrolled crossings, provide treatments that ensure bicyclists have opportunities to safely cross the intersecting roadway. If such features or conditions are not present, improvements should be implemented. See Section 6.5 for design guidance.

Where bicyclists are operating in shared lanes, travel lane widths should be the minimum widths appropriate for the context of the roadway. In the past, it was common practice to provide wider outside lanes (14 feet or greater) under the assumption that motorists in such lanes could pass a person riding a bicycle without encroaching into the adjacent lane, which would improve operating conditions and safety for both bicyclists and motorists. However, this is inconsistent with Ohio passing laws, and research has found that this configuration does not adequately provide safe passing distance and that motorists do not recognize that this additional space is intended for bicyclists. Wide lanes are therefore not recommended as a strategy to accommodate bicycling. Where existing lane widths are 12 feet or greater, roadways should at a minimum be restriped to reduce wide lanes to minimum lane widths. Additional space may be reallocated to other purposes such as bike lanes, wider sidewalks, etc.

5.1.1 Signage

To emphasize the presence of bicyclists on shared roadways, the "BICYCLES MAY USE FULL LANE" sign (R4-11) may be used in situations where motorists must either change lanes in order to pass a bicycle at a safe distance when overtaking or operate at a reduced speed behind bicyclists until an opportunity for safe passing is presented. Signs should be placed every other block or a maximum distance of 500 feet. A sign shall be placed at the beginning of the shared lane where shared lane markings are used.

The BICYCLE warning sign (W11-1) supplemented with a "SHARE THE ROAD" plaque (W16-1P) shall not be used to communicate a shared lane condition.

5.1.2 Markings

Shared lane markings are intended to let bicyclists know where to position themselves in the lane and to communicate to motorists that bicyclists are likely to occupy the travel lane. When using shared lane markings, there are three considerations – lateral placement, longitudinal placement, and intersection approaches/navigation:

- Lateral placement – Shared lane markings should be marked on an alignment that represents a practical path of bicycle travel under typical conditions. Shared lane markings shall be placed in the center of the travel lane measured from the roadway marked centerline or adjacent lane line to the center of the chevron marking. Where on-street parking is present but there is no edge line marked to establish the parking lane, the shared lane marking shall be placed in the center of the effective travel lane, accounting for an assumed 8-foot width of the unmarked parking lane. See **Figure 5**.

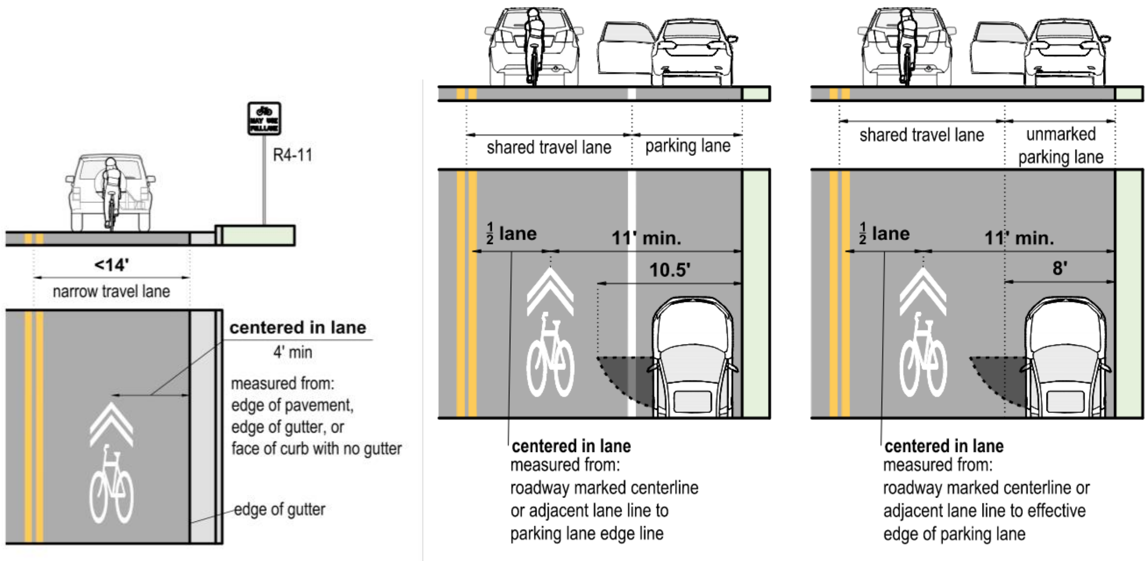


Figure 5: Lateral Placement of Shared Lane Markings

- Longitudinal spacing – Shared lane markings should be placed no more than 50 feet downstream from an intersection and spaced at intervals no greater than 250 feet thereafter (see **Figure 6**), with a minimum of one shared lane marking per block. If possible, the first marking after an intersection or driveway should be placed outside of the wheel path of turning vehicles to reduce wear.

  It may be desirable to place shared lane markings at intervals of 50 to 100 feet to increase motorist awareness of bicyclists and to provide additional guidance for bicyclists. This closer spacing should be considered in the following circumstances:

  - On streets with higher volumes of bicyclists where the shared lane condition fills a gap between bikeways
  - To guide bicyclists through intersections, weaving areas, or turn lanes where there is higher potential for conflicts with motorists
  - At locations with a history of conflicts or crashes between bicyclists and motorists
  - In locations with limited sight distance including approaches to horizontal and vertical curves
  - In shared lane conditions within tunnels and across bridges

- Intersection navigation – Shared lane markings may also be used to provide guidance to a bicyclist to change lanes on approaches to intersections or to help them traverse an intersection.

  Shared lane markings should be located in a line of travel that allows a bicyclist time to merge while minimizing conflicts and unsafe motorist passing maneuvers. In these locations, the markings may be placed as close as necessary to clearly identify the preferred travel path and maneuver. Example applications include:

- Turns through intersections
- Approaches to intersections where bicyclists must merge across one or more travel lanes
- Approaches and crossings of railroad tracks

The edge of on-street parking may be marked when bicyclists are expected. Shared lane markings combined with a striped parking lane provides a continuous point of reference to help bicyclists maintain their line of travel between shared lane markings and parked cars and encourages predictable behavior. See City of Columbus Design Memo 9.09: Parking for requirements on whether to provide a white edge line.

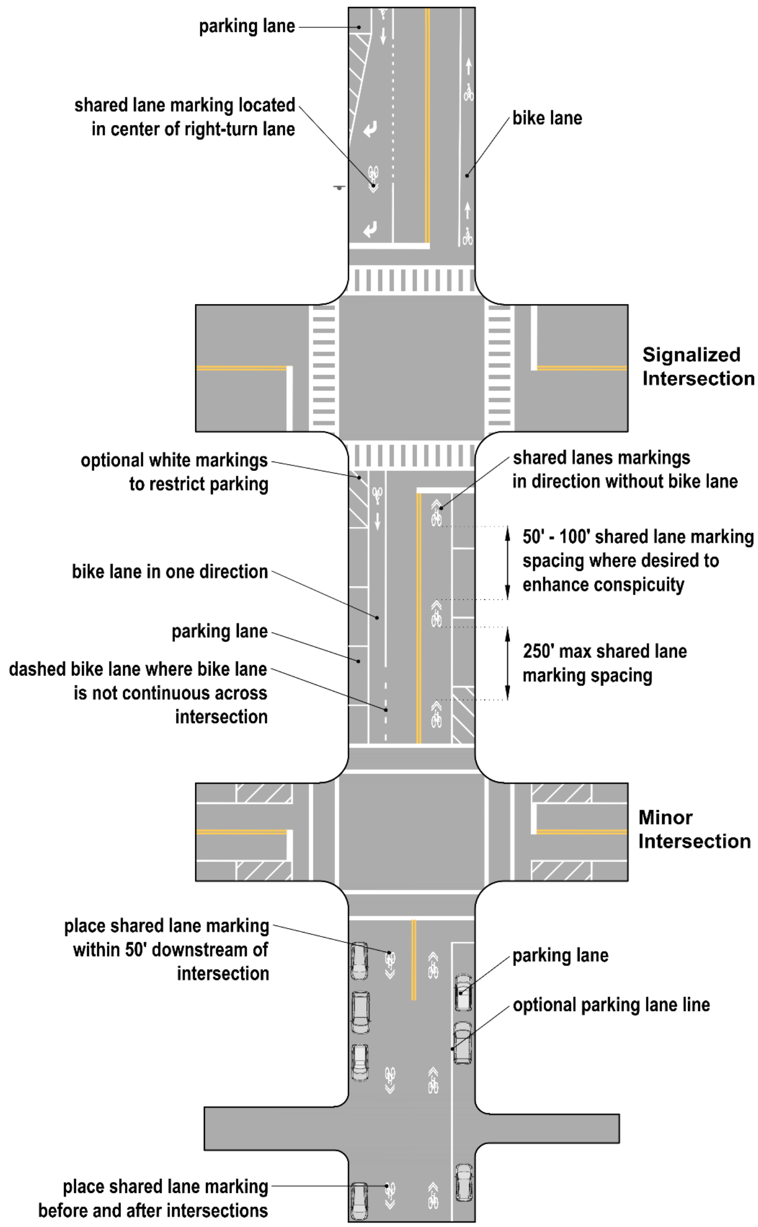


Figure 6: Examples of Longitudinal Placement of Shared Lane Markings along a Roadway
(Note: Drawing is not intended to depict parking striping standards)

5.2 Bicycle Boulevards

Bicycle boulevards, also commonly referred to as neighborhood bikeways or greenways, are low-volume and low-speed streets that enhance bicyclist safety and comfort through design treatments such as speed and/or volume reduction features, pavement markings, signage, and street crossing treatments. These treatments generally support through bicycle movements while discouraging non-local motorists from using them for through trips. Although bicycle boulevards operate as shared lanes, the following guiding principles define bicycle boulevards and set them apart from other local streets or shared lane roadways:

- Managing motorized traffic volumes and speeds
- Prioritizing bicyclist right of way at local street crossings
- Providing safe and convenient crossings at major streets

The following summarizes the typical characteristics of a bicycle boulevard:

- Volumes and speeds – Motorist speeds and volumes shall not exceed the criteria in **Table 1**. Traffic calming and diversion strategies should strive to achieve the preferred values in the table. Bicycle boulevards shall not be designated on streets with posted speed limits above 25 mph.
- Connections to local destinations – Routes should be parallel with and near major thoroughfares connected to major destinations (1/4 mile or less).
- Route directness – There should not be excessive zigzag or circuitous routing.
- Topography – Longer, more gentle slopes are preferable to shorter, steeper segments. Topography should be balanced with route directness.
- Feasibility of major street crossings – Major street crossings on routes should be designed to provide low-stress crossings as defined in Section 6.5.2.

Table 1: Bicycle Boulevard Motorized Traffic Volume and Speed Performance Criteria

	Peak Hourly Volume* (vehicles/hr)	Average Daily Traffic Volume (ADT)	Operating Speed (mph)
Preferred	150	1,000	15
Acceptable	300	2,000	20
Maximum	450	3,000	25

* Assumed to be 15% of ADT

5.2.1 Signage and Markings

A bicycle boulevard shall provide route identification and wayfinding or bicycle guide signs to navigate the route. A combination of pavement markings and signage should be used to help give a visual identity to the corridor and differentiate the slow, multimodal street from other nearby streets.

Bicycle boulevards shall be demarcated with “Neighborhood Bikeway” signage (CN-488.01) as shown in **Figure 7**. Signage shall be installed at all intersections where bicyclists must turn left or right to continue along the designated bikeway. Signage should also be installed at regular intervals along the bikeway where it continues straight.

Bicycle boulevards shall be marked with a bicycle symbol marking, a “BLVD” word marking, and an arrow marking indicating the direction of the travel. Markings should be provided at least once per block and on longer blocks should be provided with a maximum spacing of 500 feet. Bike boulevard pavement markings shall be placed to ensure they are completely visible; do not place them in such a way that parked vehicles will obscure the markings.

Where there is 18 feet or more of clear width, separate markings shall be used for each direction. On streets with less than 18 feet of clear width where both directions of traffic share a single lane (typically on narrower streets where on-street parking is permitted, also known as yield streets), a combined bicycle boulevard marking shall be used. An assumed 8-foot parking lane width should be used for unmarked on-street parking when determining the clear width. See **Figure 8**.

For additional information on intersection treatments along bicycle boulevards, see Section 6.5.

Figure 7: Bicycle Boulevard Signage (CN-488.01)

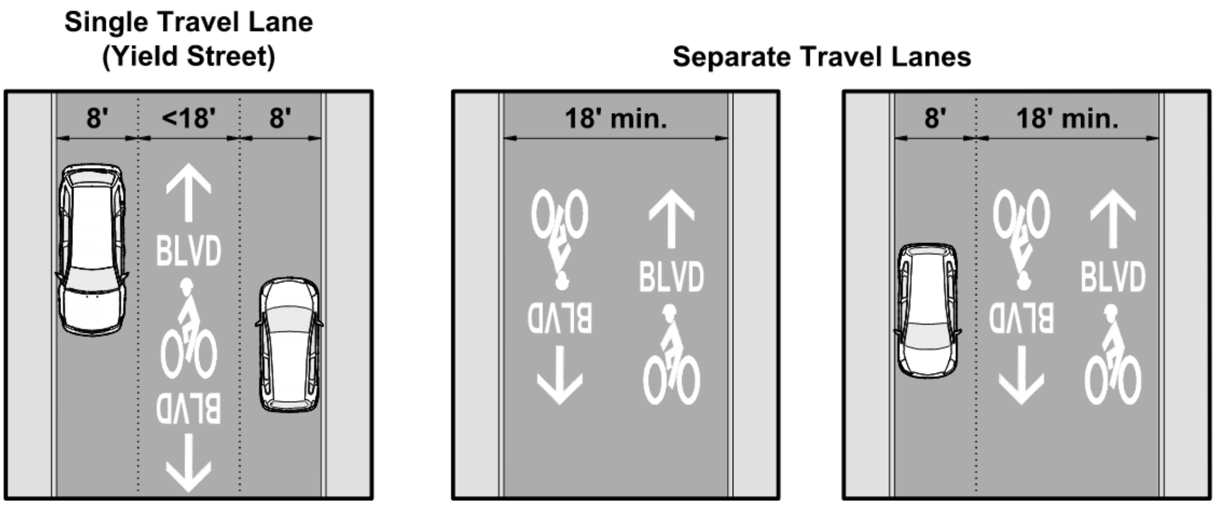


Figure 8: Types of Bicycle Boulevard Markings Based on Street Width

5.2.2 Speed and Volume Management

For roadways that do not currently meet the bicycle boulevard performance criteria shown in **Table 1** but are intended to serve as bicycle boulevards, the street and intersections should be designed to lower the motorist speed and/or volume to meet these criteria. See ODOT Multimodal Design Guide Section 6.3.2 for traffic calming principles that may be used to manage motorist speed and volumes.

5.3 Bike Lanes

Bike lanes are one-way facilities that typically carry bicycle traffic in the same direction as adjacent motor vehicle traffic and are distinguished from traffic lanes by signing and pavement markings.

In most cases, bike lanes should be provided on both sides of two-way streets. The following scenarios note when it may be acceptable to provide a bike lane on one side and how to select which side:

- On streets where downhill grades are long enough to result in bicycle speeds similar to typical motor vehicle speeds, a bike lane may be provided only in the uphill direction, with shared lane markings in the downhill direction. This design can be especially advantageous on streets where fast downhill bicycle speeds in a bike lane have the potential to increase the likelihood of crashes with fixed objects, particularly in locations with on-street parking.
- Where a roadway narrows on one side of the roadway for a short segment with an otherwise continuous bike lane.
- Where an adjacent parallel roadway of similar width provides a bike lane in the opposing direction.

When a bike lane is only provided in one direction, shared lane markings should be added in the opposing direction if the roadway speed is 35 mph or below. See Section 5.1 for shared lane design.

5.3.1 Width

The widths prescribed in **Table 2** accommodate a person's operating space, occasional passing, and shy distances to vertical elements. The width of a bike lane does not include the gutter adjacent to a curb. Where a bike lane is adjacent to a gutter, the width of the bike lane shall be measured from the edge of the gutter to the center of the bike lane edge line. Where a bike lane is adjacent to a curb with no gutter, the bike lane width shall be measured from the face of curb to the center of bike lane edge line. On streets with on-street parking, the bike lane width shall be measured from the center of the edge lines on either side of the bike lane.

The use of constrained widths may degrade safety and reduce comfort for bicyclists. Therefore, the use of constrained values shall only be used for very limited distances where the benefit of providing a constrained width facility outweighs providing no facility at all.

Table 2: Bike Lane Zone Widths

One-Way Standard Bike Lane Width Criteria		
Bike Lane Description	**Minimum Width (ft)**	**Constrained Width[3] (ft)**
Adjacent to curb[1] or edge of pavement	5	4
Between through lanes and turn lanes[2]	6	5
Adjacent to parking	6	5

[1] Width of the bike lane does not include the gutter (where present)

[2] Buffers are desirable where bike lanes are located between through lanes and turn lanes, especially as motorist speeds exceed 30 mph

[3] Constrained widths shall only be used for very limited distances where the benefit of providing a constrained width facility outweighs providing no facility at all

Wider bike lanes should be considered:

- In locations with high parking turnover;
- Where side-by-side bicycle travel is desired;
- Where roadways have irregular edges or sharp drop-offs;
- Where the bike lane is adjacent to curb with no gutter and drainage grates would extend into the bike lane, reducing the functional space for bicyclists;
- Where bike lanes are positioned between two moving travel lanes, such as a turn lane and through lane; or
- On roadways that have more than 5 percent heavy vehicles, posted speeds over 30 mph, or AADT over 6,000.

Where bike lanes wider than 7 feet are feasible, buffered bike lanes should be considered. See Section 5.4.

5.3.2 Bike Lanes on One-Way Streets

On one-way streets, bike lanes should be on the right side of the roadway unless there are a significant number of left-turning bicyclists or if a left-side bike lane would decrease conflicts, such as those caused by bus stops, heavy right-turn movements, deliveries, or on-street parking.

5.3.3 Contraflow Bike Lanes

Bike lanes should typically be provided on both streets of a one-way couplet. If a one-way roadway pair in the opposite direction does not exist or would significantly increase a bicyclist travel time due to out of direction travel, there may be an increase in wrong way riding. If sufficient width exists, a contraflow bike lane can also be added to provide for two-way bicycle travel on a one-way street.

For a bike lane to function as intended when built against the dominant flow of traffic on a one-way street, the following features should be incorporated into the design:

- The contraflow bike lane shall be placed on the correct side of the roadway consistent with the ORC (on the left side from the motorist’s perspective).
- Bike lane symbols and directional arrows should be used on both the approach and departure of each intersection, to remind bicyclists to use the bike lane in the appropriate direction, and to remind motorists to expect two-way bicycle traffic.
- Centerline markings along the left side of the contraflow bike lane shall be provided between the contraflow bike lane and adjacent travel lanes.
- Medians or traffic separators should be considered to provide more separation between motorists and bicyclists traveling in the opposing direction, particularly at intersections. This treatment is required when posted speeds exceed 35 mph. See Sections 5.5.4 and 5.5.5 for more information on appropriate treatments for separation.
- At intersecting streets, alleys, and major driveways, “DO NOT ENTER” signs, turn restriction signs, and ONE WAY signs shall include a supplemental “EXCEPT BICYCLES” plaque (R3-7bP) to establish that the street is two-way for bicyclists. The “EXCEPT BICYCLES” plaque (R3-7bP) shall be placed below the regulatory sign it supplements. See **Figure 9**.
- At traffic signals, signal heads shall be provided for contraflow bicyclists, as well as suitable bicycle detection measures. A “BICYCLE SIGNAL” sign (R10-10b) shall be installed beneath the signal to clarify its purpose.

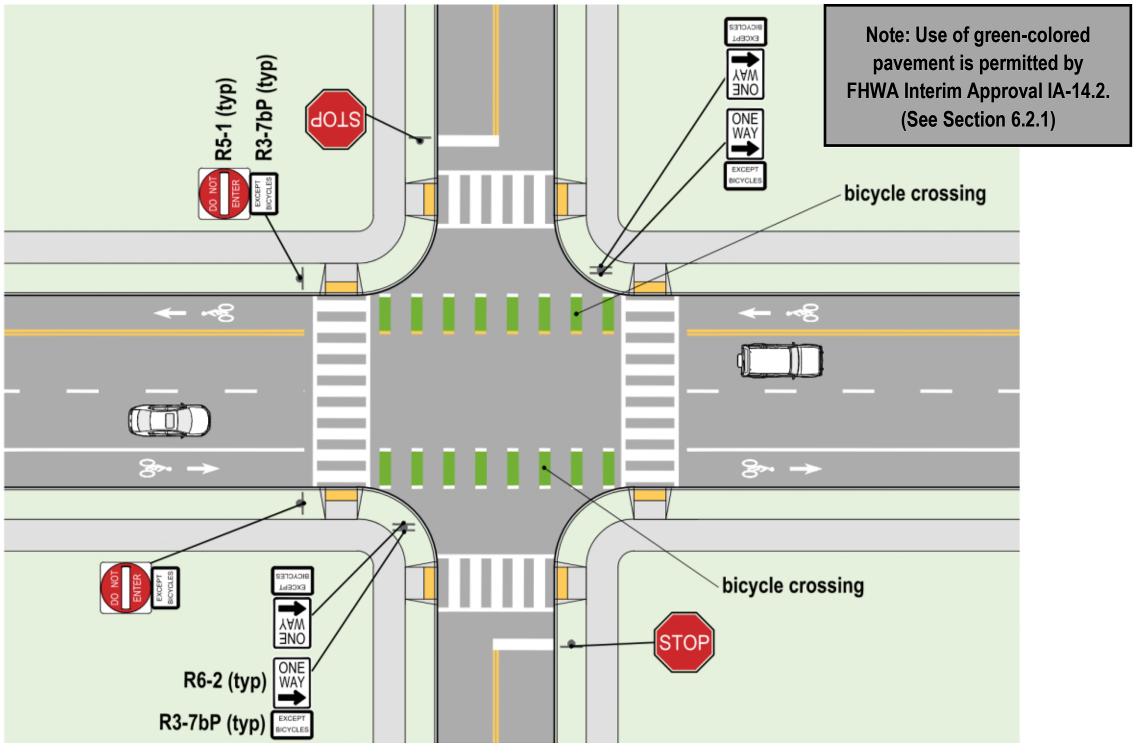


Figure 9: Contraflow Bike Lane Signage at Intersections

A bike lane should also be provided for bicyclists traveling in the same direction as motor vehicle traffic. If there is insufficient room to provide a bike lane in the dominant flow direction of the street, shared lane markings shall be installed to emphasize that bicyclists must share the travel lane on the side of the street without the contraflow bike lane. See **Figure 10** for examples of contraflow bike lanes.

Where parking is present along a contraflow bike lane, motorists leaving a parking space may have difficulty seeing oncoming bicyclists in the contraflow bike lane, as sight lines may be blocked by other parked vehicles. For this reason, the provision of contraflow bike lanes should be discouraged where high-turnover parking is present on the same side of street.

Contraflow transitions should occur at intersections or locations where bicyclists may return to normal two-way travel or naturally transition to the correct side of the street in another bikeway. If transitions are not made at logical locations, it is possible bicyclists would continue to ride contraflow in a shared lane, in a bike lane, or on a sidewalk which can substantially increase their crash risk.

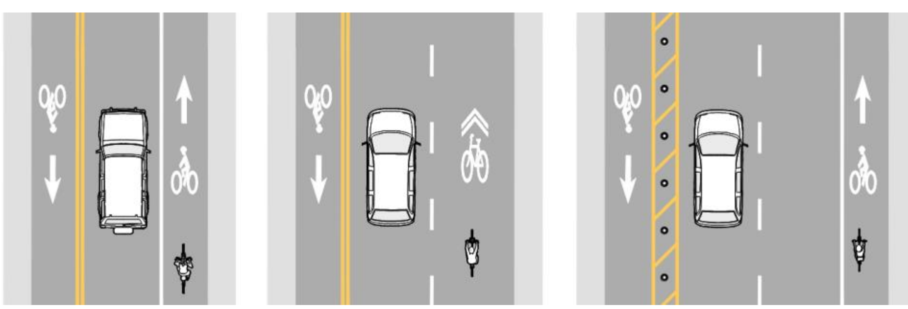


Figure 10: Contraflow Bike Lanes Examples

5.3.4 Signage

The following describes common signs needed where bike lanes are present. Section 9B of the OMUTCD provides additional guidance on bike lane signage.

BIKE LANE (R3-17) signs may be placed as needed or at periodic intervals along a bike lane (see **Figure 11**). Spacing of the sign should be determined by engineering judgment based on the prevailing speed of bicycle and other traffic, block length, and distances from adjacent intersections. Bike lane markings are typically used more frequently than BIKE LANE signs, but where the BIKE LANE sign is used it should generally be placed adjacent to a bike lane pavement marking.

The standard BIKE LANE (R3-17) sign with the AHEAD (R3-17aP) plaque may be placed in advance of the start (upstream end) of a bike lane. These signs are often considered at locations where the bike lane may be unexpected or there are sight distance restrictions to the bike lane.

The BIKE LANE sign with the ENDS (R3-17bP) plaque shall be used in advance of the end of a bike lane to warn that a bike lane is ending. The BIKE LANE ENDS sign should not be used at temporary interruptions in a bike lane, such as where a bike lane is dropped on the approach to an intersection and resumes immediately after the intersection.

A BIKE LANE ENDS warning sign may be used in advance of a BIKE LANE ENDS regulatory sign, to warn bicyclists and motorists of the upcoming condition. A BICYCLES MAY USE FULL LANE sign (R4-11) and/or shared lane markings may be installed downstream of the merge area.

For locations where warning or regulatory signs are not applicable to bicyclists, an EXCEPT BICYCLES plaque should be used to supplement the warning or regulatory sign. These plaques may be applicable to supplement a variety of signs, such as Do Not Enter, No Outlet, One Way, All Traffic Must Turn Right, etc. The R3-7bP version of the sign should only be used with other regulatory signs; the version with black letters on a warning sign panel should only be used with other warning signs.

5.3.5 Markings

Bike lanes shall be indicated with a bike symbol marking and a directional arrow marking indicating the correct direction of travel in the bike lane. The white edge line should be 6 inches wide.

Bike lane symbol markings should be placed no more than 50 feet downstream from an intersection and spaced at intervals based on engineering judgement thereafter (see **Figure 11**). The default spacing for bike lane symbol markings in urban areas is 250 feet. In less urban areas with long distances between intersections and little roadside activity, bike lane symbols may be as far apart as 1,000 feet or more. The first marking after an intersection should be placed outside of the wheel path of turning vehicles.

Bike lane symbols may be closer than 250 feet where potential conflicts between bicyclists and motorists are higher, such as approaches to areas with significant parking turnover, at the near- and far-side of intersections, and adjacent to turn lanes.

Designers shall provide conflict markings at intersections as discussed in Section 6.2 and shown in **Table 7**.

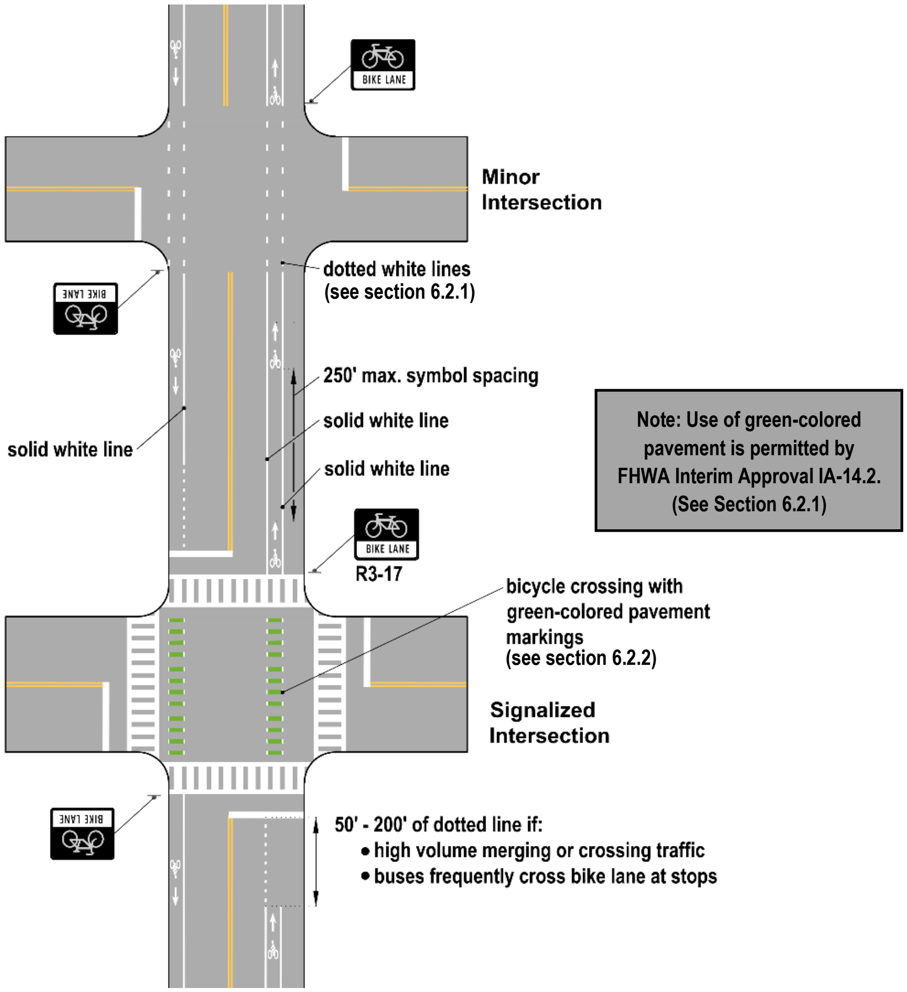


Figure 11: Typical Bike Lane Markings and Signage

5.3.6 Bike Lanes Adjacent to On-Street Parking

Where on-street parking is permitted adjacent to a bike lane, it is preferred to design the bike lane as a separated bike lane following the guidance in Section 5.5, particularly where parallel parking lanes have high turnover. When a separated bike lane is not feasible, or an interim solution is needed, a buffered bike lane should be provided following the guidance in Section 5.4.

Designers should evaluate the reduction of travel lane widths and parking lane widths if necessary to accommodate the design widths for separated bike lanes or buffered bike lanes. Designers should also evaluate if parking can be consolidated to one side of the street or removed to provide the additional space necessary to accommodate the design widths for separated bike lanes or buffered bicycle lanes.

On streets where it is not feasible to eliminate parking or to narrow or remove a travel lane to achieve the preferred dimensions, the minimum combined bike lane and parking lane width is 14 feet; however, 13 feet may be permitted in constrained conditions. All other travel lanes shall be narrowed to the allowable minimum width before the minimum combined bike and parking lane width is considered. The bike lane shall be delineated with a single white edge line on each side.

Where the total available width for the bike lane and parking is 17 feet or more, the design widths for separated bike lanes can typically be accommodated, and a separated bike lane should be provided.

5.4 Buffered Bike Lanes

Buffered bike lanes are striped on-street bike lanes paired with a painted buffer separating the bike lane from the adjacent motor vehicle travel lane. Where space is available, bike lanes can be improved through the provision of the painted buffer. Buffered bike lanes follow the same design guidance as bike lanes for widths and other design elements with the following additions.

5.4.1 Width

The width of the bike lane should follow the guidance for Bike Lanes (see **Table 2** in Section 5.3.1). However, where a buffered bike lane is provided the bike lane may be narrowed to a minimum of 4 feet to maximize the width of the buffer. While the buffer is not a part of the bike lane width, it should be anticipated to be used by bicyclists and the buffer surface shall be traversable.

5.4.2 Striped Buffer Markings

The striped buffer may include chevrons or diagonal lines depending on the conditions and widths available as specified in **Figure 12**. Where a striped buffer is provided, diagonal or chevron markings should be provided at a regular interval. A typical spacing is 15 feet with some locations reduced to as frequent as 10-foot spacing where engineering judgment determines a more frequent spacing is desirable to discourage motorist encroachment or parking. The maximum spacing in feet shall not exceed the equivalent speed limit of the roadway in miles per hour, or 40 feet, whichever is less.

When it is feasible to provide buffers wider than 4 feet, consideration should be given to installing separated bike lanes (see Section 5.5).

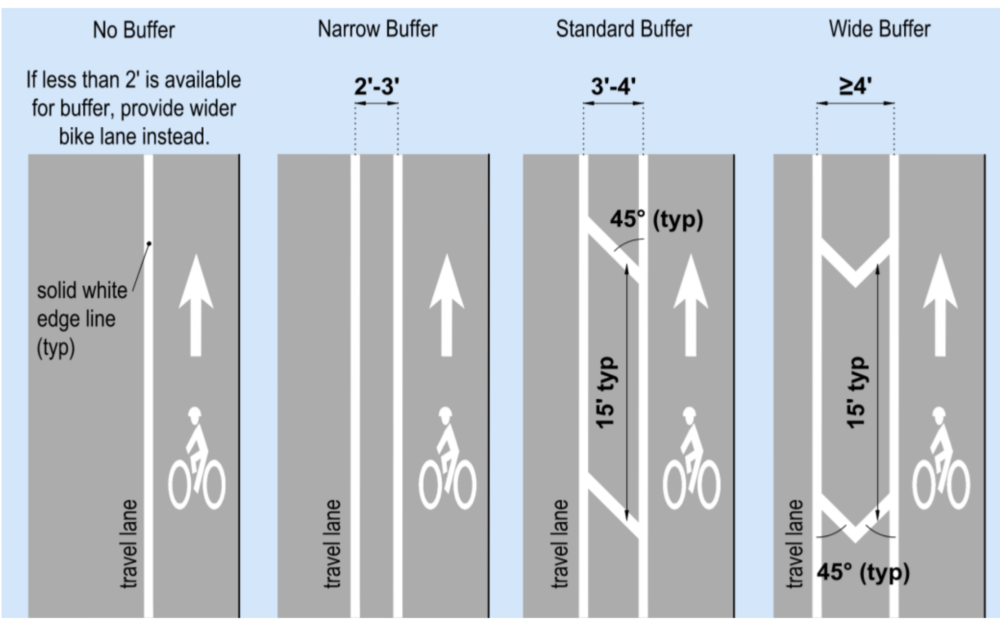


Figure 12: Typical Striped Buffer Treatments

5.5 Separated Bike Lanes

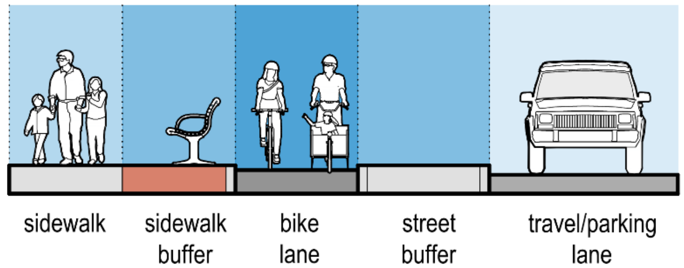


Figure 13: Separated Bike Lane Zones

Separated bike lanes are exclusive bikeways that are physically separated from motor vehicle traffic with vertical separation such as flexible delineators or a curbed median. Separated bike lanes may be located at street elevation, sidewalk elevation, or at an intermediate elevation in between the sidewalk and street. When built at sidewalk level, care must be taken to ensure the separated bike lanes are distinct from the sidewalk to discourage pedestrian encroachment. Separated bike lanes may be installed in one-way and two-way configurations.

Separated bike lanes are comprised of three distinct zones as shown in **Figure 13**:

- Bike lane – The bike lane is the space in which the bicyclist operates. It is located between the street buffer and the sidewalk buffer.
- Street buffer – The street buffer physically separates the bicycle lane from a vehicle lane or on-street parking both vertically and horizontally. See Section 5.5.4.
- Sidewalk buffer – A sidewalk buffer separates the bike lane and sidewalk zones. See Section 5.5.6.

5.5.1 Width

Separated bike lane width should be selected based on the desired elevation of the bike lane, adjacent curb type(s), anticipated volume of users, likelihood of passing maneuvers, and one-way vs. two-way operation. Bicyclists typically do not have the option to pass each other by moving out of a separated bike lane as they would in a standard bike lane because of the vertical elements between the bikeway and motor vehicle travel lane. It is therefore preferable for the width of the separated bike lane to accommodate passing and side-by-side bicycling.

The bike lane widths for one-way and two-way separated bike lanes are provided in **Table 3** and **Table 4** respectively based on the anticipated directional bicyclist volumes. The widths vary depending on adjacent curb types and account for shy distances to these different curb types. Like conventional bike lanes, the widths in these tables are measured from the center of the bike lane edge line, face of curb, or edge of the gutter.

Table 3: Minimum One-Way Separated Bike Lane Widths Based on Existing or Anticipated Volumes

Peak Hour Directional Bicyclist Volume	One-Way Separated Bike Lane Width (ft)		
	Between Vertical Curbs	Adjacent to One Vertical Curb	Between Sloped Curb, at Sidewalk Level, or Uncurbed
<150	6.5 - 8.5	6 - 8	5.5 - 7.5
150-750	8.5 - 10	8 - 9.5	7.5 - 9
>750	≥10	≥9.5	≥9
Constrained Condition*	4.5	4	3.5

* Peak Hour Directional Bicyclist Volume not applicable. For use of constrained values, see Section 5.3.1. Constrained widths shall only be used for very limited distances where the benefit of providing a constrained width facility outweighs providing no facility at all.

Table 4: Two-Way Separated Bike Lane Widths Based on Existing or Anticipated Volumes

Peak Hour Directional Bicyclist Volume	Two-Way Separated Bike Lane Width (ft)		
	Between Vertical Curbs	Adjacent to One Vertical Curb	Between Sloped Curb, at Sidewalk Level, or Uncurbed
<150	10 - 12	9.5 - 11.5	9 - 11
150-350	12 - 16	11.5 - 15.5	11 - 15
>350	≥16	≥15.5	≥15
Constrained Condition*	8.5	8	7.5

* Peak Hour Directional Bicyclist Volume not applicable. For use of constrained values, see Section 5.3.1. Constrained widths shall only be used for very limited distances where the benefit of providing a constrained width facility outweighs providing no facility at all.

5.5.2 Curbing

The following curb types are recommended for separated bike lanes in new construction or reconstruction projects (see ODOT SCD BP-5.1):

- ODOT Curb Type 10-A is a 6-inch sloping curb. Sloping curbs are preferred along any separated bike lane to reduce pedal strike hazards and to ease access to the sidewalk. See **Table 3** and **Table 4** for bike lane widths where sloping curbs are provided.
- ODOT Curb Type 10-B is a 2-inch mountable sloping curb. Mountable curbs are traversable by bicyclists, reduce pedal strike hazards, and are preferred along intermediate level bike lanes.

In general, any curb type with a height of 3 inches or less will allow a bicyclist to ride closer to the curb without fear of a pedal strike. Curb types with a height of less than 6 inches are only appropriate adjacent to intermediate-level bike lanes. ODOT Curb Types 10-A and 10-B may be adjusted based on site conditions but shall be at least 2 inches in height to be detectable by people who are blind.

Combination curb and gutter provide a longitudinal seam parallel to bicycle travel that may deteriorate, resulting in dips or ridges that increase crash risk for bicyclists. Like conventional bike lanes, gutters shall not be included in the bike lane width for separated bike lanes. For retrofit projects where separated bike lanes are added to existing roadways, combination curb and gutter may not be avoidable; however, for new roadways or roadway reconstruction projects, combination curb and gutter should not be provided along a separated bike lane.

5.5.3 One-way versus Two-way Operation

Designers must determine if it would be more appropriate to place a one-way separated bike lane on each side of the street, or to place a two-way separated bike lane or shared use path on one, or both, side(s) of the street. Selecting the appropriate configuration requires an assessment of many factors, including safety, overall connectivity, ease of access, public feedback, available right-of-way, curbside lane uses, intersection operations, ingress and egress to the bikeway, maintenance, and feasibility. The analysis should also consider benefits and trade-offs to people bicycling, walking, taking transit, and driving. The primary objectives for determining the appropriate configuration are to:

- Provide clear and intuitive transitions to existing or planned links of the bicycle network;
- Minimize conflicts between all users – bicyclists, pedestrians, and motorists; and to
- Provide convenient access to destinations.

5.5.3.1 One-way Separated Bike Lanes

One-way separated bike lanes in the direction of motorized travel are typically the easiest option to integrate into the existing operation of a roadway and are the preferred design in most situations. This configuration provides intuitive and direct connections with the surrounding transportation network, including simpler transitions to existing bike lanes and shared travel lanes. It is also the design most consistent with driver expectation since bicyclist operation is in the same direction as motor vehicle operation.

5.5.3.2 Two-way Separated Bike Lanes on One Side of the Street

A two-way separated bike lane or a shared use path on one side of the street introduce a contraflow movement for bicyclists. A two-way separated bike lane might be appropriate where key destinations exist along one side of the road, where driveways and intersections are sparse along one side of the road but frequent along the other side, or for other context-based reasons. If used, care should be given to the design of intersections, driveways, and other conflict points, as people walking and driving may not anticipate bicyclists traveling in the opposite direction. Motorists entering the roadway and needing to cross the separated bike lane often will not notice bicyclists approaching from their right and motorists turning from the roadway across the bikeway may likewise fail to notice bicyclists traveling from the opposite direction. At the terminus of the bikeway, the contraflow bicyclist shall be clearly transitioned back into traffic lanes or to a different bikeway type.

If all other factors are equal (number of conflict points, right-of-way availability, predictability, etc.), consider locating bikeways on the north side of urban roadways to reduce shading on snow and ice during winter months.

5.5.3.3 Two-way Separated Bike Lanes on Both Sides of the Street

Two-way separated bike lanes or shared use paths on both sides of a street introduce the same challenges noted above but may be appropriate on roadways with fewer crossing opportunities for bicyclists. The two-way operation on both sides of the street can allow bicyclists to make more direct connections to adjacent land uses and may prevent wrong way riding that might otherwise occur on some one-way separated bike lanes.

5.5.3.4 Considerations for Separated Bike Lane Configurations

For selecting the location of one-way or two-way bikeways on one-way or two-way roadways, designers should understand the following principles:

- Whenever possible, bikeways should be designed to operate as one-way in the direction of adjacent motor vehicle traffic, to reduce the amount of information that motorists and pedestrians will need to make decisions about safe movements. Research indicates that two-way operation resulted in a higher crash rate than one-way operation.[1]
- Where separated bicycle lanes are built on one-way streets, it is preferable to place them on the right side.[2] Where bikeways need to be installed on the left side, additional treatments to increase awareness and visibility should be considered.
- If bikeways are built on the left side of a one-way street, crashes may increase in the short term, as motorists and bicyclists become accustomed to interacting on the left side, but should normalize over time.[3] There are cases (such as on high-frequency bus routes) where it may be desirable to install the bikeway on the left side of the one-way street. In those cases, designers should consider additional treatments to increase awareness and visibility.

Table 5 and **Table 6** summarize the separated bike lane configurations for one-way and two-way roadways, along with a discussion of associated issues and considerations.

[1] Schepers, J.P., P. A. Kroeze, W. Sweers, J.C. Wüst. Road Factors and Bicycle-Motor Vehicle Crashes at Unsignalized Priority Intersections. *Accident Analysis and Prevention*, Vol. 43, 2011, pp. 853-861.

[2] Zangenehpour, S., J. Strauss, L.F. Miranda-Moreno, N. Saunier. *Are Signalized Intersections with Cycle Tracks Safer? A Case-Control Study based on Automated Surrogate Safety Analysis using Video Data*. Accident Analysis and Prevention, Vol. 86, 2016, pp. 161-172.

[3] Smith, R. L. and T. Walsh. Safety Impacts of Bicycle Lanes. In Transportation Research Record 1168. TRB, National Research Council, Washington, DC, 1988.

Table 5: Separated Bike Lane Configurations on a One-Way Street

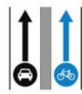
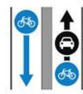
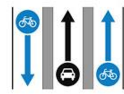
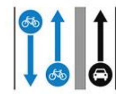
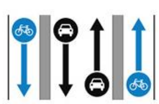
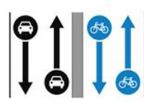
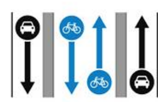
Corridor-level Planning Considerations	One-way SBL	Contraflow SBL	One-way SBL Plus Contraflow SBL	Two-way SBL
				
Access to Destinations	Limited access to other side of street		Full access to both sides of street	Limited access to other side of street
Network Connectivity	Does not address demand for counterflow bicycling, may result in wrong way riding	Requires bicyclists traveling in the direction of traffic to share the lane (may result in wrong way riding in the SBL); counterflow progression through signals may be less efficient	Accommodates two-way bicycle travel, but counterflow progression through signals may be less efficient	
Crash Risk	Lower because pedestrians and turning drivers expect concurrent bicycle traffic	Higher because pedestrians and turning drivers may not expect contraflow bicycle traffic		
Intersection Operations	May use existing signal phases; separate bicycle phase may be required depending on vehicle volumes	Typically requires additional signal equipment; separate bicycle phase may be required depending on vehicle volumes		

Table 6: Separated Bike Lane Configurations on a Two-Way Street

Corridor-level Planning Considerations	One-way SBL Pair	Two-way SBL	Median Two-way SBL
			
Access to Destinations	Full access to both sides of street	Limited access to other side of street	Limited access to both sides of street
Network Connectivity	Accommodates two-way bicycle travel		
Crash Risk	Lower because pedestrians and turning drivers expect concurrent bicycle traffic	Higher because pedestrians and turning drivers may not expect counterflow bicycle traffic	Higher because pedestrians and turning drivers may not expect counterflow bicycle traffic, but median location may improve visibility and create opportunities to separate conflicts
Intersection Operations	May use existing signal phases; separate bicycle phase may be required depending on vehicle volumes	Typically requires additional signal equipment; separate bicycle phase may be required depending on vehicle volumes	

5.5.4 Street Buffer Width

Street buffer width is a central element in separated bike lane design. Appropriate street buffer widths vary depending on the degree of separation desired, right-of-way constraints, and the types of vertical elements, features, or uses that must be accommodated within the buffer. The preferable width of a street buffer is at least 6 feet, regardless of type, both for the comfort of separated bike lane users and to improve driver yielding at intersections. Street buffers may be narrowed to a minimum of 2 feet (3 feet when on-street parking is present).

In addition to providing increased physical separation mid-block, street buffers impact bicyclists' safety at intersections, driveways, and alley crossings. Street buffer widths that provide a crossing setback between 6 feet and 16.5 feet from the motor vehicle travel lane have been shown to reduce crashes at uncontrolled separated bike lane crossings (see ODOT Multimodal Design Guide Section 6.5.2).[4, 5] This offset improves visibility between bicyclists and motorists who are turning across their path, and creates space for motorists to yield (this is discussed in more detail in Section 6).

5.5.5 Vertical Elements

Continuous or intermittent vertical elements are needed in the street buffer to provide separation between motor vehicle traffic and the bikeway operating zone, and to prevent motor vehicle encroachment into the bikeway. For new roadways and reconstruction projects, these vertical elements will typically be curbed medians. Depending on the available buffer width, it may also be possible to implement green infrastructure strategies such as linear bioretention cells within the buffered area; see the City of Columbus *Stormwater Drainage Manual*.

Street sweepers and snowplows should be able to access the bikeway. If the bikeway clear space widths are not able to accommodate the equipment, the vertical elements should be mountable or designed so that both the vertical elements and the maintenance equipment is not damaged.

For retrofit projects where separated bike lanes are being added to existing roadways, the street buffer typically consists of buffered bike lane pavement markings (see Section 5.4) and are supplemented with vertical elements. These vertical elements are typically non-continuous, which facilitates positive drainage along the established roadway crown to existing catch basins.

The placement of vertical elements within the street buffer shall consider the need for shy distances to the bikeway and to the travel lane, access to and from on-street parking, drainage, and maintenance. See ODOT Multimodal Design Guide Section 3.6.2 for more information on shy spaces.

Vertical element spacing should consider the alignment with corresponding pavement markings in the buffer and the necessary effectiveness of the vertical elements to keep vehicles from encroaching into the separated bike lane. For example, on a higher-speed suburban road where motorists are less likely to cross into the bike lane due to fewer driveways or loading and unloading needs, a wider spacing of the vertical elements may be acceptable. On lower-speed urban streets, a spacing of 15 feet or closer may be appropriate to prevent vehicles from attempting to stop or park in the bike lane. Vertical elements may also be more closely spaced approaching intersections or driveways to better see where the gaps in the

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[4] Schepers, J.P., P. A. Kroeze, W. Sweers, and J.C. Wust. Road Factors and Bicycle-Motor Vehicle Crashes at Unsignalized Priority Intersections. *Accident Analysis and Prevention*, Vol. 43, 2011, pp. 853-861.

[5] Madsen, T., and H. Lahrmann. Comparison of Five Bicycle Facility Designs in Signalized Intersections Using Traffic Conflict Studies. *Transport Research Part F*, Vol. 46, 2017, pp. 438-450.

vertical elements are provided for driveway access points while preventing vehicle encroachment too early at these conflict points.

Common options for vertical elements used within the street buffer and their design considerations are described in Sections 5.5.5.1 to 5.5.5.5 and shown in **Figure 14** to **Figure 18**. The specific vertical elements appropriate for use on a particular roadway shall be determined in consultation with the Department of Public Service and shall be subject to Department of Public Service approval.

5.5.5.1 Raised Medians

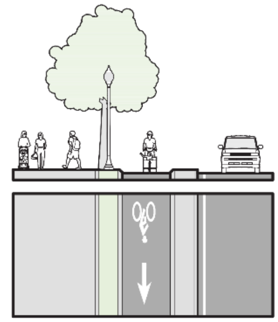


Figure 14: Raised Median in the Street Buffer

Raised medians provide a higher degree of separation and are often more attractive than other separation treatments. They may be either cast-in-place or precast concrete. They are an appropriate design solution on roads up to 45 mph.

Sloped curb should be considered for the curbing alongside the separated bike lane; see Section 5.5.2 for more information.

Stormwater must be considered, as raised medians can complicate drainage patterns, particularly when retrofitted onto existing roadways where the introduction of medians could change the flow of water into drainage structures or impact the spread of water into adjacent travel lanes. Raised medians are typically continuous but may include gaps to allow for stormwater drainage.

Raised medians may also incorporate plantings. The use of plantings within the street buffer will require Department of Public Service approval and may require a separate maintenance agreement to be executed with the Department of Public Service.

5.5.5.2 Continuous Concrete Barriers (or other Rigid Barriers)

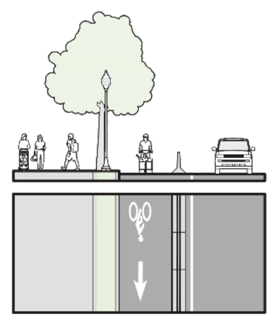


Figure 15: Concrete Barrier in the Street Buffer

Continuous concrete barriers and other rigid barriers provide continuous vertical separation. They are recommended for locations where more physical protection from motor vehicles is needed, such as on bridges or roadways with higher-speed traffic or where street buffer widths are less than the recommended widths. Continuous concrete barriers are most effective where intersections or driveways are infrequent.

Continuous concrete barriers are highly durable and increase safety and comfort for bikeway users along higher-speed roadways.

5.5.5.3 Vehicle Parking

Occupied parking lanes provide additional level of protection and comfort for bicyclists. However, space is needed between the parking lane and bikeway to allow for the opening of doors and loading/unloading. The street buffer shall be a minimum of 3 feet where on-street parking is adjacent to a separated bike lane.

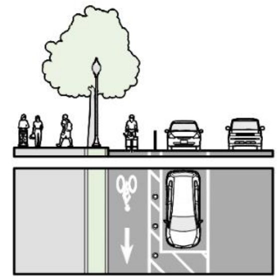


Figure 16: Vehicle Parking in the Street Buffer

Sight distance at intersections and driveways shall be checked to ensure adequate visibility between turning vehicles and the separated bike lane. See ODOT Multimodal Design Guide Section 3.5 for more information.

Other vertical objects should be provided within the buffer between the on-street parking and the separated bike lane to prevent vehicles from parking within the street buffer or bike lane. Additional vertical elements are also required at intersections and other locations where parking is prohibited.

5.5.5.4 Flexible Delineator Posts (or other Crashworthy Plastic Bollards)

Flexible delineator posts (also called “flex posts”) are most commonly used on retrofit projects. Posts shall meet OMUTCD requirements for color and retroreflectivity specifications.

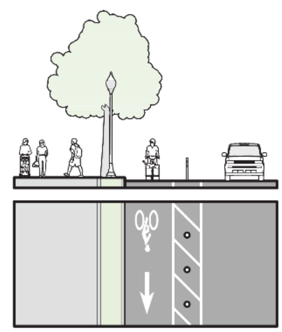


Figure 17: Flexible Delineator Posts in the Street Buffer

Flex posts require closer spacing to prevent motor vehicle encroachment. Their small footprint makes them compatible with a variety of buffer designs.

Flex posts shall be supplemented by pavement markings to delineate the buffer zone. Flex posts may be supplemented by other vertical elements such as precast curbs.

Flex posts are often considered to be less attractive than other buffer types. They have lower durability and need routine replacement, increasing long-term maintenance costs.

5.5.5.5 Precast Curbs (or other Low-Profile Vertical Delineators)

Precast curbs or other low-profile vertical delineation may be provided in various widths to fit the project conditions. Parking stops (also called “wheel stops”) and low-profile plastic separators (commonly referred to as “armadillos”) are a solution for highly constrained locations. They can be an effective solution in locations where motorist encroachment in the bike lane is anticipated to be an issue.

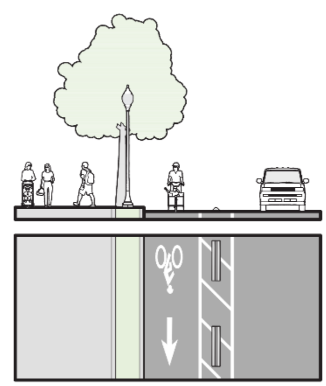


Figure 18: Precast Curbs in the Street Buffer

Precast curbs and other low-profile vertical delineators should be supplemented with flexible delineators to compensate for their reduced visibility due to their low height, particularly at intersections and driveways. Precast curbs and other low-profile vertical delineators shall also be supplemented by pavement markings to delineate the buffer zone. Consistent spacing is needed between precast curbs and delineators, and they should be anchored to the pavement.

Precast curbs that have a similar profile to cast-in-place curbs may be installed on any roadway where the installation of curb is allowed. By comparison, parking stops may not be appropriate for roadways with operating speeds that exceed 35 mph.

Precast curbs are highly durable and are easily removed to facilitate maintenance.

5.5.6 Sidewalk Buffer

The sidewalk buffer zone separates the sidewalk from the separated bike lane to communicate that the sidewalk and the separated bike lane are distinct spaces. The sidewalk buffer will vary based on context.

If the separated bike lane is at street level or an intermediate level, the sidewalk buffer is the same as the Buffer Zone described in City of Columbus Design Memo 6.03: Sidewalks, and the street curb vertically separates the sidewalk and the separated bike lane. For intermediate-level bike lanes, a mountable sloped curb should be provided to establish the separated bike lane (see Section 5.5.2).

When a separated bike lane is raised to sidewalk level, sidewalk buffers shall include a detectable edge such as directional indicators so pedestrians with low vision can distinguish between the bike lane and the sidewalk. See ODOT Multimodal Design Guide Section 4.3.3 for more information on directional indicators.

5.5.7 Drainage

For retrofit projects, most vertical elements are non-continuous or can be provided with gaps or drainage channels to allow stormwater to flow through the street buffer. This approach allows drainage patterns to remain largely unchanged from existing conditions and allows stormwater to reach existing catch basins. When some continuous vertical elements are introduced along separated bike lanes, this may impact existing drainage patterns and require alterations to a drainage system. Example separated bike lane drainage patterns are shown in ODOT Multimodal Design Guide Section 6.3.7.

5.5.8 Transitions Between Separated Bike Lanes and Other Bikeway Types

Transitions between separated bike lanes and other bikeway types are essential for all projects that include a separated bike lane. The actual transition design can vary greatly from location to location depending on many of the contextual factors discussed throughout this guide. The selected transition design should clearly communicate how bicyclists should enter and exit the separated bike lane to minimize conflicts with other users.

For more information on transitions between separated bike lanes and other bikeway types and illustrations of example transitions, see ODOT Multimodal Design Guide Section 6.3.7.

6 Intersections and Bicycle Crossings

This section discusses the design of bikeways at intersections and crossings. The preferred design treatment at every intersection and crossing should be selected based on the following design principles:

- Minimize exposure to conflicts
- Reduce speeds at conflict points
- Provide adequate sight distance
- Communicate right of way priority
- Provide clear transition between bikeway types
- Accommodate people with disabilities

6.1 General Bikeway Design at Intersections and Crossings

6.1.1 Separation of Modes

A bikeway and any physical separation provided along a bikeway should be maintained up to intersections. Sections 6.3, 6.4, and 6.5 discuss when additional physical separation may be appropriate based on speeds, volumes, and contexts. In some instances, it may not be feasible to maintain a bikeway and separation to an intersection. This will necessitate specific design considerations and may not maintain the desired level of comfort and safety for the selected bikeway.

6.1.2 Visibility of All Users

Adequate sight lines are needed between all roadway users as they approach an intersection. ODOT Multimodal Design Guide Section 3.5 defines sight distance requirements for bikeways under different intersection scenarios. Due to the mixed nature of traffic at intersections (pedestrians, bicyclists, and motorists), the designer should keep in mind the speed of each travel mode and its resulting effect on design values when considering design treatments. The fastest vehicle should be considered for approach speeds (typically the motor vehicle and bicycle) because these modes require the greatest stopping distance. By contrast, for departures from a stopped condition, the characteristics of slower users (typically pedestrians and bicyclists) should be considered due to their greater exposure to cross traffic.

It may be necessary to restrict parking and other vertical obstructions to ensure adequate sight distances are provided, particularly in these situations:

- Where a separated bike lane is located behind a parking lane
- At intersections and driveways with permissive turning movements where bicyclists and motorists are traveling in the same direction
- At intersections and driveways with stop signs, where motorists must stop before turning across the separated bike lane. In these locations, the standard parking restrictions adjacent to the intersection (20 feet minimum from a crosswalk and 30 feet prior to a traffic control device per Columbus City Code 2151.01) may be adequate.

6.1.3 Speed Minimization

Intersections where bicyclists operate should be designed to ensure slow-speed turning and weaving movements for motor vehicles. Treatments for reducing speed and improving safety at conflict points are provided in subsequent sections based on the bikeway type and roadway configuration. See City of Columbus Design Memo 9.04: Turning Radii for more information on evaluating corner radii to minimize speeds.

6.1.4 Communicate Right of Way Priority

Intersection design should provide bicyclists, pedestrians, and motorists with cues that clearly establish which user(s) have the right of way. Traffic control devices should communicate the priority right of way through the provision of:

- Marked pedestrian crossings of bikeways;
- Marked bicycle crossings (lane extensions) at intersections;
- Regulatory or warning signs for motorists and/or bicyclists who are crossing, merging, or turning where appropriate; and
- Signal phase separation where necessary.

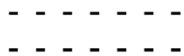
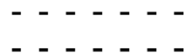
6.1.5 Separate Bicycle Signal Phases

Designers should assess the number of right and left-turning motorists across bikeways during the peak hour to identify when a protected or partially protected bicycle phase may be necessary. See ODOT Multimodal Design Guide Section 8.4.5 for more information on situations and turning volumes where separate signal phases should be considered.

6.2 Intersection Pavement Markings

Intersection pavement markings are used to highlight conflict areas and aid bicyclist navigation. **Table 7** summarizes the preferred pavement markings based on the intersection and bikeway type. **Figure 19** shows the application of bicycle crossings and other treatments at an example signalized intersection.

Table 7: Bicycle Crossing and Intersection Markings Selection Guidance

Intersection Type	Condition	Separated Bike Lane	Conventional or Buffered Bike Lane	Bicycle Boulevard
Signalized	Turn Conflict			No Markings
	No Turn Conflict			No Markings
	Bikeway Corridor Turns Left			
Unsignalized	High Turning Volume			No Markings*
	All Other Conditions			No Markings

*Additional treatment may be needed

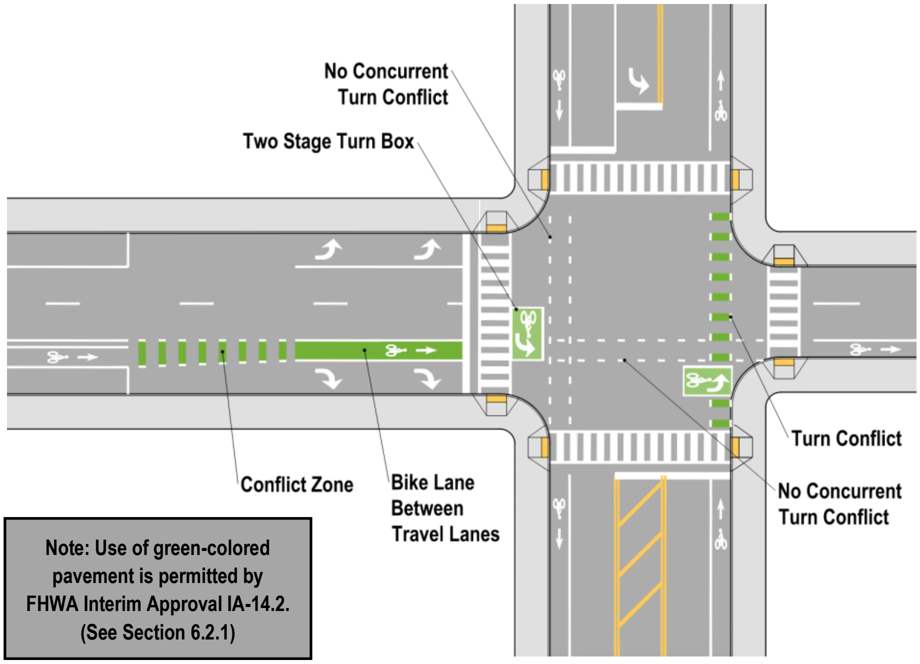


Figure 19: Example Application of Intersection Treatments at a Signalized Intersection

6.2.1 Green-Colored Pavement

Green-colored pavement is beneficial to supplement other bikeway pavement markings to communicate to road users where portions of the roadway have been designated for exclusive or preferential use by bicyclists, and to enhance the conspicuity of a bike lane, bike lane symbol, bike lane extension, bicycle crossing, bike box, or two-stage bike turn box. The use of green-colored pavement is permitted by FHWA Interim Approval IA-14.2.

The use of green-colored pavement to supplement other bikeway pavement markings, such as a shared lane marking, requires experimental approval from FHWA. Designers should look to IA-14 and FHWA requirements for experimentation when determining if an experimental design is appropriate to consider and feasible to implement.

6.2.2 Bicycle Crossing Markings (Lane Extension Lines)

Bicycle crossing markings consist of dotted lane extension lines. Bicycle crossing markings shall at least match the width of the line it is extending. **Figure 20** provides design details for bicycle crossing markings. Bicycle crossing markings are desirable to:

- Delineate a preferred path for people bicycling through the intersection, especially crossings of wide or complex intersections;
- Improve the legibility of the bike crossing to roadway users; and
- Encourage motorist yielding behavior, where motorists must merge or turn across the path of a bicyclist.

Bicycle crossing markings shall be provided where a bikeway crosses an intersection separate from a crosswalk. Bicycle crossing markings through intersections should be supplemented with green-colored pavement where turn conflicts exist based on the markings selection guidance provided in **Table 7**.

Bicycle crossing markings shall also be provided and shall be supplemented with green-colored pavement through merge areas approaching intersections where there is an added turn lane and motorists must cross the bikeway.

Where used, green-colored pavement shall align with the dotted extension line pattern of the dotted edge lines. Where installed adjacent to high-visibility crosswalks (City of Columbus Type II), the dotted extension lines and green-colored pavement should align with the crosswalk markings. See **Figure 20**. This placement will reduce pavement marking clutter and ensure that the green-colored markings are spaced to avoid motorist wheel paths and improve the longevity of the markings.

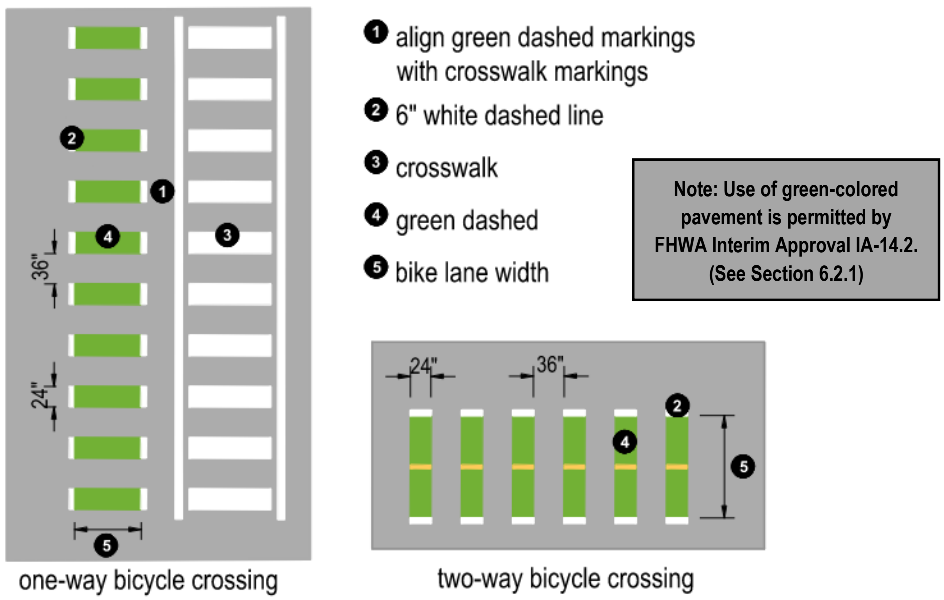


Figure 20: Bicycle Crossing Pavement Markings

6.2.3 Two-Stage Bike Turn Box

Two-stage bike turn boxes, as shown in **Figure 21**, designate an area at an intersection to provide bicyclists a place to wait to complete a two-stage turn outside of the path of moving traffic. The use of a two-stage bike turn box is permitted under FHWA Interim Approval IA-20.12.

Two-stage bike turn boxes may be used for left or right turns, and its use is preferred for making turns instead of a bike box (see Section 6.2.4), particularly on higher-volume or multi-lane roads where bicyclists need to weave across lanes to make a turn. A two-stage bike turn box may only be used at signalized intersections.

Two-stage bike turn boxes should be installed at signalized intersections where making a left turn would require a bicyclist to cross multiple lanes of traffic or where a bikeway intersects with another designated bikeway. When designing a buffered or separated bike lane, designers should plan on installing two-stage bike turn boxes at most signalized intersections to discourage merging with traffic to make a left turn before reaching intersections. When designing a conventional bike lane, if the volume of the intersecting roadway is more than 6,000 ADT or the speed limit of the intersecting roadway is 35 mph or greater, designers should consider installing two-stage bike turn boxes at signalized intersections.

A two-stage bike turn box:

- Shall be located outside of the path of through and turning traffic;
- Should be located adjacent to the direct path of bicyclist travel;
- Should be located downstream of the cross street intersection stop line and downstream of the crosswalk across the cross street;
- Shall be located in an area clearly visible to motorists;
- Should be adequately illuminated;
- Shall include a bicycle symbol oriented in the direction in which the bicyclists enter the box, along with an arrow showing the direction of the turn; and
- Shall include green-colored pavement or pavement markings to enhance the conspicuity of the box.

A NO TURN ON RED (R10-11b) sign shall be installed where a two-stage bike turn box is located within the path of right-turning traffic to prevent motorists from entering the bicycle queuing area (see City of Columbus *Traffic Signal Design Manual* Section 8.10 for sign placement requirements). The two-stage bike turn box shall be placed to ensure left-turning traffic will not cross over the box (see **Figure 22**). Signal detection zone (or loop) for detection of bicycles in the two-stage bike turn box shall be provided if detection is required to actuate the signal phase for the crossing approach.

Two-stage bicycle turn box dimensions vary based on the street operating conditions, the presence or absence of a parking lane, traffic volumes and speeds, and available street space. The queuing area should be a minimum of 6.5 feet deep measured in the longitudinal direction of bicycles sitting in the box and a minimum of 10 feet wide. The box shall be outlined with solid white lines.

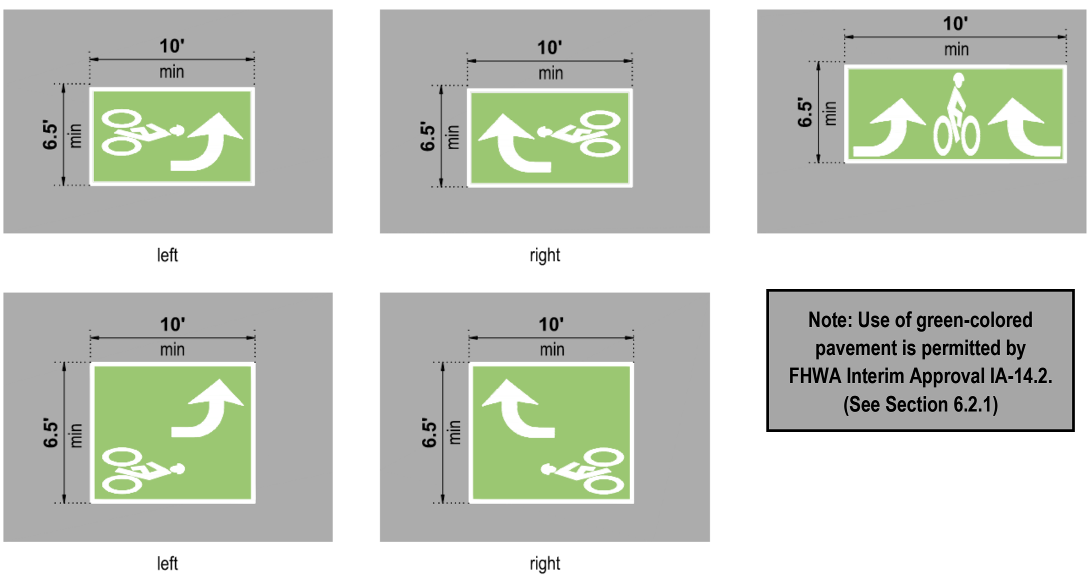


Figure 21: Two-Stage Bike Turn Box Pavement Markings

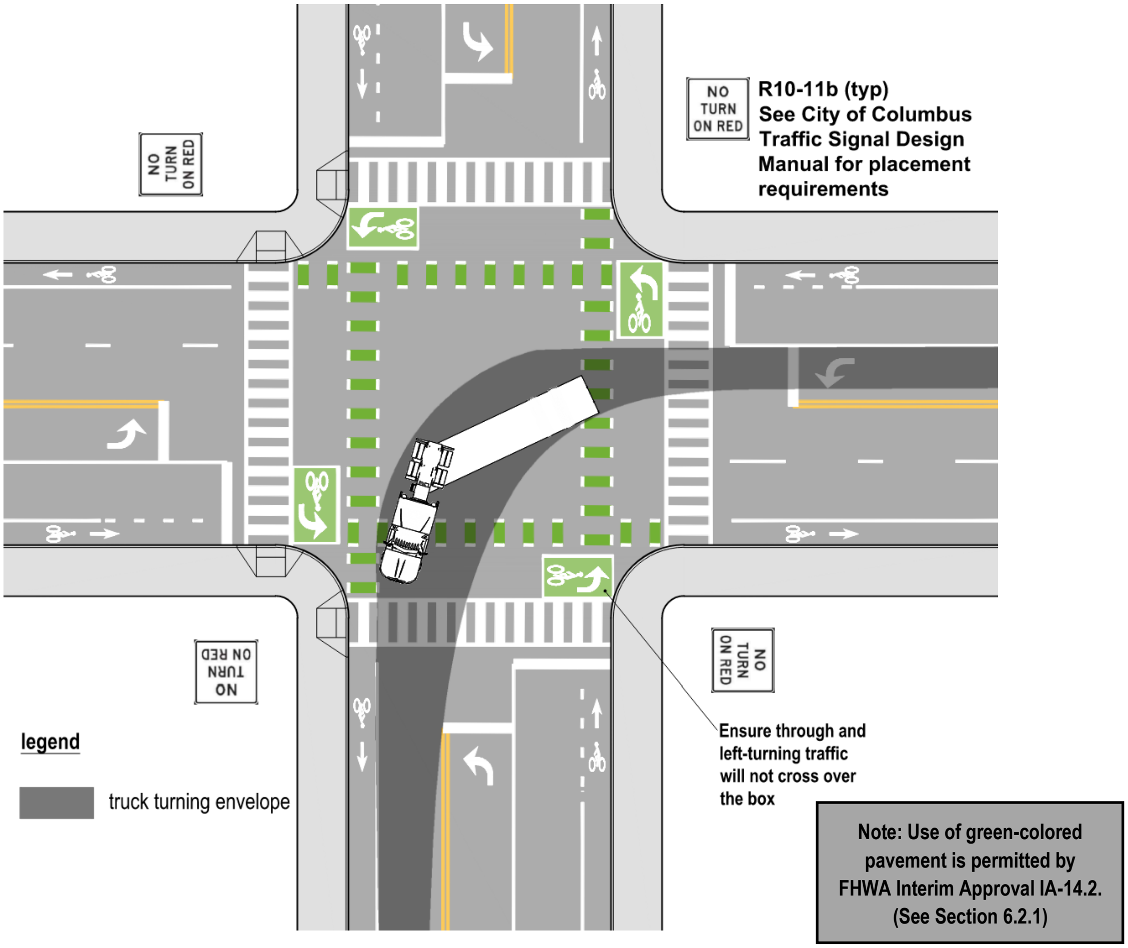


Figure 22: Two-Stage Left Turn Box Placement

6.2.4 Bike Boxes

A bike box is a designated area on the approach to a signalized intersection consisting of an advanced stop line and bicycle symbol as shown in **Figure 23**. Bike boxes mitigate conflicts between through bicyclists and right-turning motorists, reduce conflicts between motorists and bicyclists at the beginning of the green signal phase, and provide additional queuing space for bicyclists. The use of a bike box is permitted under FHWA Interim Approval IA-18.10.

Bike boxes should not be installed across more than one through travel lane with the intention of accommodating bicyclist turns; however, FHWA Interim Approval IA-18.10 does permit this installation with certain conditions. A two-stage bike turn box should instead be used to accommodate bicyclist turns (see Section 6.2.3). The use of bike boxes is limited to signalized intersections and shall not be used in other locations.

At least one bicycle symbol shall be placed in the box to indicate it is for bicycle use. Bike boxes shall be a minimum of 10 feet in depth and may be larger depending on anticipated bicyclist volumes. At least 50 feet of bike lane shall be provided on the approach to a bike box so bicyclists will not need to ride between vehicular lanes to enter the box. The approaching bike lane, and the bike box, shall be colored green.

The stop line for motorists shall be set back to coincide with the beginning of the bike box. The STOP HERE ON RED (R10-6) sign, aligned with the motorist stop line, should be installed to indicate the correct stopping location for motorists, with an EXCEPT BICYCLES (R3-7bP) word legend plaque. The STOP HERE ON RED (R10-6) sign should not be used in locations with a separate turn lane where motorists are stopping in two different locations. See City of Columbus *Traffic Signal Design Manual* Section 8.11 for additional placement requirements for the STOP HERE ON RED (R10-6) sign.

Turns on red shall be prohibited on the approach where a bike box is placed in front of traffic that has potential to turn on red, using a NO TURN ON RED sign (R10-11b), placed in accordance with the requirements of City of Columbus *Traffic Signal Design Manual* Section 8.10.

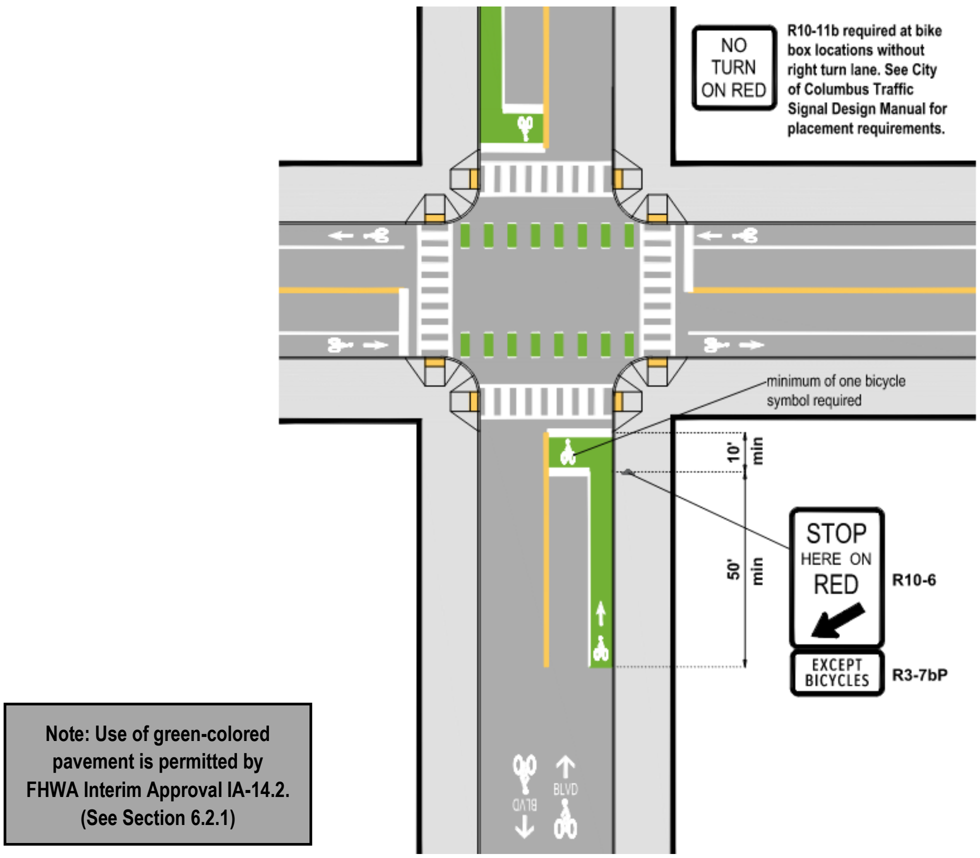


Figure 23: Bicycle Box Configuration at a Bike Boulevard

6.2.5 Additional Uses of Green-Colored Pavement

In addition to the uses described above, green-colored pavement shall be used within the bike lane when the bike lane is located between a vehicular travel lane and a turn lane. Green-colored pavement may also be used within the bike lane at complex intersections where it is desired to highlight the location of the bike lane.

6.3 Separated Bike Lanes at Intersection Design

A protected intersection is the preferred intersection treatment for separated bike lanes. Protected intersections maintain bicyclist separation in a separated bike lane up to the intersection using corner islands (vertical elements or curbing) to separate bicyclists from traffic. This design principle may be used at signalized and unsignalized intersections and driveways. See ODOT Multimodal Design Guide Section 6.5.2 for more information and guidance on protected intersection design.

When intersections are constrained, designers should consider the following (in the order listed):

1. Reduce each roadway element (motor vehicle lanes, buffers, separated bike lanes) to its minimum dimensions or minimum number of travel lanes necessary.
2. Eliminate the sidewalk buffer while still providing a detectable edge adjacent to the road for pedestrians with disabilities (see City of Columbus Design Memo 6.03: Sidewalks).
3. Provide a conventional bike lane or mixing zone (not appropriate for two-way separated bike lanes) by transitioning the separated bike lane to:
    - A conventional bike lane with an optional bicycle ramp to an adjacent shared use path for roadways with operating speeds of 35 mph or greater.
    - A conventional bike lane or shared lane for roadways with operating speeds of less than 35 mph.

These options are further discussed below and in Section 6.4 for conventional bike lane designs.

6.3.1 Reducing Speed at Conflict Points

Where motorists are permitted to turn across the path of bicyclists, intersections should be designed to reduce motorist turning speeds. Designers should apply the following treatments for reducing motorist turning speeds when feasible based on the roadway context:

- At protected intersections, the effective radius of an intersection corner plays a significant role in determining the speed at which turning motorists may negotiate the corner. See City of Columbus Design Memo 9.04: Turning Radii for design information regarding reducing turning speed by minimizing corner radius, the use of truck apron treatments, and appropriate design and check vehicles. See ODOT Multimodal Design Guide Section 6.5.2 for more information and guidance on protected intersection design.
- The speed of left-turning motorists crossing a bikeway should also be considered. Channelizing devices such as median islands (see City of Columbus Design Memo 6.05: Pedestrian Islands) can be used to establish a smaller turning radius, reducing the speed of motorists, which can improve yielding and reduce the severity of crashes.

It may also be necessary to slow the speed of bicyclists approaching an intersection, especially where the grade of the roadway will frequently result in higher speed travel, by doing the following:

- Bending the bike lane away from the adjacent motor vehicle lane is preferred, as this creates a larger offset at the intersection from turning vehicles, while also introducing horizontal deflection in the bike lane. The offset may also allow for the provision of a corner island or protected intersection. The horizontal deflection should follow the bicycle taper rate design criteria specified in ODOT Multimodal Design Guide Chapter 3 using the desired operating speed.
- Where horizontal deflection is not feasible due to geometric constraints, designers may consider vertical deflection for bicyclists, raising the elevation of the bikeway to reduce their speed as they approach an intersection. See Transitioning Bikeways Between Elevations for vertical deflection design parameters.

6.3.2 Transitioning Bikeways Between Elevations

Separated bike lanes may transition from one elevation to another to accommodate:

- Raised crossings at intersections;
- A vertical deflection to slow bicyclists as they approach an intersection; and
- At loading/unloading areas that prioritize pedestrians such as accessible parking, valet parking, transit stops, or ridesharing pick-up/drop-off.

The ramp for the bicyclist should provide a smooth vertical transition with a maximum slope of 8 percent; however, a 5 percent slope is generally preferred. Speed hump markings should be used on bicycle ramps to allow the ramp to be more visible to bicyclists. Transition ramps should typically not be located within a lateral shift or curve in the bike lane alignment near an intersection. Transition ramps shall be designed to facilitate adequate drainage, either by providing inlets upstream of the transition ramp or providing grading that maintains drainage flows along the bottom of the ramp.

For more information on bike ramps, see ODOT Multimodal Design Guide Section 6.3.8.

6.3.3 Restricting Motor Vehicles

Separated bike lanes should be marked with bicycle crossings at intersections and major driveways (with green-colored pavement markings where appropriate) as described in Section 6.2.1. These marked crossing treatments are often sufficient to communicate that motor vehicles are not the intended user of the bikeway. Bike lane symbol markings (Section 5.3.5) located close to an intersection or driveway can further reinforce the intended user.

Guidance on additional treatments that should be considered if the above treatments have been implemented and found to be ineffective can be found in ODOT Multimodal Design Guide Section 6.5.2.

6.3.4 Separated Bike Lanes with Mixing Zones at Intersections

Where protected intersections are not viable, or where separate signal phases for the separated bike lane and turning motor vehicles cannot be provided, the mixing zone option shown in **Figure 24** may be considered for separated bike lanes at intersections. Mixing zones create a defined merge point for a motorist to yield and cross paths with a bicyclist in advance of an intersection. They require removal of the physical separation between the separated bike lane and the motor vehicle travel lane and are therefore generally appropriate as an interim/retrofit solution or in situations where right-of-way constraints make it infeasible to provide a protected intersection.

The speed of motor vehicles at the merge point is a critical factor for the safety and comfort of bicyclists in mixing zones. The following strategies can be used to reduce speeds of motor vehicles entering the merge point:

- Minimize the length of the merge area to slow motorists prior to the conflict area.
- Locate the merge point as close as practical to the intersection.
- Minimize the length of the storage portion of the turn lane based on anticipated vehicle queue length (see ODOT *L&D Manual Volume 1*, Section 401.6.3).
- Provide a buffer and physical separation from the adjacent through lane after the merge area, if feasible.
- Highlight the conflict area with a green-colored pavement and dotted bike lane markings. See **Figure 24**.

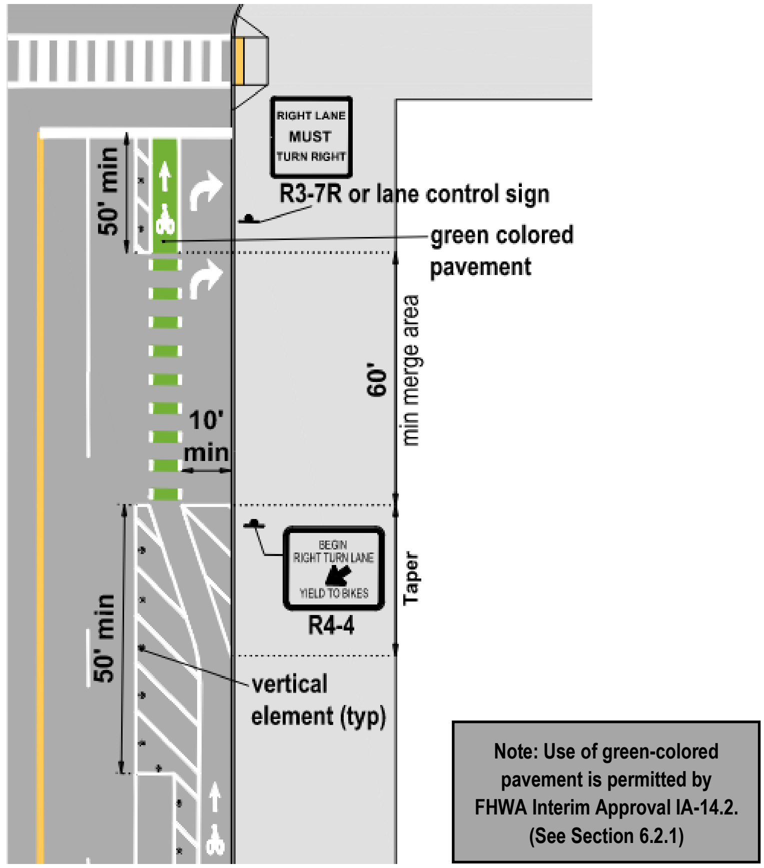


Figure 24: Separated Bike Lane to the Left of a Right-Turn Lane

6.4 Bike Lanes at Intersection Design

As a bike lane approaches an intersection, designers should provide a continuous and direct route through the intersection, driveway, or alley that is legible to all users of the roadway. Designers should minimize or eliminate conflict areas between bicyclists and motor vehicles. To minimize the potential for conflicts, designers should adhere to the following design principles:

- Designers should communicate where motorists are expected to yield to bicyclists.
- Bicyclists should not operate between turning lanes and moving lanes with traffic operating over 30 mph on either side of them for distances longer than 200 feet (see further discussion in Section 6.4.3).
- Bicycle crossings of weaving or merging movements by motor vehicles operating over 20 mph should be avoided or minimized to a length of 200 feet or less.
- It is preferable for motorists merging and crossing movements across bike lanes be confined to a location where motor vehicles are likely to be traveling at speeds less than 20 mph.
- Provide bicycle crossings through intersections as described in Section 6.2.1.

A conventional or buffered bike lane may be transitioned to a separated bike lane and follow the design of a protected intersection to increase the comfort of the bikeway at the intersection, see Section 6.3. Designers should consider this design at operating speeds of 35 mph or higher. See ODOT Multimodal Guide Chapter 3 for bike lane taper rates and ODOT Multimodal Design Guide Section 6.5.2 for protected intersection design. When a protected intersection is not feasible for operating speeds of 35 mph or greater or motor vehicle turning volumes exceed 150 turning vehicles per hour, a bicycle ramp should be considered to give bicyclists a choice to exit the roadway to a shared use path prior to the intersection. See ODOT Multimodal Design Guide Section 6.3.8 for more information on bicycle ramps.

6.4.1 Approach Markings

Bike lane lines may be dotted on the approach to and within intersections where motor vehicles are permitted to enter a bike lane to prepare for a turning, crossing, or merging maneuver.

The choice between a solid or dotted lane line should be based on several factors including the speed and volume of turning vehicles, the presence of bus stops and frequency of transit use, and the types of vehicles that may cross or enter the bike lane (see Section 6.1). A key consideration is the legibility of the bike lane network to both bicyclists and drivers.

Bike lane lines should remain solid to the intersections at locations with infrequent conflicts or where turns across the bike lane are not permitted.

Dotted lane lines should be used to delineate conflict areas within the bike lane at locations where:

- Intersections are signalized and bicyclists and motorists operate concurrently,
- Where right turn lanes are not provided and turning motorist volumes are high, or
- Buses cross the bike lane at transit stops.

As buffered bike lanes approach intersections, the buffer should not be marked where motorists must cross or enter the bike lane and a bicycle crossing should be provided through the intersection (see Section 6.2.1). The bicycle crossing should be widened to match the width of the full bike lane and buffer. As buffered bike lanes approach intersections with shared through/right lanes, the buffer may terminate with a bicycle crossing provided through the intersection. See **Figure 25**.

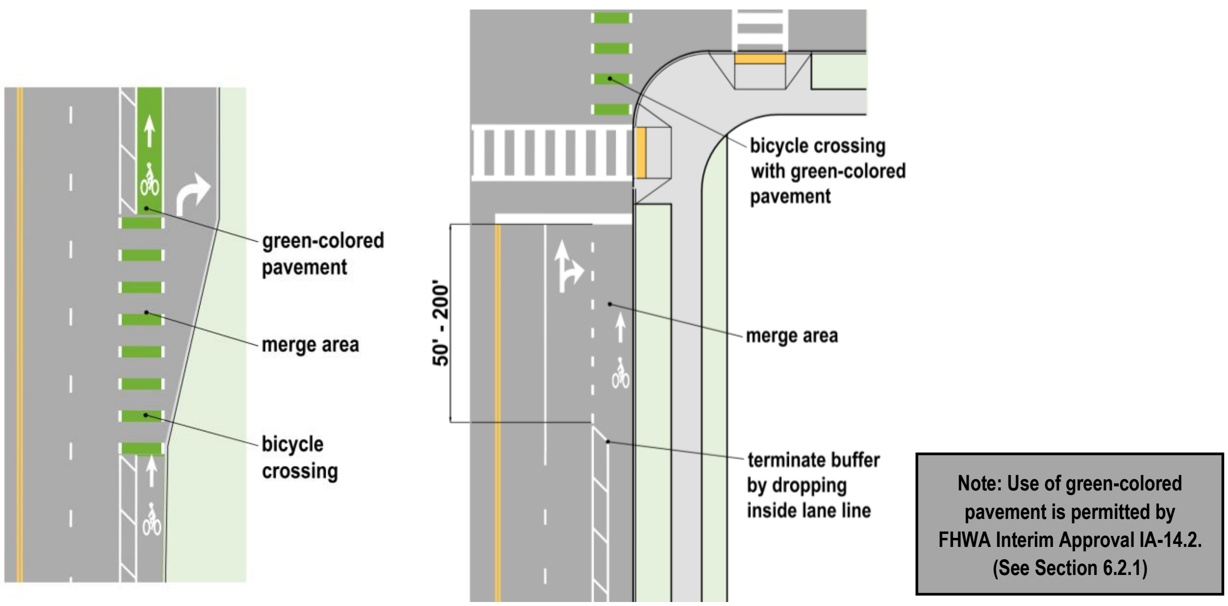


Figure 25: Buffered Bike Lane Treatment at Merge Areas and Approaching Intersections

6.4.2 Shared Through/Right Motor Vehicle Lanes

When bike lanes are present on two-lane roadways, designers should see the Approach Marking guidance in Section 6.4.1 for when to provide a solid or dotted lane at the intersection approach.

At intersection approaches with limited space where a right-turn lane is not required but there are relatively high right-turn volumes (more than 150 vehicles during the peak hour) or there is an existing crash history, designers should consider converting the conventional bike lane to a separated bike lane by adding a 2-foot wide minimum buffer with flexible delineator posts beginning at least 50 feet in advance of the intersection to provide added comfort for bicyclists, slow the speed of turning motor vehicles, and reduce the length of the conflict area (see **Figure 26**). Separate signal phases for bicyclists and turning vehicles should be considered (see Section 6.1.5).

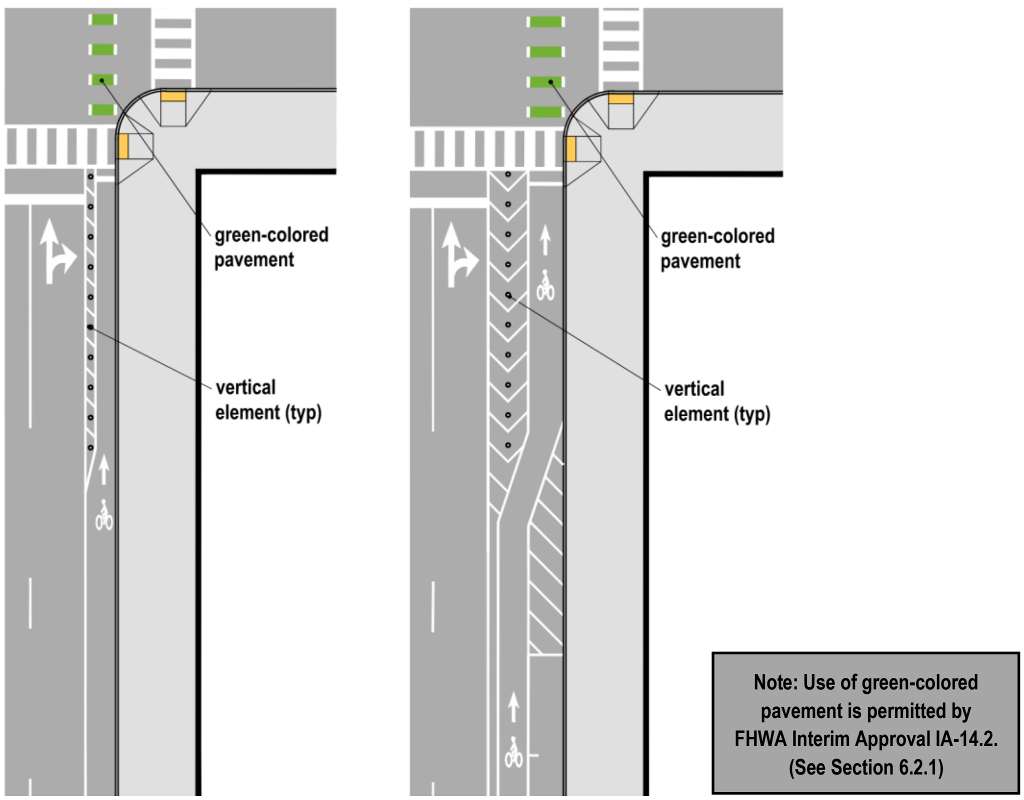


Figure 26: Bike Lane Treatment for High Turning Volumes from a Shared Through/Right Lane

6.4.3 Right-Turn Only Lanes

Vehicular right-turn only lanes are often used where higher volumes of right-turning motor vehicles warrant an exclusive right-turn lane to increase motor vehicle capacity at intersections or for safety benefits. As right turn volumes increase, the potential for conflicts between bicyclists and motor vehicles also increases at merging or crossing locations.

The following are common scenarios for bike lane approaches to intersections with right-turn lanes. These scenarios and subsequent treatments are discussed in order of most separated to least separated. Designers should work to provide the highest level of separation feasible to create a more comfortable facility and reduce motorist and bicyclist conflict points.

Where the bike lane is located on the left side of a one-way street, the same principles apply for left-turn only lanes.

6.4.3.1 Right-Turn Only Lane with Separated Bike Lane at a Signalized Intersection

At signalized intersections where a right-turn lane is provided, the bike lane can transition to a separated bike lane with the provision of a separate bicycle crossing signal phase as shown in **Figure 27**. See ODOT Multimodal Design Guide Section 8.4.5 for more information on when separate bicycle signal phasing may be necessary.

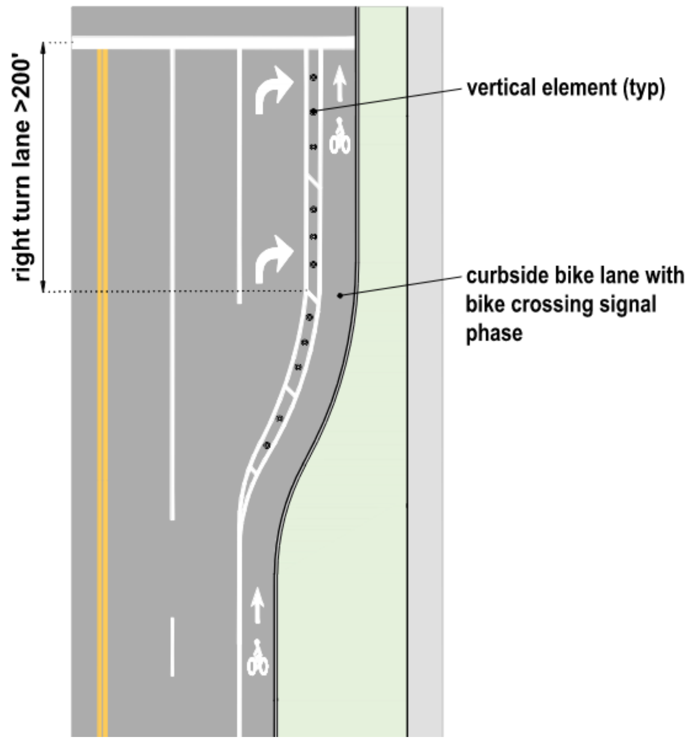


Figure 27: Example Bike Lane Approach to a Right-Turn Only Lane with Separate Bicycle Signal Phasing (signage not shown)

6.4.3.2 Right-Turn Only Lane Adjacent to Bike Lane

On roadways when a right-turn only lane is added on the approach to an intersection by either widening or by restricting on-street parking, drivers must yield to bicyclists when merging across the bike lane into the right-turn lane. To reduce bicyclist exposure on roadways with operating speeds of 35 mph or less (see **Figure 28**) and turn lanes less than 200 feet in length, designers should:

- Mark the merging area with dotted pavement markings for a length no greater than 200 feet, and
- Mark the merging area where motorists' speeds are lower, typically within 400 feet of the intersection.

For these locations, designers should:

- Provide "BEGIN RIGHT-TURN LANE YIELD TO BIKES" (R4-4) signs to remind drivers of yielding obligations.

- Add green-colored pavement to highlight the conflict area and reinforce that drivers should yield to bicyclists.
- Where space permits, include vertical elements, such as medians or flexible delineators, between the bike lane and through lane to force motorists to enter the turn lane at the clearly defined beginning, thus providing a more predictable conflict point.

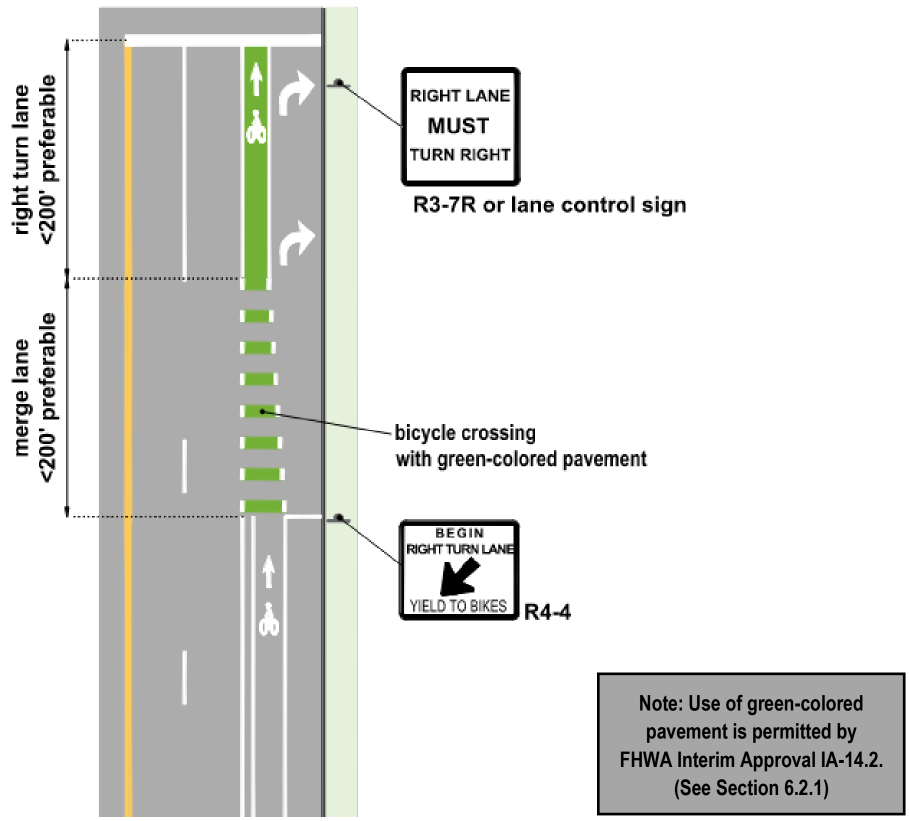


Figure 28: Example Bike Lanes on Streets with Speeds 35 mph and Under and Right-Turn Lanes < 200 feet in Length

On roadways with operating speeds over 35 mph (see **Figure 29**) or at locations where right-turn lanes exceed 200 feet in length, designers should also:

- Provide a bike lane as wide as possible, with a bike lane width of 6 feet or greater and a minimum 2-foot buffer on either side. In constrained locations, the minimum bike lane width is 4 feet with a minimum 2-foot buffer adjacent to the through traffic lane.
- Consider providing mountable medians or flexible delineators within the buffer adjacent to the through travel lane (where present) to prevent motorist encroachment into the bike lane and constrain the motorists merging area across the bike lane.

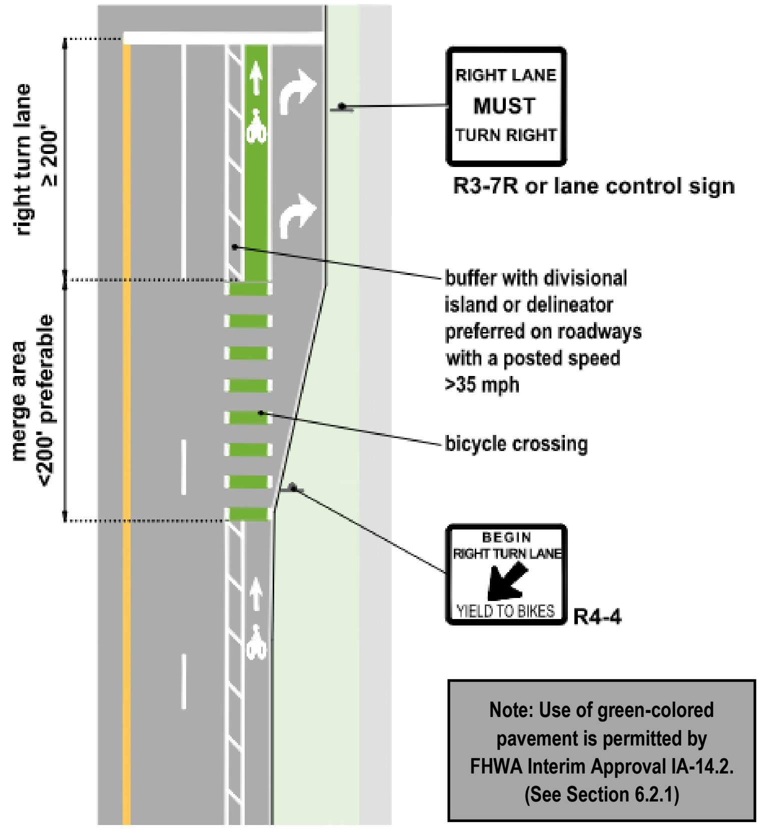


Figure 29: Example Bike Lanes on Streets over 35 mph or Right-Turn Lanes > 200 feet in Length

Where buffered bike lanes are not feasible for roadways with operating speeds greater than 35 mph or right-turn lanes that exceed 200 feet in length, the bike lane may remain along the curb until it is within 400 feet of the intersection, at which points the bike lane should transition to the left side of the right-turn lane, as shown in **Figure 30**.

6.4.3.3 Through Lane Transitions to a Right-Turn Only Lane

Avoid transitioning through lanes to right-turn only lanes on streets with bike lanes. **Figure 30** shows an intersection where this occurs. In this scenario, the bicyclist must transition to the left side of the turn lane. This is a challenging maneuver for bicyclists, and it increases crash risk as traffic speeds exceed 30 mph and motorist volumes increase. To compensate for this, the bike lane should remain along the curb until it is within 400 feet of the intersection. The bike lane drops at this point and is re-introduced on the left side of the right-turn lane. Design treatments should be selected based on the following operating speeds:

- Operating speeds of 35 mph or less – shared lane markings may be used to delineate the likely path of travel of bicyclists transitioning to the shared lane and then into the bike lane. The bike lane should not be striped diagonally across the travel lane, as this inappropriately suggests to bicyclists that they do not need to yield to motorists when moving laterally. In this situation, the BEGIN RIGHT TURN YIELD TO BIKES (R4-4) sign should not be used, since bicyclists are the users who need to yield as they are weaving across the path of motor vehicle traffic. A BICYCLE warning sign (W11-1) or BICYCLES MERGE sign should be placed where the curb side bike lane ends.

- Operating speeds over 35 mph – a bicycle ramp should be considered to allow bicyclists to exit the roadway, if desired, to an off-street bikeway prior to the merge area.

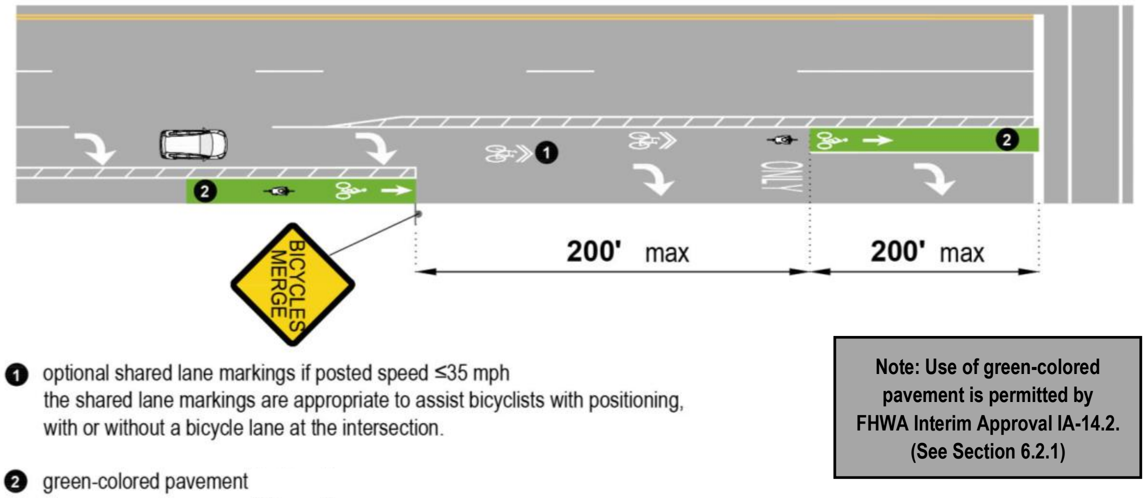


Figure 30: Through Lane Drops to Right-Turn Lane with Bike Lane

6.4.3.4 Bike Lane Ends to Develop a Right-Turn Only Lane

If there is insufficient space for a bike lane and a right-turn only lane, designers shall select from two primary design alternatives. Bicyclists often prefer to operate within the lane that has a lower traffic volume, experiences less queueing, and has lower operating speeds than the adjacent lane. Designers should select from the following list the treatment that maximizes bicyclist safety and comfort:

- Bike Lane Transitions to a Shared Right-Turn Lane – If the right-turn only lane is best suited for bicyclists, the adjacent travel lane should be narrowed to the minimum width to maximize the width of the turn lane for shared operation. At locations where the right-turn lane is 14 feet or less in width and posted speeds are 35 mph or less, shared lane markings should be located within the center of the turn lane (See **Figure 31**).
- Bike Lane Transitions to a Shared Through Lane – At locations where the right turn lane experiences extensive or frequent queuing or there is no bike lane present on the downstream side of the intersection, and posted speeds are 35 mph or less, the shared lane markings may be located within the right-most through lane instead of within the right-turn lane. In these locations, the shared lane markings should be located following the guidance provided in Section 5.1 and **Figure 6**.

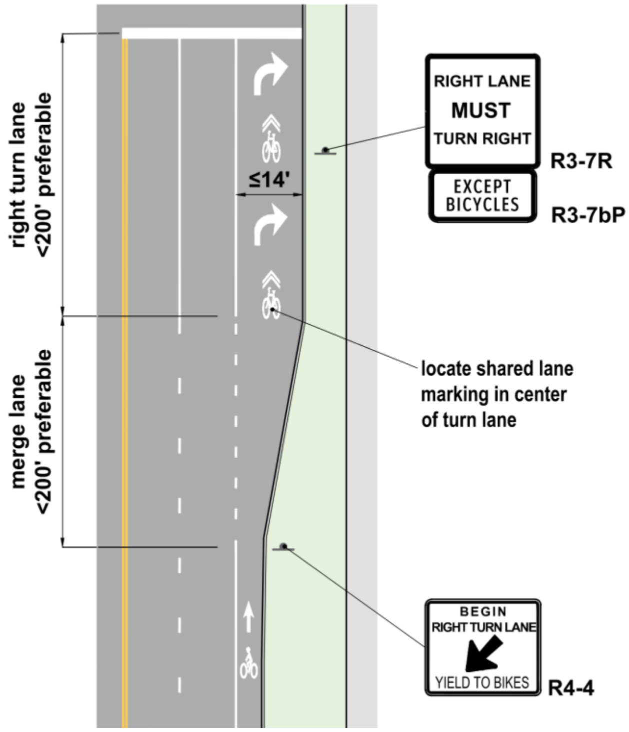


Figure 31: Example Right-Turn Only Lane with Shared Lane Markings

6.4.3.5 Dual Right-Turn Only Lanes

Avoid installing dual right-turn only lanes on streets with bike lanes. If dual right-turn lanes are necessary to accommodate heavy right-turn volumes, a designer should transition the bike lane to a separated bike lane in advance of the intersection (see **Figure 27**) and provide separate signal phases for bicyclists and turning vehicles (see Section 6.1.5).

If the bike lane cannot be transitioned to a separated bike lane, shared lane markings may be located in the adjacent through lane if posted speeds are 35 mph or less.

6.5 Bicycle Boulevard Intersections and Crossings

An important principle of bicycle boulevards is to ensure that street crossings maintain the low-stress nature of the bikeway with minimal delay (see Section 5.2 for more information on bicycle boulevards). Frequent stopping along a bicycle boulevard can significantly increase the bicyclist's total ride time and may result in reduced stop sign compliance where stops are closely spaced and crossing traffic volumes are low. For a bicycle boulevard to function as an alternative route to a parallel arterial, it should provide a similar travel time for the bicyclist as they would experience on the parallel arterial. In many cases, achieving this outcome may involve intersection control changes along the bicycle boulevard.

6.5.1 Traffic Controls for Minor Street Crossings

Many of the intersections a bicyclist will cross will be local streets crossing other local streets. Designers should consider the following at these intersections:

- Limit locations where stop control is used on the bicycle boulevard to less than one location per half mile (in the direction of travel along the bicycle boulevard). Yield controls are preferable to stop controls as it allows bicyclist to slow and assess the cross traffic without having to stop and restart.
- On long corridors with a frequent application of all-way or two-way stop control, efficiency of the bicycle boulevard can be improved by removing stop controls on the bicycle boulevard and requiring the cross street to stop or yield, or by utilizing neighborhood traffic circles.
- Parking restriction signs may be necessary to provide the required sight distance at intersections where stop signs are removed or where yield control is provided.
- Consider supplementing stop or yield signs with either CROSS TRAFFIC DOES NOT STOP (W4-4P) signs and/or Bicycle Guide Signs. When used, Bicycle Guide Signs should be installed on a separate post than the STOP sign.

Designers should be aware that the removal of stop signs can result in increased motor vehicle speeds and volumes. When bicycle boulevards run parallel to a congested arterial or is the only route through an area with few connecting streets, it may attract cut-through motorized traffic. Designers should consider traffic calming or diversion treatments to discourage or prevent increased traffic volume, speeds, or both. See ODOT Multimodal Design Guide Section 6.3.2 for speed and volume management strategies.

6.5.2 Traffic Controls for Major Street Crossings

Major street crossings along bicycle boulevards can be significant barriers. At intersections where a bicycle boulevard crosses an arterial road, or any other major road where the bicycle boulevard is stop- or yield-controlled, an uncontrolled crossing of the major roadway is common. Where traffic signals are not present, additional crossing measures may be needed to ensure bicyclists can continue along the route.

Bicycle boulevards are commonly used by families with children because they often originate in neighborhoods and provide connections between neighborhoods. At major streets, bicycle boulevard crossings may also be used by pedestrians. For these reasons, intersection crossings should assume pedestrians are crossing and include crosswalk markings, along with other appropriate design measures to accommodate pedestrian and bicycle crossings. Designers should be guided by the following performance criteria when evaluating and designing bicycle boulevard crossings at major intersections:

- Crossing time and acceleration should accommodate pedestrians and child bicyclists (See ODOT Multimodal Design Guide Section 3.3.1 and Section 3.5.2 – Case 3)
- Sight distance eye height should be measured 3.83 feet from the ground to accommodate recumbent bicyclists (ODOT Multimodal Design Guide Section 3.5)

In some instances, pedestrian hybrid beacons or traffic signals may be present to control the major street. At intersections with bicycle boulevards, it may be desirable to allow coordinated traffic signals to operate on half signal cycle lengths or to operate in “free” or uncoordinated mode during off-peak hours to reduce delays for bicyclists and provide frequent service.

6.5.3 Offset Intersections

Along a bicycle boulevard, there may be discontinuities in the street grid. To continue, a bicyclist may be required to turn or travel for a brief distance on a roadway with higher motorist volumes and/or speeds.

Without comfortable crossing treatments, offset intersections with these streets become a barrier along the corridor. Designers should select a bikeway for the major street based on the bikeway selection criteria identified in Section 3 and follow the guidance for traffic control devices at major crossings in this section. Example connections could be a bike lane with two-stage turn boxes (Section 6.2) or a two-way separated bike lane or shared use path.

6.6 Driveway and Alley Crossings

When on-street bike lanes cross driveways or alleys, the bike lane may be continued with solid white lines where driveway volumes are low. High-volume driveways should be treated like intersections, with bicycle crossing markings as shown in **Table 7**.

Where separated bike lanes intersect high-volume driveways, crossings should be designed according to the protected intersection design principles (see Sections 6.1 and 6.3). Sight distances should be kept clear to ensure motorists exiting the driveway can see oncoming bicyclists, pedestrians, and motorists before leaving the driveway, and that motorists entering the driveway can see bicyclists and pedestrians approaching the driveway entrance and yield appropriately. Designers must consider if motorists will be permitted to block a separated bike lane to view approaching motor vehicle traffic (see ODOT Multimodal Design Guide Section 3.5.2 – Case C).

Designers should minimize the width of driveways and consider access management strategies along separated bike lane routes to minimize the number and frequency of driveway crossings.

For corridors with on-street parking and non-residential driveways spaced 100 feet apart or less, designers should consider eliminating on-street parking between these driveways to maximize sight distances. For high-volume non-residential driveways, adjacent on-street parking shall be eliminated to provide the adequate sight distance (see ODOT Multimodal Design Guide Section 3.5).