4 Bikeways

Because of the great difference in skill levels among bicycle riders, the varied topography of downtown Burlington, and because the needs may differ based on the utility of each trip, different types of bicycle facilities are needed to serve riders. Some bicyclists are best served by bicycle-compatible streets designed to accommodate shared use by bicycles and motor vehicles, topography and other constraints permitting. The majority of bicycle riders will be especially interested in riding on bikeways which are designated facilities that are comfortable and convenient.

Bikeway Types

General Bikeway Considerations

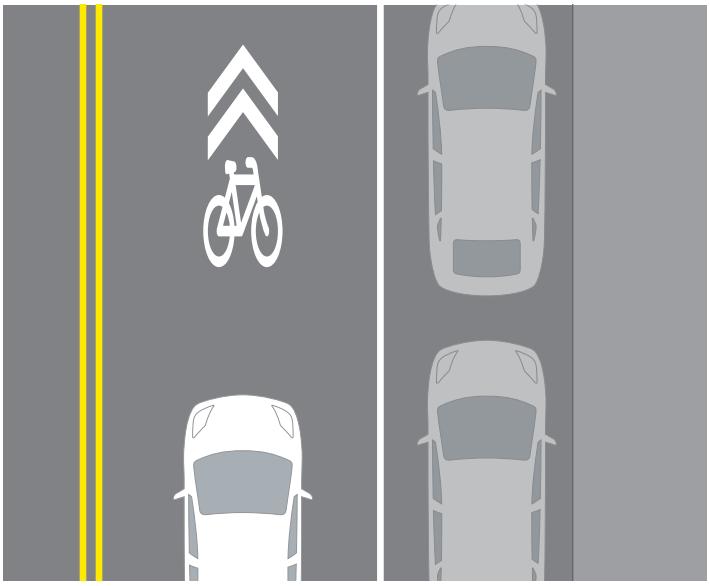
The following is a set of considerations that should be applied to all bikeway types when appropriate:

- Wider bicycle lanes are appropriate where high volumes of bicycle riders are expected.
- For bicycle lane widths on streets with grades greater than 4%, bicycle lanes should be designed with a higher design speed. Design speed will vary, but typically will range from 10–15 MPH. The following are options to adjust the design for the higher design speed.
  - Select values for horizontal curvature, stopping sight distance, and other geometric features for a higher design speed.
  - Widen lanes by one ft for grades between 4% and 6%, and 2 ft for grades over 6%.
  - Increase horizontal clearance and recovery area.
  - Use mountable curb rather than vertical or beveled curb along bike lane
  - Provide signage alerting bike riders to steep grades.

Shared Lane

Shared lanes (sharrows) are particularly appropriate in two circumstances: a) on low-speed, low-volume neighborhood streets that are designated as primary bicycle corridors; and b) in the downhill lane of a street that has a bicycle lane in the climbing direction, and where vehicle speeds are low enough that a typical downhill bicyclist will be traveling at the same speed as cars.

Shared lane markings should not be considered a substitute for bicycle lanes, protected facilities, or other separation treatments where these types of facilities are otherwise warranted or space permits. Shared lane markings can be used as a standard element in the development of bicycle boulevards to identify streets as bikeways and to provide wayfinding along the route.



Per planBTV Walk/Bike, many streets within the downtown core can utilize shared lane treatments where traffic calming and design speed allow for the safe sharing of the ROW between bicycles and other modes.

Considerations

- Shared Lane Markings shall not be used on shoulders or in designated bicycle lanes.
- Should not be used on streets with speed limits higher than 35 MPH (the City of Burlington has adopted a blanket speed limit of 20 MPH for all streets not otherwise posted), or on streets where speeds and volumes are high enough that it is not desired for bicyclists to ride in traffic.
- On narrow travel lanes adjacent to on-street parking, markings should be placed outside of the door zone of parked vehicles.
- Supplement markings with "SHARE THE ROAD" signs, and "MAY USE FULL LANE" signs where appropriate.
- Can be used to complete connections between bicycle lanes and other facilities.

Markings

- Bike-and-chevron sharrow (MUTCD Figure 9C-9)

Marking Distance

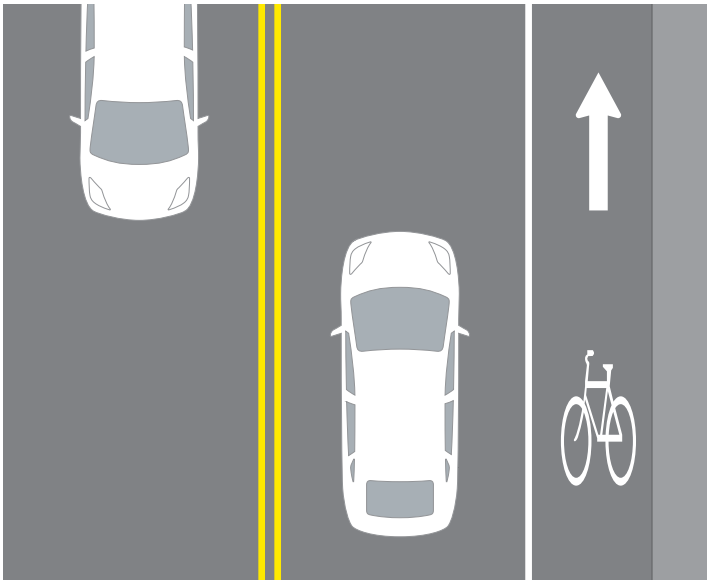
- 50' after intersections
- 50'–100' apart in frequent traffic bicycle routes
- 250' + apart in low traffic bicycle routes

Lateral Location

- Center of travel lane preferred
- 11' minimum from curb when adjacent to parking
- 4' minimum from curb when adjacent to curb

Conventional Lane Adjacent to Curb

A conventional lane is a dedicated travelway for bicycles that is separated from vehicular travel by a painted stripe. Conventional, or unbuffered bicycle lanes, are particularly appropriate for a variety of conditions, including: a) on streets with low speeds and moderate volumes; and b) on roads with higher speeds but low volumes.



A conventional bicycle lane may be used in areas where space is not available for a buffered lane.

Considerations

- Wider bicycle lanes (6'–7') enable bicyclists to pass one another on heavily traveled corridors and increase separation from faster traffic.
- Uphill bike lanes should widen when slope is 4% or greater. (See *"General Bikeway Considerations" on page 141*)
- Unbuffered bicycle lanes should not exceed 7'.
- Use colored pavements to highlight areas where conflicts might occur, such as at intersection and driveway crossings.
- Where vehicles merge into the bike lane in advance of a turn movement, lane striping should be dashed from 50 to 200 feet in advance of intersections to the intersection.
- Where drain grates or other pavement conditions may encroach into the bike lane, extra width should be provided.
- Left side lanes are an option on streets with heavy delivery or transit use, high parking turnover, or other conflicts that would prevent lanes on the right side of the street.

Dimensions

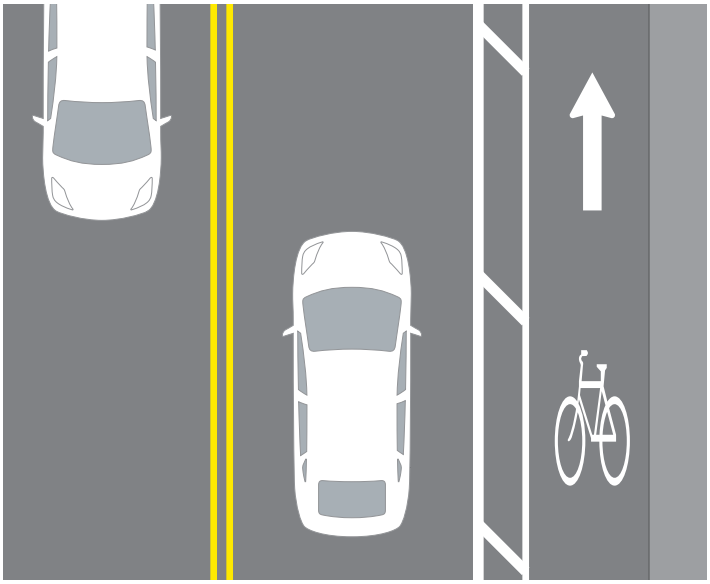
- 6' width recommended on streets with a grade >4%, or with higer volumes of of bikes to allow for passing.
- 7' width max.
- 5' width min. (4' width possible in very constrained areas, but a 5' min is required next to parking)

Markings

- 6" white line adjacent to travel lane
- See ref. dwg. **VTrans Standard E-194 Bicycle Pavement Markings and Sign Layout** in *Appendix section A-5.*

Buffered Lane Adjacent to Curb

A buffered lane is separated from vehicular travel by two painted lines up to 3' apart. Buffered bicycle lanes are preferred whenever feasible when bike lanes are considered.



A bufferedl bicycle lane may be used in areas where safety considerations demand more separation from traffic.

Considerations

- Where space is available, consider providing a buffered bicycle lane.
- Wider bicycle lanes (6'–7') enable bicyclists to pass one another on heavily traveled corridors and increase separation from faster traffic.
- Uphill bike lanes should widen when slope is 4% or greater. (See *"General Bikeway Considerations" on page 141*)
- Use colored pavements to highlight areas where conflicts might occur, such as at intersection and driveway crossings.
- Where vehicles merge into the bike lane in advance of a turn movement, lane striping should be dashed from 50 to 200 feet in advance of intersections to the intersection.
- Where drain grates or other pavement conditions may encroach in the bike lane, extra width should be provided.
- When next to parking, the buffer may be next to parking and/or next to the adjacent travel lane.
- Left side lanes are an option on streets with heavy delivery or transit use, high parking turnover, or other conflicts that would prevent lanes on the right side of the street

Dimensions

The combined width of the buffer(s) and bicycle lane should be considered "bicycle lane width." Where buffers are used, bicycle lanes can be narrower because the shy distance function is assumed by the buffer (e.g., a 3 foot buffer and 4 foot lane next to a curb can be considered a 7 foot bicycle lane). For bicycle travel next to on-street parking, a 5-foot minimum travel lane width is recommended to encourage bicyclists to ride outside of the door zone; a buffer is preferred but not required.

Buffered (preferred)

- 7.5' total width preferred (5' lane + 2.5' buffer)
- 8' total width max. (incl. buffer)

Markings

- 4" or 6" white interior line (if buffered; no interior line required when adjacent to curb)
- 6" white line adjacent to travel lane
- 4" diagonal hatching at 30–40 degrees and 10'–40' spacing if buffer is 3' or wider
- See ref. dwg. **VTrans Standard E-194 Bicycle Pavement Markings and Sign Layout** in *Appendix section A-5.*

Buffered Lane Adjacent to Parking

A buffered lane adjacent to parking is separated from the parking lane by two painted lines up to 3' apart. They provide greater shy distance between motor vehicles and bicyclists. They provide space for bicyclists to pass another bicyclist without encroaching into the adjacent motor vehicle travel lane when the buffer is between the travel lane and the bike lane. They can also encourage bicycists to ride outside of the door zone when buffer is between parked cars and the bike lane. Buffered lanes are preferred when adjacent to parking lanes whenever feasible.

Considerations

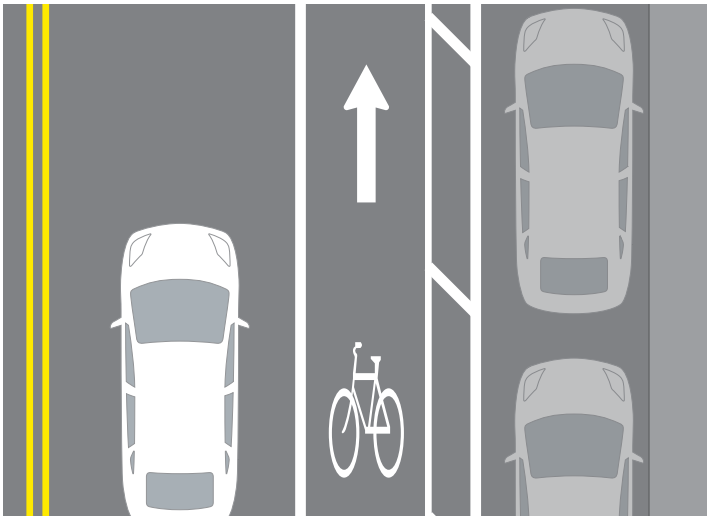
- Due to Burlington's downtown-wide 20 MPH speed limit, it is recommended that the buffer be placed on the side of the parking lane to protect from opening car doors.
- Additional options include: travel-side buffer and split buffer.
- Uphill bike lanes should widen when slope is 4% or greater. (See *"General Bikeway Considerations" on page 141*)
- Use colored pavements to highlight areas where conflicts might occur, such as intersection and driveway crossings.
- Where vehicles merge into the bike lane in advance of a turn movement, lane striping should be dashed from 50 to 200 feet in advance of intersections to the intersection

Dimensions

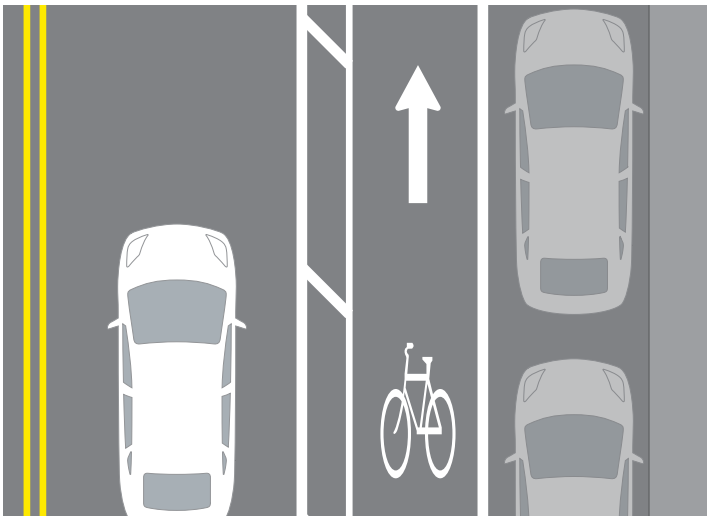
- A 5' minium lane width is recommended to encourage bicyclists to ride outside of the door zone.
- The combined width of the buffer(s) and bike lane should be considered "bike lane width" with respect to guidance given for conventional bike lanes without a buffer. For example, a 5' bike lane and 2' buffer can be considered a 7' bike lane.
- Buffers should be at least 18 inches wide because it is impractical to mark a zone narrower than that

Markings

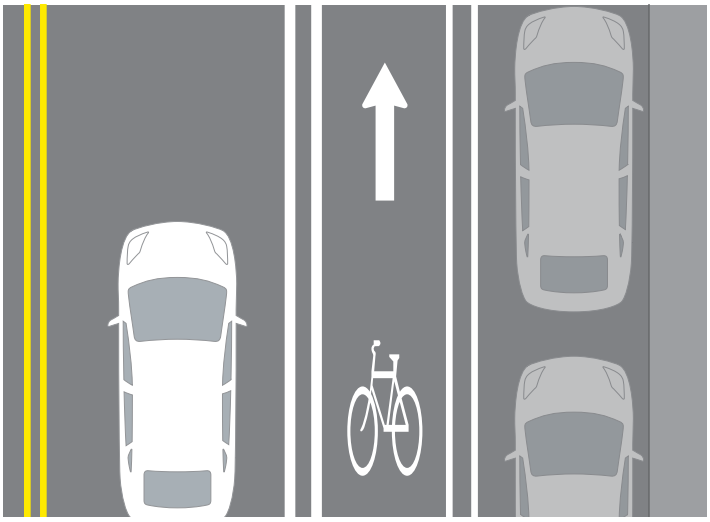
- Bicycle lane word and/or symbol and arrow markings (MUTCD Figure 9C-3) shall be used to define the bike lane and designate that portion of the street for preferential use by bicyclists.
- The buffer shall be marked with 2 solid white lines.
- 4" or 6" white interior line
- 6" white line adjacent to travel lane
- 4" diagonal hatching at 30–40 degrees and 10'–40' spacing if buffer is 3' or wider
- See ref. dwg. **VTrans Standard E-194 Bicycle Pavement Markings and Sign Layout** in *Appendix section A-5.*



Buffered bike lane with buffer adjacent to parking lane (recommended).

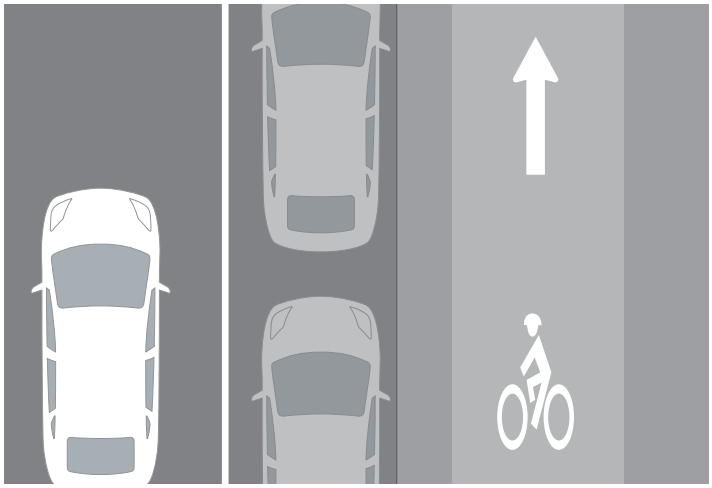


Buffered bike lane with buffer adjacent to travel lane.



Buffered bike lane with buffer on both parking lane and travel lane sides.

Protected Bicycle Lane



Protected bicycle lanes are particularly appropriate on streets that are key corridors for both bicycle and vehicle travel, and where speed, volume, and/or cross-section merit additional protection from vehicular traffic. They are particularly appropriate on streets where fewer curb cuts exist. Protected lanes may be one-way or two-way. Two-way protected lanes are best used when a majority of origins and destinations are on one side of the street (with the bike lane located on that side to reduce the need to cross the street). They can be designed at the same grade of the sidewalk separate from pedestrian travel, at the same grade as the street, physically separated from vehicular travel, or at a grade between the street and sidewalk.

Considerations

- On streets with higher volumes of bicycles, it is preferable to have the protected bicycle lane at the same grade as the sidewalk and Tree Belt/Buffer Zone as it allows easier access to/from the bicycle lanes.
- The buffer between the parked cars and bicycle lanes should be at least 3', and at the same grade as the bicycle lanes.
- There should be a one foot clearance between any fixed object in the Buffer Zone (e.g. parking meter) and the bicycle lanes.
- Wider bicycle lane widths should be used on streets with grades greater than 4%, or where high volumes of bicycles are expected. (See *"General Bikeway Considerations" on page 141*)
- The protected facility should be wrapped around the transit stop zone to reduce conflicts with transit vehicles at midblock or signal protected intersections.
- Bicyclists should yield to pedestrians in crosswalks and bikeways should be designed with the same considerations as vehicular travelways.
- 5' width or greater needed for sidewalk snow plow or sweeper; 10' width or greater needed for small truck plow.
- Two-stage turn boxes at intersections
- Bike signals and/or bike signal phasing should be considered
- Additional care needed on two-way paths at intersections and driveways, as drivers do not expect bicycles in the opposite direction

One-Way

Dimensions

- 7' preferred if bike lane is parking protected or uphill
- 6.5' min. if bike lane is raised
- 5' min. otherwise
- 5' min. at intersections and pinch points
- 3' min. painted buffer if the bike lane is parking-protected.
- 3' min. painted buffer with bollards if the bike lane is adjacent to the travel lane and at street grade.
- 1' min. buffer (at 4:1 slope) if a raised median or curb is used and nothing else is placed in it
- 5" max. vertical separation from sidewalk if bike lane is raised
- 6" max. vertical separation from roadway if bike lane is raised

Markings

- Bicycle lane word, symbol, and/or arrow markings (MUTCD Figure 9C-3) shall be placed at the beginning of a cycle track and at periodic intervals along the facility based on engineering judgment.
- Color, yield lines, and/or signs for conflict areas

Two-Way

Dimensions

- 12' preferred or uphill minimum
- 8' min. on low-volume bicycle routes
- 3' buffer from moving traffic in contraflow direction
- 3' min. painted buffer if the bike lane is parking-protected.
- 3' min. painted buffer with bollards if the bike lane is adjacent to the travel lane and at street grade.
- 1' min. buffer (at 4:1 slope) if a raised median or curb is used and nothing else is placed in it
- When vertically separated from roadway, raise bike lane to level of sidewalk—6" typical height (recommended option)
- Additional care needed on two-way paths at intersections and driveways, as drivers do not expect bicycles in the opposite direction

Markings

- Bicycle lane word, symbol, and/or arrow markings (MUTCD Figure 9C-3) shall be placed at the beginning of a cycle track and at periodic intervals along the facility based on engineering judgment.
- Color, yield lines, and/or signs for conflict areas
- Dashed centerlines should be used
- See ref. dwg. **VTrans Standard E-194 Bicycle Pavement Markings and Sign Layout** in *Appendix section A-5.*

Contra-Flow Lane

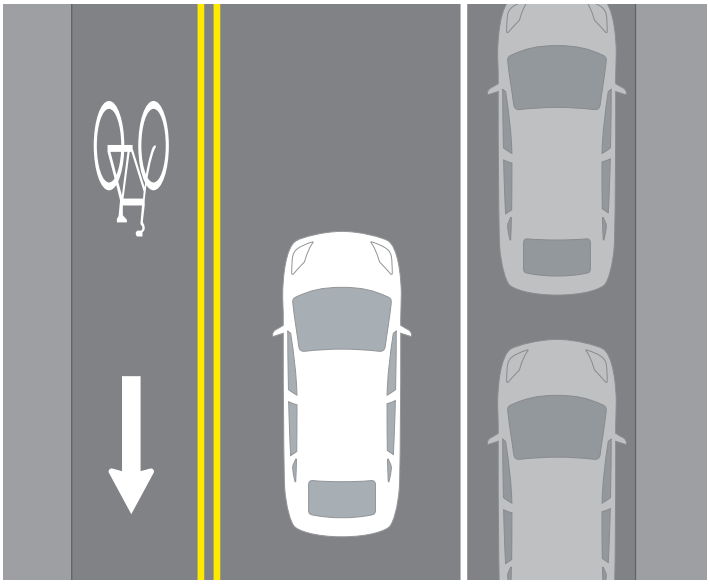


Image source: NACTO Urban Bikeway Design Guide

Contra-flow bicycle lanes are bicycle lanes designed to allow bicyclists to ride in the opposite direction of motor vehicle traffic. They convert a one-way traffic street into a two-way street: one direction for motor vehicles and bikes, and the other for bikes only. Contra-flow lanes are separated with yellow center lane striping. Contra-flow lanes are particularly appropriate on low-speed, low volume streets, unless buffer separation or physical protection is provided.

The contra-flow design introduces new design challenges and may introduce additional conflict points as motorists may not expect on-coming bicyclists.

Considerations

- Guidance for Conventional (*p. 142*) and Buffered (*p. 143, p. 144*) Bike Lanes standards may also apply.
- If sufficient space exists, a buffered bike lane design should be used. The buffer should conform with Figure 3D-4 of the MUTCD. A broken buffer may be used if on-street parking is present.
- A "ONE WAY" sign (MUTCD R6-1, R6-2) with "EXCEPT BIKES" plaque shall be posted along the facility and at intersecting streets, alleys, and driveways informing motorists to expect two-way traffic.
- Intersection traffic controls along the street (e.g., stop signs and traffic signals) shall also be installed and oriented toward bicyclists in the contra-flow lane.
- When configured without parking, a solid double yellow lane line marking should be used to separate opposing motor vehicle travel lanes from the contraflow bicycle lane.
- Where there is room, bike lanes should be used on both sides. When there is no room for a with-flow lane, shared lane markings should be used to guide with-flow bicyclists to keep to the right side of the road.

Recommended on low-speed, low volume streets, unless buffer separation or physical protection is provided.

Dimensions

- **Buffered:** 7.5' total width (5' lane + 2.5' buffer) recommended.
- **Conventional:** 6' width recommended; 7' max.; 5' min.

Consult Conventional (*p. 142*) and Buffered (*p. 143, p. 144*) Bike Lanes standards for additional guidance.

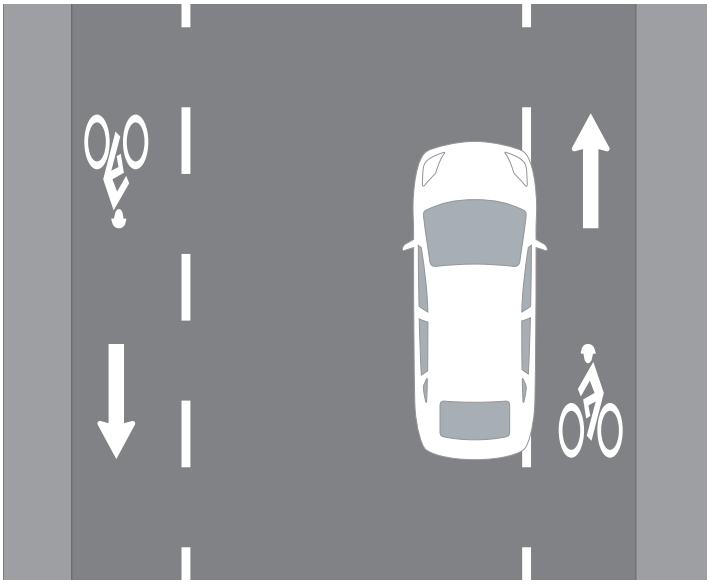
Markings

- Bicycle lane word, symbol, and arrow markings (MUTCD Figure 9C-3) shall be used to define the bike lane direction and designate that portion of the street for preferential use by bicyclists.

Advisory Lane

Where the lateral width of a street prevents the installation of both a conventional bicycle lane and a standard-width travel lane for motor vehicles, advisory bicycle lanes could be an alternative to the shared-lane marking. An advisory lane is similiar to a bike lane, creating a preferential space for people biking. On some streets without sidewalks, advisory lanes may be shared by people walking and biking. The center travel lane is shared by two-way motor vehicle traffic. Drivers enter the advisory lane when necessary to yield to oncoming traffic before passing people bicycling or walking in the advisory lane.

This treatment is currently experimental through the FHWA, but has been applied in Burlington.



Advisory lanes utilizing dashed white lines, arrows, and bicycle stencils.

Example of optional bollards and island markings to prevent vehicle encroachment into an advisory lane. (Image source: Alta Planning & Design 2017 Advisory Lane white paper)

Considerations

Dashed bicycle lanes can achieve public acceptance and generally be advantageous only where many or all of the following conditions are present:

- Traffic volume is less than 5,000 ADT and speeds are less than 25 MPH.
- The FHWA experimentation guidance suggests a minimum lateral width of 16 feet of the center space dedicated to two-way travel between the dashed advisory lanes. Other experiments are considering applications of 10 to 18 feet for two-way travel lanes.
- The street is not a designated truck or bus route, nor would the street be expected to facilitate these vehicle types to and from other facilities.
- The preferred width of the advisory lanes follow the same guidance as bicycle lane standards in this section.
- Dashed bicycle lanes can be considered on streets either with or without on-street parallel parking.

Markings

The following design elements are required to establish advisory lanes:

- Dashed white lines to indicate the advisory lane.
- Bicycle and/or pedestrian stencils and arrows in the advisory lane.
- Preferred width is 6 ft; 4 ft may be considered in appropriate constrained conditions.
- Bollards or channelizing islands along the dashed line may be considered at periodic spacing to discourage motor vehicle encroachment into the advisory lane.

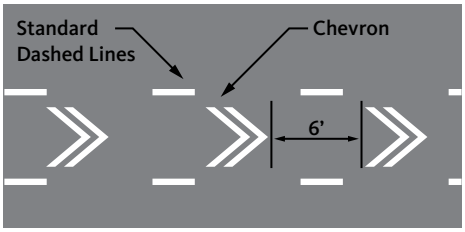
Intersections

Bicycle Crossing Markings

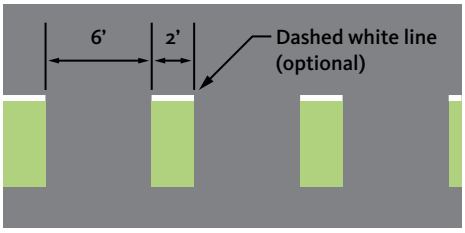
Bicycle crossing markings indicate the intended path of bicyclists. They guide bicyclists on a safe and direct path through intersections, including driveways and ramps. They provide a clear boundary between the paths of through bicyclists and either through or crossing motor vehicles in the adjacent lane.

- Dotted lines shall bind the bicycle crossing space. Consult MUTCD Section 3B.08 for dotted line extensions through intersections.
- Striping width shall be a minimum of 6" adjacent to motor vehicle travel lanes and shall otherwise match the width and lateral positioning of leading bike lane striping, except when using elephant's feet markings.
- Dotted lines should be 2' lines with 2' to 6' spacing. Markings should be white, skid resistant and retro-reflective.
- Crossing lane width should match width and positioning of the leading bike lane.
- On crossings of two-way paths and cycle tracks, markings should indicate that there is two-way traffic either by marking the path center line through the intersection, or by marking bicycle silhouettes and/or chevrons in opposite directions in the two lanes. See Two-Way Protected Bicycle Lanes (*page 145*).
- Chevrons may be used for increased visibility within conflict areas or across entire intersections. Placement shall be in the middle of the moving lanes, and close to crosswalks.
- Colored pavement may be used for increased visibility within conflict areas or across entire intersections.
- Shared lane markings (MUTCD Figure 9C-9) may be used for increased visibility within conflict areas or across entire intersections. Placement shall be in the middle of the moving lanes, and close to crosswalks.

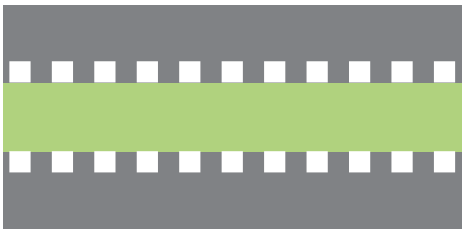
Intersection Marking Types



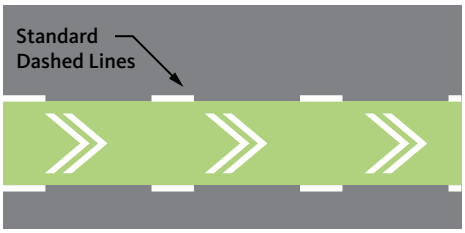
Conventional Crossbike Marking
Apply to a bike lane crossing a low volume street or high volume driveway.



VTrans High-Volume Crossbike Marking
Apply to a bike lane crossing a high volume street or turn lane. In line with crosswalk.



Green Elephant Feet Crossing Marking
Apply to a shared use path or shared bike/ped crossing of a street or commercial driveway.



Green Crossbike Marking
Apply to a neighborhood greenway crossing an intersection.

Through Bike Lanes & Advisory Lanes

For bicyclists traveling in an on-street bike lane, the approach to an intersection with vehicular turn lanes can present a significant challenge. For this reason it is vital that bicyclists are provided with an opportunity to correctly position themselves to avoid conflicts with turning vehicles- a through bike lane is one design tool to do so.

Benefits of Through Bike Lanes

- Enables bicyclists to correctly position themselves to the left of right turn lanes or to the right of left turn lanes.
- Reduces conflicts between turning motorists and bicycle through traffic.
- Provides bicyclists with guidance to follow the preferred travel path.
- Leads to more predictable bicyclist and motorist travel movements.
- Alerts motorists to expect and yield to merging bicycle traffic.
- Signifies an appropriate location for motorists to safely merge across the bike lane into the turn lane.

Typical Applications

- On streets with right-side bike lanes and right-turn only lanes at intersections.
- On streets with left-side bike lanes and left-turn only lanes at intersections.
- On streets with shared lane markings at intersections.

Design Considerations

- The desired width of a dotted bike transition lane and through bike lane is 6 feet with a minimum width of 4 feet.
- Bicycle lane word and/or symbol and arrow markings (MUTCD Figure 9C-3) shall be used to define the bike lane and designate that portion of the street for preferential use by bicyclists.
- The through bike lane shall be placed to the left of the right-turn only lane.
- Dotted lines signifying the merge area shall begin a minimum of 50 feet before the intersection (MUTCD). Dotted lines should begin 100 feet before the intersection if along a high speed/volume roadway.
- Dotted lane line transition areas to through bike lanes shall not be used on streets with double right turn lanes. Double right turn lanes are extremely difficult for bicyclists to negotiate. Shared lane markings may be used in the center of the inside turn lane to designate the preferred path of through bicycle travel.
- Accompanying signage should include R3-7R “Right Lane Must Turn Right” and R4-4 “Begin Right Turn Yield to Bikes” (MUTCD).
- Dotted white lines should be 6 inches wide and 2 feet long with a 2- to 6-foot gap between dashes (MUTCD)
- For intersections that lack the physical width to install a bicycle pocket, a combined bike/turn lane should be used..

Mixing Lane (Combined Bike Lane/Turn Lane)

A combined bike lane/turn lane places a suggested bike lane within the inside portion of a dedicated motor vehicle turn lane. Shared lane markings or conventional bicycle stencils with a dashed line can delineate the space for bicyclists and motorists within the shared lane or indicate the intended path for through bicyclists. This treatment includes signage advising motorists and bicyclists of proper positioning within the lane.

Benefits of Combined Bike Lane/Turn Lane

- Preserves positive guidance for bicyclists in a situation where the bicycle lane would otherwise be dropped prior to an intersection.
- Maintains bicyclist comfort and priority in the absence of a dedicated bicycle through lane.
- Encourages motorists to yield to bicyclists when crossing into the narrow right-turn lane.

Typical Applications

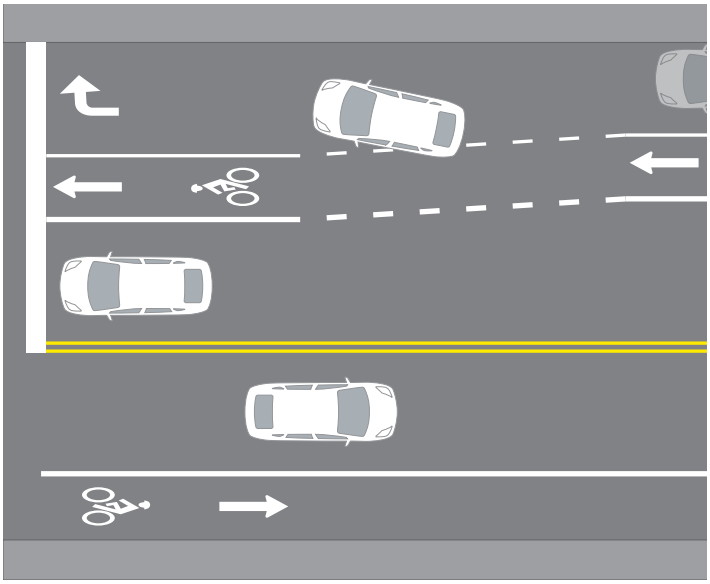
- On streets where there is a right turn lane but not enough space to maintain a standard-width bicycle lane at the intersection.
- On streets where there is no dedicated right turn lane, but on which high volumes of right turning traffic may cause conflicts between motorists and bicyclists.

Design Considerations

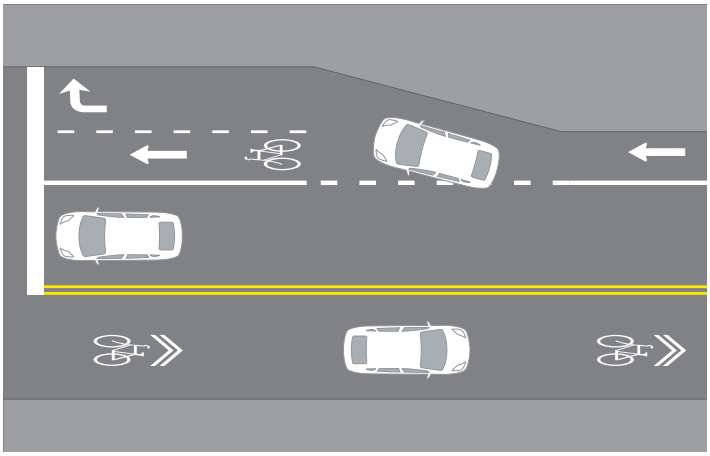
- Some form of bicycle marking shall be used to clarify bicyclist positioning within the combined lane.
- Within the combined lane, the bicycle area width should be 4 feet minimum.
- Width of combined lane should be 9 feet minimum, 13 feet maximum. A full bicycle through lane can be accommodated if the vehicle right turn only lane can be made 14 feet or wider.
- A dotted 4 inch line and bicycle lane marking should be used to clarify bicyclist positioning within the combined lane without excluding cars from the suggested bicycle area.
- A shared lane marking (MUTCD figure 9C-9) may be used as an alternative to dotted striping to clarify bicyclist position within the combined lane.

Additional References

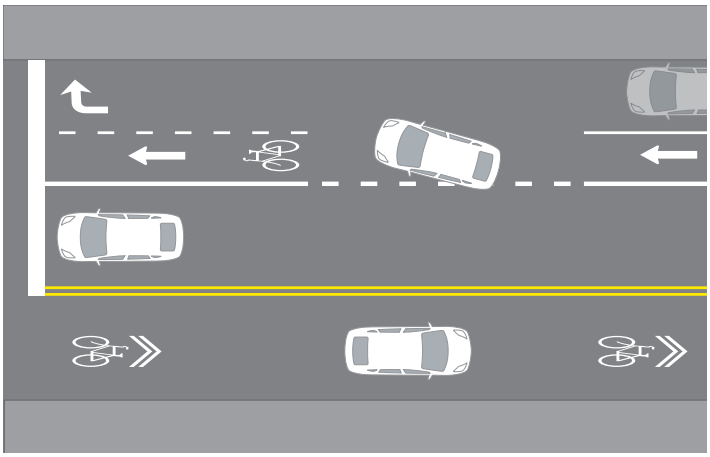
- VTrans Standard Drawings
- City of Burlington Quick Build Design Guide



Through Bike Lane. Not to scale.



Mixing Lane (Combined Bike Lane/Turn Lane). Not to scale.



Mixing Lane (Combined Bike Lane/Turn Lane) with parking lanea. Not to scale.

Protected Intersections

Protected intersections reduce the exposure of bicycle riders to conflicts with vehicles at signalized intersections. Separation from vehicular traffic is increased, and markings clarify the movements for bicycle riders, pedestrians, and vehicles. Raised islands offer protection for bicycles waiting to cross, increase their visibility, and reduce speeds of turning vehicles. Pedestrian and bicycle crossings are often raised to further increase their visibility and reduce vehicle speeds.

Protected intersections are relatively new in the United States, and current design practices are heavily informed by European designs. The design guidelines provided herein should be supplemented by a review of the most up-to-date practices at the time of design.

Benefits

- The roadway crossing distance is shortened by using corner safety islands and a forward stop bar for bicycles.
- Vehicle speeds are lower, providing more reaction time to avoid conflicts and reducing collision frequency and severity.
- Visibility of crossing bicycle riders is increased, as is yielding to crossing pedestrians
- Design provides more clear cues to priority than other treatments such as mixing zones, two-stage left turns, or bicycle boxes.

Typical Applications

Protected intersections should be considered at signalized intersections with a protected bicycle route in at least one direction. The crossing street can have protected, buffered or conventional bike lanes, adapted to be protected through the intersection.

Design Considerations

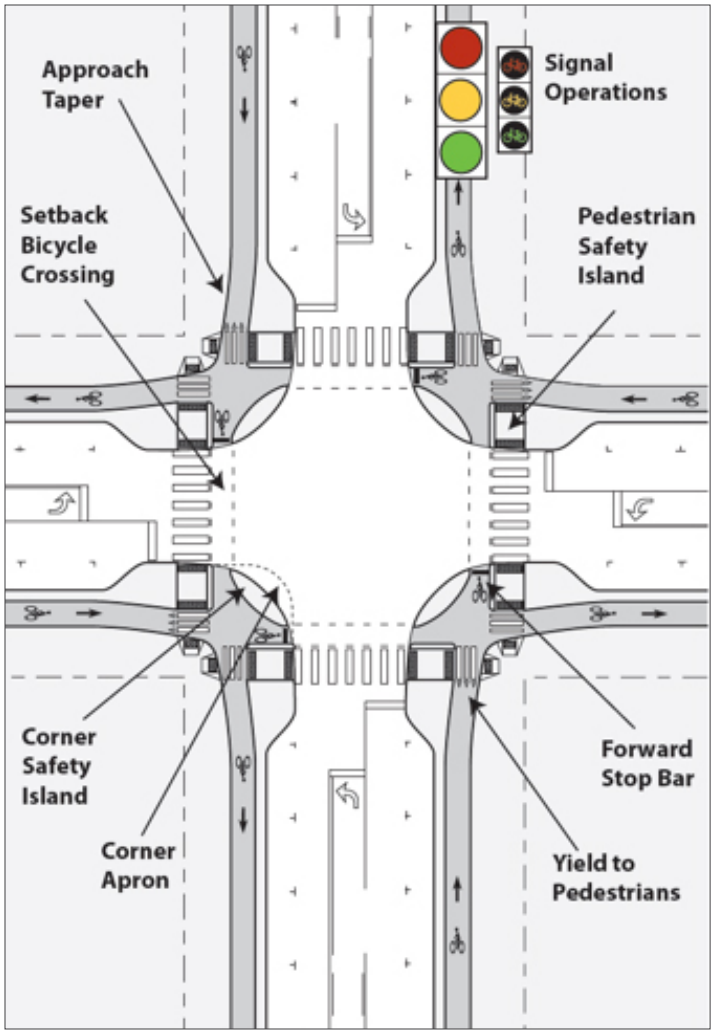
- Design practices and techniques for protected intersections are evolving in the United States. The major elements of a protected intersection include:
- Corner safety islands, that form a protected place for bicyclists to wait to cross
- Forward stop bar for bicyclists that reduce crossing distance and enhanced visibility
- Crossings for bikes and pedestrians that are set back from intersection, allowing greater visibility for turning motor vehicles
- Bicycle signal phasing, which provides an advanced green for crossing and adequate clearance time (see section on bicycle signals for more discussion). Protected intersection signalization may require a longer signal cycle, protected left turn phases, or prohibitions on right-turn-on-reds, which could increase overall delays for vehicles.

Additional Resources

Guidance on the design of protected intersections is rapidly evolving, and available at the following sources:

- www.protectedintersection.com (Alta Planning + Design website sharing information)
- MassDOT Separated Bicycle Lane Planning and Design Guide (Toole Design Group; provides a section on protected intersection design)

Protected Intersections Features and Dimensions

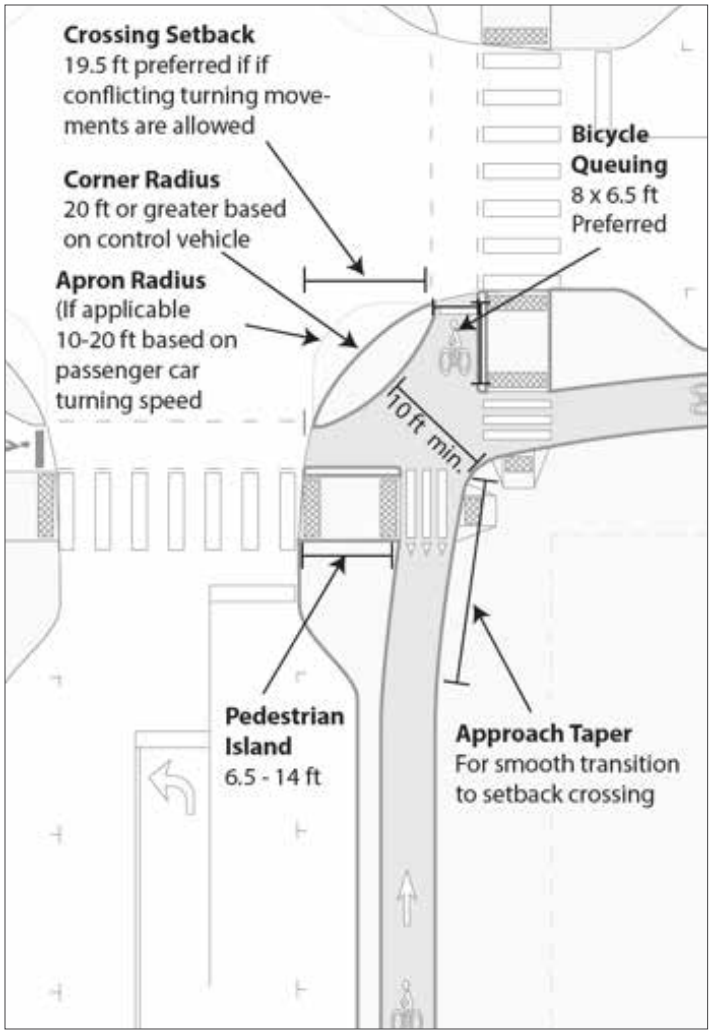


Visual illustration of key protected intersection features

Corner safety islands have multiple roles: offering a protected place for bicyclists to queue when crossing and turning, and managing the speed of turning vehicles when permitted turn conflicts are allowed.

Special attention should be paid to the amount of eflection required for both pedestrians and bicycles in advance of the intersection.

(Image source: Evolution of the Protected Intersection: Lessons Learned, Alta Planning + Design, December 2015)

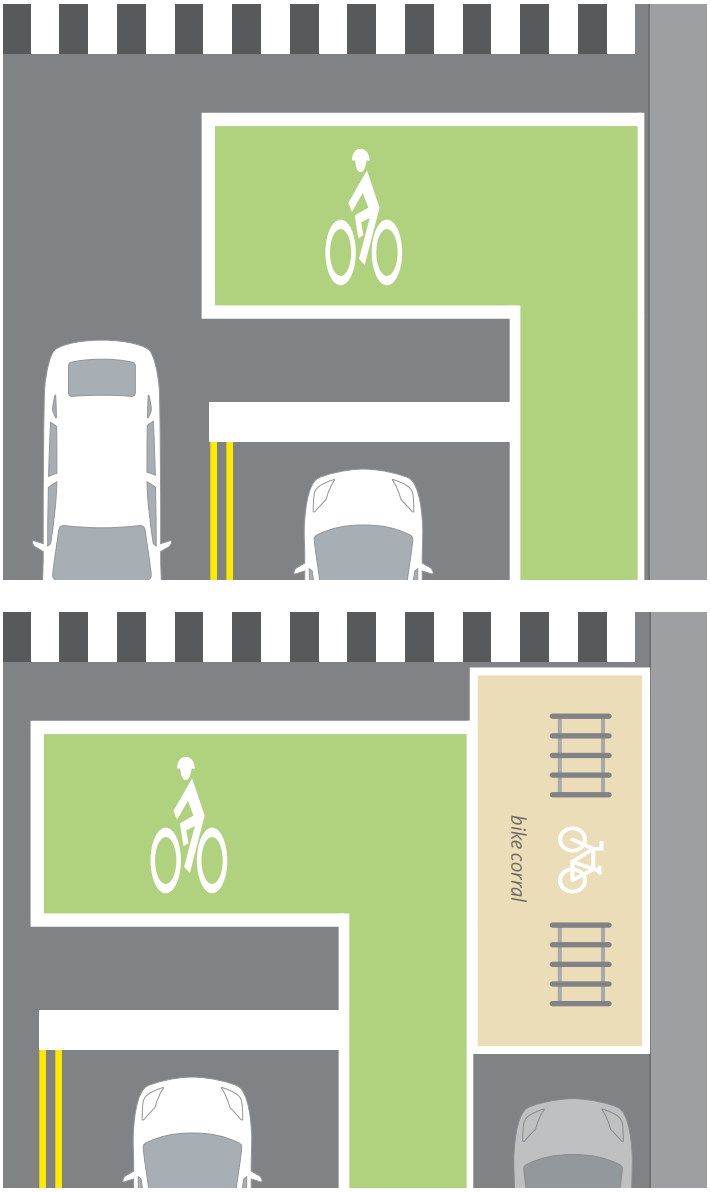


Basic geometric elements and key dimensions of a Protected Intersection

(Image source: Evolution of the Protected Intersection: Lessons Learned, Alta Planning + Design, December 2015)

Bicycle Boxes

A bike box is a dedicated area for bike riders to wait in the traffic lane at a signalized intersection, between the pedestrian crosswalk and the vehicle stop bar. They provide assistance for bicycles approaching an intersection during a red light, but not a green light, so not all conflicts are addressed. A bicycle desiring to make a left turn, and enter the bike box in front of the left turn lane, may need to wait for a red signal to enter the left turn lane bike box.



Bike box at a signalized intersection with a bike lane approach.

Considerations

- Bike boxes should be used at signalized intersections with high volumes of bicycles and/or motor vehicles, especially those with frequent bicyclist left-turns and/or motorist right-turns, and where there may be right or left-turning conflicts between bicyclists and motorists.
- Bike boxes may be combined with an exclusive bicycle signal phase or leading bicycle interval through the use of bicycle signal heads to allow clearance of the bicycle queue prior to the green indication for motorists.
- If a shared lane is narrow, the bike box may not be well utilized as it may be difficult for bikes to move around queued vehicles to enter bike box.
- Generally used with shared, conventional, or buffered bike lanes. Protected bike lanes may use protected intersection design (*page 152*).
- A “Yield to Bikes” sign should be post-mounted in advance of and in conjunction with an egress lane to reinforce that bicyclists have the right-of-way going through the intersection.
- A "No Turn on Red" sign shall be installed overhead to prevent vehicles from entering the bike box at signalized instersections.
- A “Stop Here on Red” sign should be post-mounted at the stop line to reinforce observance of the stop line.
- A “WAIT HERE” legend marking may be used to supplement the stop line and “Stop Here on Red” sign.

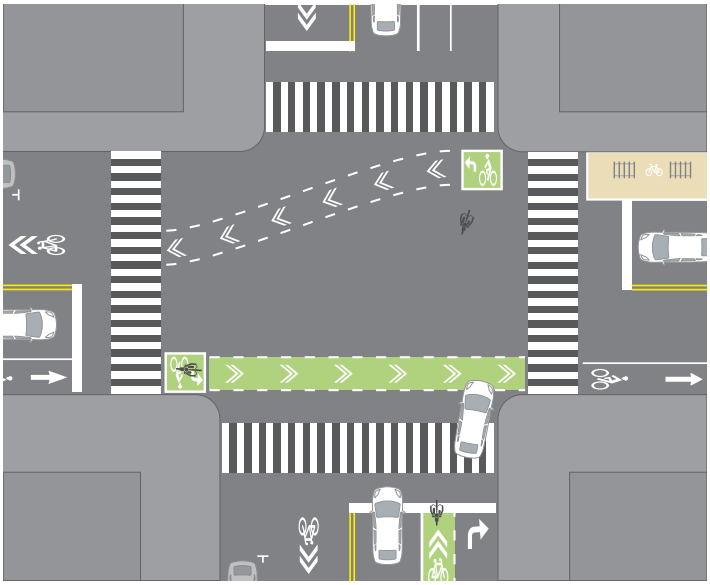
Dimensions

- A box formed by transverse lines shall be used to hold queuing bicyclists, typically 10–16 feet deep; the area between them across the full width of the approach.

Markings

- Stop lines shall be used to indicated the point behind which motor vehicles are required to stop in compliance with a traffic control signal. See MUTCD 3B.16.
- Pavement markings shall be used and centered between the crosswalk line and the stop line to designate the space as a bike box. The marking may be a Bike Symbol (MUTCD 9C-3A) or Helmeted Bicyclist Symbol (MUTCD 9C-3B).
- Colored pavement should be used as a background color within the bike box to encourage compliance by motorists.
- An ingress lane should be used to define the bicycle space. Colored pavement may be used. When color is used, length shall be 25 to 50 feet to guarantee bicycle access to the box.
- An egress lane should be used to clearly define the potential area of conflict between motorists and bicyclists in the intersection when intersection is operating on a green signal indication.
- Stop lines may be placed up to 7 feet in advance of the bike box space to limit encroachment by motor vehicles.

Two-Stage Left Turn Boxes



Two stage left turn markings are used at signalized intersections, and allow a left turning bicyclist to turn without weaving across traffic into a left turn lane. The markings provide a designated place for a left turning bicyclist to wait outside of the vehicle traffic paths for a signal to change. The markings provide more formal guidance for bicyclists making left turn maneuvers, which can be a challenge for a less experienced rider. Cyclists are not required to use the two-stage left turns, and more confident riders will often chose to make their left turn from the vehicle traffic lane. Two stage left turns will delay cyclists as they must wait for the cross street green signal.

Considerations

Should be used at signalized intersections along multi-lane roadways with a high traffic speeds and/or traffic volumes | Where a high number of bicyclists turn left from a right side bikeway, especially along cycle tracks.

- “No Turn on Red” sign shall be installed overhead to prevent vehicles from entering the queuing area. (MUTCD Section 2B.54)
- Two-stage queue box shall be placed in a "protected area," typically in line with an on-street parking lane or between the bicycle lane and crosswalk.
- A two-stage left turn box may also be used at unsignalized intersections to ismplify turns from a bicycle lane onto a neighborhood street.
- Multiple positions are available for queueing boxes, depending on intersection configuration

Dimensions

- 7' × 7' minimum square

Markings

- Bicycle stencil and turn arrow to clearly indicate proper bicycle direction and positioning
- Bicycle stencil 40" × 72"
- 6" retroreflective solid border (recommended)
- Green traffic paint, MMA, or Ruby Lake Glass (recommended)

Bicycle Signals

Bicycle signals are used in combination with an existing conventional traffic signal or hybrid beacon to provide guidance for bicyclists for bicycle only movements or leading bicycle intervals. They use standard three-lens signal heads with green, yellow, and red lenses.

Benefits

- Separates bicycle movements from conflicting motor vehicle, transit, or pedestrian movements, which may improve real and perceived safety at high-conflict areas.
- Provides priority to bicycle movements at intersections (e.g., a leading bicycle interval).
- Accommodates of bicycle-only movements within signalized intersections (e.g., providing a phase for a contra-flow bike lane that otherwise would not have a phase). Through bicycle travel may also occur simultaneously with parallel auto movement if conflicting automobile turns are restricted.
- Helps to simplify bicycle movements through complex intersections and potentially improve operations or reduce conflicts for all modes.

Typical Applications

- Bicycle signals are typically used at major intersections of bikeways with motor vehicle routes. The bikeways may be protected bike lanes or shared use paths, or conventional bike lanes that are adapted to be protected bike lanes through the intersection.
- The need for a bicycle signal should consider volumes of bicyclists, potential for conflicts or crash history, and vehicular traffic patterns. Bicycle signals should be considered for intersections with more than 50 bicycles in one direction during a peak hour combined with 1,000 or more peak hour vehicles passing through the intersection (all directions). (Many downtown Burlington intersections would likely meet these criteria.)
- Bicycle signals can be used for contra flow bike lanes at signalized intersections, where the traffic signal does not provide any guidance for the contra flow bike traffic.
- Bicycle signals can also be used to allow bicycle traffic during an all-way pedestrian scramble signal phase.

Design Considerations

- Bicycle signal phases may increase the signal cycle length and increase traffic delay.
- Consideration should be given to the number of right-or left-turning vehicles that may be crossing the path of a protected bike lane crossing, which may be addressed by separate signal phases for the bicycle traffic and turning vehicle traffic. If there are exclusive turn lanes, signal phasing can be adapted to prohibit the vehicle turns during the bicycle phase. Otherwise, permissive turns must yield to bicycles in the crossing.
- The bicycle clearance interval should be established considering the "design speed" of the bicycle traffic (often around 10 MPH), and the crossing width, using a formula:
  - $C = 3 + W/V$, where C = clearance interval; W = width of crossing in feet; and V = design speed of bicycles in feet per second (1.5 times the speed in MPH, or typically 14 ft/sec)
- The bicycle signal does not apply for bicycles who are riding in traffic lanes. They must obey the vehicular traffic signal.
- Detection for bicycles may be required, depending on the type of signal actuation or recall. Detectors can be video cameras or a magnetic loops.

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Bikeways at Bus Stops

Shared Bicycle and Bus Lanes

As the popularity of biking as an alternative mode of transportation increases in Burlington, and more on-street bike infrastructure is added, it is critical to address the relationship between bicycle accommodations and bus stops. In older cities like Burlington, right-of-way constraints often do not allow high-comfort bicycle facilities and bus stops/ bus lanes to be provided within the same right-of-way. Several shared bicycle and bus stop/bus lane marking options may be used to provide increased space and visibility for users of both modes while improving transit reliability. Shared infrastructure also provides visual continuity and clear lateral placement along streets where speeds are low and bus headways are longer than 4 minutes.

Application Guidance

Applications

Bu/bikeway network overlap.

Components

- White retroreflective traffic paint, thermoplastic, or traffic tape markings (required)
- Terracotta and green traffic paint, MMA, or Ruby Lake Glass (recommended)

Dimensions

- Curbside bus layovers and bus lanes should be a maximum of 11' in width.
- To accomodate 40' buses, bus layovers should be a minimum of 90' in length.

Design Guidance

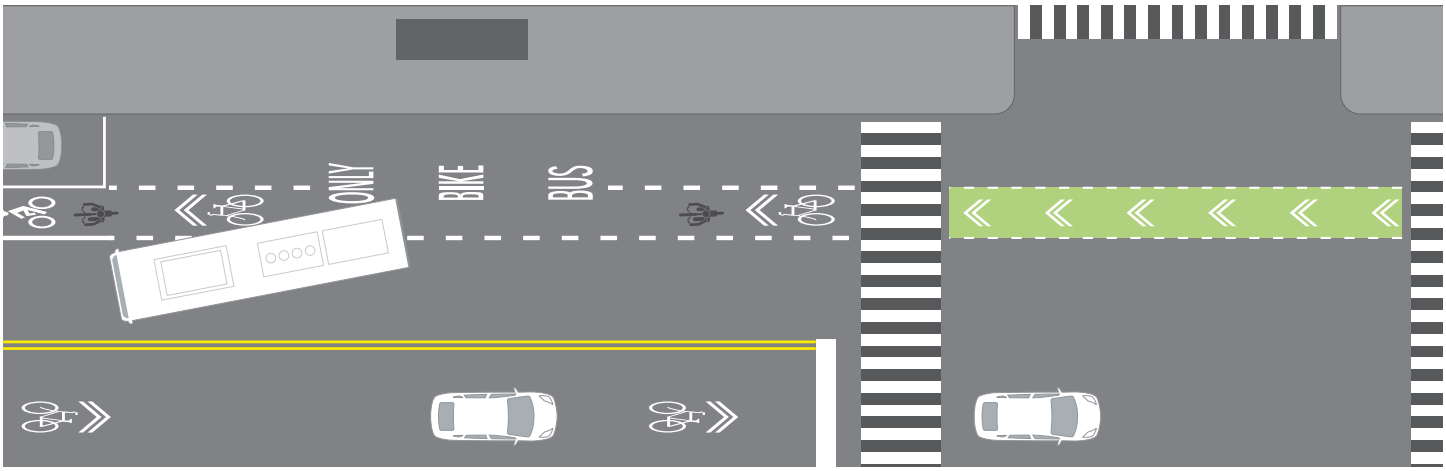
- Completely separate bus and bikeway facilities are always preferred over shared lanes or layover zones. Bus/bike lanes and bus-bike layovers should not be considered a substitute for dedicated bikeways, particularly at peak periods and on high-volume bus routes. If sharing poses real problems, emphasizing parallel neighborhood greenways or the removal of parking are two ways to separate the modes.
- To minimize conflict and resulting discomfort, bicycle/bus layover and bicycle/bus lane combos should generally be limited to streets where operating speeds average 20 MPH or less, and transit headways average every four minutes or longer.
- All bus lane pavement markings must state that the lane is dedicated to transit, including a solid white line and a "BIKE BUS ONLY" marking.
- Bus-bike lanes may be wider than the above recommended width if it allows people bicycling to overtake stopped buses on the left. This condition should include a standard dashed line and sharrow pavement marking be placed on the left edge of the bus layover, typically 9' feet from the curb face to indicate to bicyclists where to pass.In some situations adjacent travel lanes may be narrowed approaching bus stops so that a bicyclist passing zone is permitted.
- Shared use lane markings should be located in the center of the bus lane and on the left side of the bus layover at a transit stop.
- Shared bus-bike lanes can be applied where parking lanes at off-peak times.

Additional Reference

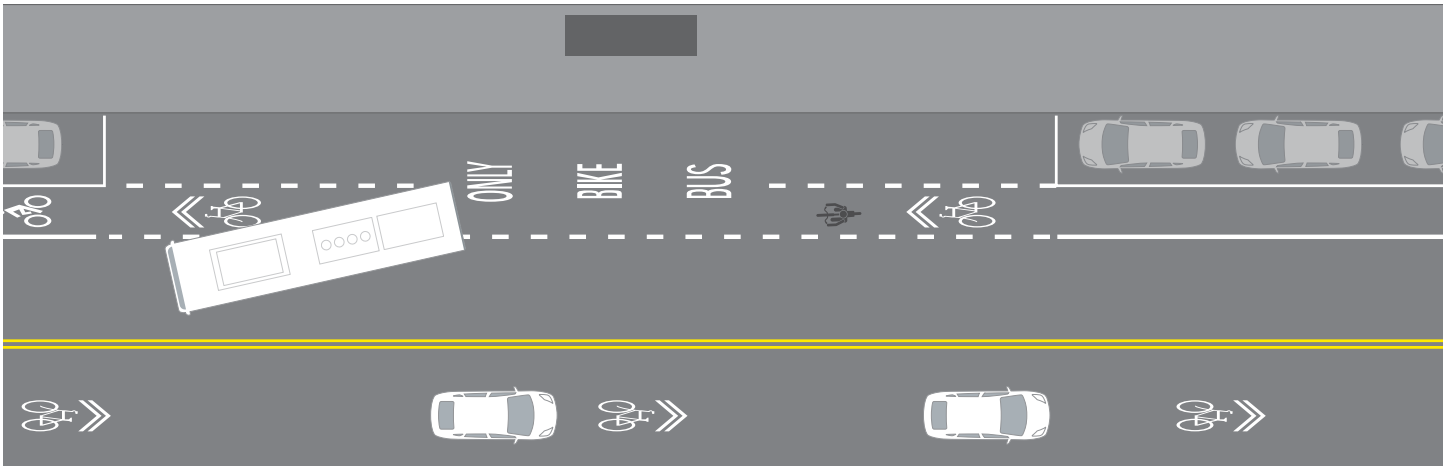
See NACTO's Urban Bikeway and Transit Street Design Guides for more details.

Curbside Bus Stop with Bike Lane Adjacent to Parking Lane

- Bike lane can be either coventional or buffered.
- Bus stop curbside next to on-street parking is the most common stop configuration.
- Uses bus queue jump at a signalized intersection in conjunction with a far-side stop.
- Bus queue jumps can be combined with bikes, and right turns.
- Bus queue jumps can be used exclusively by buses, but if curbside there must be signal control to prevent right turns in front of the bus, or right turns should be banned.
- Exclusive bus queue jumps can be set up between an exclusive right turn lane curbside, and travel lane(s) for other movements.
- Bus queue jump ideally used in conjunction with transit signal priority.
- Bike box to be determined on site specific basis: added benefit when buses are not present on the approach.



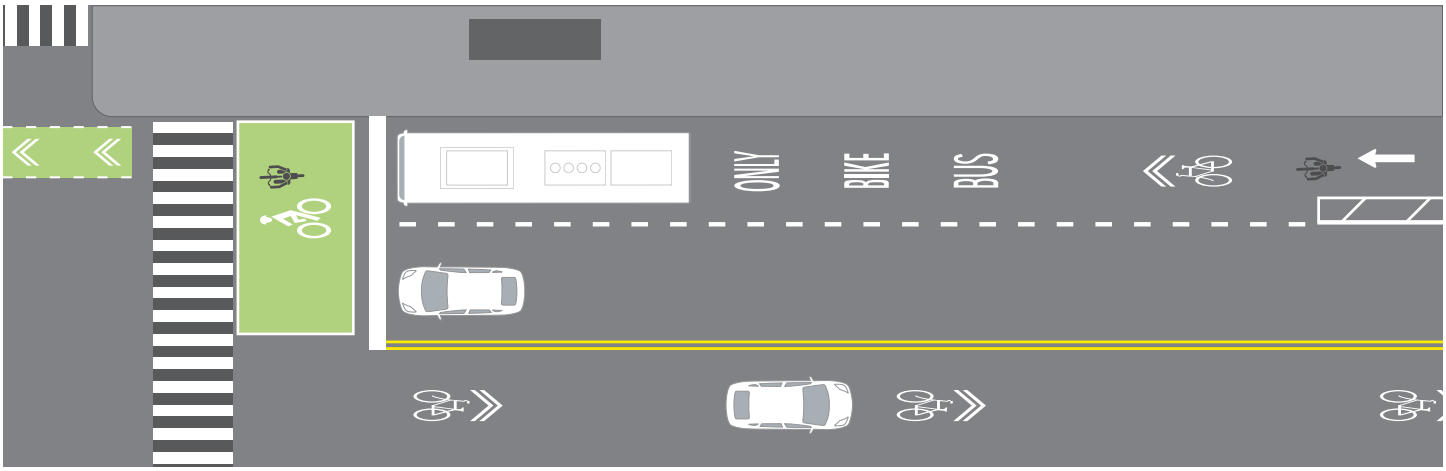
Bus stop and conventional bike lane at intersection. Can also be used with buffered bike lane adjacent to parking. (Not to scale)



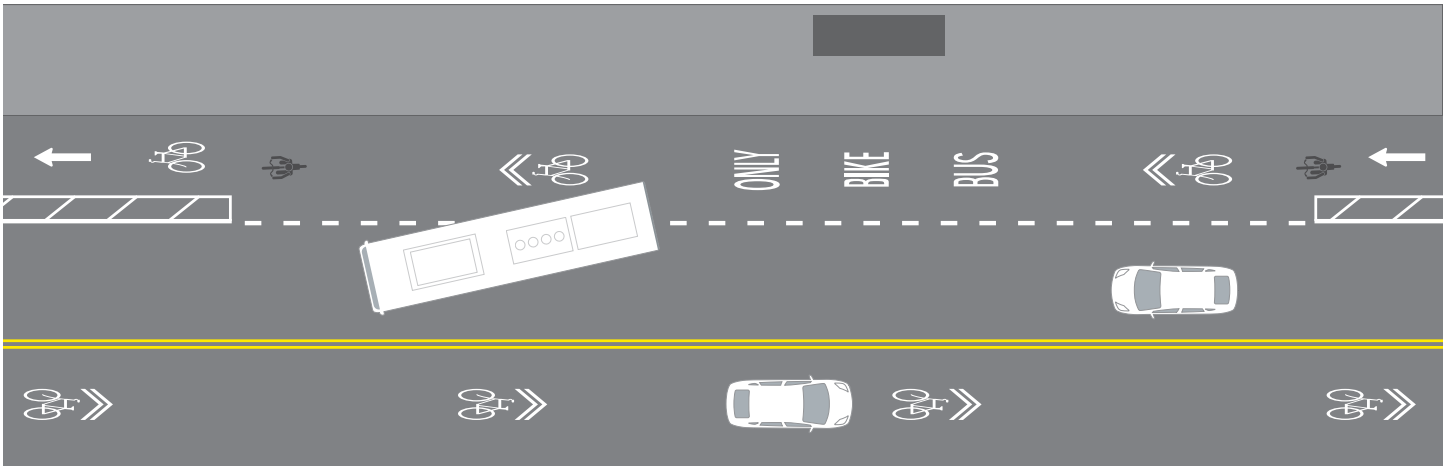
Bus stop and conventional bike lane at mid-block. Can also be used with buffered bike lane adjacent to parking. (Not to scale)

Curbside Bus Stop with Buffered Bike Lane Adjacent to Curb

- Use when bus stop is shared with bike lane.
- Stopped buses block through access for bicyclists.
- Buffered separated bike lane provides more protection for bicyclists than conventional on-street bike lane.



Bus stop and buffered bike lane at intersection. (Not to scale)



Bus stop and buffered bike lane at mid-block. (Not to scale)

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Markings, Signage & Materials

Bikeway Markings

Markings indicate the separation of the lanes for road users, assist the bicyclist by indicating assigned travel paths, indicate correct position for traffic control signal actuation, and provide advance information for turning and crossing maneuvers.

Line Width
6" normal white line

Word/Symbol/Arrow
A range of bikeway markings will help make Burlington's bicycle network more legible and intuitive for cyclists, as well as other roadway users. These symbols can be found on the following page.

Additional reference: MUTCD Figure 9C-3: Word, Symbol, and Arrow Pavement Markings for BIcycle Lanes

Colored Bike Lane
Colored pavement within a bicycle lane increases the visibility of the facility, identifies potential areas of conflict, and reinforces priority to bicyclists in conflict areas and in areas with pressure for illegal parking. Colored pavement can be utilized either as a corridor treatment along the length of a bike lane or cycle track, or as a spot treatment, such as a bike box, conflict area, or intersection crossing marking. Color can be applied along the entire length of bike lane or cycle track to increase the overall visibility of the facility. Consistent application of color across a bikeway corridor is important to promote clear understanding for all users.

The color green shall be used to minimize confusion with other standard traffic control markings. **The specific color of green varies depending on manufacturer.** The color shall comply with MUTCD daytime and nighttime chromaticity coordinates, according to FHWA memorandum "Interim Approval for Optional Use of Green Colored Pavement for Bike Lanes (IA-14)."

Color shall be applied to the road surface to delineate space, increase visibility, and emphasize proper vehicle priority.

Normal white bike lane lines shall be provided along the edges of the colored lane to provide consistency with other facilities and to enhance nighttime visibility.

Additional References
VTrans ref. dwg. Standard E-194 Bicycle Pavement Markings and Sign Layout in *Appendix section A-5.*

Urban Bikeway Design Guide: National Association of City Transportation Officials (NACTO)

Burlington Quick Build Design + Materials Standards

Signage

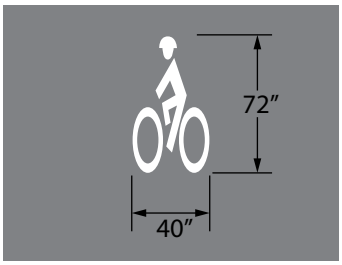
Follow MUTCD standards (Section 9B.01—Application and Placement of Signs), including mounting height and lateral placement from edge of path or roadway.

Additional References
VTrans ref. dwg. Standard E-131B Bicycle Guide Sign Details in *Appendix section A-5*

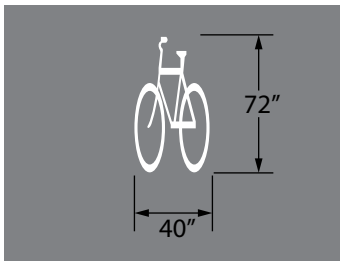
Vtrans ref. dwg. Standard E-194 Bicycle Pavement Markings and Sign Layout in *Appendix section A-5*

MUTCD Section 9B.20—Bicycle Guide Signs

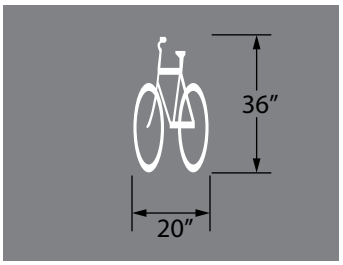
Bikway Markings Details



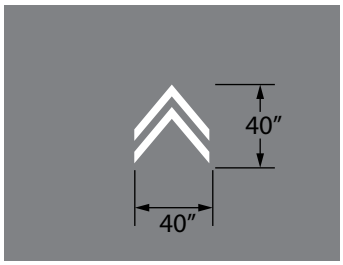
Bike Symbol



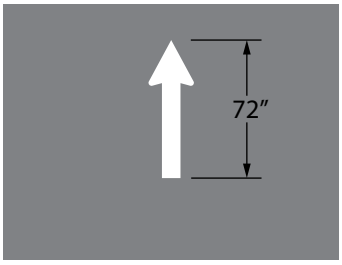
Bike Symbol



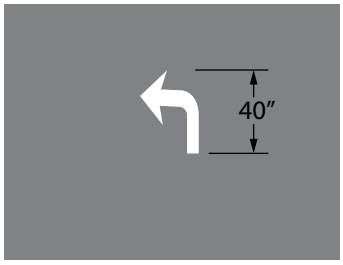
Mini Bike Symbol



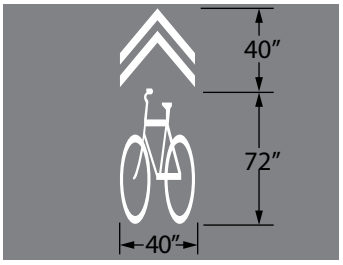
Chevron



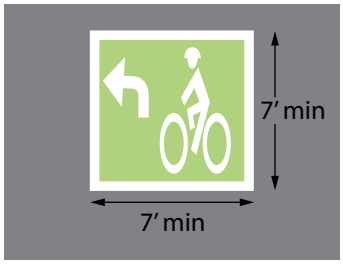
Directional Arrow



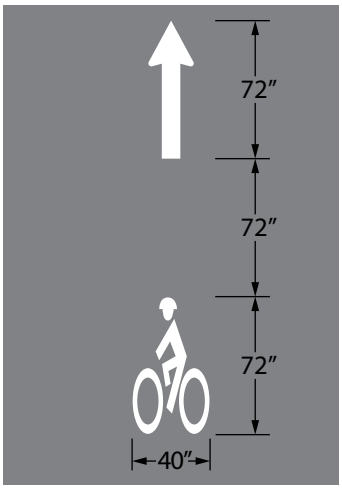
Directional Turn Arrow



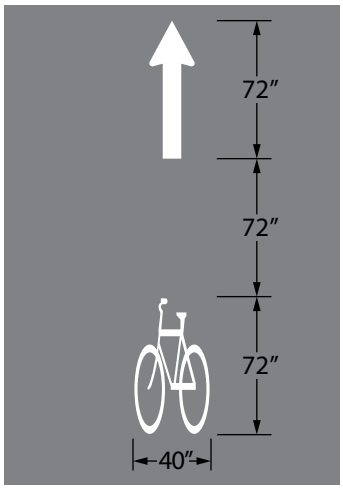
Sharrow



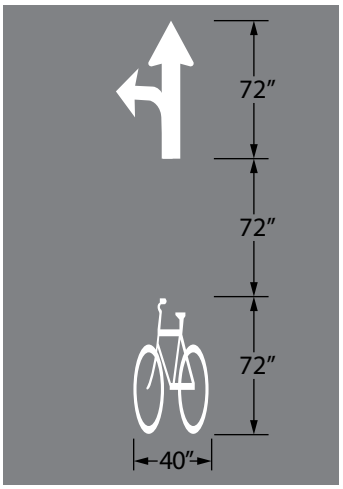
Two-Stage Queue Box



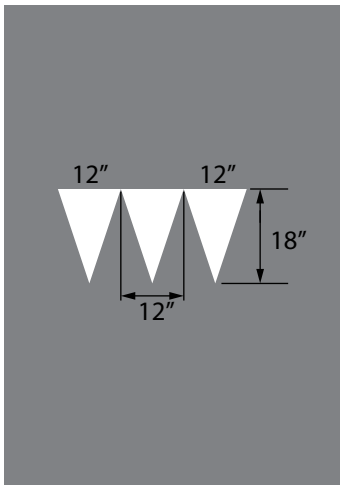
Bike Lane Symbol



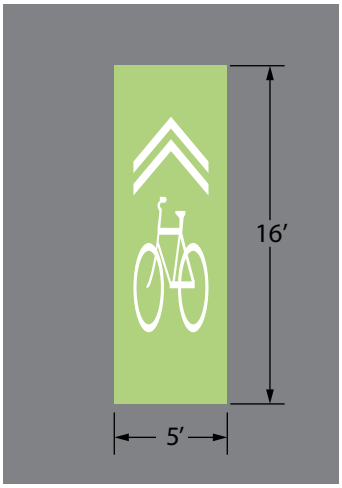
Bike Lane Symbol Alternative



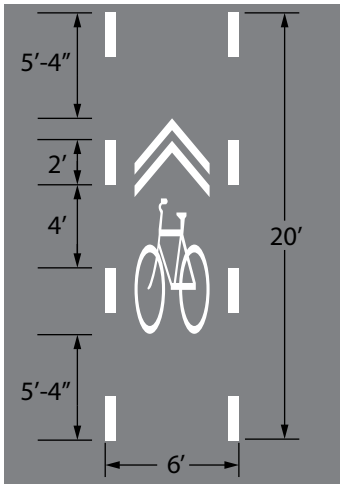
Bike Lane Turn Ahead



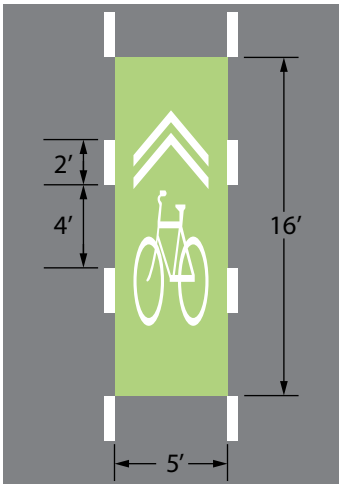
Yield Lines



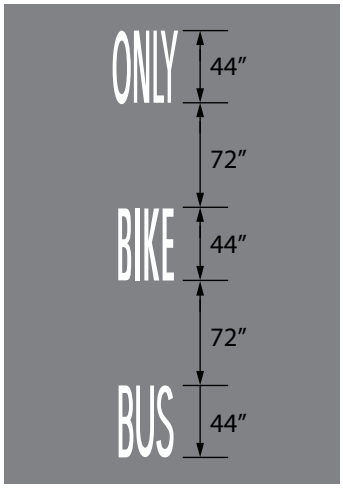
Green Backed Sharrow



Super Sharrow



Green Backed Super Sharrowa



Bus Bike Only Lane Marking

Colored Pavement Materials

Colored pavement can be utilized either as a corridor treatment along the length of a bike lane or cycle track, or in limited locations as a spot treatment, such as a bike box, conflict area, or intersection crossing marking. Colored pavement for use within bikeways treatments may take the form of an overlay, when the colored material is placed on top of the pavement or embedded, when the colored material is mixed into the pavement.

PAINT

Paint, sometimes with additives such as reflective glass beads for retro reflectivity and sand for skid resistance, is the most widely used method to mark road surfaces. Paint is considered a non-durable pavement marking, is easily worn by vehicle tires and the elements in snowy winter climates, and often requires annual reapplication. Paint is the least expensive of the overlay materials.

Spot Treatments Recommended for temporary, pilot, or experimental spot treatments.	**Pros** Easy application and moderate dry time. **Cons** Proven to wear quickly in areas with moderate to heavy motor vehicle traffic.
Corridor Treatments Recommended for corridor treatments. Ideal for protected bicycle facilities like cycle tracks.	**Pros** Cost-effective along corridors with low or no motor vehicle traffic impacts. **Cons** Can be slick when wet. Not durable in high wear locations.
Composition	Pigment and binder, glass beads and/or a fine aggregate can be added for retroreflectivity and skid resistance.
Installation Considerations	Most paints can be applied immediately to new asphalt or concrete. Primer is not required on concrete roadways. Paint dry time depends on ambient temperature.
Maintenance Considerations	Spot maintenance requires a simple reapplication of paint.
Longevity	Six months to two years based on weather, motor vehicle traffic and snow removal operations (if applicable).
Skid Resistance & Retroreflectivity	Glass beads may be added to paint for retroreflectivity and sand added for skid resistance.

DURABLE LIQUID PAVEMENT MARKINGS (DLPM)—EPOXY AND MMA

Durable Liquid Pavement Markings (DLPM) include epoxy and Methyl Methacrylate (MMA). Epoxies are adhesive, waterborne acrylics that are typically applied as a paint or spray. MMA are 2-part liquids comprised of a resin and activator. While both coatings can be skid resistant, retro reflective and can adhere to concrete or asphalt surfaces, epoxies are sensitive to moisture and temperature and may require long dry times. MMA may be installed at any temperature, is durable and dries quickly, but is more expensive than epoxy.

Spot Treatments MMA is more appropriate for spot treatments than epoxy.	**Pros** Material is durable if installed according to manufacturer specifications. MMA has quick dry times and good durability. **Cons** Epoxy can have long dry times, causing increased disruption to roadway traffic. Requires special installation equipment.
Corridor Treatments Recommended for corridor treatment.	**Pros** Materials are long-lasting and can be cheaper than thermoplastic. **Cons** Requires special installation equipment
Composition	Epoxy—epoxy/resin MMA—acrylic-based resin
Installation Considerations	Installation generally requires special equipment. Epoxy dry time increases as temperature decreases. Dry time is measured in hours. MMA dries in about one hour.
Maintenance Considerations	Some cities have reported that epoxy color intensity fades over time due to color instability under ultraviolet lighting (sunlight) exposure. Pooling water can reduce material longevity.
Longevity	Similar to thermoplastic. Poor pavement quality impacts treatment longevity.
Skid Resistance & Retroreflectivity	Material can be skid resistant and retro reflective.

THERMOPLASTIC

Thermoplastic, another type of durable pavement marking, is a type of plastic made from polymer resins that becomes a homogenized liquid when heated and hard when cooled. Thermoplastic can be pre-formed in specific shapes, such as tiles that can be assembled like a puzzle to color bicycle facilities. Thermoplastic can also be used for bicycle lane symbols, arrows, pavement legends and shared lane markings.

Thermoplastic tends to last longer than epoxy and is easier to apply then MMA. Retro reflective and anti-skid materials can be applied or mixed throughout the plastic.

Spot Treatments Recommended for spot treatments. Ideal for intersection treatments and other high-traffic conflict areas.	**Pros** Quick cure time minimizes traffic impact. Relatively low-cost equipment investment. Easy spot maintenance. Shown to wear well in conflict areas. **Cons** May be cost-prohibitive for large scale applications.
Corridor Treatments Not recommended for long corridors due to cost.	**Pros** Material is known to have long life and good performance qualities in the US and Europe **Cons** Cost-prohibitive in corridor applications.
Composition	Polymer resin, pigment, glass beads, and filler.
Installation Considerations	Many thermoplastics can be applied immediately to new asphalt, but new concrete must cure at least 30 or longer days prior to installation. Primer is typically required for application to concrete roadways and may assist with adherence on older asphalt surfaces. Cure time is measured in minutes.
Maintenance Considerations	Spot fixes are simple: a small piece of plastic is torched into place. Thermoplastic can be recessed to make edge flush with pavement or tamped down to form a seal with the roadway to reduce likelihood of snow plow impact.
Longevity	Average of 5 years, or 3 times the lifetime of paint under the same conditions. Many installations have lasted significantly longer. Poor initi al pavement quality shortens lifespan.
Skid Resistance & Retroreflectivity	Material can be skid resistant and retroreflective. Most effective materials will mix corundum and beads throughout materials rather than top coating material.

COLORED ASPHALT

Colored asphalt is composed of the same material as standard asphalt, but has a colored pigment added. The colored asphalt may be installed as a thin layer over conventional asphalt to reduce cost. Green pigment options are available.

Spot Treatments Recommended for Corridor treatments.	**Pros** Not recommended due to complexity of paving operations. **Cons** Spot maintenance is difficult and may result of color loss when trenching occurs. Requires equipment and expertise to install.
Corridor Treatments Recommended for corridor treatments.	**Pros** Long lasting treatment. Should be coupled with initial construction or repaving for cost savings. Has same lifespan of standard asphalt. Proven long-term use as an effective treatment in Europe. Requires little maintenance **Cons** Requires cleaning of machinery or maintenance of special machinery for colored applications. Colored asphalt is not retroreflective by itself; a white thermoplastic stripe may be used for visibility. Can require special attention at joints between colored and standard asphalt.
Composition	Bituminous pitch, sand/gravel, and pigment.
Installation Considerations	Standard paving considerations apply.
Maintenance Considerations	It is expected that colored asphalt at least 1 cm thick will last for the life of the pavement.
Longevity	Based on motor vehicle traffic, but typically similar to conventional asphalt.
Skid Resistance & Retroreflectivity	Skid resistance equal to uncolored asphalt. Asphalt is not retroreflective.

Green pigment colored pavement options are available.