Federal Highway Administration

SEPARATED BIKE LANE PLANNING AND DESIGN GUIDE

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Federal Highway Administration

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COMPLIANCE WITH THE MUTCD

Any traffic control devices that are used for separated bike lanes must comply with the Manual on Uniform Traffic Control Devices (MUTCD). The MUTCD is incorporated by reference in 23 Code of Federal Regulations, Part 655, Subpart F, and is approved as the national standard for designing, applying, and planning traffic control devices installed on any street, highway, or bikeway open to public travel. The FHWA issues the MUTCD, which contains all national design, application, and placement standards, guidance, options, and support provisions for traffic control devices used with separated bike lanes. The jurisdiction implementing the bike lane must ensure that the project complies with the MUTCD. Please note that interim approvals (IAs) have been issued by the FHWA for green colored pavement (IA-14) and bicycle signal faces (IA-17). Agencies who desire to use green colored pavement or bicycle signal faces must request specific approval from the FHWA using the procedure outlined in Paragraphs 14 through 22 of Section 1A.10 of the MUTCD. Please also note that bike boxes and two-stage turn boxes are still experimental. Agencies who desire to experiment with bike boxes or two-stage turn boxes must request approval from the FHWA using the procedure outlined in Paragraphs 8 through 11 of Section 1A.10 of the MUTCD. The FHWA maintains a web page regarding the MUTCD approval status of various bicycle-related treatments at http://www.fhwa.dot.gov/environment/bicycle_pedestrian/guidance/design_guidance/mutcd.

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Cover image: L Street separated bike lane in Washington, DC (Source: Alex Baca, Washington Area Bicyclist Association (WABA)

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Indianapolis, IN
Jackson, WY
Long Beach, CA
Los Angeles, CA
Madison, WI
Miami, FL
Milwaukee, WI
Minneapolis, MN
Missoula, MT
New York, NY
Philadelphia, PA
Phoenix, AZ
Pittsburgh, PA
Portland, OR
Salt Lake City, UT
San Jose, CA
San Francisco, CA
Seattle, WA
Spartanburg, SC
St. Petersburg, FL
Syracuse, NY
Washington, DC

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MENU OF DESIGN RECOMMENDATIONS

DESIGN RECOMMENDATIONS

Four Step Design Process

The separated bike lane design process can be categorized into four general categories – Directional and Width Characteristics, Forms of Separation, Midblock Considerations, and Intersection Considerations. These categories form the basis of a four-step design process where the decisions within each step inform future design decisions, resulting in an iterative design process based on available street width, transportation priorities, and other project goals. This chapter groups the design process into these four categories and provides flexible design options to best meet local conditions and the community's goals.

When designing these newer types of facilities, it is important to document the numerous decisions made throughout the design process. Documentation should demonstrate that the final design was developed based on the best available data, good engineering judgment, and sound design principles.

STEP 1: ESTABLISH DIRECTIONAL AND WIDTH CRITERIA

- The decision of one-way and two-way separated bike lanes should be based on traffic lane configurations, turning movement conflicts, parking requirements, and surrounding bicycle route network options and destinations.
- Width considerations include expected bicycle volumes, required buffer width, and maintenance requirements.
- Alignment decisions for running the separated bike lane on the right-side, left-side, or in the center of the road, include transit stop conflicts, intersection and driveway conflicts, locations of destinations, and parking placement.

STEP 2: SELECT FORMS OF SEPARATION

- Separation type decisions should be based on the presence of on-street parking, street width, cost, aesthetics, maintenance, motorized traffic volumes and speeds.

STEP 3: IDENTIFY MIDBLOCK DESIGN CHALLENGES AND SOLUTIONS

- There are several potential conflicts that may occur at midblock locations along a separated bike lane.
- Transit stops occurring on the same side of the street as the separated bike lane present a challenge due to interactions among cyclists, transit vehicles, and those accessing transit stops.
- Locating accessible parking spaces may require additional design adjustments.
- Loading zones should be well-located and designed to minimize conflicts.
- Driveways present concerns due to challenges with sight distance and driver expectations that can be minimized through design treatments and driveway consolidation.

STEP 4: DEVELOP INTERSECTION DESIGN

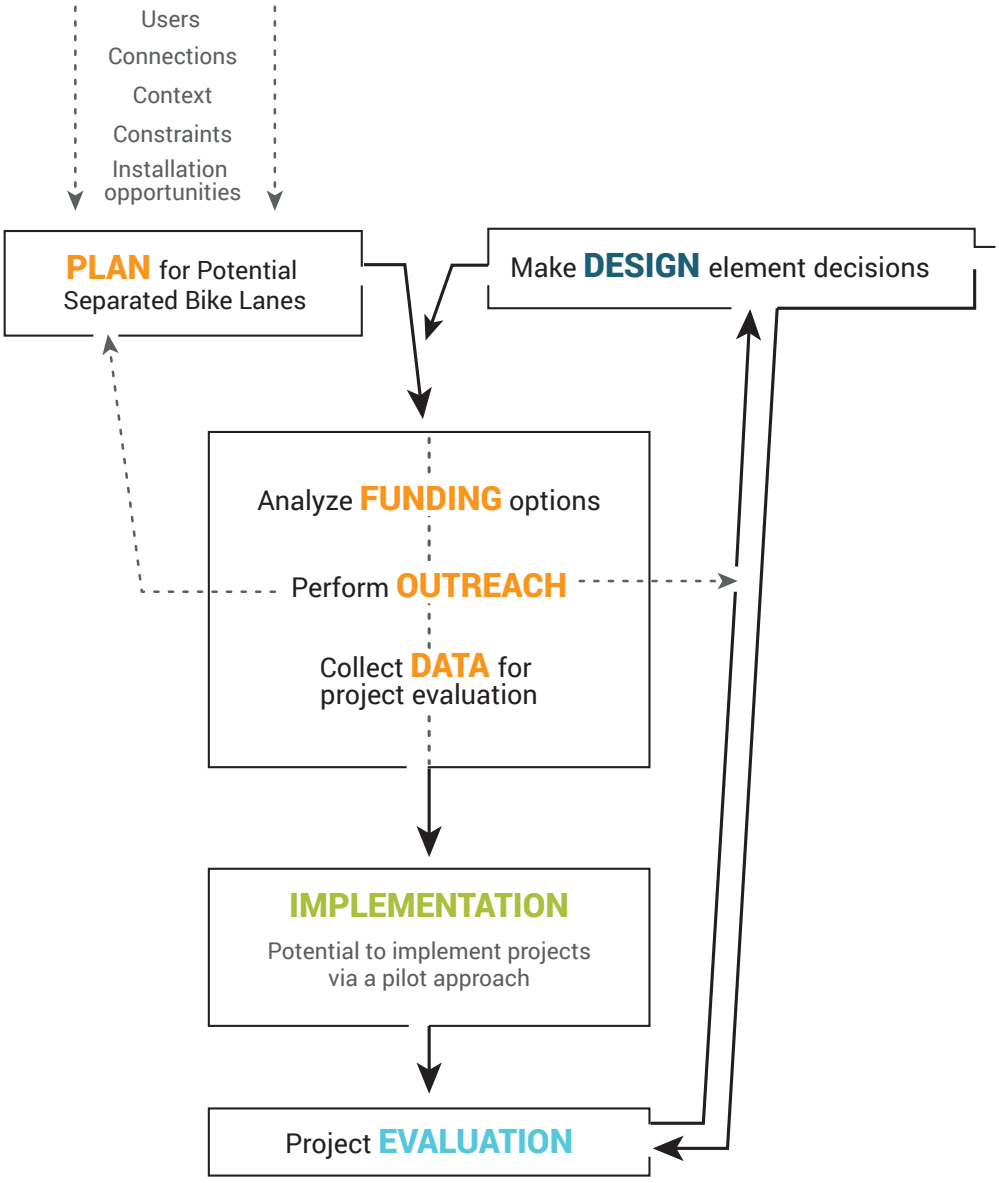
- Intersection design should focus on the safety of all users with additional consideration on delay, queuing, user expectations, motorized traffic volumes and speeds.
- Sufficient sight distance for all street users at intersection approaches should be provided.
- Designs should protect or provide safe interactions between separated bike lane users and conflicting turning movements.
- Signs and markings should be included to appropriately guide and prompt safe behaviors through intersections.

DESIGN RECOMMENDATIONS

Flexibility in the Planning and Design Process

The designs presented in this chapter are based on current design guidance and the state of the practice and are intended to be a starting point for a flexible design process that takes into account site conditions, context, and continually evolving design resources. The graphic below highlights the key elements of a successful design process, but the order and exact execution of the steps are flexible. Evaluation and design are iterative processes, with designs evolving as municipalities evaluate how a facility is functioning.

Figure 7



DIRECTIONAL AND WIDTH CHARACTERISTICS

STEP 1

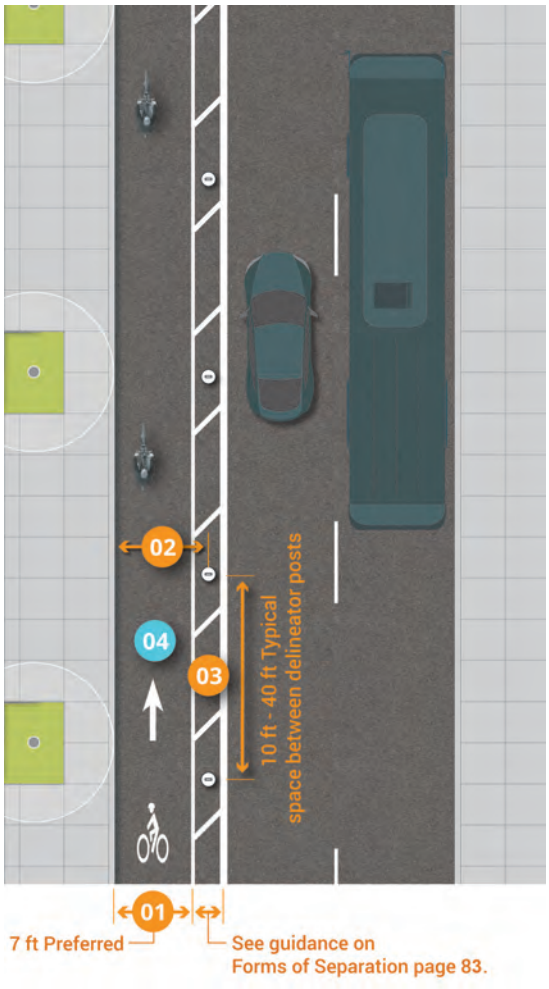
The selection of separated bike lane width and directional characteristics depends on a combination of factors that are most often determined by the existing street and surrounding network characteristics. The most critical considerations are to reduce conflicts with turning vehicles, provide sufficient width for safe operations and ease of maintenance, and ensure predictable behavior by the street users.

DIRECTION AND WIDTH

One-Way Separated Bike Lane on a One-Way Street

A one-way separated bike lane on a one-way street is the least complicated design. This type of design can most easily be implemented on existing streets through the conversion of a motor vehicle lane or removal of on-street parking. Another advantage of this type of facility is the ability to provide a reasonable signal progression for cyclists, improving travel time and signal compliance. One potential complication of this design may be wrong-way riding by bicyclists. This can occur if there are no suitable and attractive bicycle routes (such as a parallel facility) near this separated bike lane.

Figure 8



01 One-way separated bike lanes should have a minimum width of 5 ft. Wider separated bike lanes provide additional comfort and space for bicyclists and should be considered where a high volume of bicyclists is expected. Widths of 7 ft and greater are preferred as they allow for passing or side-by-side riding. Additional care should be taken with wider lanes such that the separated bike lane is not mistaken for an additional motor vehicle lane.

02 Total clear width between the curb face and vertical element should be at least the fleet maintenance (sweeping or snowplow) vehicle width. Widths (inclusive of the gutter pan and to the vertical buffer element) narrower than 7 ft will often require specialized equipment. Consultation with a Public Works department is recommended during the planning process.

03 A minimum 3 ft buffer should be used adjacent to parking. For further guidance on buffer selection and installation, see page 83.

04 For further guidance on typical signs and markings for separated bike lanes, see page 127.

One way Separated Bike Lane on a One-Way Street (Left-Side Running)

Long Beach, CA, has installed left-side, one-way separated bike lanes along a pair of one-way streets downtown. (Source: City of Long Beach)

Consider a left-side running separated bike lane under the following conditions:

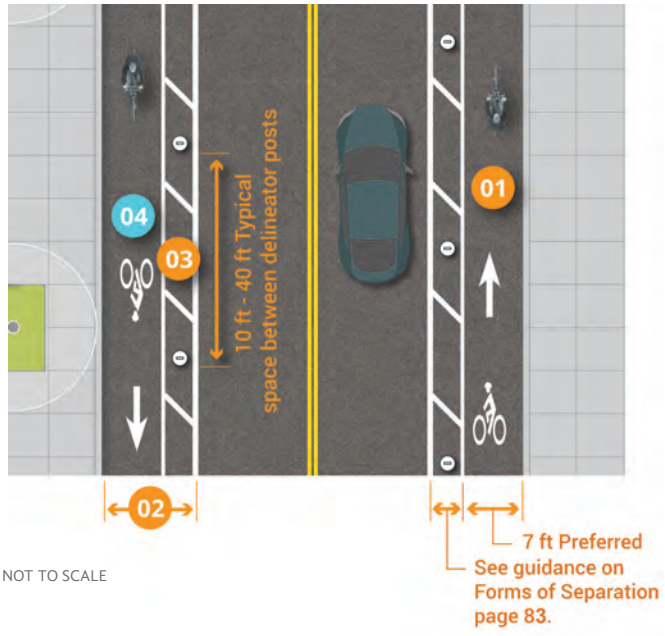
- The corridor includes a high frequency transit route resulting in potential conflicts with transit vehicles, stops, and transit riders.
- There are fewer driveways, intersections, or other conflicts on the left-side of the street.
- The most likely destinations for bicyclists are on the left-side of the street.
- On-street parking is located on the right-side of the street.

DIRECTION AND WIDTH

One-Way Separated Bike Lane on a Two-Way Street

Providing one-way separated bike lanes on each side of a two-way street creates a predictable design for managing user expectations. Typically, each separated bike lane will run to the outside of the travel lanes in a design similar to a one-way separated bike lane on a one-way street. A potential challenge with this design is it takes up more roadway space compared to the alternatives of providing a two-way separated bike lane or developing alternate corridors for directional travel.

Figure 9



01 Bike symbols should be placed periodically in the lane.

02 Drainage grates and gutter seams should generally not be included in the usable width.

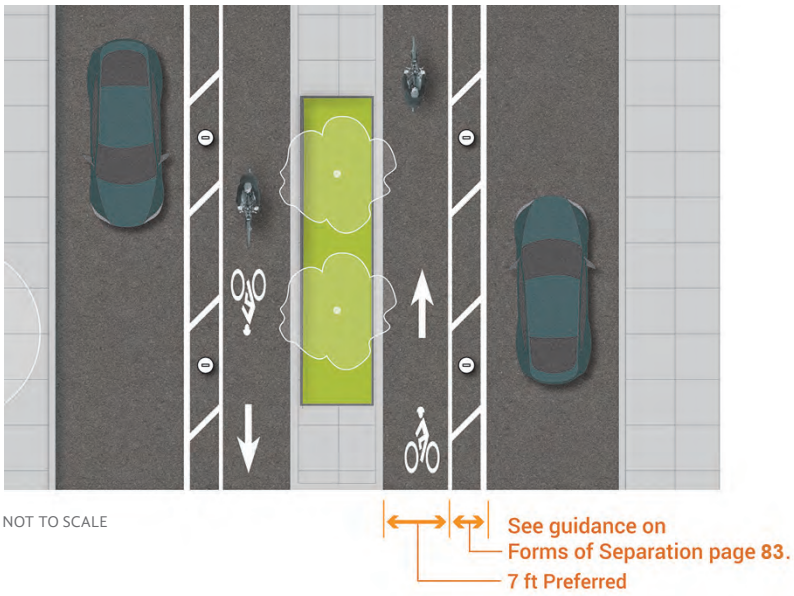
03 For further guidance on buffer selection and installation, see page 83.

04 For further guidance on typical signs and markings for separated bike lanes, see page 127.

Central Median Alternative

An alternative design places separated bike lanes adjacent to a median. This design can be considered when there are significant conflicts due to turning movements, transit activity, or other conflicting curbside uses. Depending on the width of the median, this design may result in intersection design challenges, particularly in how bicyclist right- and left-turns are made.

Figure 10



DIRECTION AND WIDTH

Two-Way Separated Bike Lane on Right-Side of One-Way Street (2 Lanes)

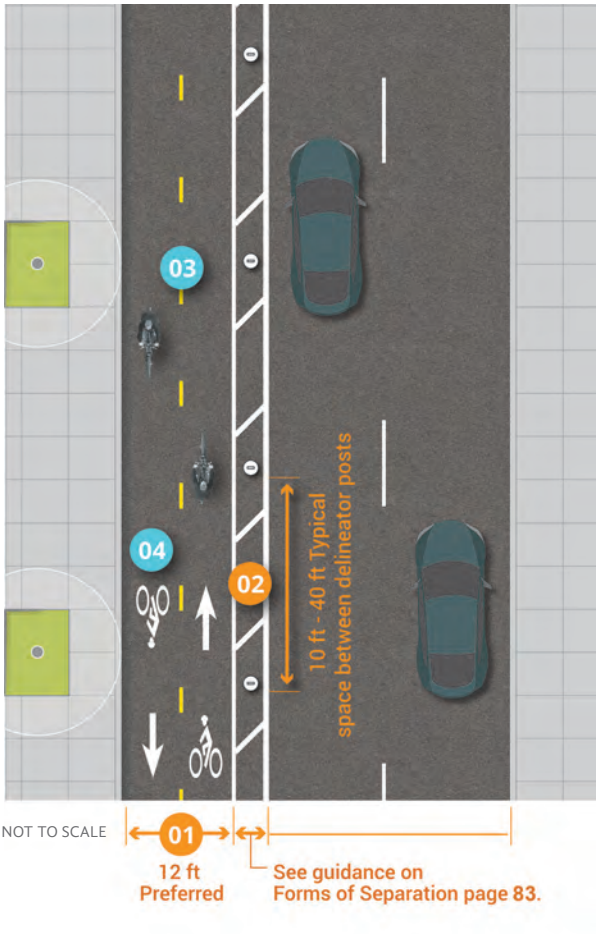
Providing a two-way separated bike lane on a one-way street may be desirable under certain circumstances. This design couples a separated bike lane with a contraflow bike lane in order to route bicyclists in the most direct or desirable way given the street network and destinations. However, this design can create some challenges for roadway user expectancy at intersections and driveways, which could be mitigated by signage suggesting to look both ways for pedestrians. Additionally, certain intersection designs are not possible.

Left-Side Running Alternative

Consider a left-side running separated bike lane under the following conditions:

- The corridor includes a high frequency transit route resulting in potential conflicts with transit vehicles, stops, and transit riders.
- There are fewer driveways, intersections, or other conflicts on the left-side of the street.
- The most likely destinations for bicyclists are on the left side of the street.
- On-street parking is located on the right side of the street.

Figure 11



01 Two-way separated bike lanes should have a preferred combined width of at least 12 ft. Given this total width, clear signs and markings should be provided such that the separated bike lane is not mistaken for an additional motor vehicle travel lane.

02 For further guidance on buffer selection and installation, see page 83.

03 A centerline to separate the two-way bicycle traffic marked in accordance with the MUTCD (2009).

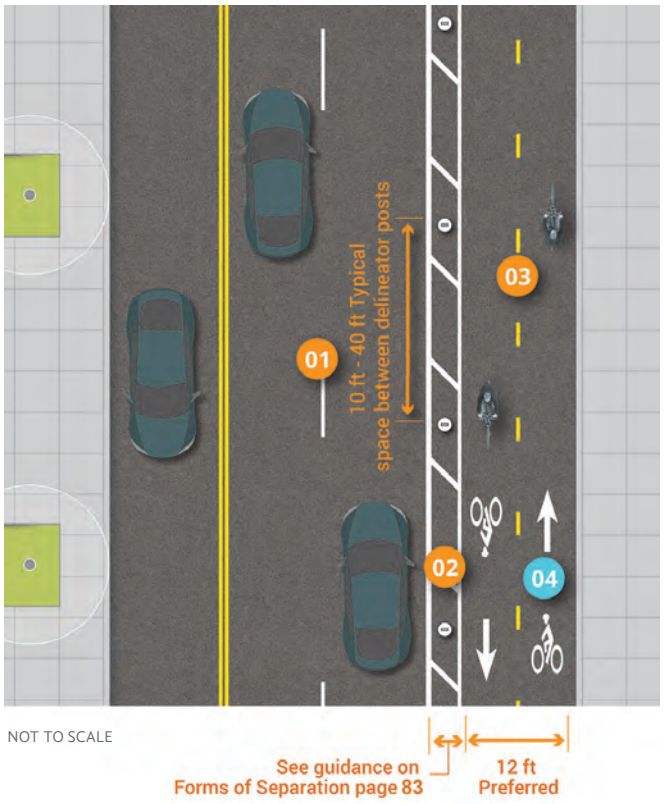
04 For further guidance on typical signs and markings for separated bike lanes, see page 127.

DIRECTION AND WIDTH

Two-Way Separated Bike Lane on Right-Side of Two-Way Street

Providing a two-way separated bike lane on a two-way street may be desirable under certain circumstances such as minimizing conflicts on high frequency transit corridors or along corridors with a higher number of intersections or driveways on one side of the street (such as along a waterfront). This design does, however, create some challenges for roadway user expectancy at intersections and driveways. Additionally, the design limits intersection design options.

Figure 12



01 Due to operational and user expectations, this design is best used when there is no room for separated bike lanes on both sides of the street.

02 For further guidance on buffer selection and installation, see page 83.

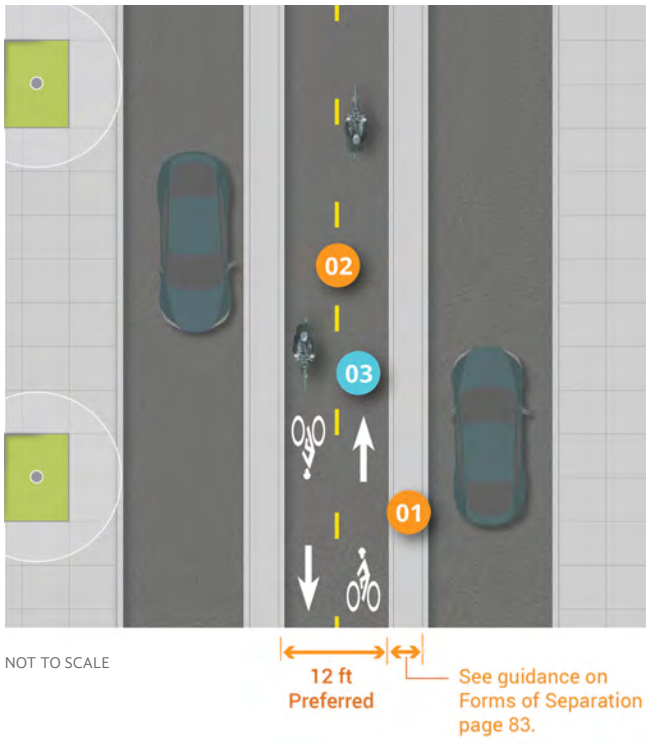
03 A centerline to separate the two-way bicycle traffic marked in accordance with the MUTCD (2009).

04 For further guidance on typical signs and markings for separated bike lanes, see page 127

Center Orientation Alternative

An alternative design places a two-way separated bike lane in the center of the street. This design is uncommon and can be considered when there are significant conflicts due to turning movements, transit activity, or other conflicting curbside uses. Depending on the width of the roadway and the amount of space that can be allocated to the separated bike lane and buffer, this design may result in intersection design challenges, particularly on how bicyclist right- and left-turns are made.

Figure 13



01 A continuously raised buffer is preferred to reduce the chance of U-turns across the separated bike lane.

For further guidance on buffer selection and installation, see page 83.

02 A centerline to separate the two-way bicycle traffic marked in accordance with the MUTCD (2009).

03 For further guidance on typical signs and markings for separated bike lanes, see page 127.

FORMS OF SEPARATION

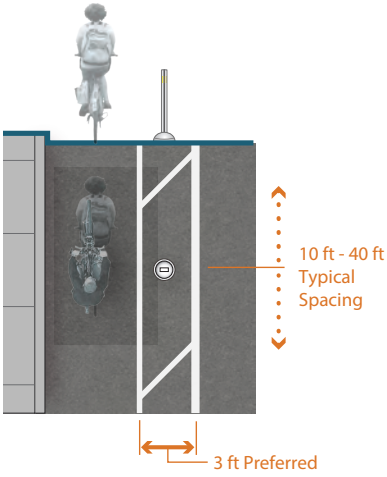
STEP 2

Vertical elements in the buffer area are critical to separated bike lane design. These separation types provide the comfort and safety that make separated bike lanes attractive facilities. The selection of separation type(s) should be based on the presence of on-street parking, overall street and buffer width, cost, durability, aesthetics, traffic speeds, emergency vehicle and service access, and maintenance. In certain circumstances, emergency vehicle access may need to be provided through low or mountable curbs or non-rigid means. The spacing and width dimensions that follow are suggestions; narrower buffer widths may be used so long as the vertical elements can be safely accommodated under the conditions of that roadway. To realize the full benefits of several treatments at a potentially lower overall cost, a combination of separation treatments may be used.

Cyclists enjoy the greatest level of comfort when buffers provide greater levels of physical separation. The National Institute for Transportation and Communities' (NITC) report, "Lessons from the Green Lanes: Evaluating Protected Bike Lanes in the U.S.," found that planters, curbs, and flexible delineator posts provided the greatest sense of comfort, and that any type of buffer shows a considerable increase in self-reported comfort levels over a striped bike lane.

FORMS OF SEPARATION

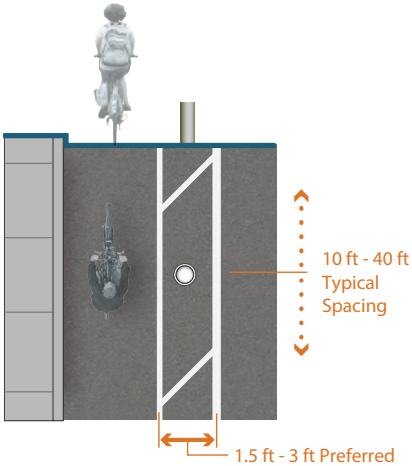
Delineator Posts



San Francisco, CA. (Source: Dianne Yee)

Flexible delineator posts are one of the most popular types of separation elements due to their low cost, visibility, and ease of installation. However, their durability and aesthetic quality can present challenges and agencies may consider converting these types of buffers to a more permanent style when design and budgets allow. Delineators can be placed in the middle of the buffer area or to one side or the other as site conditions dictate (such as street sweeper width or vehicle door opening).

Bollards

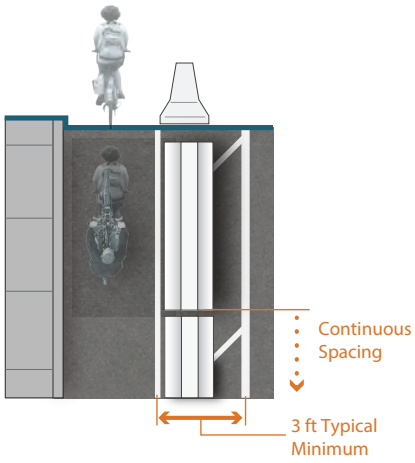


Indianapolis, IN (Source: PeopleForBikes)

Bollards are a rigid barrier solution that provides a strong vertical element to the buffer space. Depending on how frequently the bollards are placed, this form of separation may result in an increased cost compared to others, and may not be as appropriate on higher speed streets.

FORMS OF SEPARATION

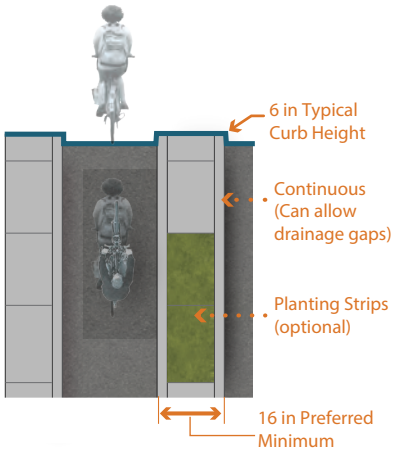
Concrete Barrier



Seattle, WA. (Source: Seattle DOT)

Concrete barriers provide the highest level of crash protection among these separation types. They are less expensive than many of the other treatments and require little maintenance. However, this barrier type may be less attractive and may require additional drainage and service vehicle solutions. A crash cushion should be installed where the barrier end is exposed.

Raised Median

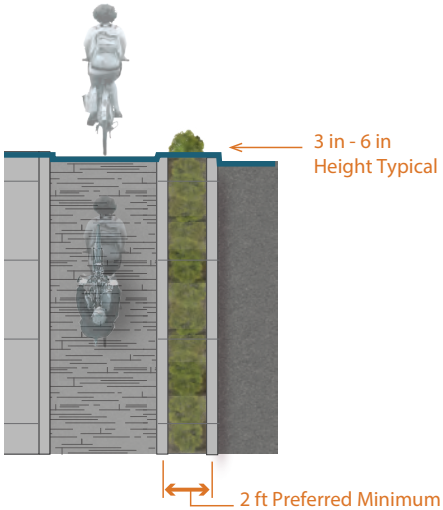


Austin, TX (Source: City of Austin)

Concrete curbs can either be cast in place or precast. This type of buffer element is more expensive to construct and install but provides a continuous raised buffer that is attractive with little long-term maintenance required. Mountable curbs are an option where emergency vehicle access may be required.

FORMS OF SEPARATION

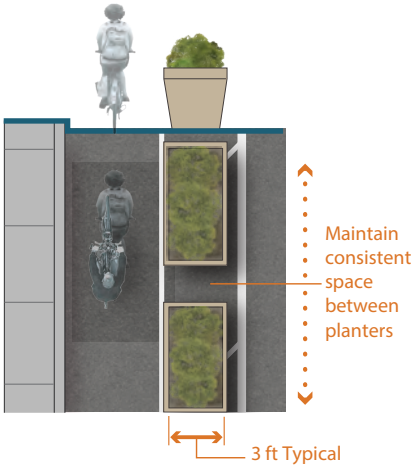
Raised Lane



Cambridge, MA. (Source: City of Cambridge)

Separated bike lanes may also be designed as raised facilities, either at sidewalk grade or at an intermediate grade. If designed at the sidewalk level, the use of different pavement types, markings, or buffers may be necessary to keep bicyclists and pedestrians separated. If placed at an intermediate level, a 3 inch mountable curb may be used to permit access of sweeping equipment.

Planters

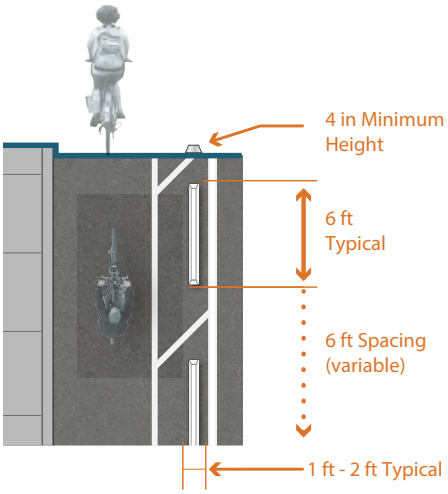


Portland, OR (Source: Oregon Transportation Research and Education Consortium)

This form of separation provides an aesthetic element to the streetscape, a suitable vertical barrier, and is quick to install. However, depending on the placement, this treatment is more expensive than other solutions, requires maintenance of the landscaping, and may not be as appropriate on higher speed streets.

FORMS OF SEPARATION

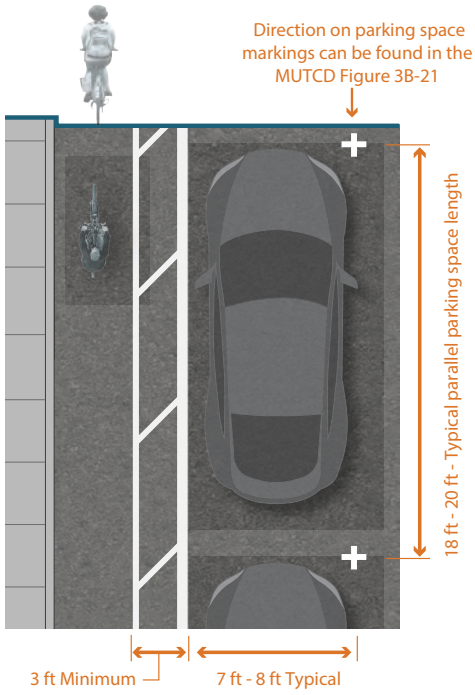
Parking Stops



Baseline Road separated bike lane in Boulder, CO. (Source: City of Boulder)

Parking stops and similar low linear barriers are inexpensive buffer solutions that offer several benefits. These barriers have a high level of durability, can provide near continuous separation, and are a good solution when minimal buffer width is available. However, using the minimum width will not provide the same level of comfort and protection due to their low height and bicyclists' proximity to traffic.

Parked Cars



Parked cars provide separation in Seattle, WA. (Source: Seattle DOT)

While not a barrier type on its own, parked cars can provide an additional level of protection and comfort for bicyclists. A minimum buffer width of 3 feet is required to allow for the opening of doors and other maneuvers. Additional vertical elements such as periodic delineator posts should be paired with this design. Barrier types that obstruct the opening of car doors or create tripping hazards should be avoided.

FORMS OF SEPARATION

Combination of Treatments

Separation types can be used in combination to realize the full benefits of several treatments at a lower overall cost. For example, delineator posts can be alternated with parking stops or other low, linear barriers to provide both horizontal and vertical elements. Planters or rigid barriers and bollards may be used at the start of a block to more clearly identify the separated bike lane and provide an aesthetic treatment, with more inexpensive treatments used midblock.

A raised lane combined with curbside bicycle and car parking provide vertical and horizontal separation from vehicular traffic on Higgins Street in Missoula, MT. (Source: City of Missoula)

Raised curb islands at intersections combined with flexible delineator posts and parked cars midblock on 9th Avenue in New York City, NY (Source: NYC DOT)

MIDBLOCK CONSIDERATIONS

STEP 3

DRIVEWAYS

Driveways that intersect with separated bike lanes create a potential crash risk due to the conflict between turning motor vehicles and through bicyclists. The risk is increased at locations where there is poor sight distance due to parked cars, landscaping, and other obstructions, or where the design may result in unexpected movements such as the contra-flow direction of travel that occurs on two-way separated bike lanes. Many of these conflicts can be mitigated through good design that improves visibility and expected behaviors. An additional measure beyond separated bike lane design is to consolidate or relocate driveways and access to minimize the number of conflict points along the corridor.

DRIVEWAYS

One Way Separated Bike Lanes

01 Parking should be prohibited at least 20 ft from the edge of a driveway, dependent on vehicle speeds and volumes. Paint alone may not be enough to keep vehicles from parking in prohibited spaces without frequent enforcement efforts. Additional elements such as delineator posts, parking stops, or concrete curb extensions can be included to ensure that this area remains clear.

02 Landscaping and other street-side elements that obscure sight distance should not be included within 15 ft of a driveway edge.

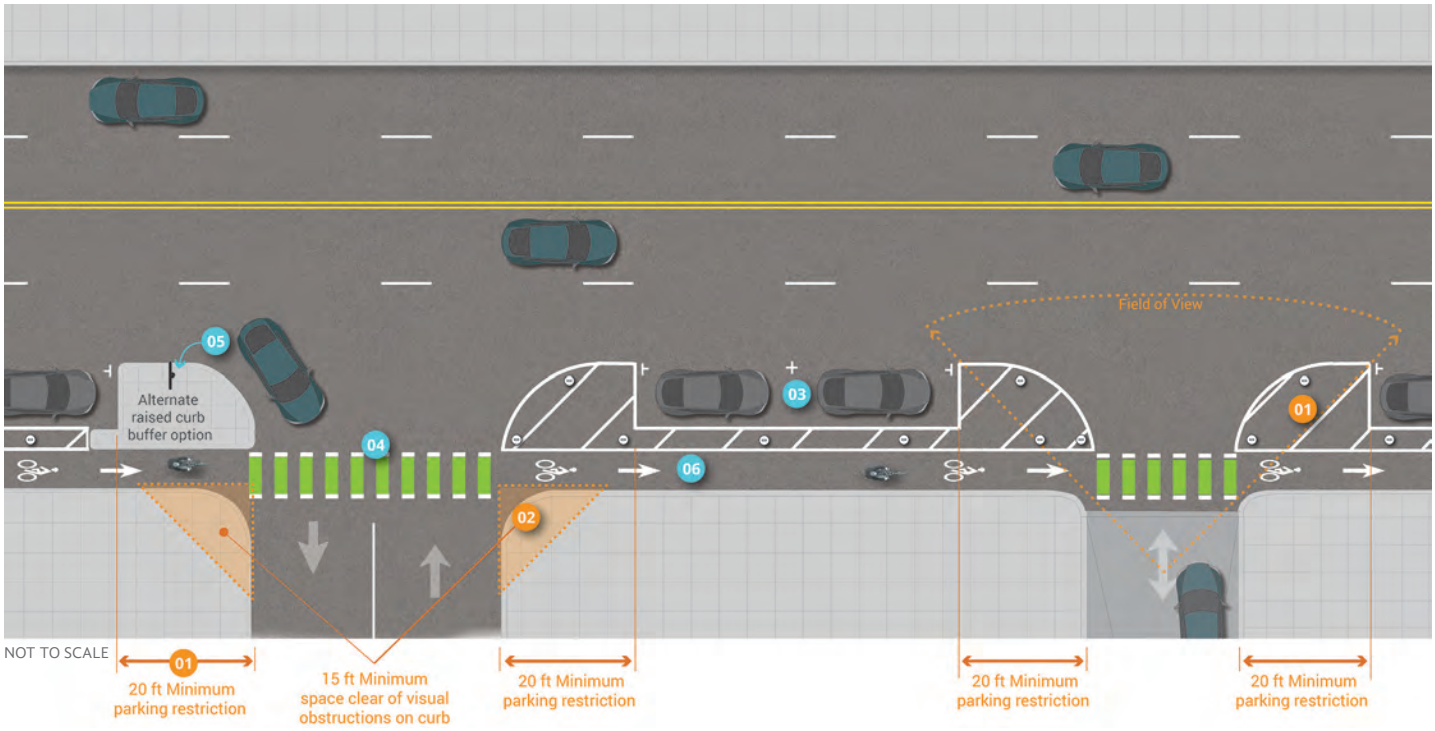
03 Guidance for parking space markings can be found in MUTCD(2009) Section 3B.19. For further guidance on buffer selection and installation, see page 83.

04 A variety of pavement marking treatments can be used to improve visibility of the separated bike lane and reinforce the expected bicyclist behaviors to motorists. For further guidance on paint and striping in conflict areas, see page 114.

05 A "turning vehicles yield to bikes" sign is often used in this scenario to alert turning vehicles to the presence of the separated bike lane; however, it should be noted that while this sign has been proposed it has not yet been specifically approved by FHWA through either the Interim Approval process or adoption into a new edition of the MUTCD.

05 For further guidance on typical signs and markings for separated bike lanes, see page 127.

Figure 14



DRIVEWAYS

Two-Way Separated Bike Lanes

01 Parking should be prohibited at least 20 ft from the edge of a driveway, dependent on vehicle speeds and volumes. Paint alone may not be enough to keep vehicles from parking in prohibited spaces without frequent enforcement efforts. Additional elements such as delineator posts, parking stops, or concrete curb extensions can be included to ensure that this area remains clear.

02 To avoid separated bike lane encroachment of vehicles exiting driveways into the street, landscaping and other street-side elements that obscure sight distance should not be included within 15 ft of a driveway edge.

03 Floating parking design downstream of driveways on one-way streets do not require parking restrictions for visibility since no conflicting traffic is approaching.

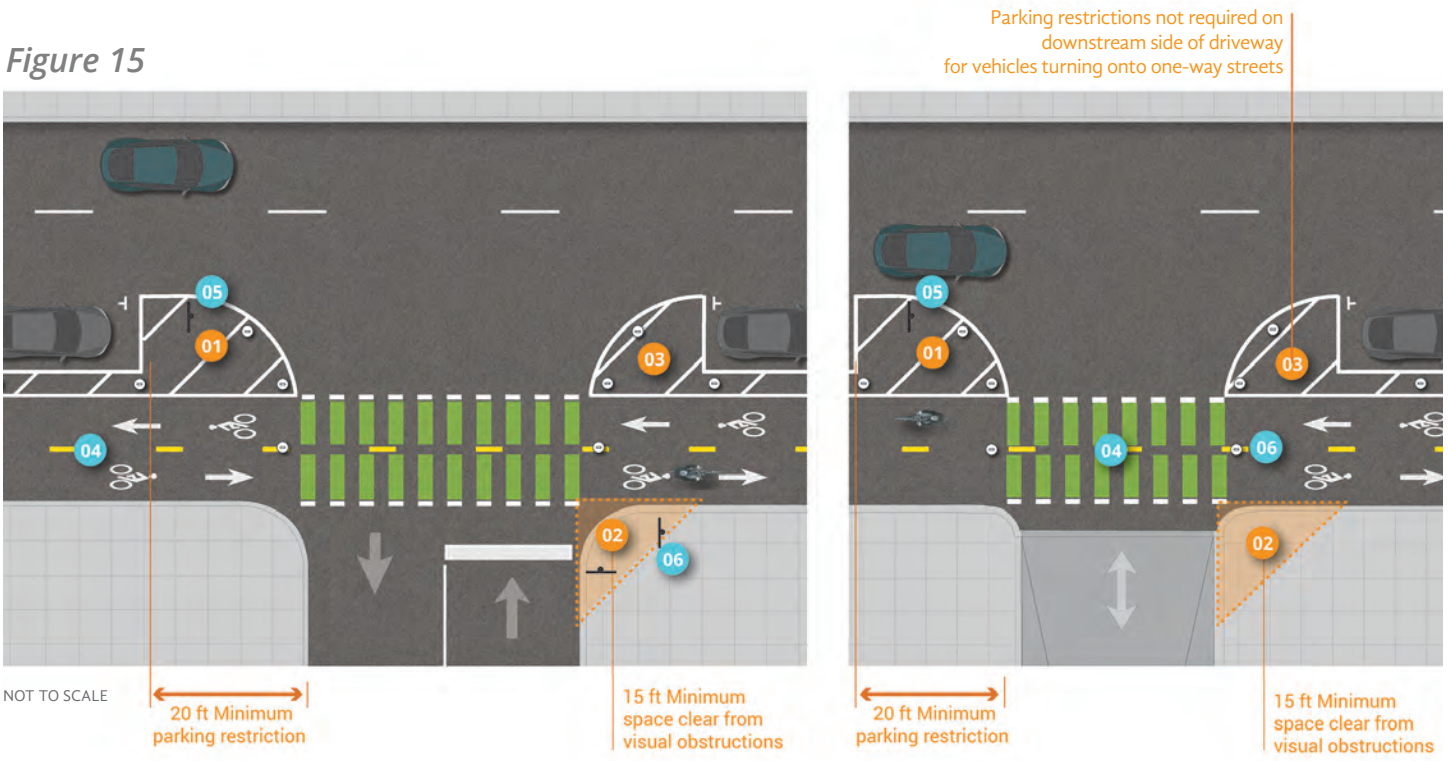
04 A variety of pavement marking treatments can be used to improve the visibility of the separated bike lane and reinforce expected bicyclist behaviors toward motorists. For further guidance on paint and striping in conflict areas, see page 114.

05 Signs on side streets or driveways can alert drivers to expect two-way bicycle traffic, especially on one-way streets.

06 Given the additional width of a two-way separated bike lane, additional measures may be used to reduce the likelihood of accidental entrance by motor vehicles:

- A "Do Not Enter" with a supplementary "Except Bicycles" plaque may be used.
- Or, a BIKE LANE sign (MUTCD R3-17) may be used.
- A delineator post may be placed on the centerline between the two directions of bicycle travel.

Figure 15



TRANSIT STOPS 3

Ideally, separated bike lanes will not operate along the same side of the roadway as high-frequency transit routes, either by using different sides of the street or different streets. However, on many corridors, this division between transit and bicycles is not possible. In these cases transit stops present a challenge among interactions with cyclists, transit vehicles, and those accessing transit stops.

Where possible, separation should continue at transit stops by routing bicyclists behind the bus platform. This type of design avoids conflicts with transit vehicles but does create potential conflicts with pedestrians who must cross the separated bike lane to access the transit stop. This potential pedestrian conflict can be mitigated through design and the provision of discrete crossing locations. Visually impaired pedestrians accessing the bus stop should be directed to the crosswalk using detectable warnings.

TRANSIT STOPS

Island Platform with No Separated Bike Lane Bend

This design may be used at locations where the transit vehicle may stop in a travel lane. In this alignment the separated bike lane does not shift, no sidewalk space is removed, and more on-street parking is allowed. Separating bicycles from bus flow also eliminates "leapfrogging" which improves cyclist comfort and bus operating speeds.

01 The front end of the platform needs 5 ft x 8 ft minimum clear space to accommodate deployment of an accessible ramp from equipped buses.

02 In circumstances without on-street parking, a narrower transit platform may be used so long as a 5 ft x 8 ft level space can be maintained.

03 With a minimum crosswalk width of 6 ft, consider a wider crosswalk dependent on transit boardings. Ideally, the crosswalk is placed at the transit vehicle exit point. If this transit stop is at a street crossing, the bike lane crosswalk should be placed at the start (upstream) end of the platform and included with the full street crossing. If a raised crosswalk is not selected, curb ramps with a marked crosswalk should be used.

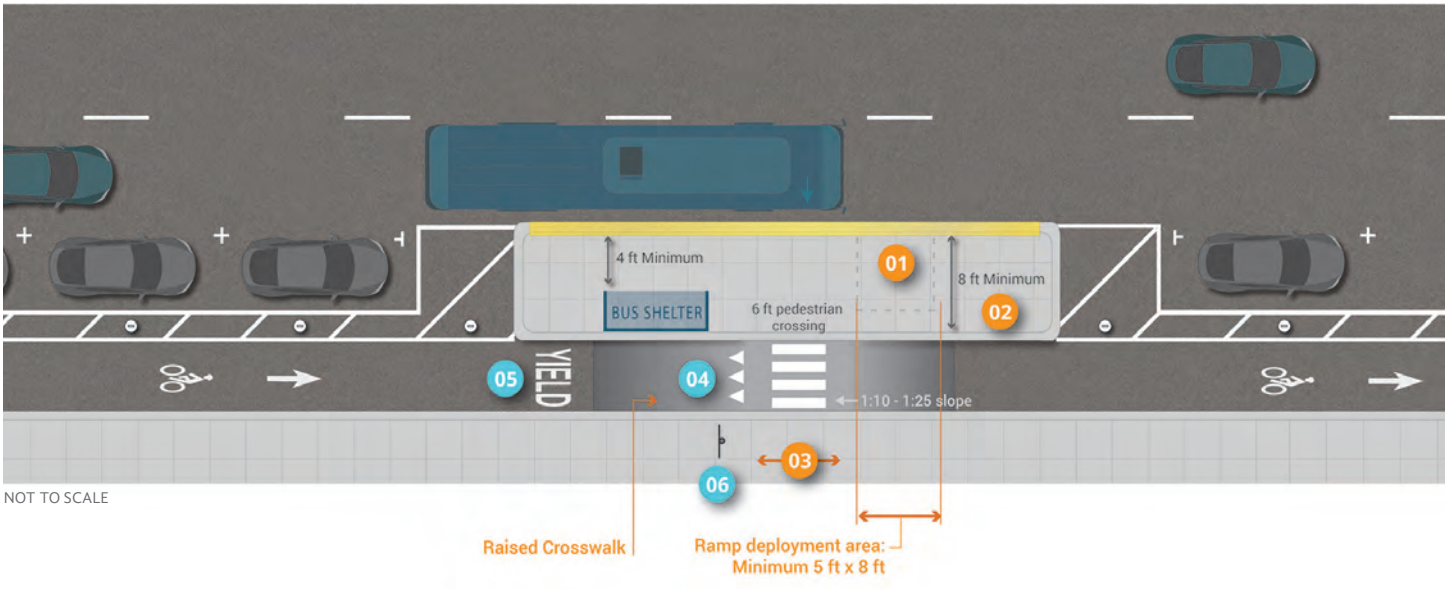
Each curb ramp should have a detectable warning surface in accordance with DOT's regulations implementing Section 504 of the Rehabilitation Act of 1973 at 49 CFR 27.3(b).

04 Place yield line pavement marking just prior to the crosswalk.

05 Optional "YIELD" markings may be placed in the bike lane.

06 Place a YIELD HERE TO PEDESTRIANS (MUTCD R1-5) sign at crosswalk.

Figure 16



NOT TO SCALE

TRANSIT STOPS

Island Platform with Separated Bike Lane Bend

At locations where it is desired to have the transit vehicle move out of the flow of traffic, a separated bike lane may need to bend around the transit platform.

01 This lateral shift of the separated bike lane must be designed based on the offset distance and bicycle design speed.

02 Front end of platform needs 5 ft x 8 ft minimum clear space to accommodate deployment of accessible ramp from equipped vehicles.

03 In circumstances without on-street parking or limited sidewalk space, a narrower transit platform may used so long as a 5 ft x 8 ft level space can be maintained.

04 Minimum crosswalk width is 6 ft. Consider a wider crosswalk dependent on transit boardings. Ideally, the crosswalk is placed at the transit vehicle exit point. If this transit stop is at a street crossing, the bike lane crosswalk should be placed at the start (upstream) end of the platform and included with the full street crossing.

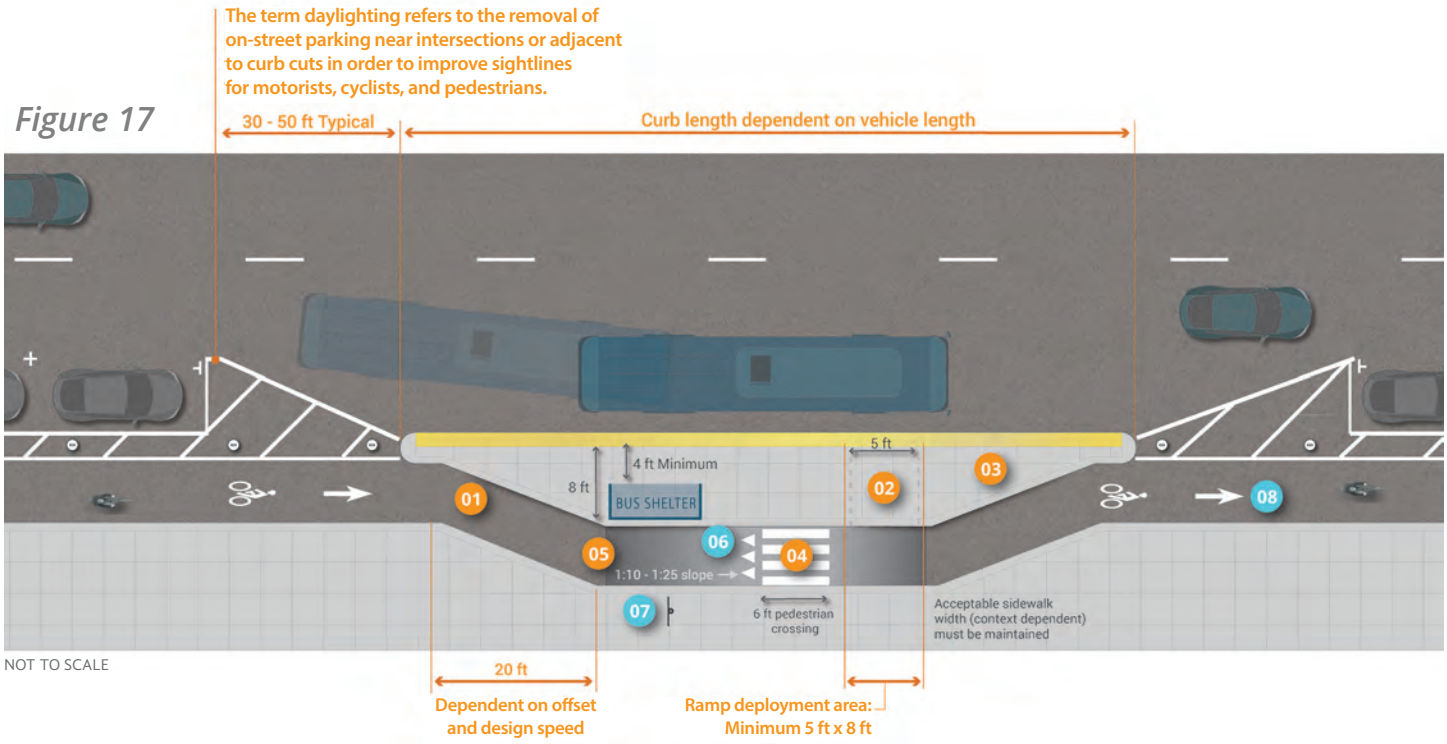
05 To increase awareness between bicyclists and transit users and to emphasize a preferred crossing location, an optional raised crosswalk may be used. Ramp up to raised crosswalk should be 1:10 – 1:25 slope.

06 Yield triangle pavement markings can be placed prior to the crosswalk in accordance with the MUTCD (2009).

07 Place a YIELD HERE TO PEDESTRIANS (MUTCD R1-5) sign at crosswalk

08 For further guidance on typical signs and markings for separated bike lanes, see page 127.

Figure 17



NOT TO SCALE

TRANSIT STOPS

Transit Stop Mixing with Separated Bike Lane

Where bus service is sufficiently infrequent (about four buses per hour or fewer), transit stops can be designed in the separated bike lane. When buses are present, cyclists merge left and pass buses boarding and alighting passengers. At all other times, at least 55 minutes of every hour, bikes continue through the bus stop uninterrupted.

01 Transit vehicles pull up to stops along the curb, across the separated bike lane. Vehicles yield to through bicyclists.

02 Front end of platform needs 5 ft x 8 ft minimum clear space to accommodate deployment of accessible ramp from equipped vehicles.

03 Optional "YIELD" markings in bike lane.

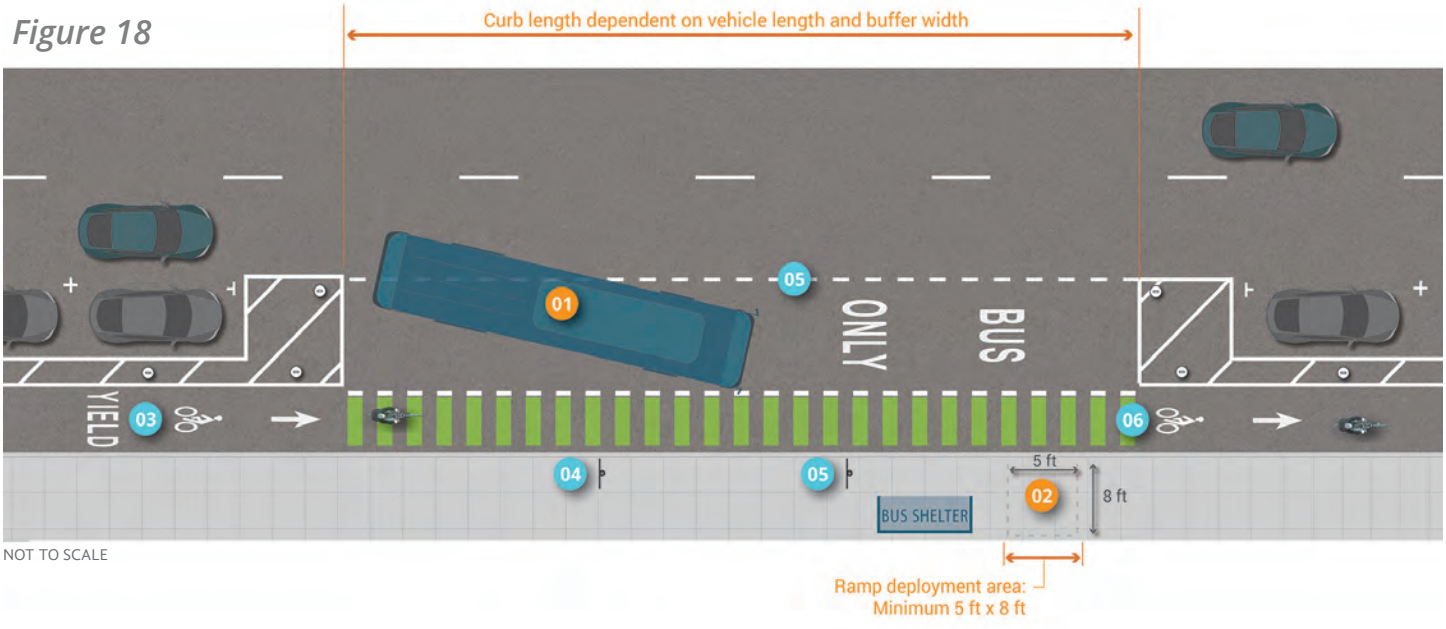
04 NO PARKING BUS STOP sign (MUTCD R7-7).

05 Optional BUS ONLY pavement markings (MUTCD Figure 3B-23).

06 For further guidance on typical signs and markings for separated bike lanes, see page 127.

Shared bus stop/bike lane configuration in Boston, MA (Source: Conor Semler)

Figure 18



NOT TO SCALE

Island bus platform adjacent to a separated bike lane in Austin, TX. (Source: Kelly Blume)

Raised crosswalk (under construction) adjacent to a transit stop island platform on Broadway in Seattle, WA. (Source: Seattle DOT)

ACCESSIBLE PARKING 3

Where designated on-street parking is provided, accessible parking must be provided. Refer to the 2010 ADA Standards and the current Public Rights of Way Accessibility Guidelines (PROWAG) published by the U.S. Access Board for more information. These spaces must be provided on the block perimeter where on-street parking is marked or metered. In many cases, the accessible parking may be provided on block faces that do not conflict with separated bike lane alignment. However, a priority for accessibility is locating the parking spaces where the street is most level and, ideally, closest to obvious destinations such as building entrances. Under these circumstances it may be necessary to include accessible parking on the same block face as a separated bike lane.

Providing accessible parking spaces at the start of a block often affords the most flexibility in designing around the separated bike lane. A painted access aisle without any vertical elements provides space to deploy a lift and allows a vehicle to park in the buffer to deploy a left-side lift, if necessary.

A dedicated accessible parking space with access aisle in Austin, TX. (Source: Kelly Blume)

ACCESSIBLE PARKING

Located Midblock Within Parking Lane

01 The design and layout of accessible parking spaces for persons with disabilities is required, and PROWAG provides the best available information on the details.

02 An access aisle shall be provided the full length of the parking space and shall connect to a pedestrian access route. The access aisle shall shall not encroach on the vehicular travel lane. Refer to PROWAG for details.

03 A 5 ft wide minimum access aisle shall be provided at street level. For ease of parking, a best practice is to provide 3 foot front and/or rear aisles.

04 A crosswalk and curb ramp shall connect the access aisle to the sidewalk.

05 No posts or other obstructions shall be placed in accessible parking space buffer. For further guidance on buffer selection and installation, see page 83.

06 Place a YIELD HERE TO PEDESTRIANS (MUTCD R1-5) sign at crosswalk.

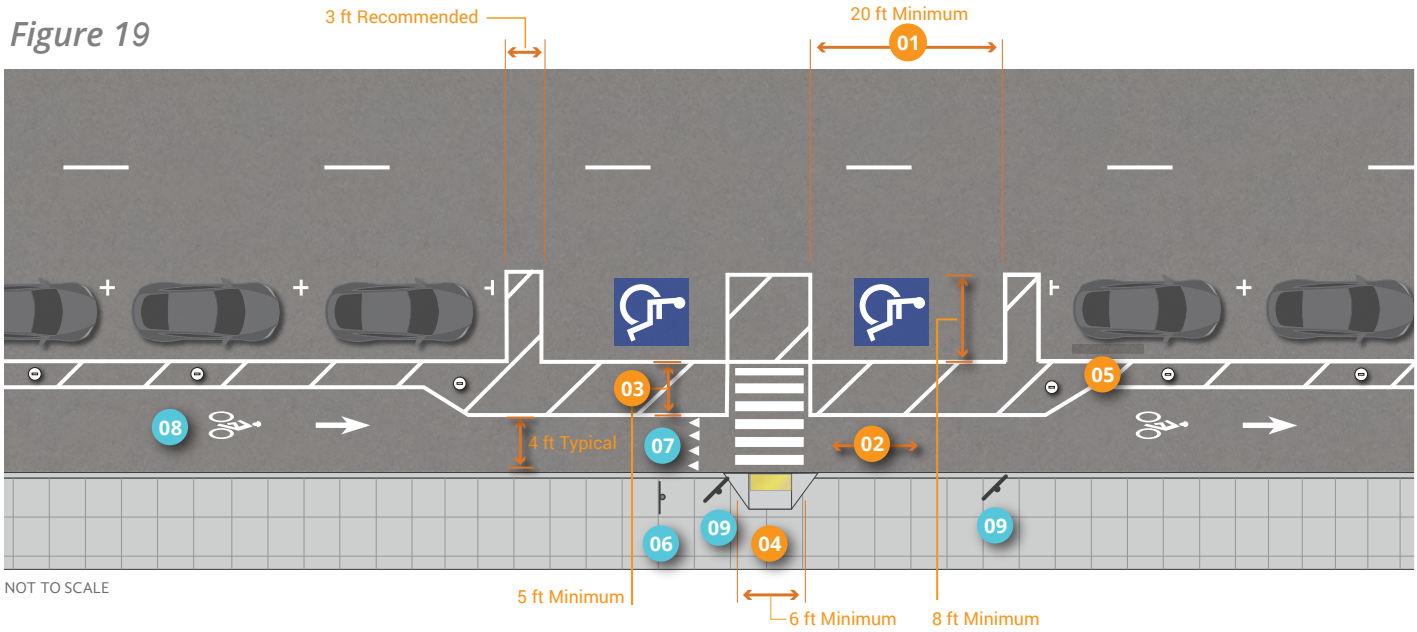
07 Yield line pavement marking may be placed prior to the crosswalk. Refer to MUTCD(2009) Section 3B.20 for pavement symbols and arrow markings.

08 For further guidance on typical signs and markings for separated bike lanes, see page 127.

09 Place an accessible parking sign (MUTCD R7-8) on the sidewalk facing each parking space.

A reserved parking sign is placed alongside a floating parking lane in Austin, Texas (Source: Kelly Blume)

Figure 19



LOADING ZONES 3

There are a number of circumstances that require access to the curb along separated bike lane corridors including loading and deliveries, temporary bus parking, and hotel drop-off zones. In some cases, these uses can simply be relocated to an adjacent block face or alley. If not, ideally these zones can be well placed and consolidated to reduce the impacts of pedestrian and vehicle intrusion into the bicycle space.

If on-street parking is used in the buffer space, the loading zone design is simpler where parking can be restricted and the pedestrian conflict crossing the bike lane can be managed. When there is not space that can be made available from on-street parking and a loading zone is still required, additional space must be acquired either from the sidewalk, through a roadway widening, through a reduction in vehicle travel lanes, or by creating a vehicle mixing zone with the separated bike lane.

Occupying Parking Lane Only

01 Parking is restricted in loading zone.

02 A 5 ft wide minimum access aisle shall be provided the full length of the accessible loading zone and shall connect to a pedestrian access route. Refer to PROWAG for details. For further guidance on buffer selection and installation, see page 83.

No posts or other obstructions in loading zone buffer.

03 Optional "LOADING ZONE" pavement markings (MUTCD Figure 3B-23). Loading zones need to be accessible – refer to PROWAG R310 for guidance.

04 Green pavement optional. For guidance on green pavement markings, see page 114.

05 NO PARKING LOADING ZONE sign placed on the sidewalk near each end of buffer (MUTCD R7-6).

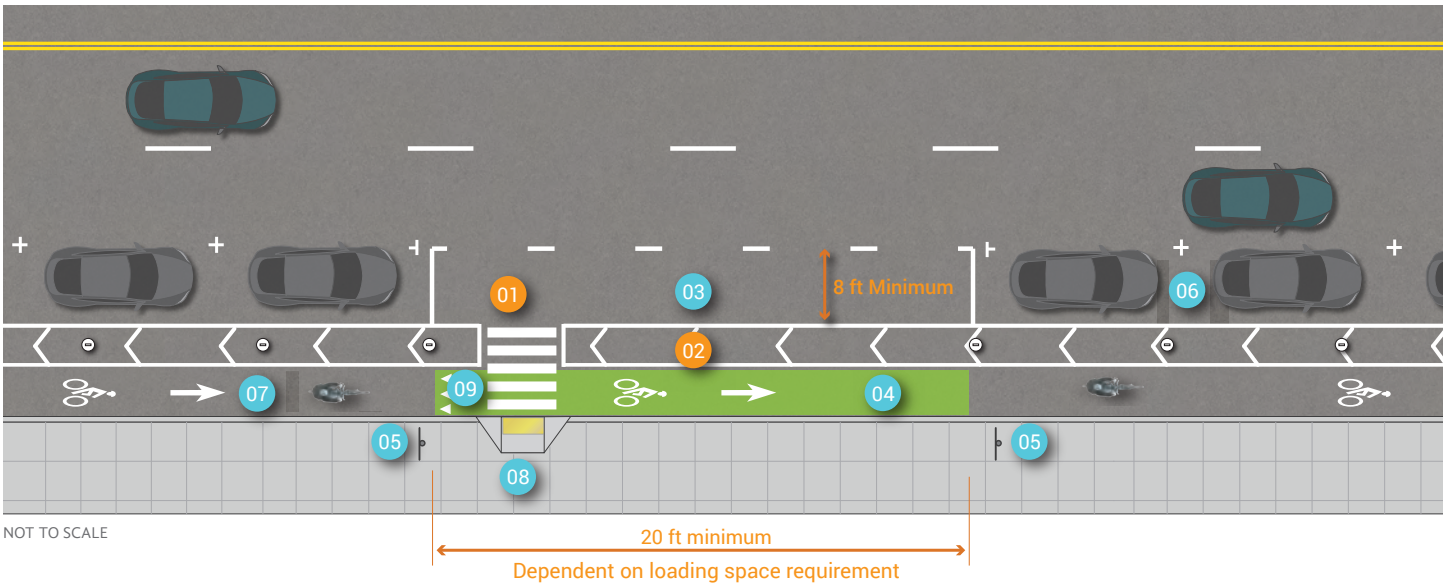
06 Guidance for parking space markings can be found in MUTCD(2009) Section 3B.19.

07 For further guidance on typical signs and markings for separated bike lanes, see page 127.

08 A crosswalk and curb ramp must connect the loading zone to the sidewalk.

09 Optional: Yield bar pavement marking may be placed prior to the crosswalk. Refer to MUTCD(2009) Section 3B.20 for pavement symbols and arrow markings.

Figure 20



LOADING ZONES

Bending Separated Bike Lane into Sidewalk

01 A lateral shift of the separated bike lane into the sidewalk may be necessary to accommodate a required loading or drop-off zone where there is no on-street parking. The shift must be designed based on the offset distance and bicycle design speed.

If a lateral shift cannot be accommodated and a loading zone is required, loading and drop-off activities may have to mix with bicycle traffic creating a conflict in high-use areas.

02 Parking is restricted in loading zone.

03 A 5 ft wide minimum access aisle shall be provided the full length of the accessible loading zone and shall connect to a pedestrian access route. Refer to PROWAG for details. For further guidance on buffer selection and installation, see page 83.

04 Optional LOADING ZONE pavement markings (MUTCD Figure 3B-23). No posts or other obstructions in loading zone buffer.

05 Green pavement is optional. For guidance on green pavement markings, see page 114.

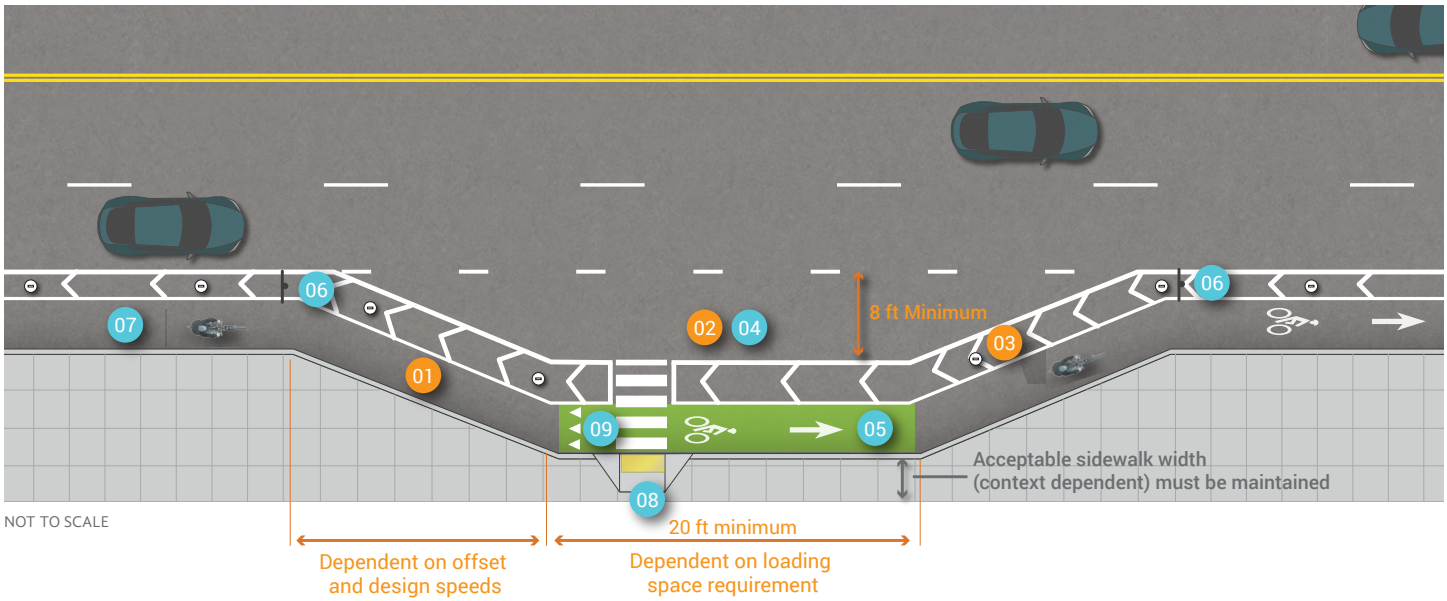
06 NO PARKING LOADING ZONE sign placed at each end in buffer (MUTCD R7-6). The NO PARKING LOADING ZONE sign can also be placed on the sidewalk, where it may be less likely to be hit by motorists and also may have less of an impact on maintenance operations.

07 For further guidance on typical signs and markings for separated bike lanes, see page 127.

08 A crosswalk and curb ramp must connect the loading zone to the sidewalk.

09 Optional: Yield bar pavement marking may be placed prior to the crosswalk. Refer to MUTCD(2009) Section 3B.20 for pavement symbols and arrow markings.

Figure 21



A dedicated loading zone along Polk Street in San Francisco, CA. (Source: Alek Pochowski)

INTERSECTION DESIGN

STEP 4

It is not possible to maintain permanent physical separation of bicycles and automobiles through intersections, where cross street and turning movements must cross the path of bicyclists. Intersections are where most bicycle-vehicle collisions occur, and where riders feel the most stress. Designers have implemented a variety of strategies, including both time- and space-separation, for maintaining the benefits of separated bike lanes through intersections. The configurations and geometries for each specific location will dictate which options are most advantageous.

Intersection design is often the most challenging separated bike lane design element. Above, an intersection along New York City's 9th Avenue facility. (Source: NYC DOT)

TURNING MOVEMENTS 4

The movements of automobiles and bicycles at intersections may conflict with each other. Therefore, design elements are needed to increase visibility of bicyclists for motorists.

Signalized and Unsignalized Treatments

Table 3

		Pros	*Cons*
Maintain Separation	**Signals:** separate through and turning movements in time	Potential elimination of turn conflict	Increased signal cycle length, possibly with increased wait times
	Bend In: position cyclists closer to turning vehicles to increase visibility **Bend Out:** provide space for right-turning vehicles to turn before encountering bicycle conflicts; provide space for queueing	Greater sense of comfort/ less traffic stress	Turning vehicle conflicts at intersections
Shift Bicycles Across Turning Vehicles	**Lateral Shift:** vehicles cross high-visibility bike lane; clear responsibility for yielding **Mixing Zone:** shared lane, requires less space	Organize conflicts; reduce right-hook risk	Greater traffic stress

Signalization

Using signalization to separate the movements of automobiles and bicyclists through an intersection removes potential conflict points which are present with other treatments. A separate signal phase allows bicyclists to proceed without right-turning vehicle conflicts and stops bicyclists at times when right-turning automobiles can proceed. This approach may be selected at intersections with high volumes of right-turning automobiles, or on one-way streets with left-turning automobiles and a left-side running separated bike lane, and where the signal phasing and cycle length can accommodate a bicycle signal phase. Signal phasing, cycle lengths, and traffic progression should all be carefully considered for bicyclists where significant delay frequently results in poor signal compliance.

TURNING MOVEMENTS

Signalization

01 A near-side bicycle signal can supplement far-side signals to improve visibility (refer to MUTCD Interim Approval IA-16).

Near-side signals are required when the far-side signal is 120 ft or greater from the stop bar, and recommended over 80 ft.

Near-side signals can be placed on the pedestrian pushbutton pole, or the bicycle pushbutton pole, if used.

02 Minimum 1 ft buffer at intersection. For further guidance on buffer selection and installation, see page 83.

03 If no dedicated right turn lane is present, bicyclists may use pedestrian walk signal. A 'Turning vehicles yield to bikes' sign may be placed on the mast arm.

04 NO TURN ON RED (MUTCD R10-11) on mast arm near signal head.

05 Guidance for parking space markings can be found in MUTCD(2009) Section 3B.19.

06 For further guidance on signal phasing, see page 119.

07 Signal detection for bicyclists is needed if the signal [or signal operation] is actuated.

An optional signal detection loop may be placed 60 - 120 ft in advance of the intersection.

08 A bicycle detector symbol marking (MUTCD Fig. 9C-7) should be placed over the loop to alert passing cyclists to the in-ground sensor.

For further guidance on typical signs and markings for separated bike lanes, see page 127.

NOT TO SCALE

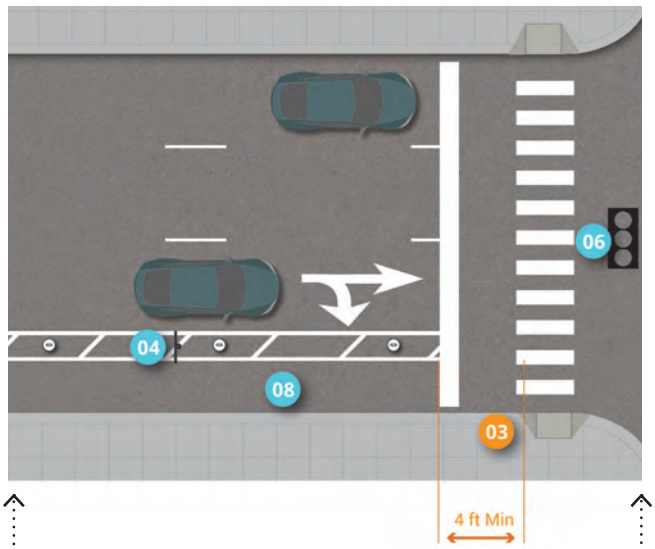
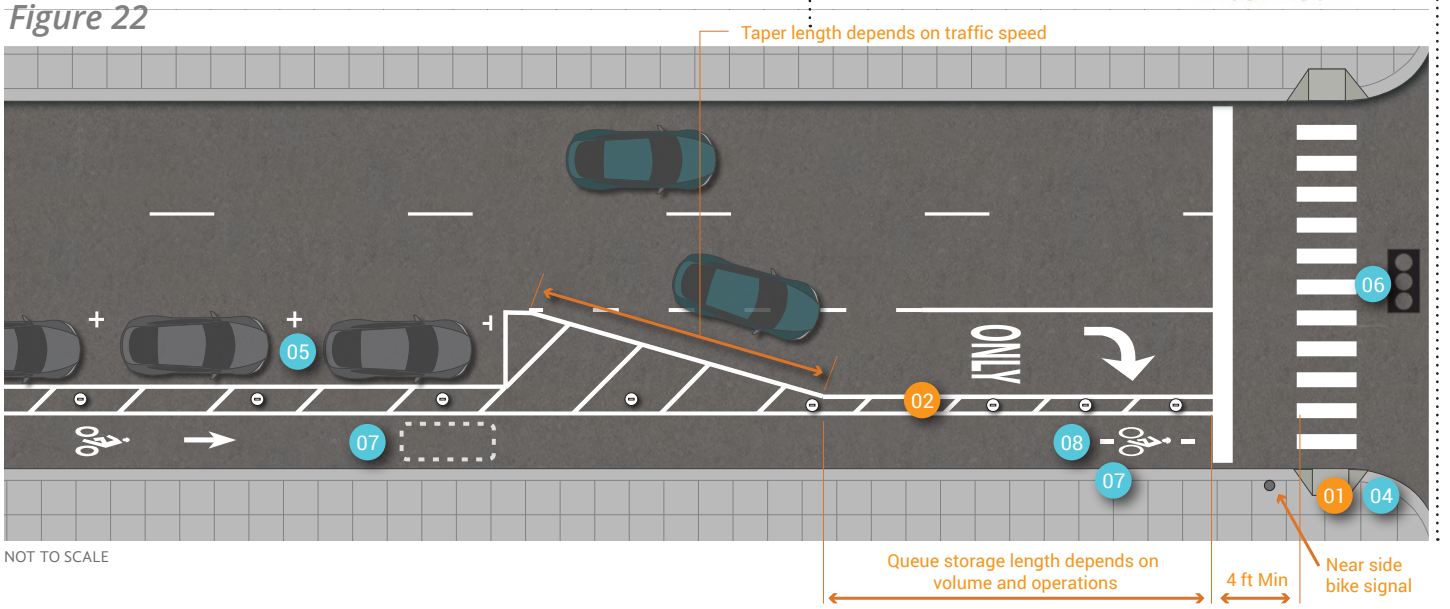


Figure 22



NOT TO SCALE

TURNING MOVEMENTS

Lateral Shift

A lateral shift moves cyclists to the left of the motor vehicle right turn lane before vehicles can move right. This places the responsibility for yielding clearly on drivers turning right, and brings bicyclists into a highly visible position. In the lateral shift configuration, like the mixing zone (see page 107), potential conflicts between right-turning vehicles and through bicyclists occur *before* the intersection. A lateral shift treatment is effective for intersections where a separate bicycle signal and signal phasing is not feasible, because bicyclists can proceed in the same signal phase as through and right-turning vehicles.

01 Provide minimum queue storage length for automobiles needed for operations, depending on right-turn volumes and signal cycle length.

02 For further guidance on bike boxes, see page 122.

03 Shift bike lane closer to motorized traffic prior to weave area so motorists and bicyclists can see each other better.

04 For further guidance on buffer selection and installation, see page 83.

05 Shorter queue storage lengths are preferred because it allows for a longer distance of midblock separation relative to the intersection and slows motor vehicle speeds.

06 Include BEGIN RIGHT TURN LANE YIELD TO BIKES (MUTCD R4-4) at end of parking restrictions.

07 The weave area should be short to force vehicles to make slow and deliberate turning movements into the right turn lane.

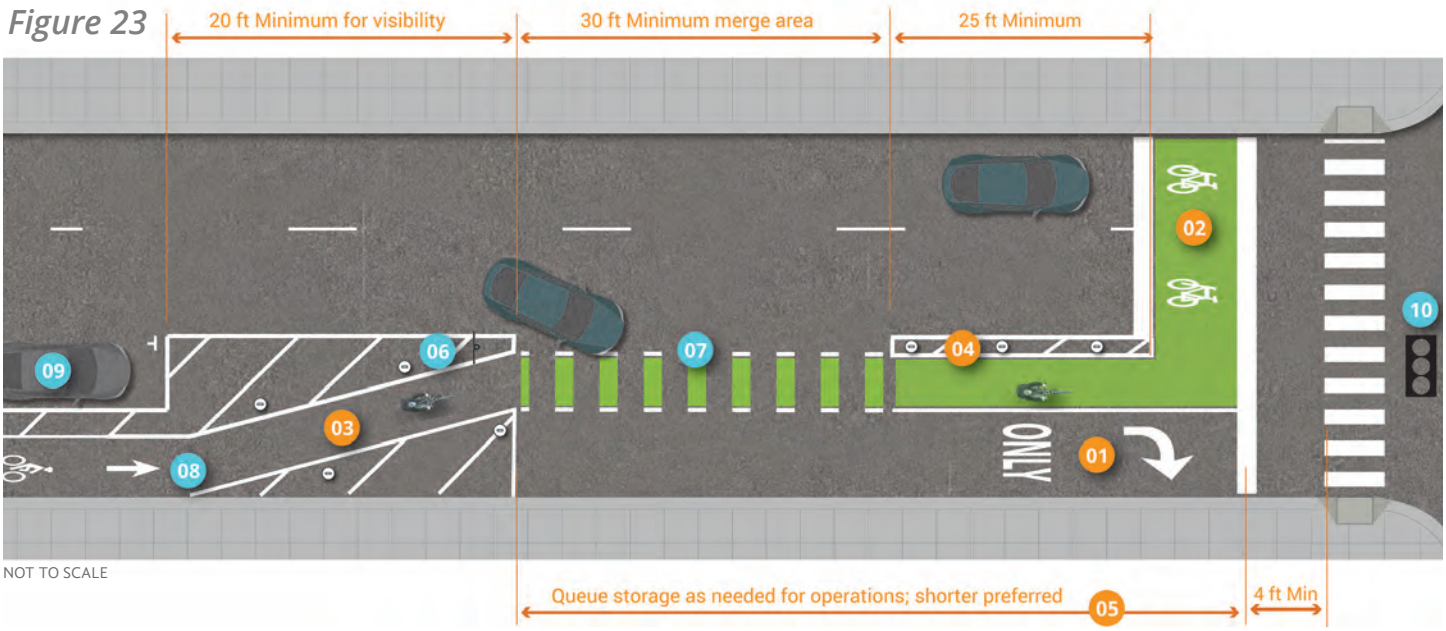
A variety of pavement marking treatments can be used to improve visibility of the separated bike lane and reinforce the expected bicyclist behaviors. For further guidance on paint and striping in conflict areas, see page 114.

08 For further guidance on typical signs and markings for separated bike lanes, see page 127.

09 Guidance for parking space markings can be found in MUTCD(2009) Section 3B.19.

10 For further signal guidance, see page 115.

Figure 23



NOT TO SCALE

CASE STUDY

Salt Lake City's Experimental Lateral Shift

Salt Lake City, Utah

300 East Corridor separated bike lane. (Source: City of Salt Lake City)

Salt Lake City used a pilot project approach to install a temporary separated bike lane along 300 East Corridor. A lane of parked cars provides additional separation between moving vehicles and cyclists; however, the City drops the parking lane in advance of intersections to improve visibility. To manage through-bicycle and right-turning vehicle conflicts at intersections, the City chose to apply an experimental lateral shift approach. Cyclists move to the left of the motor vehicle right-turn lane in advance of any opportunity for vehicles to move right. This approach places the onus of yielding to cyclists squarely on motor vehicles that need to make a right turn. The City has received positive feedback from planners and designers who have observed the facility, and plans to use design for its future separated bike lane intersection approaches where roadway width can accommodate a dedicated right turn lane.

TURNING MOVEMENTS

Mixing Zone

A mixing zone is an area where bicyclists and right-turning automobiles merge into one travel lane approaching an intersection. Mixing zones provide a design option in which the potential conflict between right-turning vehicles and through bicyclists occurs before the intersection, similar to the lateral shift. Mixing zones may provide the best option in locations without on-street parking and/or with a constrained right-of-way where the roadway width will not accommodate both a bicycle lane and a right-turn lane at the intersection.

01 Mixing zones are often used at intersections with turning vehicle volumes high enough to cause frequent conflicts, but not high enough to require signalization.

Mixing zones may be most effective at intersections with 50-150 turning vehicles in the peak hour.

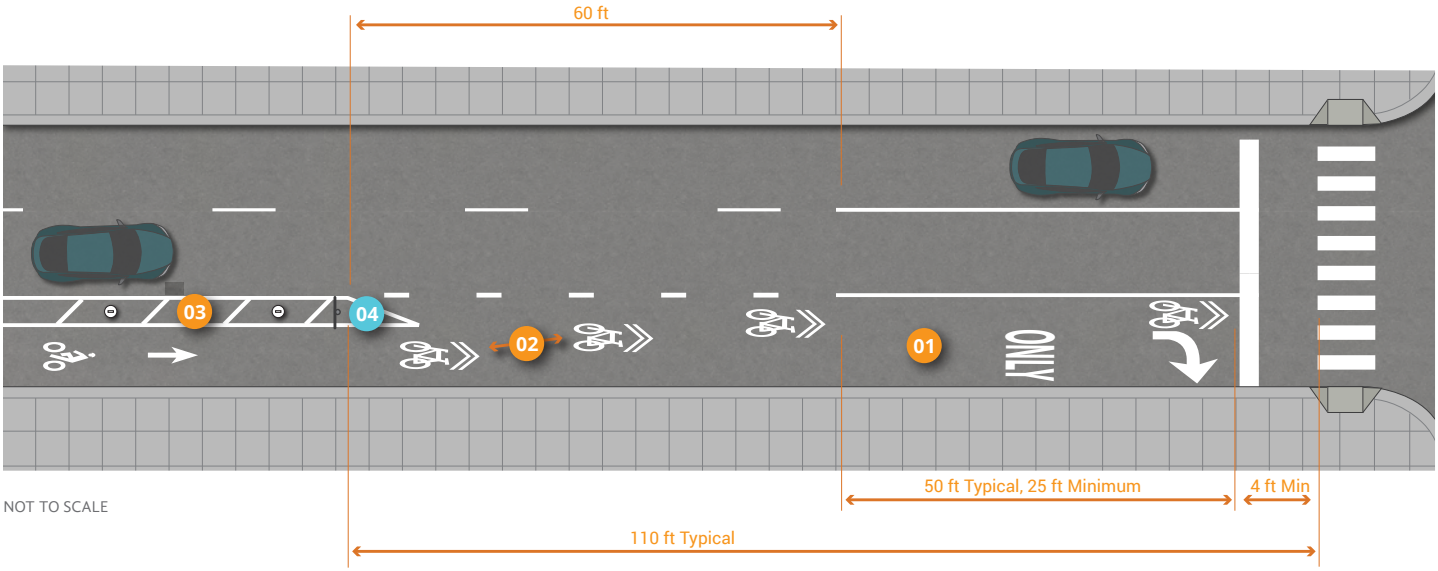
02 Shared lane markings help guide bicyclists to the left side of turning vehicles.

03 For further guidance on buffer selection and installation, see page 83.

04 Include BEGIN RIGHT TURN LANE YIELD TO BIKES (MUTCD R4-4) at end of parking restrictions.

Figure 24

Additional mixing zone designs are highlighted in the pictures on pages 50, 102, and 108.



NOT TO SCALE

A mixing zone along New York City's 2nd Avenue separated bike lane. (Source: NYC DOT)

TURNING MOVEMENTS

Bend-In and Bend-Out

When the separated bike lane approaches an intersection with right-turning vehicles still positioned to the left of the separated bike lane, the designer may choose to either "bend-in" or "bend-out" the separated bike lane at the intersection to reduce the likelihood of conflicts with right-turning vehicles. The decision to bend-in or bend-out depends on a number of factors, including buffer type and width, available right-of-way, sight distance, side-street characteristics, and other contextual factors. Considerations for selecting bend-in or bend-out are highlighted in Table 5 on the following page.

A bend-in design approaching an intersection in St. Petersburg, FL. (Source: Rory Rowan)

Table 4

	Advantages	*Disadvantages*
Bend - In	• Motorists on a side street can see bicycles and vehicles in a similar field of vision. • Requires less space than bending out	• Parking spaces close to the intersection may be lost • Bicyclists may perceive less separation due to proximity of through vehicles
Bend - Out	• Allows vehicle traffic turning across separated bike lane to queue out of the way of through traffic and before the separated bike lane. • Allows a queuing location for cyclists wanting to turn left. • Raised crossing provides traffic calming for automobiles and can also slow bicyclists.	• Requires more space • Less familiar design • Adequate sight distance may be difficult for vehicles approaching on the side street.

TURNING MOVEMENTS

Bend-In

To increase the visibility of bicyclists for turning vehicles, the bend-in design positions bicyclists adjacent to the vehicle turn lane.

01 Shift bicycle lane closer to motorized traffic so motorists and bicyclists can see each other better.

02 Bend-in design creates opportunity to build a curb extension to reduce pedestrian crossing distance.

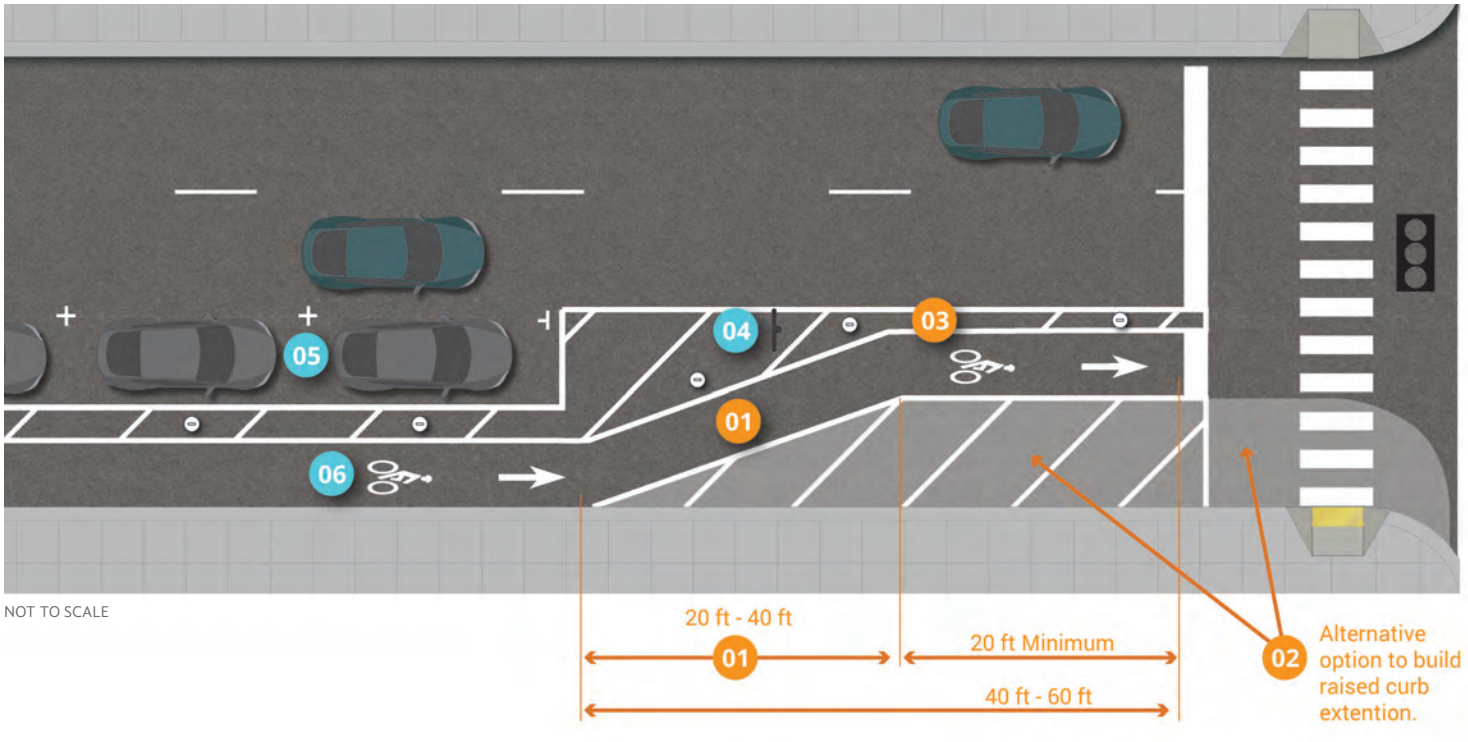
03 For further guidance on buffer selection and installation, see page 83.

04 A 'Turning vehicles yield to bikes' sign may be placed on the mast arm.

05 Guidance for parking space markings can be found in MUTCD(2009) Section 3B.19.

06 For further guidance on typical signs and markings for separated bike lanes, see page 127.

Figure 25



TURNING MOVEMENTS

Bend-Out

The bend-out design positions bicyclists downstream on the side street away from the intersection, allowing vehicles to complete turning movements before interacting with bicyclists. This design, which could be used on lower-volume side streets or driveways, provides space for a vehicle to yield to crossing bicycles without blocking through traffic on the main street. A Bicycle/Pedestrian Warning (W11-15) sign may be used as driveways approach separated bike lanes to alert drivers to be aware for bikes and pedestrians.

01 Bend-out design provides opportunity for an ample pedestrian refuge between the separated bike lane crossing and the roadway crossing.

02 Separated bike lane and crosswalk may be raised to sidewalk level through the intersection, providing a traffic calming effect.

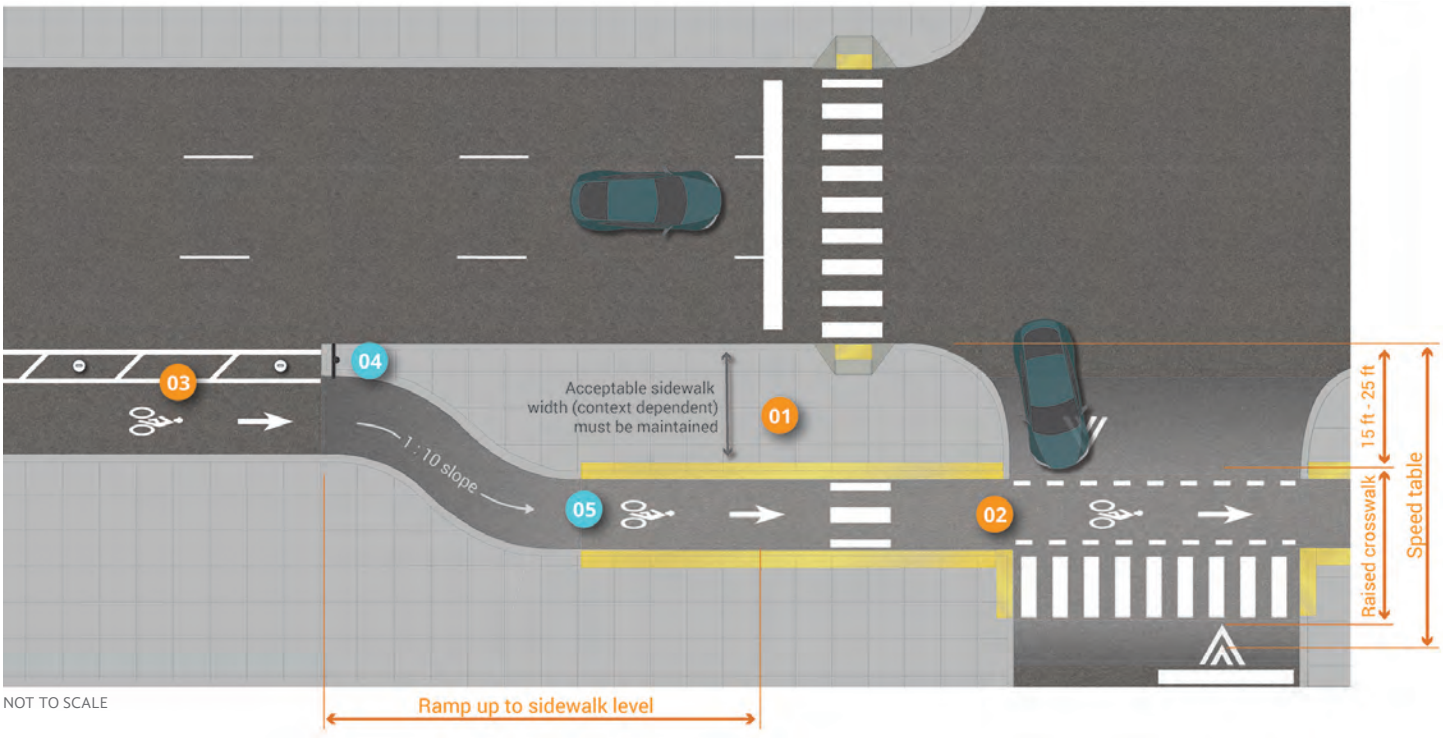
03 For further guidance on buffer selection and installation, see page 83.

04 A 'Turning vehicles yield to bikes' sign may be placed on the mast arm.

05 For further guidance on typical signs and markings for separated bike lanes, see page 127.

06 For further guidance on signal phasing, see page 119.

Figure 26



NOT TO SCALE

TURNING MOVEMENTS

Opportunities for Space Created by Bend-In

A bend-in design creates the opportunity to construct a curb extension to reduce pedestrian crossing distances. The design can create public space which could be used for:

- Bike parking corrals
- Bikeshare stations
- Parklets
- Public art exhibits
- Bioswales/rain gardens

Boulder, CO uses some of the sidewalk space created by the bend-in intersection design for bike parking. (Source: Kevin Zolkiewicz)

INTERSECTION MARKINGS 4

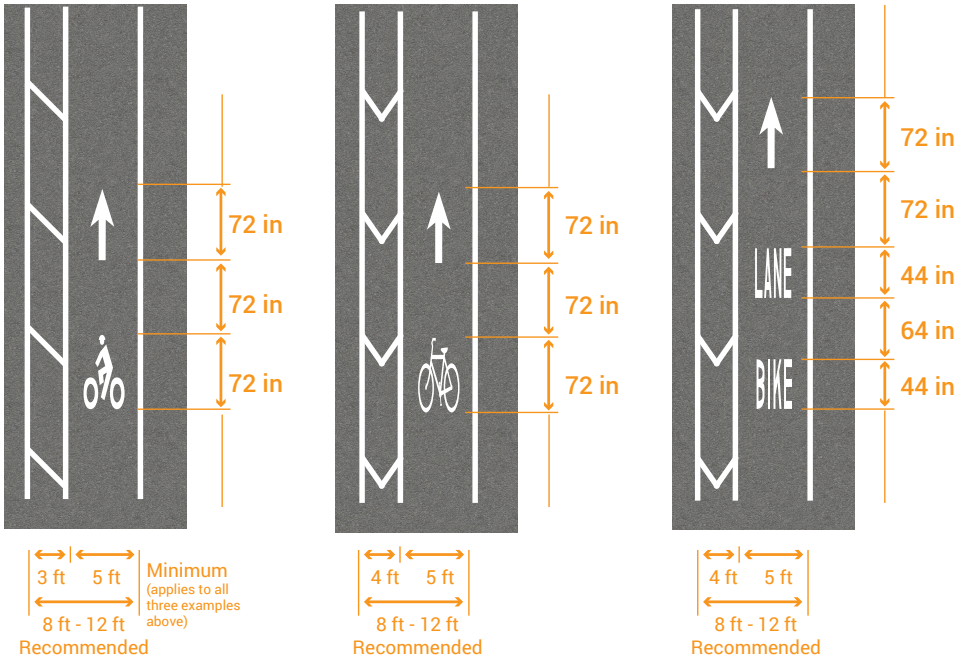
White Chevrons and White Lines

White dashed lines may be used to mark extensions of the separated bike lane through intersections or other traffic conflict areas. These dotted lines are intended to increase awareness of where bicyclists may be positioned. White chevrons should be used in wider painted buffers with a width of 4 feet and above.

Bike lane symbols should be placed periodically to reduce the intrusion of pedestrians and motorists into the separated bike lanes. The words BIKE LANE may be used as an alternative to the bike symbol. Periodic maintenance will be required to ensure markings remain visible.

Seattle's first downtown separated bike lane on Second Avenue between Pike Street and Yesler Way. (Source: SDOT)

Figure 27



Diagonal crosshatch markings are often used in narrower buffers (i.e. 3-4 feet wide) and given their typical dimensions white chevrons are generally used in buffers with a width of 4 feet and above.

INTERSECTION MARKINGS

Use of Green Colored Pavement

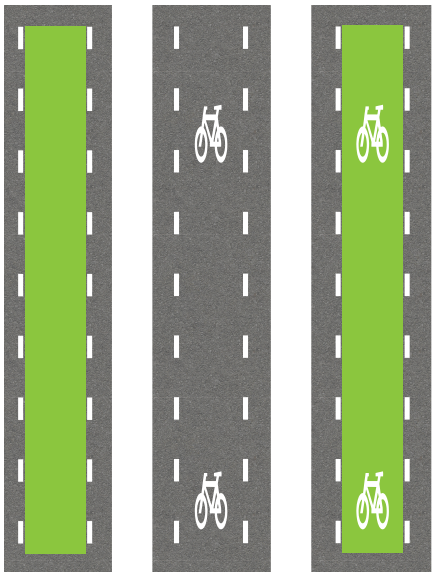
Green pavement increases awareness of bicycles and can be used to indicate an area of potential conflict with motor vehicles. The green colored pavement is an additional treatment and shall *not* be used instead of dotted lines to extend a bicycle lane across an intersection, driveway, ramp, or at the beginning of a turn bay.

Green paint across a mixing zone opening on M Street NW in Washington, DC (Source: Jason Broehm)

The pattern of the green colored pavement may be in a manner matching the pattern of the dotted lines; filling in only the areas directly between a pair of dotted line segments (MUTCD Interim Approval IA-14) as shown in the diagram above.

The green pavement and other conflict zone markings in the designs below are non-standard but currently in use by many U.S. municipalities.

Figure 28



SIGNALIZATION STRATEGIES 4

Bike Signals

Bicycle signals may be used to separate bicycle through movements from vehicle right turning movements for increased safety.

They can also be used to facilitate complex bicycle movements or help people on bicycles navigate complex intersections safely.

A leading bicycle interval, which uses a bicycle signal lens to provide three to five seconds of green time before the corresponding vehicle green indication, can be used to increase the visibility of bicyclists to motorists.

The yellow change interval and all-red clearance interval may need to be adjusted to provide for passage of bicyclists through an intersection. The yellow change interval is when the steady yellow signal indication is displayed preceding the red signal interval.

The Urban Bikeway Design Guide (NACTO) uses the following equation to calculate the total clearance interval (i.e. the time that all signals are red that follows a yellow change interval and precedes the next green interval):

$$C(i) = 3 + W / V$$

- C (i) = Total Clearance Interval
- W = Intersection Width
- V = Cyclist Speed (9.5 mph can be used as a default if no speed is known)

Dedicated bicycle signalization along New York City's 9th Avenue separated bike lane. (Source: NYC DOT)

SIGNALIZATION

Signal Phasing and Coordination

Bicyclists exert the most energy when starting from a stopped position. Decreasing the number of stops at traffic signals in a corridor will increase the comfort for people on bikes and improve bicyclist compliance with the signals.

Bicycle Progression Speed

- The bicycle progression speed should be set to minimize the chance of stopping at each intersection based on the average bicycling speed.
- The average bicycle speed on a corridor may vary depending on roadway grades and typical speeds of bicyclists. A bicycle speed study may be conducted to find the actual progression speed.
- 10 mph is a comfortable speed for the general population; more confident cyclists may travel around 15 mph.
- Bicycle progression speed is largely dependent on street grade.
- Two-way separated bike lanes on a one-way street can cause significant challenges with signal progression for bicyclists in the contra-flow direction and may lead to poor compliance with the traffic signals.

Average Bicycle Delay at Intersections

- Related to the progression speed, bicyclists are less willing to wait at red traffic signals than motorists. Cycle lengths should be short to minimize the average bicyclist delay. A maximum 90 second cycle length is recommended.

Signal Detection

- Automatic detection by loops and/or video are important devices to give bicyclists green lights.
- Other detector feedback devices should be considered to provide information for bicyclists to receive a green light. Examples include the TO REQUEST GREEN WAIT ON SYMBOL sign (MUTCD R10-22), blue light detector device, and others. For sign and markings guidance, see page 127.
- Detection across the entire separated bike lane is preferred to call a green light for the user. Bicycle detection 60 or 120 feet in advance of the intersection could be used to call a green light for the bicyclist to minimize the chance of stopping and thereby increasing cycling comfort.

A bicycle detector pavement marking (MUTCD Figure 9C-7) communicates to bicyclists where to position themselves for signal detection in Portland, Oregon (Source: Jesse Boudart)

A blue light detector feedback device along NE Multnomah Street in Portland, OR. (Source: Jesse Boudart)

SIGNALIZATION

Additional Guidance on Bicycle Signals

The California MUTCD contains thresholds for when to use a bicycle signal. The thresholds below, in particular, relate to separated bike lanes:

Volume:

- W = B x V and W > 50,000 and B > 50.
- W is volume warrant, B is the number of bicycles at the peak hour entering the intersection. V is the number of vehicles at the peak hour entering the intersection. B & V shall use the same peak hour.

Collision:

- When 2 or more bicycle/vehicle collisions of the types susceptible to correction by a bicycle signal have occurred over a 12-month period and the responsible public works official determines that a bicycle signal will reduce the number of collisions.

Geometric:

- Where a separated bike lane or multi-use path intersects a roadway.
- At other locations to facilitate a bicycle movement that is not permitted for a motor vehicle.

SIGNALIZATION

Bike Signal Alternatives

When bicycle signals cannot be used, active detection, such as a blue indicator light, inform cyclists that they have been detected by the signal and will be receiving a green signal during the cycle. Active detection may decrease frustration and improve red light compliance among cyclists.

SIGNAL PHASING 4

Considerations:

- A bicycle green signal shall not be used with coinciding vehicle green signal faces which allow permitted turning movements across bicycle movements.
- Bicycle signal faces should be placed such that visibility is maximized for bicyclists and minimized for adjacent or conflicting motor vehicle movements. If drivers could be confused by viewing bicycle signal indications, such as when the start or end of a bicycle green indication occurs at different times than concurrent motor vehicle movements, consideration should be given to using visibility-limited bicycle signal faces.
- If bicycle signals are used, NO RIGHT ON RED (or left for one way roads) signs (MUTCD R10-11) should be used.

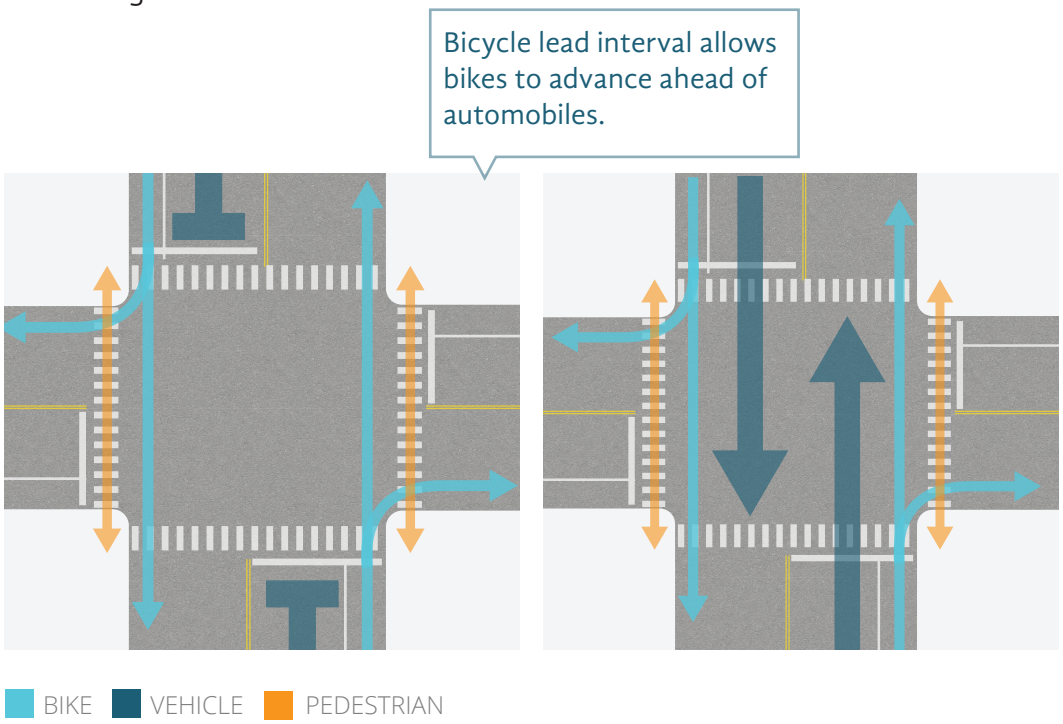
Optional:

- The interim approval (MUTCD Interim Approval IA-16) specifies the permitted use of bicycle signal phases with arrows in the signal assembly as well as the bicycle icon. The use of arrows in a bicycle signal assembly have not been implemented in the United States.

Figure 29

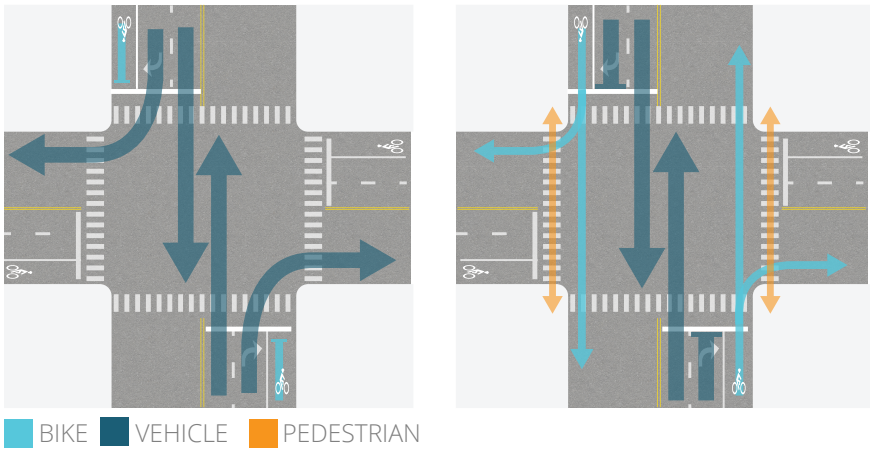
Signal Phase Example 1

A leading bicycle interval can be used to increase the visibility of a bicyclist through the intersection.



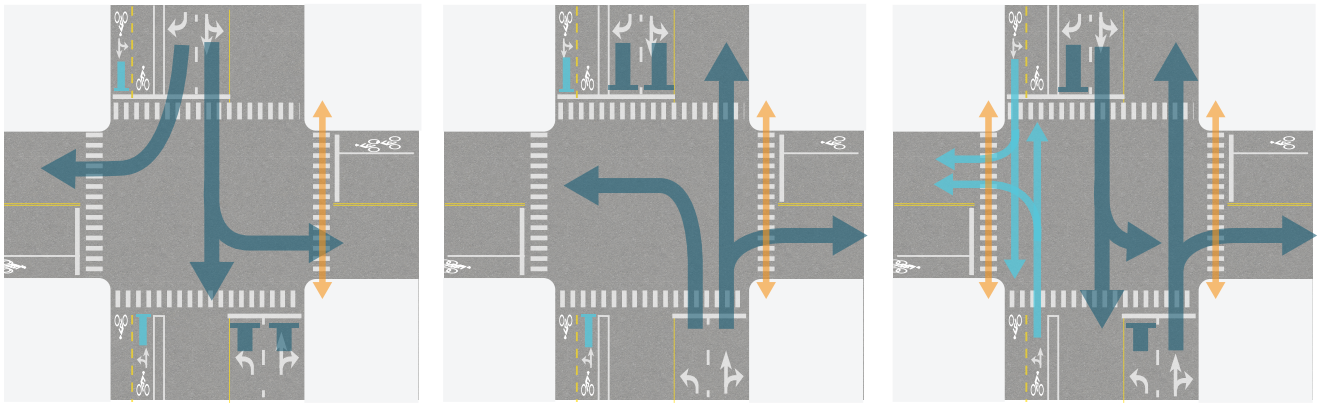
Signal Phase Example 2

Bicycle movements can be separated from conflicting vehicle movements with automobile right-turn restrictions during the bicycle through movement, and bicycle signals stopping bikes while automobiles turn right.



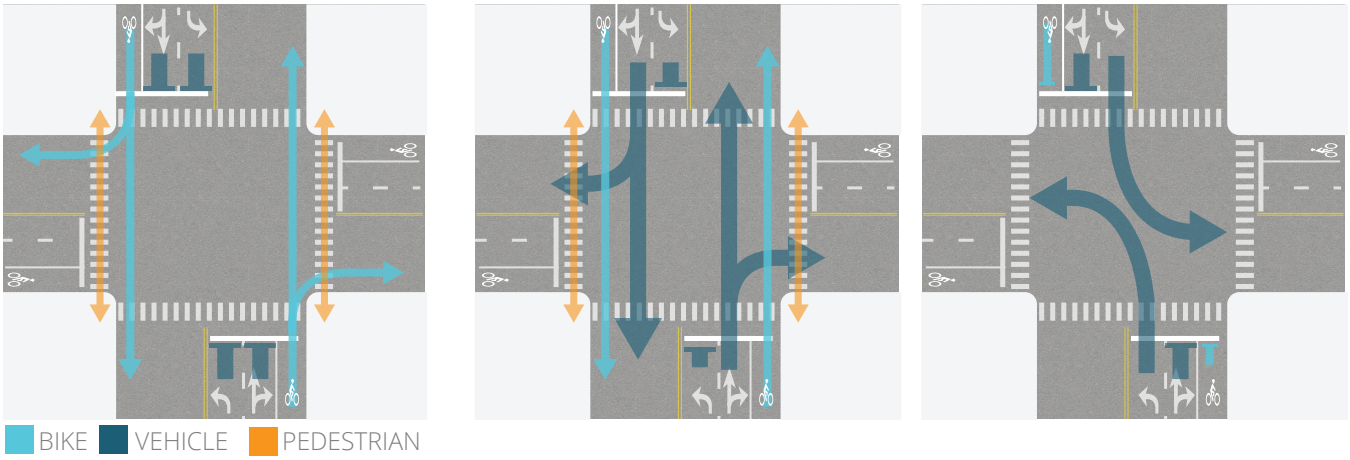
Signal Phase Example 3

A two-way separated bike lane adds complexity to signal phasing at two-way intersections. Importantly, the separated bike lane movement should be separated from conflicting vehicle turning movements.



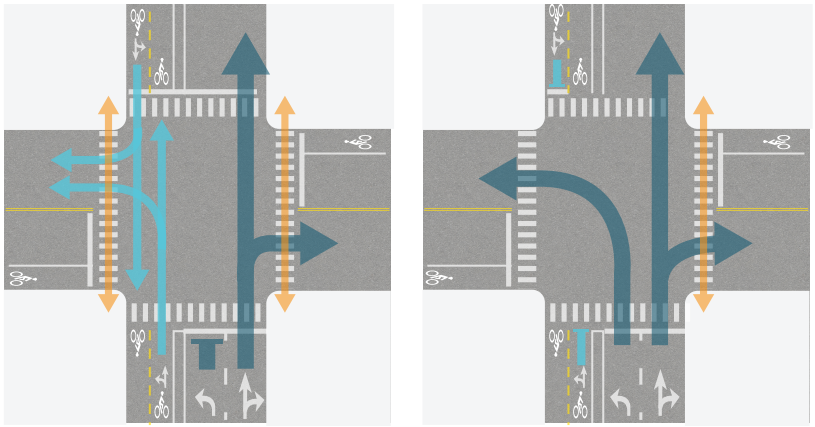
Signal Phase Example 4

In low vehicle traffic situations with separated bike lanes, a dedicated bicycle movement should be considered. The interim approval for bicycle signals (IA-16) does not permit a "bicycle scramble" (where bicycle movements are permitted from all four directions simultaneously).



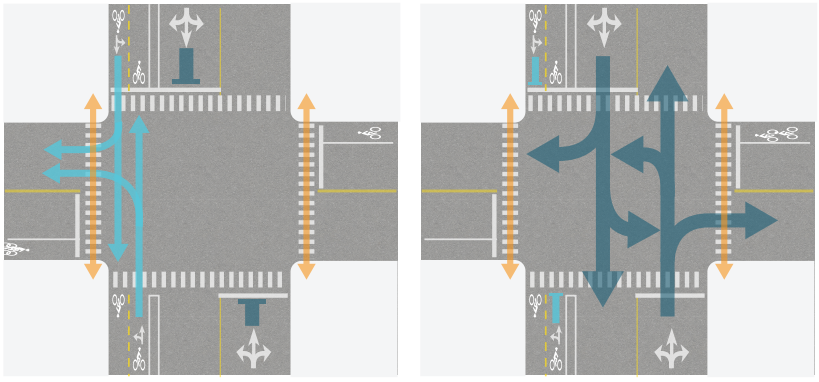
Signal Phase Example 5

One way streets with two-way separated bike lanes have fewer conflicting vehicle turning movements but should nevertheless be separated in time.



Signal Phase Example 6

When all vehicle turning movements must be accommodated, bicycle movements should be completely separated from vehicle movements.



BICYCLE TURNING MOVEMENTS 4

To allow bicyclists to comfortably navigate intersections, intersection design must account for right-turning, through, and left-turning movements where these movements are allowed. Left-turn movements (from right-side or center-running separated bike lanes) create the most potential for conflict with motor vehicles, but specific treatments such as bike boxes or two-stage turn queue boxes can facilitate safe and comfortable turning movements for bicyclists.

Bike Boxes and Early Exit

Bike boxes are designated spaces at signalized intersections that allow bicyclists to queue in front of motor vehicles at red lights. Placed between the stop line and the pedestrian crosswalk, bike boxes increase the visibility of queued bicyclists and provide them with the ability to start up and enter the intersection in front of motor vehicles when the signal turns green. Bike boxes, which have experimental status in accordance with the MUTCD, also provide bicyclists with the opportunity to position for a left turn. For more information on the MUTCD experimentation process, see http://mutcd.fhwa.dot.gov/condexper.htm. On multilane streets, the bike box may extend across all lanes up to the left turn lane to allow for left-turning bicyclists.

In locations with few travel lanes or low volumes, an early exit can allow more confident cyclists to weave from the separated bike lane into the travel lane and position themselves to turn with mixed traffic.

A cyclist approaches a bike box on M Street, Washington DC. Source: DDOT

BIKE TURNING MOVEMENTS

Bike Boxes and Early Exit

01 The bike box should include a minimum depth of 10 ft and minimum combined width of the bike lane, buffer space, and adjacent travel lane.

02 At signalized intersections, passive bicycle detection (inductive loops) may be used to give bicyclists a green light. For additional information on signal detection, see Page 116.

03 On multilane streets where left turns are allowed, bike boxes may be extended across the left turning lane.

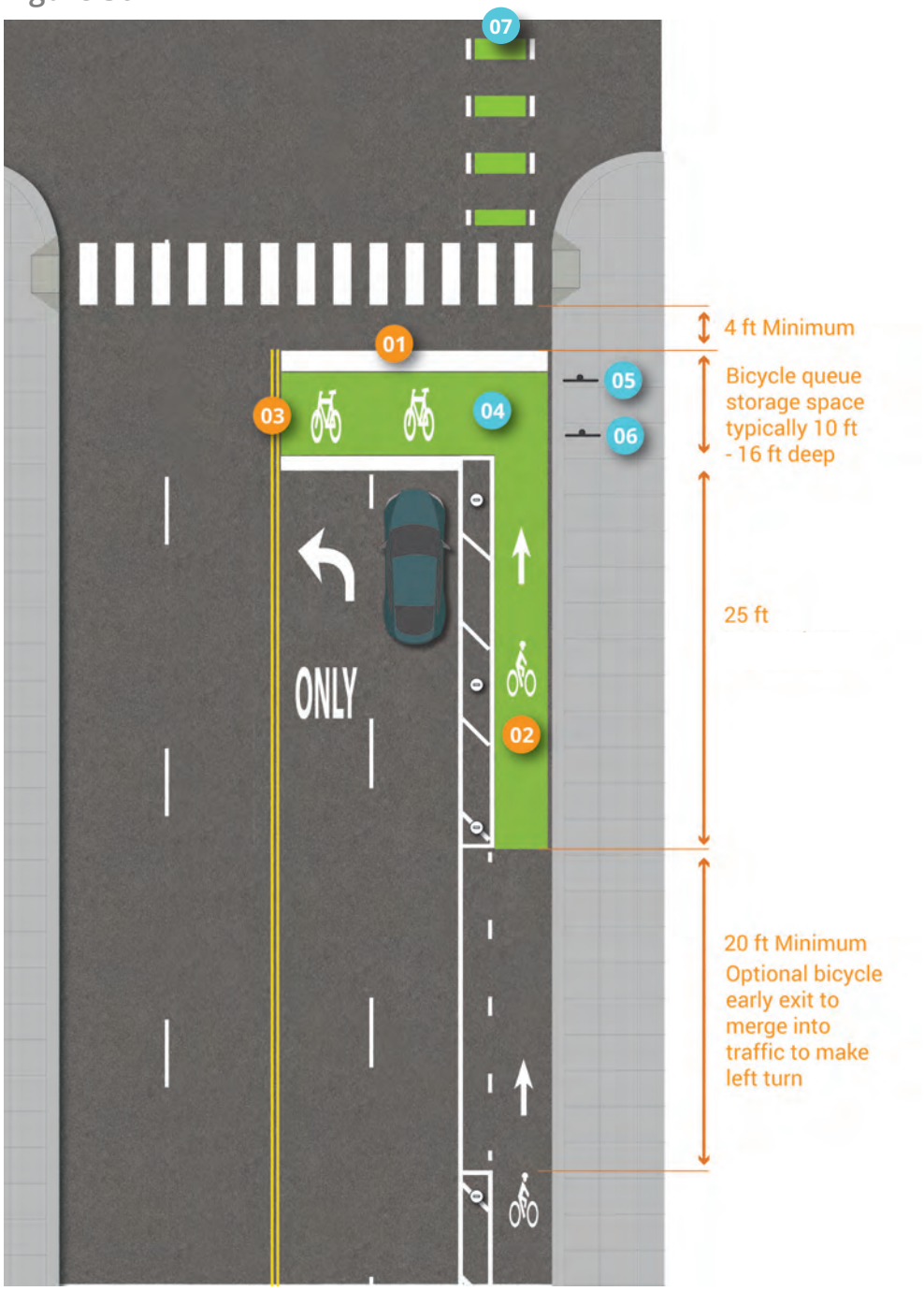
04 A variety of pavement marking treatments can be used to improve the visibility of the separated bike lane and reinforce expected bicyclist behaviors. For further guidance on paint and striping in conflict areas, see page 114.

05 A 'Turning vehicles yield to bikes' sign may be used. For further guidance on typical signs and markings for separated bike lanes, see page 127.

06 Install STOP HERE ON RED sign (MUTCD R10-6A).

07 Install NO TURN ON RED sign (MUTCD R10-11) if turns on red would otherwise be permitted.

Figure 30



NOT TO SCALE

TURNING MOVEMENTS

2- Stage Turn Queue Boxes

Two-stage turn queue boxes allow bicyclists to make left turns at multilane intersections from a right-side separated bike lane, or right turns from a left-side separated bike lane. Cyclists who arrive on a green light travel into the intersection and pull out into the two-stage turn queue box away from through-moving bicycles and in front of cross-street traffic. They may also be used at unsignalized intersections to simplify turning movements. Various positioning options are possible, depending on the corridor and intersection configuration. The two-stage turn queue box is experimental in accordance with the MUTCD.

An example of a left-turn queue box used on a bike lane in San Francisco. (Source: San Francisco Municipal Transportation Agency)

TURNING MOVEMENTS

2- Stage Turn Queue Boxes

01 The two-stage turn queue box should be designed in accordance with the MUTCD experimental approval. It should be located out of the way of through bicyclists, usually between the bike lane and crosswalk.

The two-stage left-turn box dimensions are about the same size or larger than the dimensions of four (4) cyclists standing side by side (10 ft wide X 6.5 ft deep).

02 Where on-street parking is located upstream of the intersection, the two-stage turn queue box can be located between the bike lane and vehicle travel lane.

03 Include a bicycle symbol and arrow indicating direction of turn in the two-stage queue box.

04 At signalized intersections, passive bicycle detection (inductive loops) may be used to give bicyclists a green light.

05 Install a NO TURN ON RED (MUTCD R10-11) sign where the two-stage left-turn box is installed in the path of a right turning vehicle.

06 A variety of pavement marking treatments can be used to improve the visibility of the separated bike lane and reinforce expected bicyclist behaviors. For further guidance on paint and striping in conflict areas, see page 114.

07 Guidance for parking space markings can be found in MUTCD (2009) Section 3B.19.

08 For further guidance on typical signs and markings for separated bike lanes, see page 127.

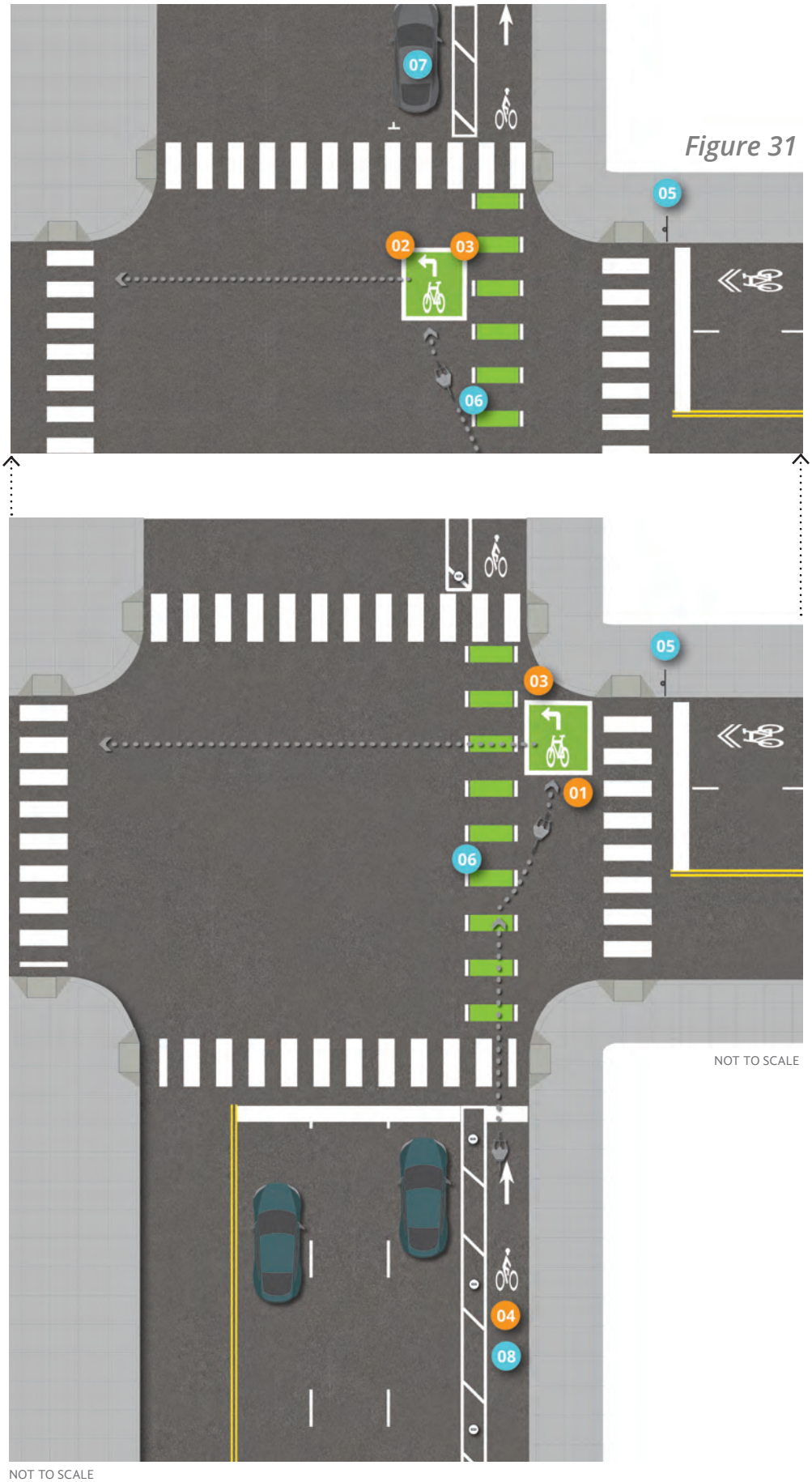


Figure 31

NOT TO SCALE

NOT TO SCALE

TURNING MOVEMENTS

No Bicycle Turning Treatments

Geometric constraints may not allow for two-stage left-turn queue boxes, or bike boxes to be located on separated bike lane routes. The provision of BICYCLISTS MAY USE FULL LANE sign (MUTCD R4-11) prior to intersections may help bicyclists cross the roadway to perform left-turns. Excluding areas to comfortably perform left-turns at intersections may discourage bicycling.

OTHER DESIGN ELEMENTS

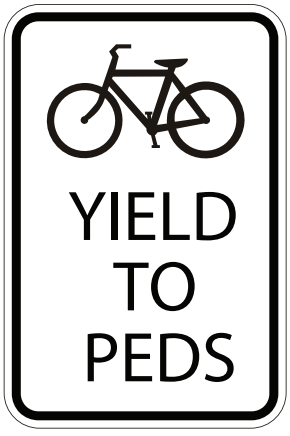
Signs and pavement markings supplement good design and reinforce appropriate behavior for all roadway users. This section provides a summary of the most commonly used signs and pavement markings related to separated bike lane installation.

SIGN GUIDANCE

Bike lane
MUTCD Sign R3-17

No turn on red
MUTCD Sign R10-11

Turning vehicles yield to bikes
MUTCD Sign R10-15 (Mod.)



Bicyclists yield to pedestrians
MUTCD Sign R9-6

Bicyclists may use full lane
MUTCD Sign R4-11

No Parking Bike Lane
MUTCD Sign R7-9

Bicycle signal actuation sign
MUTCD Sign R10-22

Right lane must turn right
MUTCD Sign R3-7R

Begin right turn lane yield to bikes
MUTCD Sign R4-4

Reserved parking for persons with disabilities
MUTCD Sign R7-8

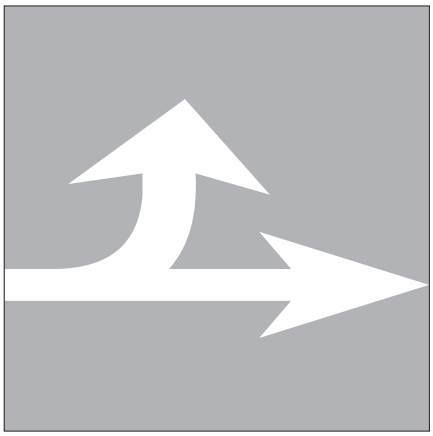
Van accessible
MUTCD Sign R7-8P

No parking loading zone
MUTCD Sign R7-6

No parking bus stop
MUTCD Sign R7-7

Bicycle/Pedestrian Warning
MUTCD Sign W11-15

MARKINGS GUIDANCE



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

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

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

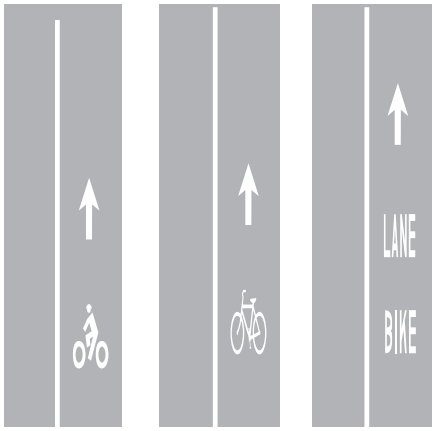
Bicycle pavement marking: word legends
MUTCD Fig. 9C-3

Pavement marking
MUTCD Fig. 9C-5

Shared lane marking
MUTCD Fig. 9C-9

Bike detector pavement marking
MUTCD Fig. 9C-7

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



Word, symbol & arrow pavement markings for bicycle lanes

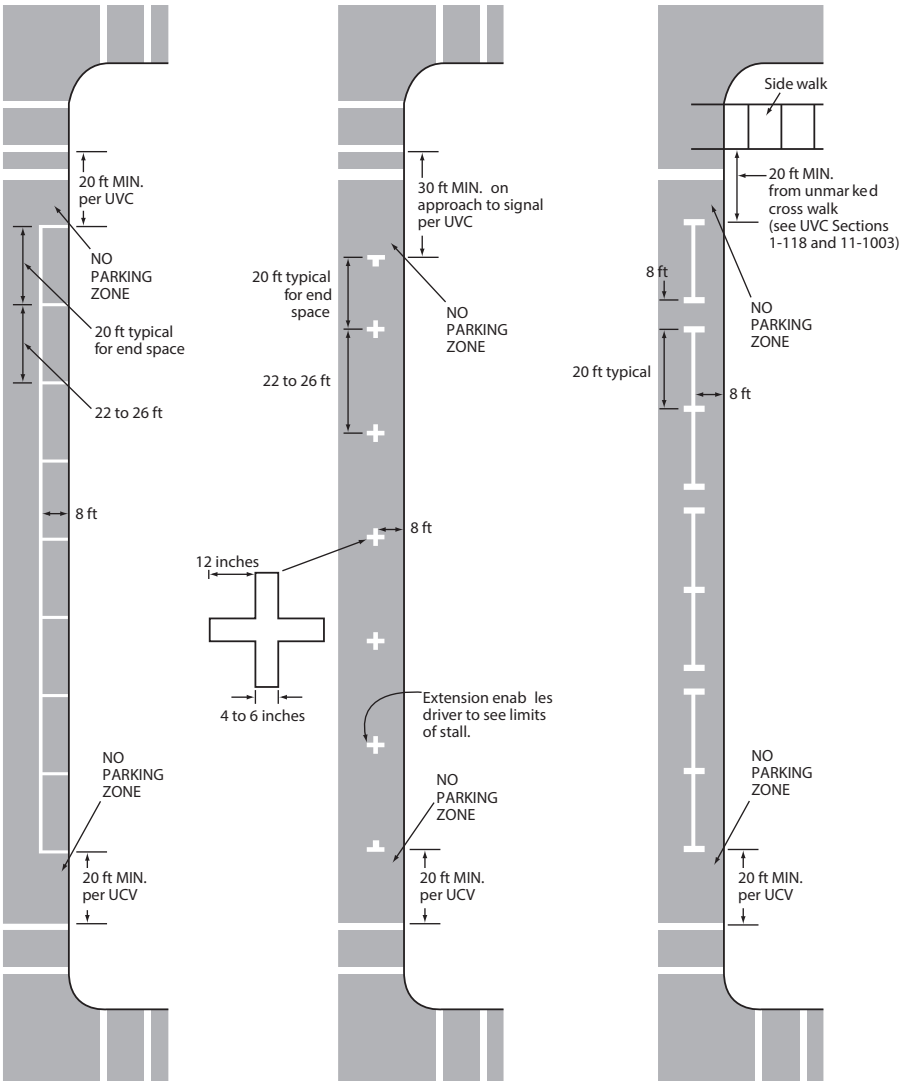
MUTCD Fig. 9C-3

SLOW pavement marking

MUTCD, Similar to Fig. 3B-23

International symbol of accessibility parking space marking

MUTCD Fig. 3B-22



Examples of Parking Space Markings

MUTCD Section 3B.19

SEPARATED BIKE LANE TRANSITIONS

A separated bike lane should be designed so users do not face uncertainty where the facility begins, ends, or intersects with another bicycle facility. Design treatments at a separated bike lane's terminus can vary significantly depending on the context. In all cases, however, planners and engineers should attempt to minimize bicycle conflicts with vehicular traffic and/or pedestrians and create clear pathways to safely enter and exit the separated facility. These transitions can be loosely categorized into five scenarios.

Transitions to Off-Street Trails or Sidepaths

When a separated bike lane terminates at an off-street trail or sidepath, designers should place markings and signage to emphasize the connection and enforce space designations for different user groups (generally differentiating space for cyclists from space for pedestrians or joggers). Green paint can be used at the junction of these facilities in order to alert different path users to the presence of cyclists entering and exiting the trail to and from the separated bike lane. Depending on the nature of the off-street trail, bicycle-specific wayfinding signage should be installed near the end of the separated bike lane to encourage the off-street trail's use.

Transitions to On-Street Bicycle Lanes

A roadway with a separated bike lane may narrow to the point that there is no longer space for separation. In other cases there may not be funding available to construct a separated lane through an entire corridor, or there may be operational or context related constraints. Designers should seek to continue the bicycle facility through on-street painted lanes (or, if necessary, shared lane markings) on the roadway beyond the end of the separated bike lane segment. Green paint prior to, through, and beyond the intersection where the separated facility terminates is advised.

Transition from a buffered bike lane to separated bike lane on 8th Avenue in New York City, NY. (Source: NYC DOT)

Transitions to Roads with No Dedicated Bicycle Facilities

Situations where a separated bike lane ends with no bicycle facility beyond it should be avoided where possible. Care should be taken to alert both cyclists and motorists to the end of the separated bike lane through green markings and signs. For cyclists approaching the end of a facility, alerts should be provided with enough advance notice to allow for a change in route to side streets or adjacent corridors, especially if the separated bike lane terminates in an area with high vehicular traffic volumes (for example, at highway interchanges or high-volume attractions like stadiums). For transitions that occur in high-volume locations, design flexibility is encouraged to create a safe landing point for cyclists, even if it requires a change in local law to allow cyclists to use sidewalks, or involves other unique treatments.

Transitions from Two-Way Separated Bike Lanes

Transitions at the beginning and end of a two-way separated bike lane require special consideration. On two-way streets, bicyclists will have to move across conflicting through vehicle movements to connect between the separated bike lane and the standard bike lane or shared lane. Bicycle signals or two-stage turn queue boxes may be needed to manage conflicts. Two-way separated bike lanes on one-way streets must accommodate contraflow bicycles getting to and exiting from the separated bike lane at either end of the facility. Cross streets or contraflow bike lanes may be used to connect bicyclists to other streets or facilities. Two-way separated bike lanes pose an additional challenge of wrong-way riding after the bike lane terminates.

Intersections with Other Separated Bike Lanes

When one separated bike lane intersects with another, practitioners should design intersections to facilitate turns between them. On high-volume corridors, this may be best accomplished through a "protected intersection" design, which includes corner islands to shield through- and turning bicycle traffic from the adjacent roadways. Cyclists turning left from a right-side running separated bike lane should be encouraged to make two-stage left turns and queue in two-stage turning boxes adjacent to corner islands. Depending on the street's existing geometry, pedestrian crosswalks may need to be set back from intersections in order to make room for the turning queue boxes. Bicycle specific wayfinding and directional signage should be installed to simplify cyclists' experience navigating the intersection. The "protected intersection" treatment can be viewed as an expansion of the "bend out" design treatment covered in the turning movements section of this chapter.

DECISION MAKING PROCESS EXAMPLES

The preceding sections highlighted numerous factors that inform the design of separated bike lanes, from the four primary design categories (directional characteristics and width, separation type, midblock considerations and intersection considerations) to secondary areas of focus. Because of space constraints and the complex nature of streets, design is often an iterative process where trade-offs between different design options must be evaluated and a change to one element of the design necessitates changes to other elements. Similarly, trade-offs may continually be made between facility design and planning considerations such as potential ridership, transit access, parking supply and maintenance throughout the design process.

This section illustrates the decision-making process for separated bike lane design through three hypothetical examples, underscoring the integrated nature of their designs.

DECISION MAKING PROCESS EXAMPLES

ONE-WAY STREET WITH LEFT-SIDE CONFLICTS

Design Challenge

While one-way separated bike lanes positioned on the left side of a one-way street offer several potential advantages, this scenario illustrates a case where the benefits of a right-side facility are seen as outweighing the drawbacks. Note: This design could also be mirrored on both sides of a two-way street to create one-way separated bike lanes in each direction.

STEP 1 DIRECTION AND WIDTH

One-way vs Two-way

Because this one-way street is coupled with, and well-connected to, a one-way street in the opposite direction a short block over, significant demand does not exist for a contra-flow bicycle facility. Therefore, a two-way bike lane is not seen as critical on this street. The narrower profile of a one-way lane also ensures that a parking lane can be preserved along with the preferred number of travel lanes. The lane and buffer are sized at 7 ft and 3 ft respectively so as to accommodate the municipality's street sweepers and snow plows until smaller models can be integrated into the fleet.

Lane Alignment

The land use patterns along the street are such that the left side of the street has many more driveways – which increase potential vehicle conflicts, detracting from the safety and comfort of a separated bike lane – than the right side. A right-side facility is seen as the safer choice. Although this option creates additional conflicts at the bus stops along the right side, the parking lane alongside the separated bike lane creates additional space to mitigate this challenge as described under the Midblock section on the following page.

STEP 2 FORMS OF SEPARATION

Buffer Type

Because this type of bicycle facility and street configuration is a new one for this jurisdiction, an interim design using low-cost and easily modified materials is preferred. Separation from traffic for the bicycle lane is provided using flexible delineator posts. Once the project has been evaluated and funding has been identified, the design can be improved if needed and built-out with more permanent materials such as a raised median with landscaping and bioswales.

STEP 3 MIDBLOCK

Transit Stops

Because a bus service runs along this street, with stops along the right side, it is necessary to carefully design the separated bike lane where it interacts with the bus stops. Having buses stop in the travel lane is not desired due to motor vehicle volumes, therefore the width provided by the parking lane along the right side is utilized to create "mixing zones" for bicyclists and stopped buses at bus stops. While not as comfortable for bicyclists as a design that maintains the separated bike lane through the bus stop, in this case it is seen as a reasonable compromise between motor vehicle capacity, bicycle facilities, transit service, and parking needs.

Curbside and Accessibility

To ensure the availability of space for commercial loading and unloading activity, dedicated loading zones are provided at intervals within the parking lane. The removal of parking along the left side of the street creates challenges for some businesses on that side of the street, which are partially mitigated by providing loading zones at the corners of the cross streets.

STEP 4 INTERSECTIONS

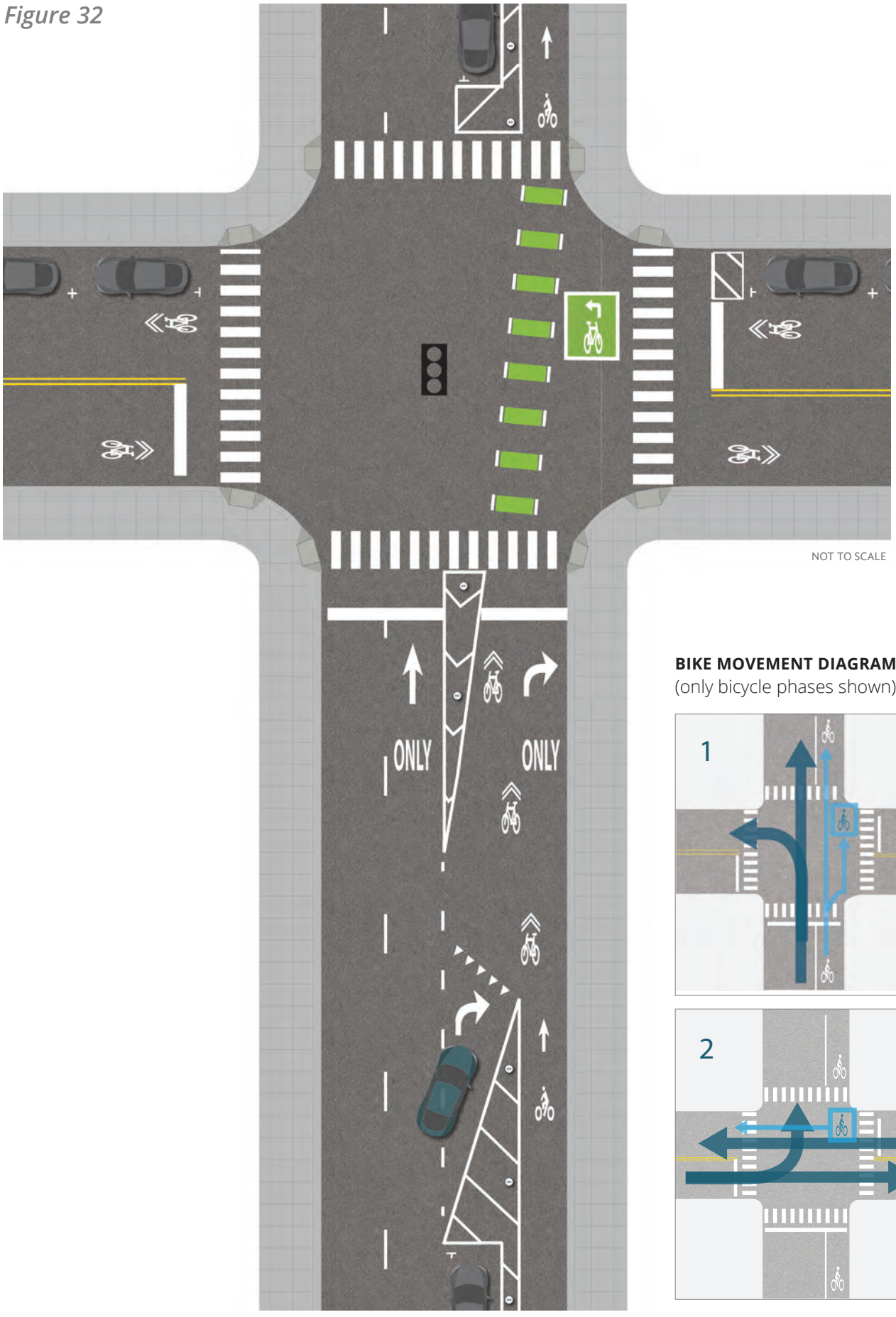
Turning Movements

Right-turning volumes at this intersection are low enough that mixing zones are employed at intersections to manage turning conflicts.

Markings and Signage

Signs and markings require motorists to yield to bicyclists when entering the mixing zones. Shared lane markings within the mixing zones guide bicyclists to the outside of right-turning automobiles, while green paint through the intersection calls attention to the bicycle lane. 2-stage bicycle turn boxes are provided on the far side of the intersections to collect left-turning bicyclists, and NO TURN ON RED signage prevents right-turning motorists from interfering with bicyclists queuing ahead of them to make 2-stage left turns.

Figure 32



NOT TO SCALE

BIKE MOVEMENT DIAGRAM
(only bicycle phases shown)

DECISION MAKING PROCESS EXAMPLES

TWO-WAY SEPARATED BIKE LANE ON ONE-WAY STREET

Design Challenge

Two-way separated bike lanes can be desirable on one-way streets when there is a high level of bicyclist demand in both directions due to limited alternatives for the contra-flow direction. However, they create additional turning conflicts that must be mitigated through careful design.

STEP 1 DIRECTION AND WIDTH

One -way vs Two-way

Bicyclists have expressed a preference to be able to utilize this street for two-way travel because of its numerous destinations, it is the most direct route and because comfortable bicycle facilities are not feasible on parallel streets. In addition, new developments along the street and related road work provides an opportunity to create an attractive, permanent bicycle facility. A comprehensive redesign of the streetscape is completed, providing a two-way separated bike lane that responds to user preferences and supports the economic development taking place along the street.

Lane Alignment

In this location, the left side is preferred for the two-way bike lane as it puts bicyclists and turning motorists moving in the same direction next to each other, maximizing visibility. Doing so also minimizes impacts on bus stops along the route.

STEP 2 FORMS OF SEPARATION

Buffer Type

It made economic sense to incorporate a permanent bicycle lane design into the road work that is already planned to address utility infrastructure and roadway condition as it would represent only an incremental cost. The bicycle lane is placed at sidewalk grade since cross streets and driveways are widely spaced and to reinforce the bicycle-oriented nature of the street. The bicycle lane is paved in asphalt rather than concrete to reinforce its purpose. A buffer zone along the curb separates the raised bicycle lane from the parking lane while a landscaped buffer separates it from the pedestrian portion of the sidewalk.

STEP 3 MIDBLOCK

Designing for Driveways

Driveways are designed to prioritize those on foot and bicycle by bringing crossing motor vehicles up to sidewalk grade rather than vice versa. To ensure that bicyclists are visible to drivers entering and exiting the few driveways along the route, ample visibility is provided through the removal of several parking spaces at each driveway to provide clear sight lines. Furthermore, the asphalt bicycle lane pavement is carried through the driveways and enhanced with green paint and warning signage to call both drivers' and bicyclists' attention to the presence of each other.

Curbside and Accessibility

Much of the loading activity for businesses along the left side of the street takes place off-street, but to minimize conflicts between on-street loading and bicyclists, dedicated loading zones are provided towards the middle of each block. Accessible parking spaces are also located mid-block by narrowing the bike lane and shifting it towards the landscaped buffer to create the necessary width.

STEP 4 INTERSECTIONS

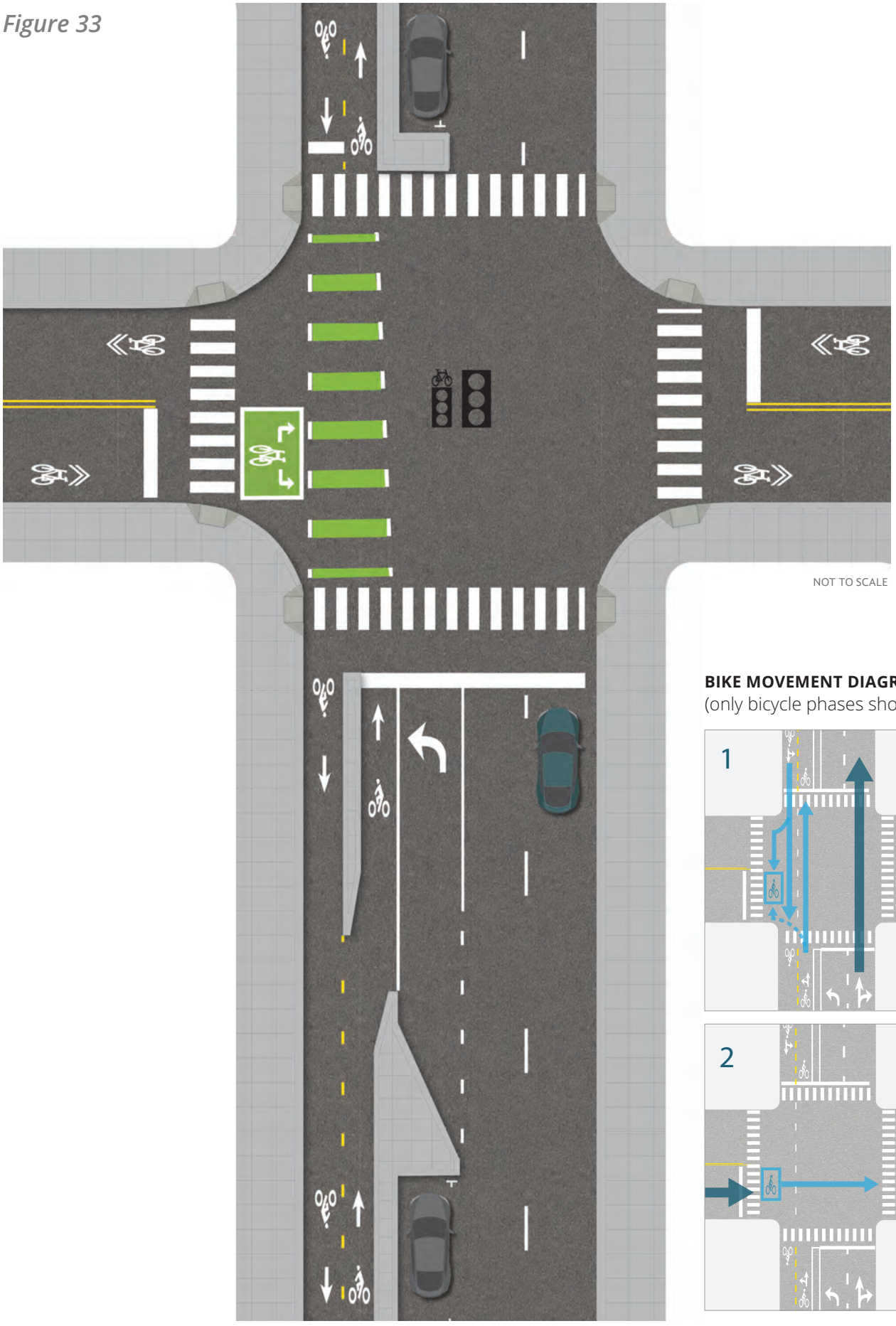
Turning Movements

Two-way separated bike lanes generally require their own protected signal phase at signal-controlled intersections where conflicting turns are allowed. Dedicated left turn bays are included at intersections (in exchange for several parking spaces) with a separate signal phase from that of the bicycle movement, and the northbound bike lane "bends in" at the intersection approach to visibly position bicyclists immediately next to left-turning drivers. In addition, minor cross streets are treated similarly to driveways with a raised pedestrian and bicycle crosswalk that slows motor vehicles while enhancing sidewalk users' visibility.

Markings and Signage

The two-way bicycle lane is painted green through intersections, whether it remains at sidewalk grade or crosses at roadway grade. A bicycle turn queue box facilitates right turns by northbound bicyclists and left turns by southbound bicyclists.

Figure 33



NOT TO SCALE

BIKE MOVEMENT DIAGRAM
(only bicycle phases shown)

DECISION MAKING PROCESS EXAMPLES

MEDIAN-RUNNING TWO-WAY SEPARATED BIKE LANE

Design Challenge

Some two-way streets lend themselves to two-way bike lanes running down the center rather than one-way bike lanes on the outside edges, particularly on a route oriented to bicycle through traffic. Such a design can create a boulevard-like experience but management of bicycle, motor vehicle and pedestrian interactions at intersections is key.

STEP 1 DIRECTION AND WIDTH

Lane Alignment

A two-way separated bicycle lane down the median of the street may be appropriate when many bicyclists use the street as a commuting "through" route; the outer edges experience a heavy combination of parking, bus stop and commercial loading activity; left turn volumes for motorists are modest; and the neighborhood plan envisioned the street serving as a grand "boulevard" with a tree-lined median. The two-way bike lane is a comfortable 12 ft wide, which also easily accommodates maintenance vehicles.

STEP 2 FORM OF SEPARATION

Buffer Type

To implement the new design in a short-term, low-cost way, the separated bike lane is primarily separated using interim materials such as markings, flexible delineator posts and landscaped planters (which are maintained by the local merchants association). However, an available grant is sufficient to build out raised islands at intersection approaches to better protect pedestrians at the crossings and move closer to the long-term boulevard vision by including large-canopy trees.

STEP 3 MIDBLOCK

Midblock Considerations

Locating the two-way separated bicycle lane within the median of the street generally eliminates midblock design issues such as transit stops, accessibility, parking, loading and driveway conflicts. This configuration concentrates design challenges at the intersections.

STEP 4
INTERSECTION

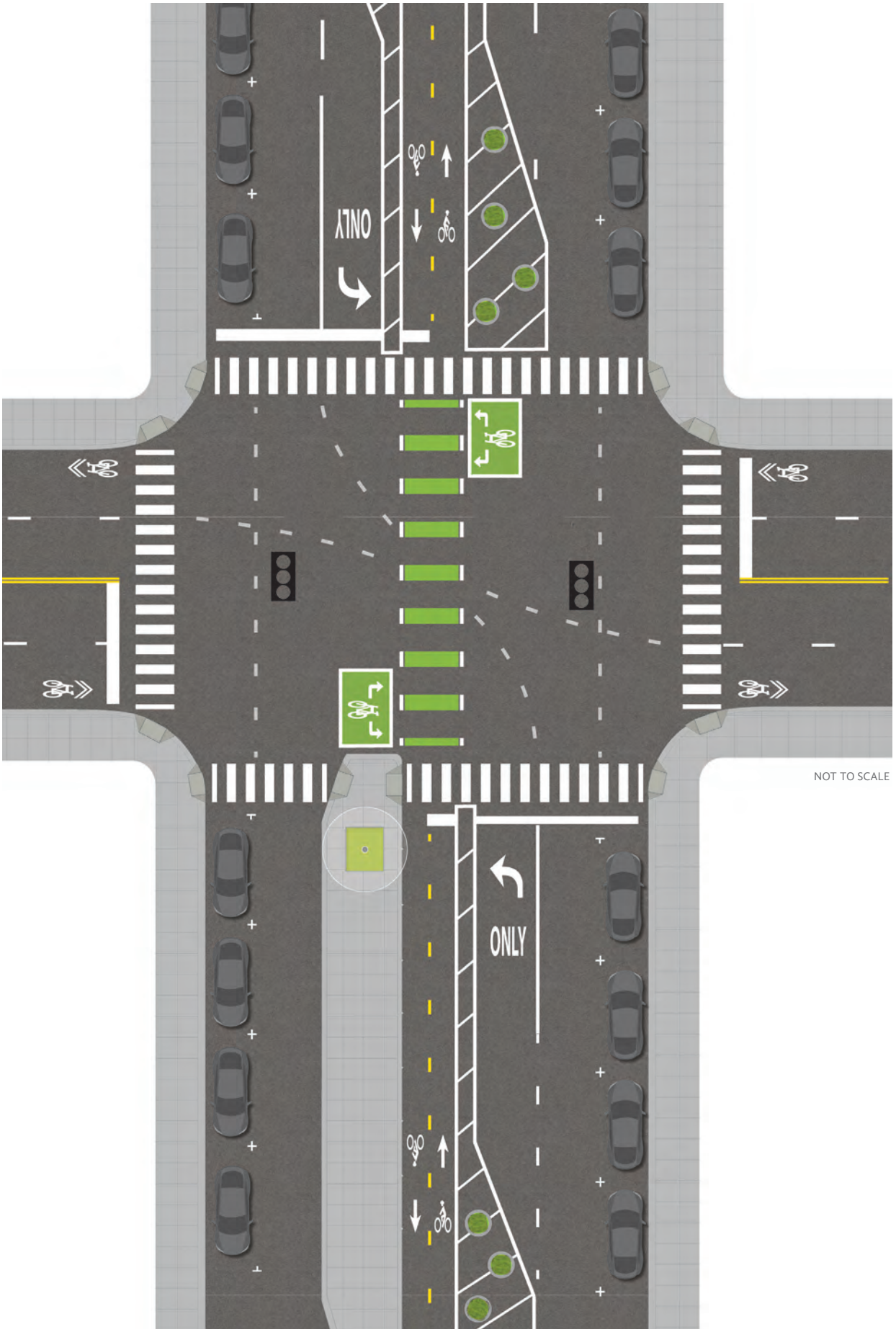
Turning Movements

"Carving out" the left turn bays from the median brings bicyclists and turning motorists directly alongside each other, improving visibility at the intersection approaches. Separate signal phases are necessary for the bike lane and left turning motor vehicles given the multiple conflicts present in this design. A stop bar is provided for bicyclists in advance of the crosswalk so that pedestrians can cross unimpeded during their "walk" phase.

Markings and Signage

The two-way bicycle lane is painted green through the intersections. Bicycle turn queue boxes are provided on the near side of the intersection (in the "shadow" of the median) to facilitate right turns by northbound bicyclists and left turns by southbound bicyclists and on the far side of the intersection for northbound left turns and southbound right turns. Dotted lane line extensions within the intersection help organize drivers' through and turning movements, particularly around the bicycle turn queue boxes. Signs reinforce the designated lanes and stopping locations and alert both motorists and bicyclists to the conflicting movements.

Figure 34



NOT TO SCALE

For More Information

Visit http://www.fhwa.dot.gov/environment/bicycle_pedestrian

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