

SEPARATED BIKE LANE

PLANNING & DESIGN GUIDE

2015

MASSACHUSETTS DEPARTMENT
OF TRANSPORTATION

SEPARATED BIKE LANE PLANNING & DESIGN GUIDE 2015

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Massachusetts Department of Transportation

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CHARLIE BAKER
GOVERNOR
COMMONWEALTH OF MASSACHUSETTS

STEPHANIE POLLACK
SECRETARY OF TRANSPORTATION AND CEO
MASSACHUSETTS DEPARTMENT OF TRANSPORTATION



It is my sincere pleasure to present the Massachusetts Department of Transportation's **Separated Bike Lane Planning & Design Guide**. MassDOT is committed to providing Massachusetts residents and visitors with a variety of safe and convenient transportation choices; for us, incorporating facilities that encourage walking and bicycling trips into projects is no longer the exception but the rule. Many people—including me—are reluctant to bicycle adjacent to busy roadways alongside fast-moving traffic. That's where separated bicycle facilities come in. Separated bike lanes are a key ingredient in the development of safe, comfortable and connected bicycle networks that will attract bicyclists of all ages and abilities.

This pioneering Guide will significantly advance bicycle facility design in the Commonwealth and, we hope, set new precedents for design in the United States. This Guide gives planners and engineers the tools to create facilities that will appeal to a broad range of potential bicyclists. As more separated bicycle facilities are built, people who would otherwise be unwilling to bicycle will hopefully choose to turn a short drive into a bike trip to work or school, to do an errand or visit friends.

I particularly want to thank the experts and advocates both inside and outside MassDOT whose expertise and willingness to share that knowledge made this Guide possible. Because of their hard work, this is the first statewide guide to provide specific guidance on planning, design and operations for separated bike lanes. It includes innovative safety features, such as the 'protected intersection' which minimizes conflicts between road users and improves visibility between people bicycling and driving. The Guide provides the tools and design flexibility that will enable both MassDOT and our partners in cities and towns throughout the Commonwealth to create protected intersections and other separated bike lane treatments as part of Complete Streets and other sustainable transportation initiatives.

This Guide builds on years of work at MassDOT to make our statewide transportation system more sustainable, encourage residents to make more use of transit, walking and biking options, and promote construction of Complete Streets that are safe and convenient for motorists, pedestrians, cyclists and transit riders alike. Our 2006 **Project Development & Design Guide** ensured that the safety and mobility of bicyclists and pedestrians would be considered equally throughout all phases of project development and design. In 2010, the **GreenDOT Policy Initiative** outlined key sustainability goals such as tripling bicycle, walking and transit trips by 2030. And the **Healthy Transportation Policy Directive** issued in 2013 committed MassDOT to ensuring that new projects increase and encourage bicycle, walking and transit trips. The Separated Bike Lane Planning & Design Guide represents the next—but not the last—step in MassDOT's continuing commitment to Complete Streets, sustainable transportation, and creating more safe and convenient transportation options for our residents.

Stephanie Pollack

Secretary of Transportation and Chief Executive Officer

Massachusetts Department of Transportation

ACKNOWLEDGMENTS

The Massachusetts Department of Transportation would like to acknowledge the people who contributed to the successful development of this Guide. Through their combined efforts and expertise, we were able to provide a responsive, comprehensive, contemporary Guide that will ultimately help to make Massachusetts a better place to be with safe multimodal choices for transportation.

PROJECT TEAM

MassDOT

Luciano Rabito, P.E., Complete Streets Engineer and Project Manager

Thomas DiPaolo, P.E., Assistant Chief Engineer

Jim Danila, P.E., Assistant State Traffic Engineer

Bonnie Polin, Chief Safety Analyst

Courtney Dwyer, District 6 Bicycle & Pedestrian Coordinator

Henry Barbaro, Environmental Division Wetlands Unit Supervisor

George Batchelor, Landscaping Unit Supervisor

Toole Design Group

Nick Jackson

Michelle Danila, P.E., PTOE

Jennifer Toole, AICP, ASLA

Patrick Baxter, P.E., PTOE

Bill Schultheiss, P.E.

John Dempsey, RLA

Jeremy Chrzan, P.E., PTOE,
LEED AP

Pete Robie

Nick Schmidt, AICP

Nathaniel Fink

WalkBoston

Wendy Landman, Executive Director

Bob Sloane, Senior Project Manager

MassBike

Richard Fries, Executive Director

Barbara Jacobson, Program Director

LivableStreets Alliance

Charlie Denison, Advocacy Director

Additional Experts

Peter G. Furth, Professor of Civil & Environmental
Engineering, Northeastern University

Clinton L. Wood, M.S.



Massachusetts Department of Transportation
10 Park Plaza, Suite 4160
Boston, MA 02116



www.massdot.state.ma.us



The Commonwealth of Massachusetts

Charlie Baker, Governor

Karyn Polito, Lieutenant Governor

Stephanie Pollack, Secretary of Transportation and Chief Executive Officer

Thomas J. Tinlin, Highway Administrator

Patricia A. Leavenworth, P.E., Chief Engineer

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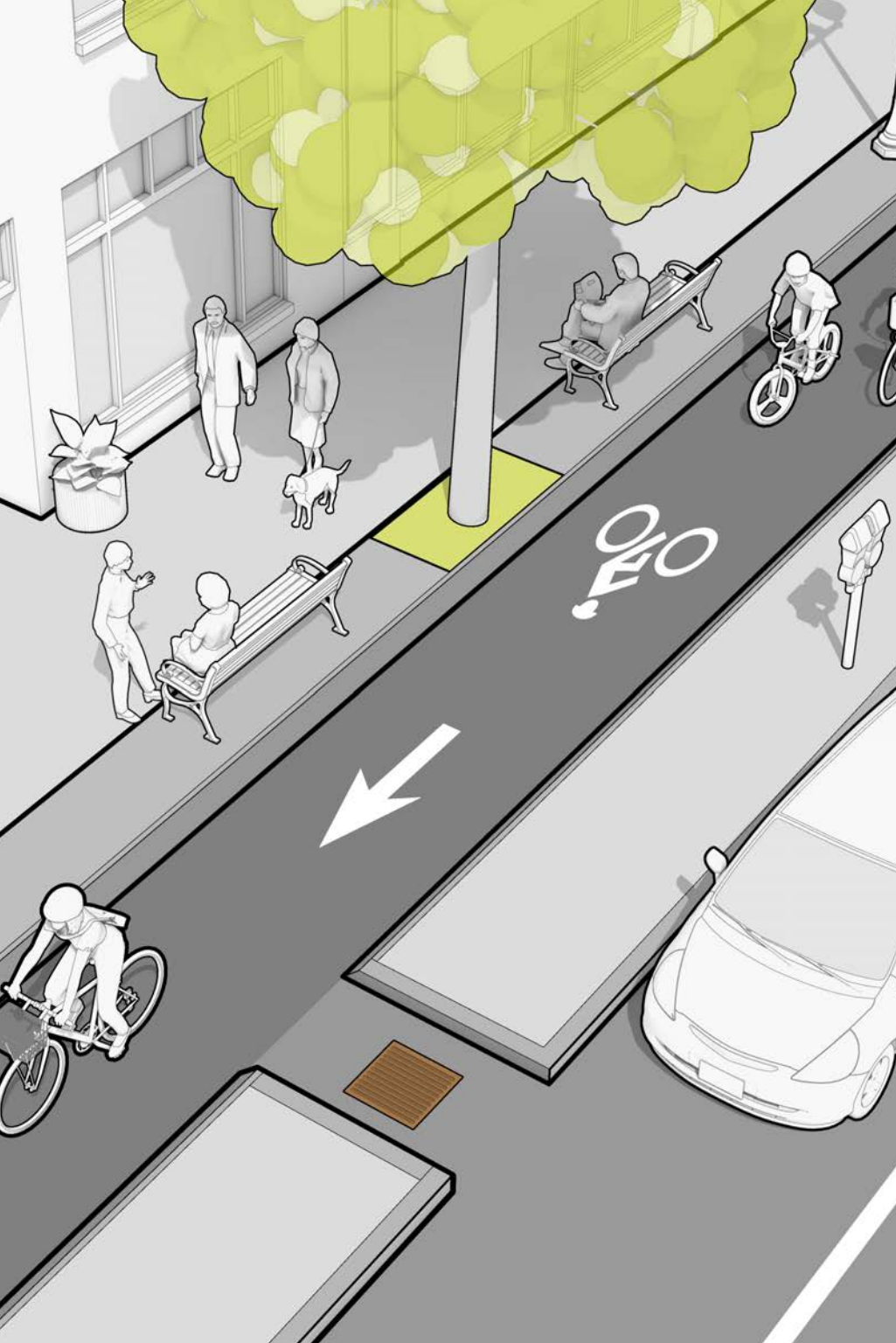
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OVERVIEW



The Massachusetts Department of Transportation's (MassDOT) [Separated Bike Lane Planning & Design Guide](#) (the Guide) presents considerations and strategies for the development of separated bike lanes. The Guide provides a framework for determining when separated bike lanes are appropriate and feasible. It presents design guidance for separation strategies, bike lane configuration, and considerations for transit stops, loading zones, utilities, drainage, parking and landscaping. The Guide defines separated bike lane design principles for intersections, introduces intersection design treatments and provides examples of typical intersection configurations. It clarifies when to consider signalization and provides guidance on signal phasing and timing as well as location of signal equipment. The Guide concludes with maintenance strategies, including seasonal operations and maintenance considerations.

1.1 SEPARATED BIKE LANE DEFINITION

A separated bike lane is an exclusive space for bicyclists along or within a roadway that is physically separated from motor vehicles and pedestrians by vertical and horizontal elements.

Just as a sidewalk creates a separate space for pedestrians, a separated bike lane creates an exclusive space for people bicycling along or within the roadway. Separated bike lanes include two fundamental elements:

- **Separation from motor vehicles both a) horizontally, with a separated space for bicycling along the street and at intersection crossings, and b) vertically, with a physical object and/or a change in elevation from the street surface.**
- **Separation from pedestrians with a vertical object, a change in elevation or visual delineation. Where separation from motor vehicles is appropriate but volumes of pedestrians and bicyclists are relatively low, a shared use path can be provided.**

Designers have flexibility in determining the type of separation. Depending on the context, separated bike lanes may be designed for one-way or two-way operation and may be constructed at street level, sidewalk level or at an intermediate level between the street and the sidewalk. The method of separation can be achieved with a variety of vertical elements including raised medians, flexible delineator posts, parked vehicles, or by a change in elevation between the bike lane and the roadway.



1.2 PURPOSE OF THE GUIDE

This Guide is a supplement to MassDOT's existing bicycle facility design guidance ([Chapters 5 and 6 of the Project Development & Design Guide](#)), providing direction on where to implement and how to design separated bike lanes as part of a safe and comfortable network of bicycle facilities.

1.2.1 POLICY CONTEXT

As part of a complete streets approach, MassDOT is committed to providing safe and comfortable travel for residents and visitors who bicycle on the Commonwealth's roads and paths. This commitment was formalized in 2006 with the release of the agency's award-winning context-sensitive design manual, the [Project Development & Design Guide \(PD&DG\)](#). By 2013 MassDOT further refined its complete streets guidance and released the [Healthy Transportation Policy Directive P-13-0001](#), also known as the [GreenDOT policy](#).

“All MassDOT funded and/or designed projects shall seek to increase and encourage more pedestrian, bicycle and transit trips.”

MassDOT Healthy Transportation Policy Directive, September 9, 2013

A component of the GreenDOT Policy requires that all MassDOT projects be designed and implemented in such a way that all customers have access to safe, comfortable and healthy transportation options including walking, bicycling and transit. This Guide is an important element in MassDOT's efforts to encourage more walking, bicycling and transit trips in the Commonwealth by 2030. Growth in bicycling will also help MassDOT meet its goals of reducing transportation-related greenhouse gas emissions.

Bicycling can also play a role in the Commonwealth's efforts to improve public health. As of 2014, approximately 66 percent of adults and 25 percent of children in Massachusetts were categorized as overweight or obese.³ The Massachusetts Department of Public Health has launched [Mass in Motion](#), a statewide obesity prevention initiative that promotes better eating habits and increased physical activity. Encouraging more daily bicycle trips can help to reduce rates of chronic diseases and rising health care costs related to physical inactivity.

MassDOT recognizes that implementing separated bike lanes is a critical strategy toward achieving many statewide goals. As stated in the [2014 Healthy Transportation Engineering Directive E-14-006](#), separated bike lanes are an appropriate substitution for other types of accommodation, and if provided, it is

BICYCLING FOR SHORT TRIPS: THE UNTAPPED POTENTIAL

Commonwealth residents make 26.5 million trips per day.¹ About half of those trips are less than 4 miles in length²—a distance that can, in many cases, be accomplished by bicycle in about the same amount of time as a motor vehicle trip. Safe, comfortable and convenient bicycle facilities make it possible to convert some short trips to bicycling, reducing traffic congestion and improving health.

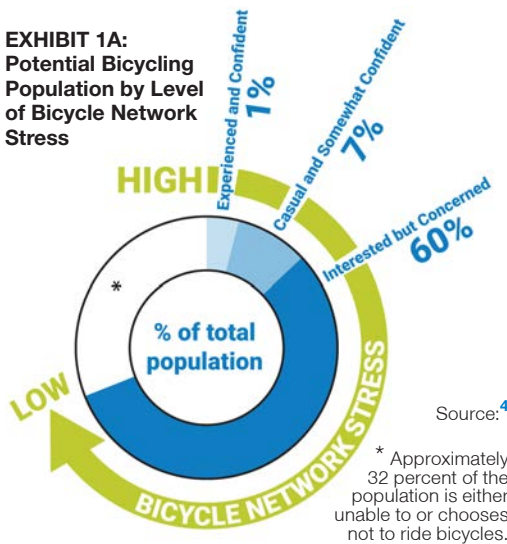
not necessary to provide any additional accommodations (e.g., conventional bike lanes).

Similar policies and guidance are provided at the federal level. The U.S. Department of Transportation (USDOT) is promoting connected and convenient multimodal networks, including high quality bicycle networks that appeal to people of all ages and abilities. As part of this initiative, the Federal Highway Administration released its [Separated Bike Lane Planning and Design Guide \(FHWA Guide\)](#) in May 2015. The FHWA Guide is based on national best practices and provides a series of case studies.

1.3 DESIGN USERS

Many people are interested in bicycling for transportation purposes but are dissuaded by stressful interactions with motor vehicles.⁴ These “interested but concerned” individuals vary by age and bicycling ability and account for a majority of the general population. While some bicyclists (i.e., the “casual and somewhat confident” or the “experienced and confident”) are more traffic tolerant, they account for a significantly smaller share of the population. By designing for those who are “interested but concerned,” separated bike lanes enhance the quality, safety and comfort of the bicycling environment for all design users. **EXHIBIT 1A** compares design users with their various tolerances for stress caused by interactions with motor vehicles.

EXHIBIT 1A:
Potential Bicycling
Population by Level
of Bicycle Network
Stress



1.4 ROLE OF SEPARATED BIKE LANES IN LOW-STRESS NETWORKS

A majority of people have serious safety concerns when bicycling in close proximity to motor vehicles, especially on higher speed, higher volume roadways (e.g., collectors and arterials) or where conflicts with parking, loading and buses are common. Only a small percentage of the population is willing to bicycle in these high-stress environments.⁴ Furthermore, research has shown that motorists also experience stress in

conditions where they are sharing lanes or operating in close proximity to bicyclists.⁵ Providing some degree of separation between bicyclists and motorists in locations with higher traffic speeds and volumes is therefore an important element in improving perceptions of safety and comfort for both groups.

Bicycling becomes more appealing to a broader segment of the population as the stress of riding a bicycle decreases (see **EXHIBIT 1B**). Bicycle networks can only expect to attract a modest percentage of people without direct and convenient low-stress routes.⁴

Low-stress bicycle networks are comprised of interconnected bicycle facilities that vary by roadway context. Shared lanes and conventional or buffered bike lanes may

Differences in mass and speed between bicycles and motor vehicles creates hazards and leads to stress for both bicyclists and motorists.

WHAT DOES RESEARCH SAY ABOUT SEPARATED BIKE LANES?

Separated bike lanes have been in use for many years in some European countries, however they are relatively new in the United States. Initial research on their use in North America has shown that:

- Separated bike lanes attract more people to bicycling.^{6,7,8}
- Separated bike lanes improve safety for all road users.^{9,10,11}
- Motorists and bicyclists prefer separated bike lanes over shared lanes or conventional bike lanes.^{5,12,13}
- Women express a preference for separated bike lanes.^{14,15,16}

create low-stress environments for most people on low-volume, low-speed streets where curbside conflicts are low. However, on busy streets with higher speeds, physical separation from motor vehicles via separated bike lanes or shared use paths is desirable to maintain a low-stress bicycling environment. Some vulnerable users, such as children and seniors, may only feel comfortable bicycling on physically separated facilities, even in locations with low traffic speeds and volumes.

Interested but Concerned



Who are they?

A mother and daughter in Western Mass. who enjoy Saturday rides to the library along the trail that runs near their house. The need to cross a busy road prevents them from riding together to elementary school during the week.

A 45-year-old father of two on the South Coast who was just diagnosed with pre-diabetes. His doctor encouraged him to be more active. He doesn't think he has time to go to the gym, so he's been thinking about commuting to work by bike. As a motorist he feels uncomfortable passing bicyclists, so he isn't sure he'd feel comfortable as a bicyclist sharing the road with cars.

A Boston-area resident who just moved to the US. He's used Hubway bike share a few times to ride home from the train station. He enjoys riding as long as he stays on quiet streets or the sidewalk. He'd like to be able to ride to the grocery store, but there are busy roads and intersections along the way.

Casual and Somewhat Confident



Who are they?

A woman on the North Shore who rides her bike downtown every morning to her job at the hospital. She prefers to ride on neighborhood streets, but doesn't mind riding the last few blocks on a busy street since there's a bike lane.

A lower-income Cape resident who rides a bicycle to save money for other household expenses. He's comfortable riding on Main Street without a conventional bike lane because it's a two-lane road and motorists usually don't pass him.

Experienced and Confident



Who are they?

A 60-year-old, life-long, daily-commuting bicyclist. He prefers direct routes to his destinations to save time. He is confident riding in mixed traffic and knows to be wary of opening car doors and turning trucks. He enjoys riding on shared use paths, but typically avoids them during congested periods.



LOWER STRESS
TOLERANCE

HIGHER STRESS
TOLERANCE

Separated bike lanes minimize conflicts with motor vehicles and heighten visibility between people bicycling and driving at intersections. Pedestrians benefit, too, from reductions in sidewalk riding and, depending on intersection design, shorter crossing distances.

1.5 BASIS OF DESIGN GUIDANCE

In developing separated bike lane guidance, MassDOT considered the design strategies from cities, states and countries that have successfully achieved a high percentage of trips by bicycle. While crucial to the overall bicycle network in these locations, separated bike lanes along busy and high speed streets are just one component. Communities with high levels of bicycle use typically provide a network of separated bike lanes, off-road paths, and shared streets where low traffic speeds and volumes enable bicyclists and drivers to coexist comfortably. [Section 2.4](#) presents a flexible approach to selecting the most appropriate bicycle facility.

This Guide draws upon experience and lessons learned from North American cities that have successfully increased bicycling while reducing crash rates through the implementation of separated bike lanes and other bicycle facilities.

The following guidelines and resources were primary sources for the development of this Guide:

- [National Association of City Transportation Officials Urban Bikeway Design Guide, Second Edition, 2014 \(NACTO UBDG\)](#)
- [American Association of State Highway and Transportation Officials Guide for the Development of Bicycle Facilities, Fourth Edition, 2012 \(AASHTO Bike Guide\)](#)
- [Massachusetts Project Development & Design Guide, 2006 \(PD&DG\)](#)
- [Federal Highway Administration Separated Bike Lane Planning and Design Guide, 2015 \(FHWA Guide\)](#)
- [Federal Highway Administration Bicycle and Pedestrian Facility Design Flexibility memorandum, 2013](#)
- [Dutch Centre for Research and Contract Standardization in Civil and Traffic Engineering \(CROW\)¹⁷ Design Manual for Bicycle Traffic, 2007 \(CROW Manual\)](#)
- [Peer reviewed academic research](#)

All design guidance conforms to the [2009 Manual of Uniform Traffic Control Devices \(MUTCD\)](#) and the [PD&DG](#), unless otherwise stated.

Design guidance for other bike facilities—shared lanes, conventional bike lanes, buffered bike lanes and shared use paths—is provided in the [PD&DG](#), [AASHTO Bike Guide](#), [MUTCD](#), [NACTO UBDG](#) and other local guidance and standards.

1.6 USING THIS GUIDE

MassDOT has created the Separated Bike Lane Planning & Design Guide for local officials, planners, designers and other project proponents to supplement the agency's current guidance and reflect recent advancements in bike facility design. The Guide supplements the eight-step project development process as outlined in the [PD&DG](#). This eight-step process formalizes the agency's commitment to a multimodal, context sensitive approach to improving and developing the transportation network throughout the Commonwealth. The information in this Guide applies to all projects where separated bike lanes are considered and when:

- [MassDOT is the proponent;](#)
- [MassDOT is responsible for project funding \(state or federal-aid projects\); or](#)
- [MassDOT controls the infrastructure \(projects on state highways\).](#)

[EXHIBIT 1C](#) highlights the relationship between this Guide and the relevant steps of the project development process. This Guide does not provide further considerations for project initiation (Step 3), programming (Step 5), procurement (Step 6) and construction (Step 7) because these processes remain similar with or without separated bike lanes. Project proponents should review Appendix D (Project Evaluation Checklist) and E (Recommended Separated Bike Lane Data Collection Protocol) of the [FHWA Separated Bike Lane Guide](#) for useful

evaluation measures and data collection methods that support project assessment (Step 8).

This Guide is also intended to be a useful resource for projects without MassDOT involvement, including those that are locally sponsored, funded, and reviewed, or under the jurisdiction of other Massachusetts authorities. Proponents of these projects are encouraged to consider this design guidance to ensure consistent and uniform design elements are used throughout the Commonwealth's bicycle network.

Readers of this Guide will find both recommended and minimum dimensions for separated bike lanes. Roadway designers should strive to incorporate recommended guidance where possible to attract bicyclists of all ages and abilities.

The guidance in this document is based on the premise that roadway design is contextual, and that design flexibility is needed to enhance safety and comfort for all users, particularly vulnerable users. This Guide includes recommended and minimum criteria to provide this flexibility. However, minimum criteria should be reserved for constrained areas only. If a design cannot meet these minimums, a Design Exception Report (DER) shall be prepared to document the site analysis and the reasons for not meeting minimum criteria (see [Section 2.11 of the PD&DG](#)).

See [Section 3.12](#) for design exceptions, Requests for Experimentation, accessibility, and shoulder requirements.

Separated Bike Lane Guide Chapter	Relationship to Project Development Process
1 Overview	Presents an overview of MassDOT and Federal policies and initiatives that create the need for separated bike lanes as part of low-stress bicycle networks. (Step 1: Problem/Need/Opportunity)
2 Planning	Clarifies when separated bike lanes are appropriate and feasible. (Step 2: Planning)
3 General Design	Presents design guidance for horizontal and vertical separation strategies, bike lane configuration, and considerations for utilities, drainage and landscaping. (Step 4: Environmental/Design/ROW Process)
4 Intersection Design	Defines separated bike lane design principles for intersections, introduces intersection design treatments and provides examples of typical intersection configurations. (Step 4: Environmental/Design/ROW Process)
5 Curbside Activity Design	Presents design guidance to reduce conflicts between separated bike lanes and curbside activities such as parking, loading and bus stops. (Step 4: Environmental/Design/ROW Process)
6 Signals	Clarifies when to consider signalization in conjunction with separated bike lanes, and provides guidance on signal phasing and timing as well as location of signal equipment. (Step 4: Environmental/Design/ROW Process)
7 Maintenance	Highlights maintenance and repair strategies for elements of separated bike lanes. Seasonal operations and maintenance are discussed as well, with a particular emphasis on winter maintenance. (Chapter 7 is beyond the scope of the project development process.)

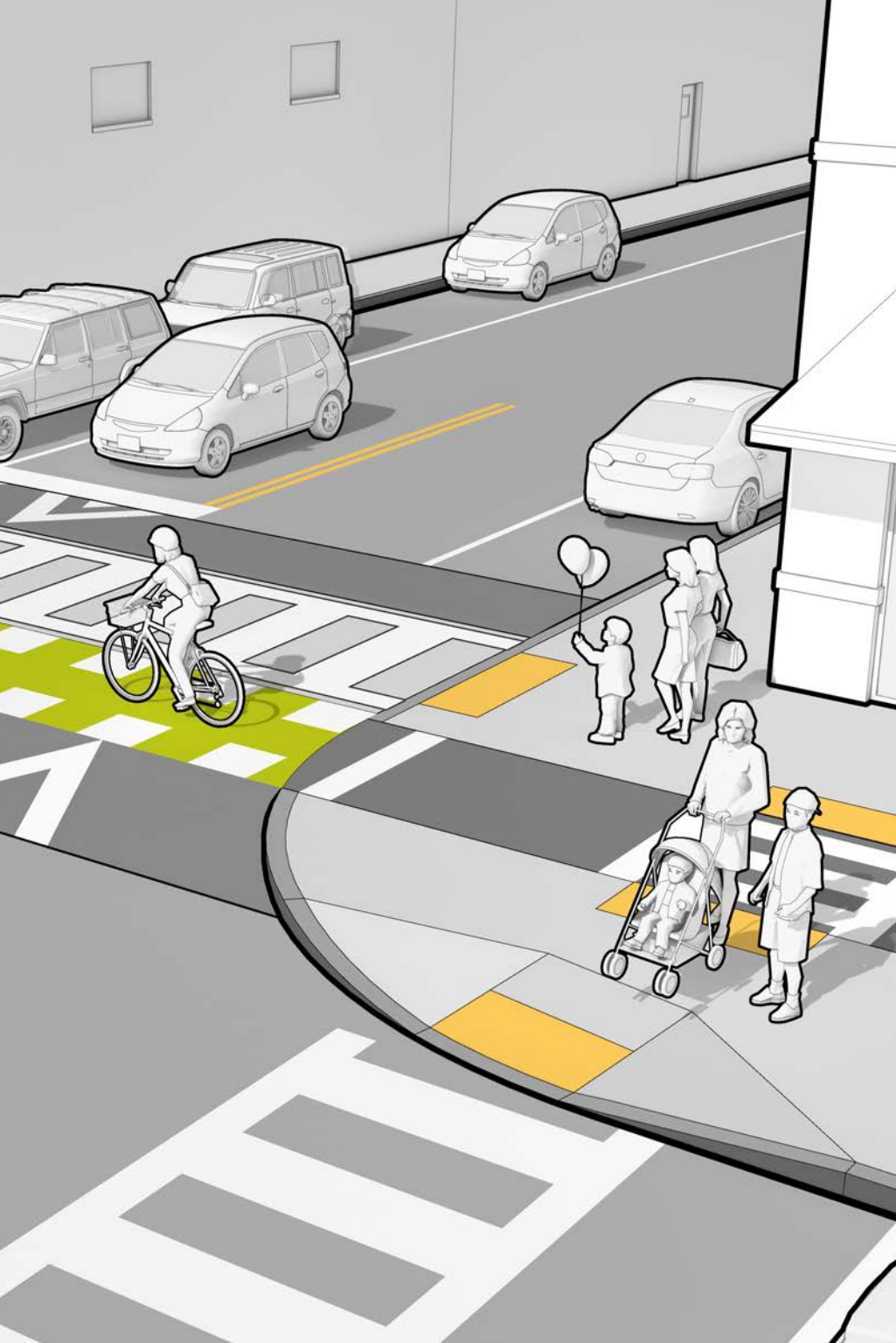
EXHIBIT 1C: Relationship between the Separated Bike Lane Planning & Design Guide and the Project Development Process

1.7 ENDNOTES

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- 17 CROW is a Dutch non-profit organization that develops and publishes design guidelines, manuals and other documents through a collaboration with external professionals in business, government and other research organizations.

2

PLANNING



The process of building a separated bike lane, like any transportation facility, should begin with planning before advancing through design, environmental review and construction. As outlined in the PD&DG, the planning process is important to ensure public engagement regarding design alternatives, and ultimately to build consensus prior to proceeding with the design. This chapter focuses on this planning process and provides an overview of low-stress bicycle networks, the role of separated bike lanes and determining the appropriate configuration.

2.1 PRINCIPLES OF LOW-STRESS NETWORKS

Separated bike lanes are an integral component of low-stress bicycling networks. Low-stress bicycle networks maximize safety and comfort for people bicycling by providing direct and convenient connections to destinations and other bike facilities in a manner that minimizes exposure to motorized traffic and conflicts with pedestrians. These three elements—**safety**, **comfort** and **connectivity**—are key principles of low-stress bicycle networks and the foundation of the planning and design guidance in this Guide.

2.1.1 SAFETY

People riding bicycles are vulnerable roadway users because they have less mass, less protection in the event of a crash, and travel more slowly than motor vehicles. Separated bike lane design should:

- **Minimize and consolidate conflict points between modes where they must occur (e.g., at intersections).**
- **Encourage desirable yielding behavior by maximizing approach sight distance, reducing speeds and enhancing visibility at intersections and conflict points.**
- **Clearly delineate roadway space by travel mode.**
- **Provide consistent and uniform treatments to promote predictable behavior for all users.**

2.1.2 COMFORT

Attention to user comfort is an important part of attracting more people to bicycling as a mode of travel. Separated bike lane design should:

- **Provide horizontal separation from motor vehicle traffic.**
- **Ensure the amount of delay for bicyclists, particularly at intersections, is reasonable and balanced with other users.**
- **Minimize exertion and energy loss of bicyclists due to starting and stopping.**
- **Minimize exposure to traffic noise and pollution.**
- **Accommodate side by side bicycling and passing movements, where feasible.**
- **Provide smooth vertical transitions and pavement surfaces free from obstructions, irregularities and seams.**



2.1.3 CONNECTIVITY

People who ride bicycles need a network of continuous low-stress routes. Separated bike lane design should:

- **Provide recognizable facilities.**
- **Provide direct and convenient connections that minimize detours.**
- **Connect at a local scale for access, and a regional scale for mobility.**
- **Integrate into the larger multimodal transportation network.**
- **Provide seamless transitions between different facility types.**



2.2 NETWORK CONNECTIVITY CONSIDERATIONS

MassDOT supports the goal of providing an interconnected network of bikeways serving all ages and abilities throughout the Commonwealth. Achieving a fully interconnected low-stress bicycle network takes a great deal of work and typically evolves over many years (and often decades) of time. The initial lack of connection to other bike facilities, therefore, should not preclude the consideration of separated bike lanes during project planning. A new separated bike lane that sees lower levels of use in its early years due to lack of connectivity may see considerably higher usage levels once connections have been made at a later date. The need for future projects to improve conditions on connecting corridors should be noted during the project development process and considered during future project programming.

Anticipated origins, destinations and route lengths should be considered when planning routes and configurations of bike facilities. When determining whether to provide separated bike lanes on a busy roadway, planners sometimes look for alternative routes on other parallel corridors. It is important to bear in mind that bicyclists operate under their own power and are sensitive to detours or out of direction travel. Most are willing to lengthen their trip only by **25 percent** to avoid difficult traffic conditions, in cases where they are able to access a low-stress bike

facility (such as a separated bike lane or off-road shared use path).¹ Consideration should therefore be given to providing a high quality bicycle facility along the busy corridor, rather than requiring a detour along a parallel route that may be too far away to attract bicyclists.

2.3 PLANNING PROCESS

Planning processes at the local, regional and statewide level should consider separated bike lanes and the implementation of low-stress bicycling networks. When consulting previously adopted plans, it is important to remember that separated bike lanes are a relatively new type of accommodation. While specific recommendations for separated bike lanes may not be included in existing plans, they should be considered along with other types of bicycle facilities such as paved shoulders and bike lanes. The following summarizes approaches for incorporating separated bike lanes into common planning processes.

- **System-wide plans** – Long-range and master transportation plans, bicycle network plans, and safety plans should identify high priority corridors or locations for separated bike lanes. A cohesive regional network of separated bike lanes and shared use paths enables bicyclists to comfortably travel longer distances.
- **Area plans** – Access and mobility are important considerations for area plans. Neighborhood and sector plans should identify key corridors where separated bike lanes will improve bicycle access and mobility to key community destinations and regional routes.
- **Corridor plans** – Corridor plans are often initiated to address issues such as safety, accessibility and congestion along a corridor. An important objective for corridor plans is to evaluate different configurations of separated bike lanes. Where right-of-way is being acquired for roadway projects, obtaining or preserving sufficient right-of-way for separated bicycle lanes should be considered.
- **Development and redevelopment site plans** – Locations where separation for bicycles is appropriate should be identified early in the review process to ensure adequate right-of-way is preserved. Site plans should facilitate connections between separated bike lanes and other bicycle facilities within the development as well as nearby.
- **Traffic impact assessments** – Analysis of traffic impacts for new or redeveloping properties should consider the ability of separated bike lanes to attract higher levels of bicycling.

2.4 A FRAMEWORK FOR SELECTING SEPARATED BIKE LANES

Separated bike lanes are one of several facilities that can contribute to a safe, comfortable and connected low-stress bicycling network. This section provides a framework for selecting and configuring separated bike lanes.

2.4.1 DETERMINING WHEN TO PROVIDE PHYSICAL SEPARATION

As discussed in [Chapter 1](#), proximity to moving traffic is a significant source of stress and discomfort for bicyclists, and for good reason—the crash and fatality risks sharply rise for vulnerable users when motor vehicle speeds exceed **25 mph**.²

Separated bike lanes are generally preferable to conventional (not separated) bike lanes because they improve visibility between bicyclists and motorists at intersections. Separated bike lanes are typically set back from the road at a greater distance than conventional bike lanes. This encourages better yielding behavior on the part of turning motorists, who are better able to detect the presence of a bicyclist and to appropriately yield the right of way (see [EXHIBIT 2A](#)). As shown in [EXHIBIT 2B](#), conventional bike lanes subject bicyclists to a higher level of exposure at intersections, as discussed in more detail in [Section 4.2.1](#).

Separated bike lanes are not necessary on every type of street. There are many locations throughout Massachusetts where motor traffic speeds and volumes are low, and most bicyclists are comfortable sharing the road with motor vehicles or riding in conventional bike lanes. On streets where operating speeds are below **25 mph** and traffic volumes are below **6,000** vehicles per day, separated bike lanes are generally not necessary.

On streets with higher operating speeds and volumes, or where conflicts with motor vehicles are common, separated bike lanes or a shared use path is recommended. Other conditions that may warrant physical separation for bicyclists include the presence of:

- **Large vehicles** – Higher percentages of trucks and buses increase risks for bicyclists due vehicle size, weight and the fact that drivers of these vehicles have limited visibility. This is a particular concern for right turns where large vehicles may appear to be proceeding straight or even turning left prior to right-turn movements.
 - **Vulnerable populations** – The presence of high concentrations of children and seniors should be considered during project planning. These groups may only feel comfortable bicycling on physically separated facilities even where motor vehicle speeds and volumes are relatively low. They are less confident in their bicycling abilities and, in the case of children, may be less visible to motorists, lack roadway experience, and may have reduced traffic awareness skills compared to adults.
 - **Low-stress network connectivity gaps** – Separated bike lanes can help close gaps in a low-stress network. Examples include on-street connections to shared use paths, or where routes connect to parks or other recreational opportunities (see [Section 4.5](#)).
 - **Unusual peak hour volumes** – On streets that experience an unusually high peak hour volume, separated bike lanes can be beneficial, particularly when the peak hour also coincides with peak volumes of bicyclists.
- **Multi-lane roadways** – Multi-lane roadways enable motor vehicle passing and weaving maneuvers at higher speeds. This creates conflicts with bicyclists, particularly at intersections.
 - **Curbside conflicts** – Conflicts with parked or temporarily stopped motor vehicles present a risk to bicyclists—high parking turnover and curbside loading may expose bicyclists to being struck by opening vehicle doors or people walking in their travel path. Stopped vehicles may require bicyclists to merge into an adjacent travel lane.³ This includes locations where transit vehicles load and unload passengers within a bicycle facility or shared curb lane.

EXHIBIT 2A: MOTORIST'S VIEW AT SEPARATED BIKE LANE

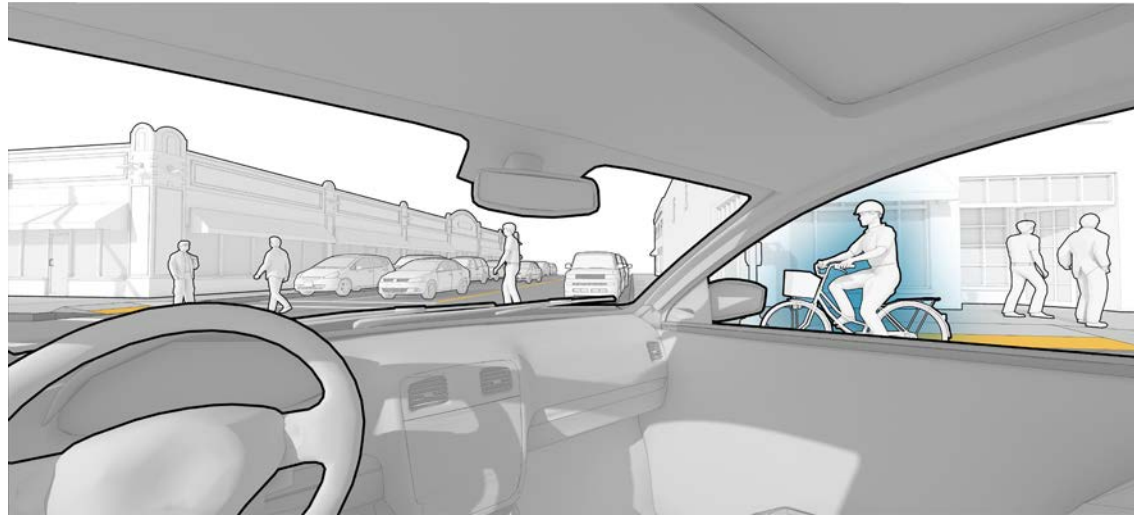
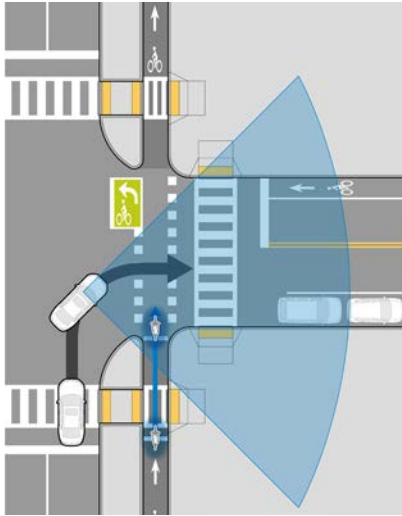
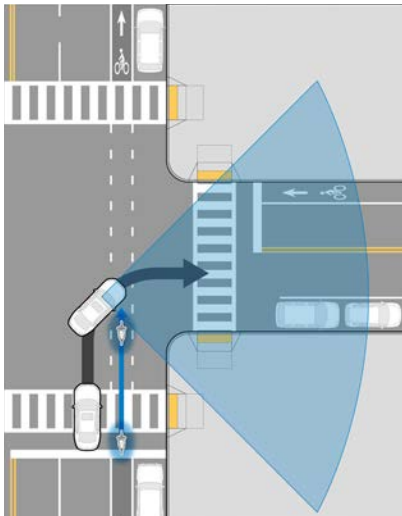


EXHIBIT 2B: MOTORIST'S VIEW AT CONVENTIONAL BIKE LANE



The Highway Capacity Manual's Bicycle Level of Service (BLOS) model is not calibrated to evaluate separated bike lanes, because this facility type did not exist in the U.S. when the model was developed. For this reason, conventional level of service tools are not well suited for determining the need for separated bike lanes. To fill this gap, the Mineta Transportation Institute developed a Level of Traffic Stress (LTS) analysis tool.⁴ This tool should be considered in lieu of BLOS when there is a need to evaluate separated bike lanes. It incorporates roadway criteria (e.g., on-street parking, speeds, number of travel lanes, heavy vehicle percentage and conditions at intersections) to determine the level of traffic stress for different facility types on individual segments in a network. When using this approach, LTS 1 and 2 will accommodate the 'interested but concerned' bicyclist.

2.4.2 CHOOSING SEPARATED BIKE LANES OR SHARED USE PATHS

The type of separated bike facility—separated bike lane or shared use path—and method of separation should be determined once it is decided that physical separation from motor vehicles should be provided.

Where both walking and bicycling demand are relatively low and are expected to remain low, a shared use path may be considered in lieu of a separated bike lane to satisfy demand for walking and bicycling in a single facility to reduce project costs. The shared use path may be located on one or both sides of the street depending

upon bicycle and pedestrian network connectivity needs. Shared use paths for this purpose should be designed with the same design principles as separated bike lanes while also accommodating pedestrian use. As volumes increase over time, the need for separation should be revisited.

The Shared-Use Path Level of Service Calculator⁵ can help project proponents understand potential volume thresholds where conflicts between bicyclists and pedestrians will limit the effectiveness of a shared use path. When Level of Service is projected to be at or below level 'C,' separate facilities for pedestrians and bicycles should be provided, unless right-of-way constraints preclude separation.

As this calculator requires user volumes and other data that may not be available

An understanding of design principles and elements is required to determine the separated bike lane configuration:

- **Chapter 3 for general design considerations**
- **Chapter 4 for intersections**
- **Chapter 5 for curbside uses**
- **Chapter 6 for signalization**
- **Chapter 7 for maintenance**

during the planning process, project proponents can estimate activity by using existing volumes on similar streets and shared use paths in the vicinity, and making adjustments as necessary to account for existing and future land uses adjacent to the facility, as well as regional trends and mode shift goals.⁶

2.4.3 DETERMINING SEPARATED BIKE LANE CONFIGURATION

Early in the planning process for a separated bike lane, it is necessary to determine the most appropriate configuration for the facility. For example, the designer must determine if it would be more appropriate to place a one-way separated bike lane on each side of the street, or to place a two-way facility on one side of the street (and if so, which side). Selecting the appropriate configuration requires an assessment of many factors, including overall connectivity, ease of access, conflict points, curbside uses, intersection operations, maintenance and feasibility. The analysis should also consider benefits and trade-offs to people bicycling, walking, taking transit and driving. The primary objectives for determining the appropriate configuration are to:

- **Accommodate bicycle desire lines.**
- **Provide direct transitions to existing or planned links of a low-stress bicycle network.**
- **Provide convenient access to destinations.**
- **Connect to the roadway network in a direct and intuitive manner.**

The planning-level analysis should determine two basic components of the separated bike lane configuration:

- **Travel direction – one-way in the direction of motorized travel, one-way contra-flow or two-way**
- **Location – left and/or right side or in the median of the roadway**

TRAVEL DIRECTION

Determining travel direction is a function of network connectivity, roadway configuration and potential intersection conflicts. A primary consideration should be connecting to existing or planned links in a low-stress bicycle network.

One-way separated bike lanes in the direction of motorized travel are typically the easiest option to integrate into the existing operation of a roadway. This configuration provides intuitive and direct connections with the surrounding transportation network, including simpler transitions to existing bike lanes and shared travel lanes.

In some situations, however, one-way separated bike lanes are not practical or desirable, due to right-of-way constraints or a variety of other factors. In these locations, the challenges of accommodating a two-way facility on one side of the roadway must be weighed against the constraints posed by one-way facilities to determine the optimum solution.

Providing a two-way facility introduces contra-flow movements which can be

challenging to accommodate. Contra-flow movements require special attention at intersections, driveways and other conflict points as people walking and driving may not anticipate contra-flow bicycle movements. It is particularly important to consider options for managing potential conflicts between contra-flow bicyclists and left turning motorists. In this scenario motorists are primarily focused on identifying gaps in oncoming traffic and may be less cognizant of bicyclists approaching the intersection. Design solutions to mitigate these conflicts are addressed in [Chapter 4](#).

Contra-flow movements may also introduce challenges at their termini, as bicyclists must be accommodated back into the traffic mix in the correct direction of travel.

On signalized corridors, the contra-flow bicycle movement on a one-way street may be less efficient because signals are typically coordinated in the direction of motor vehicle travel. If there are substantial connectivity benefits to a contra-flow facility on a one-way street, it should be determined if these challenges can be overcome by applying traffic engineering principles and following the guidance established in [Chapters 3, 4 and 5](#) of this Guide.

LOCATION

Choosing where to locate separated bike lanes within the roadway is typically a balance between enhancing connectivity and avoiding conflicts. For example, it may

be beneficial to locate the separated bike lane on one side of the street to better connect to the bicycle network or provide access to destinations such as businesses, schools, transit centers, employment centers, parks and neighborhoods. Similarly, the prevalence of motor vehicle turning conflicts, high parking turnover, loading activities or transit service on one side of the street may influence the decision to locate the separated bike lane on the other side of the street. The provision of clear and intuitive transitions are key to the success and safety of the design.

[EXHIBIT 2C](#) and [EXHIBIT 2D](#) provide overviews of configurations for typical one-way and two-way roadways with a discussion of associated issues.



EXHIBIT 2C: EXAMPLE SEPARATED BIKE LANE CONFIGURATIONS ON A ONE-WAY STREET

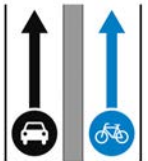
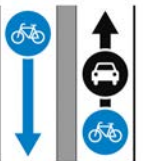
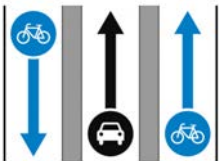
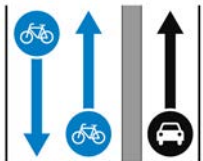
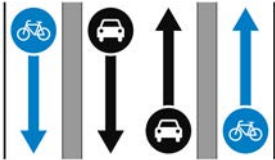
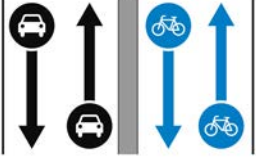
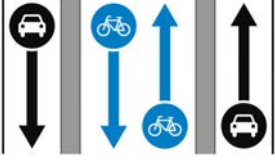
	One-way SBL	Contra-flow SBL	One-way SBL Plus Contra-flow SBL	Two-way SBL
Corridor-level Planning Considerations				
Access to Destinations	Limited access to other side of street	Limited access to other side of street	Full access to both sides of street	Limited access to other side of street
Network Connectivity	Does not address demand for contra-flow bicycling, may result in wrong way riding	Requires bicyclists traveling in the direction of traffic to share the lane (may result in wrong-way riding in the SBL); contra-flow progression through signals may be less efficient	Accommodates two-way bicycle travel, but contra-flow progression through signals may be less efficient	Accommodates two-way bicycle travel, but contra-flow progression through signals may be less efficient
Conflict Points (see Chapter 4)	Fewer because pedestrians and turning drivers expect concurrent bicycle traffic	Pedestrians and turning drivers may not expect contra-flow bicycle traffic	Pedestrians and turning drivers may not expect contra-flow bicycle traffic	Pedestrians and turning drivers may not expect contra-flow bicycle traffic
Intersection Operations (see Chapter 6)	May use existing signal phases; bike phase may be required depending on volumes	Typically requires additional signal equipment; bike phase may be required depending on volumes	Typically requires additional signal equipment; bike phase may be required depending on volumes	Typically requires additional signal equipment; bike phase may be required depending on volumes

EXHIBIT 2D: EXAMPLE SEPARATED BIKE LANE CONFIGURATIONS ON A TWO-WAY STREET

Corridor-level Planning Considerations	One-way SBL Pair	Two-way SBL	Median Two-way SBL
	Full access to both sides of street		
Access to Destinations	Full access to both sides of street	Limited access to other side of street	Limited access to both sides of street
Network Connectivity	Accommodates two-way bicycle travel	Accommodates two-way bicycle travel	Accommodates two-way bicycle travel
Conflict Points (see Chapter 4)	Fewer because pedestrians and turning drivers expect concurrent bicycle traffic	Pedestrians and turning drivers may not expect contra-flow bicycle traffic	Pedestrians and turning drivers may not expect contra-flow bicycle traffic, but median location may improve visibility and create opportunities to separate conflicts
Intersection Operations (see Chapter 6)	May use existing signal phases; bike phase may be required depending on volumes	Typically requires additional signal equipment; bike phase may be required depending on volumes	Typically requires additional signal equipment; bike phase may be required depending on volumes

2.5 FEASIBILITY

Space, funding and maintenance considerations should inform decisions made during the planning phase for separated bike lanes. When evaluating their feasibility, consideration should be given to various roadway reconfigurations, such as reducing the number of travel lanes, narrowing existing lanes or adjusting on-street parking.

Some configurations may only be feasible with reconstruction of the corridor. While more expensive than retrofit configurations within the existing curb lines, reconstruction provides greater opportunity to achieve recommended buffer widths and horizontal separation at intersections and conflict points (see [Chapter 4](#)). Reconstruction may have impacts on drainage and utility placement, among other considerations.

A lower-cost retrofit project (i.e., pavement markings and non-permanent separation methods such as flexible delineator posts, planters or temporary curbing) may be pursued to test a separated bike lane configuration in the near term while planning for permanent redesign of the roadway in the long term. Often these retrofit projects are implemented alongside planned roadway resurfacing to further reduce project costs.

Demonstration projects are a useful tool to introduce separated bike lanes to the public. Separated bike lanes can be piloted as demonstration projects using inexpensive, temporary materials for the buffers. Typically built as part of an ‘open



streets’ event or similar street festival, these projects are a great way for the public to experience and become familiar with the design of separated bike lanes. They are generally set up and taken down within the same day. Event staff and/or local traffic enforcement officials can be on site to supervise and provide information about the facility. Event planners should consider involving stakeholders, such as neighborhood groups or local advocacy organizations, in planning, promoting and staffing a pilot separated bike lane.

Project proponents should consider long-term maintenance costs of retrofit projects, including repairing and replacing treatments as well as compatibility with existing maintenance equipment and potential costs of increased labor (see [Chapter 7](#)).

Due to constraints within a corridor, separation may not be achievable for the entire length of the route, and it may be

necessary to install conventional bike lanes in these locations. Consideration should be given to development of project limits that create safe and seamless transitions as recommended in [Chapter 4](#).

The need for future projects to improve connections on adjacent corridors should also be noted during project development and considered in future programming.

If it is determined that separated bike lanes are an appropriate accommodation given the context, but not feasible given constraints of available space and or funding, the highest quality feasible alternative should be provided on the corridor (e.g., a shared use path, buffered bike lanes, or standard bike lanes). In these circumstances, consideration should also be given to identifying a parallel route to accommodate the ‘interested but concerned’ users (per the discussion in [Section 2.2](#)).

2.6 PUBLIC PROCESS

As with any project, effective public engagement is a critical element for the success of a separated bike lane project. When conducting public engagement on projects that include separated bike lanes, the project team should give consideration to the fact that many people may not have experience with these types of facilities. Presentations should include precedent images, videos, and/or detailed illustrations that depict the designs. As separated bike lanes appeal to a larger percentage of the population, including many people who may not identify themselves as bicyclists, it is important to communicate the benefits of these designs for all users of the roadway. As alterations to the existing cross section occur with the implementation of separated bike lanes, additional outreach with stakeholders should be considered throughout the life of the project.



2.7 ENDNOTES

- 1 Monsere, C., McNeil, N., Dill, J. (2012). Multiuser perspectives on separated, on-street bicycle infrastructure. *Transportation Research Record: Journal of the Transportation Research Board*, 2314(1), 22-30.
- 2 Transportation Planning Council Committee 5P-8. (1999). *Traditional Neighborhood Development: Street Design Guidelines*. Institute of Transportation Engineers.
- 3 Meng D. (2012). *Cyclist Behavior in Bicycle Priority Lanes, Bike Lanes in Commercial Areas and at Traffic Signals*. Department of Civil and Environmental Engineering, Northeastern University. Retrieved from <http://www.northeastern.edu/peter.furth/wp-content/uploads/2014/08/Bicyclist-Behavior-in-Bicycle-Priority-Lanes-at-Red-Lights-and-in-Bike-Lanes-in-Commercial-Areas.-Masters-Report-Dun-Meng-Manny.pdf>.
- 4 Mekuria, M., Furth, P., Nixon, H. (2012) *Low-Stress Bicycling and Network Connectivity*. Mineta Transportation Institute, MTI Report 11-19
- 5 Hummer, J., et. al. (2006). *Evaluation of Safety, Design, and Operation of Shared-Use Paths*. Federal Highway Administration. FHWA-HRT-05-137.
- 6 Ewing, R., Cervero, R. (2010). *Travel and the Built Environment - A Meta-Analysis*. *Journal of the American Planning Association*, Vol. 6, No. 3.

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3

GENERAL DESIGN CONSIDERATIONS

This chapter introduces various configurations and dimensions of separated bike lanes. It explains design treatments and other considerations that impact the safety and functionality of separated bike lanes. Refer to [Chapter 4](#) for design considerations at intersections and [Chapter 5](#) for design considerations adjacent to curbside activities such as loading, parking and bus stops.



3.1 SEPARATED BIKE LANE ZONES

The cross section of a separated bike lane is composed of three separate zones (see [EXHIBIT 3A](#) and [EXHIBIT 3B](#)):

- **Bike lane** – the bike lane is the space in which the bicyclist operates. It is located between the street buffer and the sidewalk buffer.
- **Street buffer** – the street buffer separates the bike lane from motor vehicle traffic.
- **Sidewalk buffer** – the sidewalk buffer separates the bike lane from the sidewalk.

While each zone has unique considerations, design choices in one often affects the others and may result in trade-offs that alter the utility and attractiveness of the separated bike lane cross section (see [Section 3.6](#) for evaluating trade-offs

by zone). The following general design principles should be followed with respect to the design of the zones to appeal to those who are interested in bicycling but concerned about their safety on the roadway:

- Changes in the bike lane elevation and horizontal alignment should be smooth and minimized (see [Section 3.2](#)).
- The bike lane should be wide enough to accommodate existing and anticipated bicycle volumes (see [Section 3.3.2](#)).
- The bike lane should allow passing of slower bicyclists and side by side travel, where feasible (see [Section 3.3.2](#)).
- The bike lane edges should be free from pedal and handlebar hazards (see [Section 3.3.3](#)).

- The street buffer should provide adequate horizontal and vertical separation from motor vehicles, including curbside activities like parking, loading and transit (see [Section 3.4](#)).
- The sidewalk buffer should discourage pedestrians from walking in the separated bike lane and discourage bicyclists from operating on the sidewalk (see [Section 3.5](#)).
- The sidewalk should accommodate pedestrian demand (see [Section 3.5](#)).

Additional considerations that should be evaluated for their effect on the separated bike lane cross section include drainage and stormwater management, lighting, utilities, curbside activities, landscaping and maintenance.

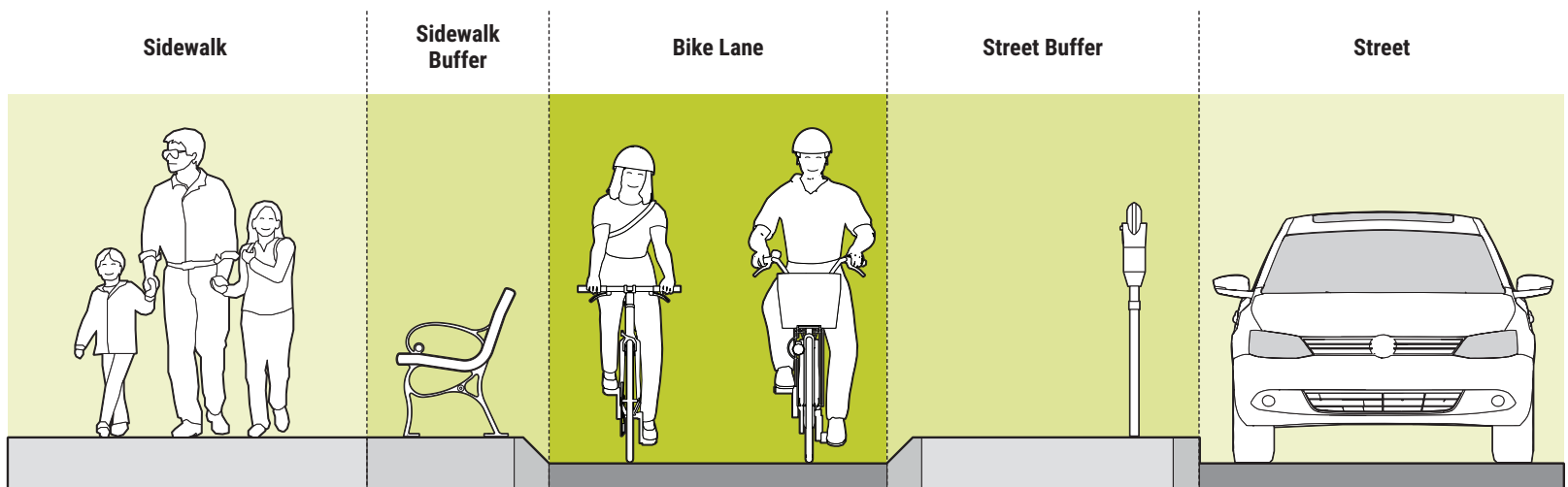


EXHIBIT 3A: Separated Bike Lane Zones

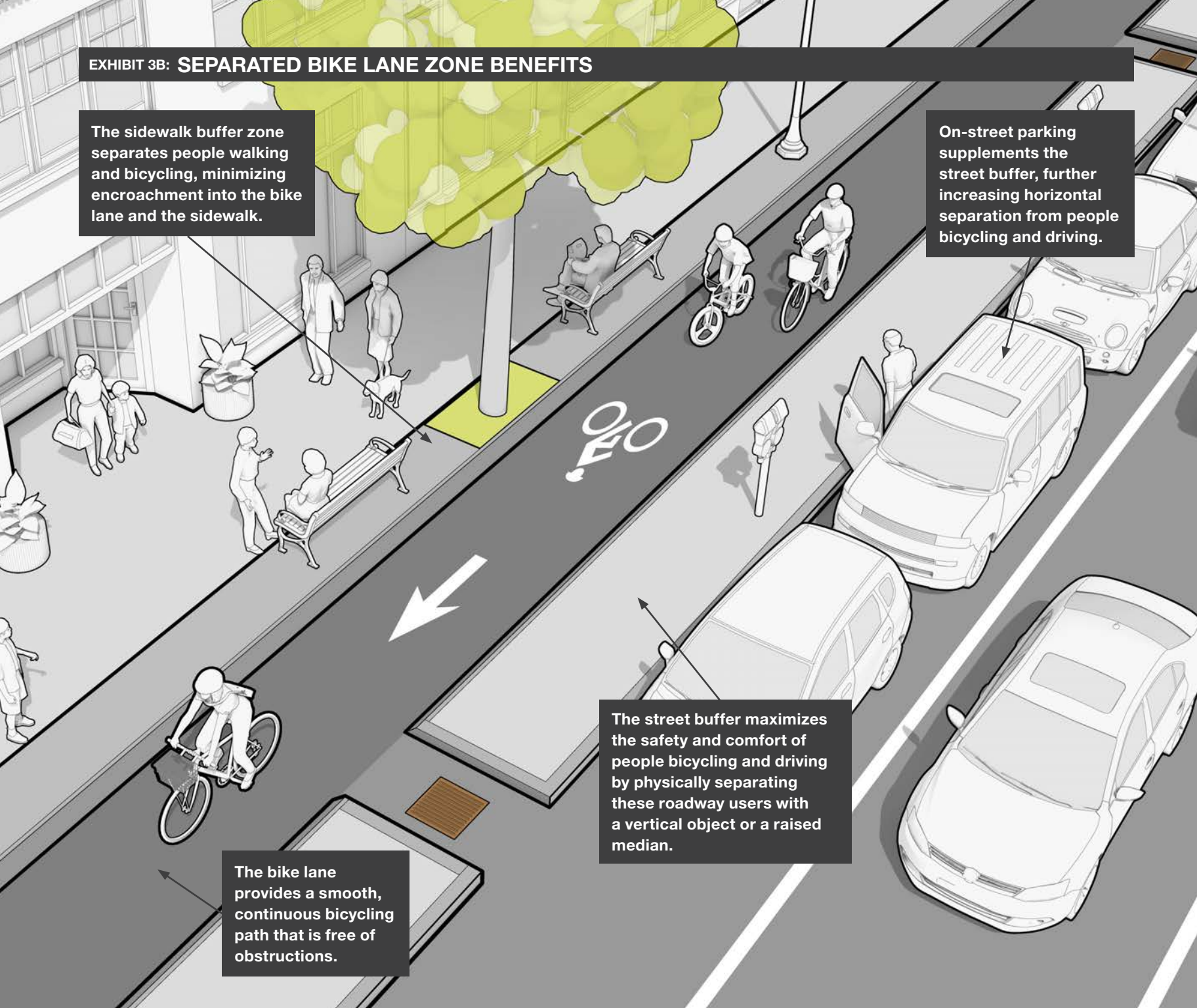
EXHIBIT 3B: SEPARATED BIKE LANE ZONE BENEFITS

The sidewalk buffer zone separates people walking and bicycling, minimizing encroachment into the bike lane and the sidewalk.

On-street parking supplements the street buffer, further increasing horizontal separation from people bicycling and driving.

The street buffer maximizes the safety and comfort of people bicycling and driving by physically separating these roadway users with a vertical object or a raised median.

The bike lane provides a smooth, continuous bicycling path that is free of obstructions.



3.2 BIKE LANE ELEVATION

Separated bike lanes may be flush with the sidewalk or street, or located at an intermediate elevation in between (see [EXHIBIT 3C](#)). Providing vertical separation between people walking and bicycling is the primary consideration for separated bike lane elevation. A separated bike lane flush with the sidewalk may encourage pedestrian and bicyclist encroachment unless discouraged with a continuous sidewalk buffer. Where used, a **2 in. minimum** change in elevation between the sidewalk and separated bike lane should be used to provide a detectable edge for the visually impaired.

The bike lane elevation may vary within a single corridor via bicycle transition ramps, rising or sinking as needed at pedestrian crossings, bus stops and intersections. It is important that a network and corridor-wide perspective is maintained during the design process, as frequent elevation changes may result in an uncomfortable bicycling environment.

Often the decision about elevation is based on physical constraints and feasibility, especially in retrofit situations where the separated bike lane is incorporated into the existing cross section. However, for new construction or substantial reconstruction, there are a number of factors to consider when deciding whether the bike lane should be at street level, sidewalk level or a level in between.

Reasons to place the bike lane at a lower elevation than the adjacent sidewalk:

- Minimizes pedestrian encroachment in the bike lane and vice versa.
- May simplify design of accessible on-street parking and loading zones (see [Chapter 5](#)).
- May enable the use of existing drainage infrastructure (see [Section 3.8](#)).

Reasons to place the bike lane at the same elevation as the adjacent sidewalk:

- Allows separation from motor vehicles in locations where the street buffer width is constrained.

- Maximizes the usable bike lane width (see [Section 3.3.3](#)).
- Makes it easier to create raised bicycle crossings at driveways, alleys or streets (see [Section 4.2.2](#)).
- May provide level landing areas for parking, loading or bus stops along the street buffer (see [Chapter 5](#)).
- May reduce maintenance needs by prohibiting debris build up from roadway run-off (see [Section 7.3.2](#)).
- May simplify plowing operations (see [Section 7.3.4](#)).

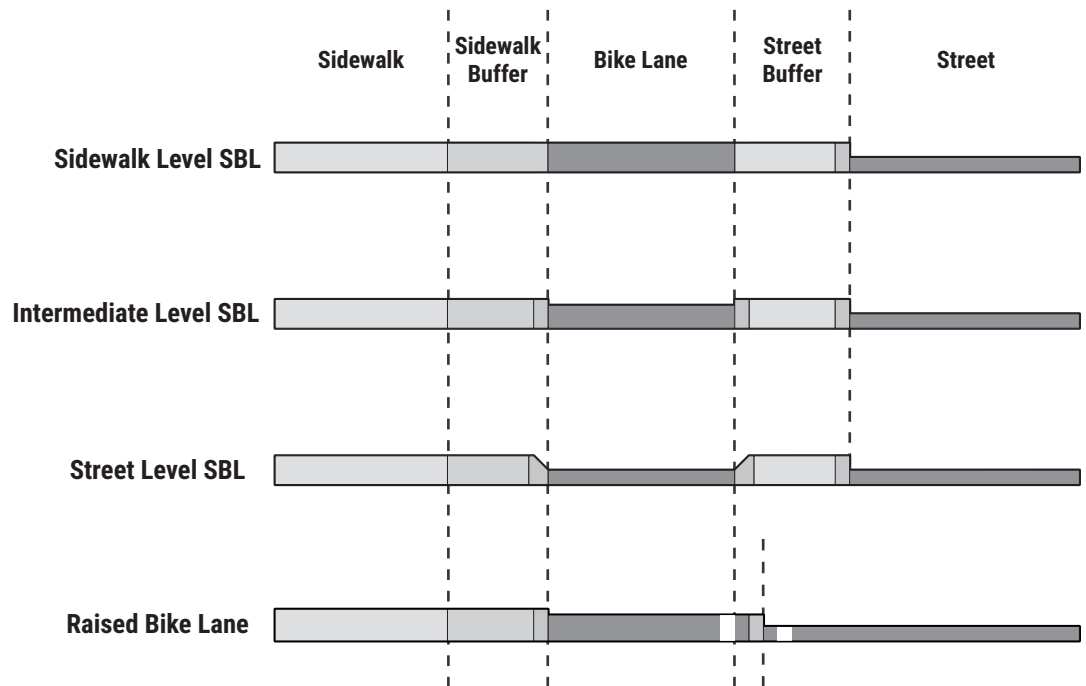


EXHIBIT 3C: Bike Lane Elevation

3.2.1 SIDEWALK LEVEL SEPARATED BIKE LANE

Sidewalk level separated bike lanes are typically separated from the roadway by a standard vertical curb (see [EXHIBIT 3D](#)). The design of sidewalk level bike lanes should provide a sidewalk buffer that discourages pedestrian encroachment into the bike lane and bicyclist encroachment onto the sidewalk. This can be achieved by providing a wide buffer, a sidewalk buffer with frequent vertical elements, or a significant visual contrast between the sidewalk and bike lane. In constrained corridors, the sidewalk level separated bike lanes may help facilitate passing maneuvers in areas of low bicycle or pedestrian volumes if a portion of either the sidewalk or street buffer space is usable by bicyclists.

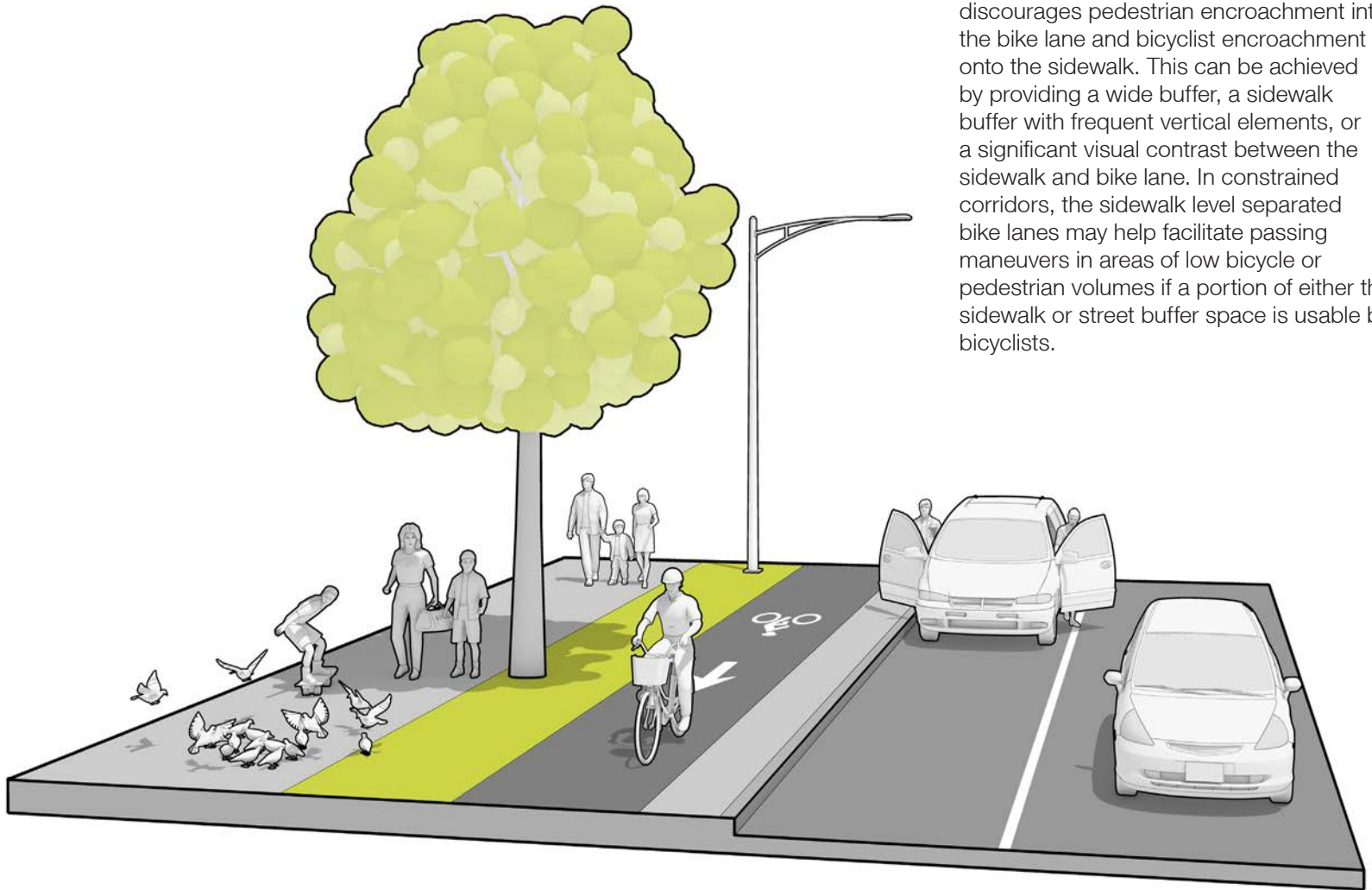


EXHIBIT 3D: Sidewalk Level Separated Bike Lane

3.2.2 STREET LEVEL SEPARATED BIKE LANE

Street level separated bike lanes are common in retrofit situations where a separated bike lane is incorporated into the existing cross section of the street (see [EXHIBIT 3E](#)). They are also used for new construction where there is a desire to provide a strong delineation between the sidewalk and the bike lane in order to reduce pedestrian encroachment in the bike lane. Street level separated bike lanes are usually compatible with accessible on-street parking and loading zones. Street level separated bike lanes may also minimize the need to relocate or reconfigure existing drainage infrastructure.

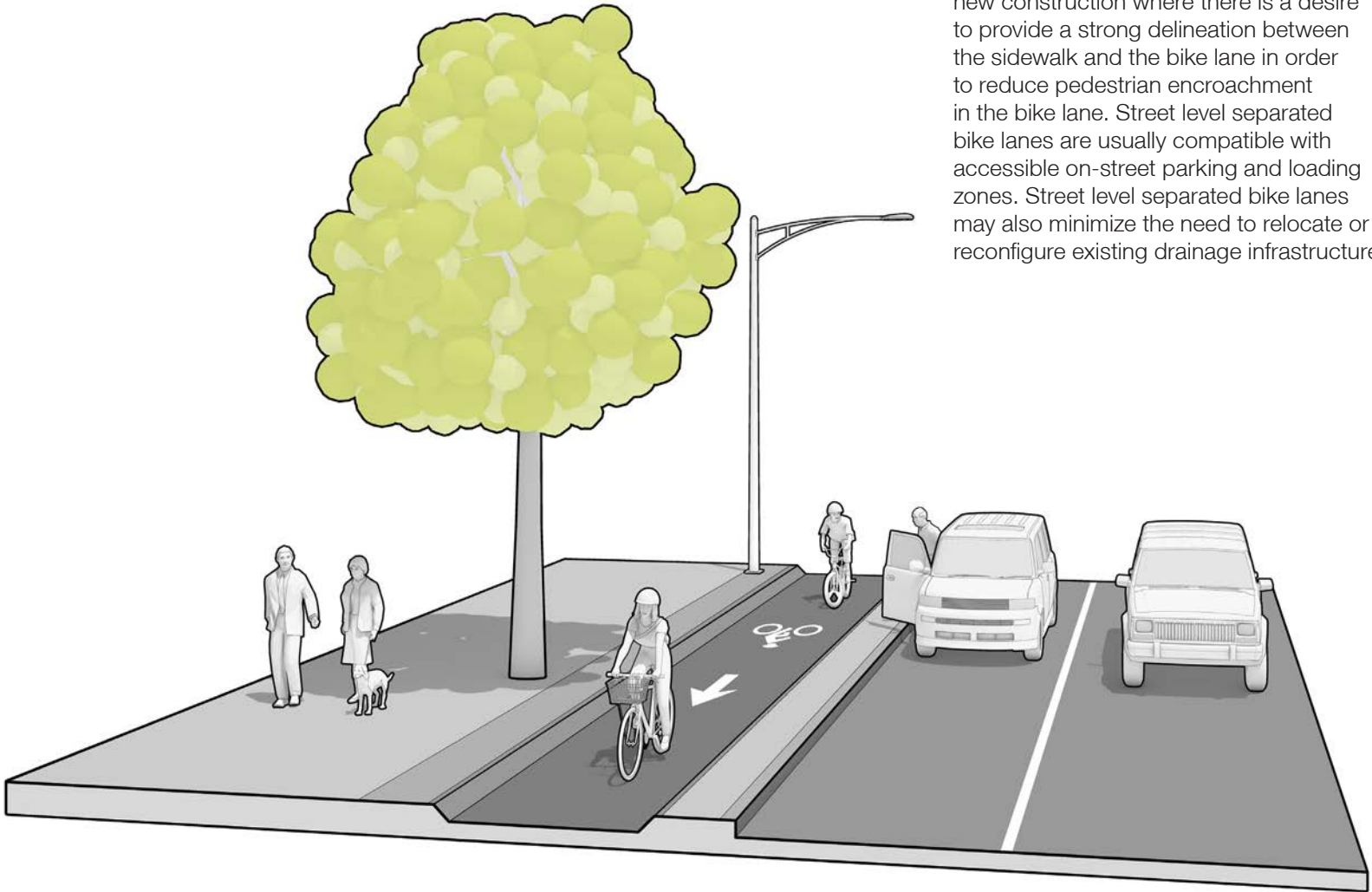


EXHIBIT 3E: Street Level Separated Bike Lane

3.2.3 INTERMEDIATE LEVEL SEPARATED BIKE LANE

Intermediate level separated bike lanes provide greater design flexibility for curb reveal and drainage (see [EXHIBIT 3F](#)). They provide many of the safety and comfort benefits of sidewalk and street level separated bike lanes, and require smaller transitions when changing elevation to and from street or sidewalk level bicycle crossings at intersections.

A curb reveal of **2-3 in.** below sidewalk level is recommended to provide vertical separation to the adjacent sidewalk or sidewalk buffer, and to provide a detectable edge for visually impaired pedestrians. Where the curb reveal is greater than **3 in.**, a beveled or mountable curb is recommended to minimize pedal strikes (see [Section 3.3.4](#)). Stormwater may drain either toward the street buffer, or to existing catch basins along the sidewalk buffer.

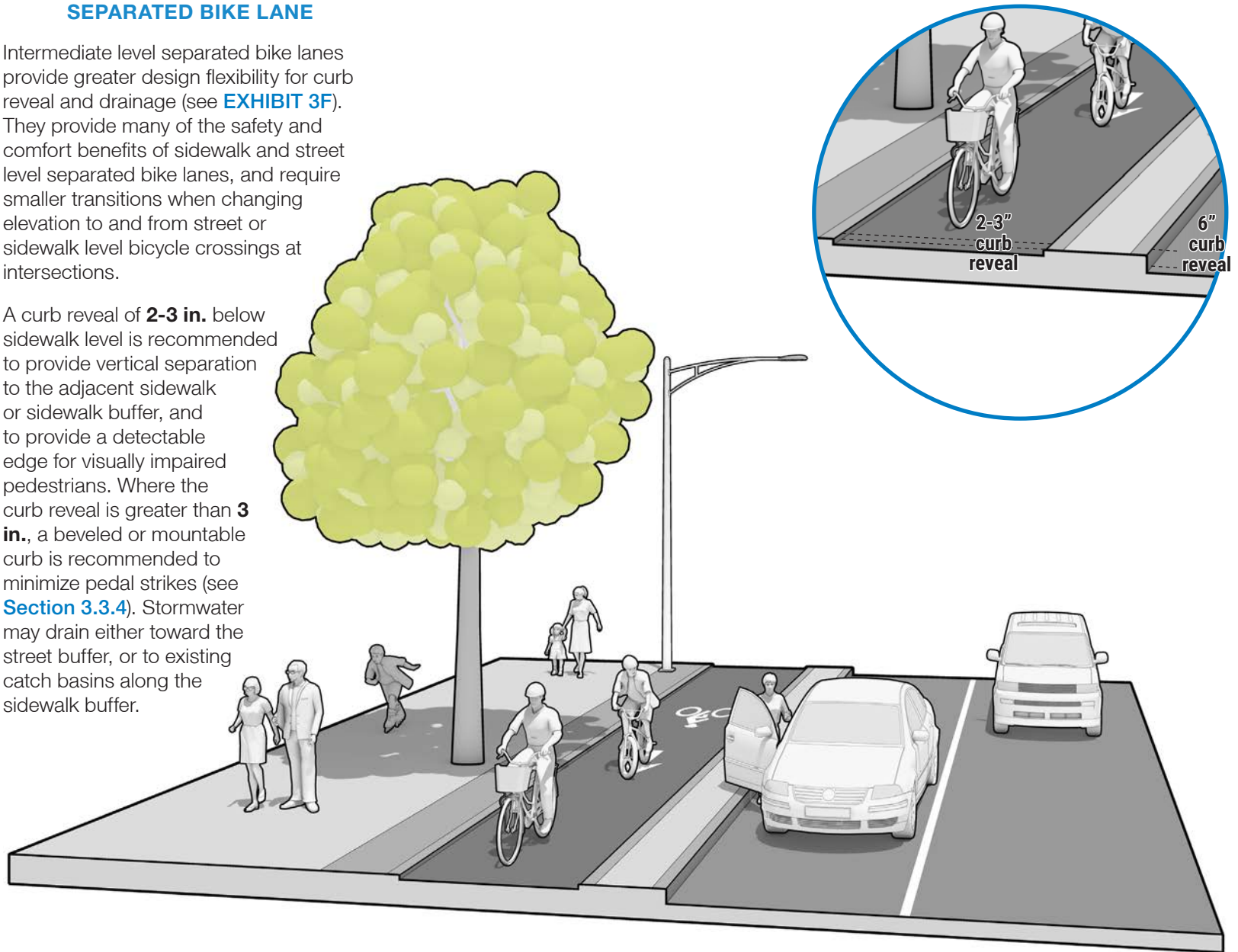


EXHIBIT 3F: Intermediate Level Separated Bike Lane

3.2.4 RAISED BIKE LANE

Like intermediate level separated bike lanes, raised bike lanes may be built at any level between the sidewalk and the street (see [EXHIBIT 3G](#)). They are directly adjacent to motor vehicle travel lanes at locations where provision of a street buffer is not feasible. Their street-facing curbs are flush with the bike lane surface and may be mountable to motorists and bicyclists. Mountable curbs are preferred if encroachment is desired, otherwise vertical curbs should be used to prohibit encroachment (see [Section 3.3.4](#)). Stormwater may drain either toward the street buffer, or to existing catch basins along the sidewalk buffer.

Raised bike lanes are only appropriate in constrained locations where the combined bike lane and street buffer width is **less than 7 ft.** and sidewalks are narrow or the sidewalk buffer is eliminated (see [Section 3.6](#)). Because of their narrow street buffer, raised bike lanes are not recommended for two-way operation or adjacent to on-street parking. Their narrow street buffer also presents snow storage challenges.

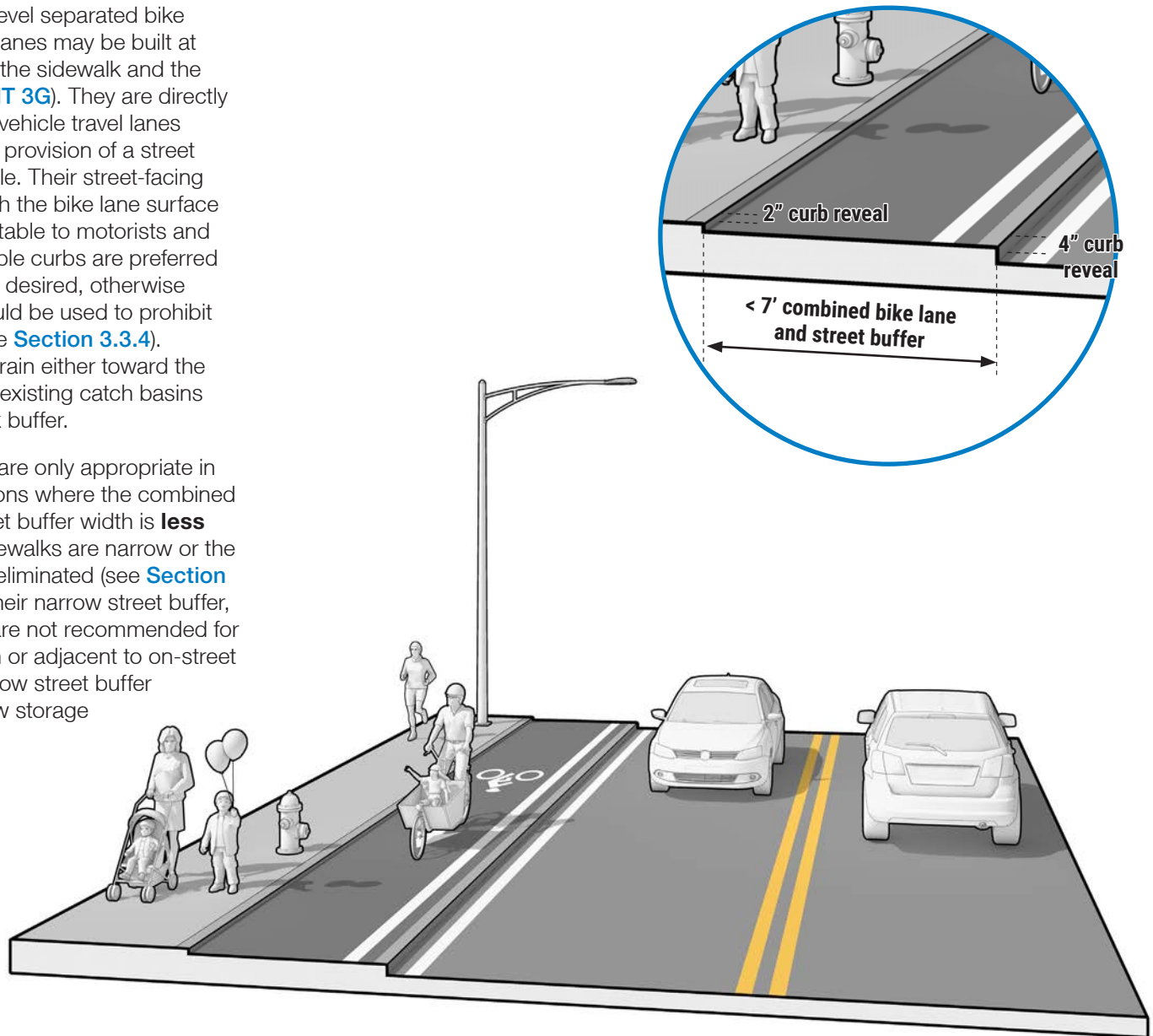


EXHIBIT 3G: Raised Bike Lane

3.3 BIKE LANE ZONE

3.3.1 BIKE LANE SURFACE

Bicyclists are sensitive to pavement defects. Asphalt is generally recommended for the surface of the bike lane zone because it provides a smooth, stable and slip resistant riding surface. If concrete is chosen, joints should be saw-cut to maintain a smooth riding surface. Subsurface preparation is critical to avoid future surface irregularities. The use of unit pavers should generally be avoided, as they require extensive subsurface preparation and are more susceptible to

becoming dislodged over time, creating hazards for people bicycling and long-term maintenance challenges.

In some cases, a permeable surface is desired. More information on permeable surfaces is found in [Section 3.8.2](#).

The bike lane should provide a smooth, continuous bicycling path and must be free from obstructions. Refer to [Section 3.8.1](#) for preferred drainage grate type and placement, and [Section 3.11](#) for recommended placement of utility covers.

In general, people operating two-wheel bicycles are not affected by the cross slope of a street. However, to maintain comfort for people bicycling with more than two wheels (e.g., cargo bike or tricycle) or with a trailer, bike lane cross slopes should not exceed **2 percent**. Gentler cross slopes are recommended where these bicycles are more common. Steeper cross slopes of up to **8 percent** are acceptable for limited distances in retrofit conditions.



3.3.2 BIKE LANE WIDTH

The decision regarding the width of the bike lane zone is impacted by the elevation of the bike lane and the volume of users. Separated bike lanes generally attract a wider spectrum of bicyclists, some of whom operate at slower speeds, such as children or seniors. Because of the elements used to separate the bike lane from the adjacent motor vehicle lane, bicyclists usually do not have the option to pass each other by moving out of the separated bike lane. The bike lane zone should therefore be sufficiently wide to enable passing maneuvers between bicyclists. On constrained corridors with steep grades for example, it may be more desirable to provide wider bike lanes on the uphill portion of the roadway than the downhill portion to enable a faster moving bicyclist to pass a slower moving bicyclist.

The bike lane zone should also be wide enough to accommodate the volume of users. For one-way separated bike lanes with low volumes of bicyclists (**less than 150 per peak hour**), the recommended width of the bike lane zone is **6.5 ft.** (see [EXHIBIT 3H](#)). This is the width needed to enable passing movements between bicyclists. In constrained conditions where the recommended width cannot be achieved, the bike lane zone can be a minimum of **5 ft.** wide. Where additional space is available, **6.5 ft.** wide passing zones should be provided.

In locations with higher volumes of bicyclists, a wider bike lane zone should be provided, as shown in [EXHIBIT 3H](#). When considering the volume of users, the designer should be aware that peak hour volumes for bicycling may not correspond to the parallel roadway motorized traffic

volumes. For example, peak bicycle activity may occur during the mid-day on a weekend if the separated bike lane connects to a popular regional trail. There may also be significant land use driven (e.g., university or school) or seasonal (e.g., summer vs. winter) variability in bicycling activity that should be considered when evaluating volume counts or projections. Lastly, when estimating future volumes of bicyclists, the designer should be aware that separated bike lanes have been documented to significantly increase bicycling once constructed over baseline conditions with shared lanes or on-road bicycle lanes.

There is more flexibility with respect to the width of the bike lane zone when it is not separated from adjacent zones with vertical curbs. When the bike lane zone is located at the same elevation as the adjacent buffer zones, the bicyclist can operate more closely to the edges of the bike lane during passing movements.



Beveled or short curbs (2-3 in.) are recommended for separated bike lanes <6.5 ft. wide (see Section 3.3.3).

Separated bike lanes <5 ft. wide and between two curbs must be raised to sidewalk level.

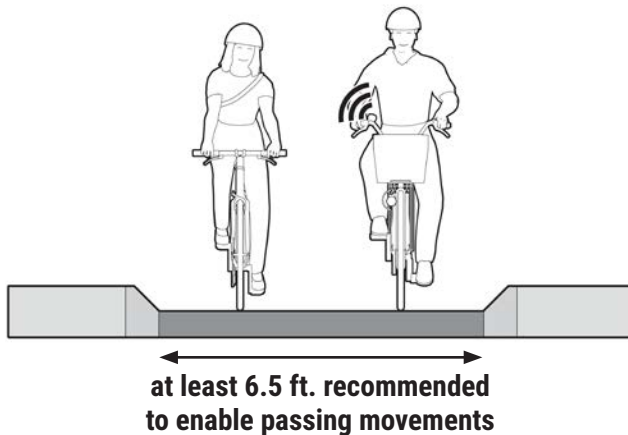
A bike lane width narrower than 5 ft. requires a design exception.

Narrower widths are not recommended in locations where there are higher volumes of pedestrians or bicyclists during peak hours. In extremely constrained conditions where the recommended or minimum width cannot be achieved, it may be acceptable to reduce the bike lane width to **4 ft.** for short distances such as around bus stops or accessible parking spaces (see [Chapter 5](#)). Separated bike lanes narrower than **5 ft.**

and between two curbs must be raised to sidewalk level.

Two-way bike lanes are wider than one-way bike lanes to reduce the risk of collisions between opposing directions of travel. For two-way bike lanes with low volumes of bicyclists (**less than 150 per peak hour**), the recommended width of the bike lane zone between two curbs is **10 ft.**

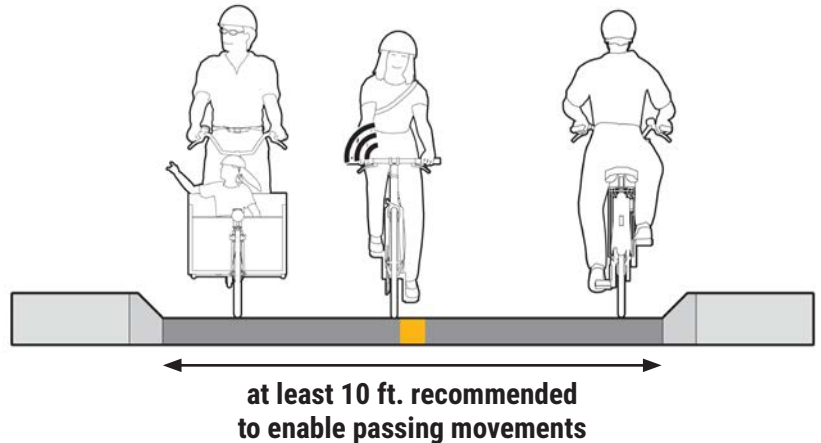
In constrained conditions where the recommended width cannot be achieved, the bike lane zone should be a minimum of **8 ft.** wide. In locations with higher volumes of bicyclists, wider two-way bike lanes should be provided to accommodate passing in the same and opposing directions of travel simultaneously, as shown in [EXHIBIT 3I](#).



Same Direction Bicyclists/ Peak Hour	Bike Lane Width (ft.)	
	Rec.	Min.*
<150	6.5	5.0
150-750	8.0	6.5
>750	10.0	8.0

* A design exception is required for designs below the minimum width.

EXHIBIT 3H: Bike Lane Widths for One-way Operation



Bidirectional Bicyclists/ Peak Hour	Bike Lane Width (ft.)	
	Rec.	Min.*
<150	10.0	8.0
150-400	11.0	10.0
>400	14.0	11.0

* A design exception is required for designs below the minimum width.

EXHIBIT 3I: Bike Lane Widths for Two-way Operation

3.3.3 SHY DISTANCE

Proximity to objects or vertical curbs along the bike lane edge can affect the operation of a separated bike lane. Bicyclists shy away from vertical obstructions to avoid handlebar or pedal strikes. The rideable surface of the bike lane is reduced when vertical objects are adjacent to the bike lane zone.

For this reason, the type of curbs adjacent to the bike lane zone is an important factor. [Section 3.3.4](#) on the following page discusses various types of curbs and their appropriate use.

Any object that is less than **36 in.** in height from the bike lane surface does not require an offset and can be directly adjacent to the separated bike lane.

Any object that is greater than or equal to **36 in.** in height from the bike lane surface should be offset from the bike lane zone. Where a curb separates the bike lane zone from the adjacent buffer zones, there should be a minimum **6 in.** offset between the face of curb and the edge of a vertical object such as a sign post or parking meter. Where there is no curb, a minimum **12 in.** offset is needed between the edge of the bike lane zone and a vertical object.

A **100 in.** vertical clearance should be maintained over the bike lane surface.



3.3.4 CURBS

The selection of appropriate curb angle and height is an important design consideration for separated bike lane zone buffers.

CURB ANGLE

The curb angle—vertical, beveled or mountable—influences the crash risk to bicyclists and ease of encroachment:

- **Vertical curbs** are designed to prohibit encroachment by motor vehicles and bicycles. They present a crash risk to people bicycling if their wheels or pedals strike the curb. They may be granite or concrete.
- **Beveled curbs** are angled to reduce pedal strike hazards for bicyclists and to ease access to the sidewalk for dismounted bicyclists. They may be granite or concrete.
- **Mountable curbs** are designed to be encroached by motor vehicles and bicycles. Their forgiving angle allows safe traversal for bicyclists and eliminates pedal strike hazards, but consumes more cross-section width that may otherwise be allocated to the bike lane or a buffer. Mountable curbs help bicyclists safely exit the bike lane without impeding other bicyclists. They may be concrete or asphalt, or constructed as a berm.

CURB HEIGHT

Curbs may be constructed at heights between **2-6 in.** from the roadway surface. Short curbs (**2-3 in.** from the roadway) of any angle eliminate pedal strike risk,

increasing the usable bike lane width by permitting bicyclists to safely ride closer to the edge of the bike lane. Note that even short vertical curbs may be unforgiving if struck by a bicycle wheel. Tall vertical or beveled curbs (**6 in.** from the roadway) discourage encroachment by motor vehicles. Mountable curbs at any height encourage encroachment.

SELECTING CURBS BY PROJECT TYPE

In retrofit situations, separated bike lanes are typically incorporated into the existing cross section of a street with standard vertical curbs. However, designers should consider curb angle and height in tandem for new construction or substantial reconstruction, as these characteristics are directly related to the safety and comfort of the separated bike lane.

- **Short curbs (2-3 in.)** are recommended adjacent to the bike lane zone to increase usable width of the bike lane and reduce pedal strike crash risks. Beveled or mountable curbs are recommended adjacent to shops and other destinations to ease access to the adjacent sidewalk. Where a taller curb along the bike lane is unavoidable (e.g., to accommodate drainage patterns), a beveled curb is recommended to somewhat mitigate pedal strike hazards.
- **Standard 6 in. vertical curbs** are recommended adjacent to motor vehicle travel lanes and on-street parking to discourage encroachment into the separated bike lane.

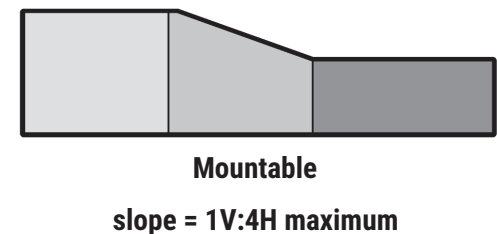
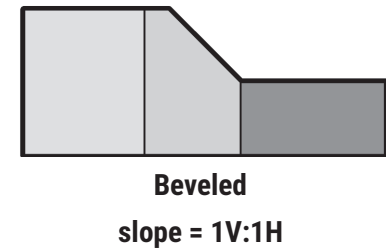
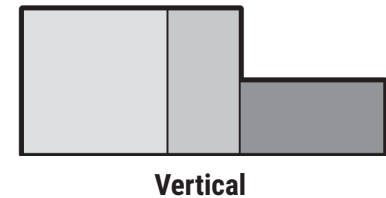


EXHIBIT 3J: Curb Profiles

3.4 STREET BUFFER ZONE

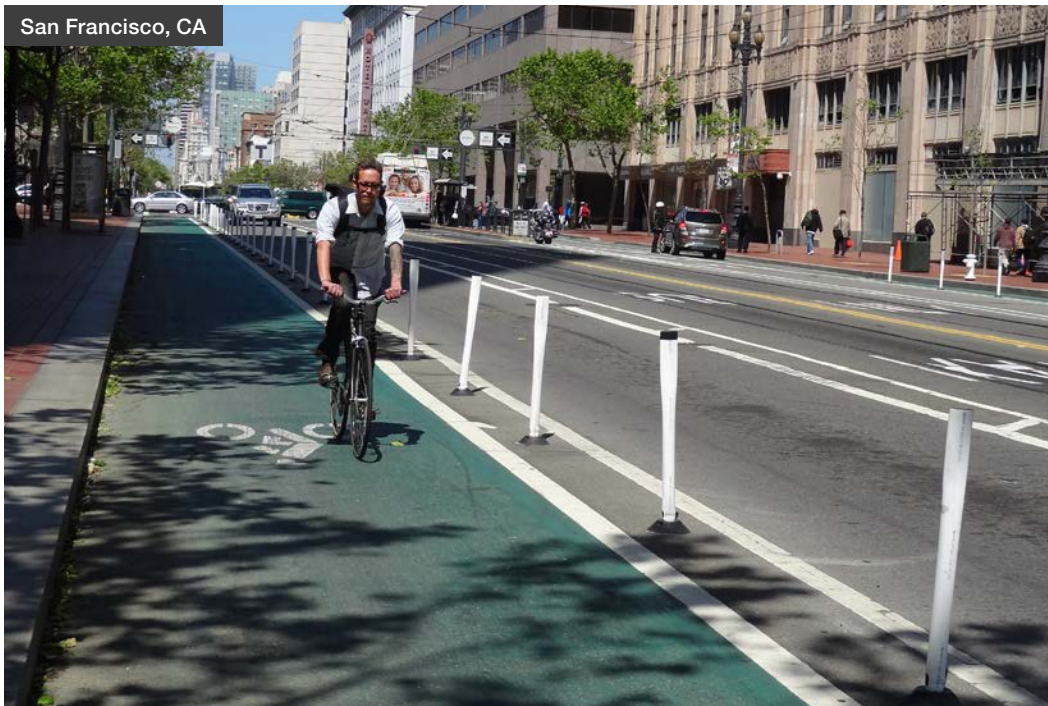
The street buffer zone is one of the most important elements of separated bike lane design. The goal of the street buffer is to maximize the safety and comfort of people bicycling and driving by physically separating these roadway users with a vertical object or a raised median. The width of the street buffer also influences intersection operations and bicyclists safety, particularly at locations where motorists may turn across the bike lane (see [Chapter 4](#)). Many factors influence design decisions for the street buffer, including number of travel lanes, motor

vehicle speeds and volumes, bike lane elevation, right-of-way constraints, drainage patterns and maintenance activities. Aesthetics, durability, cost, and long-term maintenance needs should be considered as well.

The street buffer can consist of parked cars, vertical objects, raised medians, landscaped medians, and a variety of other elements. Elements that must be accessed from the street (e.g., mailboxes) should be located in the street buffer. The minimum width of the street buffer is directly related to the type of buffer.

3.4.1 STREET BUFFER WIDTH

Central to the design of the street buffer is its width. Appropriate street buffer widths vary greatly depending on the degree of separation desired, right-of-way constraints, and the types of structures or uses that must be accommodated within the buffer. In general, the recommended width of a street buffer is **6 ft.**, regardless of the type of street buffer. Street buffers may be narrowed to a minimum of **2 ft.** in constrained conditions, or a minimum of **1 ft.** alongside a raised bike lane.



A wider street buffer may be desirable to improve bicyclists' comfort on multi-lane, higher speed roadways. Clear zone requirements for higher speed roadways may also impose additional requirements for street buffer width that should be considered (see [Section 5.6.1 of the PD&DG](#) for clear zone guidance).

In addition to providing increased physical separation mid-block, street buffers also affect bicyclists' safety at intersections, including driveways and alley crossings. Street buffer widths that result in a recessed crossing between **6 ft.** and **16.5 ft.** from the motor vehicle travel lane have been shown to significantly reduce crashes at uncontrolled separated bike lane crossings¹ (see [EXHIBIT 3K](#)). This offset improves visibility between bicyclists and motorists who are turning across their path, and creates space for motorists to yield (this is discussed in more detail in [Chapter 4](#)).

It is important that a corridor-wide perspective be maintained during the evaluation and design process, as excessive lateral changes between midblock sections and intersections may result in an uncomfortable bicycling environment. The designer will need to carefully consider intersection operations as the horizontal alignment is determined.

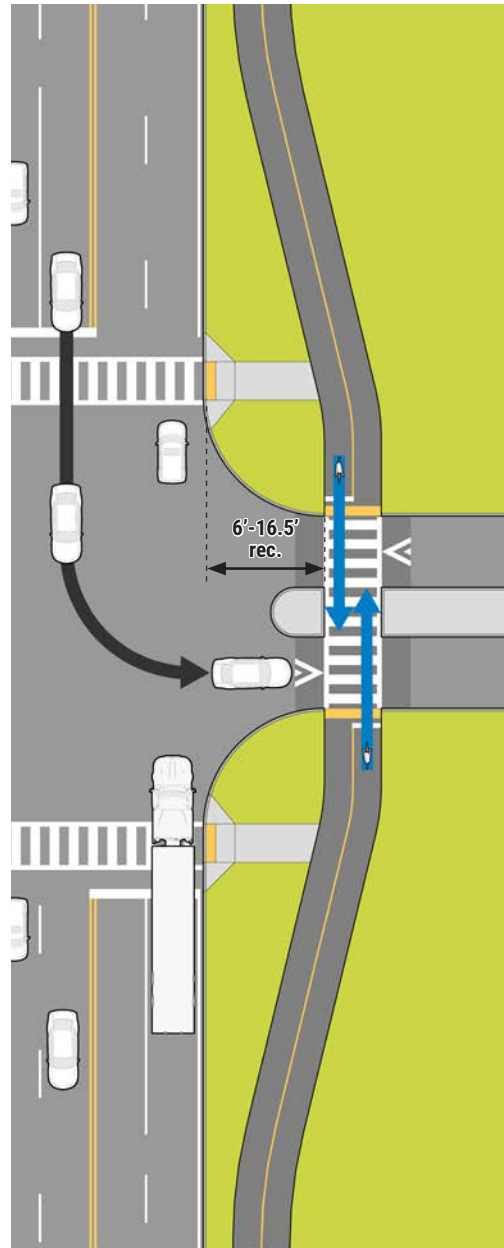


EXHIBIT 3K: Recessed Crossing at Shared Use Path Intersection

3.4.2 VERTICAL OBJECTS

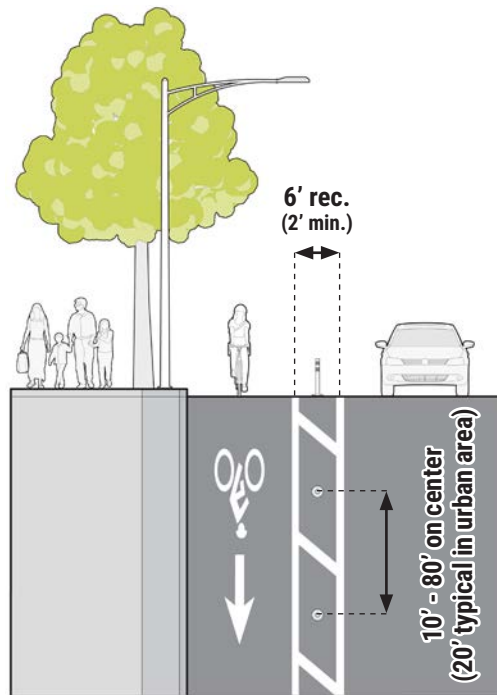
For street level separated bike lanes without a raised median, vertical objects are needed in the street buffer to provide separation. Examples of vertical objects include flexible delineator posts, parking stops, planter boxes, concrete barriers or rigid bollards (see [EXHIBIT 3L](#)). They must be supplemented with a painted median to mark the buffer (see [Section 3.7](#)). The horizontal placement of vertical objects within the buffer should consider the need for shy distance to the bike lane and to the travel lane. Preference should be given to locating the vertical object to maximize the width of the bicycle lane.

It may be necessary to utilize more frequently spaced vertical objects where motor vehicle encroachment in the bike lane is observed or anticipated. Where on-street parking is located adjacent to the street buffer, it may not be necessary to provide vertical objects to improve separation, except in locations where parking is absent, such as near intersections. Exceptions include locations where on-street parking is prohibited for portions of the day, commercial areas where on-street parking turnover is high, or locations where parking demand is low.

EXHIBIT 3L: VERTICAL OBJECTS IN THE STREET BUFFER ZONE

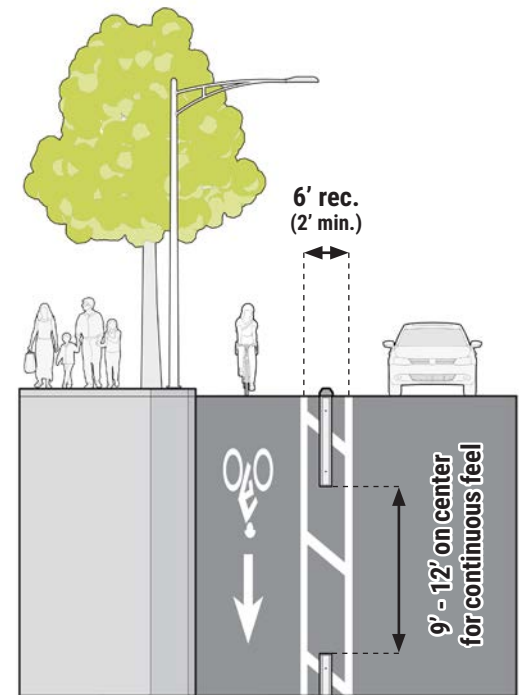
Capital costs for vertical objects are typically lower than raised medians, making them ideal for retrofit projects. However, vertical objects may require routine maintenance and replacement, increasing long-term costs. Some vertical objects may be temporarily removed to accommodate standard sweeping and snow clearance (see [Section 7.3](#)). Most vertical objects are non-continuous, which facilitates positive drainage along the established roadway crown to existing catch basins.

Ensuring the vertical separation is visible to approaching bicyclists and motorists should be considered. Vertical objects in the street buffer are considered delineators and must be retroreflective, per the MUTCD.



Flexible Delineator Posts

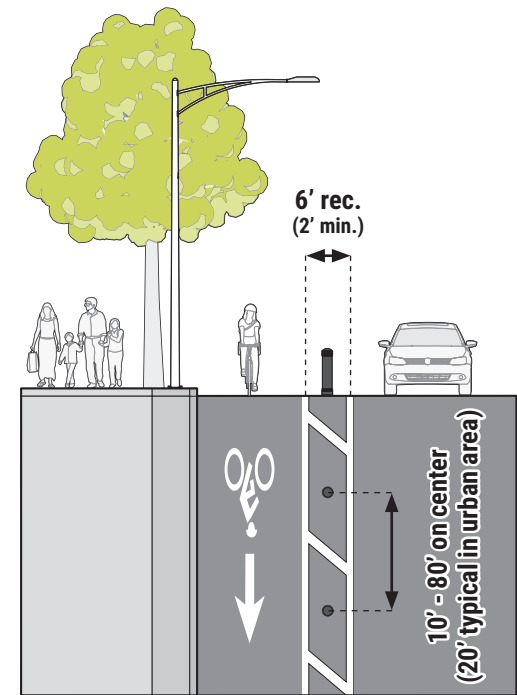
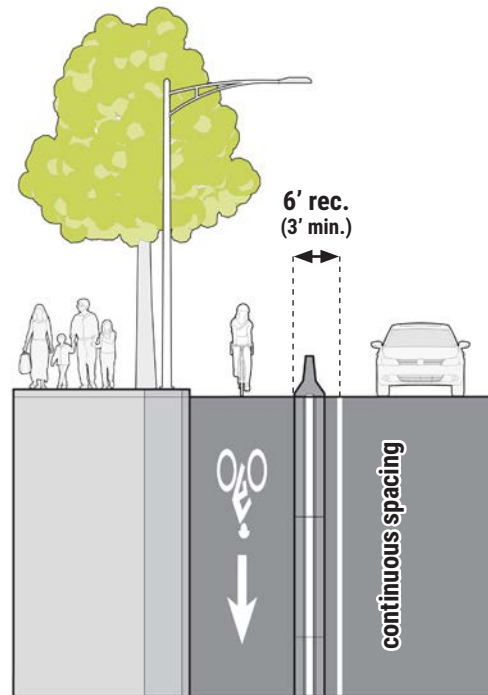
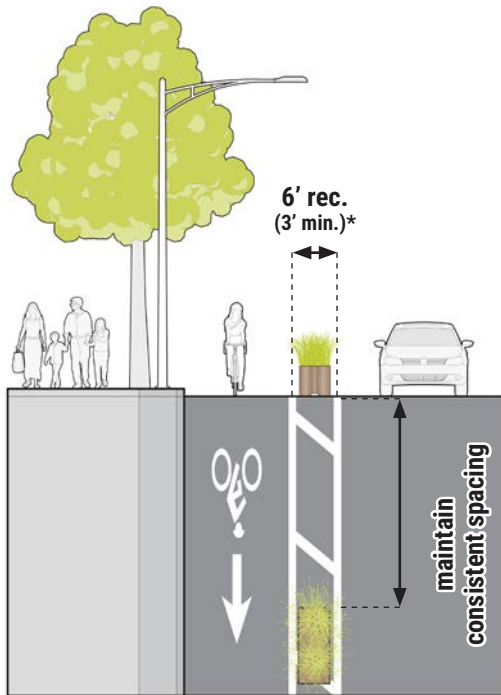
- Removable
- Lowest initial capital costs
- May require closer spacing where parking encroachment is likely
- Small footprint compatible with variety of buffer designs
- Low durability
- May need routine replacement, increasing long-term maintenance costs.



Parking Stops

- Maintain consistent spacing between parking stops
- Removable
- Highly durable
- May need supplemental vertical objects or on-street parking to increase visibility

EXHIBIT 3L: VERTICAL OBJECTS IN THE STREET BUFFER ZONE (CONTINUED)



Planter Boxes

- Removable
- May be closely spaced for near-continuous vertical separation
- Can be used to enhance community aesthetics
- May serve as a gateway treatment
- May be incompatible with clear zone requirements for roadways with higher motor vehicle speeds
- Plants require routine care, increasing long-term maintenance costs

* Buffer may need to be wider when adjacent to on-street parking to accommodate an open motor vehicle door.

Concrete Barriers

- Provides continuous vertical separation
- Highly durable
- Recommended for locations where physical protection from motor vehicles is needed, for example on bridges with high speed traffic
- May need crash cushion at barrier ends
- Incompatible with on-street parking

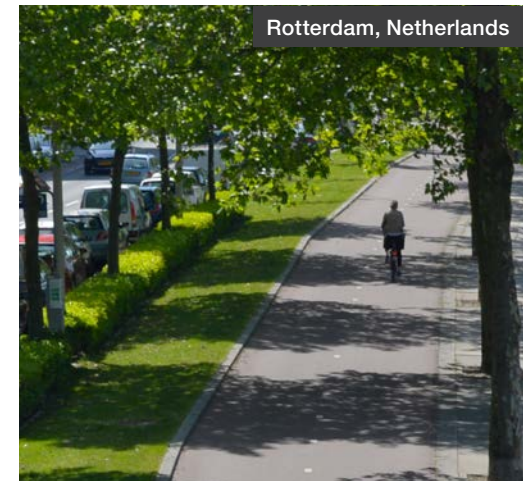
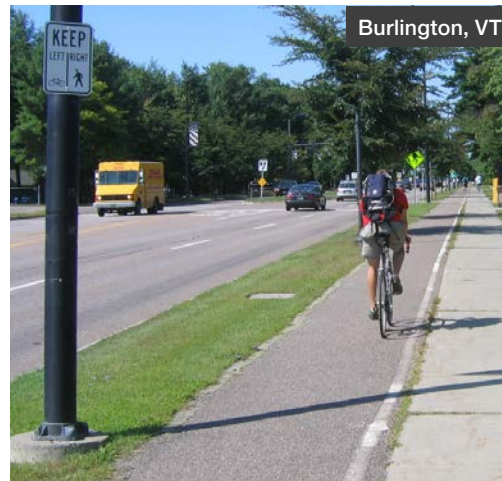
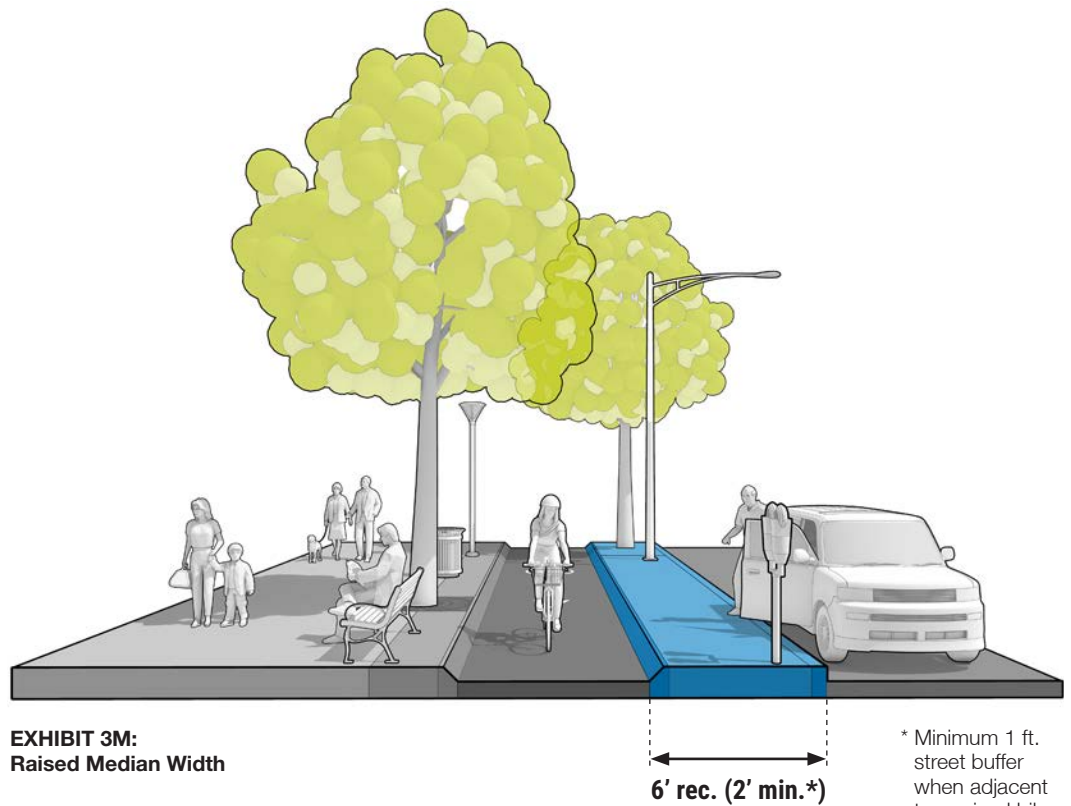
Rigid Bollards

- Typically permanent
- Higher capital cost
- May require closer spacing where parking encroachment is likely
- May be incompatible with clear zone requirements for roadways with higher motor vehicle speeds
- Refer to MUTCD 3H.01 for color and retroreflectivity specifications
- Removable rigid bollards may require substantial maintenance

3.4.3 RAISED MEDIANS

A raised median provides curb separation from motor vehicles (see [EXHIBIT 3M](#)). Raised medians offer a high degree of design flexibility: they are compatible with street, intermediate and sidewalk level separated bike lanes as well as a variety of street furniture and landscaping treatments. They are typically continuous but may include curb cuts for drainage gaps. Capital costs for raised medians are often higher than vertical objects, but their high durability requires less long-term maintenance.

A **2-3 in.** curb is recommended along the bike lane zone to reduce pedal strike hazards and encourage full use of the bike lane width; where a taller curb is required along the bike lane, a beveled curb is recommended to mitigate pedal strike hazards (see [Section 3.3.4](#)). A standard **6 in.** vertical curb facing the street is recommended to discourage motor vehicle encroachment in the bike lane.



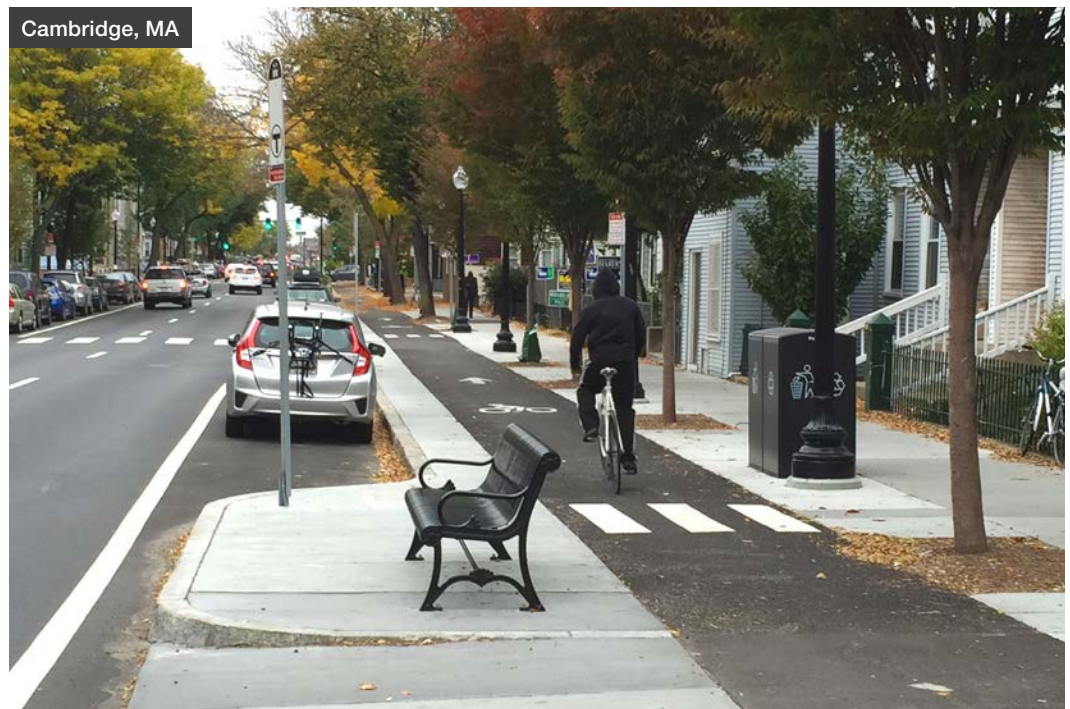
3.5 SIDEWALK BUFFER ZONE

The sidewalk buffer zone separates the bike lane from the sidewalk. It communicates that the sidewalk and the bike lane are distinct spaces. By separating people walking and bicycling, encroachment into these spaces is minimized and the safety and comfort is enhanced for both users. Design strategies for the sidewalk buffer include object separation (e.g., street furniture or landscaping), curb separation or visual separation (i.e., variation of surface materials). The design team may use a combination of these strategies, for example supplementing street furniture with brick or unit pavers.

Physical separation with street furniture, landscaping or other objects is recommended for the sidewalk buffer provided that an accessible path of travel and sufficient sidewalk width is maintained for unobstructed pedestrian flow.

In constrained locations where physical separation is desirable because of moderate to high pedestrian demand, for example town centers and urban areas, curb separation is preferable to ensure pedestrians do not walk in the bike lane, and bicyclists do not ride on the sidewalk. However it is also possible to achieve the desired separation when the sidewalk and bike lane are at the same elevation and are directly adjacent to each other by providing a high degree of visual contrast between the two. This can be accomplished through the utilization of different materials for each zone, stained surfaces, or applied surface colorization materials.

- Sidewalks must provide a **4 ft. minimum continuous and unobstructed clear width, excluding the width of the curb.**
- **A sidewalk width narrower than 5 ft. excluding the width of the curb requires a design exception. Wider sidewalks ranging from 6 ft. to 20+ ft. are recommended for town centers and urban areas (see Section 5.3.1 of the PD&DG).**
- **Shy distances to objects and curbs may impact the usable width of the bike lane (see Section 3.3.3) and the sidewalk (see Section 5.3.1 of the PD&DG).**
- Maintain adequate offsets between objects (e.g., trees, streetlights, hydrants, etc.) and locations (e.g., driveways, loading zones, transit stops and intersections).
- Refer to local streetscape and historic district guidelines for recommended sidewalk buffer materials.
- Sidewalk buffer may utilize permeable pavers to assist with on-site stormwater management (see Section 3.8.2).



3.6 DETERMINING ZONE WIDTHS IN CONSTRAINED CORRIDORS

When designing separated bike lanes in constrained corridors, designers may need to minimize some portions of the cross section, including separated bike lane zones, to achieve a context-sensitive design that safely and comfortably accommodates all users.

3.6.1 CONSIDERATIONS FOR MINIMIZING ZONE WIDTHS

Designers should initially consider reducing the number of travel lanes, narrowing existing lanes or adjusting on-street parking. **1** Space captured from these uses can be allocated to separated bike lane zones. If needed, designers should

then consider minimizing the width of the separated bike lane and associated buffer and sidewalk zones.

The sidewalk **2** should accommodate pedestrian demand (see [Section 3.5](#) for minimum and recommended sidewalk widths). All sidewalks must meet accessibility requirements of the Americans with Disabilities Act (ADA) and the Massachusetts Architectural Access Board (AAB). When narrowing the sidewalk buffer, **3** appropriate separation between the sidewalk and the bike lane should be provided, preferably through vertical separation (see [Section 3.5](#)). Where pedestrian demand is low, consider a shared use path in lieu of a separated bike lane (see [Section 2.4.2](#)).

The street buffer **4** is critical to the safety of separated bike lanes, therefore narrowing or eliminating it should be

avoided wherever possible. Providing a larger buffer at intersections can be achieved by tapering the bike lane toward the sidewalk as it approaches the intersection. In this case, sidewalk buffer width is transferred to the street buffer as the bike lane shifts toward the sidewalk. For example, a cross section with a **4 ft.** sidewalk buffer and a **2 ft.** street buffer at mid-block can transition to a cross section with no sidewalk buffer and **6 ft.** street buffer at the intersection (see [Section 4.3.2](#)). If appropriate, designers may consider a raised bike lane to further reduce the street buffer width (see [Section 3.2.4](#)).

If necessary, designers may also use the minimum bike lane width **5** for the appropriate bicycle volume threshold (see [Section 3.3.2](#)).

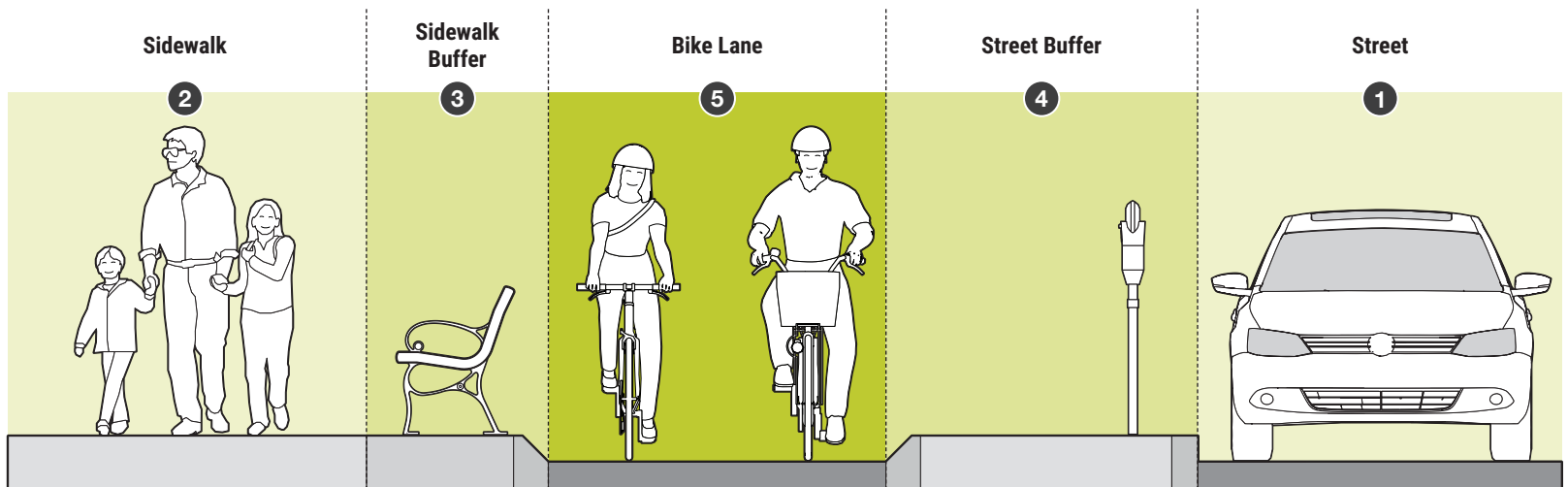


EXHIBIT 3N: Considerations for Minimizing Zone Widths

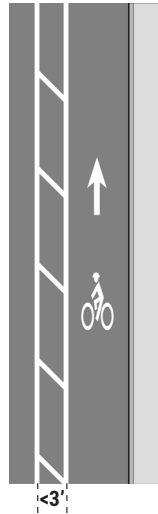
3.7 PAVEMENT MARKINGS AND SIGNS

Standard bike lane symbols and arrows may be provided in separated bike lanes (see [EXHIBIT 30](#)). In some cases, the size of the symbols and arrows may be reduced to fit within the lane. Two-way separated bike lanes should have yellow centerlines: dotted to indicate where passing is permitted and solid to indicate where passing is undesirable. Green markings or surface colors should be reserved for conflict points including driveways and intersections, which are further detailed in [Chapter 4](#). It may be desirable to demarcate the edges of vertical curbs or other objects with solid white edge lines on either side of the bike lane to improve night time visibility. Street level painted medians must be marked with diagonal cross hatching or, if **3 ft. or wider**, chevrons.

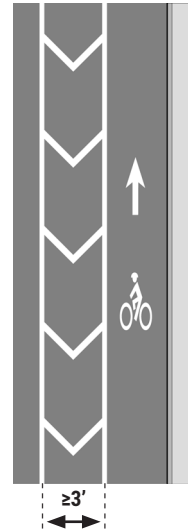
See [Section 5.4 of the AASHTO Bike Guide](#), [Chapter 5 of the FHWA Separated Bike Lane Planning and Design Guide](#) and [Chapter 9 of the MUTCD](#) for additional guidance on the use of pavement markings for midblock locations.

Standard bike lane signage is not required to identify the separated bike lane; however, the R9-7 sign may be considered for locations with sidewalk level separated bike lanes to further communicate the appropriate use of each space. Wayfinding signage should be provided in accordance with MUTCD and local standards.

Cross Hatching



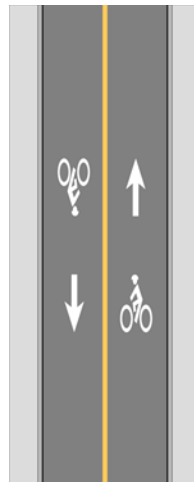
Chevrons



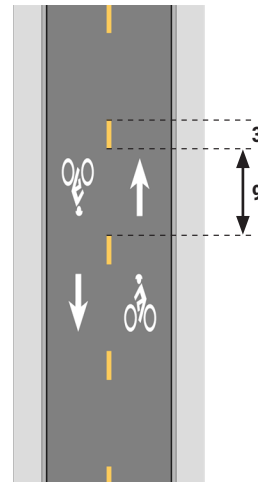
MUTCD R9-7



Two-way SBL/Path Passing Prohibited



Two-way SBL/Path Passing Permitted



Raised Bike Lane Edge Line



EXHIBIT 30: Mid-block Pavement Markings and Signs

3.8 DRAINAGE AND STORMWATER MANAGEMENT

Providing proper drainage as part of separated bike lane projects enhances the safety and comfort of all users by reducing water ponding and the accumulation of debris. Proper drainage also protects the longevity of the roadway infrastructure and ensures that drainage features are adequate to accommodate MassDOT requirements to manage stormwater and minimize erosion.

Runoff from bike lanes must also be properly managed to minimize the environmental impacts associated with urban runoff and to meet current regulatory requirements, including applicable Massachusetts Stormwater Management Standards to the maximum extent practicable (see MassDOT's drainage design guidelines in [Chapter 8 of the PD&DG](#), and in [MassDOT's Stormwater Handbook for Highways and Bridges](#)).

3.8.1 DRAINAGE PATTERNS

Many factors influence the decision to manage the flow of stormwater from paved bike lanes. In urban areas, stormwater may

need to be directed toward the sidewalk buffer, street buffer or both, depending on the elevation of the separated bike lane (see [Section 3.2](#)), the presence of a raised median in the street buffer (see [Section 3.4.3](#)), the locations of existing catch basins and utilities, and the project budget. Illustrative separated bike lane drainage patterns for urban areas are shown in [EXHIBIT 3P](#). In suburban and rural areas, the preferred practice would be to direct runoff onto adjacent vegetated areas, where soils and slopes allow for runoff to naturally infiltrate (a practice known as 'pavement disconnection'). Alternatively, other 'green infrastructure' practices can be considered (see [Section 3.8.2](#)).

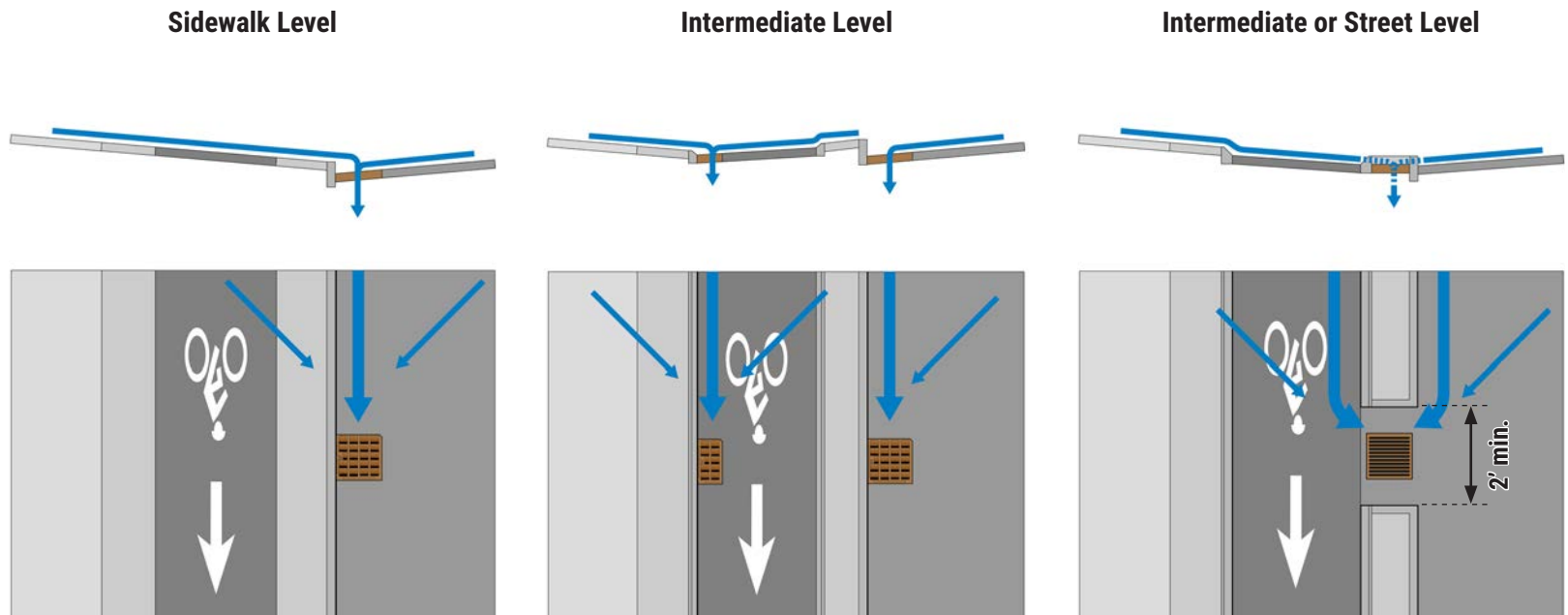


EXHIBIT 3P: Examples of Separated Bike Lane Drainage Options

Where such green infrastructure designs are impracticable, it is recommended to connect into closed drainage systems where they exist. For sidewalk and intermediate level separated bike lanes, new catch basins and/or trunk conveyance systems in the street or sidewalk buffers may be required to connect to existing trunk lines. For street level separated bike lanes, gaps between vertical objects or openings in raised medians may be used to channelize stormwater across the street buffer towards existing catch basins along the sidewalk

Drainage design for separated bike lanes should follow general design principles outlined in the PD&DG and the MassDOT Stormwater Handbook.

buffer. These median cuts may be open channels or covered with steel plates. Steel plates should be considered in areas where parallel parking is proposed and should meet **AASHTO HS20** loading conditions to accommodate traversing people.

Where the roadway will drain across the bike lane, the design team should consider supplementary catch basins in the street buffer or more frequent raised median curb cuts to control the speed and spread of flow of water along the roadway and

within the separated bike lane. Spread of flow within the roadway should follow the guidance provided in **Chapter 8 of the PD&DG**; however, spread of flow (and velocity) within the bike lane should consider the volume of bicyclists, the depth of flow within the bike lane, and the potential for the accumulation of debris or ice associated with larger stormwater spreads. Low points should be specifically considered for curbed street-level facilities to address safety and drainage issues associated with the spread of flow within the bike lane.

Drainage grates should be located outside of the bike lane whenever feasible to maintain a comfortable riding surface. However, grate location will largely be determined by the location of existing catch basins. When their placement in the bike lane cannot be avoided, drainage grates must be bicycle-friendly (e.g., hook lock cascade grates as noted in **Engineering Design Directive E-09-002**). Designers should consider narrower grates in the bike lane, as illustrated in **EXHIBIT 3P**, or eliminating bike lane grates in favor of trench grates in buffer areas or curb inlets.

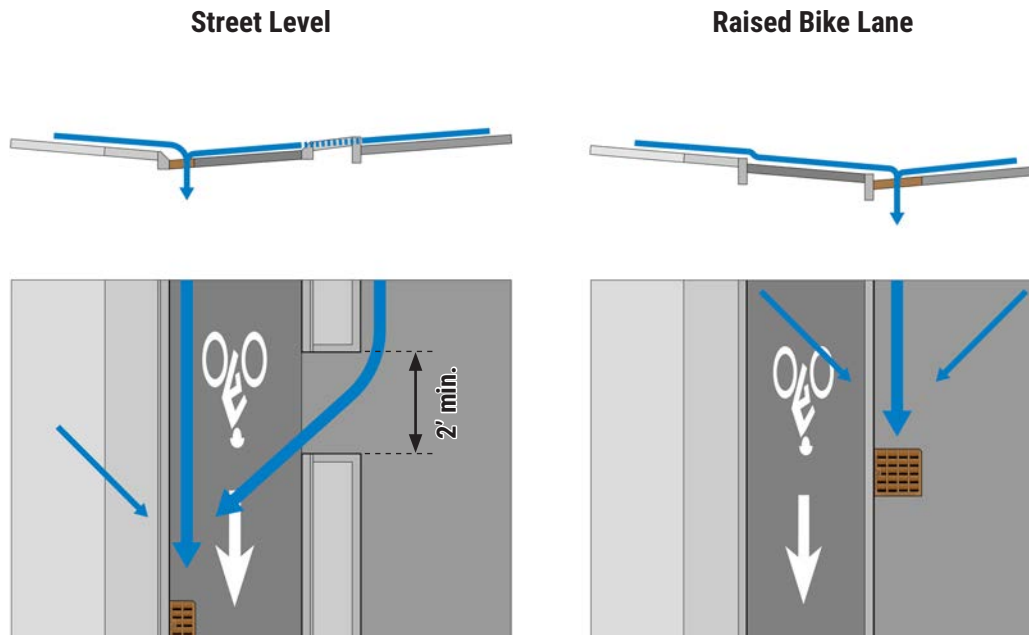


EXHIBIT 3P: Examples of Separated Bike Lane Drainage Options (Continued)

3.8.2 GREEN STORMWATER INFRASTRUCTURE

Green stormwater infrastructure increases infiltration of water back into the ground, which improves water quality and reduces flooding. The addition of separated bike lanes to a roadway presents an opportunity to introduce stormwater management strategies, including continuous treatments (e.g., permeable hardscape surfaces, linear bioretention areas, and linear water quality swales) and those that may only be implemented at spot locations (e.g., bioretention areas, bioretention curb extension area, and tree boxes) (see [EXHIBIT 3Q](#)). Their inclusion into the design of separated bike lanes is both a functional use of buffer areas and a sustainable way to enhance corridor aesthetics.

The design team should consider project objectives, regulatory requirements, maintenance requirements, cost-effectiveness of treatments, and the location of existing utilities, buildings and other physical features when screening and selecting stormwater treatments. The opportunities to include green stormwater infrastructure will largely be determined by the available street buffer or sidewalk buffer width; as such, the widths of these buffers

should be a significant consideration during the design of the separated bike lane and the stormwater management planning.

In addition to buffer areas, the use of permeable asphalt or concrete may be considered for the bike lane zone. By facilitating gradual absorption of water into the ground, permeable pavement can

increase bike lane traction and reduce icing by providing an outlet for standing water, provided that the surface is vacuumed periodically to remove dirt and debris.

It is preferred to maintain natural drainage patterns through the use of vegetated swales and medians in rural and lower-density suburban areas that lack curbing or drainage systems (see [Section 3.9.2](#)).

The addition of separated bike lanes into a roadway presents an opportunity to introduce 'green infrastructure' stormwater management strategies.

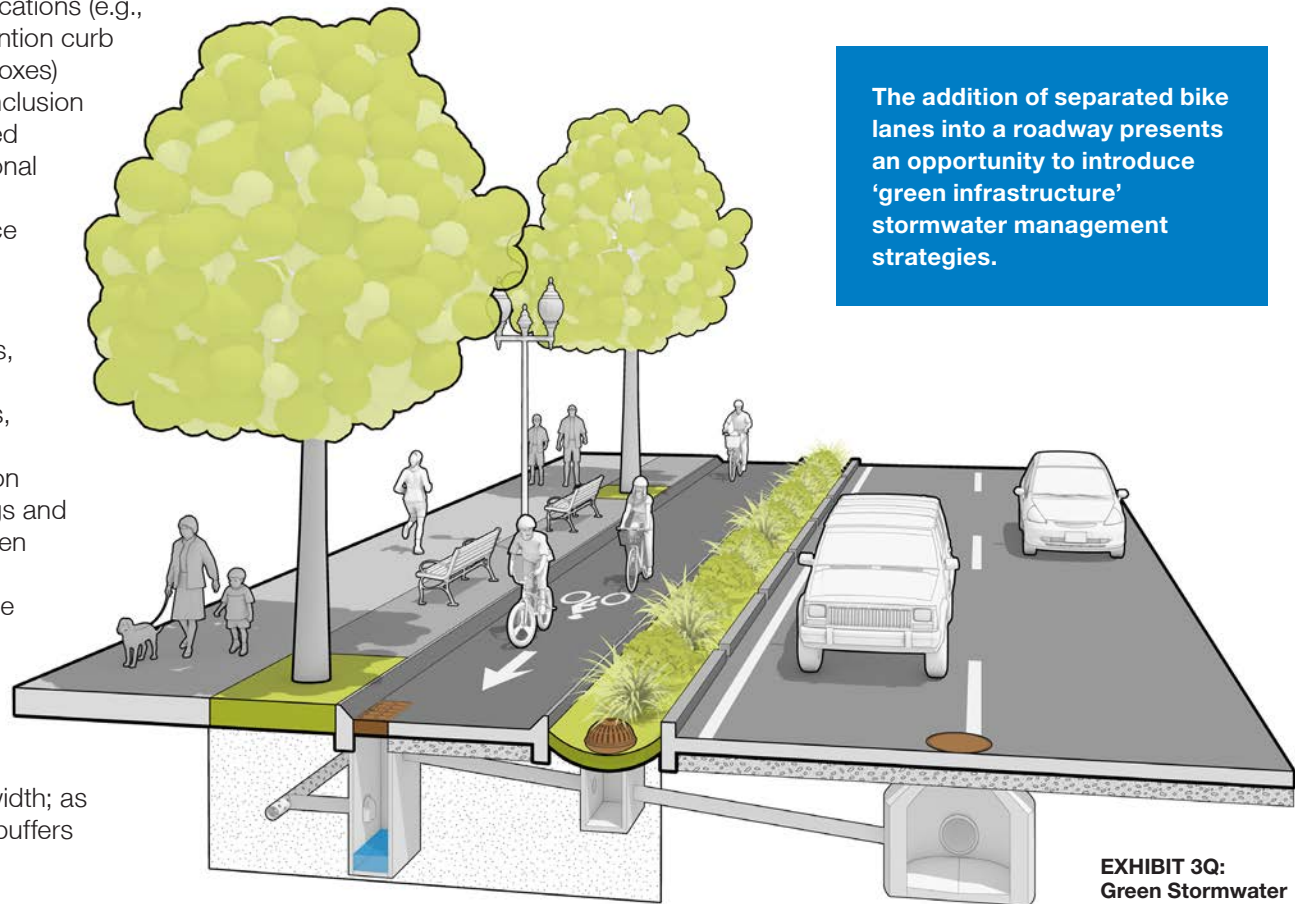


EXHIBIT 3Q:
Green Stormwater
Infrastructure
Options

3.9 LANDSCAPING

Well-designed landscaping—trees, shrubs and grasses—alongside separated bike lanes creates a more pleasant bicycling environment, improves community aesthetics and provides a traffic calming benefit by visually narrowing the roadway. Buffer designs should incorporate native species whenever possible. Landscaping, including defining maintenance roles, should be coordinated during preliminary design stages. Refer to [Chapter 13 of the PD&DG](#) for comprehensive landscape design guidance.

3.9.1 LANDSCAPING ON ROADWAYS THROUGH DEVELOPED AREAS

Street trees are the primary considerations for landscape design along separated bike lanes in urban and well-developed suburban environments. With respect to the separated bike lane cross section, trees may be located in the street or sidewalk buffers. The street buffer is the recommended tree planting location to preserve usable sidewalk width and enhance separation, but the sidewalk buffer may be considered to provide shade for the sidewalk or where the street buffer is too narrow (see [EXHIBIT 3R](#)).

- When selecting tree species, ensure compatibility with the bicyclist operating height (100 in. from bike lane surface to tree branches). Avoid shallow rooted species and species that produce an abundance of fruits, nuts and leaf litter. Properly designed tree trenches, tree pits or raised tree beds can support root growth to preserve pavement quality of the adjacent separated bike lane.
- Where on-street parking is present, intermittent curb extensions with street trees between parking spaces can preserve sidewalk space and visually narrow the roadway for traffic calming.
- Integrate tree plantings with stormwater management techniques, including permeable surface treatments (see [Section 3.8.2](#)).

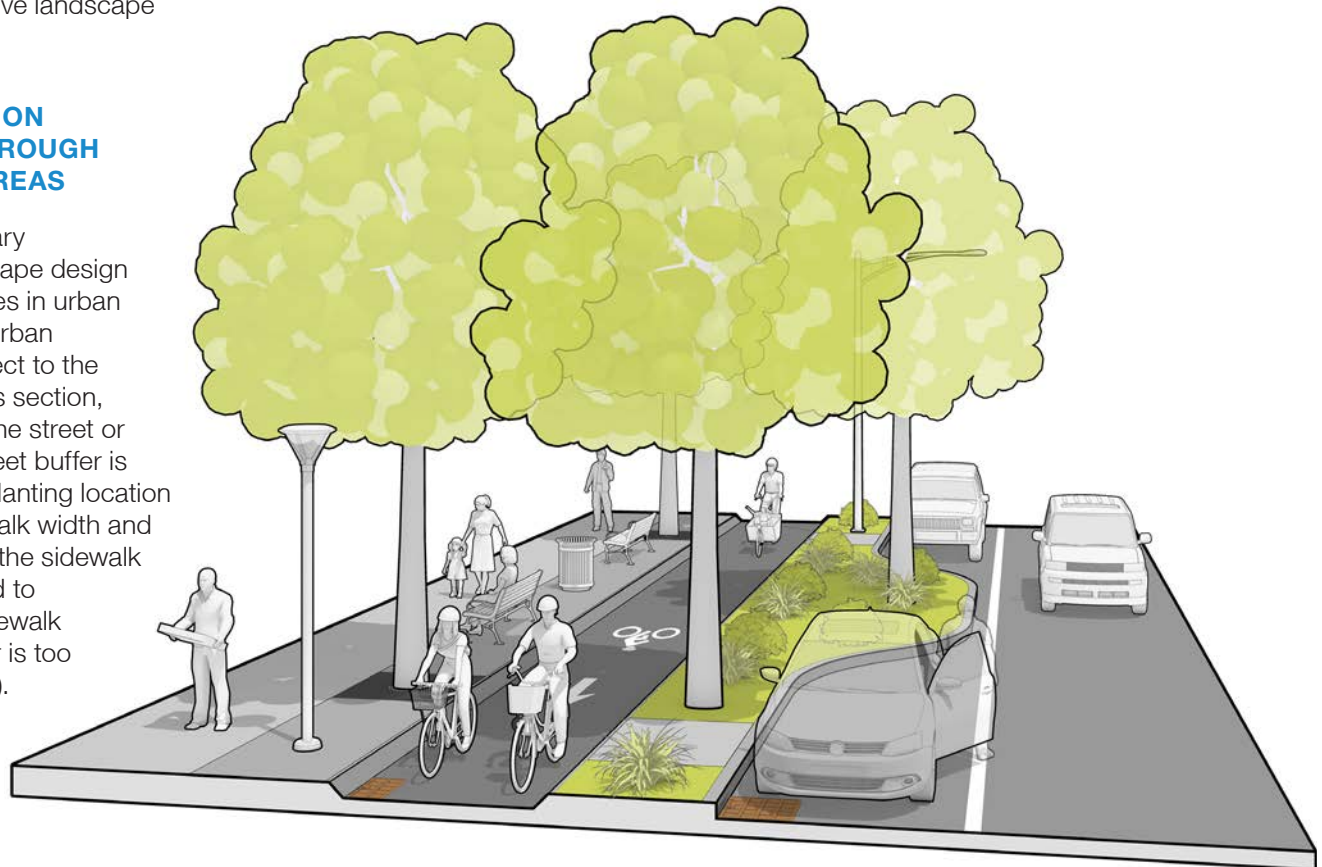


EXHIBIT 3R:
Landscaping on
Roadways through
Developed Areas

3.9.2 LANDSCAPING ON ROADWAYS THROUGH SUBURBAN AND RURAL AREAS

The design of separated bike lanes and shared use paths in rural and low-density suburban communities should follow natural roadside design considerations. Natural roadside corridors are bound by the limits of the right-of-way and are relatively undisturbed beyond basic

roadway infrastructure, open drainage systems and minimal utilities (see [EXHIBIT 3S](#)). Motor vehicle speeds in these corridors are typically higher than urban environments, so the design team may need to consider clear zone requirements with regard to the design of the street buffer (see [Section 5.6.1 of the PD&DG](#)) and should be mindful of sight lines at curves and intersections.

- Fit the separated bike lane or sidepath to the natural terrain, but maintain grades that are comfortable for bicycling.
- Avoid and minimize impacts to wetland resources or other natural environments.
- Maintain all natural drainage patterns and minimize erosion through the use of vegetated drainage channels in the street buffer.
- Maintain access for periodic mowing and other maintenance activities.
- Where available right-of-way is sufficient, consider directing runoff from the separated bike lane or shared use path onto adjacent vegetated surfaces where topography and soils are suitable for managing runoff using 'pavement disconnection' practices.

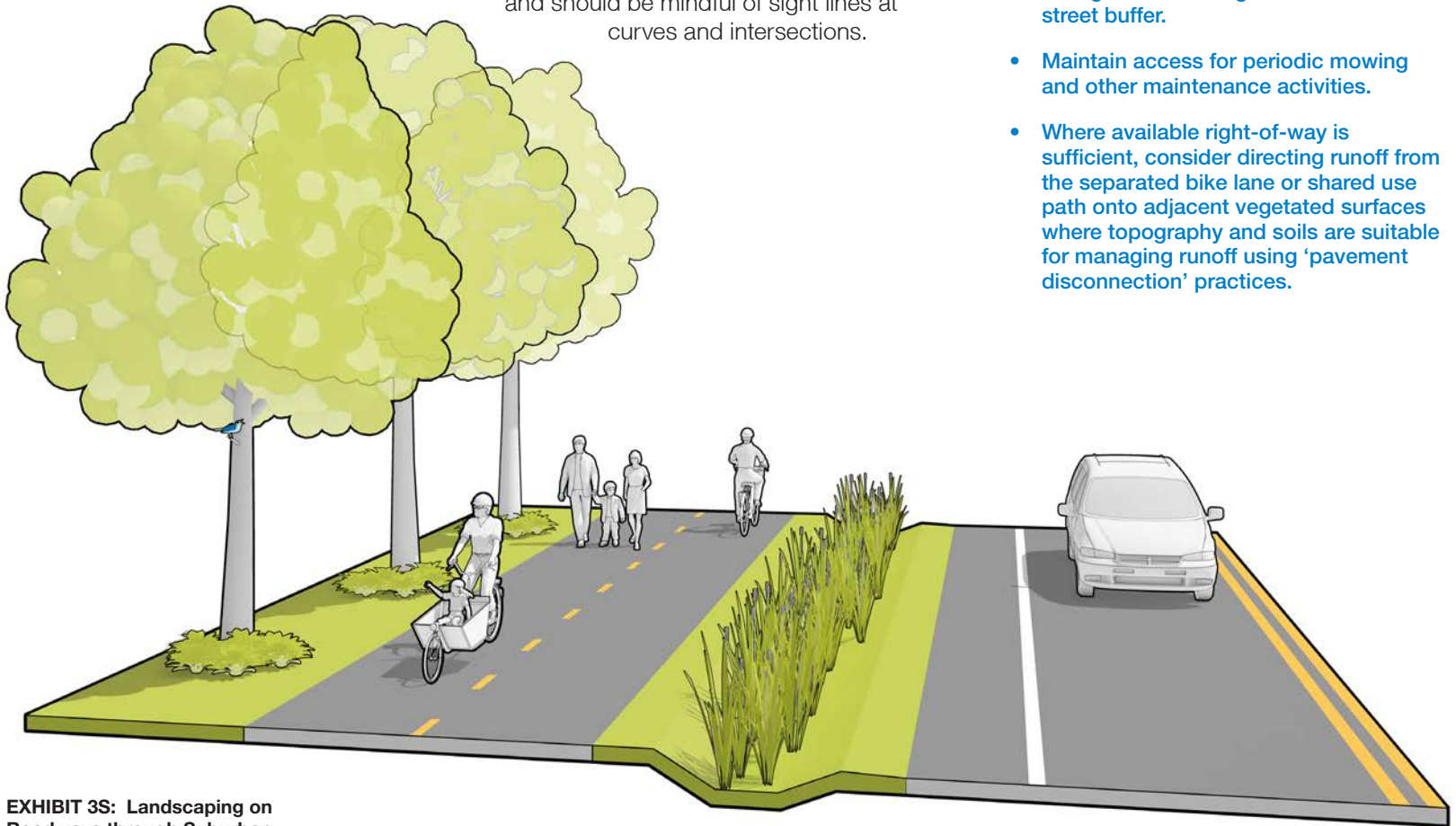


EXHIBIT 3S: Landscaping on Roadways through Suburban and Rural Areas

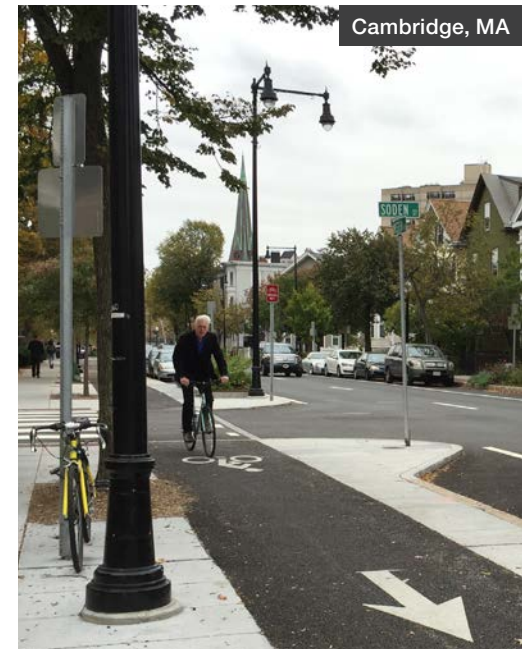
3.10 LIGHTING

The type, spacing and location of streetlights are important considerations for the safety and comfort of separated bike lanes. Sufficient and even illumination of the roadway, separated bike lane and sidewalk should be the primary considerations when deciding where to locate streetlights.

Streetlights may be located in the street buffer, sidewalk buffer or both, depending on the available width of the buffer areas. Pedestrian-scale acorn fixtures (between **11 ft.** and **16 ft.** in height) are recommended for their ability to enhance the attractiveness of the street. They may be used in combination with pendant or contemporary fixtures (up to **25 ft.** in height) to further illuminate intersections and areas of conflict. In constrained corridors taller fixtures may be sufficient on their own.

Motor vehicle headlights may pose a blinding hazard for contra-flow bicyclists where ambient light is low. Designers should consider increased lighting along two-way or contra-flow separated bike lanes to reduce this risk.

Streetlight design for separated bike lanes should follow local streetscape and historic district guidelines as well as guidance from FHWA and the Illumination Engineering Society.



3.11 UTILITY PLACEMENT

The placement of utilities and utility covers should also be considered during the design of separated bike lanes. Because bicyclists are sensitive to surface irregularities and shy away from nearby vertical objects, awkward placement of utilities may reduce the comfort and attractiveness of separated bike lanes.

Implementing separated bike lanes may present an opportunity to perform utility work in a corridor. Designers should coordinate with utility companies in advance of construction in order to minimize disruption.

Addressing utility location may not be practical in retrofit situations where minimal reconstruction is anticipated. However, new construction or substantial reconstruction presents opportunities to proactively address utility placement.

- **The usable width of the bike lane is reduced if utility poles are located too closely to the separated bike lane. Designers should locate utility poles and all other vertical objects at least 6 in. from the face of the curb adjacent to the bike lane zone, and at least 18 in. from the face of the curb adjacent to the motor vehicle lane.**
- **It is preferable to locate fire hydrants in the sidewalk buffer to avoid proximity to on-street parking. Hydrants should be located at least 6 in. from the face of the curb adjacent to the bike lane zone. Designers should coordinate with the local fire department to determine final placement.**

- **Utility covers should be located outside of the bike lane zone and in the street buffer or sidewalk buffer, where feasible, to maintain a level bicycling surface and minimize detours during utility work. Where unavoidable, utility covers in the bike lane should be smooth and flush with the bike lane surface, and placed in a manner that minimizes the need for avoidance maneuvering by bicyclists.**

3.12 OTHER POLICIES AND GUIDELINES

3.12.1 DESIGN EXCEPTIONS

A Design Exception Report (DER) is required when any of FHWA's applicable controlling criteria are not met (<http://safety.fhwa.dot.gov>). Additionally, there are requirements for pedestrian and bicycle accommodations under the **Healthy Transportation Compact** and **Engineering Directive E-14-006**.

3.12.2 REQUEST FOR EXPERIMENTATION

While the decision to provide separated bike lanes in federally funded projects does not require a Request for Experimentation (RFE) from FHWA, some traffic control devices and treatments, such as non-standard pavement markings, may require an approved RFE from FHWA. FHWA must approve the RFE prior to the **100**

percent design submittal. The designer should consult the FHWA website section on bicycle facilities and the MUTCD to determine the current approval status of potential treatments.

3.12.3 ACCESSIBILITY

Separated bike lanes, like all MassDOT designs and projects, shall maintain equal access for disabled individuals, as required by the **Americans with Disabilities Act of 1990**. Design guidance in this document is consistent with all applicable accessibility standards and guidelines, including **521 CMR** (Rules and Regulations of the Massachusetts Architectural Access Board) and proposed **PROWAG** guidelines to the extent possible, given the fact that separated bike lanes are a relatively new facility type and are not specifically addressed in existing standards and guidelines.

3.12.4 SHOULDER REQUIREMENTS

MassDOT requires an analysis of applicable design criteria for outside shoulder width for all projects. In urban areas with constrained right-of-way, separated bike lanes with or without on-street parking fulfill some shoulder functions including bicycle use, drainage, lateral support of pavement, and, in street and sidewalk buffer areas, snow storage. Therefore, an additional shoulder is not required provided that a design exception is obtained. However, in suburban and rural areas with fewer

right-of-way constraints and higher motor vehicle speeds, a paved shoulder may be necessary in addition to a separated bike lane. For shoulder function and width criteria, refer to [Section 5.3.3.1 of the PD&DG](#).

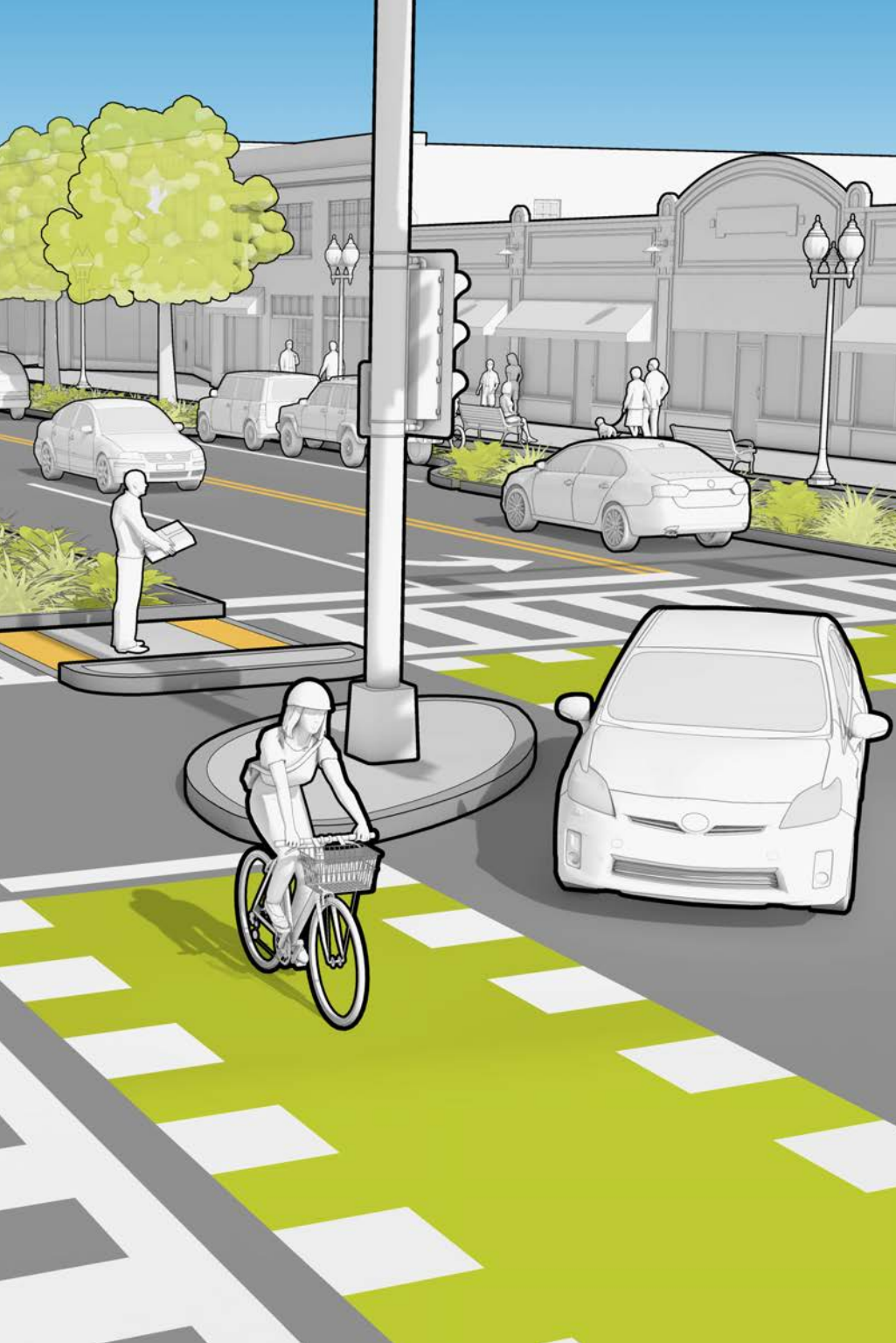
3.13 ENDNOTES

- 1 J.P. Schepers, P.A. Kroeze, W. Sweers, J.C. Wüst. (2011) Road factors and bicycle–motor vehicle crashes at unsignalized priority intersections. Accident Analysis and Prevention. Volume 43.

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4

INTERSECTION DESIGN



This chapter provides key principles that should be used to develop and evaluate design approaches and treatments that will result in intersections that support all ages and abilities of bicyclists. This chapter illustrates the application of these principles for common intersection configurations which include protected intersections, roundabouts, mixing zones and driveway crossings. Intersection design also requires consideration of parking, loading and bus stops (see [Chapter 5](#)), and signal operations (see [Chapter 6](#)).

4.1 CONTEXT

Safe and comfortable intersections minimize delays, reduce conflicts and reduce the risk of injury for all users in the event of a crash. Intersections include not only bicycle crossings of streets, but also crossings with driveways, alleys, sidewalks, shared use paths and other separated bike lanes. Intersections are likely to be locations where bicyclists transition into and out of separated bike lanes to other types of bikeway accommodations. These transitions should be intuitive to all users of the intersection.

The following variables have an impact on intersection design:

VOLUMES

User volumes affect the widths of separated bike lanes and sidewalks, as well as the required number of lanes for motorized traffic.

USER DELAY

A careful balance is needed to minimize delay for all users without favoring one travel mode at the expense of all others.

DESIGN SPEED

Key elements such as sight distance and geometric design at intersections are dependent on the approach speed of the motorist and bicyclist and the crossing speed of a pedestrian. The speed at which motorists merge, weave or turn across

a bicyclist's path significantly affects bicyclists' safety and comfort. Intersection geometry and corner radius design affects the merging or turning speed of the motorist.

Bicyclists have operating characteristics that are quite different from pedestrians. The approach speed of a bicyclist operating in a separated bike lane is typically between **10 and 15 mph** on flat ground. This speed can be three to eight times higher than the typical walking speed of a pedestrian entering an intersection, thus additional measures are needed to reduce conflicts between bicyclists and motorists at street crossings.

BIKE LANE OPERATION

The operation of one-way separated bike lanes is similar to normal motor vehicle operations on the street, which can simplify signalized intersection operations. Where a two-way separated bike lane is installed on one side of a street, the contra-flow direction of bicycle travel introduces an unexpected movement at the intersection. The contra-flow movement requires special consideration at intersections and at terminus points.

BUS STOPS

The location of bus stops adjacent to a separated bike lane can potentially introduce conflicts between bus patrons and through-moving bicyclists. The

availability of right-of-way and stopping location of the bus (in-lane versus bus bay; as well as near-side, far-side and mid-block stop location) are factors that impact the design of separated bike lanes (see [Chapter 5](#)).

TERRAIN

The existing terrain and sight conditions will affect available sight lines and approach speeds of bicyclists and motorists.

ON-STREET PARKING

The presence of on-street parking increases the degree of separation between bicyclists and motor vehicle traffic. This generally improves the comfort of both bicyclist and motorist. However, this will also increase the frequency at which pedestrians have to cross the separated bike lane to access cars in the parking lane. This is a particular concern in areas with high parking turnover. The presence of on-street parking can also reduce sight distances at intersections and driveways; this may require parking restrictions or the removal of parking spaces on the approach to intersections.

LAND USE

Adjacent land uses impact the volume of bicyclists and pedestrians in the corridor. Higher density land uses are likely to have higher volumes of pedestrians and bicyclists with closely spaced intersections

and less frequent driveways. Lower-density land uses may have low volumes of pedestrian and bicycle activity but frequent driveway access points for each property and increased distances between street intersections. Separated bike lanes are easier to implement in locations with fewer driveway crossings.

STREET BUFFER

The space available between the motor vehicle travel lane and the separated bike lane affects bicyclist comfort and has a significant impact on geometric design options at intersections.

AVAILABLE RIGHT-OF-WAY

The availability of right-of-way and the placement of utilities may create significant constraints on geometric design options, bike lane widths, buffer widths and sidewalk widths. Where right-of-way is being acquired for roadway projects, sufficient right-of-way should be secured for separated bike lanes.

TYPE OF PROJECT

Reconstruction projects provide the greatest opportunity to achieve preferred design dimensions and intersection treatments. Retrofit projects, which frequently are limited to repaving and restriping, are often constrained by existing street widths.



4.2 DESIGN PRINCIPLES

As separated bike lanes approach an intersection, the designer must determine whether to maintain separation through the intersection or to reintegrate the bicyclist into the street.

Bicycles, pedestrians and motor vehicles inevitably cross paths at intersections (unless their movements are grade separated). Intersections with separated bike lanes should be designed to minimize bicyclist exposure to motorized traffic and should minimize the speed differential at the points where travel movements intersect. The goal is to provide clear messages regarding right of way to all users moving through the intersection in conjunction with geometric features that result in higher compliance where users are expected to yield.

The following principles should be applied to the design of intersections with separated bike lanes to maximize safety and comfort for all users:

- 1. MINIMIZE EXPOSURE TO CONFLICTS**
- 2. REDUCE SPEEDS AT CONFLICT POINTS**
- 3. COMMUNICATE RIGHT-OF-WAY PRIORITY**
- 4. PROVIDE ADEQUATE SIGHT DISTANCE**

4.2.1 MINIMIZE EXPOSURE TO CONFLICTS

In urban areas, the majority of crashes between bicyclists and motorists occur at intersections and driveways and are often related to turning or merging movements. **EXHIBIT 4A** provides a comparison of bicyclist exposure at various types of intersections.

While they do occasionally occur, crashes between bicyclists and pedestrians are comparatively rare. It is important to enable pedestrians to see approaching bicyclists at locations where they cross a separated bike lane. Care should be taken to avoid the placement of infrastructure that may block a pedestrian's view of approaching bicyclists.

It is also important to provide clear and direct paths for pedestrians to reduce the likelihood that they use the bike lane as a walkway. For this reason, strategies for accommodating pedestrians on streets with separated bike lanes are provided throughout this guide.

The majority of conflicts and crashes in urban areas between bicyclists and motorists are related to motor vehicle turning movements at intersections. While they do occasionally occur, crashes between bicyclists and pedestrians are comparatively rare.

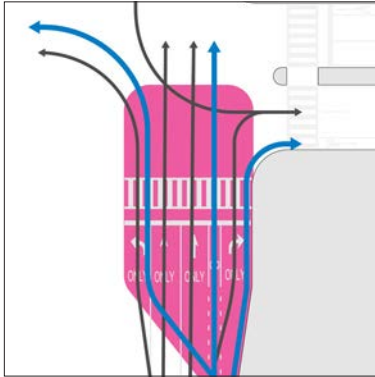
To improve bicyclist comfort and safety, it is preferable to maintain separation within intersections to reduce exposure to merging motor vehicles. Where merging areas, crossings and locations with shared operating spaces are required, they should be designed to minimize exposure. This can be accomplished by:

- **Shortening crossing distance with curb extensions.**
- **Providing two-stage turn queuing areas which allow bicyclists to avoid merging across multiple lanes of traffic during turning movements.**
- **Providing median refuge areas for two-stage crossings.**
- **Providing wider street buffers for bicycle queuing and pedestrian storage to shorten crossing distances.**

EXHIBIT 4A: COMPARISON OF BICYCLIST EXPOSURE AT INTERSECTIONS

The diagrams on this page provide a comparison of the levels of exposure associated with various types of intersection designs.

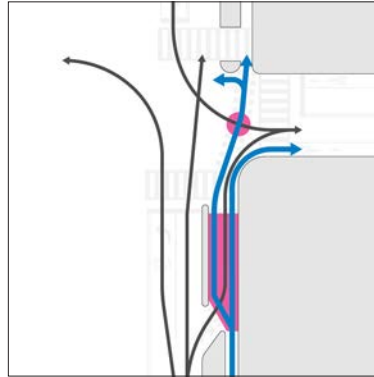
Exposure Level:
High



CONVENTIONAL BIKE LANES AND SHARED LANES

Bike lanes and shared lanes require bicyclists to share and negotiate space with motor vehicles as they move through intersections. Motorists have a large advantage in this negotiation as they are driving a vehicle with significantly more mass and are usually operating at a higher speed than bicyclists. This creates a stressful environment for bicyclists, particularly as the speed differential between bicyclists and motorists increases. For these reasons, it is preferable to provide separation through the intersection.

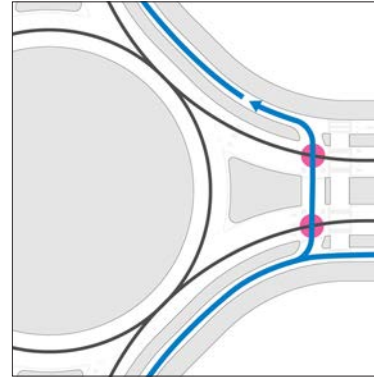
Exposure Level:
High to Medium



SEPARATED BIKE LANES WITH MIXING ZONES

One strategy that has been used in the U.S. at constrained intersections on streets with separated bike lanes is to reintroduce the bicyclist into motor vehicle travel lanes (and turn lanes) at intersections, removing the separation between the two modes of travel. This design is less preferable to providing a protected intersection for the same reasons as discussed under conventional bike lanes and shared lanes. Where provided, mixing zones should be designed to reduce motor vehicle speeds and minimize the area of exposure for bicyclists.

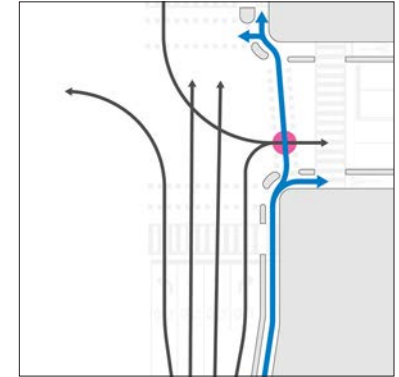
Exposure Level:
Medium to Low



SEPARATED BIKE LANES THROUGH ROUNDABOUTS

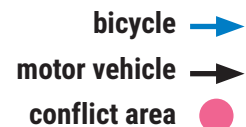
Separated bike lanes can be continued through roundabouts, with crossings that are similar to, and typically adjacent to, pedestrian crosswalks. Motorists approach the bicycle crossings at a perpendicular angle, maximizing visibility of approaching bicyclists. Bicyclists must travel a more circuitous route if turning left and must cross four separate motor vehicle path approaches. Yielding rates are higher at single-lane roundabouts.¹

Exposure Level:
Low



PROTECTED INTERSECTIONS

A protected intersection maintains the physical separation through the intersection, thereby eliminating the merging and weaving movements inherent in conventional bike lane and shared lane designs. This reduces the conflicts to a single location where turning traffic crosses the bike lane. This single conflict point can be eliminated by providing a separate signal phase for turning traffic



Where conflicts with motor vehicles are more significant due to high traffic volumes, high speed turns across the separated bike lane, or at locations with limited sight distance, steps should be taken to reduce or eliminate conflicts with other strategies, such as restricting turn movements (see [Section 4.3.7](#)), providing traffic signal phasing that allows for fully protected bicycle movements (see [Section 6.4](#)), or providing grade separation (see [Section 4.3.8](#)).

4.2.2 REDUCE SPEEDS AT CONFLICT POINTS

Reducing motor vehicle speeds at intersections improves the motorist's ability to appropriately react to and yield to bicyclists and pedestrians. Slower motor vehicle speeds reduce stopping sight distance requirements and reduce the likelihood of severe injuries and fatalities for bicyclists and pedestrians in the event of a crash.

Intersections with separated bike lanes should be designed to ensure slow-speed turning movements (**10 mph or less**) and weaving movements (**20 mph or less** in the area where weaving movements occur). Mixing zones should be designed to encourage the weaving movement to occur in close proximity to the corner at a location where motorists have slowed their speed in anticipation of the turn so they are more likely to yield to bicyclists (see [Section 4.3.3](#)).

MINIMIZE CURB RADIUS

The smallest feasible curb radius should be selected for corner designs based upon the design vehicle's effective turning radius. A small curb radius requires motorists to slow down, which improves yielding and reduces stopping distance requirements. This strategy can also help to increase the size of bicycle and pedestrian queuing areas, thereby enabling greater flexibility in the placement of curb ramps and reducing crossing distances.

Many factors influence corner design, and a flexible approach is necessary depending on the type of street, the number and configuration of travel lanes, and characteristics of the design vehicle. The design vehicle should be selected according to the types of vehicles using the intersection with consideration given to relative volumes and frequencies under normal traffic conditions. Further information on selecting the appropriate design vehicle can be found in [Section 6.3.3 of the PD&DG](#).

At locations where the accommodation of trucks and buses is required, consideration should be given to allowing encroachment into approaching and/or departure lanes to reduce the design curb radius to the minimum (see [Section 6.7.2 of the PD&DG](#)). Where encroachment is not desirable a compound curve may be used in place of a simple curve to minimize the effective curb radius to slow turns while still accommodating larger vehicles.

At signalized intersections where additional space is needed to accommodate turning vehicles, consideration can be given to recessing the stop line on the receiving street to enable a large vehicle to use a portion of or the entire width of the receiving roadway (encroaching on the opposing travel lane) as shown in [EXHIBIT 4B](#).

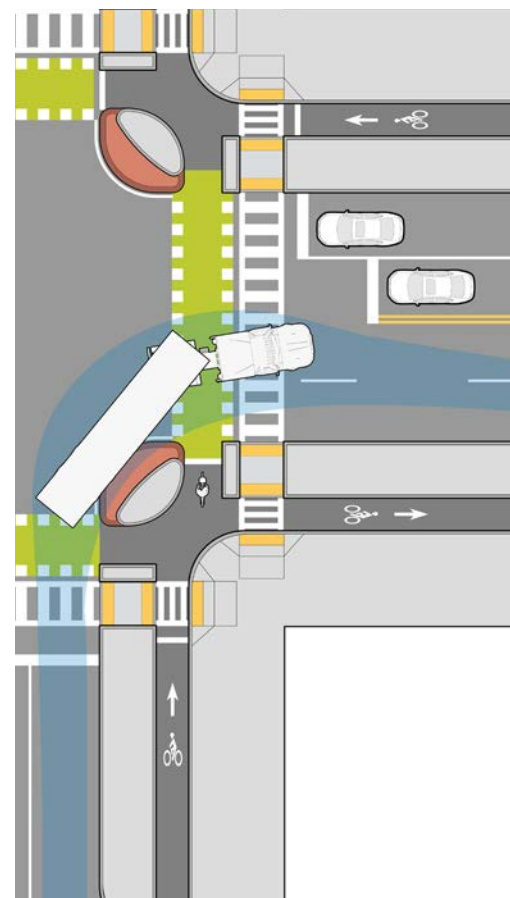


EXHIBIT 4B: Recessed Stop Line for Large Vehicle Turn with Mountable Truck Apron

MOUNTABLE TRUCK APRONS

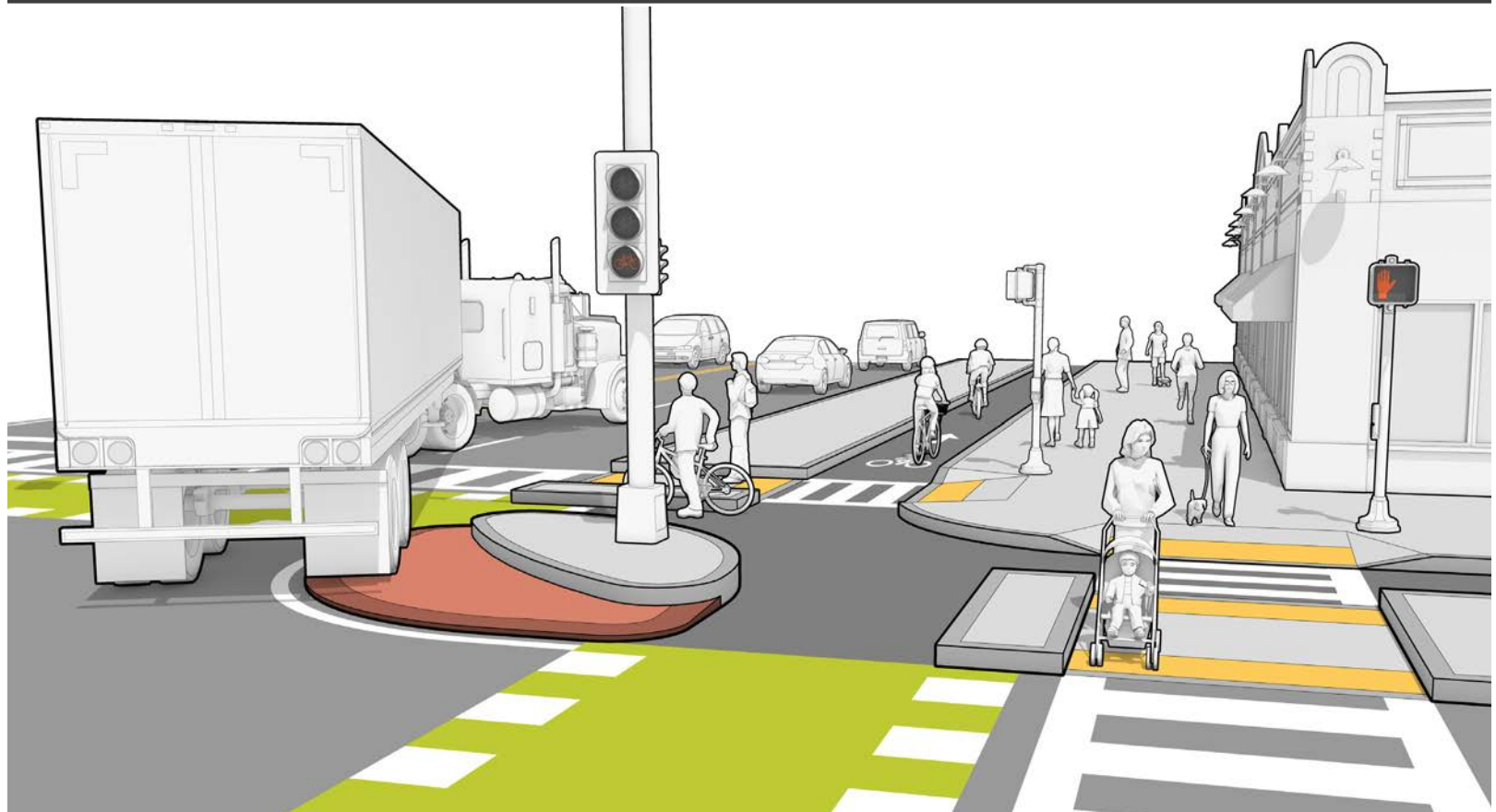
While bicyclist and pedestrian safety is negatively impacted by wide crossings, bicyclists and pedestrians are also at risk if the curb radius is too small. This can result in the rear wheels of a truck tracking over queuing areas at the corner. Maintenance problems are also caused when trucks must regularly drive over street corners to make turns.

Mountable truck aprons are a solution that can reduce turning speeds for passenger vehicles while accommodating the off-tracking of larger vehicles where a larger corner radius is necessary (see [EXHIBIT 4C](#)).

Mountable truck aprons are part of the traveled way and as such should be designed to discourage pedestrian or bicycle refuge. Bicycle stop bars,

detectable warning panels, traffic signal equipment and other intersection features must be located behind the mountable surface area. The mountable surface should be visually distinct from the adjacent travel lane, sidewalk and separated bike lane. The heights of mountable areas and curbs should be a maximum of **3 in.** above the travel lane to accommodate lowboy trailers.

EXHIBIT 4C: MOUNTABLE TRUCK APRON





Delft, Netherlands

RAISED CROSSINGS

Raised crossings are an effective strategy for reducing crashes between motorists and bicyclists because they slow the turning speed of motor vehicles, increase visibility of vulnerable street users, and increase yielding behavior of motorists.^{2,3,4} Raised crossings should be considered for separated bike lane crossings where motorists are required to yield the right-of-way to bicyclists while turning or crossing. Examples where this treatment may be particularly beneficial are at the following types of crossings:

- **Collector and local street crossings (see Section 16.3 of the PD&DG).**
- **Crossings of driveways and alleys.**
- **Crossings of channelized right turn lanes and roundabouts.**
- **Intersections where a large corner radius is required to accommodate heavy vehicles.**

Raised crossings are usually appropriate only on minor road crossings. Raised crossings across an arterial roadway require a design exception.

Raised crossings should have the following design characteristics (see [EXHIBIT 4D](#), [EXHIBIT 4E](#), and [EXHIBIT 4F](#)):

- They should be elevated 4-6 in. above the street.
- Motor vehicle approach ramps should be sloped as follows:
 - Streets: 5-8 percent slope
 - Driveways and alleys: 5-15 percent slope
- Yield lines or speed hump markings should be used on uncontrolled motor vehicle approaches.
- The surface materials, color and texture of the separated bike lane and adjacent sidewalk should extend through the crossing, maintaining visual continuity to encourage motorists to yield at the crossing.

- **Intersection design must meet the accessibility requirements of the Americans with Disabilities Act (ADA) and the Massachusetts Architectural Access Board (MAAB). Special attention should be given to ensuring people with vision impairments are given sufficient cues at intersections to prevent them from unintentionally moving into the street.**

See [Section 4.4](#) for additional traffic control considerations.

Where the bike lane is not at the same elevation as the raised crossing, it is necessary to provide transition ramps for bicyclists. The ramp should provide a smooth vertical transition with a maximum slope of **10 percent**. To allow bicyclists to

focus their attention on the crossing, the transition ramp should generally not be located within a lateral shift or curve in the bike lane alignment. Speed hump markings on the transition ramp should be provided for ramps **6 ft. or more** in length with slopes that exceed **5 percent**, otherwise they are optional.

Designers should consider raising the entire separated bike lane to intermediate or sidewalk level where the density of bus stops, driveways, alleys or minor street crossings would otherwise result in a relatively quick succession of transition ramps. Too many transition ramps in close proximity can result in an uncomfortable bicycling environment.

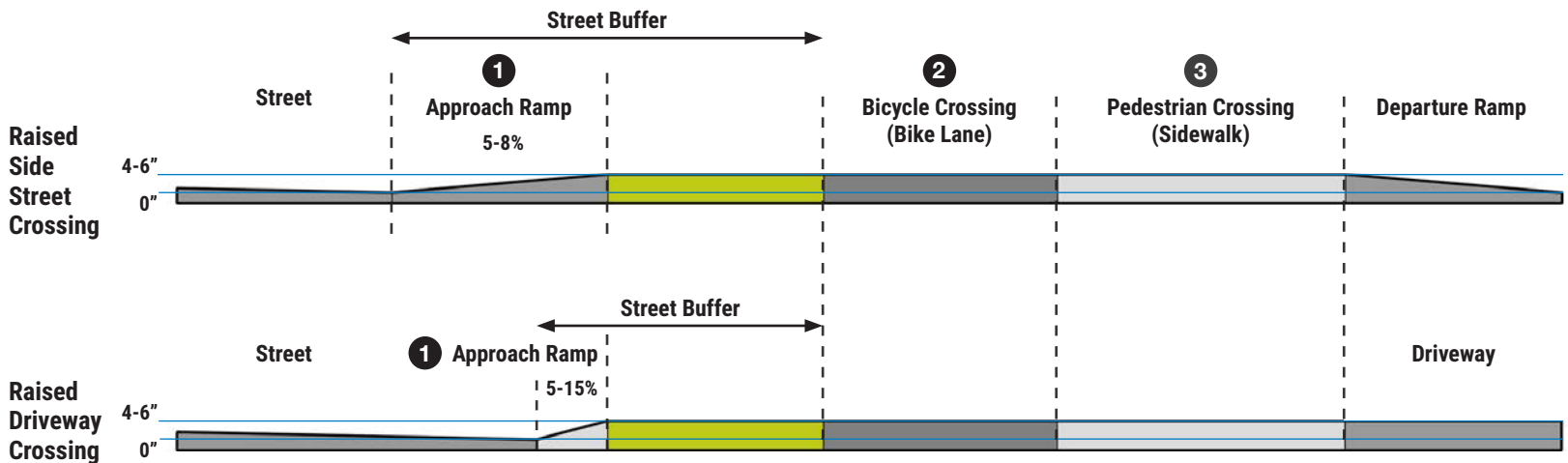
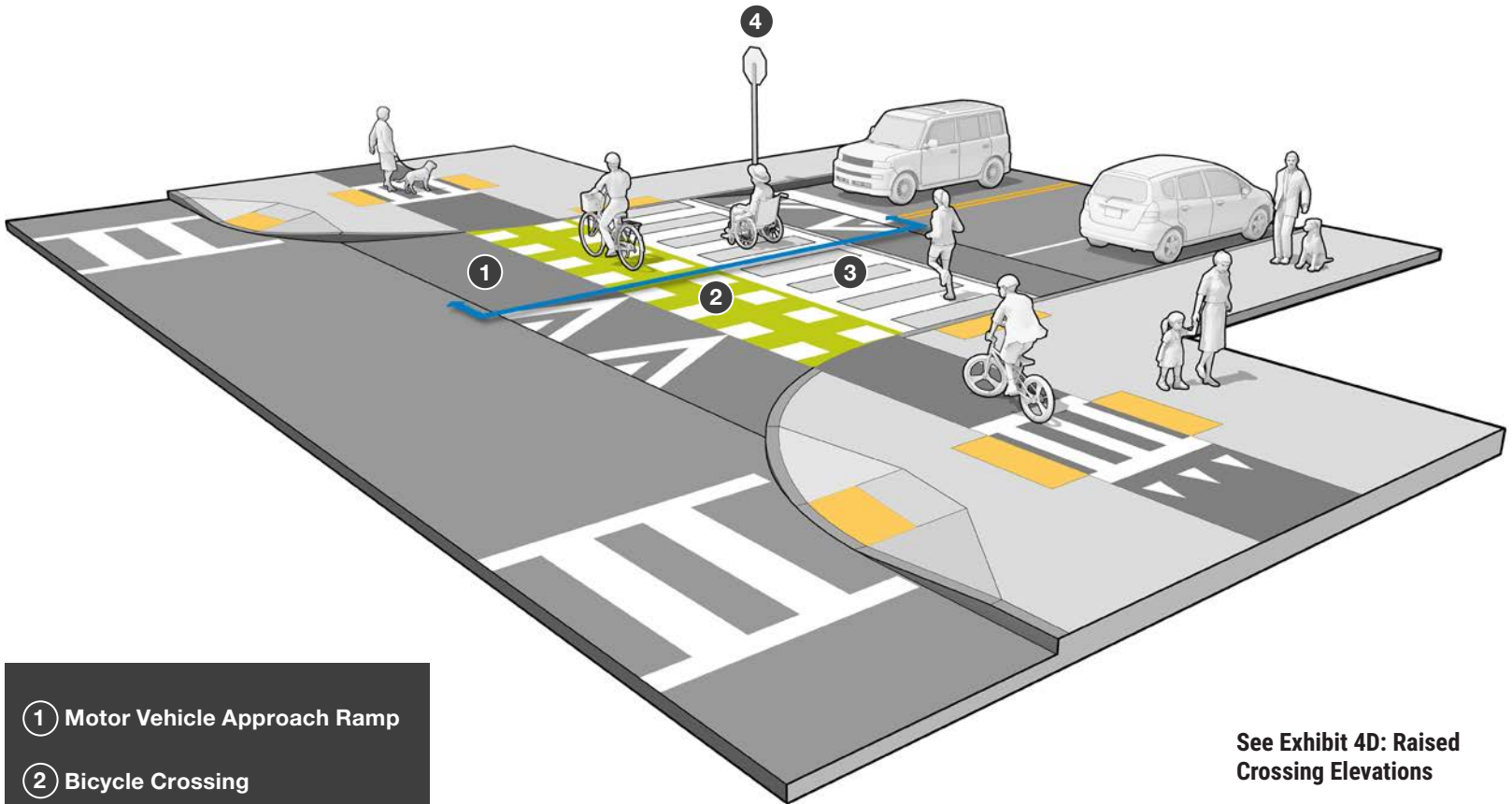


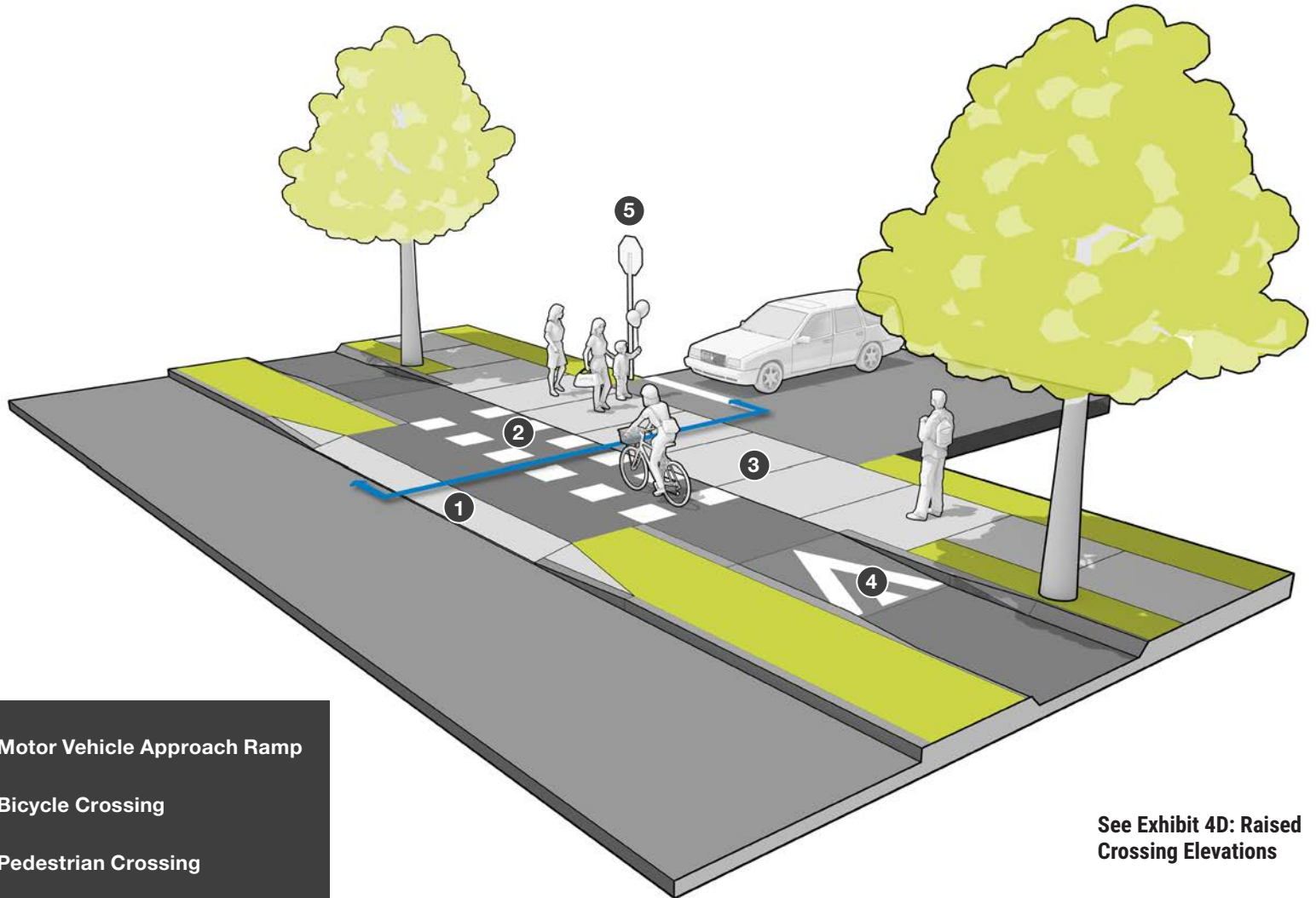
EXHIBIT 4D: Raised Crossing Elevations (Profile View)

EXHIBIT 4E: RAISED SIDE STREET CROSSING



- ① Motor Vehicle Approach Ramp
- ② Bicycle Crossing
- ③ Pedestrian Crossing
- ④ Stop Sign

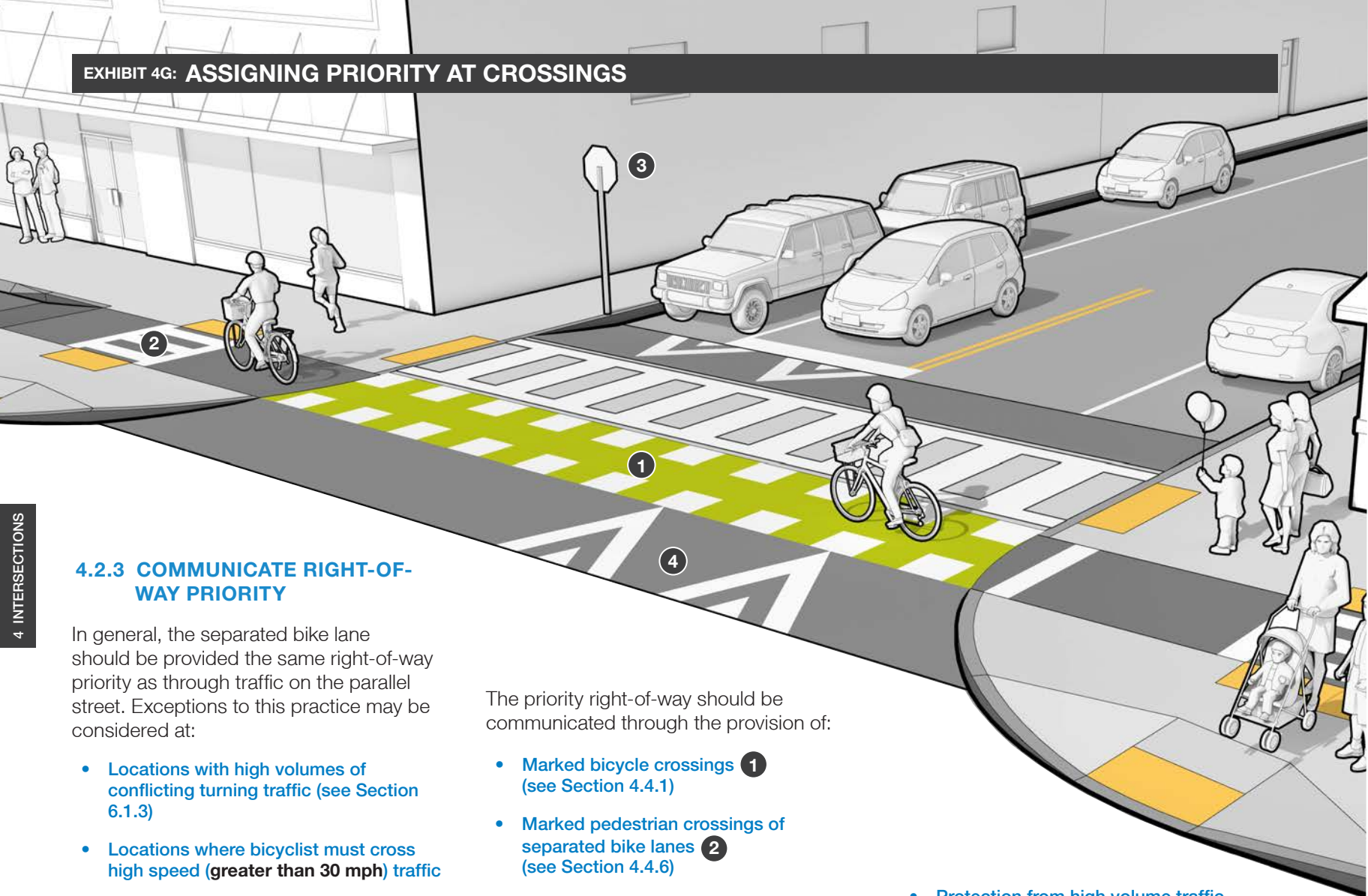
See Exhibit 4D: Raised Crossing Elevations



- ① Motor Vehicle Approach Ramp
- ② Bicycle Crossing
- ③ Pedestrian Crossing
- ④ Bicycle Transition Ramp*
- ⑤ Stop Sign

See Exhibit 4D: Raised Crossing Elevations

* Speed hump markings are typical for ramps 6 ft. or more in length with slopes that exceed 5 percent; otherwise they are optional.



4.2.3 COMMUNICATE RIGHT-OF-WAY PRIORITY

In general, the separated bike lane should be provided the same right-of-way priority as through traffic on the parallel street. Exceptions to this practice may be considered at:

- Locations with high volumes of conflicting turning traffic (see Section 6.1.3)
- Locations where bicyclist must cross high speed (greater than 30 mph) traffic

All street users should be provided with visual cues that clearly establish which users have the right of way and consistently communicate expected yielding behavior (see EXHIBIT 4G).

The priority right-of-way should be communicated through the provision of:

- Marked bicycle crossings **1** (see Section 4.4.1)
- Marked pedestrian crossings of separated bike lanes **2** (see Section 4.4.6)
- Regulatory signs, if appropriate, for merging or turning traffic (see Section 4.4.4)
- Regulatory signs, if appropriate, for side street or driveway traffic (STOP or YIELD) (see Section 4.4.5) **3**

- Protection from high volume traffic conflicts (see Section 4.3.7) **4**

Locations with two-way separated bike lanes may benefit from placement of warning signs that indicate two-way bicycle travel in advance of the crossing.

4.2.4 PROVIDE ADEQUATE SIGHT DISTANCE

Under [Massachusetts General Law \(M.G.L. c.90 §14\)](#), a turning motorist must yield to a through bicyclist unless the motorist is at a safe distance from the bicyclist and making the turn at a reasonable speed. Bicyclists must yield to motorists that are within the intersection or so close thereto as to constitute an immediate hazard. Bicyclists and motorists must yield to pedestrians within a crosswalk at uncontrolled locations. To comply with this law, it is necessary to provide adequate sight distances between bicyclists, motorists and pedestrians as they approach intersections with streets, alleys, and driveways. In general, sight distances that conform to standard street design principles established in the [AASHTO Green Book](#) and [AASHTO Bike Guide](#) are sufficient for streets with separated bike lanes.

When a separated bike lane is located behind a parking lane, it may be necessary to restrict parking and other vertical obstructions in the vicinity of a crossing to ensure adequate sight distances are provided. To determine parking restrictions near the crossing, it is necessary to know the approach speed of the bicyclist and the turning speed of the motorist. The overall objective of the design is to provide adequate sight distances for each user to detect a conflicting movement of another user and to react appropriately. The approach to the conflict point is comprised by these three zones:

MASSACHUSETTS GENERAL LAW (M.G.L. CHAPTER 90, SECTION 14)

“No person operating a vehicle that overtakes and passes a bicyclist proceeding in the same direction shall make a right turn at an intersection or driveway unless the turn can be made at a safe distance from the bicyclist at a speed that is reasonable and proper . . . When turning to the left within an intersection or into an alley, private road or driveway an operator shall yield the right of way to any vehicle approaching from the opposite direction, including a bicycle on the right of the other approaching vehicles, which is within the intersection or so close thereto as to constitute an immediate hazard . . .”

- **Recognition zone** – the approaching bicyclist and motorist have an opportunity to see each other and evaluate their respective approach speeds.
- **Decision zone** – the bicyclist or motorist identifies who is likely to arrive at the intersection first and adjust their speed to yield or stop if necessary.
- **Yield/stop zone** – space for the motorist or bicyclist to stop if needed.

At intersections with permissive turning movements where bicyclists and motorists are traveling in the same direction, there are two yielding scenarios that occur depending upon who arrives at the crossing first.



RIGHT TURNING MOTORIST YIELDS TO THROUGH BICYCLIST

This scenario occurs when a through moving bicyclist arrives at the crossing prior to a turning motorist, who must stop or yield to the through bicyclist. Parking must be set back sufficiently for the motorist to see the approaching bicyclist (see [EXHIBIT 4H](#)).

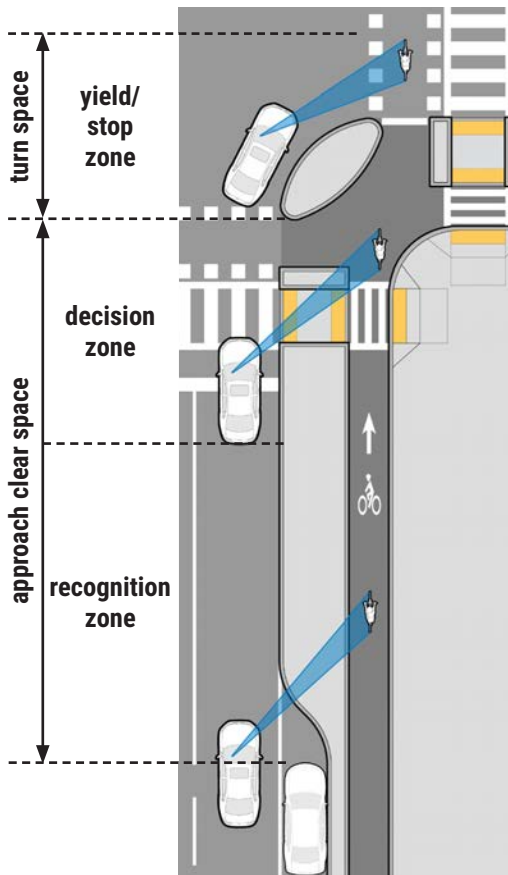


EXHIBIT 4H: Right Turning Motorist Yields to Through Bicyclist

THROUGH BICYCLIST YIELDS TO TURNING MOTORIST

This scenario occurs when a turning motorist arrives at the crossing prior to a through moving bicyclist. Again, parking must be set back sufficiently to enable bicyclists and motorists to see and react to each other (see [EXHIBIT 4I](#)).

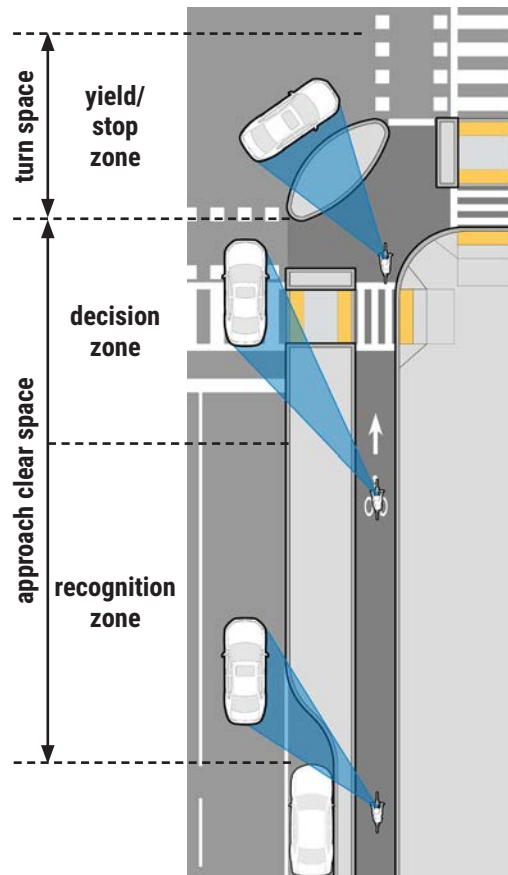


EXHIBIT 4I: Through Bicyclist Yields to Right Turning Motorist

4.2.5 APPROACH CLEAR SPACE

The following provides sight distance considerations for situations where motorists turn right, left, or cross separated bike lanes. The recommended approach clear space assumes the bicyclist is approaching the intersection at a constant speed of **15 mph**. Clear space recommendations are provided for various turning speeds of motorists which may vary from **10 to 20 mph** based on the geometric design of the corner and the travel path of the motorist. The recommended clear space allows one second of reaction time for both parties as they approach the intersection. If bicyclists' speeds are slower (such as on an uphill approach) or motorists' turning speeds are slower than **10 mph**, the clear space can be reduced. Where either party may be traveling faster, such as on downhill grades, the clear space may benefit from an extension.

[EXHIBIT 4J](#) provides various examples of how to determine the approach clear space for different turning movements.

Vehicular Turning Design Speed	Approach Clear Space
10 mph	40 ft.
15 mph	50 ft.
20 mph	60 ft.

EXHIBIT 4J: Approach Clear Space Distance by Vehicular Turning Design Speed⁵

CASE A – RIGHT TURNING MOTORIST

This case applies when a motorist is making a permissive right turn at a traffic signal or from an uncontrolled approach (e.g., a right turn from an arterial onto a local street or driveway), and a parking lane is present on the approach (see [EXHIBIT 4H](#) and [EXHIBIT 4I](#) on the previous page).

In this case the motorist will be decelerating for the right turn in advance of the intersection. The motorist's turning speed will be controlled by the corner geometry and width of the receiving roadway.

[EXHIBIT 4J](#) identifies the minimum approach clear space measured from the start of the point of curvature (PC) of the curb or pavement edge. This table applies to intersections with streets or higher volume commercial driveways and alleys. For locations with two-way separated bike lanes additional approach clear space will not be required as the recognition zone between the contra-flow movement bicyclist and right turning motorists exceeds the recommended clear space. Low volume driveways and alleys where motorist turning speeds can be anticipated to be less than **10 mph** should provide a minimum clear space of **20 ft**.

CASE B – LEFT TURNING MOTORIST

This case applies when a motorist is making a permissive left turn at a traffic signal or from an uncontrolled approach (e.g., a left turn from an arterial onto a local street or driveway) (see [EXHIBIT 4K](#)). On one-way streets with a left side separated bike lane, this case has the same operational dynamics and approach clear space requirements as Case A since the left turning motorist will be turning adjacent to the separated bike lane. For locations with two-way separated bike lanes on the left side, additional approach clear space will not be required as the recognition zone between the contra-flow movement bicyclist and left turning motorist exceeds the recommended clear space. Low volume driveways and alleys where motorists' turning speeds can be anticipated to be less than **10 mph** should provide a minimum clear space of **20 ft**.

On streets with two-way traffic flow, the operational dynamic of a motorist looking for gaps in traffic creates unique challenges that cannot be resolved strictly through the provision of parking restrictions to improve sight distance. This is a challenging maneuver because the motorist is primarily looking for gaps in oncoming traffic, and is less likely to scan for bicyclists approaching from behind. Unlike for Case A or Case B on one-way streets where the motorist

is decelerating towards the crossing, the motorist in this instance will be accelerating towards the crossing once they perceive a gap in traffic. This creates a higher potential for conflict on streets with:

- High traffic volumes and multiple lanes
- Higher operating speeds
- Heavy left turn volumes

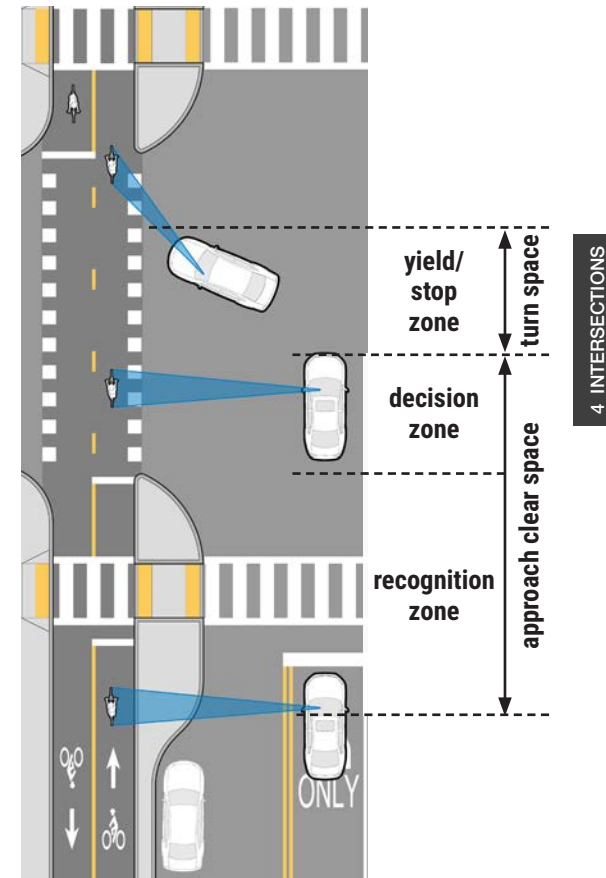


EXHIBIT 4K: Left Turning Motorist Yields to Through Bicyclist



Rotterdam, Netherlands

For this reason, one or more of the following design elements should be considered to mitigate conflicts:

- Implement a protected left turn phase for motorists that does not conflict with the bicycle crossing movement (see Chapter 6).
- Install a TURNING VEHICLES YIELD TO BICYCLES AND PEDESTRIANS sign (R10-15 alt.) (see Section 4.4.4).
- Supplement the bicycle crossing with green surfacing.
- Raise the crossing (see Section 4.2.2).
- Recess the crossing (see Section 4.3.6).
- Restrict left turns (see Section 4.3.7).

Where these measures prove ineffective, or where it is not feasible to eliminate the conflict, it may be necessary to reevaluate whether a two-way separated bike lane is appropriate at the location.

CASE C1 – MOTORIST CROSSES NEAR SIDE SEPARATED BIKE LANE

This case applies when a motorist exits a non-signal controlled street, alley or driveway to cross a near side separated bike lane (see [EXHIBIT 4L](#)). These intersections are commonly stop controlled.

Providing a minimum clear space of **20 ft.** between the stop line and the bicycle crossing will typically provide an approaching motorist with the ability to see approaching bicyclists in the separated bike lane. In many locations, the effective clear space will be larger than **20 ft.** to accommodate pedestrian crosswalks. At locations where the motorist must pull into the crossing to view traffic gaps and is likely to block the separated bike lane, other treatments such as signaling the crossing (see [Chapter 6](#)), raising the crossing (see [Section 4.2.2](#)), or recessing the bicycle crossing (see [Section 4.3.6](#)) should be considered.

CASE C2 – MOTORIST CROSSES FAR SIDE SEPARATED BIKE LANE

This case applies when a motorist exits a non-signal controlled street, alley or driveway to cross a far side separated bike lane (see [EXHIBIT 4L](#)). These intersections are commonly stop controlled.

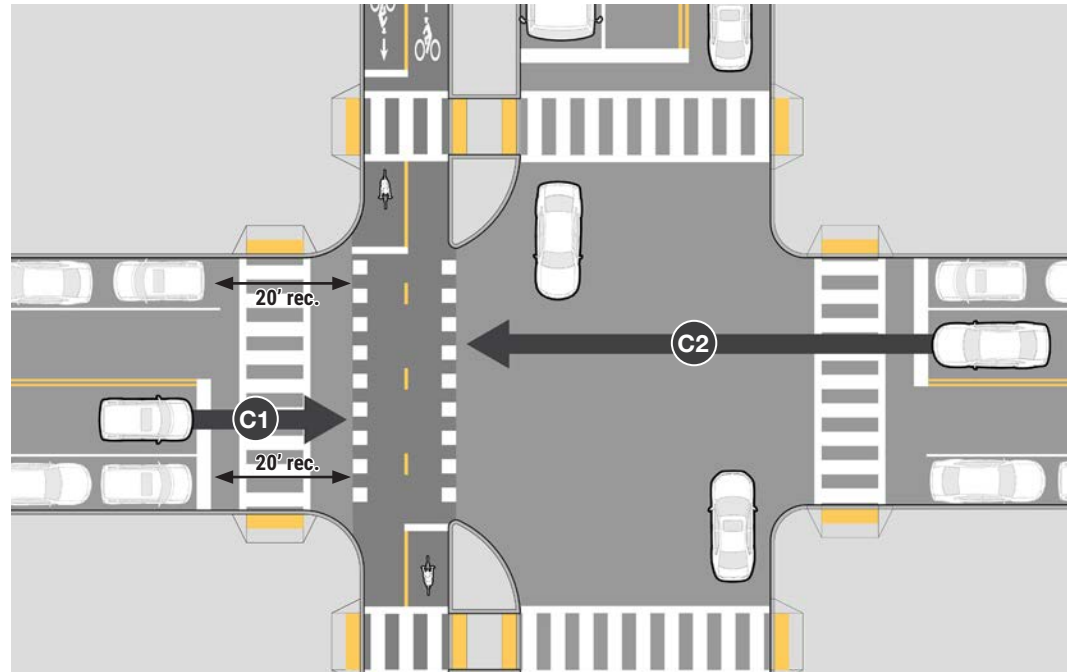
As with Case B, this case creates a challenging dynamic that is difficult to resolve with additional parking restrictions on the cross street. It may be difficult to restrict parking enough to provide the required sight distance to judge gaps that allow a crossing of all the travel lanes and the separated bike lane on the opposite side of the street. As such, designers should consider the frequency of through movements at these types of intersections

and provide adequate sight distance for bicyclists to perceive a crossing vehicle and stop if necessary.

For this reason these potential mitigations should be considered:

- [Install a traffic signal \(see Chapter 6\).](#)
- [Raise the crossing \(see Section 4.2.2\).](#)
- [Recess the crossing \(see Section 4.3.6\).](#)
- [Restrict crossing movements \(see Section 4.3.7\).](#)

EXHIBIT 4L: Case C1 and C2 – Motorist Crossing Near- and Far-side Separated Bike Lane



4.3 COMMON INTERSECTION DESIGN TREATMENTS

This section provides guidance for the design of separated bike lanes at common intersection configurations to improve comfort, efficiency and safety for bicyclists. Each configuration includes examples of the application of signs and markings. Signal design is discussed in [Chapter 6](#).

4.3.1 ELEMENTS OF PROTECTED INTERSECTIONS

Well-designed protected intersections are intuitive and comfortable, provide clear right-of-way assignment, promote predictability of movement, and allow eye contact between motorists, bicyclists and pedestrians. They also clearly define pedestrian and bicyclist operating spaces within the intersection and minimize potential conflicts between users.

The following discussion focuses on design guidance for the geometric elements of a protected intersection (see [EXHIBIT 4M](#) and [EXHIBIT 4N](#)).

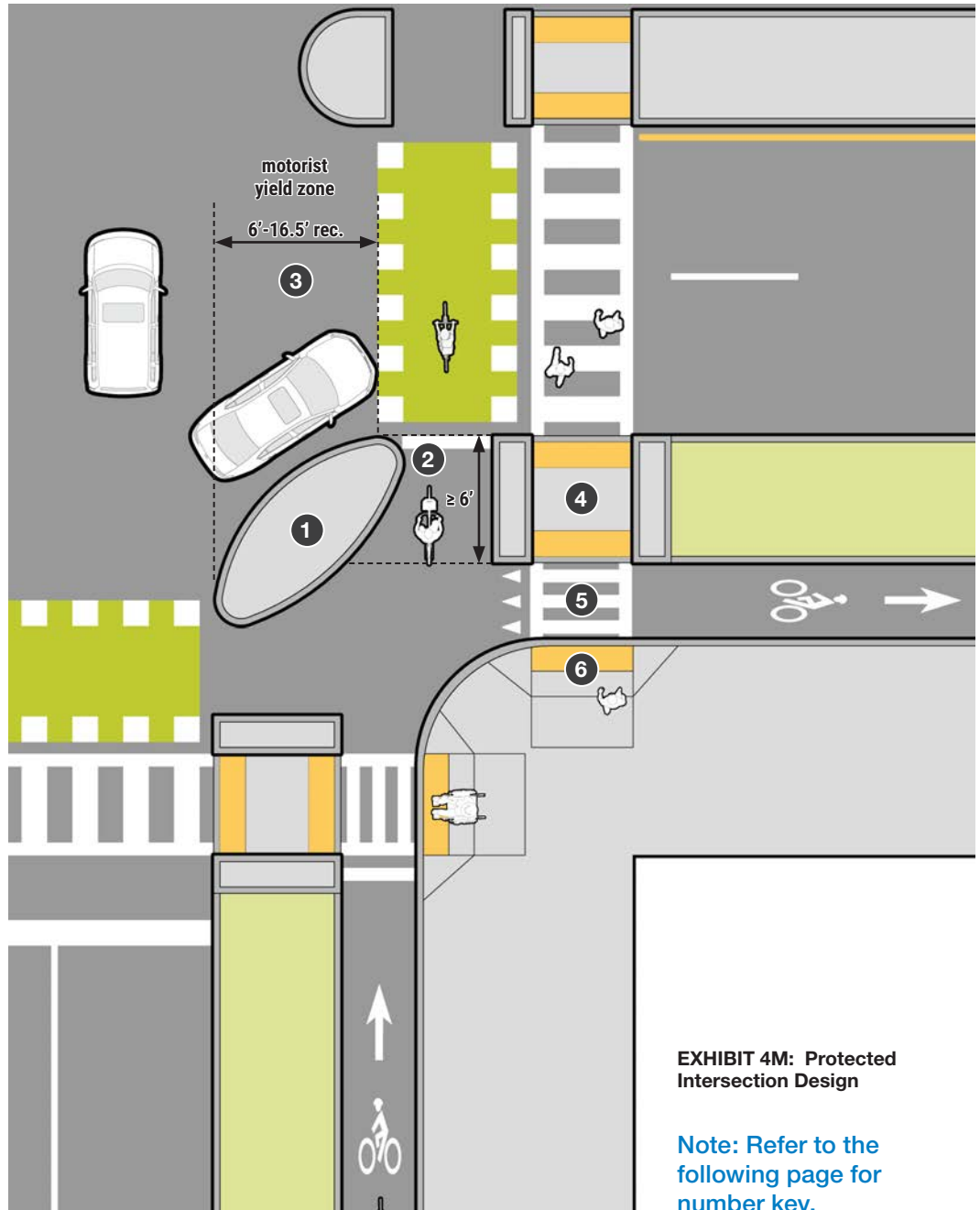
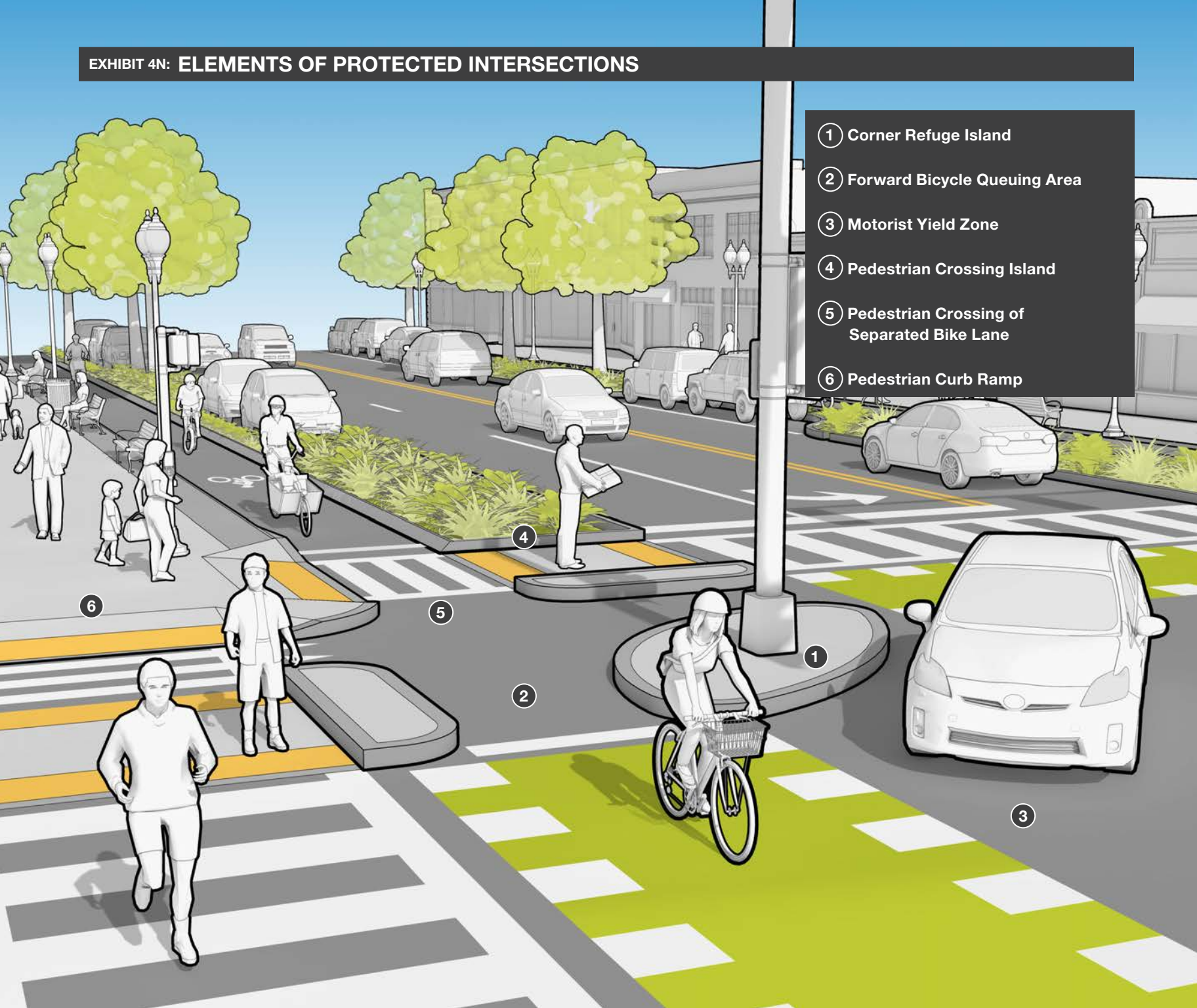


EXHIBIT 4M: Protected Intersection Design

Note: Refer to the following page for number key.

EXHIBIT 4N: ELEMENTS OF PROTECTED INTERSECTIONS



- ① Corner Refuge Island
- ② Forward Bicycle Queuing Area
- ③ Motorist Yield Zone
- ④ Pedestrian Crossing Island
- ⑤ Pedestrian Crossing of Separated Bike Lane
- ⑥ Pedestrian Curb Ramp

1. CORNER REFUGE ISLAND

The corner refuge island allows the bike lane to be physically separated up to the intersection crossing point where potential conflicts with turning motorists can be controlled more easily. It serves an important purpose in protecting the bicyclist from right-turning motor vehicle traffic. The corner island also provides the following benefits:

- **Creates space for a forward bicycle queuing area.**
- **Creates additional space for vehicles to wait while yielding to bicyclists and pedestrians who are crossing the road.**
- **Reduces crossing distances.**
- **Controls motorist turning speeds.**

The corner island geometry will vary greatly depending upon available space, location and width of buffers, and the corner radius. The corner island should be constructed with a standard vertical curb to discourage motor vehicle encroachment. Where the design vehicle exceeds an SU-30, a mountable truck apron should be considered to supplement the corner refuge island (see [Section 4.2.2](#)).

2. FORWARD BICYCLE QUEUING AREA

The forward bicycle queuing area provides space for stopped bicyclists to wait that is fully within the view of motorists who are waiting at the stop bar, thus improving bicyclist visibility. This design enables bicyclists to enter the intersection prior to turning motorists, enabling them to establish the right-of-way in a similar manner as a leading bicycle interval. Ideally, the bicycle queuing area should be **at least 6 ft.** long to accommodate a typical bicycle length. The opening at the entrance and exit of the crossing to the street should typically be the same width as the bike zone, but no less than **6 ft.** wide. Where stops are required, a stop line should be placed near the edge of the crossing roadway.

Where feasible, the designer should consider providing additional queuing space on streets with high volumes of bicyclists.

3. MOTORIST YIELD ZONE

Bicycle and pedestrian crossings set back from the intersection create space for turning motorists to yield to bicyclists and pedestrians. Research has found crash reduction benefits at locations where bicycle crossings are set back from the motorist travel way by a distance of **6 ft. to 16.5 ft.**^{6,7,8,9} As shown in [EXHIBIT 4U](#) in [Section 4.3.6](#), this offset provides the following benefits:

- **Improves motorist view of approaching bicyclists by reducing need for motorists to turn their head.**
- **Eliminates the need to rely on the use of mirrors to look behind for bicyclists.**
- **Creates space for a motorist to yield to bicyclists and pedestrians without blocking traffic and to stop prior to the crossing.**
- **Provides additional time for bicyclists and pedestrians to react to turning motorists.**
- **Bicycle and pedestrian crossings should be separate but parallel to consolidate conflicts for motorists unless the crossing is a shared use path.**

4. PEDESTRIAN CROSSING ISLAND

The pedestrian crossing island is a space within the street buffer where pedestrians may wait between the street and the separated bike lane. It should be a **minimum of 6 ft.** wide and should include detectable warning panels. Pedestrian islands provide the following benefits:

- Enable pedestrians to negotiate potential bicycle and motor vehicle conflicts separately.
- Shortens pedestrian crossing distance of the street.
- Reduce the likelihood that pedestrians will block the bike lane while waiting for the walk signal.

The crossing island path may be directly adjacent to the forward bicycle queuing area, but these spaces should not overlap unless the facility is a shared use path. Separation via a raised median improves comfort and compliance among pedestrians and bicyclists (pedestrians are less likely to wander into the bike lane zone, and vice versa). The opening in the crossing island should match the width of the pedestrian crosswalk.

5. PEDESTRIAN CROSSING OF SEPARATED BIKE LANE

Pedestrian crossings should be provided to indicate a preferred crossing of the separated bike lane and to communicate a clear message to bicyclists that pedestrians have the right-of-way. The crossing should typically align with crosswalks in the street. Yield lines in the bike lane in advance of the pedestrian crosswalk are typically used to emphasize pedestrian priority.

It is also important to provide clear and direct paths for pedestrians to reduce the likelihood that they will step into or walk within the bike lane except at designated crossings.

6. PEDESTRIAN CURB RAMP

Pedestrian curb ramps may be required to transition pedestrians from the sidewalk to the street where there is a change in elevation between the two. It is preferable to use perpendicular or parallel curb ramps. The ramp must comply with ADA and MassDOT guidelines. Detectable warning panels must be provided at the edges of all street and bike zone crossings.



Rotterdam, Netherlands

4.3.2 DESIGN STRATEGIES FOR CONSTRAINED LOCATIONS

At constrained locations, it may not be feasible to maintain the preferred widths of motor vehicle lanes, buffers, bike lanes, and sidewalks to the corner. (However, sidewalk widths cannot be reduced below the required ADA minimums.) As discussed in [Section 3.6](#) it may be necessary to narrow a zone to the minimum dimensions or to eliminate the sidewalk buffer to achieve the desired design. At locations where there are no conflicts with turning vehicles, the street buffer can be minimized and the motorist yield zone can be reduced or eliminated. See [EXHIBIT 4N](#) for an illustration of the motorist yield zone. Where conflicts remain, it is preferable to maintain a motorist yield zone.

Where it is necessary to laterally shift the separated bike lane within a constrained intersection, the shift should generally

occur gradually, at no greater than a **taper of 3:1**. Additionally alternative curb ramp designs, spot sidewalk widening, or modifications to the sidewalk and/or bike lane elevation may be required to provide a satisfactory design solution.

The minimum width of a raised street buffer zone is **2 ft**.

The following strategies may be considered to maintain a protected intersection design in a constrained location.

I. Bend-out Deflection

It may be desirable to bend-out the separated bike lane as it approaches the intersection (see [EXHIBIT 4O](#)). This creates:

- **A larger yielding zone for motorists.**
- **Larger queuing areas for bicyclists and pedestrians within the street buffer.**

This may be particularly beneficial at locations with permissive left turn conflicts where turning motorists are focused on identifying gaps in opposing traffic, as it can be used to provide a place for a left-turning vehicle to wait while yielding to bicyclists.

Bend-out deflection may also be desirable where it is necessary to create a pedestrian platform for transit stops, queuing space for loading or parking activities (see [Chapter 5](#)).

II. Bend-in Deflection

In general, it is not desirable to bend-in the separated bike lane unless it is to maintain minimum sidewalk widths in constrained corridors that require elimination of sidewalk buffers and narrowing of street buffers. The provision of a motorist yield zone should be provided by increasing the size of the corner island as shown in [EXHIBIT 4P](#).



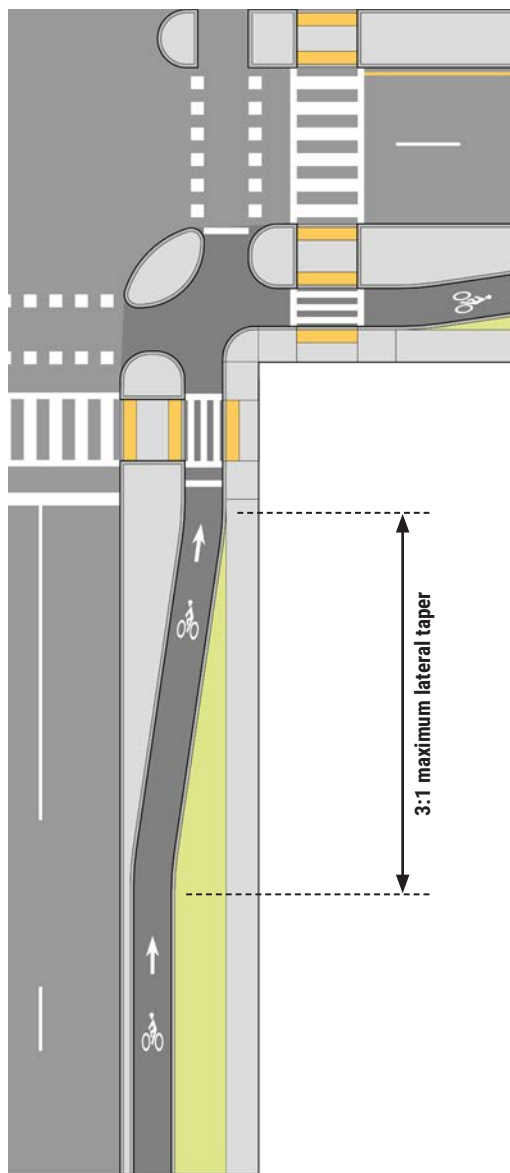


EXHIBIT 40: Bend-out Example

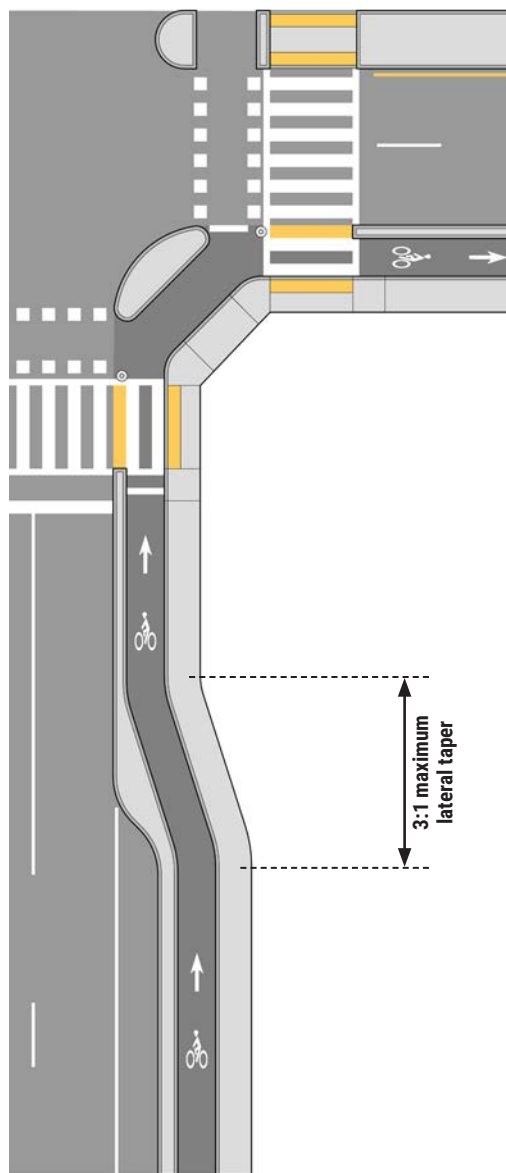


EXHIBIT 4P: Bend-in Constrained Example



Zwolle, Netherlands

4.3.3 MIXING ZONE TRANSITIONS

Mixing zones create a defined merge point for a motorist to yield and cross paths with a bicyclist in advance of an intersection. They require removal of the physical separation between the bike lane and the motor vehicle travel lane. This allows motorists and bicyclists to cross paths within a travel lane to either reach a conventional bike lane near the stop bar (see **EXHIBIT 4Q**), or to share a motor vehicle lane (see **EXHIBIT 4R**). For both situations, a clearly defined, slow speed merging area increases the predictability and safety of all users.

Protected intersections are preferable to mixing zones. Mixing zones are generally appropriate as an interim solution or in situations where severe right-of-way constraints make it infeasible to provide a protected intersection.

Mixing zones are only appropriate on street segments with one-way separated bike lanes. They are not appropriate for two-way separated bike lanes due to the contra-flow bicycle movement. The following design principals should be applied to mixing zones:

- **Locate the merge point where the entering speeds of motor vehicles will be 20 mph or less by:**
 - Minimizing the length of the merge area (50 ft. minimum to 100 ft. maximum).
 - Locating the merge point as close as practical to the intersection.

- Minimize the length of the storage portion of the turn lane.
- Provide a buffer and physical separation (e.g., flexible delineator posts) from the adjacent through lane after the merge area, if feasible.
- Highlight the conflict area with a green surface coloring and dashed bike lane markings, as necessary, or shared lane markings placed on a green box.
- Provide a **BEGIN RIGHT (or LEFT) TURN LANE YIELD TO BIKES** sign (R4-4) at the beginning of the merge area.
- Restrict parking within the merge area.
- At locations where raised separated bike lanes are approaching the intersection, the bike lane should transition to street elevation at the point where parking terminates.

Where posted speeds are **35 mph** or higher, or at locations where it is necessary to provide storage for queued vehicles, it may be necessary to provide a deceleration/storage lane in advance of the merge point.



New York, NY

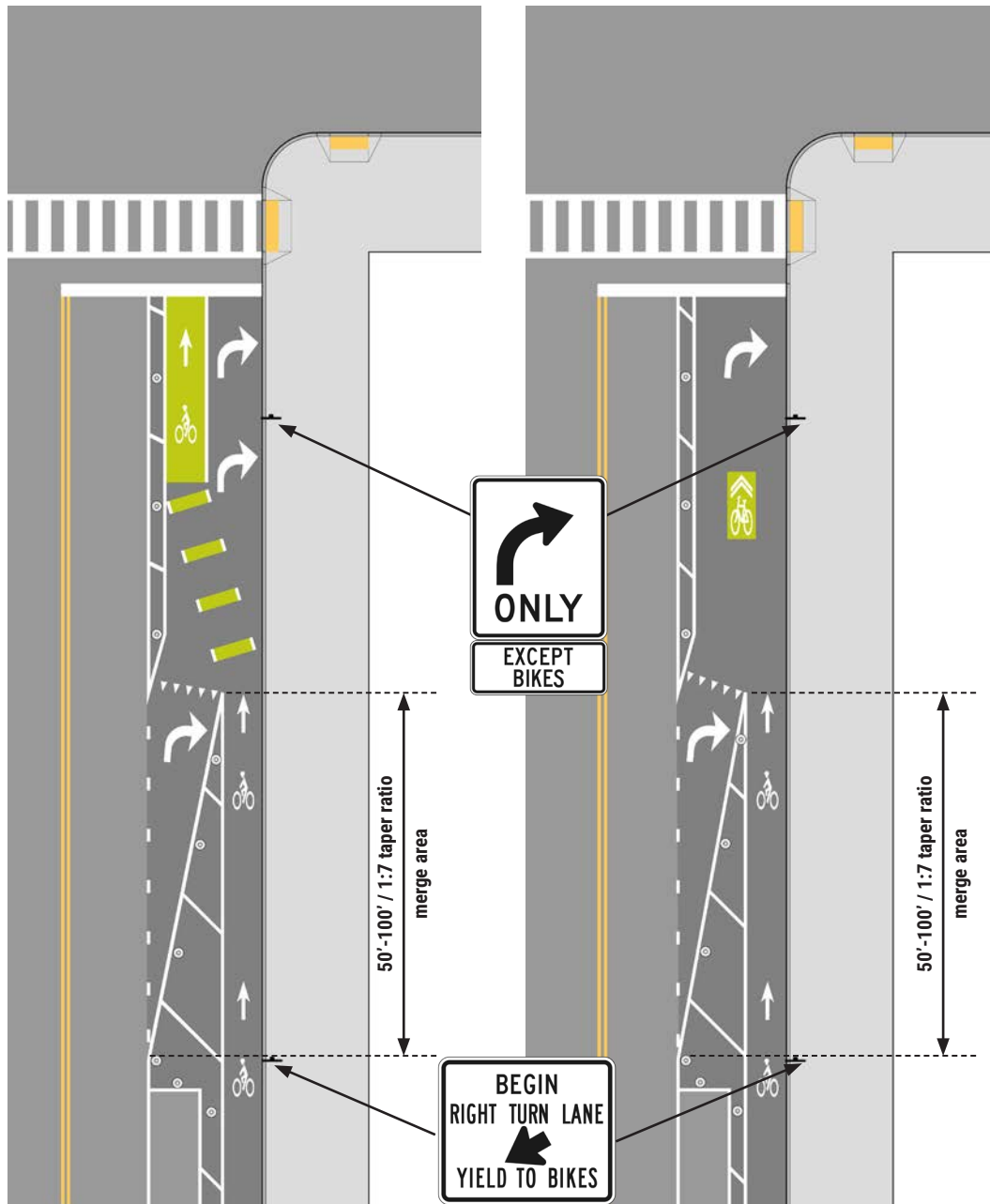


EXHIBIT 4Q: Angled Crossing Mixing Zone with Bike Lane

EXHIBIT 4R: Angled Crossing Mixing Zone with Shared Lane



New York, NY

4.3.4 ROUNDABOUT DESIGN WITH SEPARATED BIKE LANES

When separated bike lanes are provided at roundabouts, they should be continuous around the intersection, parallel to the sidewalk (see EXHIBIT 4S). Separated bike lanes should generally follow the contour of the circular intersection. The design of the street crossings should include the following features (see EXHIBIT 4T):

- The bicycle crossing should be immediately adjacent to and parallel with the pedestrian crossing, and both should be at the same elevation. 1
- Consider providing supplemental yield lines at roundabout exits to indicate priority at these crossings. 2
- The decision of whether to use yield control or stop control at the bicycle crossing should be based on available sight distance. 3
- The separated bike lane approach to the bicycle crossing should result in bicyclists arriving at the queuing area at a perpendicular angle to approaching motorists. 4
- Curb radius should be a minimum of 5 ft. to enable bicyclists to turn into the queuing area. 4

- Channelizing islands are preferred to maintain separation between bicyclists and pedestrians, but may be eliminated if different surface materials are used. 5
- Place BICYCLE/PEDESTRIAN WARNING signs (W11-15) as close as practical to the bicycle and pedestrian crossings (see Section 4.4.9). 6

At crossing locations of multi-lane roundabouts or roundabouts where the exit geometry will result in faster exiting speeds by motorists (thus reducing the likelihood that they will yield to bicyclists and pedestrians), additional measures should be considered to induce yielding such as providing an actuated device such as a Rapid Flashing Beacon or Pedestrian Hybrid Beacon.

EXHIBIT 4S: Design for Roundabout with Separated Bike Lanes

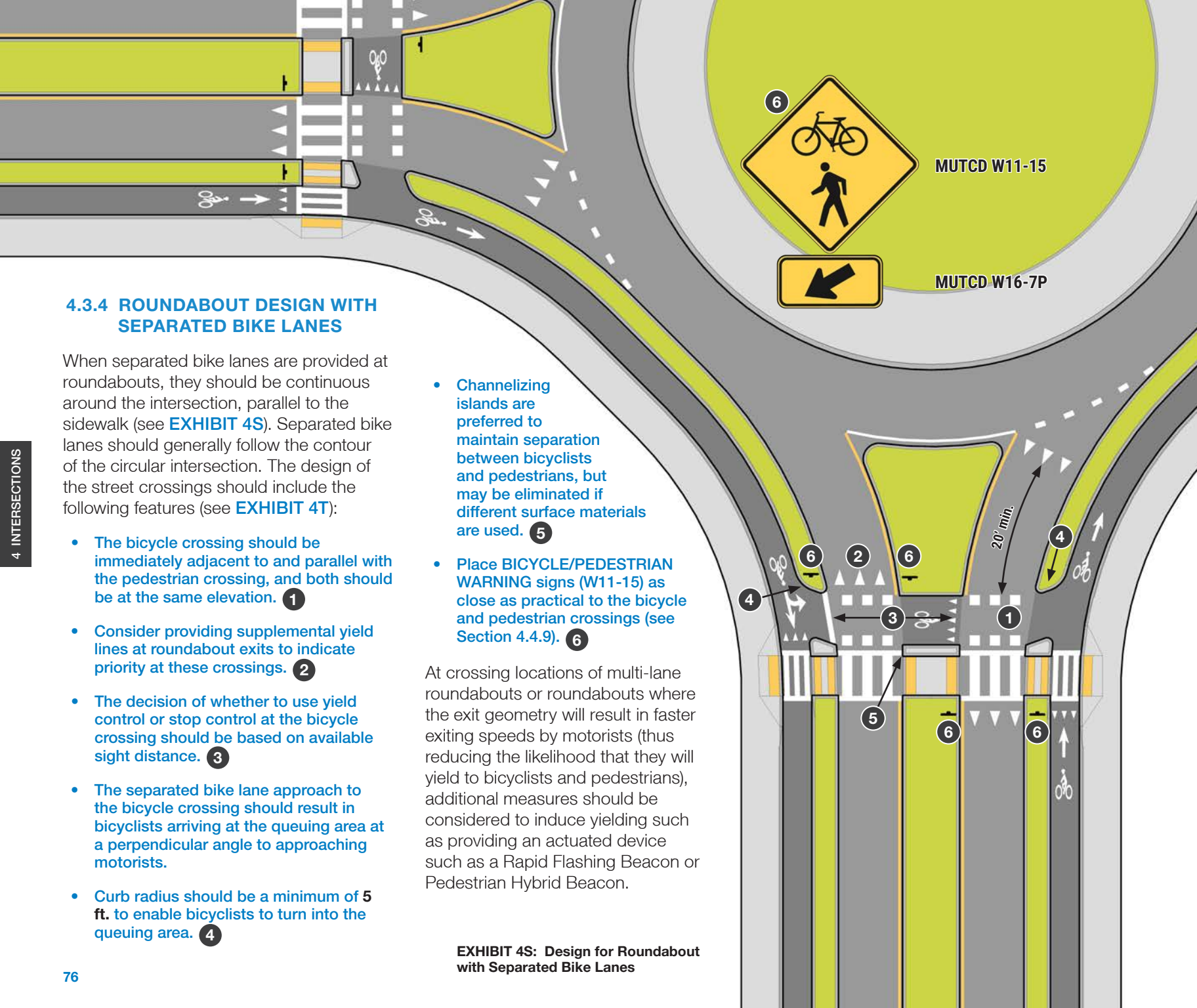
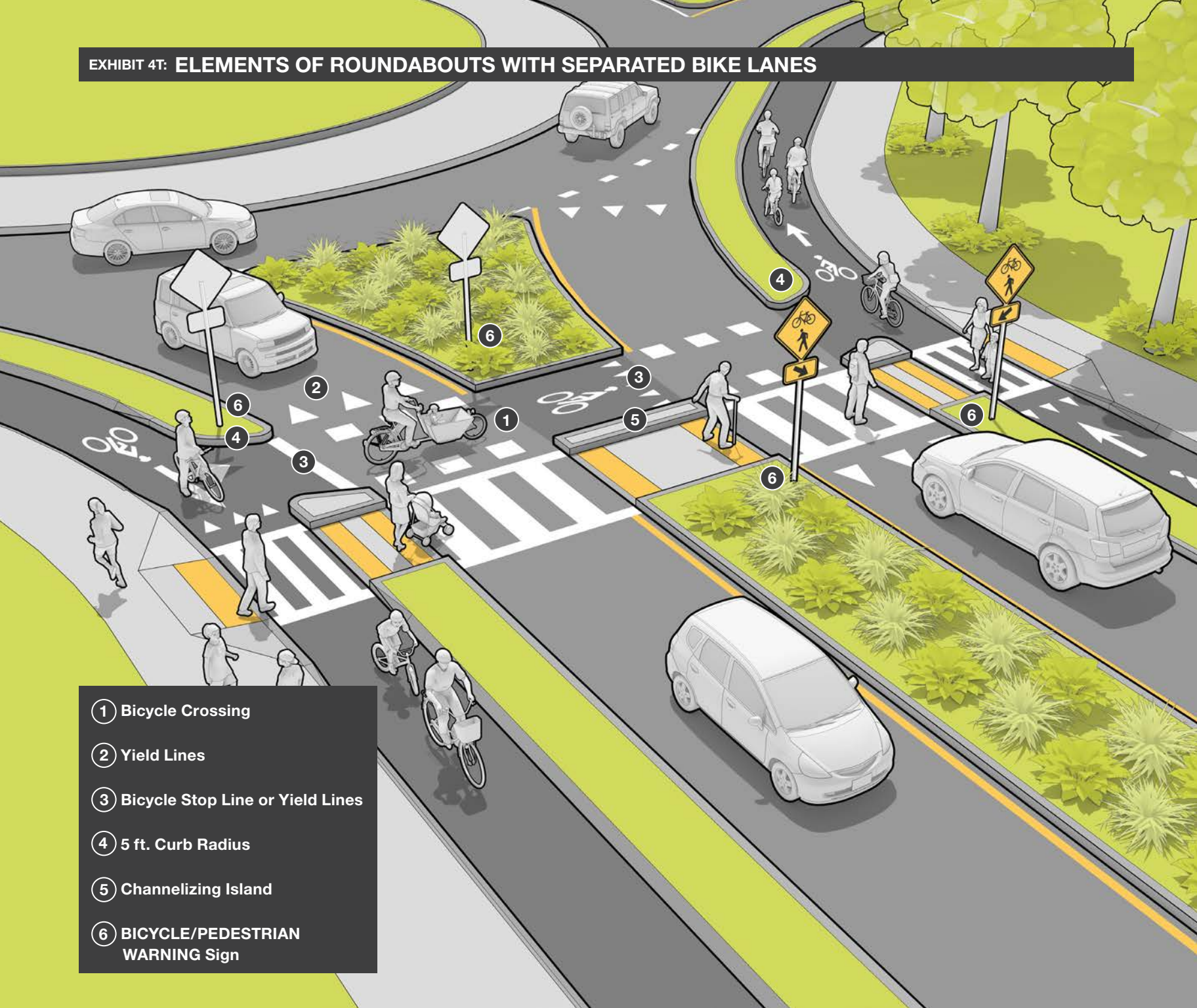


EXHIBIT 4T: ELEMENTS OF ROUNDABOUTS WITH SEPARATED BIKE LANES



- 1 Bicycle Crossing
- 2 Yield Lines
- 3 Bicycle Stop Line or Yield Lines
- 4 5 ft. Curb Radius
- 5 Channelizing Island
- 6 BICYCLE/PEDESTRIAN WARNING Sign

4.3.5 DRIVEWAY CROSSINGS

The design of driveways will follow the **PD&DG**, which has design criteria based on the primary use of the driveway: residential, commercial or industrial (see **Chapter 15 of the PD&DG**). In general, the width of the driveway crossing should be minimized and access management strategies should be considered along separated bike lane routes to minimize the frequency of driveway crossings.

Where separated bike lanes cross driveways, the design should clearly communicate that bicyclists have the right-of-way by continuing the surface treatment of the bike lane across the driveway. Per **Section 4.2.2**, raised crossings should be considered to improve bicyclist safety.

For low volume residential driveways, the driveway crossing should be clearly marked with a bicycle crossing. It does not need stop or yield signs for motorists exiting the driveway unless an engineering study indicates a need.

At crossings (both controlled and uncontrolled) of high volume residential or commercial driveways, or any industrial driveway, a protected intersection design is preferred. If a protected intersection is not feasible, the driveway should provide a raised crossing with green conflict zone pavement markings.

At uncontrolled high volume driveways where a protected intersection is not feasible, a raised crossing with green conflict zone markings should be provided along with a BICYCLE WARNING sign (W11-1) or BICYCLE/PEDESTRIAN

WARNING sign (W11-15) (see **Section 4.4.8 and Section 4.4.9**). At locations with two-way separated bike lanes, the W11-1 or W11-15 sign should be supplemented with a two-directional arrow (W1-7 alt.) supplemental plaque (see **Section 4.4.8**).

If parking is allowed parallel to the separated bike lane, it should be restricted in advance of the driveway crossing to achieve adequate approach sight distance (see **EXHIBIT 4J**). A clear line of sight should be provided between motorists exiting and entering the driveway and approaching bicyclists. Sight lines should be examined before major reconstruction projects to identify strategies to further improve visibility while balancing on-street parking availability (e.g., relocating streetscape elements, lengthening curb extensions, etc.).



4.3.6 RECESSED (SET BACK) CROSSINGS

Recessed bicycle and pedestrian crossings are a central element of the protected intersection discussed in [Section 4.3.1](#). The benefits of a recessed crossing apply equally to shared use path intersections with streets, driveways or alleys where permissive motorist turns are allowed. Similar to roundabouts, a recessed

crossing can reduce conflicts at crossings by creating space for the motorist to yield to approaching bicyclists followed by an additional space of approximately one car length to wait at the edge of the roadway to look for a gap in traffic without blocking the path. Raised crosswalks and refuge islands can be incorporated into the treatment to provide additional safety benefits. [EXHIBIT 4U](#) provides an example of a recessed crossing at a shared use path intersection.

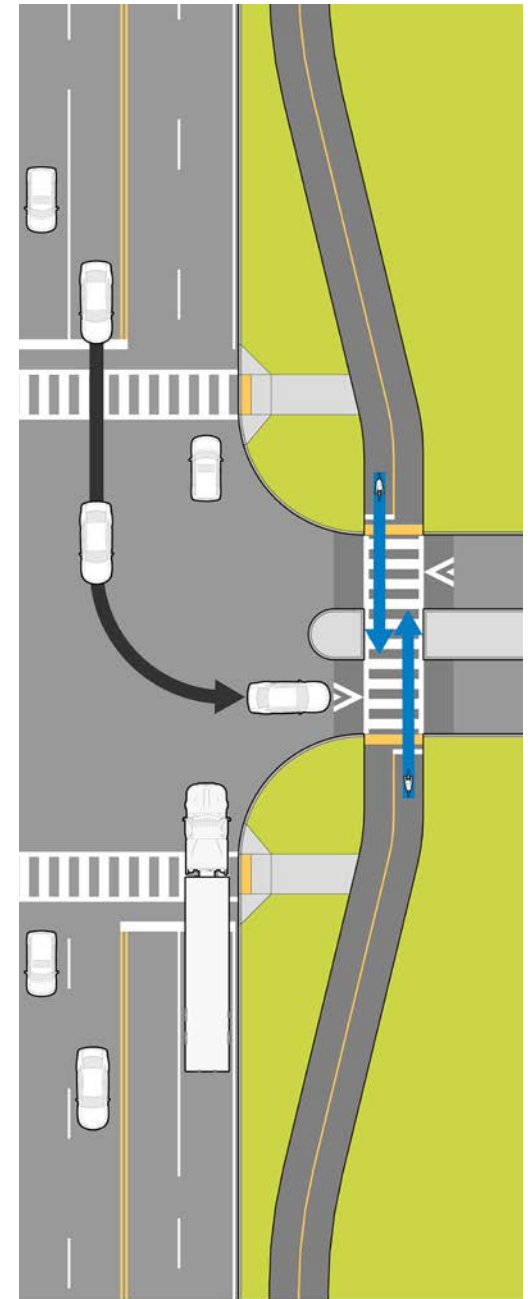
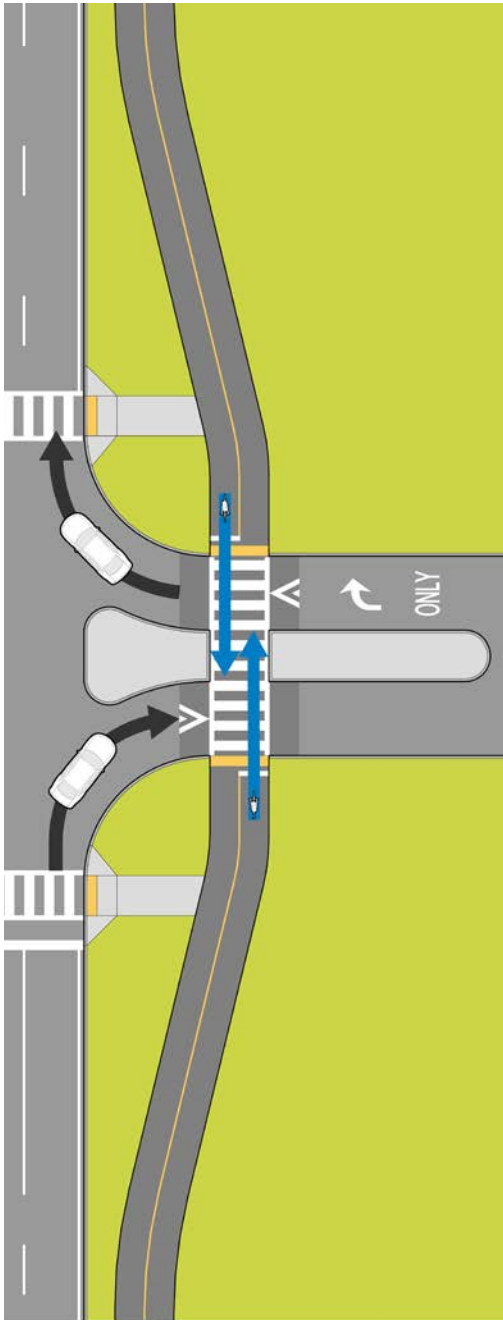


EXHIBIT 4U: Recessed Crossing at Shared Use Path Intersection



4.3.7 ACCESS MANAGEMENT

It may be feasible or desirable in some locations to implement access management principles to improve overall traffic flow and safety within a corridor as well as to eliminate motorist conflicts with bicyclists in the separated bike lane. Specific strategies that should be considered include:

- Restrict left turns and/or through crossings of a separated bike lane.
- Construct medians.
- Introduce regulatory sign restrictions.
- Consolidate driveways to reduce potential frequency of conflicts.
- Restrict turn-on-red to maintain integrity of crossings and bicycle queuing areas.

EXHIBIT 4V provides an example of a recessed crossing combined with a median refuge to restrict through crossings and left turns across a shared use path intersection.

EXHIBIT 4V: Recessed Crossing at a Shared Use Path Intersection with Left Turn and Through Crossing Restrictions

4.3.8 GRADE SEPARATION

Grade separation is achieved through the provision of a bridge or underpass. This is likely to be a relatively rare design strategy due to cost and space constraints. It may be a desirable solution for crossing limited access highways or other high volume (**more than 20,000 vehicles/day**), high speed (**more than 45 mph**) streets where motorists are not likely to yield, gaps in traffic are infrequent, and provision of a signalized crossing is not viable. The structure should be constructed to accommodate bicyclists and pedestrians. The design of a bridge or tunnel for a separated bike lane should follow the guidance provided for shared use paths in **Chapter 11 of the PD&DG** and **Section 5.2.10 of the AASHTO Bike Guide**. In areas where pedestrian and bicycle volumes are higher, it is recommended that separate treadways for bicyclists and pedestrians be maintained across the structure.

4.4 PAVEMENT MARKING AND TRAFFIC SIGN GUIDANCE

The design of traffic control devices is controlled by the **Manual on Uniform Traffic Control Devices (MUTCD)** as adopted with amendments by MassDOT and the Standard Municipal Traffic Code. The following discussion provides an overview of key traffic control markings and signs that are frequently required at separated bike lane crossings. Traffic signals are discussed in **Chapter 6**.

4.4.1 BICYCLE CROSSING

A bicycle crossing is a marked crossing of an intersection with a street, driveway or alley. The purpose of the crossing is to

- Delineate a preferred path for people bicycling through the intersection.
- Encourage motorist yielding behavior, where applicable.

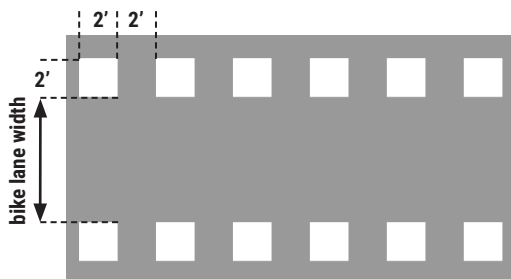


EXHIBIT 4W: One-way Bicycle Crossing

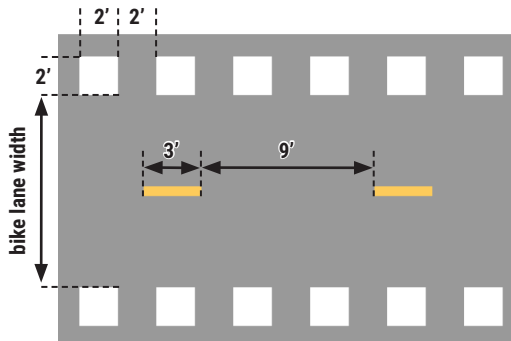


EXHIBIT 4X: Two-way Bicycle Crossing

EXHIBIT 4W and EXHIBIT 4X indicate the standard dimensions of marked bicycle crossings. It is preferable, if adequate space exists, to place the markings on the outside of the bike lane width (i.e., maintaining the clear width of the bike lane through the intersection with the markings placed on the outside). If this is not feasible due to space constraints, the markings can be placed on the inside of the bike lane. The bicycle crossing may be supplemented with a green colored surface to improve contrast with the surrounding roadway and adjacent pedestrian crossing, if present. Green surfacing may be desirable at crossings where concurrent vehicle crossing movements are allowed.

4.4.2 BICYCLE STOP LINE

Bicycle stop lines indicate the desired place for bicyclists to stop within a separated bike lane in compliance with a stop sign (R1-1) or traffic signal. At locations with bicycle queuing areas, a **1 ft.** wide stop line should be placed near the edge of the crossing roadway. In constrained locations where there is no bicycle queuing area, the stop line should be located prior to the pedestrian crosswalk or crossing separated bike lane to prevent queued bicyclists from blocking the path of a crossing pedestrian or bicyclist.

4.4.3 YIELD LINES

Yield lines (**12 in. by 18 in.**) are typically used in advance of pedestrian crossings of separated bike lanes to emphasize pedestrian priority (see EXHIBIT 4Y). Yield lines (**24 in. by 36 in.**) may be used in advance of bicycle crossings to emphasize bicyclist priority at the following locations (see EXHIBIT 4Z):

- Uncontrolled crossings.
- On the exit leg of signalized intersections where motorists turn across a bicycle crossing during a concurrent phase.
- Bicycle crossings located within roundabouts.
- Motorists yield points at mixing zones with advanced queuing lanes (see Section 4.3.3).

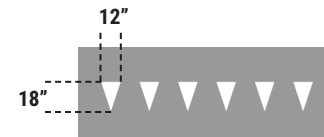


EXHIBIT 4Y: Yield Lines for Use in Separated Bike Lanes



EXHIBIT 4Z: Yield Lines for Use in Roadways

4.4.4 TURNING VEHICLES YIELD TO BICYCLES AND PEDESTRIANS SIGN

The TURNING VEHICLES YIELD TO BICYCLES AND PEDESTRIANS (R10-15 alt.) sign may be used to notify permissive left or right turning motorists of the requirement to yield to bicyclists at the crossing (see [EXHIBIT 4AA](#)). If used at a crossing, the sign should be mounted on the far side of the intersection to improve visibility to left turning motorists. If possible, it should be mounted on the vehicle sign face.



R10-15 alt.

EXHIBIT 4AA: TURNING VEHICLES YIELD TO BICYCLES AND PEDESTRIANS Sign

4.4.5 YIELD HERE TO BICYCLES SIGNS

At locations where yield lines are provided to denote the location for motorists to yield to bicyclists in crossings of separated bike lanes, a YIELD HERE TO BICYCLES (R1-5 alt. A) sign may be used (see [EXHIBIT 4AB](#)). If the yield condition includes pedestrians, the YIELD HERE TO BICYCLES AND PEDESTRIANS (R1-5 alt. B) sign may be used (see [EXHIBIT 4AC](#)). These signs are not required, and should not be used in locations where sign clutter is an issue.



R1-5 alt. A

EXHIBIT 4AB: YIELD HERE TO BICYCLES Sign



R1-5 alt. B

EXHIBIT 4AC: YIELD HERE TO BICYCLES AND PEDESTRIANS Sign



Washington, DC

4.4.6 PEDESTRIAN CROSSING

Marked crosswalks delineate the desired crossing point for pedestrians across a separated bike lane. They increase awareness of the crossing point for bicyclists and pedestrians, indicate priority for pedestrians at the crossing, and guide pedestrians across the bike lane in a direct path. Pedestrian crossings of the bike lane should be marked with continental striping. At uncontrolled crossings, yield lines may be provided on the bike lane approach to the crossing to indicate pedestrian priority. [Section 4.3.1](#) provides additional guidance on curb ramps and accessibility

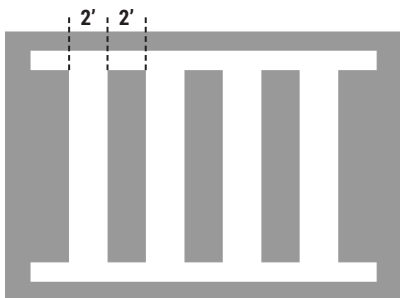


EXHIBIT 4AD: Pedestrian Crosswalk in Bike Lane, Option 1

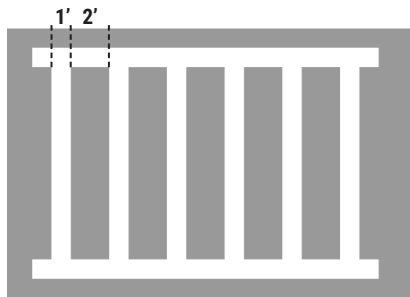


EXHIBIT 4AE: Pedestrian Crosswalk in Bike Lane, Option 2

considerations, such as detectable warning panels. [EXHIBIT 4AD](#) and [EXHIBIT 4AE](#) illustrate crosswalk design options for pedestrian crossings of separated bike lanes. Narrower width crosswalks are preferable at locations where separated bike lanes are less than **6 ft.** in width.

4.4.7 BEGIN RIGHT TURN YIELD TO BIKES SIGN

The BEGIN RIGHT TURN YIELD TO BIKES sign (R4-4) should be placed at locations where the beginning of the right turn lane corresponds with the merge point where motorists cross the separated bike lane (see [EXHIBIT 4AF](#)).



MUTCD R4-4

EXHIBIT 4AF: BEGIN RIGHT TURN YIELD TO BIKES Sign

4.4.8 BICYCLE WARNING SIGN

The BICYCLE WARNING sign (W11-1) may be placed at, or in advance of, uncontrolled crossings of separated bike lanes to alert motorists of approaching bicyclists.

The use of the sign should be limited to locations where the bike lane may be unexpected to crossing motorists. A TWO-WAY (W1-7 alt.) supplemental plaque should be mounted below the W11-1 where the separated bike lane operates as a two-way facility (see [EXHIBIT 4AG](#)).

If used at a crossing, the sign should be mounted as close as practical to the crossing.

If used in advance of the crossing, the sign should be located a minimum of **100 ft.** prior to the crossing in a location visible to the motorist. A NEXT RIGHT or NEXT LEFT supplemental plaque may be mounted below the W11-1 if appropriate.



MUTCD W11-1



W1-7 alt.

EXHIBIT 4AG: BICYCLE WARNING Sign and TWO-WAY sub-plaque

4.4.9 BICYCLE/PEDESTRIAN WARNING SIGN

The BICYCLE/PEDESTRIAN WARNING sign (W11-15) may be used in lieu of the W11-1 at locations where a sidewalk is parallel to the separated bike lane and motorists may not be expecting to cross either the bicycle or pedestrian crossing (see EXHIBIT 4AH).



MUTCD W11-15

EXHIBIT 4AH: BICYCLE/PEDESTRIAN WARNING Sign

4.4.10 TWO-STAGE TURN QUEUE BOX

A two-stage turn queue box should be considered where separated bike lanes are continued up to an intersection and a protected intersection is not provided. The two-stage turn queue box designates a space for bicyclists to wait while performing a two-stage turn across a street at an intersection outside the path of traffic (see EXHIBIT 4AI).

At the present time, two-stage turn queue boxes are considered experimental, therefore FHWA must approve the RFE prior to the 100 percent design submittal.

Two-stage turn queue box dimensions will vary based on the street operating conditions, the presence or absence of a parking lane, traffic volumes and speeds, and available street space. The queuing area should be a **minimum of 6.5 ft.** deep (measured in the longitudinal direction of bicycles sitting in the box). The box should consist of a green box outlined with solid white lines supplemented with a bicycle symbol. A turn arrow may be used to emphasize the crossing direction.

The turn box may be placed in a variety of locations including in front of the pedestrian crossing (the crosswalk location may need to be adjusted), in a 'jug-handle' configuration within a sidewalk, or at the tail end of a parking lane or a median island. The queuing area should be placed to provide clear visibility of bicyclists by motorists. Dashed bike lane extension markings may be used to indicate the path of travel across the intersection. NO TURN ON RED (R10-11) restrictions should be used to prevent vehicles from entering the queuing area.

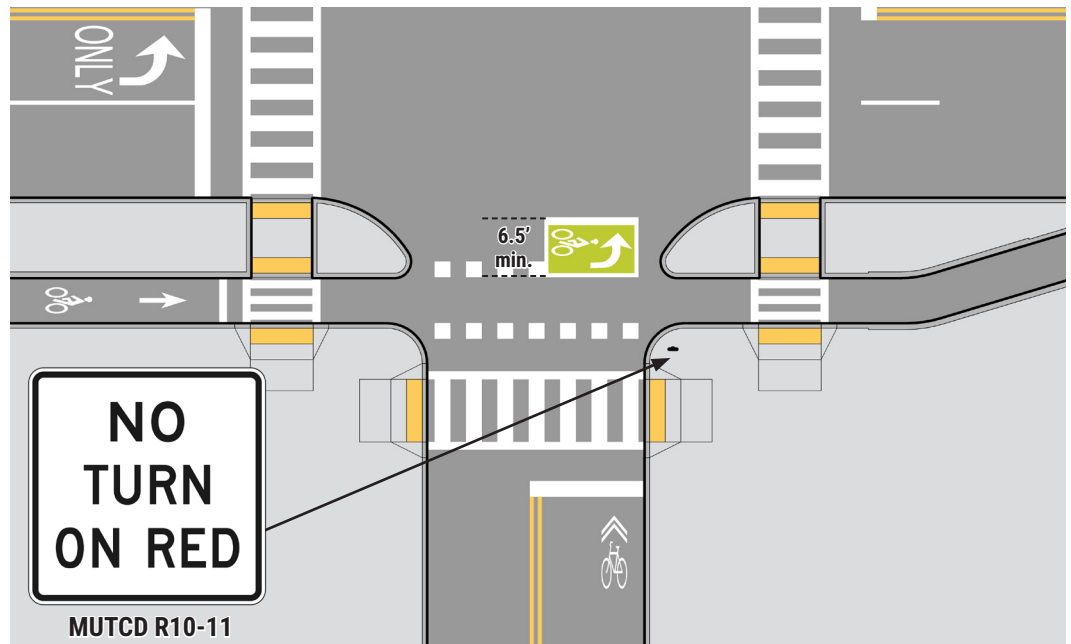


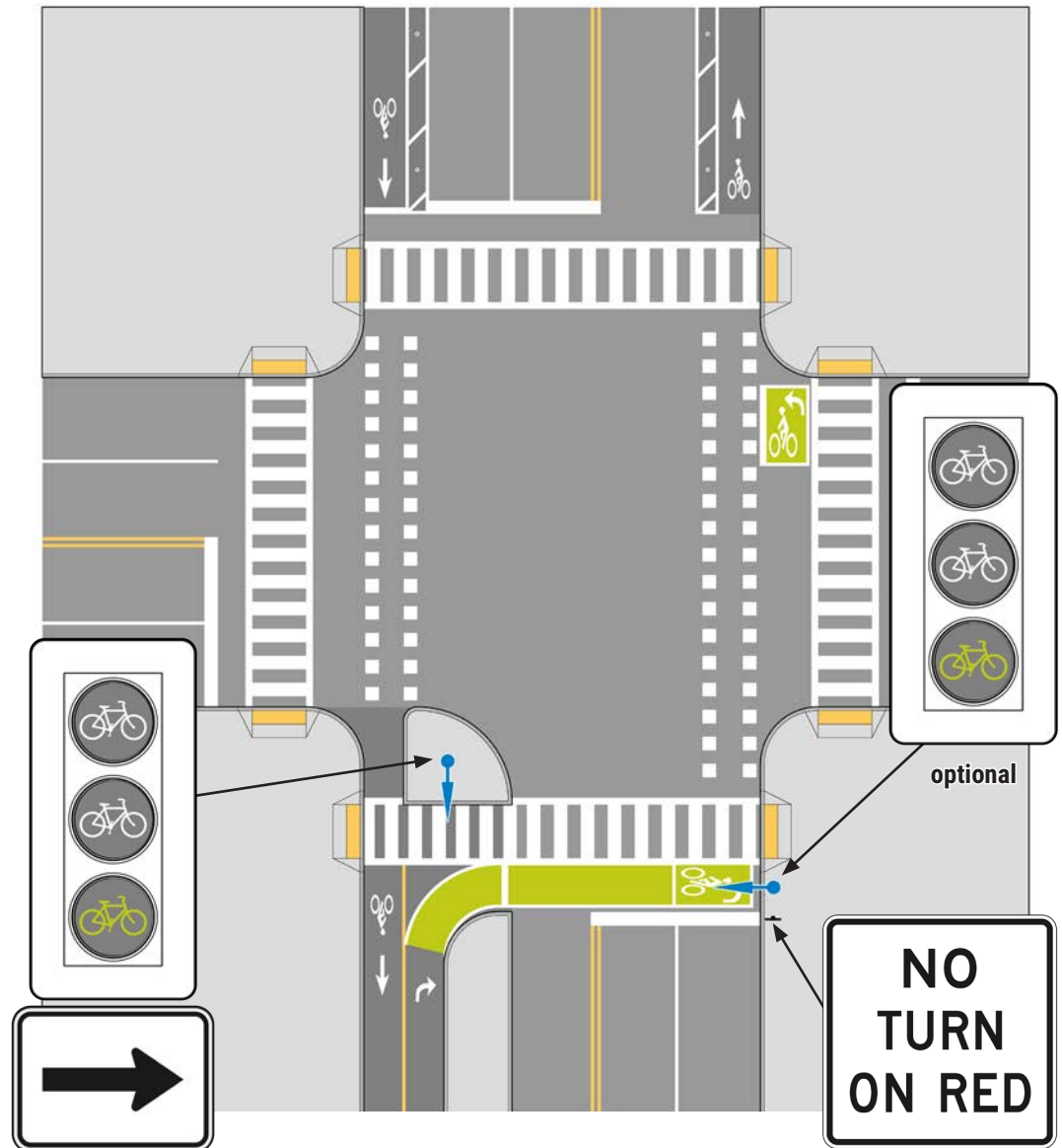
EXHIBIT 4AI: Two-stage Turn Queue Box and NO TURN ON RED Sign

4.5 EXAMPLES OF TRANSITIONS BETWEEN BIKEWAY TYPES

Transitions between separated bike lanes and other bikeway types will typically be required for all projects. The actual transition design will vary greatly from location to location depending upon many of the contextual factors discussed in [Section 4.1](#). The transition design should clearly communicate how bicyclists are intended to enter and exit the separated bike lane minimizing conflicts with other users.

Transitions of two-way separated bike lanes to bikeways or shared streets that require one-way bicycle operation require particular attention. Bicyclist operating contra-flow to traffic will be required to cross the roadway. Failure to provide a clear transition to the desired one-way operation may result in wrong way bicycle riding. The use of directional islands can provide positive direction for bicyclists to follow the desired transition route. It may also be desirable to use green crossings and two-stage queue boxes to provide strong visual guidance to all users of the intended path across the intersection. The crossing may warrant bicycle signals at signalized crossings. The signal should be coordinated with the cross street signal phase.

[EXHIBIT 4AJ](#) to [EXHIBIT 4AM](#) provide illustrations of some example transitions.

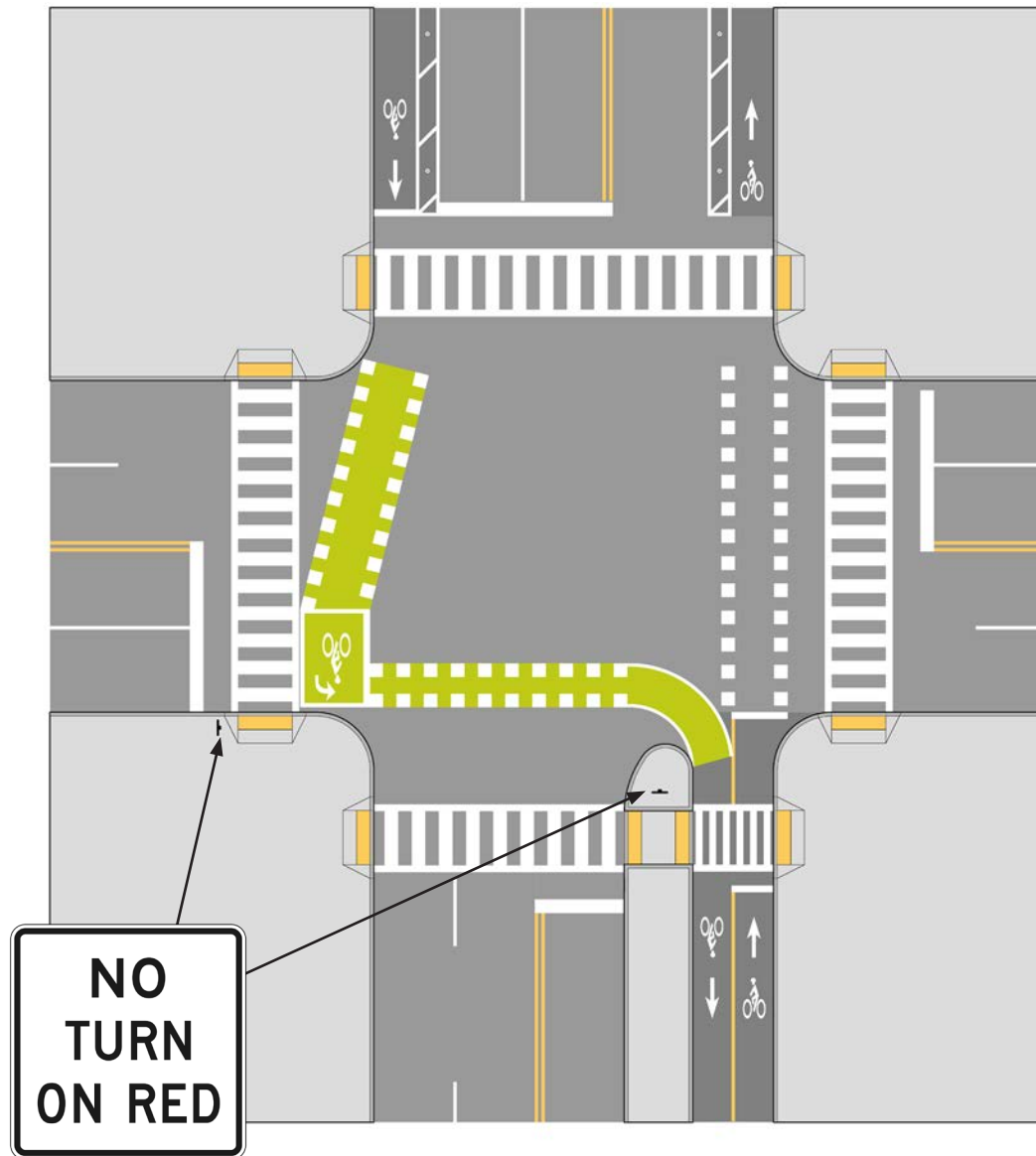


MUTCD M6-1

EXHIBIT 4AJ: Transition from a Two-way Separated Bike Lane

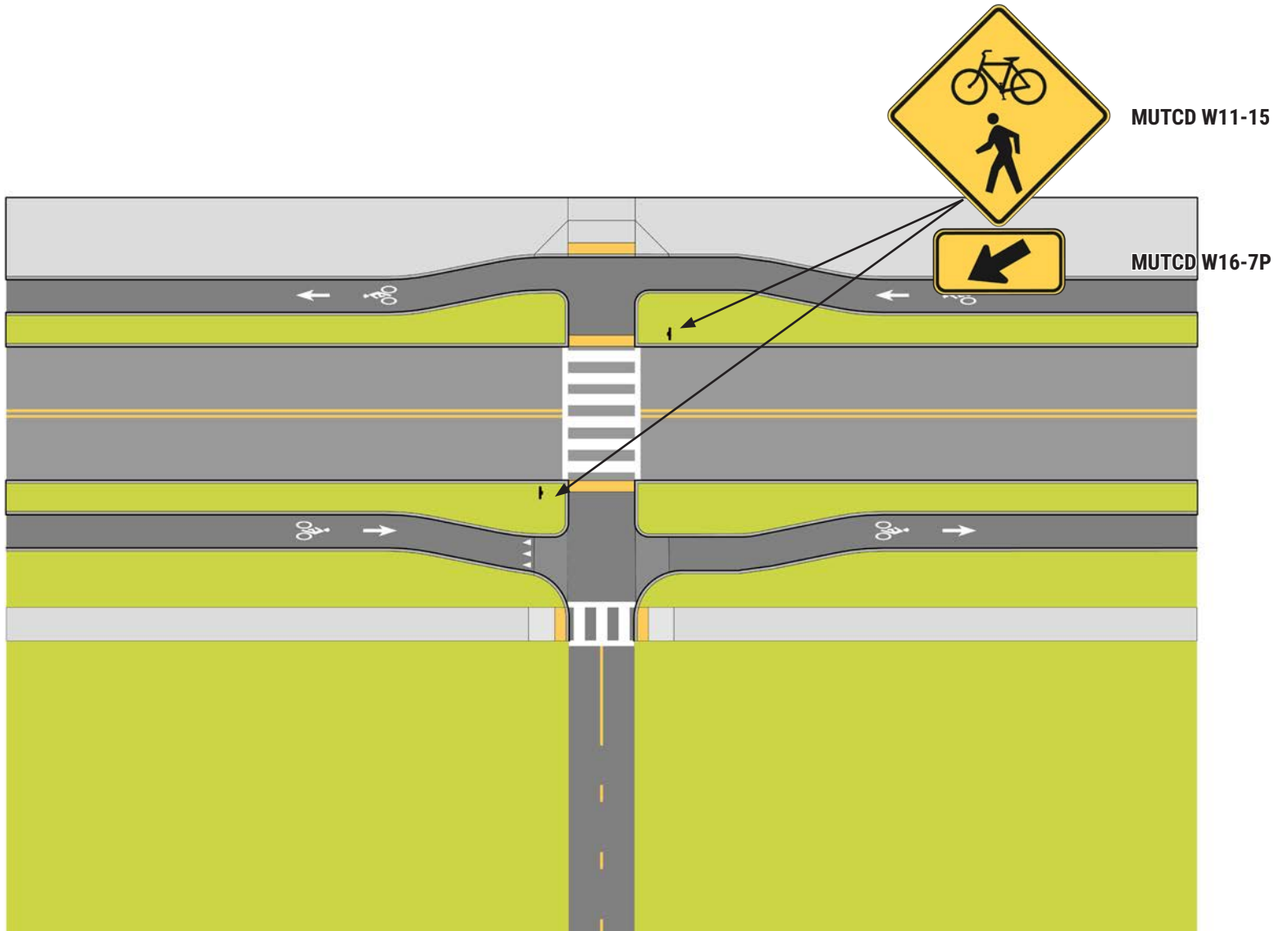
MUTCD R10-11

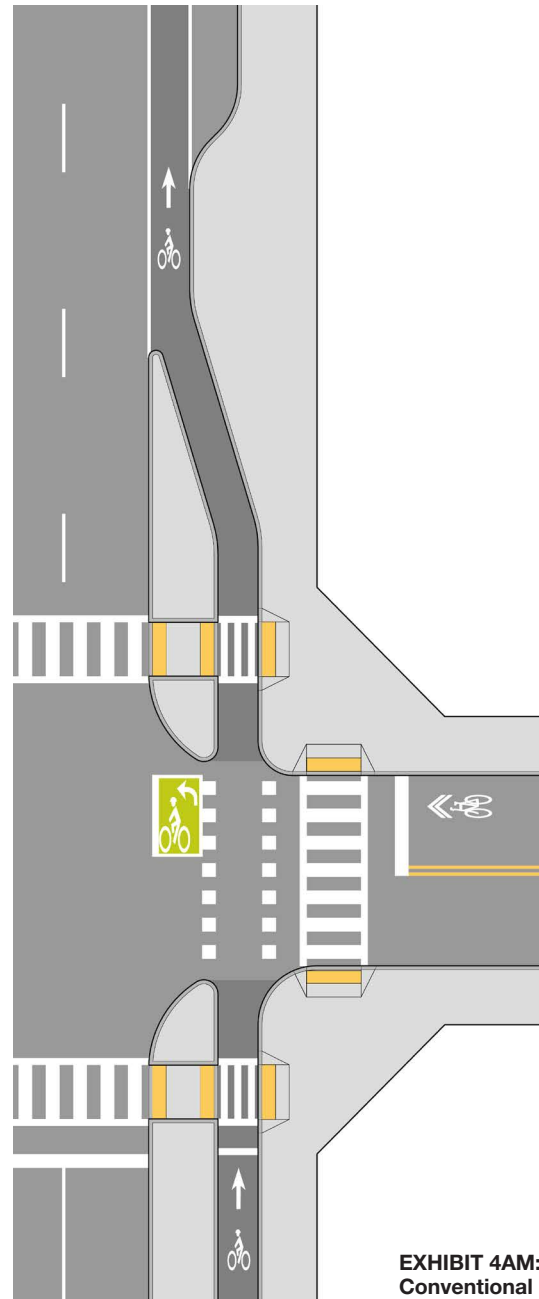
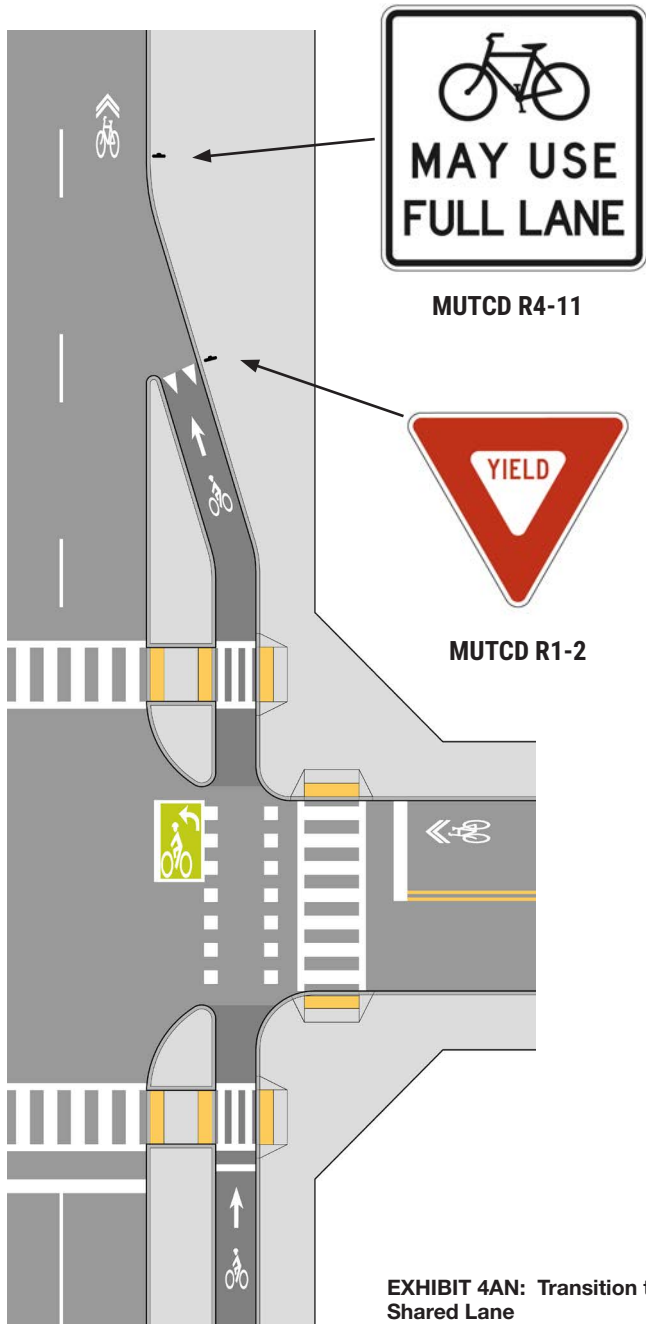
EXHIBIT 4AK: TRANSITION INTO A TWO-WAY SEPARATED BIKE LANE



MUTCD R10-11

EXHIBIT 4AL: TRANSITION BETWEEN SEPARATED BIKE LANES AND SHARED USE PATHS





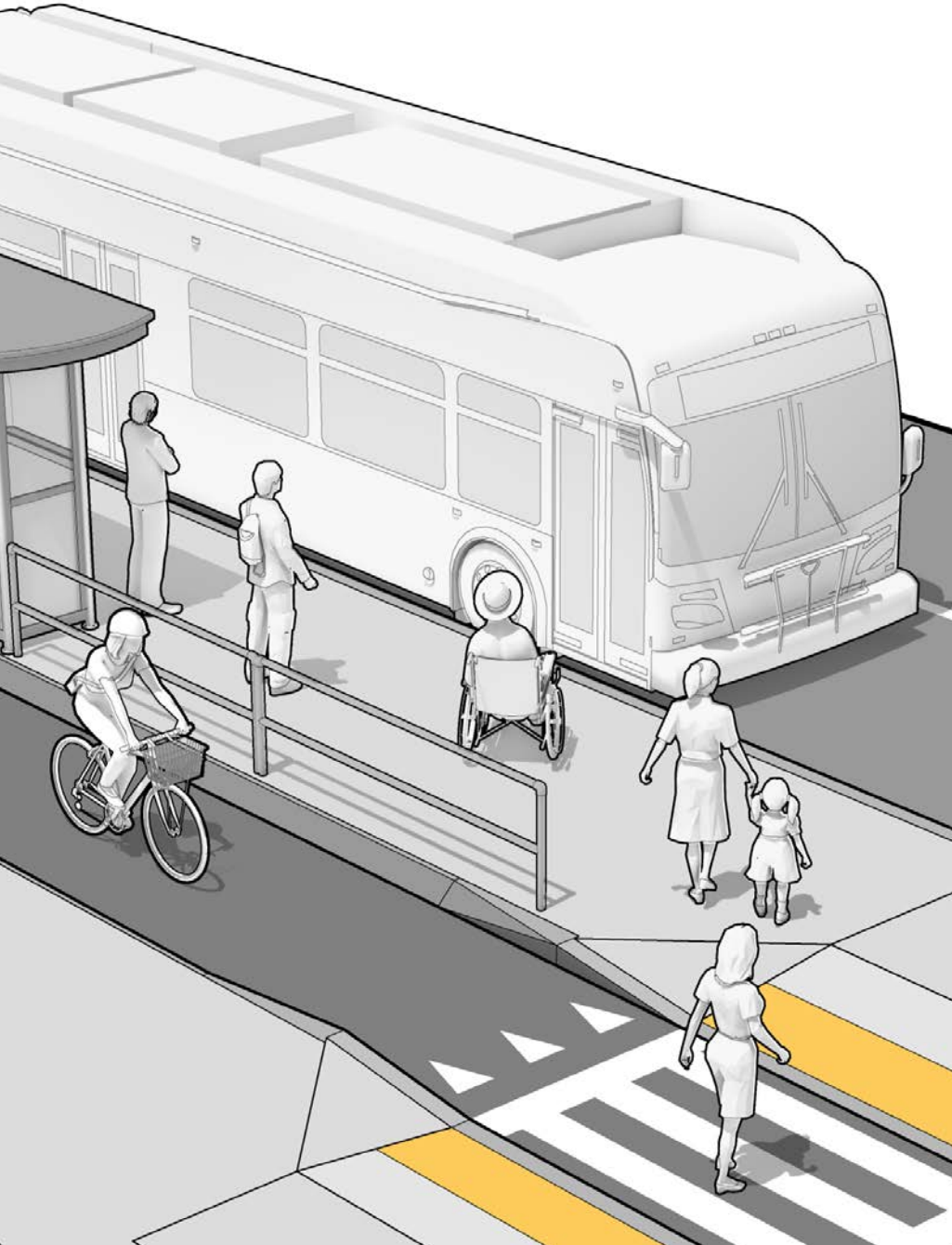
4.6 ENDNOTES

- 1 Salamati et al., 2013. Event-based Modeling of Driver Yielding Behavior to Pedestrians and Two-Lane Roundabout Approaches. Transportation Research Record, 2013(2389): 1-11. Accessed via: <http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3947582/>
- 2 Schepers et al., 2010. Road factors and bicycle-motor vehicle crashes at unsignalised priority intersections
- 3 Garder et al., 1998. Measuring the safety effect of raised bicycle crossings using a new research methodology
- 4 Schepers J, Kroeze P, Sweers W, Wust J, 2010. Road factors and bicycle-motor vehicle crashes at unsignalized priority intersections. Accidents Analysis and Preventions 43 (2011) 853-861.
- 5 Assumes motorists approach turn decelerating at rate of 11.2 ft./sec.², constant bicycle speed of 14 mph on level terrain, 1 second reaction times for bicyclists and motorists
- 6 Schepers, J. P., Kroeze, P. A., Sweers, W., & Wüst, J. C., 2011. Road factors and bicycle-motor vehicle crashes at unsignalized priority intersections. Accident Analysis & Prevention, 43(3), 853-861.
- 7 Brüde, Ulf and Jörgen Larsson, 1992. "Road Safety at Urban Junctions." Swedish Road and Traffic Research Institute. Report VTI Meddelande 685, 1992.
- 8 Schnüll, R., Lange, J., et al., 1992. Cyclist Safety at Urban Intersections , in German (Sicherung von Radfahrern an städtischen Knotenpunkten). BAST [German Federal Highway Research Institute], Bergisch Gladbach.
- 9 Welleman, A.G., Dijkstra, A., 1988. Safety Aspects of Urban Cycle Tracks (Veiligheidsaspecten van Stedelijke Fietspaden). Institute for Road Safety Research, Leidschendam.

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5

CURBSIDE ACTIVITY DESIGN



This chapter provides design guidance for separated bike lanes adjacent to curbside activities including parking, loading and bus stops. Typical configurations are presented for mid-block and intersection locations.

Curbside activities often present daily challenges for people with disabilities. Design guidance presented in this chapter conforms to federal and state accessibility requirements to ensure that separated bike lane designs adhere to accessibility standards:

- [Proposed Guidelines for Pedestrian Facilities in the Public Right-of-Way, United States Access Board – 2011 \(or subsequent guidance that may supersede these guidelines in the future\)](#)
- [Massachusetts Architectural Access Board \(AAB\) Rules and Regulations \(521 CMR\) - 2006](#)

5.1 ON-STREET MOTOR VEHICLE PARKING

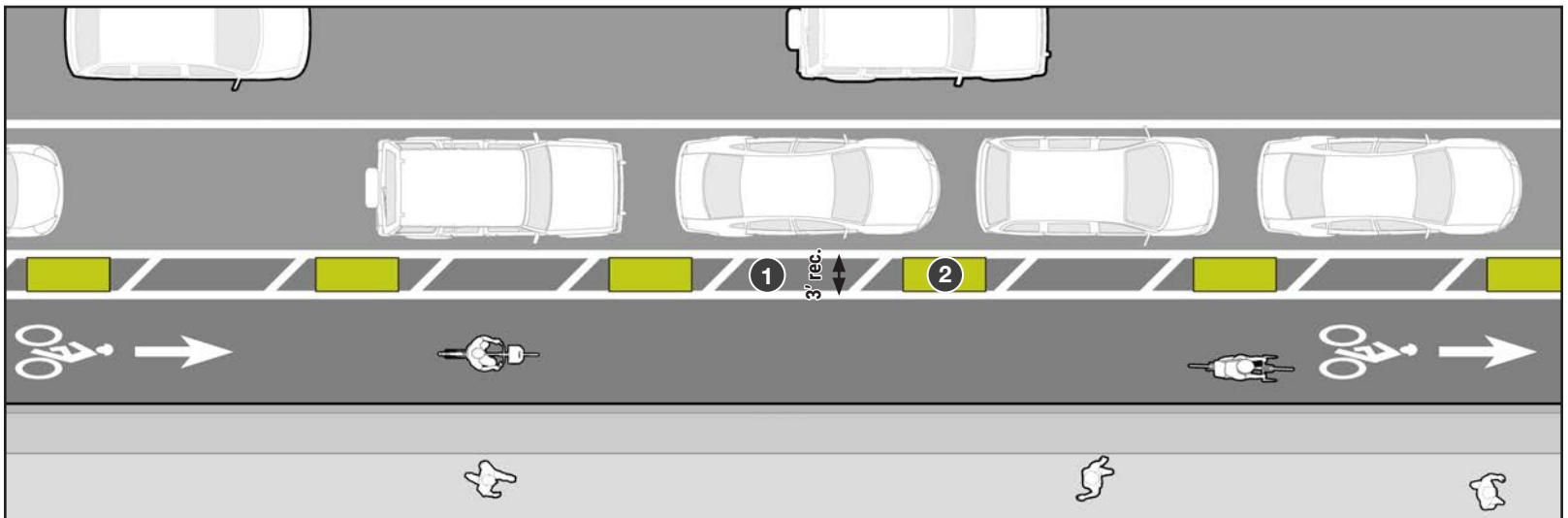
5.1.1 CONVENTIONAL MOTOR VEHICLE PARKING

On-street motor vehicle parking increases the comfort of people bicycling in the separated bike lane by providing physical separation (see [EXHIBIT 5A](#)). On-street motor vehicle parking can also coexist with contra-flow separated bicycle lanes since risk of injury from dooring to a contra-flow cyclist is much smaller than when riding with the flow of traffic due to the reduced frequency of passenger door openings and the passenger visibility of on-coming cyclists. On-street parking is typically common along roadways through more

developed areas such as village and town centers, urban neighborhoods and central business districts.

- Compatible with street, intermediate or sidewalk level separated bike lanes.
- **3 ft. street buffer recommended (2 ft. minimum) when adjacent to on-street parking to avoid conflicts with motor vehicle doors. ①**
- It may not be necessary to provide vertical objects adjacent to on-street parking, except in locations where parking is absent, such as near intersections.
- Vertical objects should be provided in all locations where on-street parking is prohibited for portions of the day, commercial areas where on-street parking turnover is high, or locations where parking demand is low.
- Locate vertical objects in a manner that minimizes conflicts with motor vehicle doors. ②
- Ensure parking does not encroach into the intersection approach clear space (see Section 4.2.5).
- Locate parking meters on a raised median in the street buffer. Where raised median is too narrow, place parking meters in the sidewalk buffer zone near a crosswalk.

EXHIBIT 5A: CONVENTIONAL ON-STREET MOTOR VEHICLE PARKING (MID-BLOCK)



5.1.2 ACCESSIBLE MOTOR VEHICLE PARKING

PROWAG R214 requires a minimum number of accessible on-street parking spaces on a block perimeter where marked or metered on-street parking is provided. Proximity to key destinations or roadway grades may require locating accessible parking on a block face with separated bike lanes.

- Refer to **PROWAG R309** for accessible parking guidance and **PROWAG R302.7** for surface guidance.

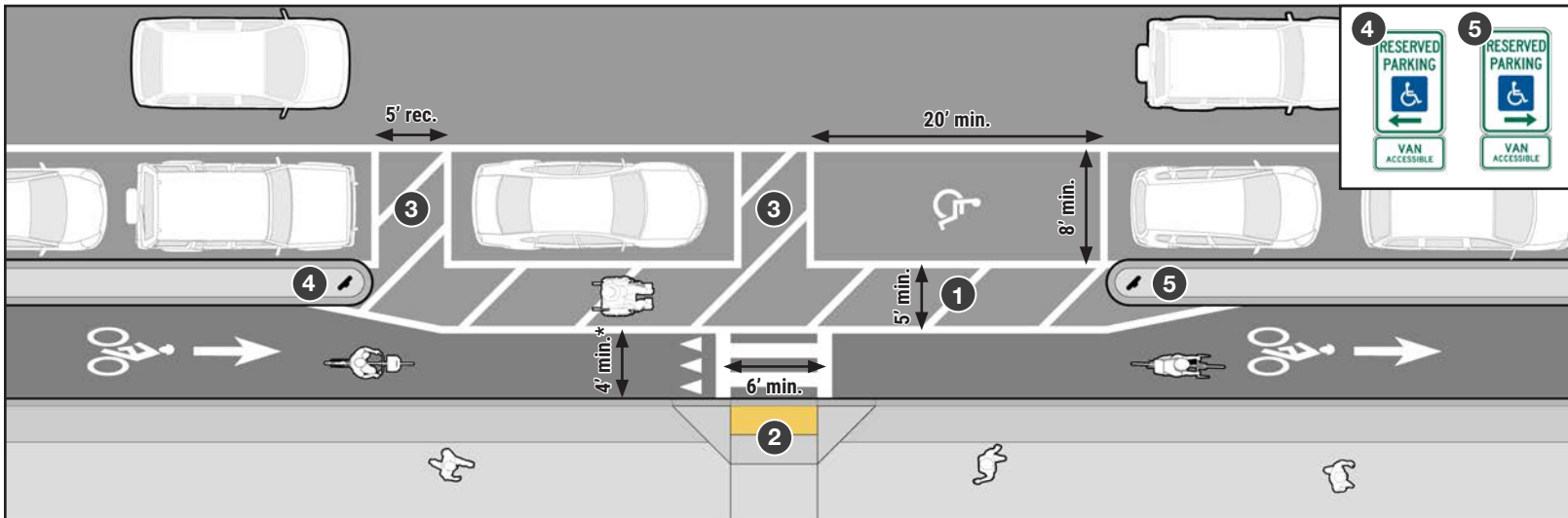
- The bike lane may be narrowed to **4 ft.** at accessible parking spaces with a design exception.
- A **5 ft. minimum street level access aisle is required where sidewalk width exceeds 14 ft.** **1** It must be free from obstructions, extend the full length of the parking space and connect to a pedestrian access route via curb ramp or blended transition. **2**
- Where an access aisle is not required, signed accessible space must be located at the end of the block face and adjacent sidewalk must be free of obstructions for vehicle lift deployment.

- Rear access aisles are recommended for driver side access to the sidewalk. **3**
- Place **RESERVED PARKING (R7-8)** and, if applicable, **VAN ACCESSIBLE (R7-8P)** sign at the head of each accessible parking space. **4 5**

MID-BLOCK LOCATIONS

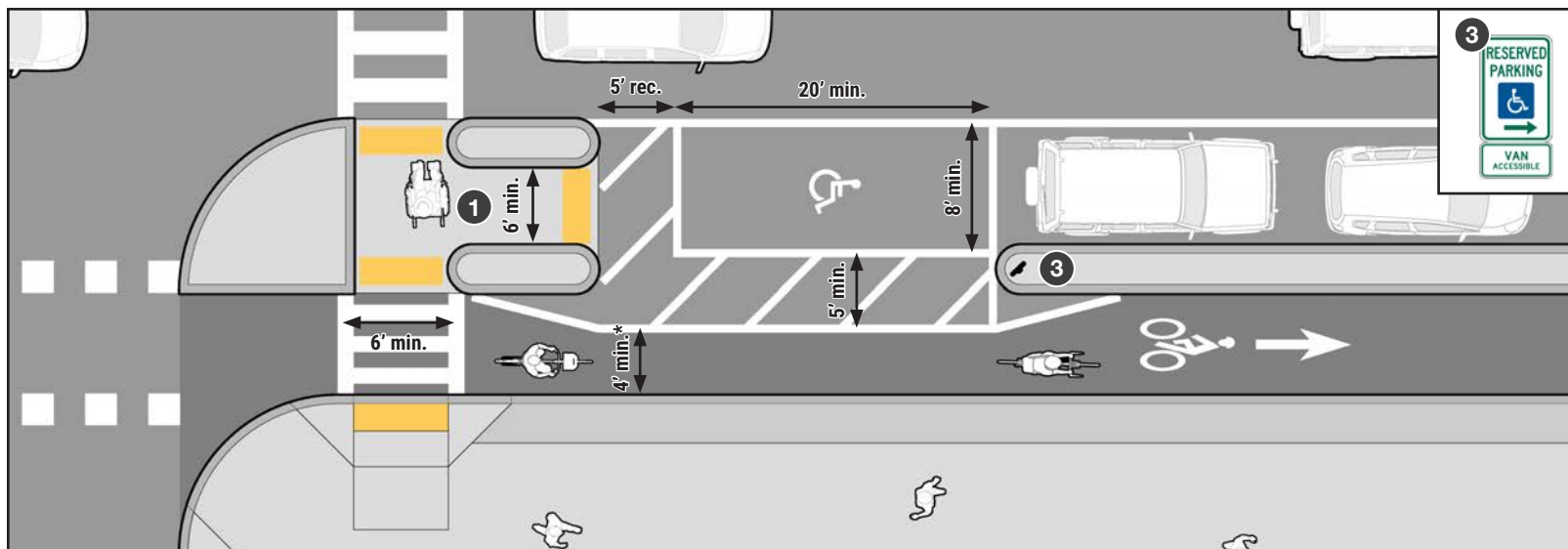
Locate accessible parking at a mid-block location (see **EXHIBIT 5B**) where intersection locations are infeasible or if proximity to a specific destination is advantageous.

EXHIBIT 5B: ACCESSIBLE ON-STREET MOTOR VEHICLE PARKING (MID-BLOCK)



* A bike lane width narrower than 5 ft. requires a design exception.

EXHIBIT 5C: ACCESSIBLE ON-STREET MOTOR VEHICLE PARKING (INTERSECTION)

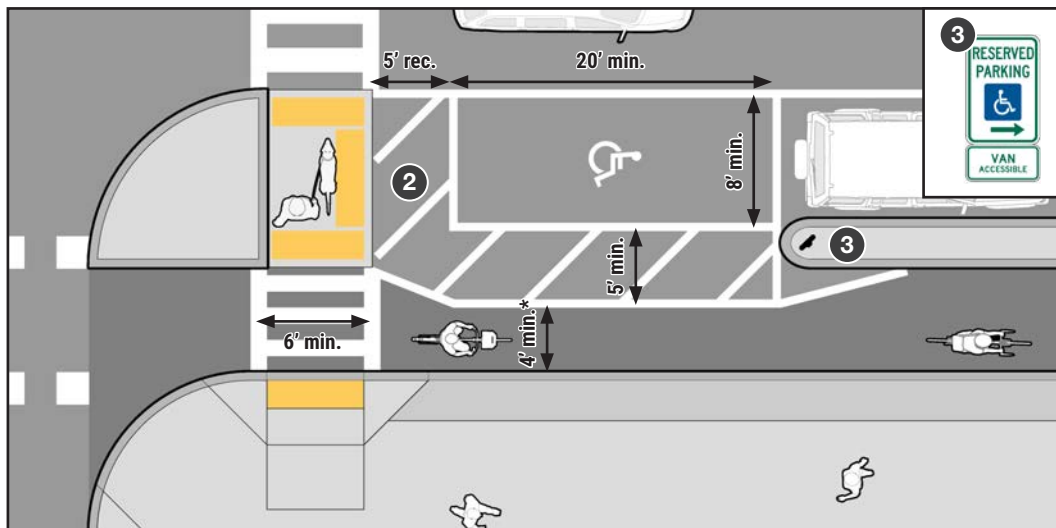


* A bike lane width narrower than 5 ft. requires a design exception.

INTERSECTION LOCATIONS

Locate accessible parking near an intersection to connect to curb ramps (see [EXHIBIT 5C](#)). Where feasible, avoid placing accessible spaces in near-side locations to preserve intersection approach clear space (see [Section 4.2.5](#)). Consider side street locations for accessible parking where far-side placement conflicts with bus operations.

- Pedestrian crossing islands with cut-throughs are recommended to prevent parking encroachment. **1**
- A rear access aisle may abut pedestrian crossing island in constrained situations. **2**



* A bike lane width narrower than 5 ft. requires a design exception.

5.2 LOADING ZONES

Designated loading zones may accommodate passenger loading (e.g., pick-up and drop-off at schools, hotels, hospitals, taxi stands, etc.), commercial loading (e.g., goods or parcel deliveries), or both.

5.2.1 COMMERCIAL LOADING

Commercial loading zones are often a restricted and managed portion of conventional on-street parking. They are typically longer than a single parking space to accommodate large commercial vehicles. They are not required to be accessible, and designers should follow conventional on-street parking guidance in [Section 5.1.1](#).

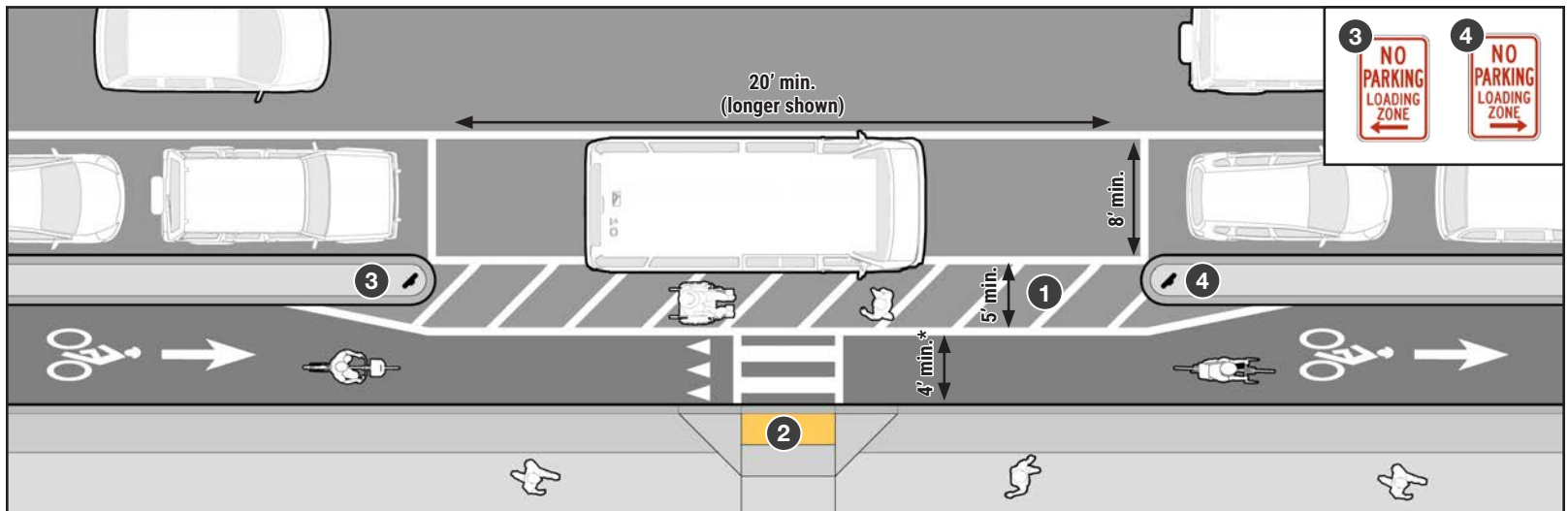
5.2.2 PASSENGER LOADING

PROWAG R310 requires at least one accessible loading zone per **100 ft.** of continuous loading zone space when passenger loading is provided (see [EXHIBIT 5D](#)).

- Refer to **PROWAG R310** for accessible passenger loading guidance and **PROWAG R302.7** for surface guidance.
- The bike lane may be narrowed to **4 ft.** at accessible loading zones with a design exception.

- Length of the passenger loading zone should accommodate the length of the typical passenger vehicle that will use the zone. Longer zones may be needed if vehicle queues are anticipated.
- The access aisle must be at the same level as the motor vehicle pull-up space.
1 It must be free from obstructions, extend the full length of the accessible loading zone and connect to a pedestrian access route via curb ramp or blended transition. **2**
- Curb ramps are recommended to accommodate dollies/hand trucks. **2**
- Place **NO PARKING LOADING ZONE (R7-6)** at the rear and head of an accessible loading zone. **3 4**

EXHIBIT 5D: ACCESSIBLE LOADING ZONE (MID-BLOCK WITH PARKING)



* A bike lane width narrower than 5 ft. requires a design exception.

In locations without on-street parking, a lateral deflection of the separated bike lane may be required to accommodate an accessible loading zone (see [EXHIBIT 5E](#)).

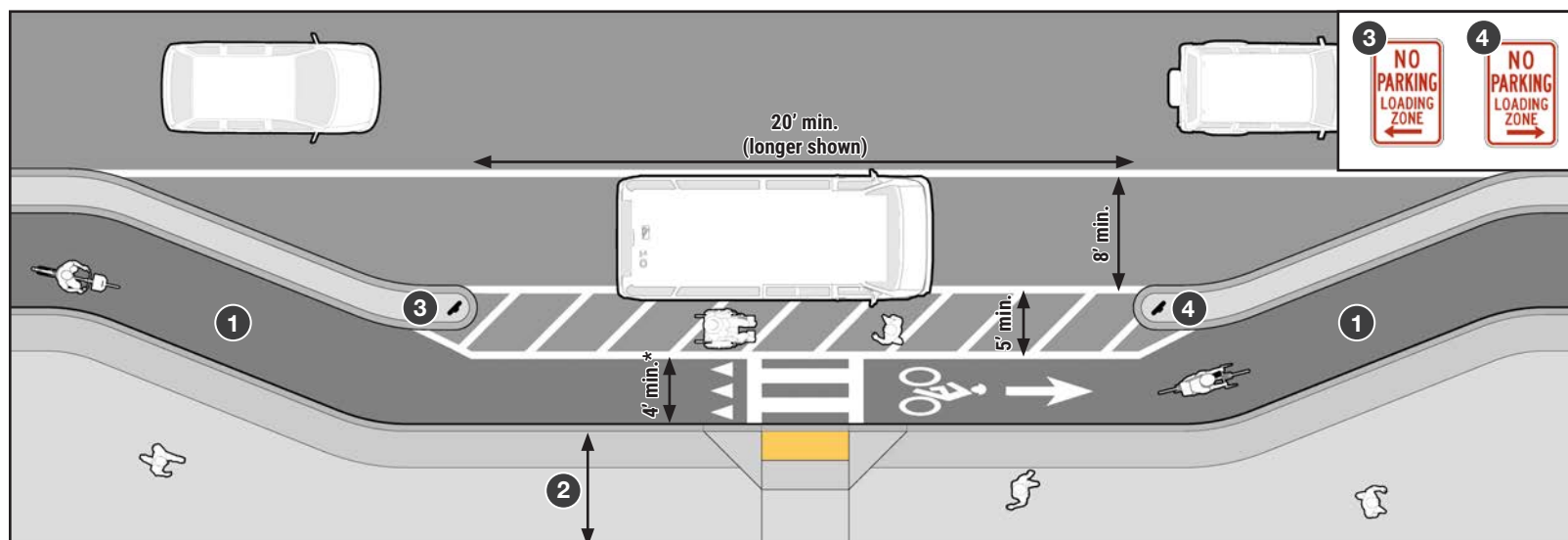
- **Bike lane deflection should occur gradually, but not greater than a 3:1 taper to maintain bicyclist safety and comfort (see Section 4.3.2).** ①
- **An appropriate sidewalk width, which is often wider than the minimum pedestrian access route, must be maintained.** ②



INTERSECTION LOCATIONS

As demonstrated in [EXHIBIT 5D](#), accessible loading zones are nearly identical to accessible on-street parking spaces. Designers should consult [EXHIBIT 5C](#) when designing accessible loading zones at intersections.

EXHIBIT 5E: ACCESSIBLE LOADING ZONE (MID-BLOCK WITHOUT PARKING)



* A bike lane width narrower than 5 ft. requires a design exception.

5.3 ON-STREET BIKE PARKING

On-street bike parking reduces conflicts between bicyclists and pedestrians, helps preserve sidewalk width, provides direct connections to bike lanes, and increases bicycle parking capacity and visibility (see [EXHIBIT 5F](#) and [EXHIBIT 5G](#)). When converted to space for bicycle parking, a single on-street motor vehicle parking space can store up to 14 bicycles or 10 bike share bicycles, thus increasing overall parking capacity for adjacent businesses. Bike parking should be considered in locations with observed demand, for example where bicycles are locked to trees, signs, parking meters and other streetscape elements. Adjacent businesses may be willing to fund and/or maintain on-street bike parking, including bike share stations.

- **A 2 ft. street buffer recommended (1 ft. minimum) and should be free of obstructions. ①**
- **Parking should be flush with the bike lane or accessible by a mountable curb (see Section 3.3.4).**
- **Consider locating vertical objects between bike and motor vehicle parking to increase visibility for motorists and to protect bicycles from motor vehicle encroachment. ②**
- **Locate bike parking close to destinations or transit connections.**
- **Bike share stations and temporary bike parking corrals may be removed seasonally for snow clearance and removal. ③**

EXHIBIT 5F: ON-STREET BIKE PARKING (MID-BLOCK)

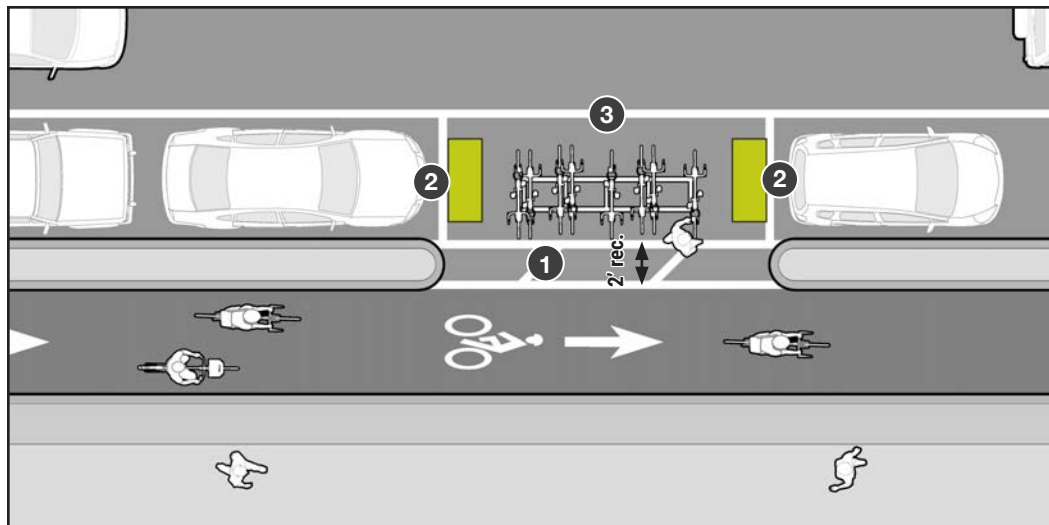
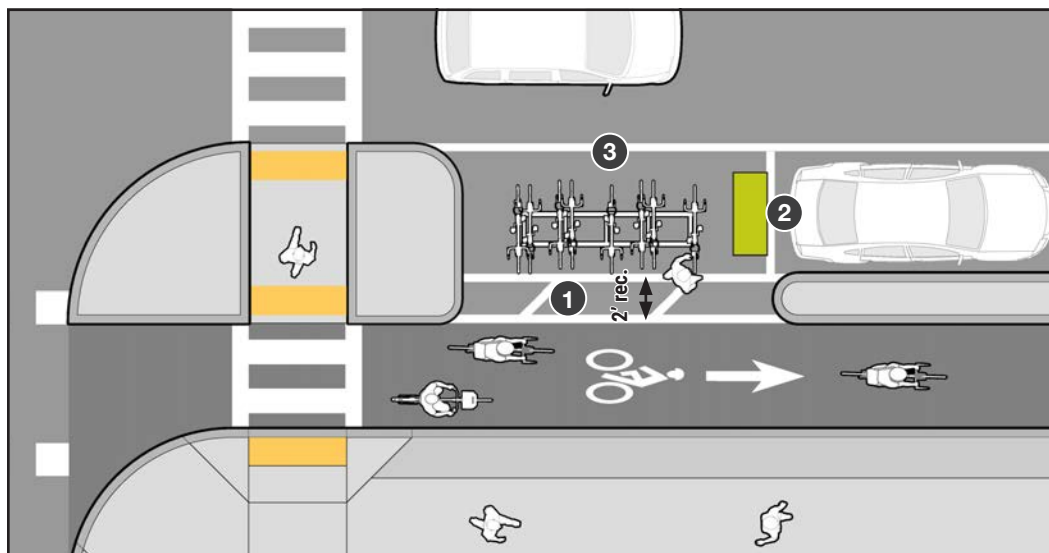


EXHIBIT 5G: ON-STREET BIKE PARKING (INTERSECTION)



5.4 BUS STOPS

Separated bike lanes can be integrated with a variety of bus stop designs. They are compatible with mid-block, near-side and far-side bus stop locations. Where feasible, separated bike lanes should be routed behind bus stops to eliminate conflicts between buses and bicyclists. This recommended configuration—referred to as “a floating bus stop”—repurposes the street buffer into a dedicated passenger platform between the motor vehicle lane and the bike lane.

Bus passengers must cross the separated bike lane when entering and exiting the platform. Designers can communicate expectations for people bicycling and taking transit by following these principles to the maximum extent feasible:

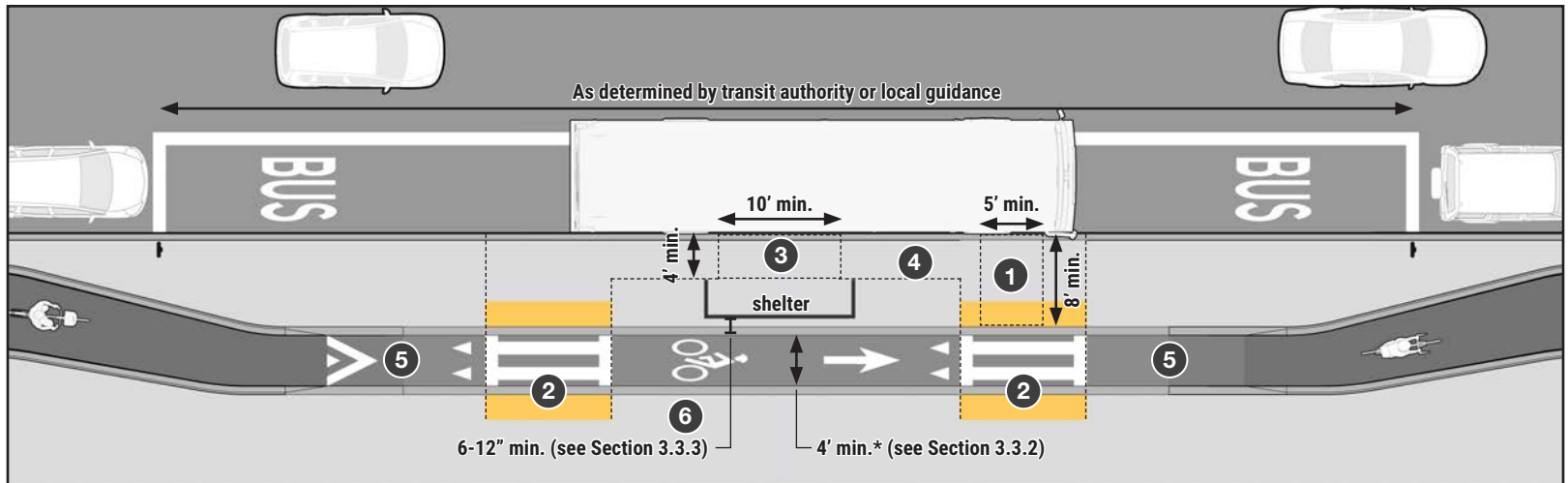
- **Guide bus passengers across the bike lane at clearly marked locations.**
- **Provide clear direction to people bicycling when they are expected to yield to pedestrians crossing the bike lane at bus stops.**

Designers should consider in-lane bus stops to preserve space for the street buffer, maintain separated bike lane width, and simplify bus re-entry into traffic. Where on-street parking is present, a curb extension is required to provide an in-lane stop, as shown in [EXHIBIT 5J](#).

Bus stops are natural locations for bike parking. Bike racks increase the catchment area of bus stops, providing a longer-range and faster first- and last-mile connection compared to walking. See to [Section 5.3](#) for on-street bike parking.



EXHIBIT 5H: BUS STOP DESIGN ELEMENTS



* A bike lane width narrower than 5 ft. requires a design exception.

5.4.1 DESIGN ELEMENTS

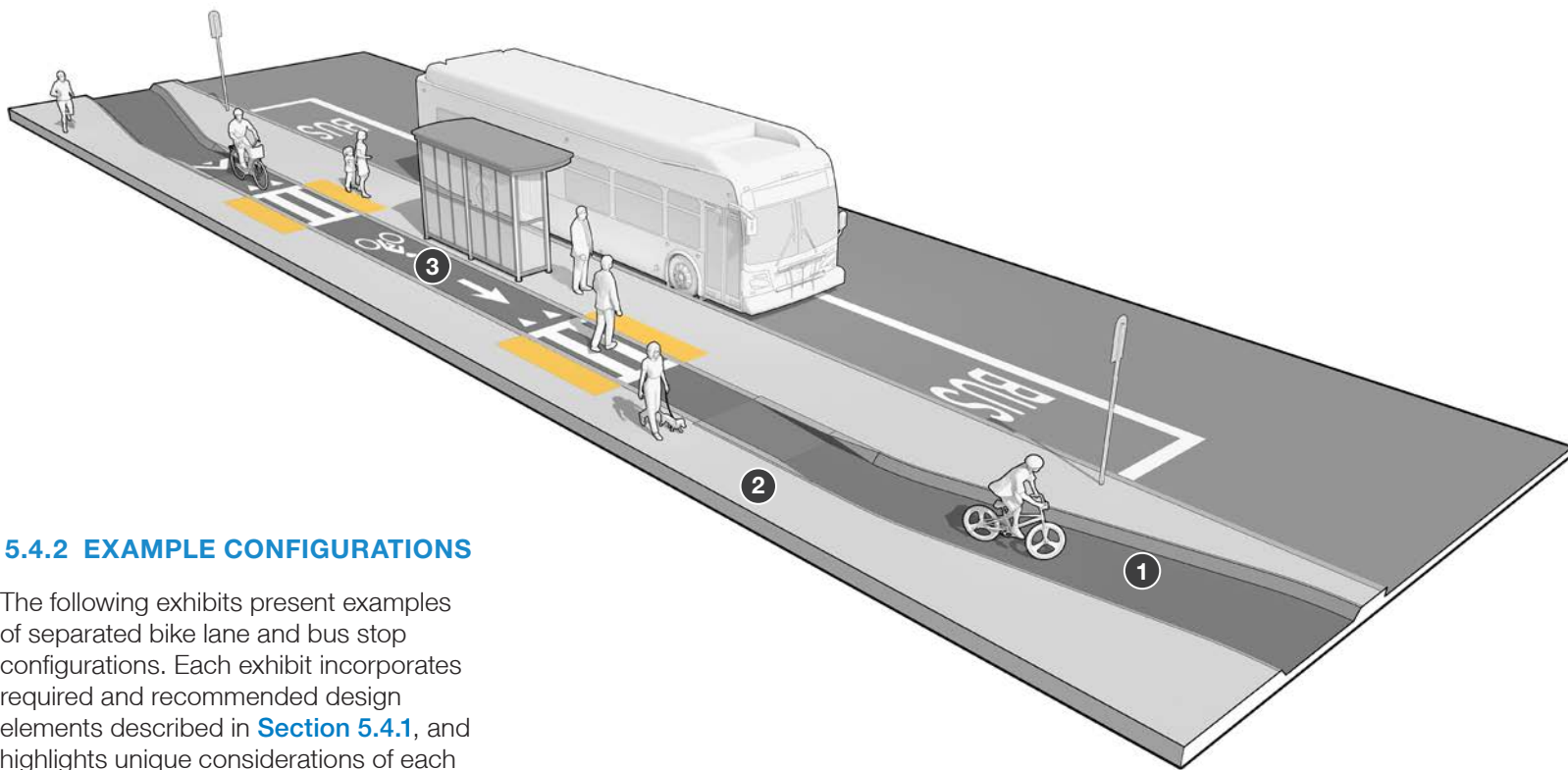
All bus stops should include a common set of required design elements to provide accessible, high-quality transit service (see [EXHIBIT 5H](#)). Elements that may influence separated bike lane design are highlighted in this section. Designers should consult MBTA or local guidelines for more detail, including for the design of amenities beyond the scope of this Guide (e.g., trash receptacles, informational signage, etc.).

- **Preserve a clear boarding and alighting area that connects to a pedestrian access route. Advanced lateral deflection of the bike lane may be necessary to accommodate the boarding and alighting area (see Section 4.3.1).** ①

- **Maintain a pedestrian access route between the sidewalk, the boarding and alighting area, and shelters and benches. Two pedestrian crossings are recommended, but not required.** ②
- **Include a rear door clear zone connected to a pedestrian access route.** ③ **It is preferable to have a continuous clear zone to connect the boarding and alighting area and the rear door clear zone.** ④

Additional design elements are recommended to improve operations at bus stops.

- **Transition the bike lane to sidewalk level in constrained situations or to provide level pedestrian crossings. Locate bicycle transition ramps near crosswalks and outside of any lateral shift of the bike lane.** ⑤
- **Locate shelters and other vertical objects that are 36 in. or higher a minimum of 6-12 in. from the bike lane edge (see Section 3.3.3).** ⑥
- **Place railings or planters (3 ft. maximum height) at the back of the platform for high ridership stops or along two-way separated bike lanes to channelize pedestrians to designated crossings. Ends of railings should be flared inward toward the bus stop and away from the bike lane for a safer bicycling environment.**



5.4.2 EXAMPLE CONFIGURATIONS

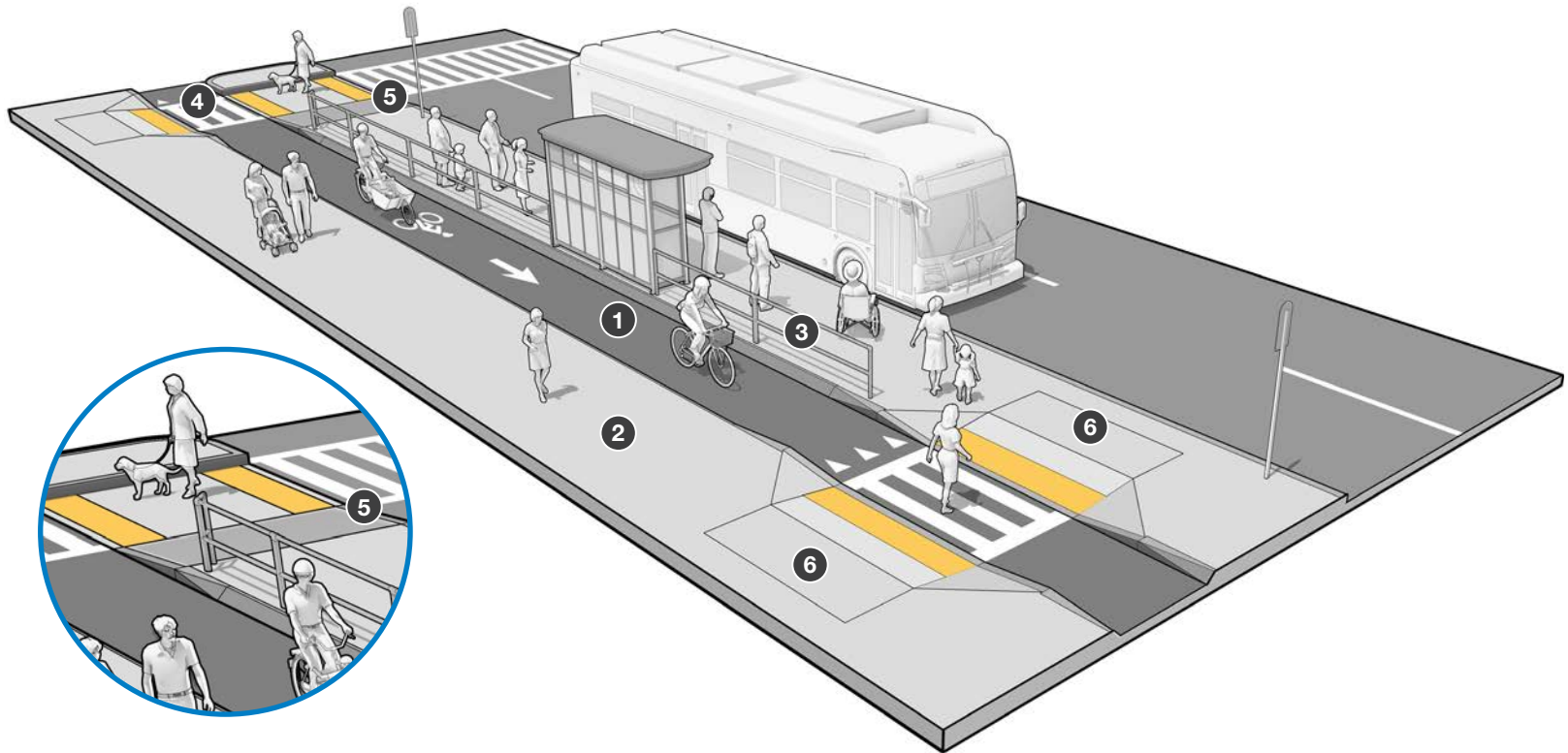
The following exhibits present examples of separated bike lane and bus stop configurations. Each exhibit incorporates required and recommended design elements described in [Section 5.4.1](#), and highlights unique considerations of each configuration.

FLOATING BUS STOP (MID-BLOCK)

EXHIBIT 5I shows a raised separated bike lane alongside a mid-block floating bus stop. This is a typical curbside stop located between parked motor vehicles, which minimizes traffic impacts by requiring the bus driver to pull into and out of the stop.

- Where street buffer is less than 8 ft., taper the bike lane to create space for the bus stop. ①
- Maintain an appropriate sidewalk width, which is typically wider than the minimum pedestrian access route. ②
- Consider railing or planters to channelize pedestrian access to and from busy bus stops.
- Narrow the bike lane along the bus stop to maintain an accessible sidewalk and bus stop in constrained areas. Where narrowed to 4 ft. (less than 5 ft. requires a design exception), elevate the bike lane to sidewalk level to minimize pedal strike risks on curbs. In the case of two-way facilities, a minimum width of 8 ft. should be used. ③

EXHIBIT 5J: FLOATING BUS STOP (INTERSECTION)



FLOATING BUS STOP (INTERSECTION)

EXHIBIT 5J shows a street level separated bike lane alongside a far-side floating bus stop. Transit operators generally prefer far-side stops because conflicts with crossing pedestrians and turning motor vehicles are minimized.

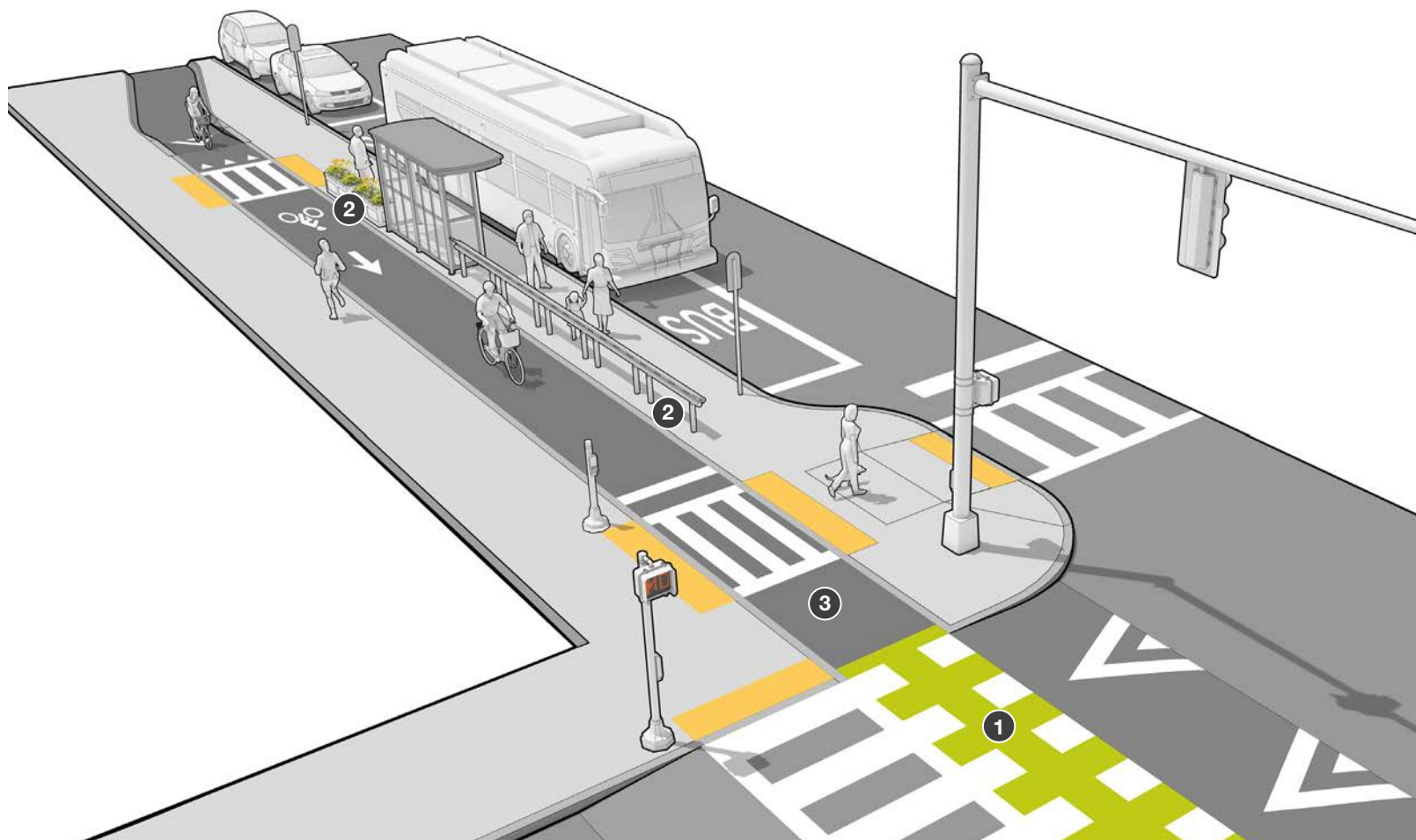
This stop is located on a curb extension, also known as a bus bulb. Bus bulbs minimize the loss of on-street parking, simplify maneuvers for bus operators and provide more space for passenger amenities.

- Consider bus bulbs adjacent to separated bike lanes to preserve right-of-way for the separated bike lane and sidewalk. ① ②
- Consider railing or planters to channelize pedestrian access to and from busy bus stops. ③
- Integrate bus stop into the pedestrian crossing at the intersection for convenient access. ④
- Ramp to street level pedestrian cut-through must not exceed 8.3 percent. ⑤
- Provide level landing at curb ramps (4 ft. by 4 ft. minimum). ⑥

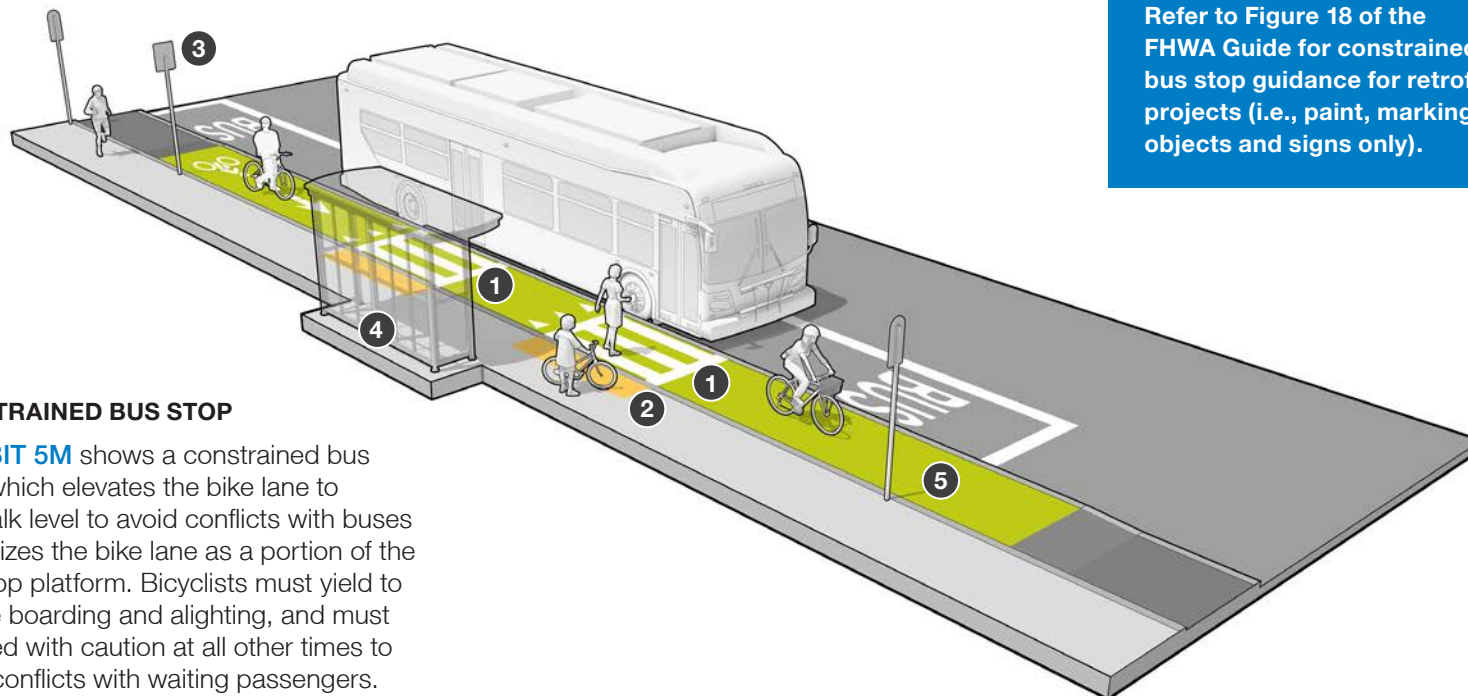
EXHIBIT 5K: FLOATING BUS STOP (NEAR-SIDE)

EXHIBIT 5K shows a raised separated bike lane alongside a near-side floating bus stop. When occupied by a bus, near-side stops reduce approach sight distance for right-turning motorists before crossing the separated bike lane (see [Section 4.2.3](#)).

- Consider raised crossings if near-side bus stop diminishes motorist approach sight distance or increases the effective turning radius for motor vehicles. ①
- Consider railing or planters to channelize pedestrian access to and from busy bus stops. ②
- Locate near-side stop far enough from the cross street to provide space for a forward bicycle queuing area and, if applicable, a corner refuge island. ③



Refer to Figure 18 of the FHWA Guide for constrained bus stop guidance for retrofit projects (i.e., paint, markings, objects and signs only).



CONSTRAINED BUS STOP

EXHIBIT 5M shows a constrained bus stop, which elevates the bike lane to sidewalk level to avoid conflicts with buses but utilizes the bike lane as a portion of the bus stop platform. Bicyclists must yield to people boarding and alighting, and must proceed with caution at all other times to avoid conflicts with waiting passengers.

Constrained bus stops should only be considered when the introduction of a floating bus stop would do one of the following:

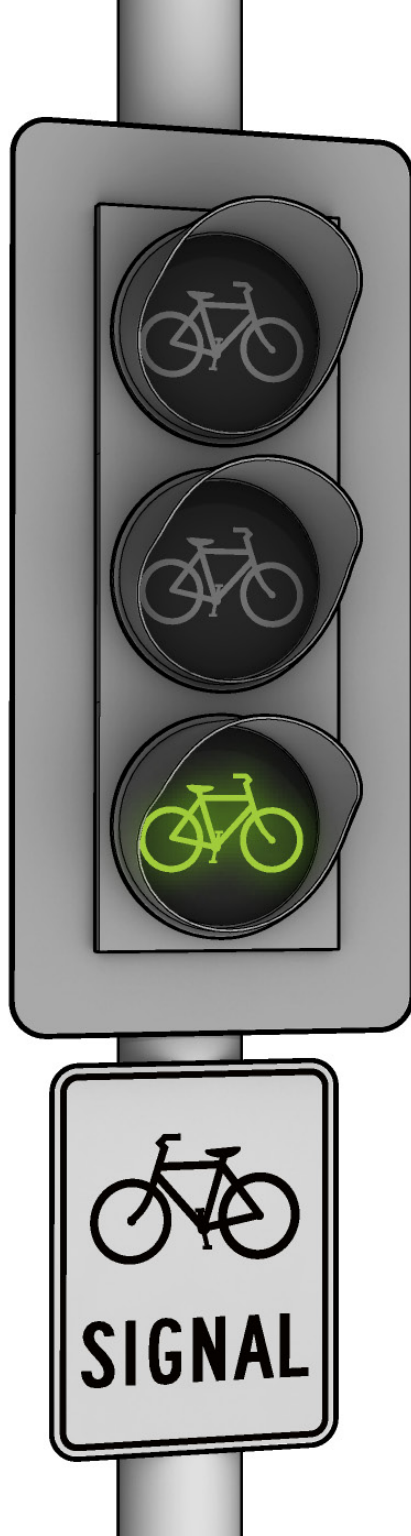
- Create non-compliant elements of the public right-of-way according to the most recent accessibility standards.
- Narrow the sidewalk below an appropriate width given pedestrian volumes and context of the built environment.
- Narrow the bike lane below 4 ft. along the bus stop (less than 5 ft. requires a design exception).

Constrained bus stops require additional considerations:

- Place crosswalks with blended transitions at the boarding and alighting area and the rear door clear zone to align with bus doors. Coordinate with the local transit agency to identify vehicle type(s) anticipated to serve the stop. ①
- Provide combined bike lane and sidewalk width equal to at least 8 ft. to qualify as an accessible boarding and alighting area. ②
- Place DO NOT PASS WHEN BUS IS STOPPED sign in advance of the first pedestrian crossing a bicyclist approaches (i.e., the rear door clear zone). ③
- When included, place shelter and/or bench at the back of the sidewalk. ④
- Consider optional colored pavement within the constrained bike lane. ⑤

6

SIGNALS



Bicyclists have unique needs at signalized intersections. Bicycle movements may be controlled by the same indications that control motor vehicle movements, by pedestrian signals, or by bicycle-specific traffic signals. As discussed in [Chapter 1](#), bicyclists have unique operating characteristics that may be addressed with bike signals. In addition, as discussed in [Chapter 4](#), the introduction of separated bike lanes creates situations that may require leading or protected phases for bicycle traffic, or place bicyclists outside the cone of vision of existing signal equipment. In these situations, provision of signals for bicycle traffic will be required.

6.1 GUIDANCE FOR SIGNALIZATION

The designer should review existing traffic volumes, traffic signal equipment, and phasing for any signalized intersection along a separated bike lane. Bike signal control may be achieved through minor modification of existing signal equipment or with installation of a new traffic signal.

Consideration should be given to:

- Existing signal equipment and visibility
- Existing signal timing and phasing
- Conflicts between turning vehicles and bicycles
- Sight lines between turning vehicles and bicycles
- Signal timing and clearances for bicycles
- Signal detection for bicycles

This chapter discusses the need for bike signals, as well as design controls for signal phasing and equipment.

6.1.1 TRAFFIC SIGNAL WARRANT

In general, the addition of a separated bike lane at an intersection will not require installation of a new traffic control signal at existing unsignalized intersections. The decision to use traffic signals should follow the signal warrants specified in the MUTCD.

When evaluating warrants for a potential signal, the designer should be aware that separated bike lanes attract additional users which could result in an intersection meeting warrants for a signal within a short time of the facility opening. Therefore anticipated future volumes of bicyclists should be considered during any warrant analysis effort. The designer should also evaluate the pedestrian hybrid beacon warrant, counting bicyclists as pedestrians, for crossings of high volume (**more than 250 vehicles/hour**) or high speed (**greater than 30 mph**) roadways.

6.1.2 BIKE SIGNAL HEAD WARRANT

Bike signals should generally be installed at all traffic control signals where separated bike lanes are present to provide a uniform indication for bicyclists. Requiring bicyclists to follow a mixture of pedestrian signal, vehicle signal and bike signal indications may result in confusion and lower signal compliance. While the use of bike signal heads is not required, under the following circumstances bike signal heads shall be provided to ensure safety for bicyclists:

- Locations where leading or protected phases are provided for bicyclists
- Locations with contra-flow bicycle movements
- Locations where existing traffic signal heads are not visible to approaching bicyclists
- Locations where bicyclists are physically separated from motorists and pedestrians

6.1.3 CONSIDERATIONS FOR PROVIDING A PROTECTED BICYCLE PHASE

Separate bicycle phases are not required at signal controlled intersections. The decision to provide a protected bicycle phase should be based on a need to eliminate conflicts. The provision of protected movements may require the presence of motor vehicle turn lanes on the intersection approach. Scenarios where provision of a separate phase should be considered are discussed on the following page. These include:

- Locations with two-way or contra-flow bicycle movements
- Locations with unique or high volume bicycle movements
- Locations with high volumes of turning traffic

LOCATIONS WITH TWO-WAY OR CONTRA-FLOW BICYCLE MOVEMENTS

As discussed in [Chapter 4](#), bicyclists may be exposed to increased conflicts with left turning motorists on two-way streets with two-way separated bike lanes on one or both sides. The conflicts result when the bicyclists traveling in the same direction as the left turning motorist is not seen. While the motorist is scanning for a gap in traffic, they may not detect a bicyclist arriving from behind them and entering the crossing. Depending upon the time of arrival and the size of the intersection, there may be little time for either party to react. Where geometric solutions such as raised crossings or recessed crossings are not feasible or do not mitigate the conflict, the provision of a protected left turn phase or a protected bike phase should be considered to separate this conflict in time. Examples of potential phasing are shown in [EXHIBIT 6J](#), [EXHIBIT 6K](#), and [EXHIBIT 6L](#).

LOCATIONS WITH UNIQUE OR HIGH VOLUME BICYCLE MOVEMENTS

At locations where bicycle volumes and/or parallel pedestrian volumes are high, turning vehicles may find it difficult to find a safe gap to turn across. Separating the turning vehicle movements from the through bicycle and pedestrian movements may reduce delays and frustrations for all users.

LOCATIONS WITH HIGH VOLUMES OF TURNING TRAFFIC

Time-separated turning movements should be considered in locations with the motor vehicle turn volumes in [EXHIBIT 6A](#).

In locations where the roadway width does not allow for the provision of turn lanes and therefore limits phasing options, the designer should consider access management measures to reduce conflicts (see [Section 4.3.7](#)). Where conflicts with permissive turns are necessary, enhanced treatments should be considered to reduce speeds and increase sight distance (see [Section 4.3.1](#)).

6.1.4 CONSIDERATIONS FOR PROVIDING A LEADING BICYCLE INTERVAL

At locations where bicycle volumes and/or motorist turning volumes are lower than the threshold to provide a protected phase, or at locations where provision of a protected phase is not feasible, there may be benefits to providing a leading bicycle phase. A leading bicycle interval allows a bicyclist to enter the street crossing prior to a turning motorist, thereby improving their visibility. In some cases, a leading bicycle interval may allow bicyclists to clear the conflict point before motor vehicles enter. A parallel leading pedestrian interval should also be provided. An example of potential phasing is shown in [EXHIBIT 6I](#).

Separated Bike Lane Operation	Motor Vehicles per Hour Turning across Separated Bike Lane			
	Two-way Street			One-way Street
	Right Turn	Left Turn across One Lane	Left Turn across Two Lanes	Right or Left Turn
One-way	150	100	50	150
Two-way	100	50	0	100

EXHIBIT 6A: Considerations for Time-separated Bicycle Movements

6.2 SIGNAL DESIGN

6.2.1 TYPES OF BIKE SIGNALS

Bike signals take on two typical forms, as illustrated in [EXHIBIT 6B](#). The first is a standard three section head with circular signal faces. A BICYCLE SIGNAL sign (R10-10b) mounted below the signal head designates the signal for the exclusive use of bicyclist movements. It is permitted for general use under the MUTCD.

The second form of bike signal provides a three section head with bicycle symbols on each face. The use of bike signal faces has been approved by FHWA (see [Interim Approval IA-16](#) for further details). The application and use of bike signal faces should be designed in accordance with the latest version of the MUTCD and associated interim approvals. If bicycles signals are to be used, the controlling municipality should amend the local traffic code to define their meaning.

6.2.2 BIKE SIGNAL EQUIPMENT

The layout of traffic signals is an important task for ensuring the safe operation of a separated bike lane (see [EXHIBIT 6C](#)). The MUTCD establishes requirements for where traffic signal displays can be placed in an intersection. The following guidance supplements the MUTCD.

EXHIBIT 6B: Typical Forms of Bike Signals

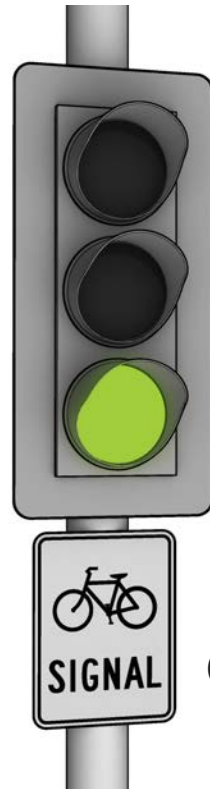
SIZE OF DISPLAYS

Standard traffic signals are **12 in.** in diameter. The MUTCD permits the use of an **8 in.** circular indication for the sole purpose of controlling a bikeway or a bicycle movement (see [MUTCD Section 4D.07](#)). The interim approval also authorizes the use of **4 in.** bicycle faces as a supplemental near-side signal.

NUMBER OF DISPLAYS

The MUTCD prescribes the use of two signal faces for the primary movement. In the case of a separated bike lane, one signal face is sufficient, however supplemental near-side signal may be used for clarifying traffic control at the intersection for bicyclists.

Standard Signal Faces



R10-10b
(required)

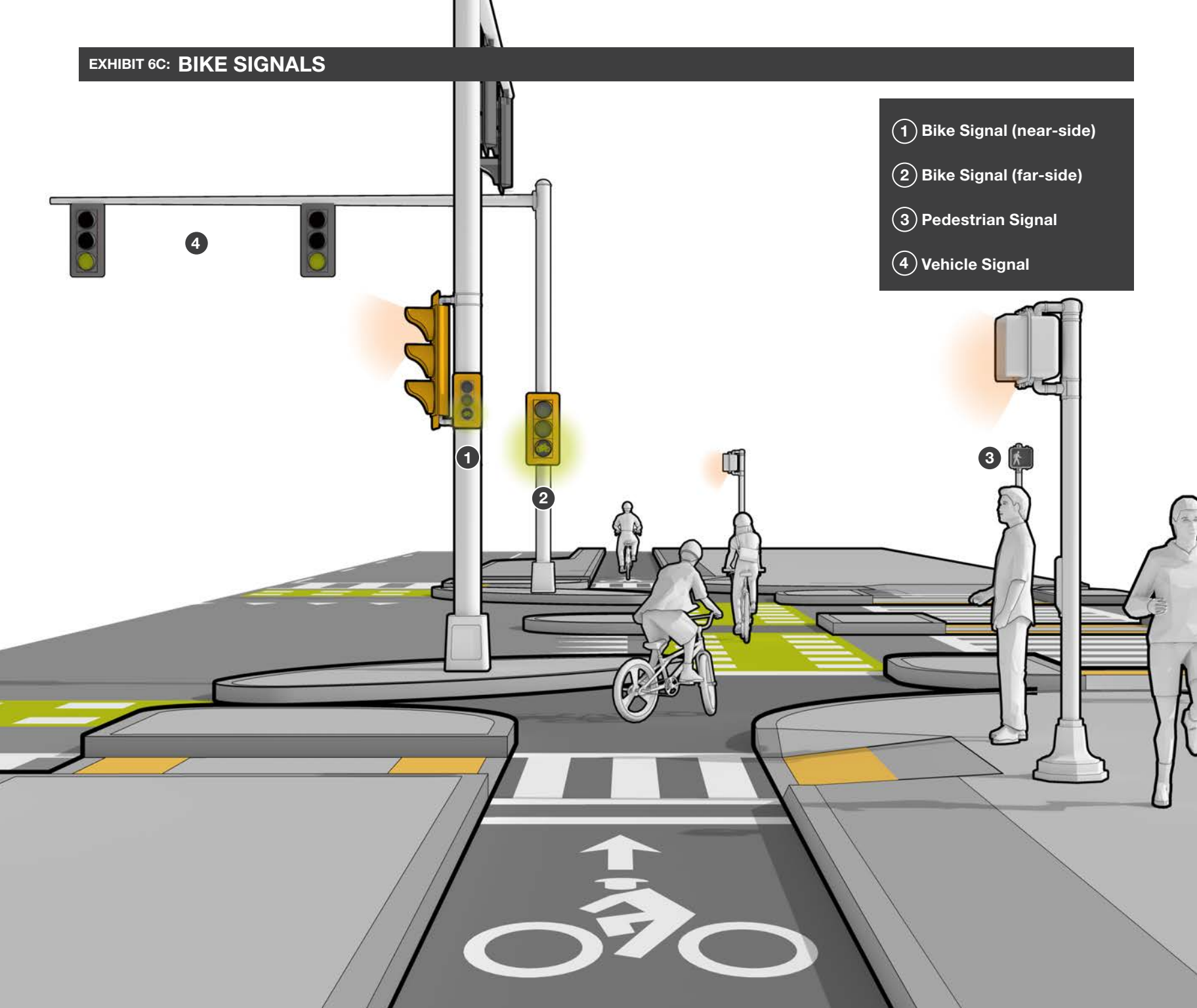
Bike Signal Faces



R10-10b
(optional)

EXHIBIT 6C: BIKE SIGNALS

- ① Bike Signal (near-side)
- ② Bike Signal (far-side)
- ③ Pedestrian Signal
- ④ Vehicle Signal



VISIBILITY OF SIGNAL FACES

The designer should take care to ensure traffic signals and bike signal heads are visible for approaching bicyclists. Where existing traffic signals are anticipated to be the sole source of guidance for bicyclists, they should be located within the cone of vision measured from the bike stop bar (see [MUTCD Section 4D.13](#) for further detail). This is especially important to consider in locations with contra-flow or two-way bike facilities. If the signals fall outside the cone of vision, supplementary bike signal heads shall be provided.

[Section 4D.12 of the MUTCD](#) states that signals should be designed to “optimize the visibility of signal indications to approaching traffic” and that road users shall be given a clear unmistakable indication of their right-of-way assignment. For separated bike lanes, this may mean that the bicycle traffic signal face should be optically programmed or shielded with louvers to prevent confusion for parallel motor vehicle traffic.

Designers should also ensure optically programmed or shielded signals are visible to approaching bicyclists where bicyclists are required to follow traffic signals or pedestrian signals.

LATERAL POSITION

Sight distance and signal visibility should be considered in design. Wherever possible, the bike signal face should be located at the far side of the intersection within **5 ft.** of the edge of the bike lane. This may include signals mounted overhead or side mounted. See [EXHIBIT 6D](#) for recommended and optional locations for the installation of signal equipment for bicycles, pedestrians, and vehicles.

The bicycle traffic signal should be mounted to the right of the bike lane where possible for consistency and to reduce the potential for pedestrians to block the view of the signal for approaching bicyclists. The bike signal face should not be placed such that it is located between vehicle signal faces, as this causes confusion for users.

The placement of the bicycle traffic signal may make it difficult to meet the lateral signal separation requirement of **8 ft.** as indicated by the MUTCD (see [MUTCD Section 4D.13.03](#)). Several agencies have placed traffic and bike signals closer than **8 ft.** to one another (Minneapolis, MN, and Long Beach, CA) without any operational or safety difficulties. Under this scenario, optical programming or shielding should be provided on both signal faces to prevent confusion.



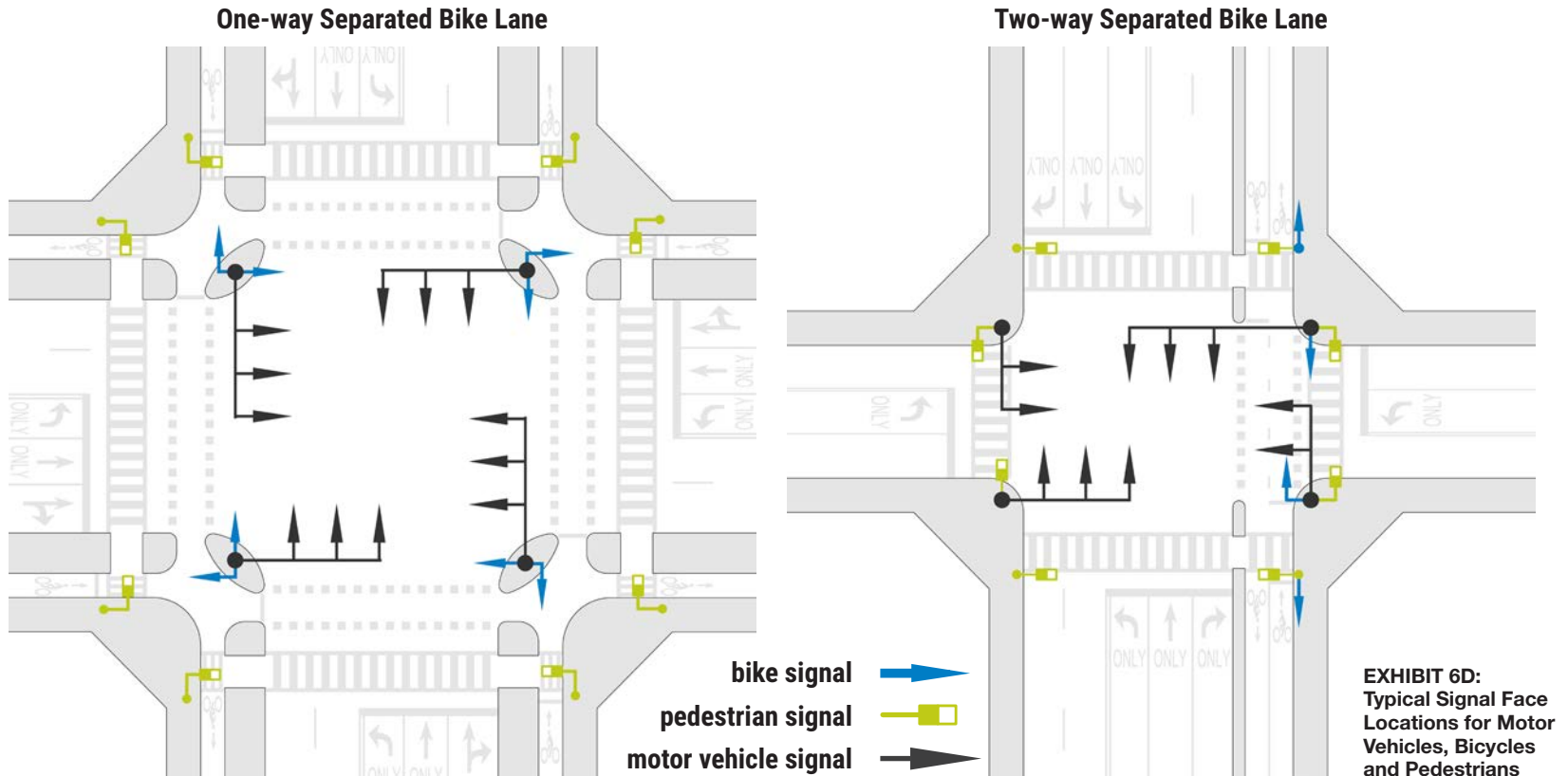
LONGITUDINAL POSITION

Assuming a **20 mph** approach speed for bicycles, a minimum sight distance is **175 ft.** before the stop line for the signal display (based on [Table 4D-2 in the 2009 MUTCD](#)). The intersection design should allow a continuous view of at least one signal face. If the intersection is more than **120 ft.** wide, a supplemental near-side bicycle traffic signal should be installed.

MOUNTING HEIGHT

The mounting heights are often based on the type of existing poles and the types of traffic signal faces chosen. Bike signal heads should be mounted such that the bottom of the signal housing is no less than **8 ft.** above the ground or sidewalk. In locations where far-side bike signals share a pedestal with a pedestrian signal, the bike signal should not be located below the pedestrian signal.

See [EXHIBIT 6D](#) for recommended and optional locations for installation of traffic signals including vehicle signals, bike signals and pedestrian signals. Designers should minimize the number of mast arms and/or pedestals by combining equipment where possible. This minimizes the number of fixed objects, reduces clutter, and reduces future maintenance costs.



6.3 SIGNAL OPERATIONS

6.2.3 PEDESTRIAN SIGNAL EQUIPMENT

The designer should carefully consider the placement of pedestrian signal equipment with relation to the separated bike lane. Under all scenarios, designers must ensure that all proposed pedestrian ramps, push buttons, and signals meet current accessibility guidance, including the minimum separation of **10 ft.** between accessible pedestrian push buttons (see [EXHIBIT 6E](#)).

Pedestrian signal timing should include sufficient clearance time for a pedestrian to cross the entire roadway including the bike lanes and street buffers. Pedestrian signal equipment should be located within the sidewalk buffer adjacent to the curb ramp outside of the bike lane. Designers should ensure that pedestrian signals meet all current accessibility guidelines with regards to proximity to the level landing area and reach range for the push button.

Designers should minimize the number of mast arms and/or pedestals by combining equipment where possible. This minimizes the number of fixed objects, reduces clutter and minimizes future maintenance costs.

6.3.1 SIGNAL PHASING

Traffic signal phasing represents the fundamental method by which a traffic signal accommodates the various users at an intersection in a safe and efficient manner. Under the control of a bicycle-specific traffic signal, bicyclists' movement may occur concurrently with other compatible vehicle phases or exclusively on a separate phase.

The signal phasing for bikes may provide concurrent phasing with through vehicle traffic, a leading bicycle interval, a protected bicycle phase, or turning bike phases.

As described in [Section 6.1](#), the designer will have to evaluate the need to provide a protected bicycle phase where left and right turn motor vehicle volumes across the bike lane are high. Designers should consider providing protected-only left turn phasing wherever feasible for signalized approaches where left turning motor vehicle movements cross a separated bike lane.

Protected right turn phases are desirable in locations where high volumes of right turning vehicles conflict with a parallel separated bike lane. However, provision of a protected right turn phase carries several challenges, including the need for a right turn lane and impacts to level of service and queueing. In locations where parking lanes are provided, elimination of

the parking on the intersection approach can allow for the provision of a right turn lane to accommodate a protected phase. If it is not possible to provide protected turn signal phasing, designers should consider implementing flashing yellow arrow signal phasing for permissive right or left turn movements that conflict with a concurrent bike movement. Further guidance for the installation and operation of flashing yellow arrow indications for permissive left and right turn movements may be found in [section 4D.18 and 4D.22 of the MUTCD](#), respectively.

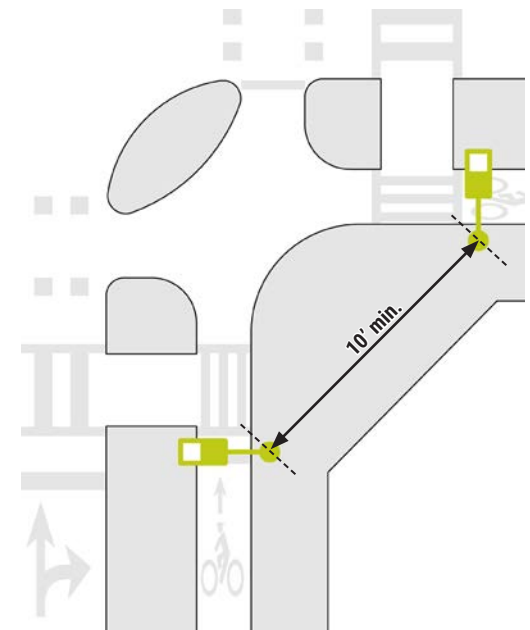


EXHIBIT 6E: Minimum Separation between Accessible Pedestrian Push Buttons

EXHIBIT 6H through **EXHIBIT 6L** (at the end of this chapter) show five scenarios for bike signal phasing, ranging from fully concurrent to protected phasing that should be considered at intersections with separated bike lanes.

6.3.2 SIGNAL TIMING

The updated **Traffic Signal Timing Manual** (FHWA, 2nd Edition, 2015) has guidance on intervals for accommodating and encouraging bicycle travel. In locations where bike signals are not provided, signal timing for standard traffic signals along a corridor with a separated bike lane must be designed to accommodate bicyclists. The designer must consider the differing operating characteristics of bicyclists which impact parameters such as minimum green time, extension time, and clearance intervals. In locations where bike signals are provided, the designer may provide separate signal timing for bicycles, reducing unnecessary delay for vehicles in the adjacent travel lanes.

MINIMUM GREEN TIME

Minimum green time is used to allow people to react to the start of the green interval and meet reasonable expectations for how long a signal will be green (see **Traffic Signal Timing Manual**). Traffic signal control for a separated bike lane must provide sufficient minimum green time for a bicyclist to clear the intersection from

a stopped position. The designer should consider the operating characteristics of a bicycle when calculating the required minimum green time. In locations where bike signals are not provided, the designer should allow for a minimum bicycle green time as a part of the timing for the concurrent vehicle signal phase. In locations where bicycle detection is provided within the separated bike lane, the signal timing should be designed to allow for an actuated minimum bicycle green time, if possible.

EXTENSION TIME (PASSAGE GAP)

In locations where bike detection is provided for actuated signal phasing, extension time may be provided as appropriate to extend the bicycle green phase up to the maximum green time. Bicycle detectors used for extension purposes should be located at the stop bar.

CHANGE AND CLEARANCE INTERVALS

The intent of the vehicle phase change and clearance intervals is to provide a safe transition of right-of-way. Traffic signal control for bicyclists should provide adequate clearance time to allow a bicyclist who enters at the end of the green phase to safely cross the intersection prior to the beginning of the conflicting signal phase. Designers should ensure that the combined yellow and all-red intervals for

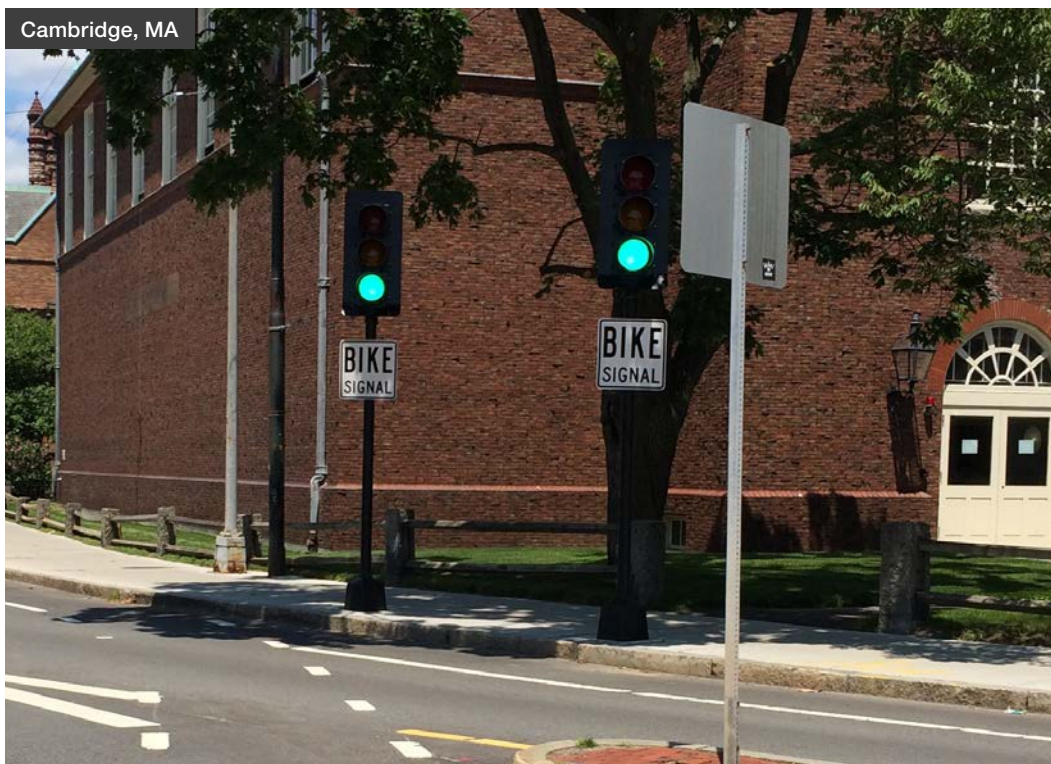


concurrent bicycle and vehicle movements are equal. However, the individual yellow and all-red interval values may vary between modes based on engineering judgement. In calculating the clearance intervals, designers should include any grade differential through the intersection, which may significantly impact bicycle crossing time. In locations where bike signals are not provided, the bicycle crossing time may be accommodated during the combined yellow and all-red vehicle intervals.

6.3.3 NO TURN ON RED RESTRICTIONS

Careful consideration should be given to implementing NO TURN ON RED restrictions at locations where right or left turning motorists may cross a separated bike lane. NO TURN ON RED restrictions may be implemented through full time restrictions or part-time restrictions via dynamic signs with bicycle detection. There are five primary scenarios where designers should consider restricting turns on red:

- **Two-stage turn queue box** – At locations where a two-stage turn queue box is provided for turns from the separated bike lane, turns on red should be restricted from the side street, as turning motorists may otherwise obstruct the queue box.
- **Two-way separated bike lanes** – At locations where two-way separated bike lanes are provided, turns on red should be restricted from the side street adjacent to the facility, because motorists may not anticipate conflicts from bicyclists approaching in the contra-flow direction.
- **Contra-flow separated bike lanes** – At locations where contra-flow separated bike lanes are provided, turns on red should be restricted from the side street adjacent to the facility, because motorists may not anticipate conflicts from bicyclists approaching in the contra-flow direction.
- **Protected bike phase** – At locations where traffic signal phasing includes a protected bike phase, the designer should consider restricting turns on red for all movements which would conflict with the protected phase.
- **Protected right turns** – At locations where protected right turns are implemented to separate bicycle and pedestrian movements, turns on red should be restricted for the same movement.
- **Leading bike phase** – At locations where a leading bike phase is provided, designers should consider restricting turns on red for conflicting movements.



6.4 BICYCLE DETECTION

Bicycle detection is used at traffic signals to alert the signal controller to bicycle demand on a particular approach. Properly located detection enables the length of green time to fluctuate based on demand.

The addition of a separated bike lane may create a need to add a protected phase to separate turning motorists from through bicyclists. In those situations, it may be desirable to convert a pre-timed intersection into partially actuated intersection to maximize signal efficiency. In those locations, the addition of detection for bicyclists and relevant motorist turn lanes can minimize lost time. Regardless, the designer must consider the need for signal detection for any location where a separated bike lane will interact with a traffic signal.

The addition of detection and signal timing ensures that bicycles are provided safe crossing opportunities and reduces the potential for red-light running (provided that the signal timing is responsive to the bike lane). Detection also allows the intersection to operate more efficiently, especially during off-peak periods when traffic volumes are lower.

Bicycle detection may also be used to activate variable turn on red restriction signs to further increase safety.

Signal detection may be necessary or provide operational improvements under several scenarios:

- **Actuated signals** – Where the bicycle facility is located on any approach where the green phase may not be automatically called during every cycle, bicycle detection must be provided to ensure that bicyclists receive a green signal indication.
- **Bicycle minimum green** – In locations where vehicle minimum green times may be too short for a bicyclist to clear an intersection after starting from a stopped condition, the detection of a bicyclists should trigger an extension of the vehicle minimum green to provide the bicyclist minimum green time.
- **Protected bicycle phases** – In locations where protected bicycle phases are provided or where time-separated turn restrictions exist, bicycle detection should enable the signal to skip phases dynamically when bicyclists are not present.

The designer should ensure that detection significantly covers the entire approach. For locations where passive detection is used to capture both motorists and bicyclists, detection zones should be designed to capture approaching vehicles as well as bicycles within the separated bike lane. Where feasible, designers should provide passive detection, as it is more reliable in detecting bicycles and may be designed to limit the number of detectors required for parallel vehicle and bicycle approaches. Designers should ensure that, if used, loop detectors located within the vehicle travel lanes are still capable of functioning for bicyclists in order to accommodate those who approach from outside of the separated bike lane.

In addition to bicycle detection at the stop line, advance detection can be used to increase the responsiveness of the traffic signal to the bicycle movement. Advance detection may be used within **100 ft.** from the intersection to call a green for an approaching bicyclist or extend the green phase up to the maximum as appropriate in order to reduce unnecessary stops, especially during off-peak periods when demand is light. See **EXHIBIT 6F** for typical detector locations.

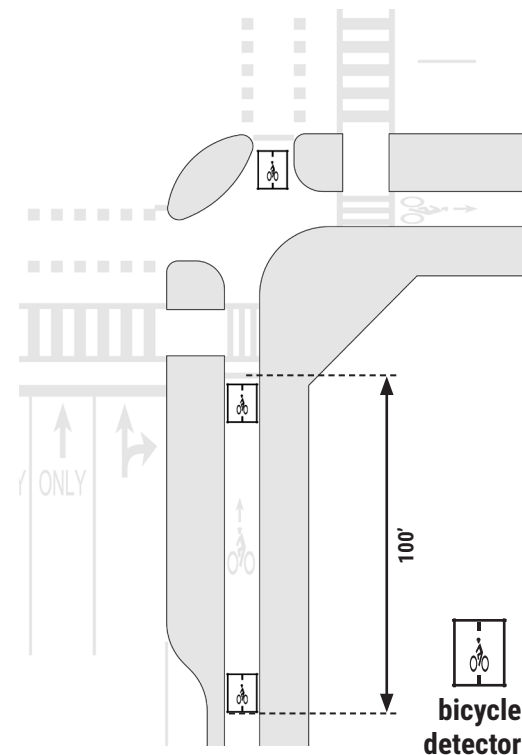
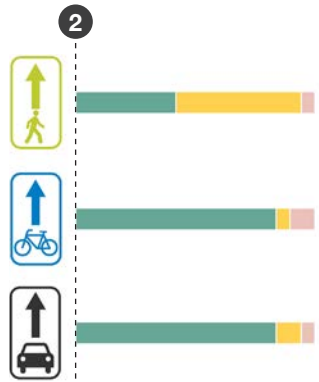
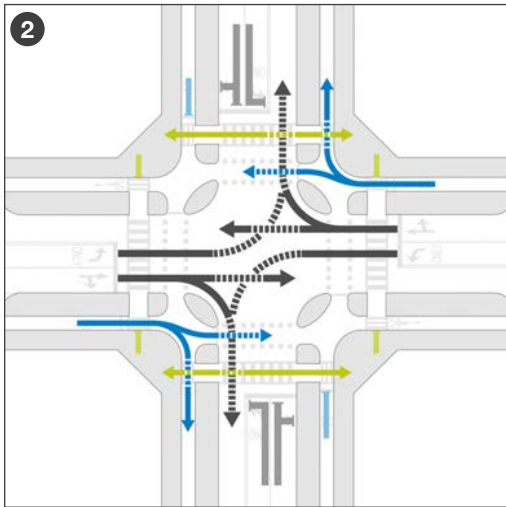
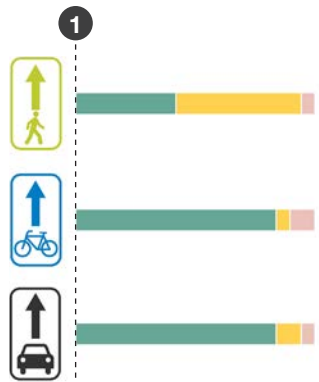
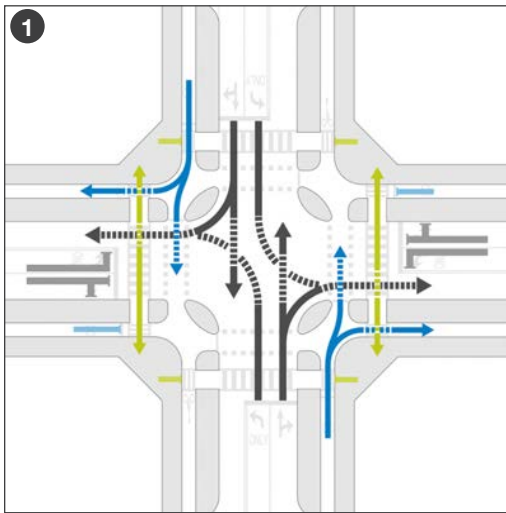


EXHIBIT 6F: Typical Bicycle Detector Locations

Phasing Scheme	Description	Pros	Cons
Concurrent Bike Phase with Concurrent Permissive Vehicle Turns (see EXHIBIT 6H)	Provides a bicycle phase that runs concurrently with the parallel vehicle phase.	<ul style="list-style-type: none"> Increased compliance when compared to following vehicle signals. 	<ul style="list-style-type: none"> Not appropriate in locations with high vehicle turning volumes. Requires vehicles to yield when turning.
Concurrent Bike Phase with Leading Interval (see EXHIBIT 6I)	Provides an advanced green indication for the bike signal. Lead interval may provide 3 to 7 seconds of green time for bicycles prior to the green phase for the concurrent vehicle traffic. Lead bike intervals may typically be provided concurrently with lead pedestrian intervals.	<ul style="list-style-type: none"> Allows bicyclists to enter the intersection prior to vehicles. Improved visibility for turning vehicles. 	<ul style="list-style-type: none"> Small increase to delay and queueing for vehicles. Concurrent turns may not be appropriate with higher vehicle or bike volumes.
Concurrent Protected Bike Phase (see EXHIBIT 6J and EXHIBIT 6K)	Provides a bicycle phase that runs concurrently with the parallel through vehicle phase. Right and left vehicle turns across the bicycle facility operate under protected phases before or after the through phase.	<ul style="list-style-type: none"> Provides full separation between turning vehicles and bicyclists. Motorists are not required to yield when turning. 	<ul style="list-style-type: none"> Additional signal phase may increase delay, require longer cycle length. Protected right turns require the provision of a right-turn lane.
Protected Bike Phase (see EXHIBIT 6L)	Provides a protected bike phase where all motor vehicle traffic is stopped. This may run concurrently with a parallel pedestrian phase. May be appropriate at locations with complex signal phasing for vehicles and/or unusual geometry for a bicycle facility may result in unexpected conflicts between users.	<ul style="list-style-type: none"> Provides maximum separation between vehicles and bicyclists. Allows turns from the bike facility across the vehicle lanes. 	<ul style="list-style-type: none"> Increases delay for motor vehicles. Increases delay for bicyclists.

EXHIBIT 6G: Bike Signal Phasing Scenarios

EXHIBIT 6H: CONCURRENT BIKE PHASE WITH CONCURRENT PERMISSIVE VEHICLE TURNS



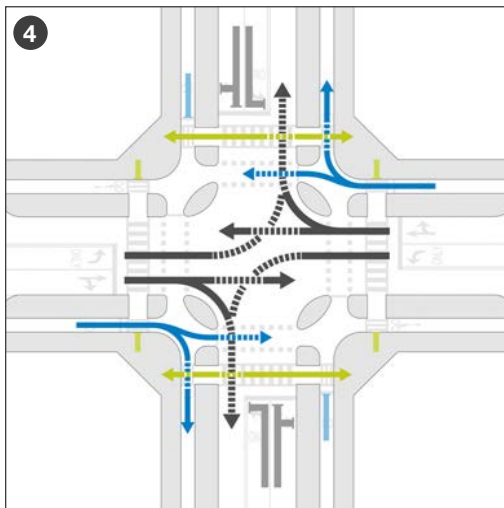
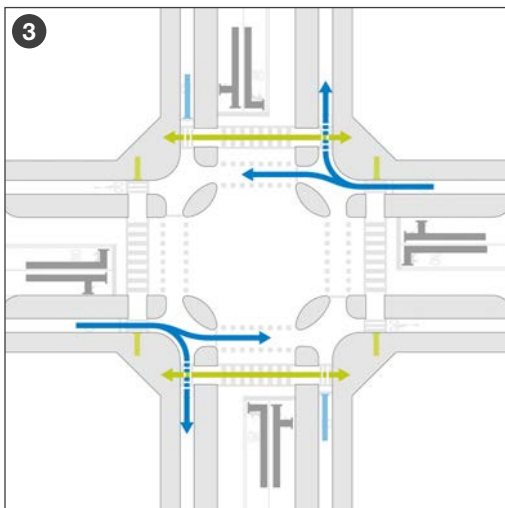
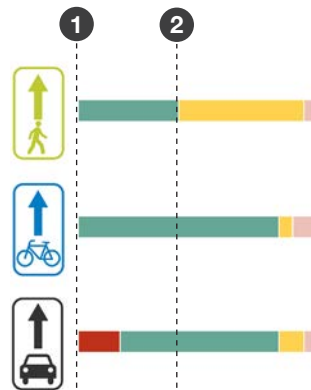
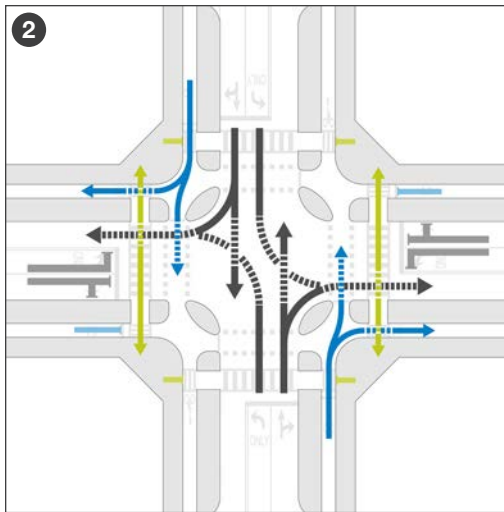
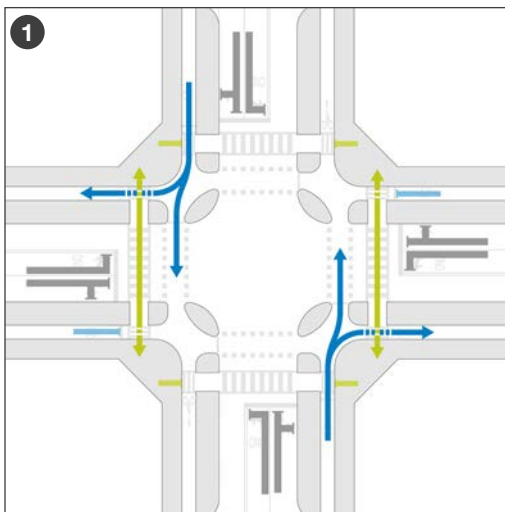
Movements

pedestrian
 bicycle
 motor vehicle

dashes denote conflicts

green interval
 yellow change interval
 red clearance interval

EXHIBIT 6I: CONCURRENT BIKE PHASE WITH LEADING INTERVAL



Movements

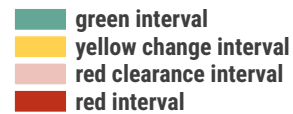


EXHIBIT 6J: CONCURRENT PROTECTED BIKE PHASE

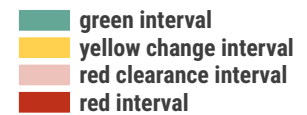
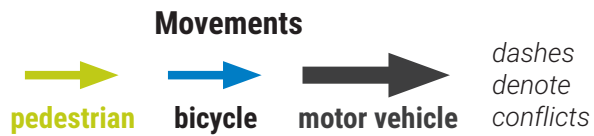
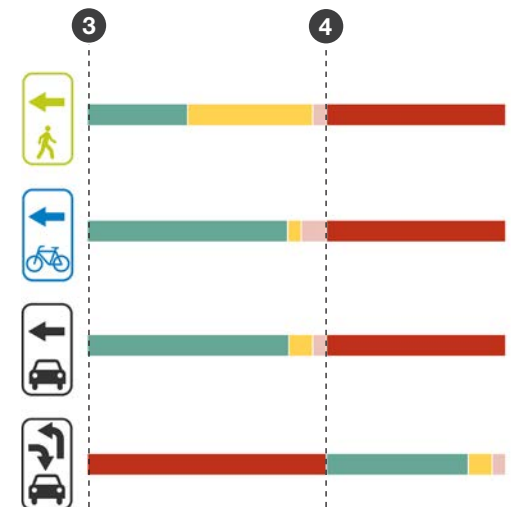
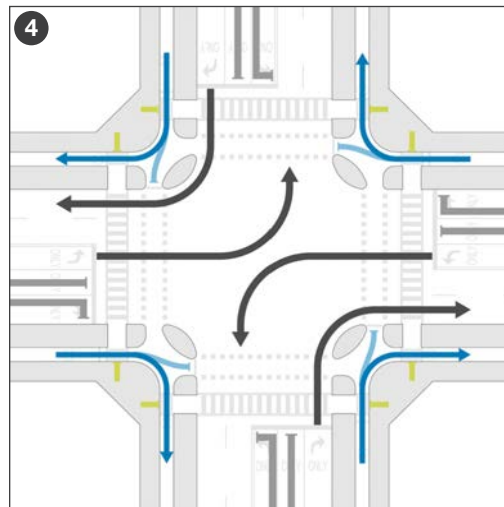
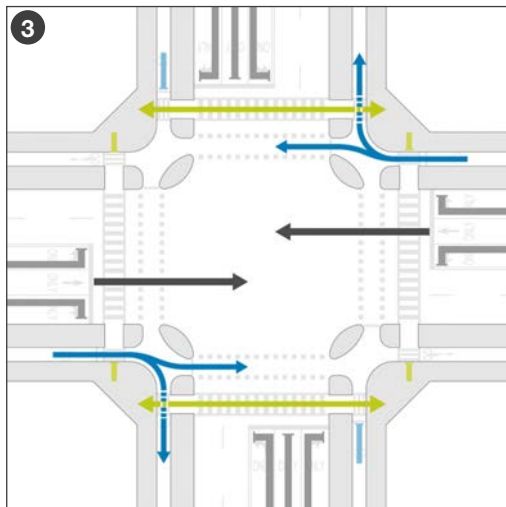
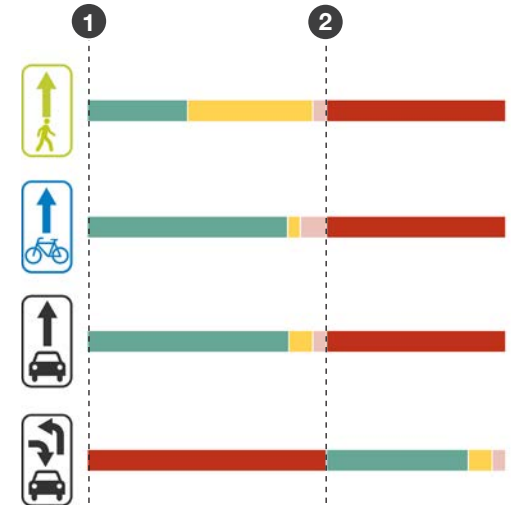
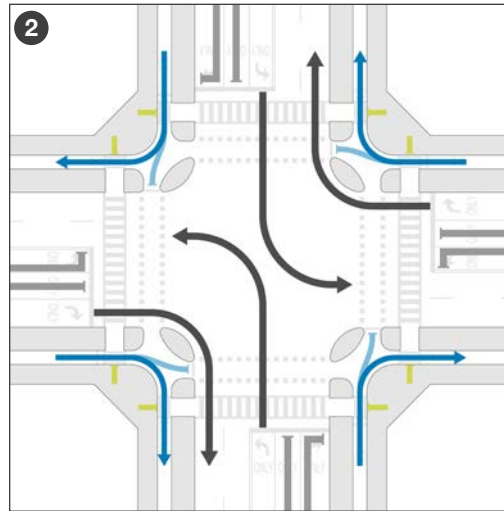
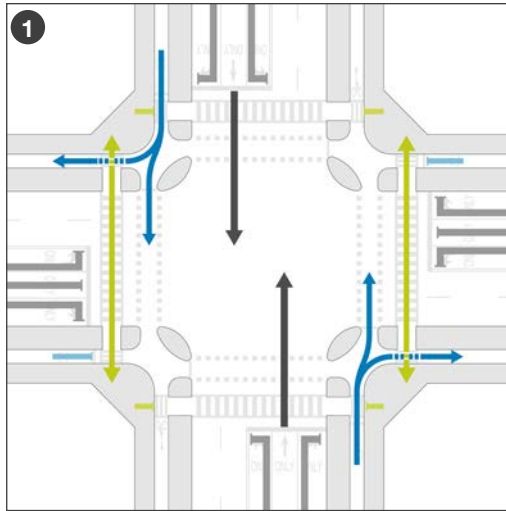
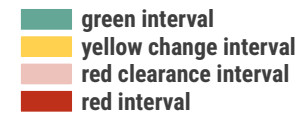
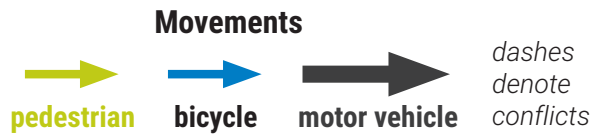
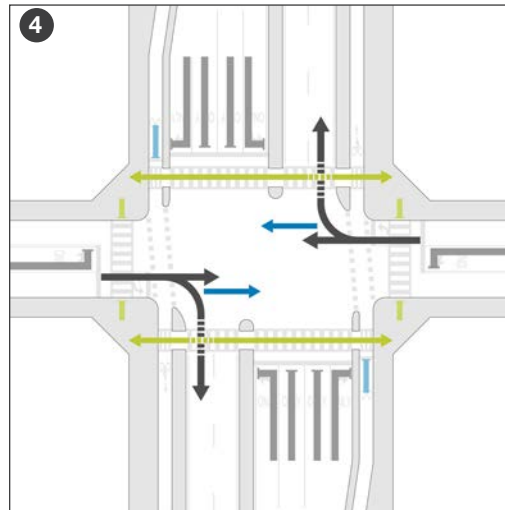
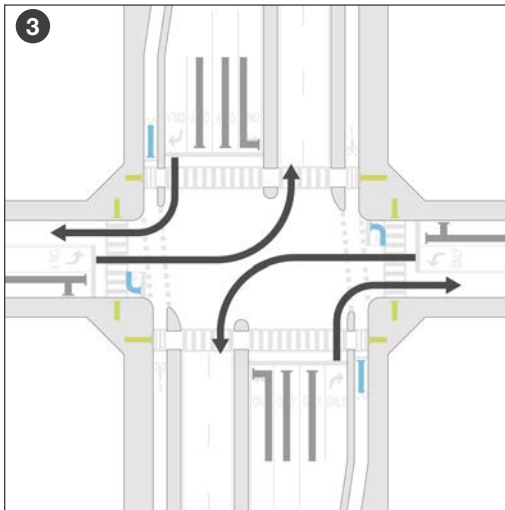
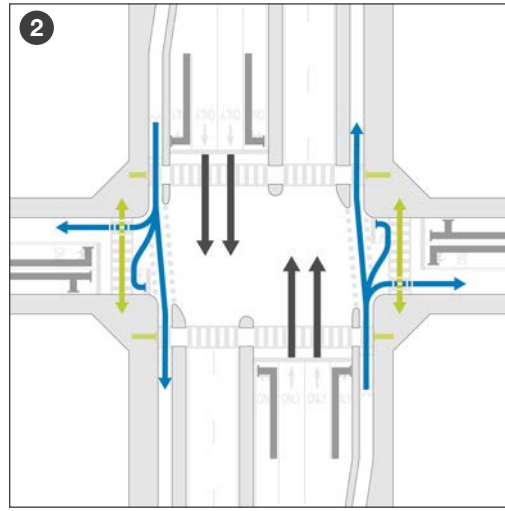
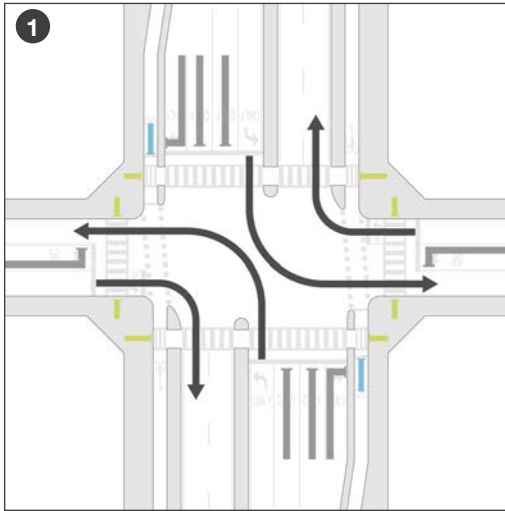
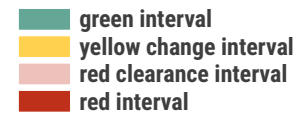
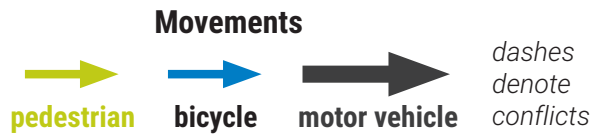
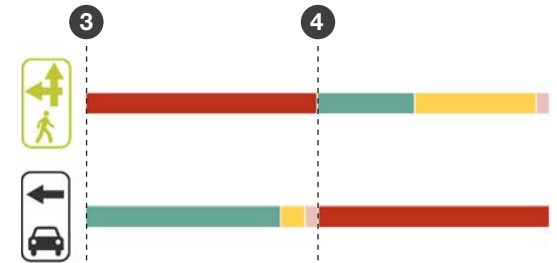
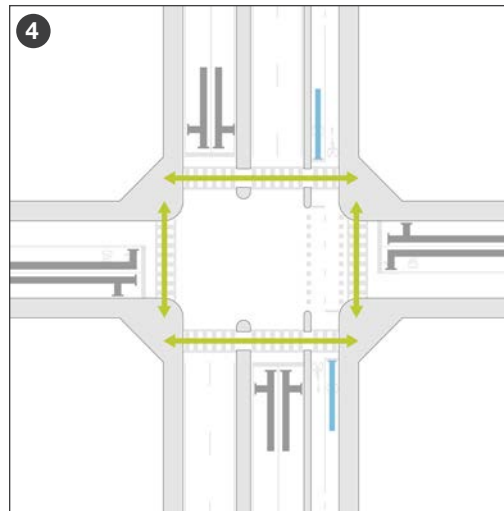
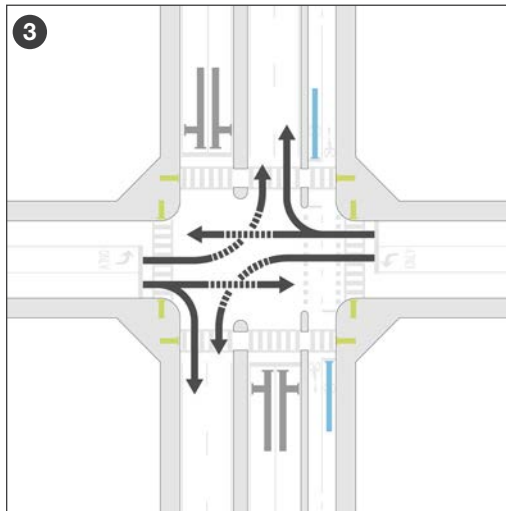
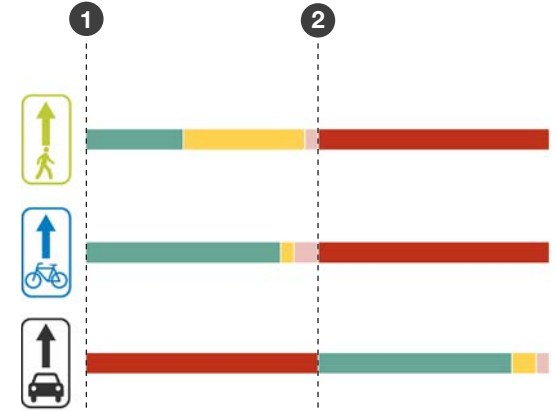
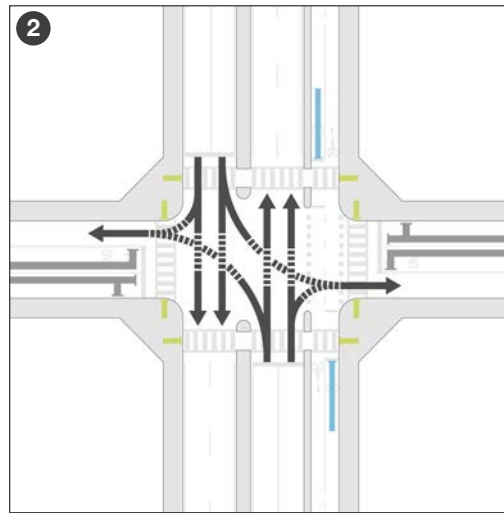
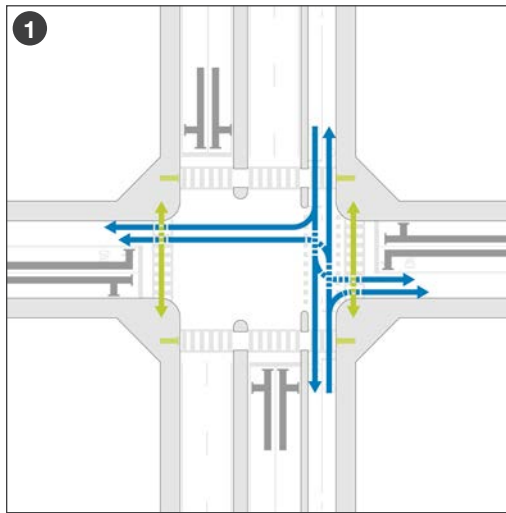


EXHIBIT 6K: CONCURRENT PROTECTED BIKE PHASE FOR MAJOR AND MINOR STREET INTERSECTION



6 SIGNALS

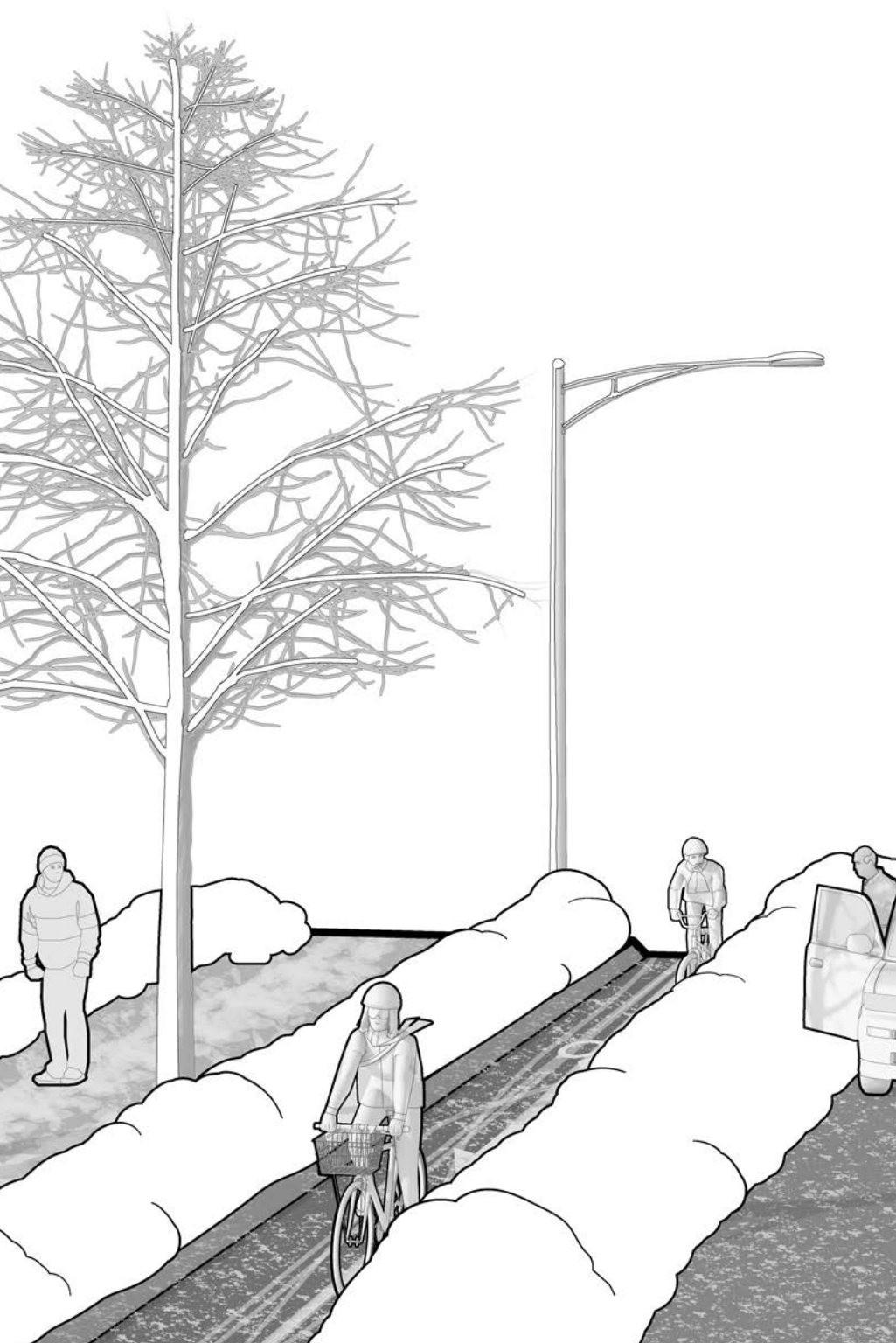
EXHIBIT 6L: PROTECTED BIKE PHASE



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7

MAINTENANCE



Separated bike lanes require routine maintenance to ensure they provide safe bicycling conditions. Because of their location on the edge of the roadway, separated bike lanes are more likely to accumulate debris in all seasons. During the freeze/thaw cycles of the winter months, separated bike lanes are particularly susceptible to icing. As bicyclists are typically inhibited from exiting separated bike lanes, they may have no opportunity to avoid obstacles such as debris, obstructions, slippery surfaces, and pavement damage and defects.

This chapter provides best practices for the maintenance of separated bike lanes. It addresses typical elements of maintenance plans, seasonal maintenance activities, repair and replacement considerations, and strategies for construction zones.

7.1 INTRODUCTION

One challenge to maintaining separated bike lanes is the size of standard street maintenance equipment, which is often wider or less maneuverable than can be accommodated in a separated bike lane. During the planning and design process, it is therefore important to consider the widths and operating constraints of existing maintenance vehicles, as well as vehicles or equipment used by partner agencies or organizations who may be tasked with maintaining the separated bike lane. Some agencies choose to procure new vehicles for the specific purpose of maintaining separated bike lanes.

Separated bike lanes are an emerging roadway design treatment in the U.S., therefore maintenance practices are evolving. Those responsible for maintaining separated bike lanes are encouraged to periodically evaluate maintenance practices, identify creative partnerships to ensure they are maintained in a safe and usable condition, and inform designers and managers of ways to improve facilities. Personnel that perform maintenance tasks on a regular basis should be an integral part of the planning and design team.

7.2 MAINTENANCE PLANS AND AGREEMENTS

A separated bike lane should be maintained in a similar manner as the adjacent roadway, regardless of whether the separated bike lane is at street level or

sidewalk level. Maintenance of separated bike lanes is therefore the responsibility of the public or private agency that is responsible for maintaining the adjacent roadway. This may contrast with responsibility for maintaining the adjacent sidewalk, which in some cases will be that of the abutting landowner.

Careful planning and agreement is important in areas where limited space for snow storage may pose a challenge for keeping both sidewalks and bike lanes free of snow. This is particularly true in retrofit situations with attached sidewalks, as those responsible for clearing the sidewalk may tend to move snow to the bike lane, and vice versa. It may be necessary to remove snow to an off-site location in these areas after large snow events.

Separated bike lane maintenance plans should address the routine removal of debris as well as long-term maintenance issues, such as repair and replacement of vertical elements, pavement surfaces, and traffic control devices. Plans should also address routine maintenance of landscaping located in the street and sidewalk buffers. While maintenance of separated bike lanes can be integrated into existing operations, these facilities occasionally require amending established maintenance practices and procedures, and purchasing specialized equipment.

Maintenance plans for separated bike lanes should be considered during the project development process. Maintenance plans

should identify involved parties, outline routine maintenance procedures and frequency, assign responsibilities, estimate annual costs and identify funding sources. Often these plans will be straightforward updates to existing municipal maintenance procedures.

Responsible parties may include one or more state agencies and municipalities, as determined by right-of-way ownership, abutting land ownership, or the number of jurisdictions spanned by the separated bike lane. Public authorities may also develop partnerships with business improvement districts, school districts, universities, park agencies, institutions, developers or utility companies to help fund or take part in separated bike lane maintenance activities. Where agreements exist, maintenance plans should address transition areas so there are no sudden gaps in the quality of the bicycling environment.

In such partnerships, parties may be able to 'trade' maintenance responsibilities and save mobilization costs and time. For example, a school may agree to clear a bike lane simultaneously with sidewalk along their frontage in exchange for a parks department clearing a nearby path. This also serves to get facilities near critical areas (e.g., schools) open more quickly.

7.3 SEASONAL MAINTENANCE

An effective seasonal maintenance program requires the right equipment, a well-trained crew, proper execution of strategies and preventative measures, and adequate funding.

7.3.1 VEHICLES

Chief among maintenance considerations during design are routine sweeping to remove debris and plowing to clear snow. Generally, separated bike lane widths of **8 ft. or more** are compatible with smaller sweepers and plows, but responsible parties may have larger and incompatible maintenance fleets. Narrower sweepers

and plows (approximately **4 ft. to 5 ft.** minimum operating width, as shown in **EXHIBIT 7A**) may be required to clear one-way separated bike lanes. Some vehicles can serve both as snow clearance equipment during the winter and street sweepers throughout the rest of the year. This versatility is usually accomplished with a system that allows attachment of various machines to the front of the main vehicle, such as plow blades, loaders or brooms.

The purchase of narrow sweepers and plows may be avoided by establishing maintenance agreements with partners or ensuring that vertical objects in the street buffer are removable in order to accommodate conventional vehicles that

are already owned. However, the up-front expense of purchasing narrower vehicles may save money over time when factoring in additional time and labor to remove, repair or replace damaged vertical objects. Removal and reinstallation of objects in the roadway also places workers in the street more frequently and increases the risk of crashes and mobilization costs for maintenance crews.

Permeable pavements have unique maintenance needs. With respect to vehicle design, permeable pavements should be maintained with plows that are outfitted with rubber edged blades to protect the pavement. Street vacuums may also be required to maintain permeable pavement.

EXHIBIT 7A: Narrow Maintenance Vehicles



Source: PeopleForBikes



Source: City of Cambridge, MA

7.3.2 SWEEPING AND DEBRIS REMOVAL

Separated bike lanes should be incorporated into established street sweeping programs. Additional sweeping of the buffer zones may be necessary to remove leaves, gravel, trash and other debris that can create slippery surfaces and increase bicyclists' stopping distance. More frequent street sweeping is usually needed in the fall and spring seasons when trees shed leaves and other organic matter at a faster rate.

For street level separated bike lanes without raised medians, debris can collect in the street buffer area between vertical objects and can migrate into the bike lane if not routinely collected. Landscaped areas, including green stormwater infrastructure, can also collect debris and require regular attention. Fine debris can settle into permeable pavement and inhibit surface infiltration unless vacuumed on a routine basis. At a minimum, permeable pavement should be vacuumed several times per year, depending on material type. Permeable pavement may need additional attention along areas where runoff routinely carries sediment, and during winter months because of sand and salt accumulation.

There are several types of permeable pavement systems that may be used. This depends on traffic loads and intensity of use, aesthetics, availability of materials, and maintenance capacity. Permeable pavements may be specified in order to meet post-construction stormwater management requirements. They are meant to be used in areas where the

contributing drainage areas are stabilized and there are relatively low fine grained, or suspended solids, in the runoff that drains to the pavement. Local regulations may dictate the inspection and maintenance requirements and the maintenance cycle.

7.3.3 TRASH COLLECTION

Where separated bike lanes are introduced, the general public, public works staff and contractors should be trained to place garbage bins in the street buffer zone to avoid obstructing the bike lane. Sidewalk buffers may be used to store bins where street buffers are too narrow. Special consideration may be required in separated bike lane design for access to large dumpsters which require the use of automated arms. This may require spot restrictions of on-street parking or curb cuts to dumpster storage in order to accommodate access.



Cambridge, MA

EXHIBIT 7B: MINIMUM SEPARATED BIKE LANE CLEARANCE

7.3.4 WINTER MAINTENANCE

Ice, snow, slush and rain are commonplace during winter months in Massachusetts. Therefore, separated bike lanes should be incorporated into established winter maintenance strategies and practices.

SNOW CLEARANCE

Snow and ice should be cleared from separated bike lanes to maintain safe and comfortable access by bicycle during winter months. A minimum **4 ft.** clearance per direction (i.e., **8 ft.** minimum for two-way facilities) should be provided in the bike lane zone as soon as practical after snow events. Snow from the separated bike lane should not be placed in the clear width of the sidewalk or vice versa.

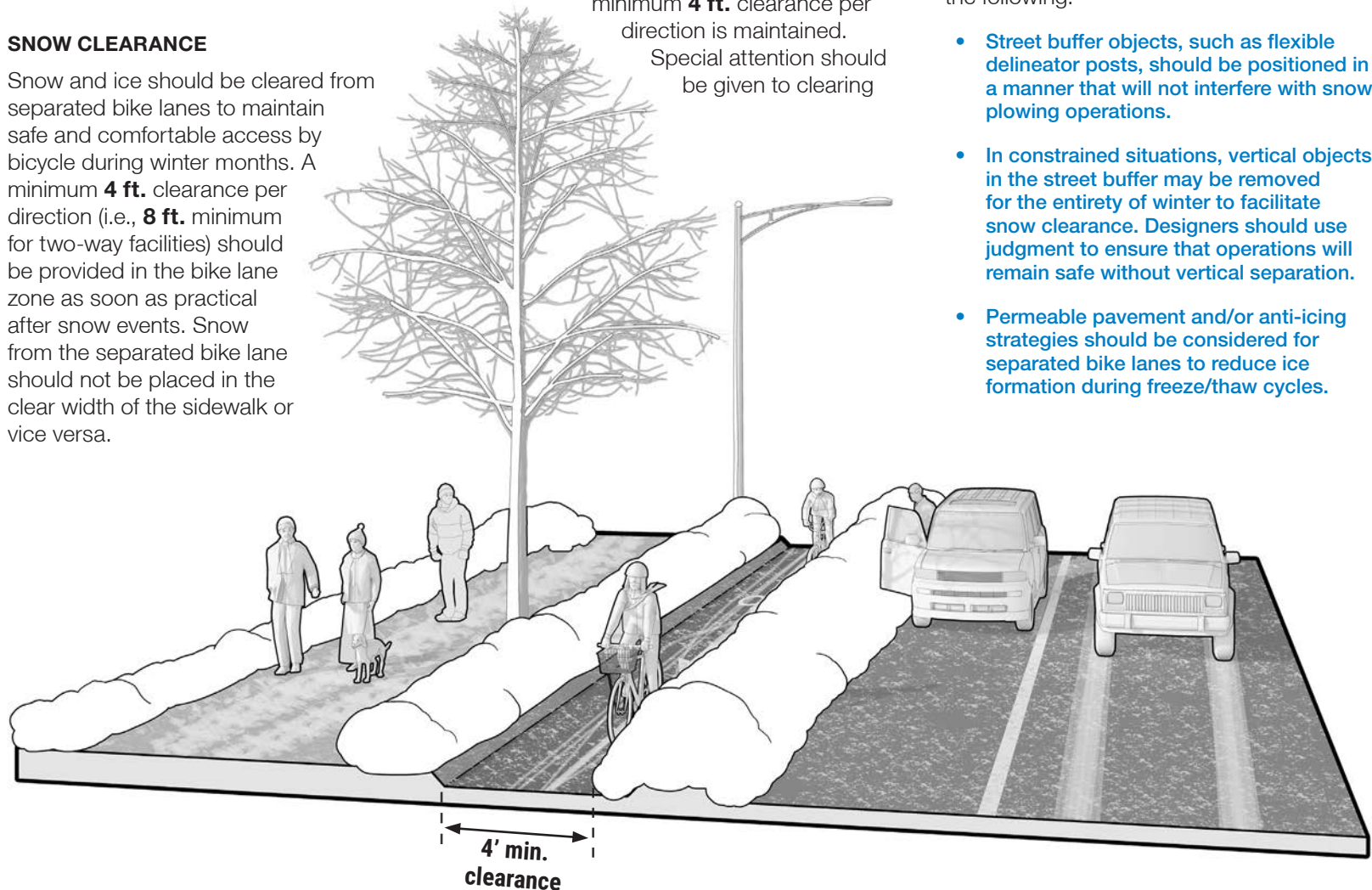
Sidewalk and street buffers may be used for snow storage, as shown in **EXHIBIT 7B**, but maintenance crews should avoid piling snow at intersections in order to maintain visibility at conflict points. The width of the separated bike lane can be constrained during a snow event provided that the minimum **4 ft.** clearance per direction is maintained.

Special attention should be given to clearing

snow along the curb as it may block drainage infrastructure and create icy patches of pavement during freeze/thaw cycles.

Additional considerations for snow clearance in separated bike lanes include the following:

- **Street buffer objects, such as flexible delineator posts, should be positioned in a manner that will not interfere with snow plowing operations.**
- **In constrained situations, vertical objects in the street buffer may be removed for the entirety of winter to facilitate snow clearance. Designers should use judgment to ensure that operations will remain safe without vertical separation.**
- **Permeable pavement and/or anti-icing strategies should be considered for separated bike lanes to reduce ice formation during freeze/thaw cycles.**



SNOW REMOVAL

Snow removal, off-site storage, and/or snow melting may be necessary to maintain safety and access in separated bike lanes during harsh winters and major snow events when buffer zones are insufficient for storing snow. Special equipment or procedures may be needed. Consider inspecting and clearing separated bike lanes after snow events which trigger an on-street parking ban—snow removal is often easier when vehicles are not parked on the street.

ANTI-ICING AND DE-ICING STRATEGIES

Even a small patch of black ice can cause a serious crash for a bicyclist. Therefore, after a snow event when daytime temperatures rise above freezing, it is particularly important to de-ice separated bike lane surfaces.

Where possible, environmentally friendly anti-icing and de-icing strategies should be deployed for separated bike lanes. It is recommended that anti-icing materials be applied prior to snow fall and de-icers applied again while clearing snow to help prevent ice formation. Special equipment may be required for these strategies in separated bike lanes. However, standard anti-icing and de-icing vehicles may be sufficient in the event of an on-street parking ban if they can operate closer to the bike lane zone and adequately cover the separated bike lane from the adjacent travel lane or parking lane.

Maintaining proper drainage will help prevent ice formation on surfaces during freeze/thaw conditions and after plowing. Bioretention curb extension areas, tree boxes, linear water quality swales, and linear bioretention areas in the buffer zones may further aid in reducing ice formation by providing additional drainage outlets. It may be desirable to limit the use of evergreen trees or structures which may prevent the sun from melting ice and snow at locations on the bike lane where falls could be particularly hazardous to fall (e.g., near grade changes, intersections, or lateral shifts in alignment).

The use of sands and abrasives on permeable pavement systems will result in clogging of the surface. Separated bike lanes with permeable pavement minimize the need for de-icing methods because meltwater naturally drains through the surface instead of refreezing. Permeable pavement can reduce road salt consumption by up to **75 percent** compared to impermeable pavement,¹ but the potential effects of salt and brine infiltration on tree roots, the permeable surface, and underground utilities should be considered. Permeable concrete surfaces are sensitive to road salts which may cause the degradation of the surface.

Consider state and local operating procedures related to anti-icing and de-icing strategies. Consult the Massachusetts Storm Water Handbook Appendix: Operating and Source Control BMPs for further considerations and best practices.

WINTER MAINTENANCE ROUTE PRIORITIZATION

Snow events can be prolonged, heavy, and unpredictable in both duration and location. Limited budgets ensure that there will always be some delay in clearing snow from transportation facilities, whether for motorists, bicyclists, or pedestrians. Route prioritization is important to ensure that those with greatest need are served first. It is important that this route prioritization information is available to the public so that all road users know where they can expect to find clear routes when the snow does begin to fall.

Motor vehicle travel lanes normally take precedence for snow clearing in order to maintain access for emergency vehicles. Communities should consider developing a prioritization plan for clearing bicycle routes, including separated bike lanes

and shared use paths. In the event the separated bike lanes are not cleared, it should be anticipated that bicyclists will be operating within the street and/or sidewalk. On high-volume streets, this may result in a degradation of safety for the bicyclist or reduced bicycling. Within a bicycle network, shared use paths and separated bike lanes may be ideal candidates for prioritization as they are likely to be routes with the highest user volumes. Other considerations for route prioritization include routes near schools, equipment

needs, width of facilities, obstacles such as separation methods, and other constraints such as time and location. Route prioritization and responsibilities for snow clearance should be clearly defined in maintenance plans when separated bike lanes span multiple jurisdictions.

7.4 REPAIR AND REPLACEMENT

7.4.1 INVENTORY AND INSPECTION

Components of separated bike lanes will need to be cared for, repaired and replaced and should be incorporated into the responsible jurisdiction's inspection program. Some jurisdictions have encouraged bicyclists to report maintenance needs and have established programs that supplement roadway inspections via call-in telephone numbers, websites or smartphone applications.

7.4.2 CONSIDERATIONS

When street maintenance is performed in a separated bike lane, for example during utility or pavement repair operations, maintenance crews should follow standard procedures supplemented with the following considerations.

SEPARATED BIKE LANE SURFACE

Longitudinal pavement seams, trenches or other surface depressions should not be left in the bike lane because they create hazards for people bicycling. Where trenching must occur, for example to access utilities, consider repaving the full width of a one-way bike lane or to the centerline of a two-way bike lane to place the resulting longitudinal seam outside of bicyclists' paths.

Gravel or other maintenance debris should be completely removed from the bike lane because these can puncture tires or lead to bicycle crashes.

STREET AND SIDEWALK BUFFERS

Repairs to curbs in the street and sidewalk buffers should follow standard repair procedures for damage or cracking.

Regular inspection for damaged or displaced vertical objects in the street buffer is recommended. Responsible parties should keep a supply of these objects for quick replacement when needed. Street buffer striping should be inspected and replaced along the same maintenance schedule and per the same retroreflectivity specifications as other roadway striping.

Trees and low-growth landscaping in the street and sidewalk buffers should be pruned to ensure proper sight distances at intersection approaches (see [Chapter 4](#)). Tree branches should be pruned to within **12 in.** from the outside the bike lane and

up to **100 in.** over the bike lane surface to ensure proper vertical clearance (see [Section 3.3.3](#)).

Regular inspection for loose or damaged unit pavers in the sidewalk buffer is recommended.

PAVEMENT MARKINGS AND SIGNAL EQUIPMENT

Separated bike lane pavement markings, including lane markings and intersection markings, should be inspected as part of a routine pavement marking program and restriped as necessary.

Bicycle signals and push buttons should be maintained on the same schedule as motor vehicle traffic signals.

Maintenance crews should ensure that signal faces remain visible to bicyclists in the separated bike lane, per guidance established in [Chapter 6](#).

Bicycle detectors, such as inductive loops or video detectors, should be maintained on the same schedule as in motor vehicle travel lanes.

7.5 CONSTRUCTION ZONES

Construction zones can create particular hazards for bicyclists because they may create width constraints, surface irregularities, surface debris, detours, or transitions between bicycle accommodations. These conditions may be in place for long periods of time or may abruptly change. Additionally, increased truck traffic and unfamiliar patterns of motor vehicle operation are of particular concern for bicyclists where operating space must be shared.

A **Temporary Traffic Control Plan (TTCP)** should provide detailed guidance to proactively address bicyclists' safety and operational needs in accordance with the **Work Zone Management** discussion in the **PD&DG**. Refer to **MassDOT Construction Standard Details** for the following examples of work zone bicycle accommodations that may be adapted to separated bike lanes:

- **Bicycle lane closures**
- **Bicycle lane detours**
- **Temporary path detours**

The TTCP should strive to meet the following objectives:

- **Educate all responsible parties of the operating characteristics of bicycles and bicyclists.**
- **Maintain separation of bicyclists from pedestrians through the construction zone at all times.**
- **Maintain separation of bicyclists from motor vehicles where feasible. Where not feasible, clearly delineate a preferred route through the construction zone. Where detours are necessary, limit out-of-direction travel for bicyclists.**
- **Avoid placing signs or equipment in the separated bike lane.**
- **Avoid requiring bicyclists to dismount.**
- **Minimize redirection of bicyclists to the opposite side of the roadway.**
- **Inspect the construction zone for compliance with the TTCP.**
- **Coordinate with advocates for feedback to improve TTCP.**
- **Minimize surface irregularities.**
- **Minimize the accumulation of debris.**
- **Provide smooth vertical and horizontal transitions that can be traversed safely by bicyclists.**

Where conditions require a deviation from a separated bike lane condition, the distance and duration of this condition should be kept to a minimum. These transitions may require temporary asphalt curb ramps. Transitions should be well signed and include pavement markings for all roadway users to minimize conflicts.

7.6 ENDNOTES

- 1 http://www.unh.edu/unhsc/sites/unh.edu.unhsc/files/pubs_specs_info/unhsc_houle_thesis_9_08.pdf