LincolnBikePlan

On-Street Bicycle Facilities Plan

DRAFT

Bicycle Facility Design Guide

2018

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City of Lincoln Bicycle Facility Design Guide
2018

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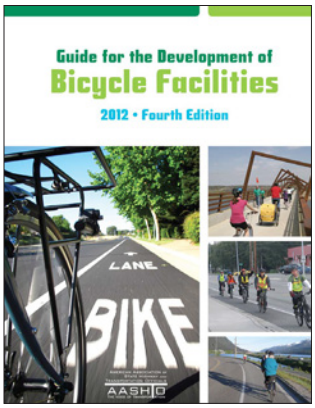
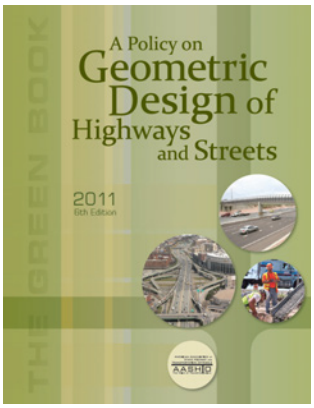
NATIONAL STANDARDS AND RESOURCES

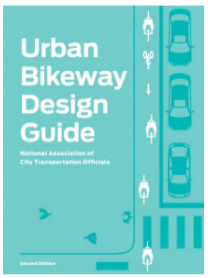
The publications listed here are excellent resources for planning and design guidance in implementing safe, comfortable accommodations for bicyclists in a variety of environments. Many of these resources are available on-line at no cost. For full citation information, see Appendix A.





American Association of State Highway and Transportation Officials (AASHTO)

- Guide for the Development of Bicycle Facilities (2012) (Update anticipated in 2019)
- A Policy on Geometric Design of Highways and Streets, 6th Edition (2011)

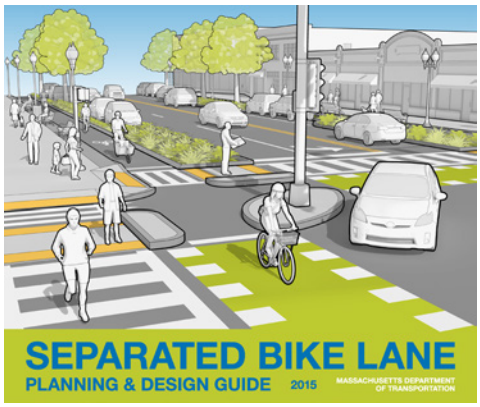


National Association of City Transportation Officials (NACTO)

- Urban Street Design Guide (2013)
- Transit Street Design Guide (2016)
- Urban Bikeway Design Guide (2014)

Federal Highway Administration (FHWA)

- Achieving Multimodal Networks: Applying Design Flexibility and Reducing Conflicts (2016)
- Separated Bike Lane Planning and Design Guide (2015)



Massachusetts Department of Transportation (MassDOT)

- Separated Bike Lane Planning & Design Guide (2015)

GLOSSARY

There are many terms used to describe different components of the transportation system, treatments, and bikeway facility types. To promote consistency and ease of understanding, the following terms are used throughout this Guide.

Amenities – Elements such as benches, kiosks, bicycle parking, points of interest displays, or trash receptacles that are placed on a sidewalk, pedestrian mall, or at transit stops in order to improve the convenience and attractiveness of the facility.[1]

Average Daily Traffic (ADT) – The total volume of traffic on a street during a given time period divided by the number of days in that time period.[1]

Bicycle Boulevard – Bicycle boulevards are streets with low motorized traffic volumes and speeds, designated and designed to give bicycle travel priority. Bicycle boulevards use signs, pavement markings, and speed and volume management measures to discourage through trips by motor vehicles and create safe, convenient bicycle crossings of busy arterial streets.[5]

Bicycle Box – Designated area on the approach to a signalized intersection consisting of an advanced stop line and bicycle symbols. Bicycle boxes should be primarily considered to mitigate conflicts between through bicyclists and right-turning motorists and to reduce conflicts between motorists and bicyclists at the beginning of the green signal phase.

Bicycle Detection – A system of hardware and software that detects the presence of bicyclists at a traffic signal and calls the green signal for the activated approach. Bicycle detection may consist of inductive loops, microwave, magnetometers, or pushbutton technologies.

Bicycle Level of Service (BLOS) – Model used to estimate bicyclists' average perception of the quality of service of a section of roadway between two intersections.[1]

Bicycle Signal – Traffic control device used to improve intersection safety and operations for bicyclists. Bicycle signal heads can be installed at signalized intersections to indicate bicycle signal phases and other bicycle-specific timing strategies.[2, 5]

Bicycle Signal Head – An assembly of one or more signal faces that is provided for controlling bicycle traffic movements on one or more intersection approaches.[3]

Bike Lane – A portion of a roadway that has been designated for preferential or exclusive use by bicyclists by pavement markings and, if used, signs.[3]

Bike Route – A signed route that is preferred for bicycling due to low traffic or access to destinations. Does not necessarily have a delineated or dedicated space for bicycling.

Bikeway – Any type of bicycle facility, including paths in separate rights-of-way and on-street bikeways. Includes bike lanes, paved shoulders, signed bike routes, and sidepaths.

Clear Width – The width of a pedestrian facility or route that is unobstructed and passable. Minimum clear width requirements under various built environment conditions are provided in the *Americans with Disabilities Act Accessibility Guidelines* (ADAAG) and the *Proposed Accessibility Guidelines for Pedestrian Facilities in the Public Right-of-Way* (PROWAG).

Clear Zone – The total roadside border area, starting at the edge of the traveled way, available for safe use by errant vehicles.[2]

Cone of Vision – A transportation safety concept pertaining to the visual acuity of the human eye and the area of focus by a motorist or other roadway user. Motorists tend to focus on the roaday at a distance three to four times the stopping sight distance. Because of this tendency, as motorists drive at higher speeds, they are less likely to notice objects, pedestrians, or bicyclists in the area of their peripheral vision.

Conflict Areas – A two-dimensional zone within which potential travel paths cross and crashes could occur between users of the same mode or users of differing modes. Typical conflict areas include approaches to intersections, intersections, and driveways.

Confirmation Sign – Wayfinding signage to let bicyclists know they are on a designated bikeway and alert motorists to the likely presence of bicyclists. Sometimes referred to as Identification Signs. The MUTCD recommends that confirmation signs be repeated at regular intervals so that bicyclists entering from side streets are made aware that they are on a designated bicycle route. A confirmation assembly is a set of wayfinding signs comprised of confirmation signs.

Contra-Flow Bikeway – A bikeway (usually a bike lane) in the opposite direct of motor vehicle traffic on a one-way street. Contra-flow bikeways require careful consideration of traffic control and conflicts with motor vehicle traffic.

Crossing Island – Raised islands placed on a street at intersections or midblock locations to separate crossing pedestrians from motor vehicles. Also known as refuge areas, refuge islands, center islands, pedestrian islands, or median slow points.[2]

Crosswalk – Legal crosswalks exist at all intersections, whether marked or unmarked. Midblock crosswalks must be marked in order for pedestrians to legally have the right-of-way.

Curb Extension – Treatment or application designed to visually and physically narrow the roadway in order to create safer and shorter crossing distances for pedestrians while increasing the available space for street furniture, benches, plantings, and trees.[5]

Curb Radius – The radius of the arc formed where two intersecting curbs meet. Smaller curb radii encourage slower turning speeds at intersections.

GLOSSARY (CONTINUED)

Curb Ramp – The transition for pedestrians from the sidewalk to the street. ADA Standards require all pedestrian crossings to be accessible to people with disabilities by providing curb ramps at intersections and mid-block crossings as well as other locations where pedestrians can be expected to enter the street.

Design Speed – Design speed is a selected speed used to determine various geometric design features of the roadway. The assumed design speed should be logical with respect to the topography, anticipated operating speed, adjacent land uses, and the functional classification of the roadway.[1]

Detectable Warning – Standardized feature usually comprised of truncated domes of a contrasting color, which are built into, or applied to, walking surfaces. Detectable warnings alert people with vision impairments that they have reached a location where caution should be exercised. At these locations, visually-impaired pedestrians typically stop and determine their position relative to the roadway before proceeding further.[1]

Flexible Delineator Posts – Flexible delineator posts, also called flex posts or flex stakes, are used to provide vertical demarcation of a roadway feature, including some bike lanes. These posts are typically made of plastic with an internal spring mechanism mounted to a base plate. Flexible delineator posts can be secured to the pavement using bolts, epoxy, or other techniques. The color of the plastic post should match the color of the pavement marking or striping with which it is associated.

High-Intensity Activated Crosswalk Beacon (HAWK) – The pedestrian hybrid beacon (also known as the **H**igh-Intensity **A**ctivated cross**W**al**K**, or HAWK) is a pedestrian-activated warning device located on the roadside or on mast arms over midblock pedestrian crossings. The beacon head consists of two red lenses above a single yellow lens. Chapter 4F of the MUTCD includes information on the HAWK pedestrian hybrid beacon and how it should be used.[3]

Horizontal Alignment – The design of a path that determines whether a path continues straight or curves to the left or right.

Horizontal Radius – The horizontal radius indicates the radius of a curve along the horizontal alignment of a path. The minimum recommended radii are intended to allow bicycle travelers to follow the curve of a path without slowing substantially.

Horizontal Deflection Treatment – Traffic calming techniques that compel motorists to reduce their travel speed by changing the width or directionality of travel lanes at defined locations along a street. Examples include narrow lanes, chicanes, neckdowns, traffic circles, and curb extensions.

Landing Area – A level area at a curb ramp or raised crossing with less than 2% grade or cross slope, designed for wheelchair users to wait, maneuver into or out of a curb ramp, or to bypass a ramp altogether.[1]

Lane Diet – See Lane Narrowing

Lane Narrowing – A design strategy used for traffic calming effects and for reallocating existing pavement width to create designated space for other uses, including bicycle lanes.

Level of Traffic Stress (LTS) – A rating system to estimate the levels of tolerance for traffic stress, which is a combination of perceived danger and other stressors associated with riding a bicycle close to motor vehicle traffic. People can be classified into groups based on their tolerance of traffic stress (Highly Confident, Somewhat Confident, Interested but Concerned, and Not Able or Interested). Bicycle facilities can be rated based on the degree of traffic stress they impose on bicyclists, determined by bikeway facility width, proximity to traffic, traffic speeds and volumes, and likelihood of bikeway obstruction.

Mast Arm – A structure, also referred to as a cantilevered signal structure, that is rigidly attached to a vertical pole and is used to provide overhead support of traffic signal faces or grade crossing signal units. Traffic control signs may also be mounted to a mast arm.[3]

Mid-Block Crossing – Designated crosswalks away from an established intersection provided to facilitate crossings at places where there is a significant pedestrian desire line such as bus stops, parks, and building entrances.[5]

Mile Markers – Signage to help shared use path users measure distance traveled and provide important reference points in case of emergency. Mile markers should be placed every 1/4 to 1/2 mile along a shared use path.

Mixing Zone – A mixing zone requires turning motorists to merge across a separated bike lane at a defined location in advance of an intersection. Unlike a standard bike lane, where a motorist can merge across at any point, a mixing zone design limits bicyclists' exposure to motor vehicles by defining a limited merge area for the turning motorist. Mixing zones are compatible only with one-way separated bike lanes.

Mountable Curb/Curb Apron – Mountable curbs with curb aprons deter passenger vehicles from making higher-speed turns but accommodate the occasional large vehicle without encroachment or off-tracking into pedestrian areas.

MUTCD – The *Manual on Uniform Traffic Control Devices* is a compilation of national standards for all traffic control devices, including traffic signals.[3]

Neighborhood Traffic Circles – Raised islands typically built at the intersections of local residential streets to reduce motor vehicle speeds. They may be operated without stop control, or as two-way or all-way stop-controlled intersections. Neighborhood traffic circles frequently do not include raised channelization to guide approaching traffic into the circulatory roadway.[2, 6]

Offset Intersection – Offset intersections are locations where two segments of a street connection do not directly align where they meet another street. These configurations are most challenging for bicyclists when offset local streets serving as bike routes or bike boulevards intersect with larger collector or arterial streets.

Parking T – A short vertical white line to mark the side of a parking space, coupled with a short horizontal white line crossing it to mark each end of the space.[3]

Path – Short for "shared use path" and often synonymous with the word "trail," a path is a separated facility, typically in an independent right-of-way such as a greenbelt or abandoned railroad. See Shared Use Path.

GLOSSARY (CONTINUED)

Paved Shoulder – Paved area at the edges of rural roadways. A paved shoulder is suitable for bicyclists if it is at least 4 feet in width.

Pavement Markings – Pavement markings are used to convey messages to roadway (or shared use path) users. They indicate which part of the road to use, provide information about conditions ahead, and indicate where passing is allowed. Yellow lines separate traffic flowing in opposite directions. White lines separate lanes in which travel is in the same direction. Symbols are used to indicate permitted lane uses. The MUTCD provides specifications regarding pavement markings.[3]

Peak Hour Volume – The volume of traffic that uses the approach, lane, or lane group in question during the hour of the day that sees the highest traffic volumes for that intersection.

Pedestrian Hybrid Beacon – See High-Intensity Activated Crosswalk Beacon (HAWK).

Raised Crosswalk – Traffic calming device at a pedestrian crossing or crosswalk that raises the entire wheelbase of a vehicle to encourage motorists to reduce speed.[5]

Rectangular Rapid Flashing Beacon (RRFB) – User-actuated amber light-emitting diodes (LEDs) that supplement warning signs at unsignalized intersections or mid-block crosswalks. The can be activated by pedestrians manually by a push button or passively by a pedestrian detection system.[2]

Regulatory Signage – Regulatory signs are used to inform road users of selected traffic laws or regulations and indicate the applicability of the legal requirements. Chapter 2B of the MUTCD provides specifications regarding regulatory signage.[3]

Right(s)-of-Way – Land or property that is used for public purposes including streets, sidewalks, utilities, etc.

Road Diet – A short-hand term referring to reconfiguring a roadway to remove lanes in order to provide more space for pedestrians and bicyclists. Road diets are most typically performed on roadways where traffic volumes do not necessitate the existing number of lanes.

Roadway – The paved portion of a street, from curb to curb, designed to convey motor vehicle, bicycle, transit, and/or freight traffic.

Rumble Strip – A textured or grooved pavement treatment designed to create noise and vibration to alert motorists of a need to change their path or speed. Longitudinal rumble strips are sometimes used on or along shoulders or center lines of highways to alert motorists who stray from the appropriate traveled way. Transverse rumble strips are placed on the roadway surface in the travel lane, perpendicular to the direction of travel. Rumble strip dimensions vary depending on their purpose and jurisdiction.[1]

Separated Bike Lane – One- or two-way bikeway that combines the user experience of a sidepath with the on-street infrastructure of a conventional bike lane. They are physically separated from both motor vehicle and pedestrian traffic.

Shallow Grade – An area that is relatively smooth with minimal slope (2% or less).

Shared Lane Marking – Shared lane markings (or "sharrows") are pavement markings that denote shared bicycle and motor vehicle travel lanes. The markings are two chevrons positioned above a bicycle symbol, placed where the bicyclist is anticipated to operate.

Shared Roadway – Roadway that is open to both bicycle and motor vehicle travel.

Shared Use Path – Shared use paths, also commonly referred to as trails or greenways, are paths designed for and generally used by bicyclists, pedestrians, and other non-motorized users. Shared use paths are generally the preferred type of infrastructure for the majority of bicyclists in the "interested but concerned" category, due to their separation from the roadway and vehicular traffic. In many states, the term "trail" refers to an unimproved recreational facility intended for uses such as walking, hiking, and mountain biking. Care should be taken when using this term, as in some parts of the country, trails have distinctly different design guidelines.

Shoulder – The portion of the roadway contiguous with the traveled way that accommodates stopped vehicles, emergency use, and lateral support of the subbase, base, and surface courses. Shoulders, where paved, are often used by bicyclists.[1]

Sidepath – A separated path along a roadway that serves people bicycling and walking within the street right-of-way. Compared to paths in independent rights-of-way, sidepaths have a higher likelihood of interactions with motor vehicles at driveways and intersections.

Sidewalk Buffer – The space between the sidewalk and the adjacent roadway designed to improve pedestrian safety and to enhance the overall walking experience. Sidewalk buffers also provide an area for snow storage and splash protection for pedestrians, as well as space for curb ramps, light poles and traffic signs.[1]

Sight Distance – Sight distance is the visually unobstructued distance required to execute a stopping maneuver (stopping sight distance), pass another vehicle (passing sight distance), perform an unexpected maneuver (decision sight distance), or execute a movement at an intersection (intersection sight distance). Sight distances depend on roadway geometry, travel speeds, deceleration rates, and reaction times.

Signal Timing – The process of selecting appropriate values for timing parameters implemented in traffic signal controllers and associated system software.[7]

Signalized Intersection – Intersection between two traveled ways (roadway/roadway or roadway/shared use path) where user movements are regulated by a traffic control signal.

Speed Cushion – Speed cushions are either speed humps or speed tables that include wheel cutouts to allow large vehicles to pass unaffected, while reducing passenger car speeds. Speed cushions extend across one direction of travel from the centerline, with a longitudinal gap provided to allow vehicles with wide wheel bases to straddle the hump.[5]

Speed Hump – Parabolic vertical traffic calming devices intended to slow traffic speeds on low-volume, low-speed streets.[5]

GLOSSARY (CONTINUED)

Stop Bar – Solid white pavement marking line extending across approach lanes to indicate the point at which a stop is intended or required to be made.[3]

Street – A public corridor designed to provide access to businesses, housing, parks, and civic buildings within a city. The entire right-of-way, including sidewalks, the roadway, vegetated buffers, etc. is considered part of the street.

Street Buffer – The portion of a separated bike lane design that divides the bike lane from motor vehicle traffic [4]

Street Furniture Zone – The section of the sidewalk between the curb and the through zone in which street furniture and amenities, such as lighting, benches, newspaper kiosks, utility poles, tree pits, and bicycle parking are provided. The street furniture zone may also consist of green infrastructure elements, such as rain gardens or flow-through planters.[5]

Traffic Calming – A strategy and toolkit to slow the speeds of motor vehicle traffic to a "desired speed" by incorporating physical features, such as chicanes, mini traffic circles, speed humps, and curb extensions.

Traffic Control – Devices such as traffic signals, warning signs, stop signs, yield signs, and other regulatory signs.

Traffic Diversion – A traffic calming technique in which raised areas are constructed to redirect motor vehicle traffic to alternate routes but permit passage of bicyclists and pedestrians. Traffic diverters are common treatments on bicycle boulevards.

Traffic Volume – The number of vehicles passing a given point over a specific period of time.

Transit Stop– Location where public transportation vehicles (bus or rail) will stop to allow passengers to board or alight the transit vehicle.

Transit Stop Wheelchair Landing Pad – The wheelchair landing is a portion of the waiting pad at a paved bus stop. This landing provides a location with a curb-height solid surface for buses to "kneel" and deploy the bus wheelchair ramp. Wheelchair landings must comply with ADA guidelines.[8]

Truncated Dome – See Detectable Warning.

Two-Stage Turn Queue Box – Two-stage turn queue boxes are areas set aside for bicyclists to queue to turn at signalized intersections outside of the traveled path of motor vehicles and other bicycles. In addition to mitigating conflicts inherent in merging across traffic to turn, two-stage bicycle turn boxes reduce conflicts between bicycles and pedestrians and separate queued bicyclists waiting to turn from through bicyclists moving on the green signal.[3]

Vertical Deflection Treatment – Traffic calming techniques that compel motorists to reduce their travel speed by changing the elevation of the roadway at defined locations along a street. Examples include speed humps, speed tables, and raised crosswalks.

Wayfinding – A system of directional signs along streets or paths that assist people in finding major destinations. Wayfinding can be designed specifically for drivers, bicyclists, or pedestrians.

GLOSSARY RESOURCES

[1] American Association of State Highway Transportation Officials (AASHTO)

[2] Federal Highway Administration (FHWA)

[3] Manual on Uniform Traffic Control Devices (MUTCD)

[4] Massachusetts Department of Transportation (MassDOT)

[5] National Association of City Transportation Officials (NACTO)

[6] National Center for Safe Routes to School

[7] National Cooperative Highway Research Program (NCHRP)

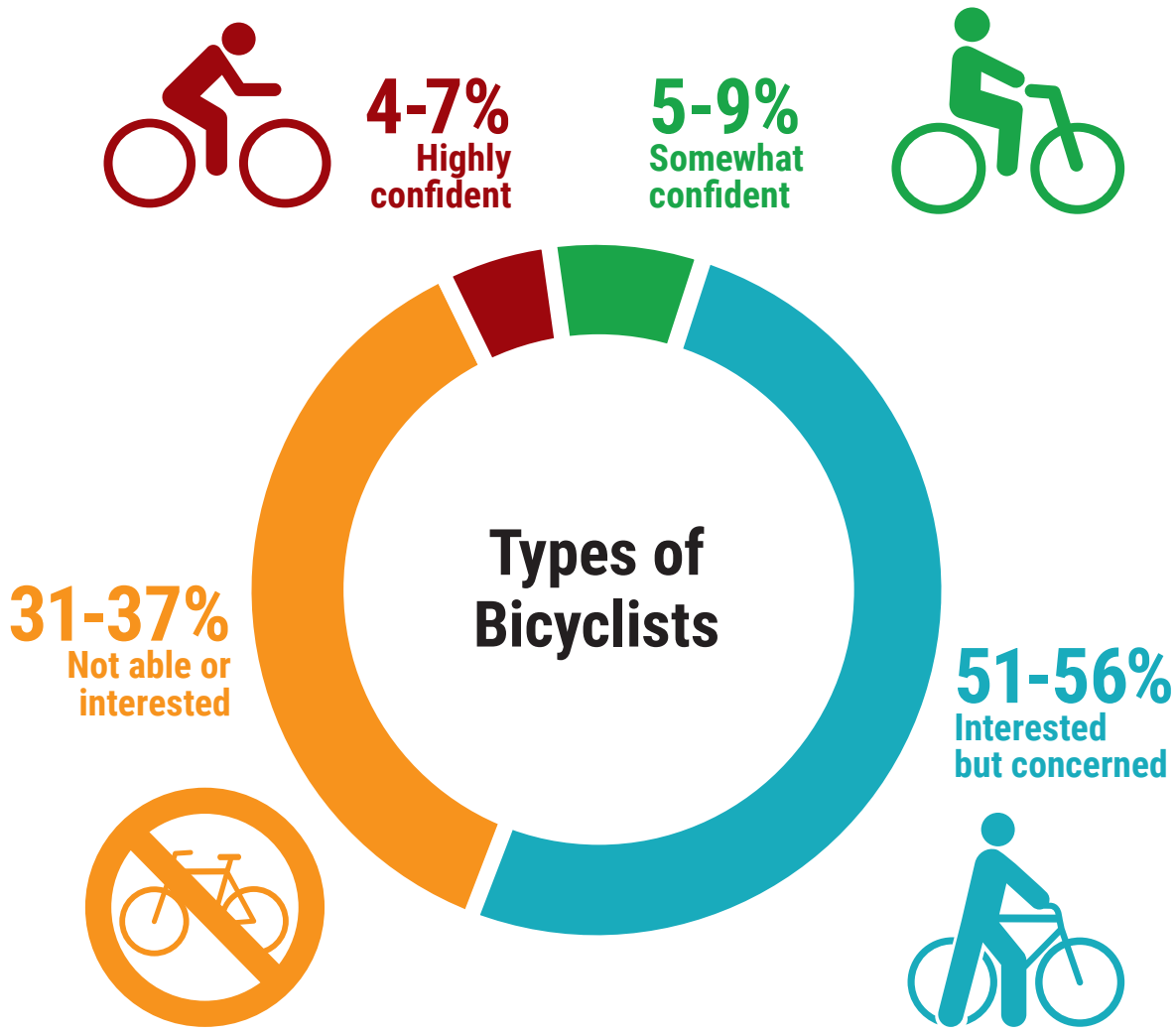
[8] Transit Cooperative Research Program (TCRP)

BIKEWAY FACILITY SELECTION

TYPES OF BICYCLISTS

The figure below illustrates a typical range of bicyclists. Estimates show the greatest percentage of the population—over half—fall into the "Interested but Concerned" category. The "Interested but Concerned" are most comfortable biking when separated from motorized vehicles. On the other end of the spectrum, "Highly confident" people are comfortable sharing the road with motorized vehicles. In the middle, "Somewhat Confident" people are comfortable biking for short distances with motorized vehicles. See Page 14 and the Bikeway Facilities Selection Chart to determine which facility types best serve the majority of bicyclists.

People generally fall into one of four categories based on their level of comfort:



These percentage values are typical ranges for most US communities.

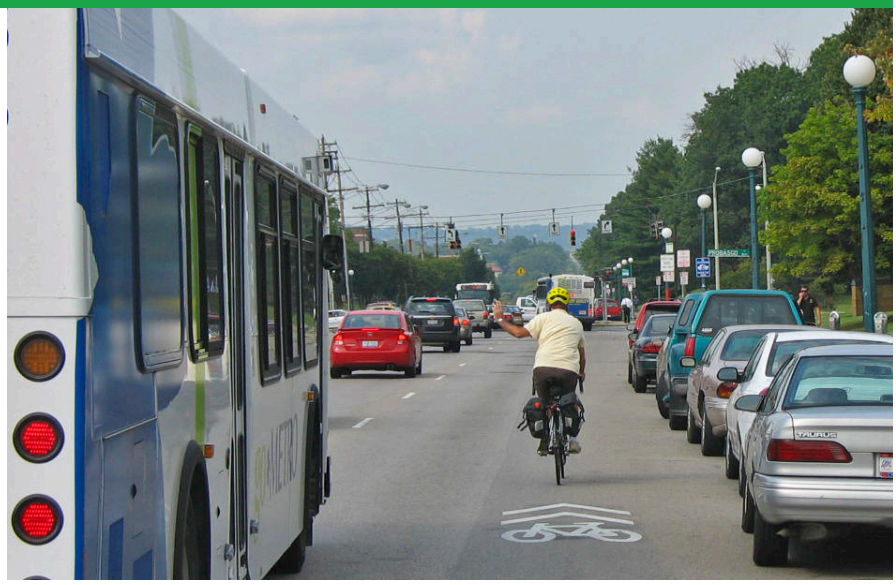
SOURCE

Dill, Jennifer and McNeil, Nathan, Revisiting the Four Types of Cyclists: Findings from a National Survey, Transportation Research Record: Journal of the Transportation Research Board, January 12, 2016.

Interested but concerned bicyclists require physical bicycle infrastructure improvements before they will choose to ride.

Somewhat confident bicyclists will ride comfortably on most types of streets, but may be uncomfortable in certain situations or road conditions.

Highly confident bicyclists will ride in nearly any road conditions or environment.



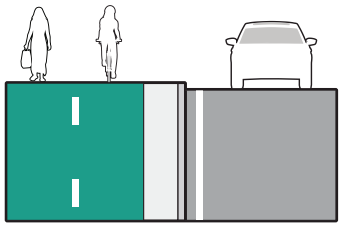
People who identify as **Not able or interested** will not ride a bicycle, no matter the circumstances.

BICYCLE FACILITY OVERVIEW

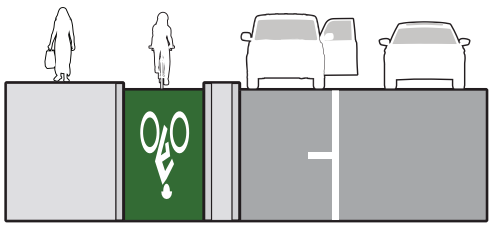
Various types of bicycle facilities are available, offering a range of separation from motor vehicle and pedestrian traffic. All things equal, facilities that provide more separation are more comfortable and safer. However, facilities with little to no separation, such as bike lanes and shared roadways, can be appropriate on low-speed, low-traffic streets.

TYPICAL APPLICATION

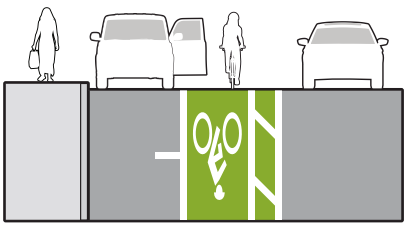
Shared Use Path SUP



Separated Bike Lane SBL



Buffered Bike Lane BBL



MOST COMFORTABLE

Shared use paths can generally be considered on any road with one or more of the following characteristics:

+ Total traffic lanes: 3 lanes or *more*
+ Posted speed limit: 30 mph or *higher*
+ Average Daily Traffic: 9,000 vehicles or more
+ Parking turnover: frequent
+ Bike lane obstruction: likely to be frequent
+ Streets that are designated as truck or bus routes

Shared use paths may be preferable to separated bike lanes in low density areas where pedestrians volumes are anticipated to be fewer than 200 people per hour on the path.

Separated bike lanes can generally be considered on any road with one or more of the following characteristics:

+ Total traffic lanes: 3 lanes or *more*
+ Posted speed limit: 30 mph or *higher*
+ Average Daily Traffic: 9,000 vehicles or more
+ Parking turnover: frequent
+ Bike lane obstruction: likely to be frequent
+ Streets that are designated as truck or bus routes

Preferred in higher density areas, adjacent to commercial and mixed-use development, and near major transit stations or locations where observed or anticipated pedestrian volumes will be higher.

Buffered bike lanes can generally be considered on any road with one or more of the following characteristics:

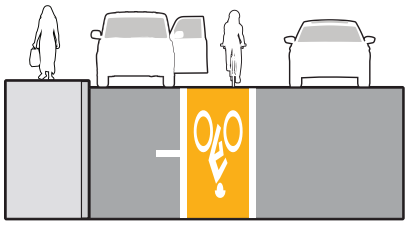
+ Total traffic lanes: 3 lanes or *fewer*
+ Posted speed limit: 30 mph or *lower*
+ Average Daily Traffic: Up to 9,000 vehicles
+ Parking turnover: infrequent.
+ Bike lane obstruction: likely to be infrequent
+ Where a separated bike lane or sidepath is infeasible or not desirable due to cost, lack of public support, etc.
+ Buffer may be located on the parking lane side of the bike lane, the travel lane side of the bike lane, or on both sides of the bike lane.

NOTE

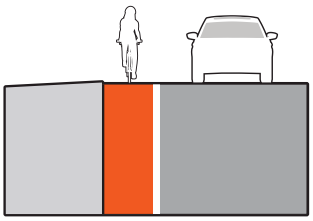
Contra-flow examples of most of these facilities are possible with consideration given to traffic control, sight lines, placement to the left of oncoming motor vehicle traffic, and low levels of driveway traffic.

TYPICAL APPLICATION

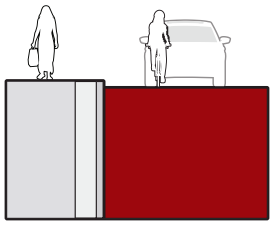
Bike Lane BL



Shoulder Bikeway SB



Shared Roadway SR



LEAST COMFORTABLE

Conventional bike lanes can generally be considered on any road with one or more of the following characteristics:

- Total traffic lanes: 3 lanes or *fewer*
- Posted speed limit: 30 mph or *lower*
- Average Daily Traffic: Up to 7,500 vehicles
- Parking turnover: infrequent
- Bike lane obstruction: likely to be infrequent
- Where a separated bike lane or sidepath is infeasible or not desirable

Shoulder bike lanes can generally be considered on any road without on-street parking and one or more of the following characteristics:

- Total traffic lanes: 3 lanes or *fewer*
- Average Daily Traffic: Up to 7,500 vehicles
- Shoulder obstruction: likely to be infrequent
- Where a separated bike lane or sidepath is infeasible or not desirable

The minimum width of a shoulder bikeway is 4' (exclusive of the gutter if one exists). Wider shoulders should be provided on streets or roads with average daily traffic higher than 3,500 vehicles.

Shared roadways can be considered on any road with one or more of the following characteristics:

- Total traffic lanes: 3 lanes or *fewer*
- Posted speed limit: 25 mph or *lower*
- Average Daily Traffic: Up to 3,000 vehicles
- Where a separated bike lane or sidepath is infeasible or not desirable

NOTE

Contra-flow examples of most of these facilities are possible with consideration given to traffic control, sight lines, placement to the left of oncoming motor vehicle traffic, and low levels of driveway traffic.

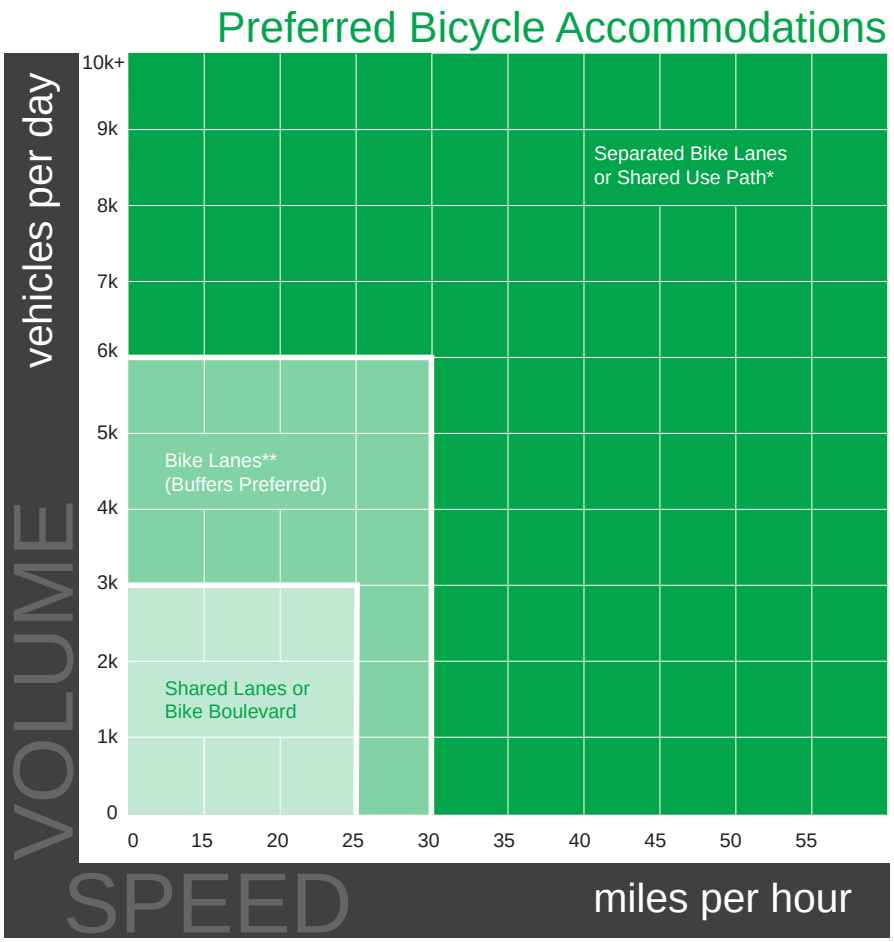
BICYCLE FACILITY SELECTION

Motor vehicle traffic volume and speed are critical contextual considerations for bicyclist safety and comfort. Proximity to motor vehicle traffic is a significant source of stress, safety risks, and discomfort for bicyclists, and corresponds with sharp rises in crash severity and fatality risks for vulnerable users when motor vehicle speeds exceed 25 miles per hour. Furthermore, as motorized traffic volumes increase above 3,000 vehicles per day, it becomes increasingly difficult for motorists and bicyclists to share roadway space.

Designing for All Users

From a bicyclist comfort point of view, separated bike lanes and shared use paths are generally preferable to bicycle lanes, shoulders, or buffered bike lanes once traffic volumes reach 6,000 vehicles per day or prevailing motor vehicle speeds exceed 35 miles per hour.

The figure below is used to determine the bicycle facility for a street project. It illustrates the baseline optimal bicyclist accommodations for the projected traffic context of the street. The speed and volume thresholds shown below correlate with a Level of Traffic Stress rating (see Glossary) of LTS2 on streets without on-street parking. On streets with on-street parking and speeds above 30 miles per hour, separated bike lanes should be used.



*To determine whether to provide a shared-use path or separated bike lane, consider pedestrian and bicycle volumes or, in the absence of volume, consider land use.
**Advisory bike lanes may be an option where traffic volume < 4K ADT

FACILITY DETAILS:

See the Bicycle Facility Overview section on pages 12-13 for explanations and typical widths of the facilities described in this chart.

CHART REFERENCES

+ Transitions are based on a shift in the Highway Capacity Manual (HCM) Bike Level of Service (BLOS) from A to B (assuming no parking, 12 ft outside travel lane, 6 ft bike lane, 8 ft buffered bike lane). This roughly translates to a BLOS C to D transition with on-street parking (8 ft parking lane).

+ Speed thresholds based on Level of Traffic Stress. "Interested but Concerned" riders are sensitive to increases in volume or speed, based on Dill's research, *Categorizing Cyclists: What Do We Know? Insights from Portland, OR* on the four types of bicyclists.

STRATEGIES FOR CONSTRAINED RIGHT-OF-WAY

The configuration and width of travel lanes, bike lanes, center turn lanes, and parking lanes has a great impact on the availability of space on Lincoln's streets. Especially in developed areas of the city, every foot of roadway and right-of-way width is a precious commodity. Therefore, during road reconstruction and some resurfacing projects, the reallocation of street space may be necessary to achieve the modal priorities of the street and incorporate streetscape and landscape elements as appropriate.

Design solutions during resurfacing projects are likely to be different than road reconstruction projects (e.g., projects in which curb location and subsurface elements are impacted). Road reconstruction projects are an opportunity to reconsider all aspects of the cross section and to achieve a balance between all users. This may be accomplished by relocating the curb, widening or adding sidewalks, installing bicycle facilities, providing transit lanes, and/or incorporating green street elements (e.g., bioswales).

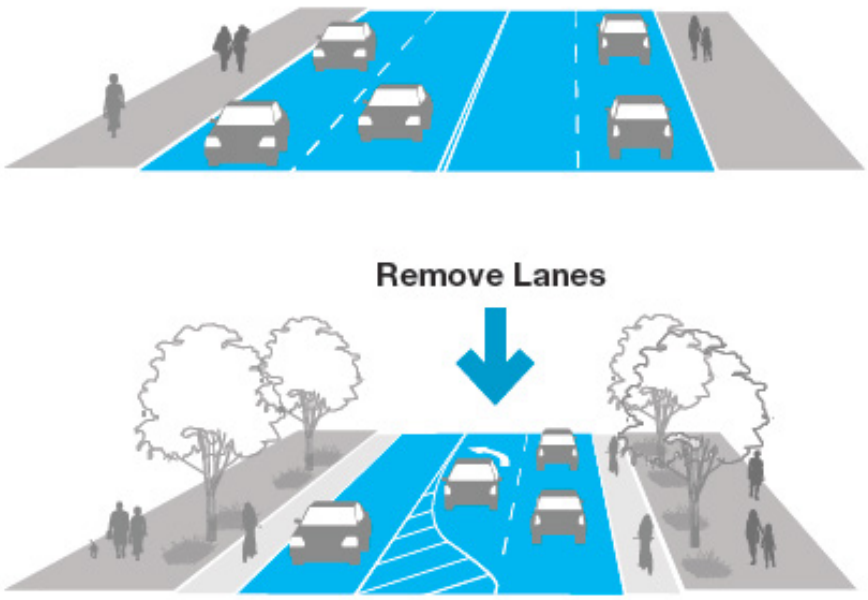
Resurfacing and restriping projects, on the other hand, are typically much lower in cost and are implemented more quickly. As such, the curb location is typically fixed and these types of projects are limited to opportunities for design solutions that reallocate existing street space within the same footprint to accommodate bicycle and transit facilities without widening the roadway.

Whether the project is a simple resurfacing or a more complex reconstruction, there are two primary strategies available to optimize the use of street space: road diets and lane diets.

Road Diets

A road diet is a reduction in the number of motor vehicle through lanes.

Road diets are sometimes possible on streets with excess capacity, in which space can be reallocated by removing one or more parking or travel lanes. To reduce excessive delay for motor vehicle traffic, it may be necessary to add or retain turn lanes at intersections and/or adjust signal timing. A capacity analysis is often necessary to evaluate the impacts of the proposed design on the operation of the roadway or the adjacent road network.



Example Applications

Road diets should be considered on four-lane undivided roadways, which can be converted to a three-lane cross section (one lane in each direction with a center turn lane or center median), and multi-lane streets with extra capacity where one or more lanes can be removed.

As a rule of thumb, converting a four-lane street to a two-lane street with a center turn lane is feasible for streets with traffic volumes up to 15,000 to 20,000 ADT. See the FHWA's Road Diet Informational Guide for more information on traffic volume. Such conversions typically improve traffic flow and reduce crashes for all modes.

Opportunities for Reallocating Space

During reconstruction projects, space can be reallocated to widen sidewalks, create curb extensions, plant street trees or green-scape elements, install street furniture, implement bicycle lanes or separated bike lanes, or provide on-street parking lanes.

For road diets implemented through resurfacing and restriping projects, removing travel or parking lanes can provide additional space to install bicycle lanes or separated bike lanes. On roadways with on-street parking and bicycle lanes, it is advantageous to provide additional width to either the parking lane or the bicycle lane, particularly in areas with high parking turnover, to reduce the likelihood that a bicyclist will be struck by a motorist opening a car door.

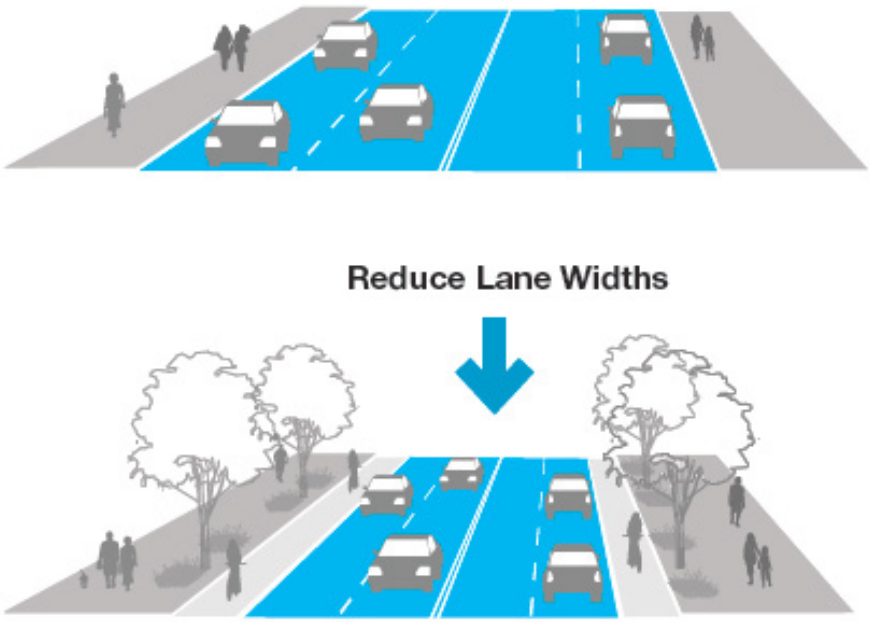
STRATEGIES FOR CONSTRAINED RIGHT-OF-WAY (CONTINUED)

Lane Diets

A lane diet is a reduction in travel lane width.

Lane diets are possible on some streets with lanes wider than 11 feet. Reduced lane widths encourage slower motor vehicle speeds and can reduce crossing distances, further improving conditions for pedestrians and bicyclists.

On some streets, lanes narrower than 12 feet may not be appropriate. Consideration should be given to transit operations and truck routes when evaluating lane diet opportunities.



Example Applications

Lane diets should be considered for streets with travel lanes that are more than 11 feet wide, streets with wide parking lanes, and streets with wide center turn lanes.

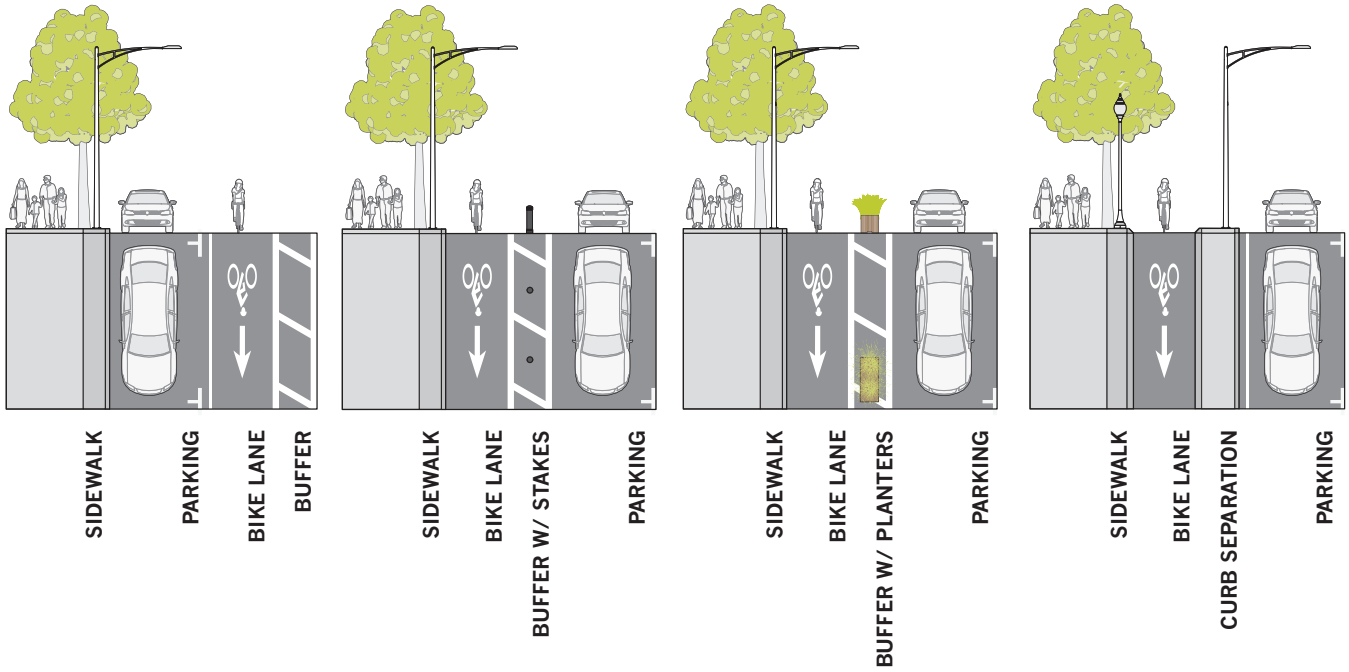
Opportunities for Reallocating Space

During reconstruction projects, narrowing lanes can allow space to be reallocated to widen sidewalks, create curb extensions, plant street trees or greenscape elements, install street furniture, implement bicycle lanes or separated bike lanes, or provide on-street parking lanes.

For lane diets implemented through resurfacing and restriping projects, installing minimum-width travel lanes can provide additional space to install bike lanes or separated bike lanes. On roadways with on-street parking and bike lanes, it is advantageous to provide additional width to either the parking lane or the bike lane, particularly in areas with high parking turnover, to reduce the likelihood that a bicyclist will be struck by a motorist opening a car door.

EVOLUTION OF A BIKE LANE

Standard bike lanes can be installed as temporary or interim solutions and gradually converted to separated bike lanes over time. This makes implementing separated bike lanes as low-cost retrofit projects (e.g. using flex posts and paint within the existing right-of-way) a viable path toward more permanent forms of separation, such as curb separation, which cost more and are less flexible once implemented. A phased implementation approach, where "pilot" projects transition to permanent separated bike lanes, may solve both of these problems, by implementing the facility slowly and troubleshooting before permanent materials and higher costs are necessary.



Progression from pilot project to separated bike lane

CONSIDERATIONS

Lower-cost retrofits or demonstration projects allow for quick implementation, responsiveness to public perception and ongoing evaluation. Separation types for short-term separated bike lane designs often include non-permanent separation, such as flexible delineator posts, planters or parking stops. Pilot projects allow the agency to:

+ Test the separated bike lane configuration for bicyclists and traffic operations
+ Evaluate public reaction, design performance, and safety effectiveness
+ Make changes if necessary
+ Transition to permanent design

DESIGN CRITERIA

+ Permanent separation designs provide a high level of protection and often have greater potential for placemaking, quality aesthetics, and integration with features such as green stormwater infrastructure. Agencies often implement permanent separation designs by leveraging private development (potentially through developer contribution), major capital construction, and including protected bike lanes in roadway reconstruction designs. Examples of permanent separation materials include rigid bollards, raised medians and grade-separated bike lanes at an intermediate or sidewalk level.

REFERENCES

NACTO Urban Street Design Guide (2013)

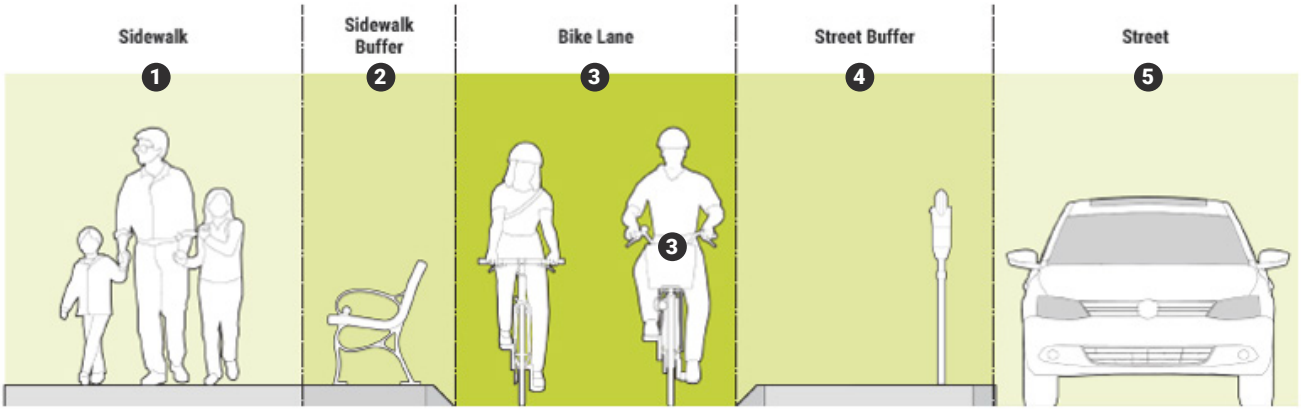
FHWA Separated Bike Lane Planning and Design Guide (2015)

BIKEWAY FACILITY PARAMETERS

SEPARATED BIKE LANES

Separated bike lanes, also known as cycle tracks, are exclusive bicycle facilities physically separated by a vertical element from the adjacent motor vehicle lanes. Separation can be achieved through a vertical curb, a parking lane, flexposts, plantings, removable curbs, or other measures. Buffered bike lanes that do not include a vertical element are not considered separated bike lanes.

Separated bike lanes dramatically increase bicyclist safety and decrease stress. They can be used by a broad spectrum of bicyclists including very young riders and more cautious bicyclists. Separated bike lanes may be used on many different street types and are especially welcome on higher-speed, higher-volume roadways. Studies show that bicyclists prefer separation from motor vehicles on most types of roadways, which suggests that separation can contribute to expanding bicycle mode share.



ZONES

1. The sidewalk width should be determined by context zone and the anticipated peak hour pedestrian volume. The sidewalk should not be narrowed beyond the minimum necessary to accommodate pedestrian demand.

2. The sidewalk buffer is desirable, but not required. The sidewalk buffer zone separates the bike lane from the sidewalk, communicating each as distinct spaces. By separating people walking and bicycling, encroachment into these spaces is minimized and the safety and comfort is enhanced for both users. The sidewalk buffer may be eliminated at locations with low pedestrian volume.

3. The width of the bike lane zone should be determined by the peak hour 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 the elements used to separate the bike lane from the adjacent motor vehicle lane include some vertical component, 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.

    - The bike lane width should be at least 6.5 feet for one-way bike lanes and 8 feet for two-way bikeways, to ensure bicyclists can safely pass each other.
    - A minimum shy distance of 1 foot should be provided between any vertical objects in the sidewalk or street buffer and the bike lane.

4. The street buffer is required and should provide separation from the street with vertical objects or a median. The street buffer can consist of parked cars, vertical delineators, raised medians, landscaped medians, and a variety of other elements. The buffer should be at least 2 feet wide at midblock locations and should be between 6 feet and 20 feet at intersections to provide maximum safety benefits. Intersections must be designed with consideration of potential conflicts with motor vehicle traffic. Where the buffer is reduced below 6 feet, a raised bicycle crossing or signal phase separation should be considered.

5. Travel lanes and parking should be narrowed to the minimum widths in constrained corridors.

CONFIGURATIONS

There are four basic configurations for separated bike lanes:

+ Sidewalk-level bike lanes
+ Bike lanes constructed at an intermediate level between the sidewalk and the street
+ Street-level bike lanes separated from traffic or parking by a curb or median
+ Street-level bike lanes separated from traffic or parking by a vertical object (planters, flexposts, on-street parking, etc.)

REFERENCES

AASHTO Guide for the Development of Bicycle Facilities (2012)

NACTO Urban Bikeway Design Guide (2014)

MassDOT Separated Bike Lane Planning and Design Guide (2015)

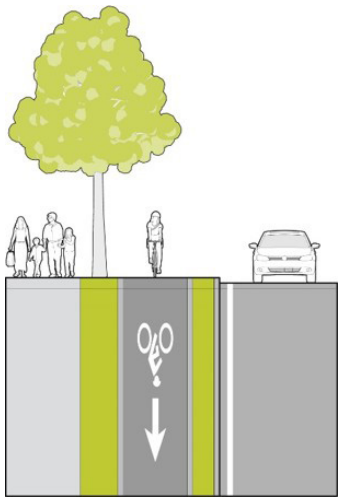
FHWA Separated Bike Lane Planning and Design Guide (2015)

SEPARATED BIKE LANE DESIGN EXAMPLES

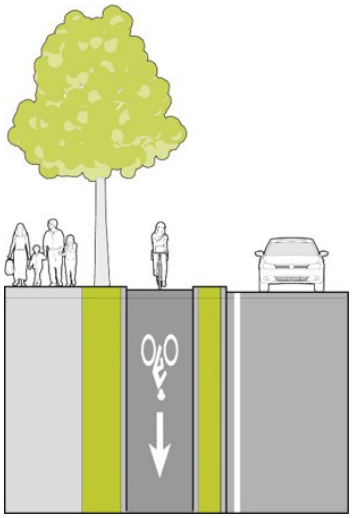
Separated bike lanes can be one-directional (provided on both sides of a street) or two-directional (provided on one side of a street). One-way separated bike lanes in the direction of motorized travel can provide intuitive and simplified transitions to existing bike lanes and shared travel lanes.

ONE-WAY SEPARATED BIKE LANES

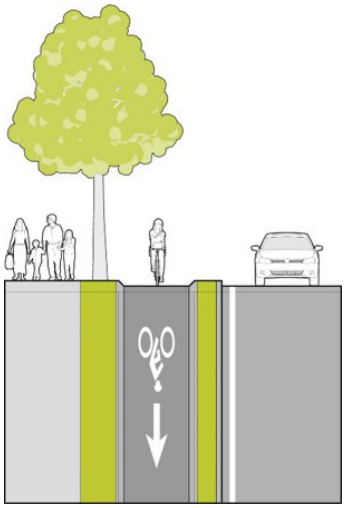
One-way separated bike lanes in the direction of motorized travel provide intuitive and simplified transitions to existing bike lanes and shared travel lanes.



One-way Sidewalk-level Separated Bike Lane



One-way Intermediate-level Separated Bike Lane

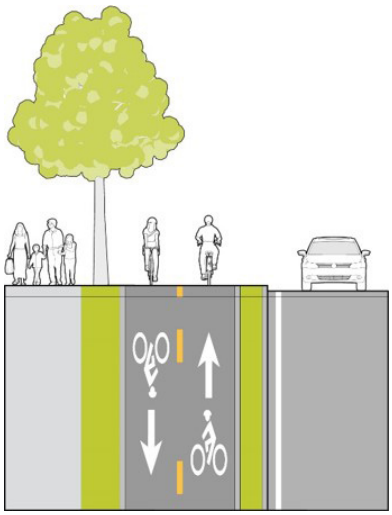


One-way Street-level Separated Bike Lane

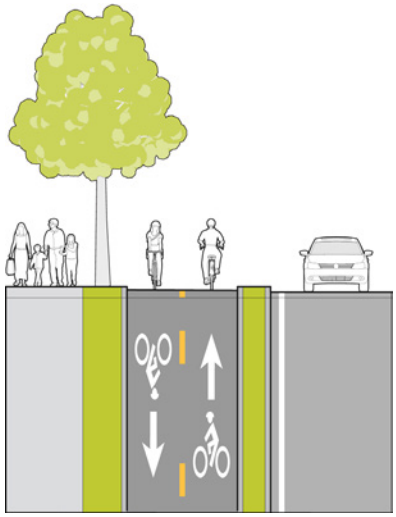
TWO-WAY SEPARATED BIKE LANES

Two-way separated bike lanes will require special attention to transition the contra-flow bicyclist into existing bike lanes and shared travel lanes.

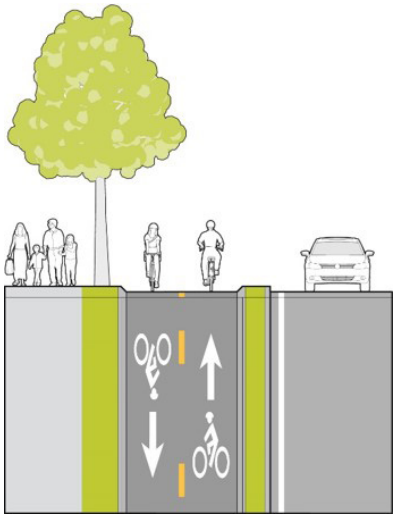
Depending on context, motorists may not expect bicyclists to approach crossings from both directions. For this reason, two-way separated bike lanes may require detailed treatments at alley, driveway, and cross street crossings to enhance the safety of these crossings.



Two-way Sidewalk-level Separated Bike Lane



Two-way Intermediate-level Separated Bike Lane



Two-way Street-level Separated Bike Lane

SEPARATED BIKE LANE DESIGN PARAMETERS

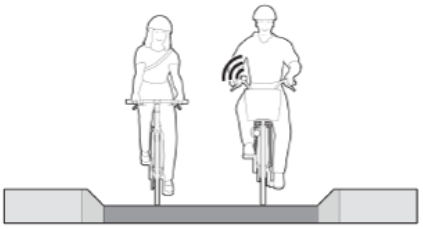
Separated bike lanes may be located at sidewalk level, street level, or at an elevation intermediate to the sidewalk and street. Separated bike lanes are physically separated from motor vehicles and pedestrians by vertical and horizontal elements.

CONSIDERATIONS

- Separated bike lanes can be useful on streets that provide connections to off-street paths, since bicyclists on these streets may be more accustomed to riding in an area separated from traffic.
- Intersection design for protected bike lanes is complex and requires careful attention to conflicts with turning vehicles. For more information, see the NACTO *Urban Bikeway Design Guide*.
- Adjacent to on-street parking, a minimum 3-foot buffer should be provided between parking and the separated bike lane; the buffer serves as a pedestrian loading and unloading zone and helps keep bicyclists out of the door zone of parked vehicles.
- Vertical curb separation should be considered where on-street parking is not present. Snow clearance and stormwater drainage will need to be considered with this option. Street-level protected bike lanes may be combined with islands at corners and crossings.
- At transit stops, protected bike lanes should be routed between the passenger waiting area and the sidewalk to reduce conflicts while passengers are boarding and alighting. Signage and/or markings may be added to alert transit riders and bicyclists of the conflict zone as pedestrians cross the bike lane from the sidewalk to the transit stop.

ONE-WAY SEPARATED BIKE LANES

- The recommended minimum width of a one-way separated bicycle lane is:

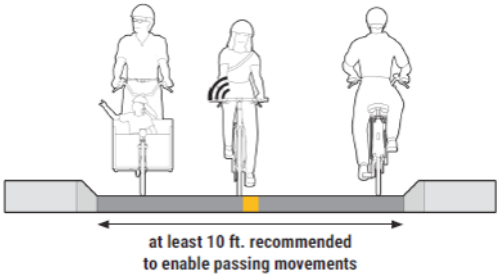


Same Direction Bicyclists/ Peak Hour	Bike Lane Width (ft.)	
	Rec.	Min.
<150	6.5	5.0
150-750	8.0	6.5
>750	10.0	8.0

- A constrained bicycle lane width of 4 feet (one-way only) may be used for short distances to navigate around transit stops, accessible parking spaces, or other obstacles.

TWO-WAY SEPARATED BIKE LANES

The recommended minimum width of a two-way separated bicycle lane is:



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

REFERENCES

AASHTO Guide for the Development of Bicycle Facilities (2012)

NACTO Urban Bikeway Design Guide (2014)

MassDOT Separated Bike Lane Planning and Design Guide (2015)

FHWA Separated Bike Lane Planning and Design Guide (2015)

SIDEPATHS

A shared use path constructed parallel to and within the right-of-way of a roadway is referred to as a sidepath. Sidepaths may be desirable along high-volume or high-speed roadways, where accommodating bicyclists within the roadway in a safe and comfortable way is impractical. Since sidepaths are shared by bicyclists and pedestrians, they are most appropriate where pedestrian volumes are relatively low. Sidepaths may present increased conflicts between path users and motor vehicles at intersections and driveway crossings.

The design of sidepaths closely resembles the design of shared use paths between intersections. However, sidepaths should be designed similarly to separated bike lanes at intersections.

CONSIDERATIONS

+ Sidepaths are most appropriate where driveways and intersections are limited. Where intersection crossings are necessary, conflicts can be reduced by providing high-visibility crossing treatments. Raised crossings are recommended to slow motor vehicle traffic and also double as traffic-calming features at entrances to neighborhoods.

+ In areas with high concentrations of driveways and intersections, on-street accommodations (including bike lanes, buffered bike lanes, and separated bike lanes) are preferred because they are proven to be safer.

+ For intersections between arterial roads and collector/local roads, there should be 15 to 25 feet of sidepath setback from the curb line of the parallel road, with the path offset bend beginning at least 115 feet from the intersection with curve radii at least 40 feet. The setback creates a larger yielding zone for motorists and increases visibility. The offset bend serves to regulate the speed of bicyclists approaching the crossing.

+ For intersections between two arterial roads, the crossings should be closer to the intersection and bicycle-specific signal heads should be used. Grade-separated crossings of arterial roadways should be considered where feasible.

+ Signage for paths along roadways should follow the same regulatory controls as the parallel roadway. For example, a stop sign should not be placed along the path at an intersection or driveway unless the parallel roadway also has a stop sign at the same location. Instead, the perpendicular street should include a stop bar behind the path crossing and warning signage for both the motorists and the path users. At such a location, the motorist should always yield to the path user. Warning signs for motorists turning across sidepaths may be appropriate at high traffic areas.

DESIGN CRITERIA

+ The minimum width of a sidepath is 10 feet (12 feet preferred). Widths exceeding 10 feet are recommended in areas with higher sidepath traffic volumes or with a higher proportion of pedestrians. A minimum of 11 feet is required for users to pass with a user traveling in the other direction.

+ In locations with heavy volumes or a high proportion of pedestrians, it may be beneficial to separate bicyclists from pedestrians by constructing separate sidewalks and separated bike lanes instead of a sidepath.

+ Widths as narrow as 8 feet are acceptable for short distances under physical constraint. Warning signs should be considered at these locations.

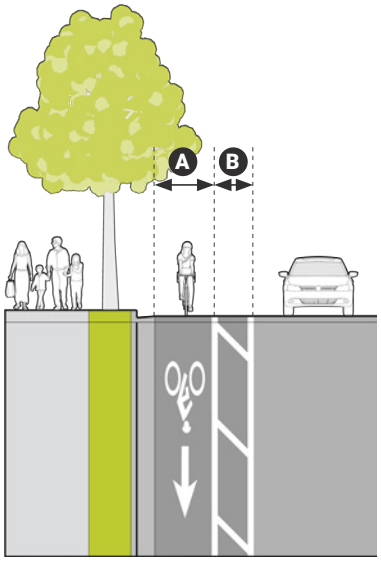
+ Paths must be designed according to state and national standards. This includes establishing a design speed (typically 18 mph) and designing path geometry accordingly. Consult the AASHTO *Guide for the Development of Bicycle Facilities* for guidance on geometry, clearances, traffic control, railings, drainage, and pavement design.

REFERENCES

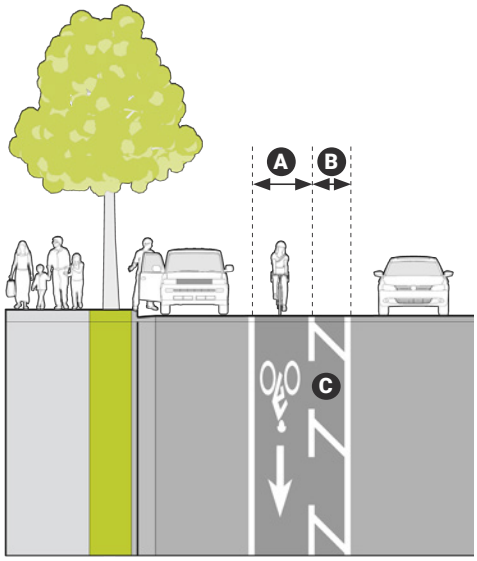
AASHTO Guide for the Development of Bicycle Facilities (2012)
FHWA Shared-Use Path Level of Service Calculator (2006)
Manual on Uniform Traffic Control Devices (2009)
CROW Design Manual for Bicycle Traffic (2007)

BUFFERED BIKE LANES

Buffered bicycle lanes are created by painting or otherwise creating a flush buffer zone between a bicycle lane and the adjacent travel lane. While buffers are typically used between bicycle lanes and motor vehicle travel lanes to increase bicyclist comfort, they can also be provided between bicycle lanes and parking lanes in locations with high parking turn-over to discourage bicyclists from riding too close to parked vehicles.



Buffered Bike Lane Adjacent to a Curb



Buffered Bike Lane Adjacent to Parking

CONSIDERATIONS

+ Preferable to a conventional bicycle lanes when used as a contra-flow bike lane on one-way streets.
+ Typically installed by reallocating existing street space.
+ Can be used on one-way or two-way streets.
+ Consider placing buffer next to parking lane where there is commercial or metered parking.
+ Consider placing buffer next to travel lane where speeds are 30 mph or greater or when traffic volume exceeds 6,000 vehicles per day.
+ Where there is 7 feet of roadway width available for a bicycle lane, a buffered bike lane should be installed instead of a conventional bike lane. The preferred configuration is a 5-foot or wider bike lane (A) and an 18-inch or wider buffer. Typical buffer widths are 3 to 5 feet.(B)
+ Buffered bike lanes allow bicyclists to ride side by side or to pass slower moving bicyclists.
+ Research has documented buffered bicycle lanes increase the perception of safety.

DESIGN CRITERIA

(A) The minimum width of a buffered bike lane adjacent to parking or a curb is 4 feet exclusive of gutter (if present); a desirable width is 6 feet.

(B) The minimum buffer width is 18 inches. There is no maximum width. Diagonal cross hatching should be used for buffers <3 feet in width. Chevron cross hatching should be used for buffers >3 feet in width.

(C) Buffers are to be broken where curbside parking is present to allow cars to cross the bike lane.

REFERENCES

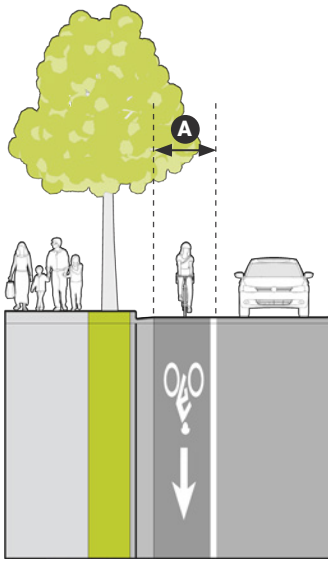
AASHTO Guide for the Development of Bicycle Facilities (2012)

NACTO *Urban Bikeway Design Guide (2014)*

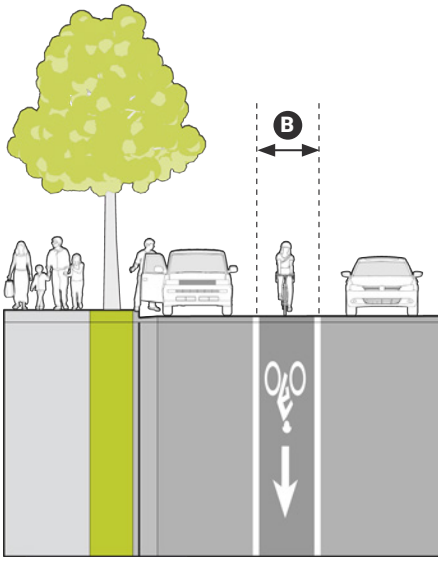
Evaluation of Innovative Bicycle Facilities: SW Broadway Cycle Track & SW Stark/Oak Street Buffered Bike Lanes. Final Report. (2011)

BIKE LANES

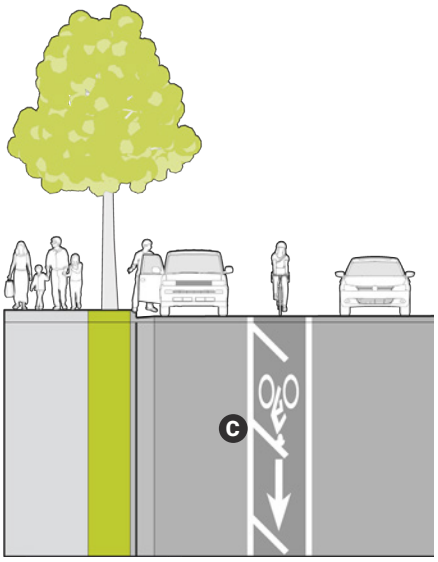
Bicycle lanes provide an exclusive space for bicyclists in the roadway. Bicycle lanes are established through the use of lines and symbols on the roadway surface. Bicycle lanes are for one-way travel and are normally provided in both directions on two-way streets and/or on one side of a one-way street. Bicyclists are not required to remain in a bicycle lane when traveling on a street and may leave the bicycle lane as necessary to make turns, pass other bicyclists, or to properly position themselves for other necessary movements. Bicycle lanes may only be used temporarily by vehicles accessing parking spaces and entering and exiting driveways and alleys. Stopping, standing and parking in bike lanes is prohibited.



Bike Lane Adjacent to a Curb



Bike Lane Adjacent to Parking



Bike Lane with Door Zone Marking

CONSIDERATIONS

+ Standard bike lanes may be 6 feet wide, which provides greater separation between bicycles and cars, accommodates people who are pulling bike trailers, and may allow passing without leaving the bike lane.
+ If street width is available to provide bike lanes wider than 6 feet, consider painting a buffer between the bike lane and travel lane and/or between the bike lane and the parking lane to provide additional separation and reduce the threat of dooring. A separated bike lane (discussed in detail on pages 20-21) with flexposts or other vertical separation may also be considered.
+ If bike lanes are adjacent to guardrails, walls, or other vertical barriers, additional bicycle lane width is desired to account for bicyclist shy distance from the barrier.
+ Bike lanes adjacent to on-street parking present safety concerns to people biking. These concerns include "dooring" (when a driver or passenger opens a car door and hits a passing bicyclist). Another common safety issue is backing motor vehicles exiting angled on-street parking and colliding with passing bicyclists. Wider bike lanes or buffered bike lanes are preferable at locations with high parking turnover. Back-in parking is preferable where angle parking is provided.

DESIGN CRITERIA

A The minimum width of a bike lane adjacent to a curb is 5 feet exclusive of a gutter (4 feet in highly constrained locations); a desirable width is 6 feet.

B The minimum width of a bike lane adjacent to parking is 5 feet; a desirable width is 6 feet.

C Optional parking T's or hatch marks can highlight the door zone on constrained corridors with high parking turnover to guide bicyclists away from motor vehicle doors.

REFERENCES

AASHTO Guide for the Development of Bicycle Facilities (2012)

NACTO Urban Bikeway Design Guide (2014)

BICYCLE BOULEVARDS

Bicycle boulevards incorporate traffic calming treatments with the primary goal of prioritizing bicycle through-travel, while discouraging motor vehicle traffic and maintaining relatively low motor vehicle speeds. These treatments are typically applied on quiet streets, often through residential neighborhoods. Treatments vary depending on context, but often include traffic diverters, speed attenuators such as speed humps or chicanes, pavement markings, and signs. Bicycle boulevards are also known as neighborhood greenways and neighborhood bikeways, among other locally-preferred terms.

CONSIDERATIONS

Many cities already have signed bike routes along neighborhood streets that provide an alternative to traveling on high-volume, high-speed arterials. Applying bicycle boulevard treatments to these routes makes them more suitable for bicyclists of all abilities and can reduce crashes as well.

Stop signs or traffic signals should be placed along the bicycle boulevard in a way that prioritizes the bicycle movement, minimizing stops for bicyclists whenever possible.

Bicycle boulevard treatments include traffic calming measures such as street trees, traffic circles, chicanes, and speed humps. Traffic management devices such as diverters or semi-diverters can redirect cut-through vehicle traffic and reduce traffic volume while still enabling local access to the street.

Communities should begin by implementing bicycle boulevard treatments on one pilot corridor to measure the impacts and gain community support. The pilot program should include before-and-after crash studies, motor vehicle counts, and bicyclist counts on both the bicycle boulevard and parallel streets. Findings from the pilot program can be used to justify bicycle boulevard treatments on other neighborhood streets.

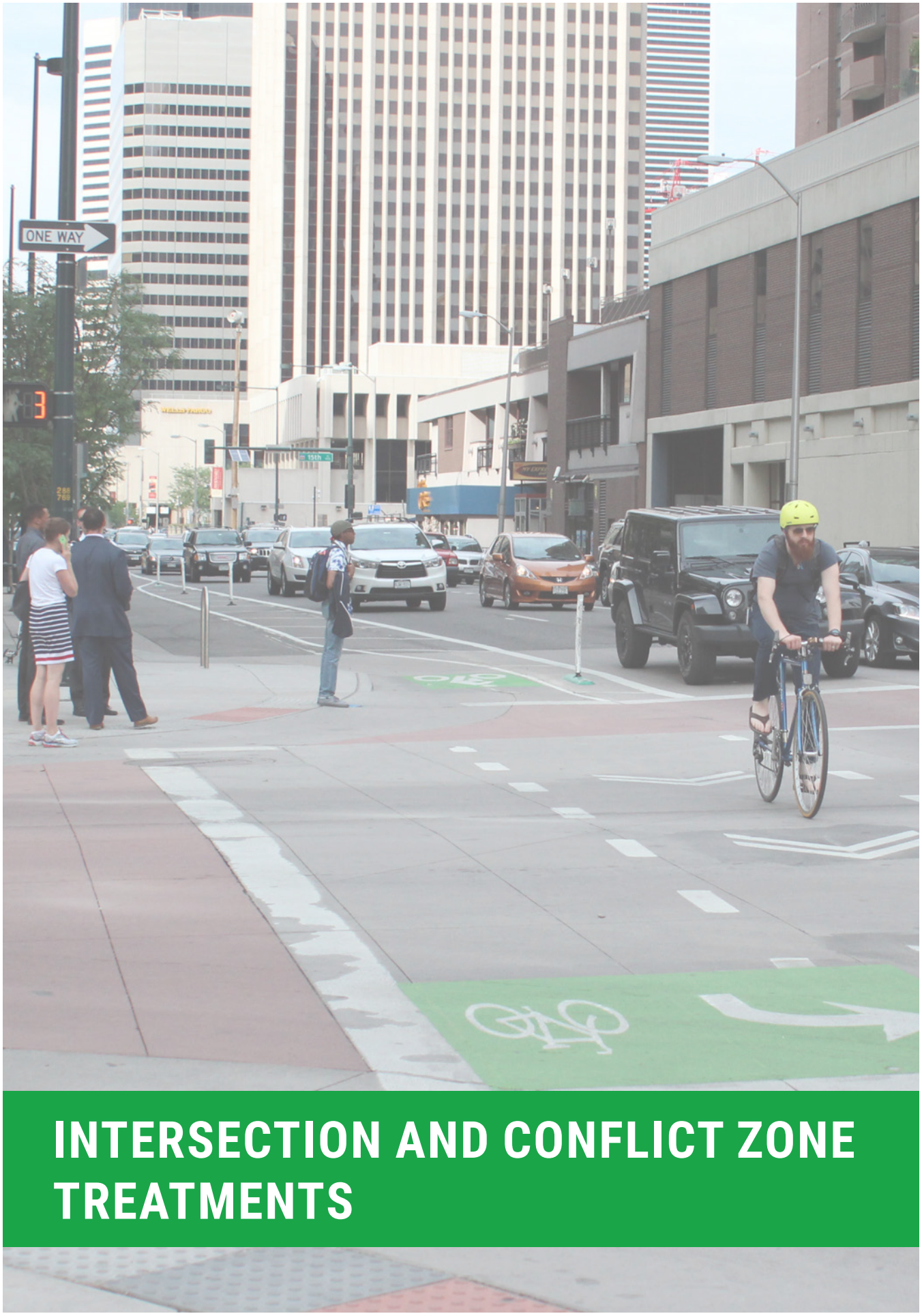
Additional treatments for major street crossings may be needed, such as median refuge islands, rapid flash beacons, bicycle signals, and pedestrian hybrid beacons or half signals.

DESIGN CRITERIA

- Maximum Average Daily Traffic (ADT): 3,000
- Preferred ADT: Up to 1,000
- Target speeds for motor vehicle traffic are typically around 20 mph; there should be a maximum 15 mph speed differential between bicyclists and vehicles.

REFERENCES

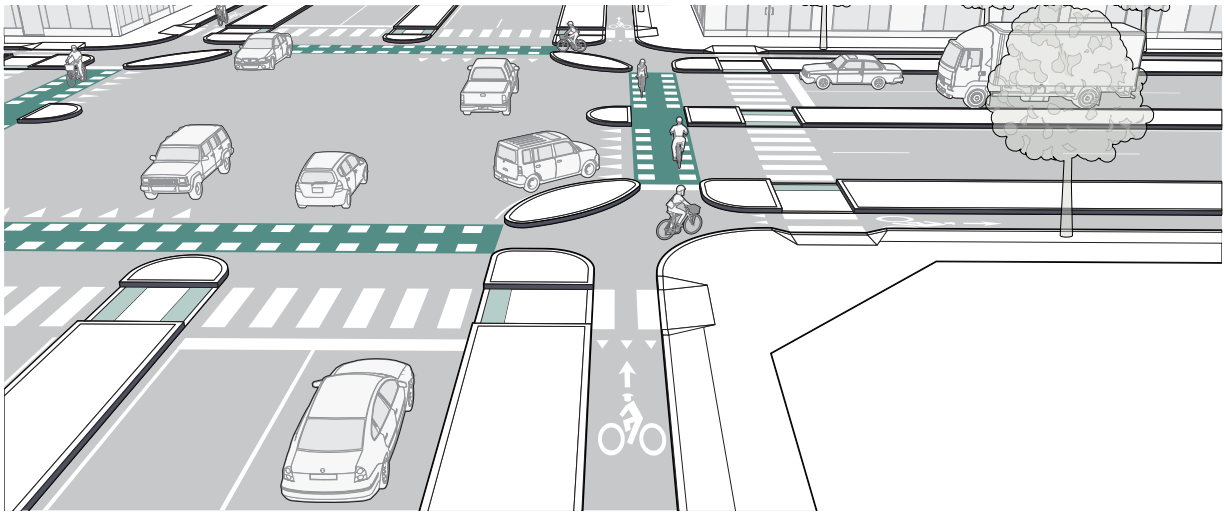
AASHTO Guide for the Development of Bicycle Facilities (2012)
NACTO Urban Bikeway Design Guide (2012)
Manual on Uniform Traffic Control Devices (2009)
Fundamentals of Bicycle Boulevard Planning & Design (2009)



INTERSECTION AND CONFLICT ZONE TREATMENTS

PROTECTED INTERSECTIONS

Separated bicycle lanes and sidepaths provide an exclusive travel way alongside roadways that is separate from motor vehicle travel lanes and parking lanes. While sidepaths serve both bicycle and pedestrian traffic, separated bike lanes are separate from sidewalks. Separated bike lane and sidepath designs at intersections should manage conflicts with turning vehicles and increase visibility for all users.



CONSIDERATIONS

- Shared lane markings and/or colored pavement can supplement short dashed lines to demarcate the protected bike lane through intersections, where engineering judgment deems appropriate.
- Increasing visibility and awareness are two key design goals for protected bike lanes at intersections. In some cases, parking restrictions between 20 to 40 feet are needed to ensure the visibility of bicyclists at intersections approaches. Markings and signage should be used at intersections to give priority to separated bicycle lane and sidepath users.
- At non-signalized intersections, design treatments to increase visibility and safety include warning signs, raised intersections or crosswalks, special pavement markings (including colored surface treatment), and parking restrictions in advance of the intersection.
- When separated bike lanes are provided at roundabouts, they should be continuous around the intersection, and par¬allel to the sidewalk. Separated bike lanes should generally follow the contour of the circular intersection.

DESIGN CRITERIA

- Protected intersection designs that maintain the separation of the separated bike lane or sidepath through the intersection are preferred over unprotected designs that introduce the bicyclist into the street with a merge lane. The MassDOT *Separated Bike Lane Planning and Design Guide* provides detailed guidance on the geometric and signal design of protected intersections.
- Where it is not possible to provide a protected intersection, merge zones should be designed to increase the visibility of bicyclists and reduce motor vehicle speeds. Other measures such as pavement color, shared lane markings and bike boxes should be incorporated where appropriate. Merge zones are not appropriate for sidepaths.
- Separated bicycle lane and sidepath designs at intersections should consider signal operations and phasing in order to manage conflicts between turning vehicles, bicyclists, and pedestrians. Dedicated phases should be considered at locations with two-way or contra-flow bicycle movements, with unique or high-volume bicycle movements, or with high volumes of turning traffic.
- Bike signal heads should generally be installed at all traffic control signals where separated bike lanes are present to provide a uniform indication for bicyclists. While not required, bike signal heads are especially important in locations where leading or protected phases are provided for bicyclists, where contra-flow bicycle movements exist (including two-way separated bike lanes), where existing traffic signal heads are not visible to bicyclists, and where bicyclists are physically separated from motorists and pedestrians.

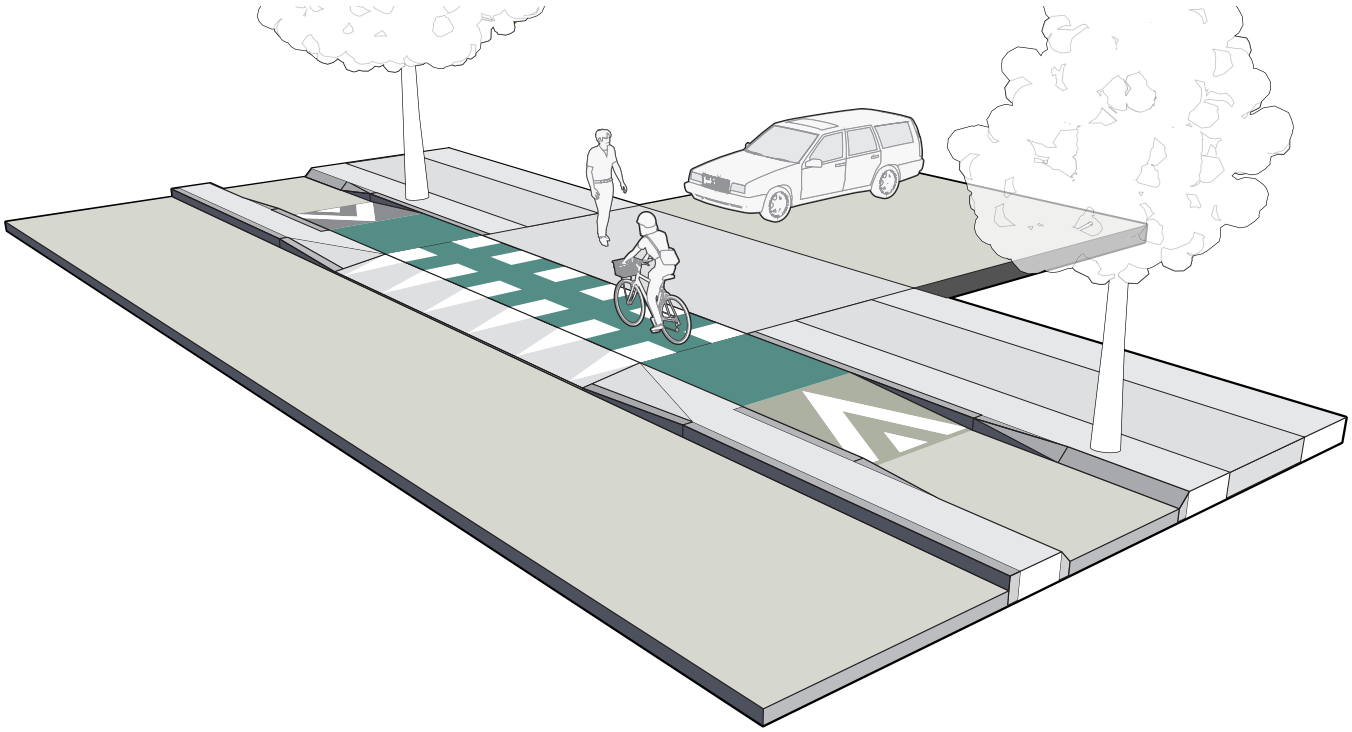
REFERENCES

AASHTO Guide for the Development of Bicycle Facilities (2012)

NACTO *Urban Bikeway Design Guide (2014)*

SEPARATED BIKE LANES AT DRIVEWAYS

Most bicycle facilities will need to cross streets, driveways, or alleys at multiple locations along a corridor. At these locations, the crossings should be designed to 1) delineate a preferred path for people bicycling through the intersection with the driveway and 2) to encourage driver yielding behavior, where applicable. Bicycle crossings may be supplemented with green pavement, yield lines, and/or regulatory signs.



CONSIDERATIONS

+ Supplemental yield lines, otherwise known as shark's teeth, can be used to indicate priority for people bicycling and may be used in advance of unsignalized crossings at driveways, at signalized intersections where motorists may turn across a bicycle crossing during a concurrent phase, and in advance of bicycle crossings located within roundabouts.
+ Raised bicycle crossings further promote driver yielding behavior by slowing their speed before the crossing and increasing visibility of people bicycling.

DESIGN CRITERIA

+ The bicycle crossing may be bounded by 12-inch (perpendicular) and 24-inch (parallel) white pavement dashes, otherwise known as elephant's feet. Spacing for these markings should be coordinated with zebra, continental, or ladder striping of the adjacent crosswalk.
+ The bicycle crossing should be at least 6 feet wide for one-way travel and at least 10 feet wide for two-way travel, as measured from the outer edge of the elephant's feet. Bicycle lane symbol markings should be avoided in bicycle crossings. Directional arrows are preferred within two-way bicycle crossings.
+ Dashed green colored pavement may be utilized within the bicycle crossing to increase the conspicuity of the crossing where permitted conflicts occur. Green color may be desirable at crossings where concurrent vehicle crossing movements are allowed and where sightlines are constrained, or where motor vehicle turning speeds exceed 10 mph.

REFERENCES

MassDOT Separated Bike Lane Planning and Design Guide (2015)

FHWA Separated Bike Lane Planning and Design Guide (2015)

SEPARATED BIKE LANE MIXING ZONES

A mixing zone requires turning motorists to merge across a separated bike lane at a defined location in advance of an intersection. Unlike a standard bike lane, where a motorist can merge across at any point, a mixing zone design limits bicyclists' exposure to motor vehicles by defining a limited merge area for the turning motorist. Mixing zones are compatible only with one-way separated bike lanes.

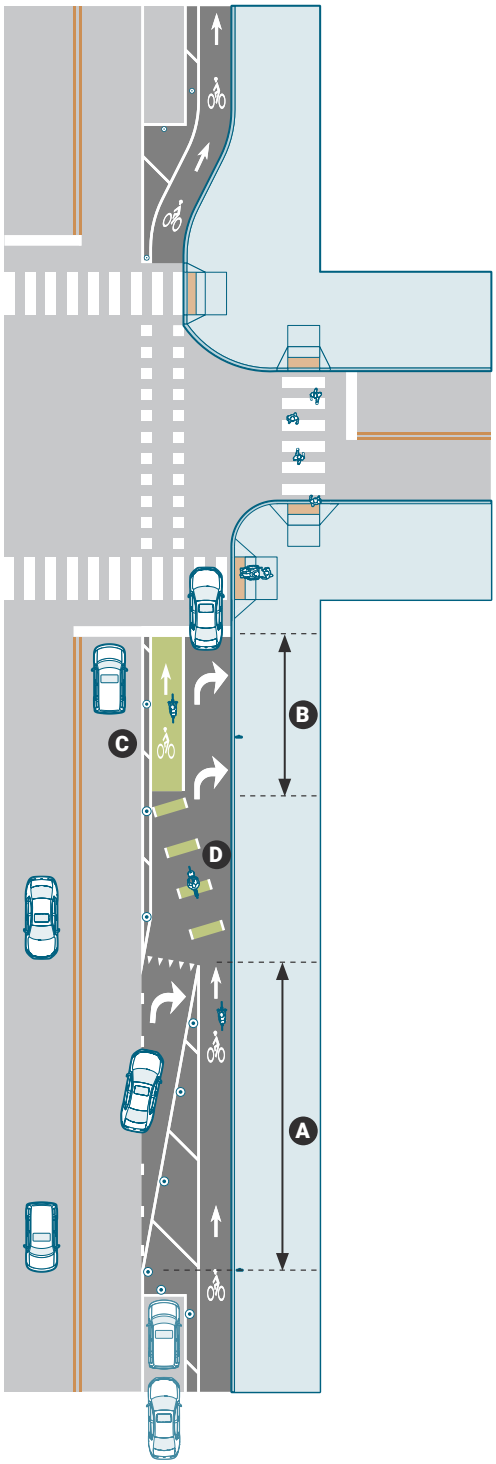
CONSIDERATIONS

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.

GUIDANCE

- **A** Locate merge points where the entering speeds of motor vehicles will be 20 mph or less by (a) minimizing the length of the merge area and (b) locating the merge point as close as practical to the intersection.
- **B** Minimize the length of the storage portion of the turn lane
- **C** Provide a buffer and physical separation (e.g. flexible delineator posts) from the adjacent through lane after the merge area, if feasible.
- **D** Highlight the conflict area with 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 approach 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.



REFERENCES

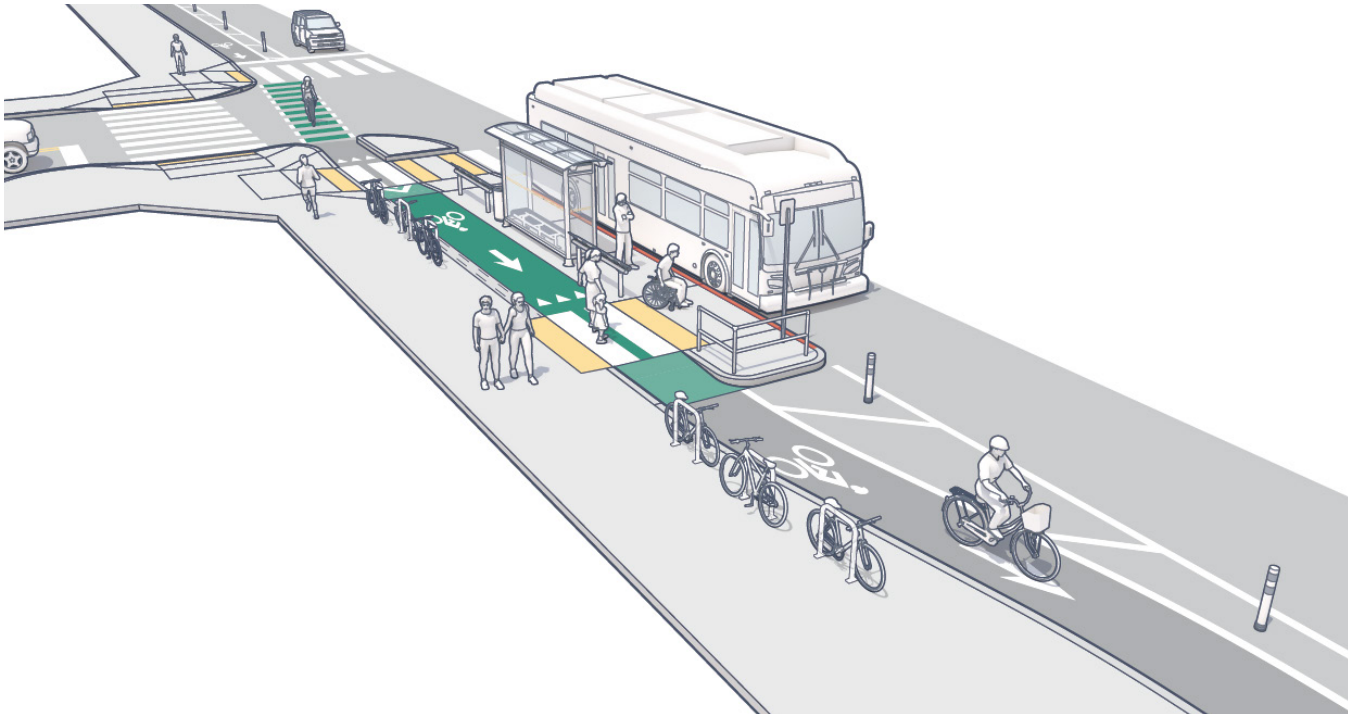
NACTO Urban Bikeway Design Guide (2014)

MassDOT Separated Bike Lane Planning and Design Guide (2015)

FHWA Separated Bike Lane Planning and Design Guide (2015)

SEPARATED BIKE LANES AT BUS STOPS

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



CONSIDERATIONS

- Conflicts between buses and bicyclists in a separated bike lane can be addressed by constructing a floating bus stop. With a floating bus stop, the separated bike lane is routed behind the bus stop, which minimizes conflicts between the bicycle movement and the bus boarding/alighting operation. The design elements at the floating bus stop and the furnishing zone should be located at least one foot from the edge of the bicycle facility.
- Consider in-lane transit stops to preserve space for the street buffer, maintain separated bike lane width, and simplify bus re-entry into traffic.

DESIGN CRITERIA

- There are many different forms of vertical separation that can be used in a separated bike lane and there are several guidebooks discussing their benefits and drawbacks, including the FHWA *Separated Bike Lane Planning and Design Guide*. In general, any form of approved vertical separation can be compatible with a floating bus stop design.
- Guide transit passengers across the bike lane at clearly marked locations. Two pedestrian crossings are recommended, but not required.
- Channelizing railings, planters, or other treatments can be used to help direct pedestrians, particularly those with vision disabilities, to the crossing locations.
- Provide clear sight lines between pedestrians and bicyclists at expected crossing locations. If transit shelters are provided, ensure that the shelter structure or shelter advertising do not limit sight distances.

REFERENCES

NACTO Urban Bikeway Design Guide (2014)

MassDOT Separated Bike Lane Planning and Design Guide (2015)

FHWA Separated Bike Lane Planning and Design Guide (2015)

STANDARD BIKE LANES AT INTERSECTIONS

Bike lane striping should be continued through unsignalized intersections and complicated signalized intersections to provide additional guidance and safety measures for motorists and bicyclists. This design principle is especially important at intersections where there are conflicting motor vehicle movements, unsignalized crossings, and/or crossings of more than four travel lanes. Signalized intersections may not require striping through each intersection and should be evaluated on a case-by-case basis.

CONSIDERATIONS

- Standard details for bicycle lane markings at intersections are provided in the NACTO *Urban Bikeway Design Guide*. Additional guidance can also be found in the MUTCD and AASHTO *Guide for the Development of Bicycle Facilities*.
- Dedicated bicycle lanes should be provided on intersection approaches where space is available.
- At intersections with a dedicated right-turn lane, bicycle lanes should be positioned to the left of the right turn only lane unless bicycle signals and dedicated phasing is provided.

DESIGN CRITERIA

- Bike lane markings, including green-colored pavement, shared lane markings, dashed bicycle lane lines, and signage may be provided through intersections per engineering judgment.
- Selective removal of parking spaces may be needed to provide adequate visibility and to establish sufficient bicycle lane width at approaches to intersections.
- Shared lane markings may be used where space is not available for bicycle lanes at intersections; however, this should only be done if no other design is possible.
- Reference the latest editions of the AASHTO *Guide for the Development of Bicycle Facilities* and the NACTO *Urban Bikeway Design Guide* for details on signal timing needs of bicyclists at intersections. The AASHTO *Guide for the Development of Bicycle Facilities* provides the technical information necessary to calculate minimum green time and other aspects of signal design to accommodate bicycles. The NACTO *Urban Bikeway Design Guide* provides less technical detail, but provides information regarding bike signal heads.

REFERENCES

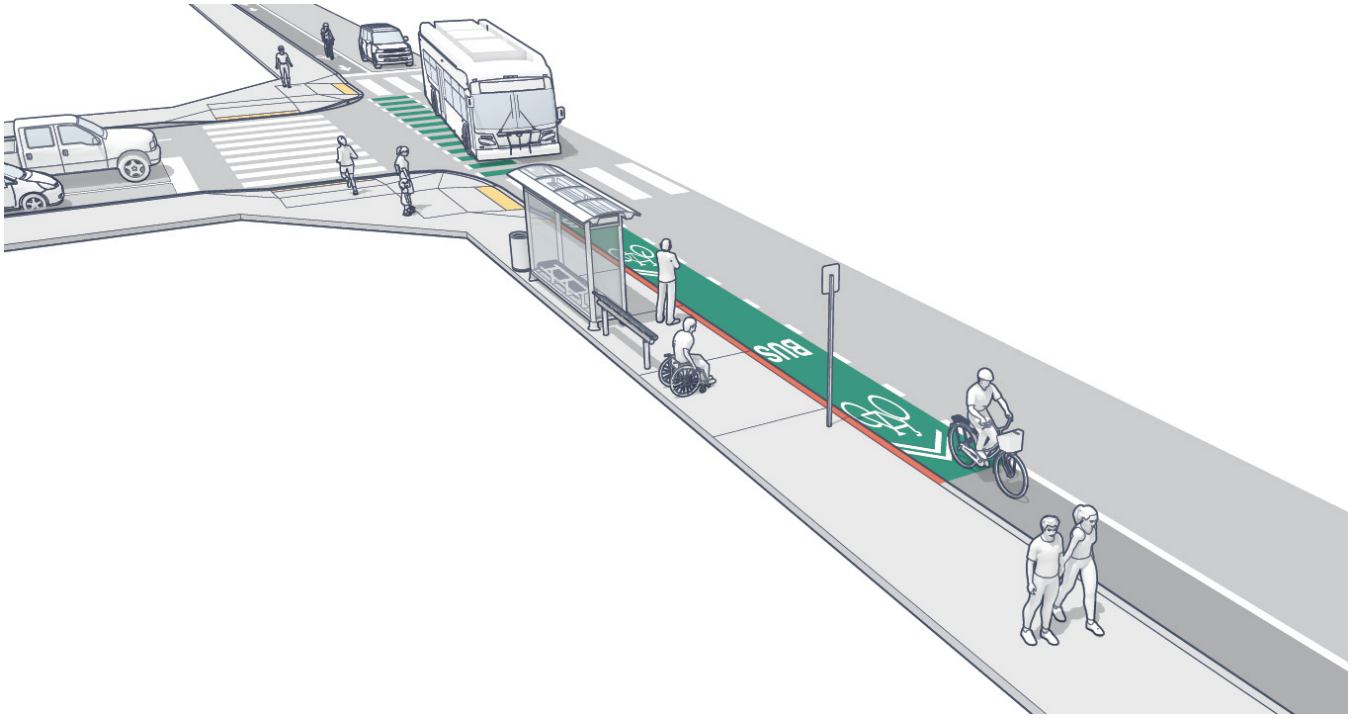
AASHTO Guide for the Development of Bicycle Facilities (2012)

NACTO Urban Bikeway Design Guide (2014)

FHWA Separated Bike Lane Planning and Design Guide (2015)

STANDARD BIKE LANES AT BUS STOPS

Interactions between transit vehicles and bicycles can be hazardous to bicyclists. Transit vehicles such as buses and streetcars have different operating characteristics than standard motor vehicles and must frequently access curb locations to service stops. Where dedicated bus lanes are not practicable and buses must use the travel lanes, buses typically cross back and forth over the bike lane to reach the curb. These crossover points create large conflict zones within the bike lane.



CONSIDERATIONS

- Opportunities should be explored to locate bike lanes on streets without frequent bus service to avoid interactions between buses and bicyclists.
- If the bus stop is aligned with on-street parking, the bike lane can pass along the outside of the bus stop.
- Where feasible, striped bike lanes can also be routed onto the sidewalk and behind the bus stop, with an alignment similar to a floating bus stop.

DESIGN CRITERIA

- Where buses must frequently enter or stop in bicycle lanes, the bicycle lanes should be dotted along the length of the bus stop.
- Green paint can be used to supplement dotted lane lines and increase awareness of the conflict zone at the bus stop.
- To reduce conflicts with transit vehicles, it may be preferable to route bicycle lanes behind transit stops to create short sections of separated bike lanes where continuous separation is not feasible (i.e., a floating bus stop).

REFERENCES

AASHTO Guide for the Development of Bicycle Facilities (2012)

CROSSING TREATMENTS

While the street segments of a bicycle boulevard or other traffic-calmed street may be generally comfortable for bicyclists without significant improvement, major street crossings should be addressed to provide safe, convenient and comfortable travel along the entire route. Treatments provide waiting space for bicyclists, control cross traffic, or ease bicyclist use by removing traffic control for travel along the bicycle boulevard route.

Median Diverter

Bicycle Box with Lead-In Bike Lane

Pedestrian Hybrid Beacon

Offset Crossing Left Turn Box with Lead-In Bike Lane

CONSIDERATIONS

- Adjustments to traffic control such as implementation of a pedestrian hybrid beacon or adjustments to stop signs may require a traffic study.
- Median islands may be constructed to require right-in/right-out turns by motor vehicles while still allowing left turns by bicyclists at offset intersections.
- Numerous treatments exist to accommodate offset intersection crossings for bicyclists, and the full range of design treatments should be considered in these situations. These treatments include turn queue boxes, two-way center left-turn lanes (optionally designed solely for bicyclists), median left-turn pockets and short sidepath segments.

DESIGN CRITERIA

Medians should be a minimum of 6 feet in width, though 8 feet is desirable to allow adequate space for a bicycle.

Intersections along a bicycle boulevard route may need treatment in the following situations:

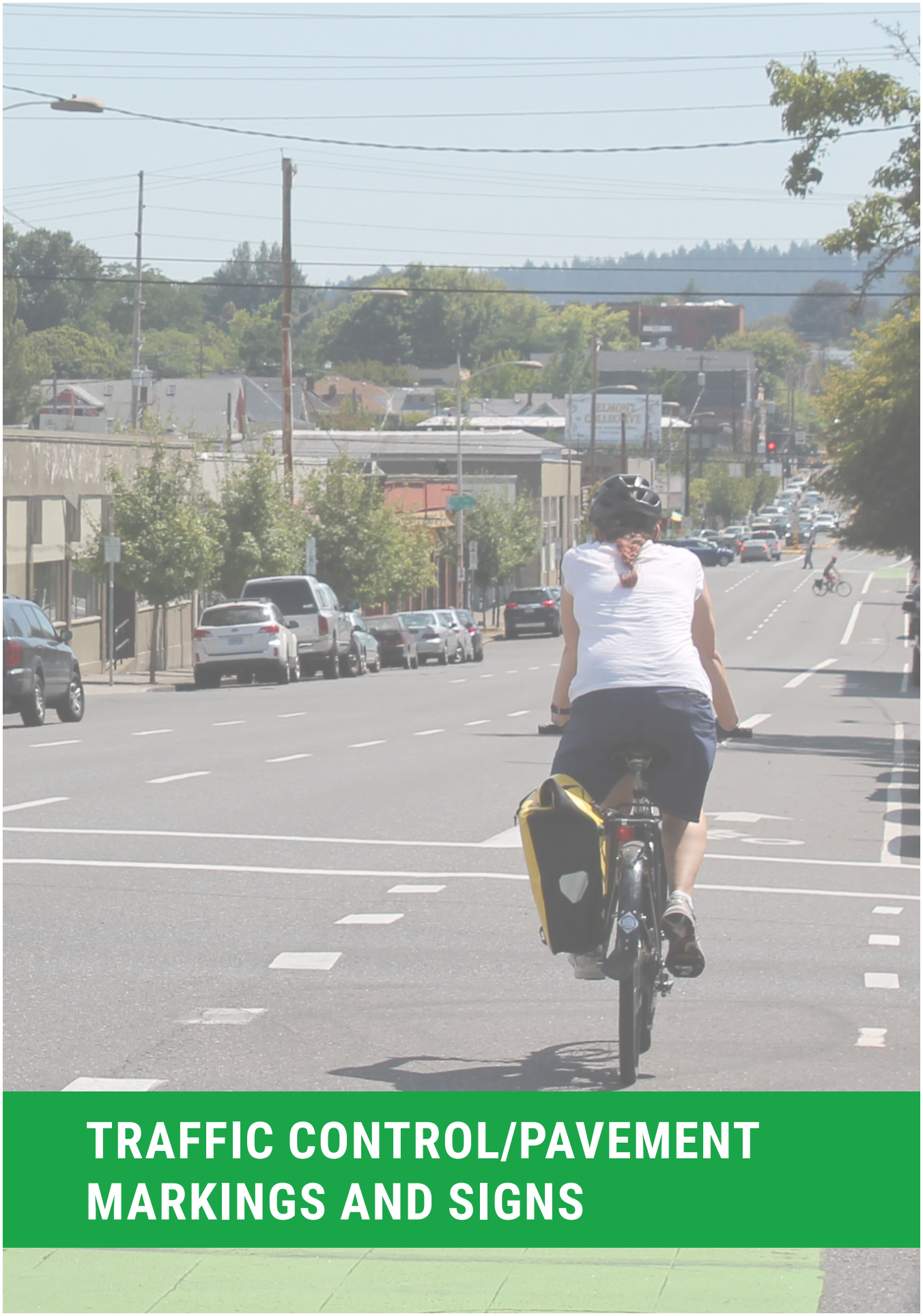
- Unsignalized crossings of arterial or collector streets with high traffic volumes and speeds.
- Offset intersections where the bike boulevard route makes two turns in short succession.

REFERENCES

Fundamentals of Bicycle Boulevard Planning & Design (2009)

NACTO Urban Bikeway Design Guide (2014)

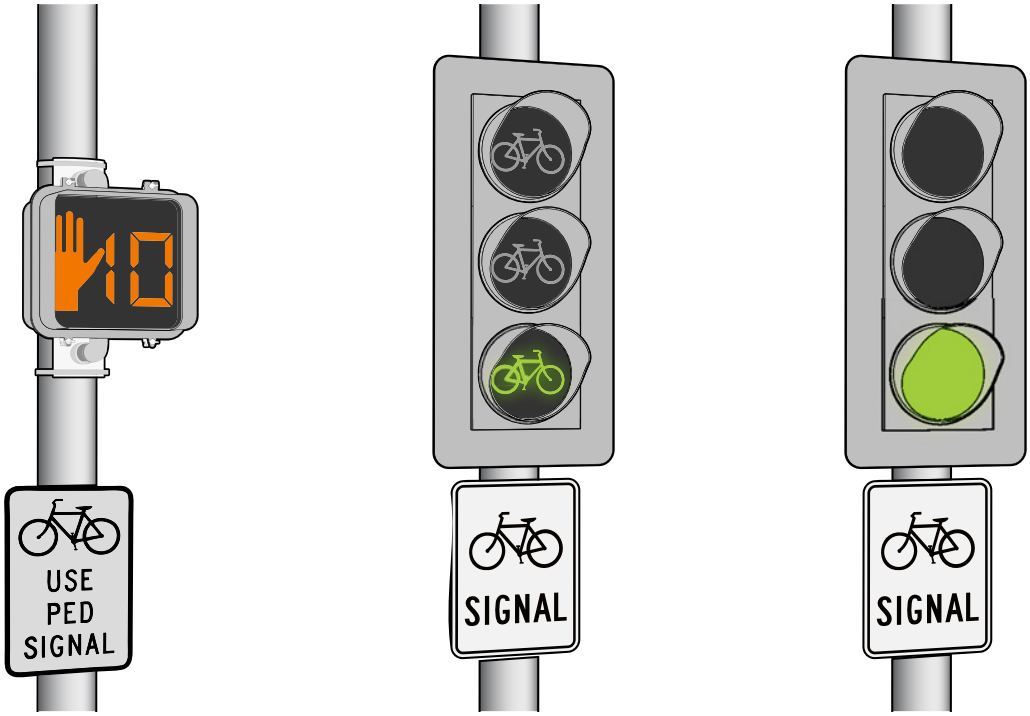
Portland's Neighborhood Greenway Assessment Report (2015)



TRAFFIC CONTROL/PAVEMENT MARKINGS AND SIGNS

BICYCLE SIGNALS, DETECTION, AND ACTUATION

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. 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.



CONSIDERATIONS

- Bicycle-specific signals may be appropriate to provide additional guidance or separate phasing for bicyclists per the 2012 AASHTO ***Guide for the Development of Bicycle Facilities***.
- It may be desirable to install advanced bicycle detection on the intersection approach to extend the phase, or to prompt the phase and allow for continuous bicycle through movements.
- Video detection, microwave, and infrared detection can be alternatives to loop detectors.
- Another strategy in signal timing is coordinating signals to provide a "green wave", such that bicyclists will receive a green indication as they reach each signal and not be required to stop. Several cities including Denver (CO), Portland (OR), and San Francisco (CA) have implemented "green waves" for bicycles.

DESIGN CRITERIA

- A stationary, or "standing", bicyclist entering the intersection at the beginning of the green indication can typically be accommodated by increasing the minimum green time on an approach per the 2012 AASHTO ***Guide for the Development of Bicycle Facilities***.
- A moving, or "rolling", bicyclist approaching the intersection towards the end of the phase can typically be accommodated by increases to the red times (change and clearance intervals) per the 2012 AASHTO ***Guide for the Development of Bicycle Facilities***.
- Set loop detectors to the highest sensitivity level possible without detecting vehicles in adjacent lanes and field check. Type D and type Q loops are preferred for detecting bicyclists.
- Install bicycle detector pavement markings and signs per the MUTCD, 2012 AASHTO ***Guide for the Development of Bicycle Facilities***, and the NACTO ***Urban Bikeway Design Guide***.

REFERENCES

AASHTO Guide for the Development of Bicycle Facilities (2012)

NACTO Urban Bikeway Design Guide (2014)

Manual on Uniform Traffic Control Devices (2009)

BICYCLE ROUTING / DESTINATION WAYFINDING

Wayfinding is a highly visible way to improve bicycling in an area because it helps identify the best routes to destinations, helps people overcome a barrier of not knowing where to ride, and reminds motorists to anticipate the presence of bicyclists. A wayfinding system typically combines signage and pavement markings to guide bicyclists along preferred routes to destinations across the community, county, or region. The routes may or may not be numbered, named, or color-coded. Signs may also indicate distances or travel time to destinations. Similar wayfinding systems can be devised for pedestrian travel.

D11-1

D1-3c

CONSIDERATIONS

A bicycle wayfinding protocol should coordinate with bicycle route maps and provide three general forms of guidance:

+ Decision assemblies, which consist of Bike Route identification and optional destination fingerboards, placed at decision points where routes intersect or on the approaches to a designated bike route.
+ Decision signs, which consist of Bike Route panels and arrow plaques, placed where a designated bike route turns from one street to another.
+ Confirmation assemblies, which consist of Bike Route panels and optional destination fingerboards, placed on the far side of intersections to confirm route choice and the distance (and optionally, time) to destinations.

Sign design can be customized to add distinct community branding, but the clarity and accuracy of the information must be the top priority.

DESIGN CRITERIA

+ Basic bicycle route signs consist of a MUTCD-style "Bike Route" sign (D11-1 shown above) placed every half mile on a major bike route and on the approach to major bike routes at decision points. Unique numbered routes can be designated and can incorporate a route name or agency logos.
+ Bike route signs can be supplemented with "fingerboard" panels showing destinations, directions, and distances (MUTCD D1 series).
+ Place directional signs on the near side of intersections and confirmation signs on the far side of intersections.

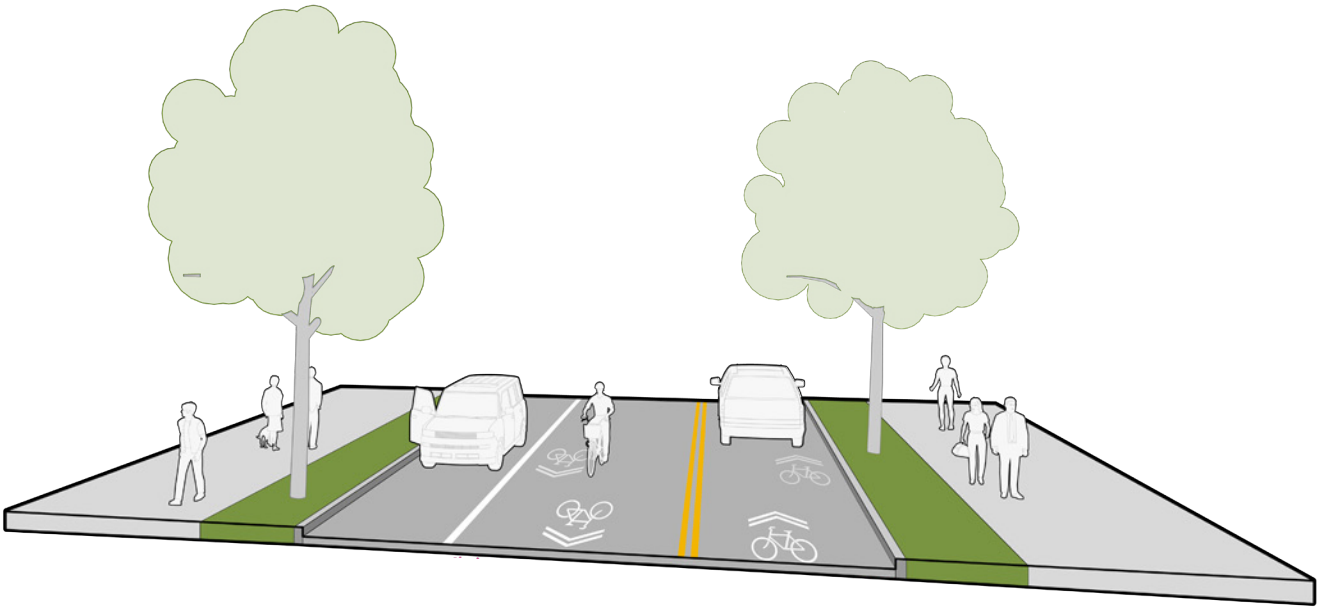
REFERENCES

NACTO Urban Bikeway Design Guide (2014)

Manual on Uniform Traffic Control Devices (2009)

SHARED LANE MARKINGS

Shared lane markings (or "sharrows") are pavement markings that denote shared bicycle and motor vehicle travel lanes. The markings are two chevrons positioned above a bicycle symbol, placed where the bicyclist is anticipated to operate. In general, this is a design solution that should only be used in locations with low traffic speeds and volumes as part of a signed route or bicycle boulevard. Shared lane markings are sometimes used as a temporary solution on constrained, higher-traffic streets (up to 10,000 vehicles per day) until additional right-of-way can be acquired, but should not be considered a permanent solution in these contexts.



CONSIDERATIONS

- Typically used on local, collector, or minor arterial streets with low traffic volumes. Commonly used on bicycle boulevards to reinforce the priority for bicyclists.
- Typically feasible within existing right-of-way and pavement width even in constrained situations that preclude dedicated facilities.
- May be used as interim treatments to fill gaps between bike lanes or other dedicated facilities for short segments where there are space constraints.
- May be used for downhill bicycle travel in conjunction with climbing lanes intended for uphill travel.
- Typically supplemented by signs, especially Bikes May Use Full Lane (R4-11).

DESIGN CRITERIA

- Intended for use only on streets with posted speed limits of up to 25 mph and traffic volumes of less than 4,000 vehicles per day. Maximum posted speed of street: 35 mph.
- May be used as a temporary solution on constrained streets with up to 10,000 vehicles per day until a more appropriate bikeway facility can be implemented. Maximum posted speed of street: 35 mph.
- Intended for use on lanes up to 14 feet wide (up to 13 feet preferred). For lanes 15 feet wide or greater, stripe a 4-foot bike lane instead of using shared lane markings.
- The marking's centerline must be at least 4 feet from curb or edge of pavement where parking is prohibited.
- The marking's centerline must be at least 11 feet from curb where parking is permitted, so that it is outside the door zone of parked vehicles.
- For narrow lanes (11 feet or less), it may be desirable to center shared lane markings along the centerline of the outside travel lane.

REFERENCES

AASHTO Guide for the Development of Bicycle Facilities (2012)

NACTO Urban Bikeway Design Guide (2014)

Manual on Uniform Traffic Control Devices (2009)

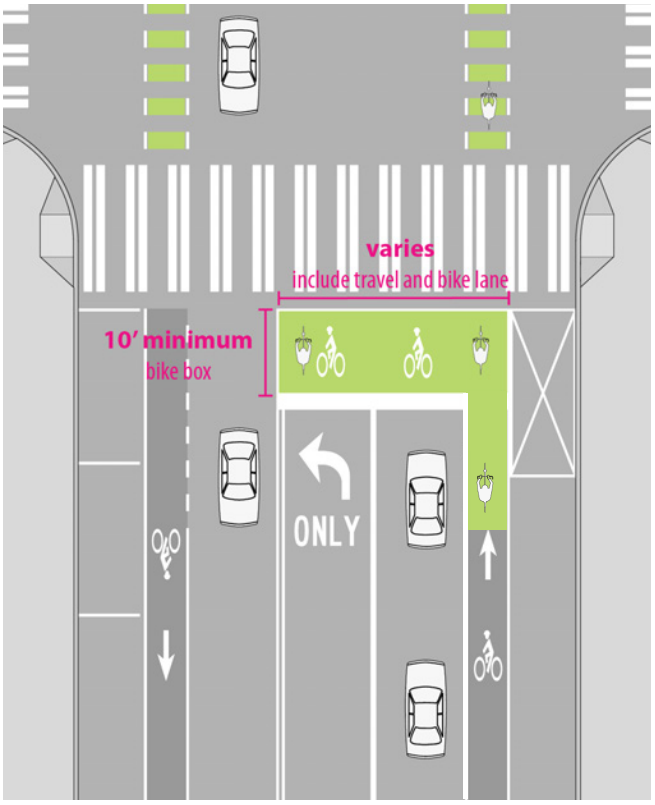
BIKE BOXES

A bicycle box provides dedicated space between the crosswalk and vehicle stop line where bicyclists can wait during the red light at signalized intersections. The bicycle box allows a bicyclist to take a position in front of motor vehicles at the intersection, which improves visibility and motorist awareness, and allows bicyclists to "claim the lane" if desired. Bike boxes aid bicyclists in making turning maneuvers at the intersection, and provide more queuing space for multiple bicyclists than that provided by a typical bicycle lane.

CONSIDERATIONS

In locations with high volumes of turning movements by bicyclists, a bicycle box should be used to allow bicyclists to shift towards the desired side of the travel way. Depending on the position of the bicycle lane, bicyclists can shift sides of the street to align themselves with vehicles making the same movement through the intersection.

In locations where motor vehicles can continue straight or cross through a right-side bicycle lane while turning right, the bicycle box allows bicyclists to move to the front of the traffic queue and make their movement first, minimizing conflicts with the turning. When a bicycle box is implemented in front of a vehicle lane that previously allowed right turn on red, the right turn on red movement must be restricted using signage and enforcement following installation of the bike box.



GUIDANCE

+ Bicycle boxes are typically painted green and are a minimum of 10 feet in depth and are the width of the entire travel lane(s).
+ Bicycle box design should be supplemented with appropriate signage according to the latest version of the MUTCD.
+ Bicycle box design should include appropriate signalization adjustment in determining the minimum green time.
+ Where right-turn lanes for motor vehicles exist, bicycle lanes should be designed to the left of the turn lane. If right turns on red are permitted, consider ending the bicycle box at the edge of the bicycle lane to allow motor vehicles to make this turning movement.

REFERENCES

NACTO Urban Bikeway Design Guide - Bike Boxes (2014)

FHWA Separated Bike Lane Planning and Design Guide (2015)

MassDOT Separated Bike Lane Planning & Design Guide (2015)

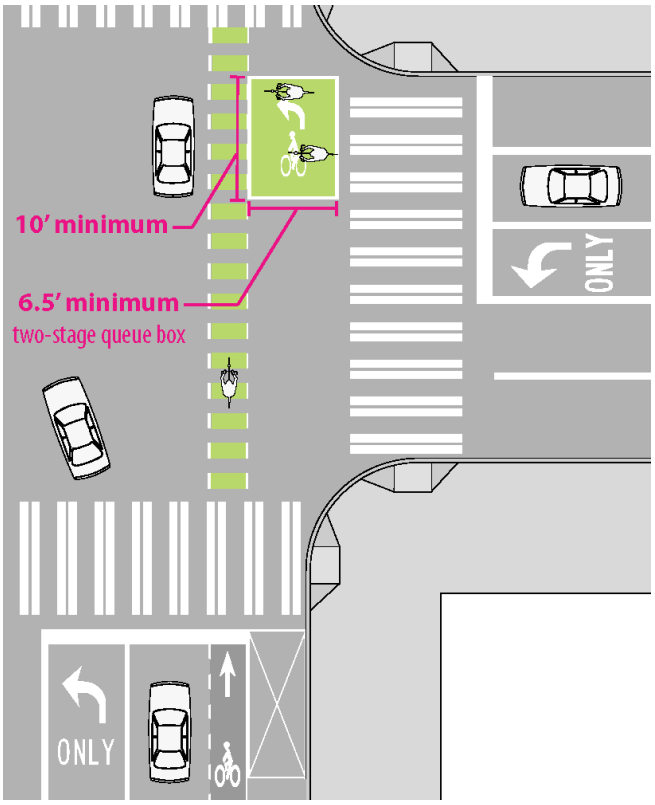
TWO-STAGE TURN QUEUE BOX

A two-stage turn queue box should be considered where 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 a location outside the path of traffic.

CONSIDERATIONS

FHWA granted interim approval to two-stage turn queue boxes on July 13, 2017.

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 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.



GUIDANCE

- A minimum width of 10 feet is recommended.
- A minimum depth of 6.5 feet is recommended.
- 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.
- The use of a supplemental sign instructing bicyclists how to use the box is optional.
- The box should consist of a green box outlined with solid white lines supplemented with a bicycle symbol and a turn arrow to emphasize the crossing direction.

REFERENCES

NACTO Urban Bikeway Design Guide (2014)

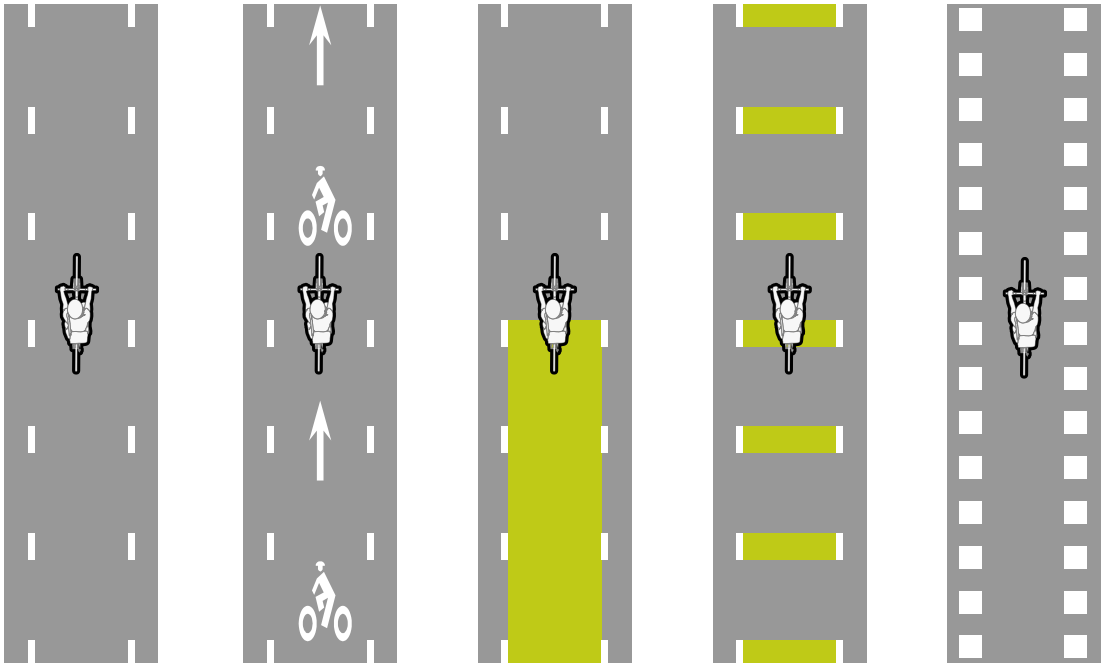
MassDOT Separated Bike Lane Planning and Design Guide (2015)

FHWA Separated Bike Lane Planning and Design Guide (2015)

FHWA Bicycle Facilities and the Manual on Uniform Traffic Control Devices - Two-Stage Turn Box (2015)

CONFLICT AREA MARKING

Conflict area markings are intersection pavement markings designed to improve bicyclist visibility, alert all roadway users of expected behaviors, and to reduce conflicts with turning vehicles.



Dotted Line Extensions | **Bike Lane Markings** | **Colored Conflict Area** | **Colored Dash** | **Elephant's Feet**

CONSIDERATIONS

- The appropriate treatment for conflict areas can depend on the desired emphasis and visibility. Dotted lane lines may be sufficient for guiding bicyclists through intersections and alerting drivers to the likelihood of the presence of bicyclists; however, consider providing enhanced markings with green pavement and/or symbols at complex intersections or at intersections with safety concerns.
- Symbol placement within intersections should consider vehicle wheel paths and minimize maintenance needs associated with wheel wear.
- Driveways with higher volumes may require additional pavement markings and signage.
- Consideration should be given to using intersection conflict markings as spot treatments or standard intersection treatments. A corridor-wide treatment can maintain consistency; however, spot treatments can be used to highlight conflict locations.

DESIGN CRITERIA

- The width of conflict area markings should be as wide as the bike lanes on either side of the intersection.
- Dotted white lane lines should conform to the latest edition of the MUTCD. These markings can be used through different types of intersections based on engineering judgment.
- A variety of pavement marking symbols can enhance intersection treatments to guide bicyclists and warn of potential conflicts.
- Green pavement markings can be used along the length of a corridor or in select conflict locations.

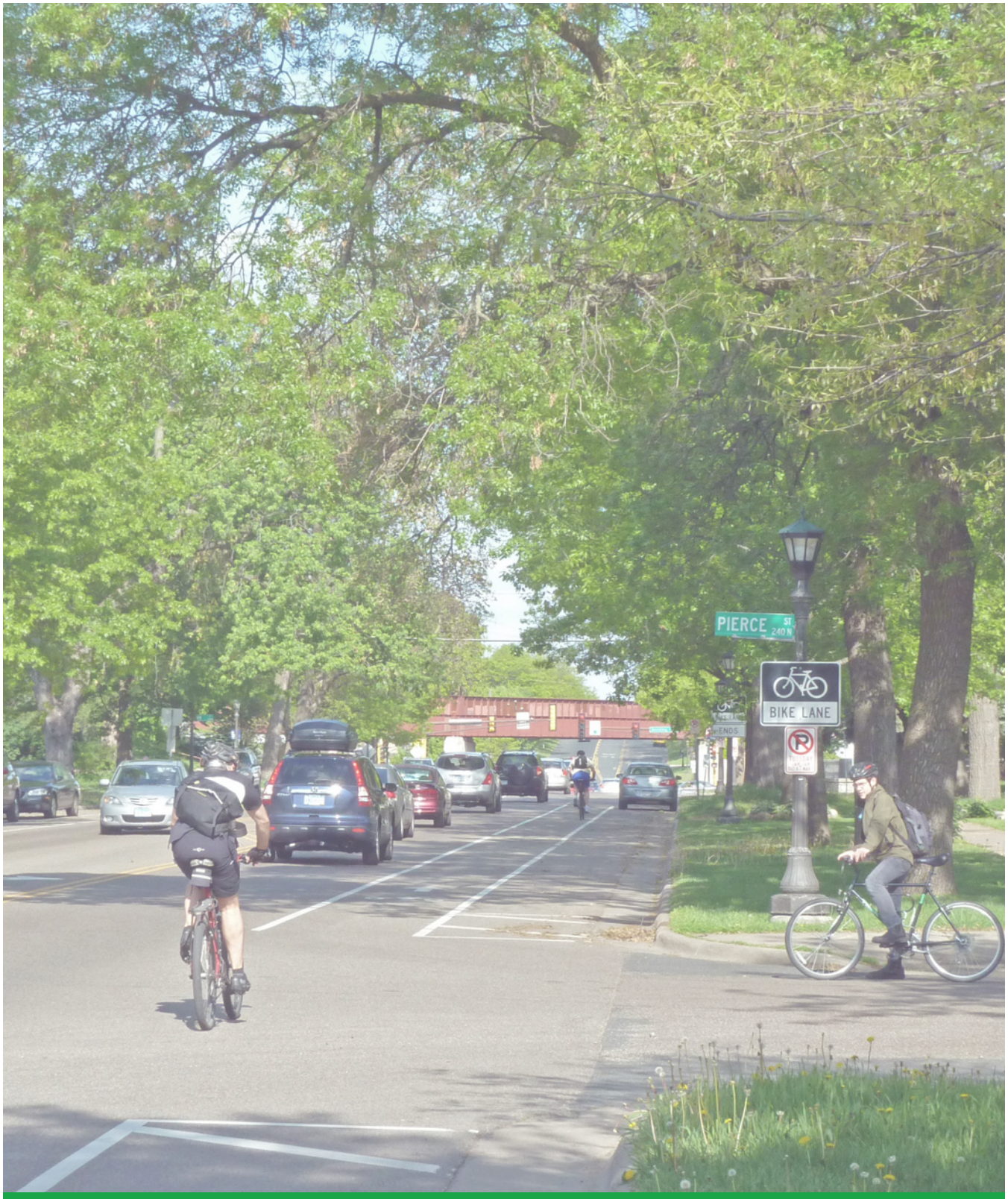
REFERENCES

AASHTO Guide for the Development of Bicycle Facilities (2012)

NACTO Urban Bikeway Design Guide (2014)

FHWA Separated Bike Lane Planning and Design Guide (2015)

Manual on Uniform Traffic Control Devices (2009)



APPENDICES

APPENDIX A: RESOURCES & ADDITIONAL INFORMATION

Resources cited throughout this Guide are listed here.

Achieving Multimodal Networks: Applying Design Flexibility and Reducing Conflicts. Federal Highway Administration (FHWA). 2016. *https://www.fhwa.dot.gov/environment/bicycle_pedestrian/publications/multimodal_networks/*

ADA Accessibility Guidelines (ADAAG). United States Access Board. 2002. *https://www.access-board.gov/guidelines-and-standards/buildings-and-sites/about-the-ada-standards/background/adaag*

APBP Essentials of Bike Parking: Selecting and Installing Bike Parking that Works (2015)

A Policy on Geometric Design of Highways and Streets. 6th Edition. American Association of State Highway and Transportation Officials (AASHTO). 2011. (Errata issued November 2013.)

Bicycle Facilities and the Manual on Uniform Traffic Control Devices (website). Bicycle and Pedestrian Program. Federal Highway Administration (FHWA). 2016. *http://www.fhwa.dot.gov/environment/bicycle_pedestrian/guidance/mutcd/index.cfm*

Bicycle Parking Guidelines. 2nd Edition. Association of Pedestrian and Bicycle Professionals (APBP). 2010.

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