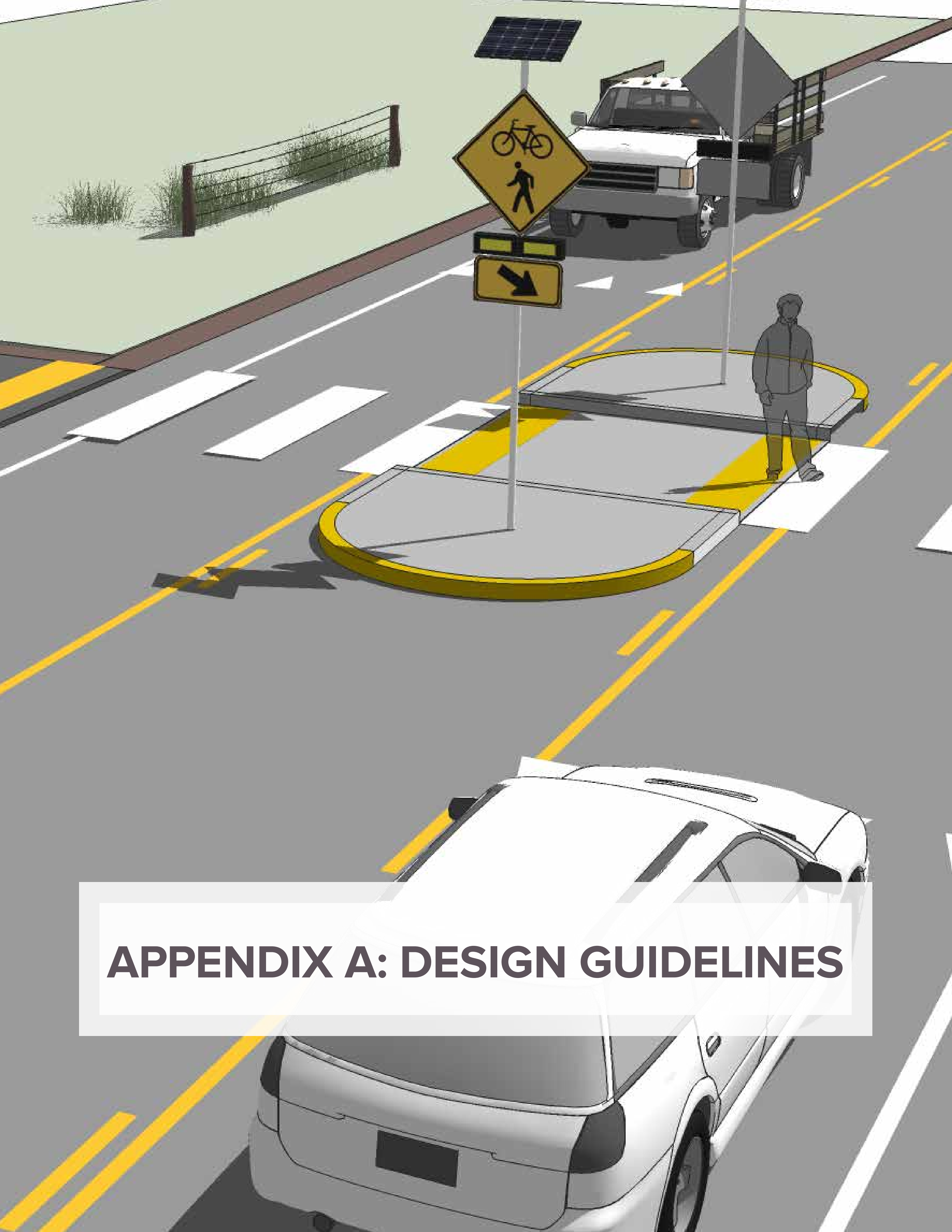


APPENDIX A: DESIGN GUIDELINES

Table of Contents

CONTEXT

The sections that follow serve as an inventory of pedestrian, bicycle, and trail design treatments and provide guidelines for their development. These treatments and design guidelines are important because they represent the tools for creating a safe and accessible Northbrook. The guidelines are not, however, a substitute for a more thorough evaluation by a landscape architect or engineer upon design of facility improvements.

Guidance Basis

The sections that follow serve as an inventory of bicycle and trail design treatments and provide guidelines for their development. These treatments and design guidelines are important because they represent the tools for creating a safe and accessible community. The guidelines are not, however, a substitute for a more thorough evaluation by a landscape architect or engineer upon implementation of facility improvements.

National Guidance

The following standards and guidelines are referred to in this guide:

» The Federal Highway Administration's (FHWA) ***Manual on Uniform Traffic Control Devices (MUTCD)*** defines the standards used by road managers nationwide to install and maintain traffic control devices on all public streets, highways, bikeways, and private roads open to public traffic The MUTCD is the primary source for guidance on lane striping requirements, signal warrants, and recommended signage and pavement markings.

» American Association of State Highway and Transportation Officials (AASHTO) ***Guide for the Development of Bicycle Facilities*** (2012) provides guidance on dimensions, use, and layout of specific bicycle facilities.

» The National Association of City Transportation Officials' (NACTO) ***Urban Bikeway Design Guide*** (2012) is the newest publication of nationally recognized bikeway design standards, and offers guidance on the current state of the practice designs.

» The AASHTO ***A Policy on Geometric Design of Highways and Streets*** (2011) commonly referred to as the "Green Book," contains the current design research and practices for highway and street geometric design.

» The United States Access Board accessibility guidelines, known as ***PROWAG (2011),*** provides guidelines for accessible public rights of way, including geometric design.

National guidance is periodically updated. Refer to report websites for updated guidance.

Local Guidance

The following standards and guidelines are referred to in this guide:

» Illinois Department of Transportation's ***Bureau of Design and Environment Manual*** (2015) provides guidance for bike and pedestrian facilities in the state. The manual states that when the DOT is "planning transportation improvements, the Department considers the travel needs of all users of a transportation corridor, including bicyclists and pedestrians".

» The Chicago Department of Transportation's ***Complete Streets Chicago Design Guidelines*** (2013) provides design guidance to make streets safer for all users.

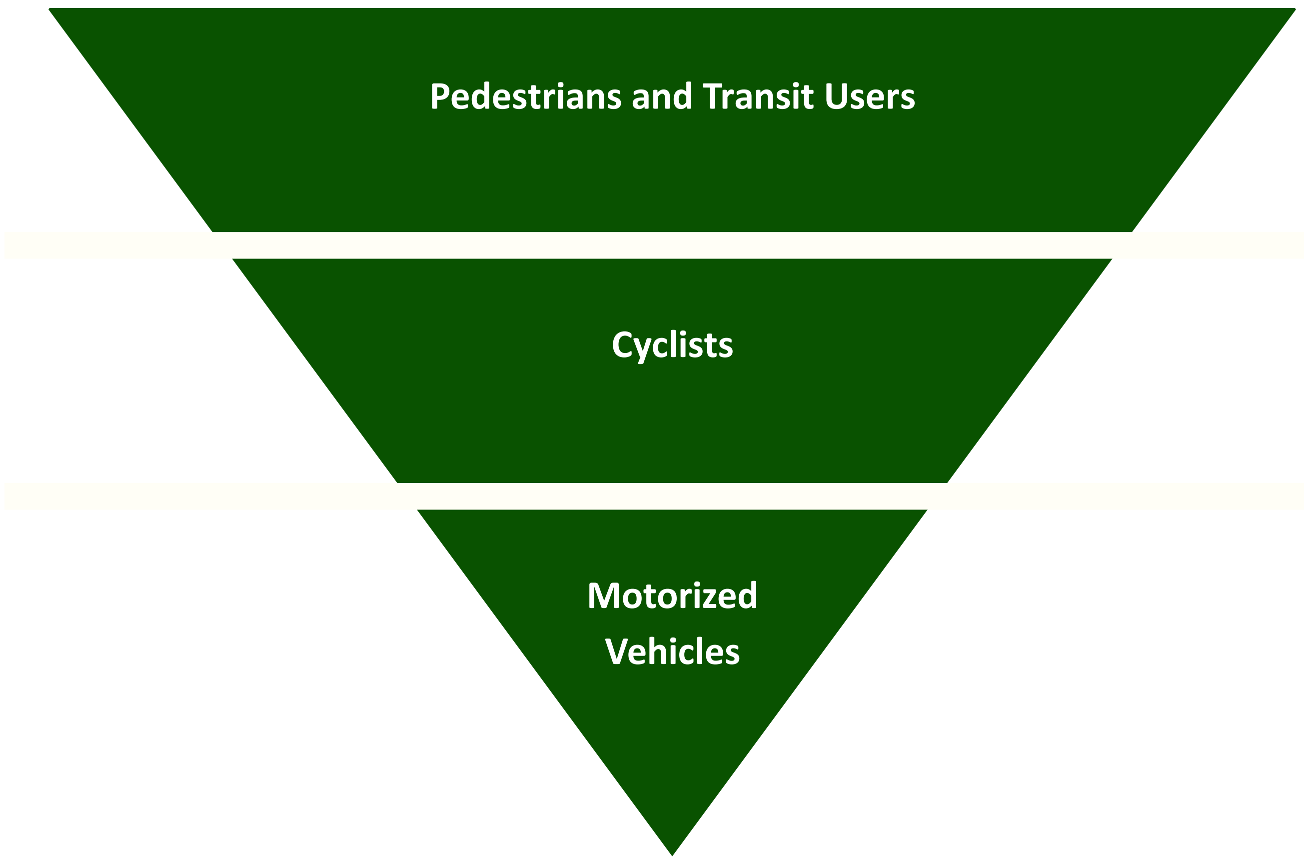
Impact on Safety and Crashes

Bicycle facilities can have a significant influence on user safety. The Federal Highway Administration ***Crash Modification Factor Clearinghouse*** (http://www.cmfclearinghouse.org/) is a web-based database of Crash Modification Factors (CMF) to help transportation engineers identify the most appropriate countermeasure for their safety needs. Where available and appropriate, CMFs or similar study results are included for each treatment.

Roadway User Hierarchy

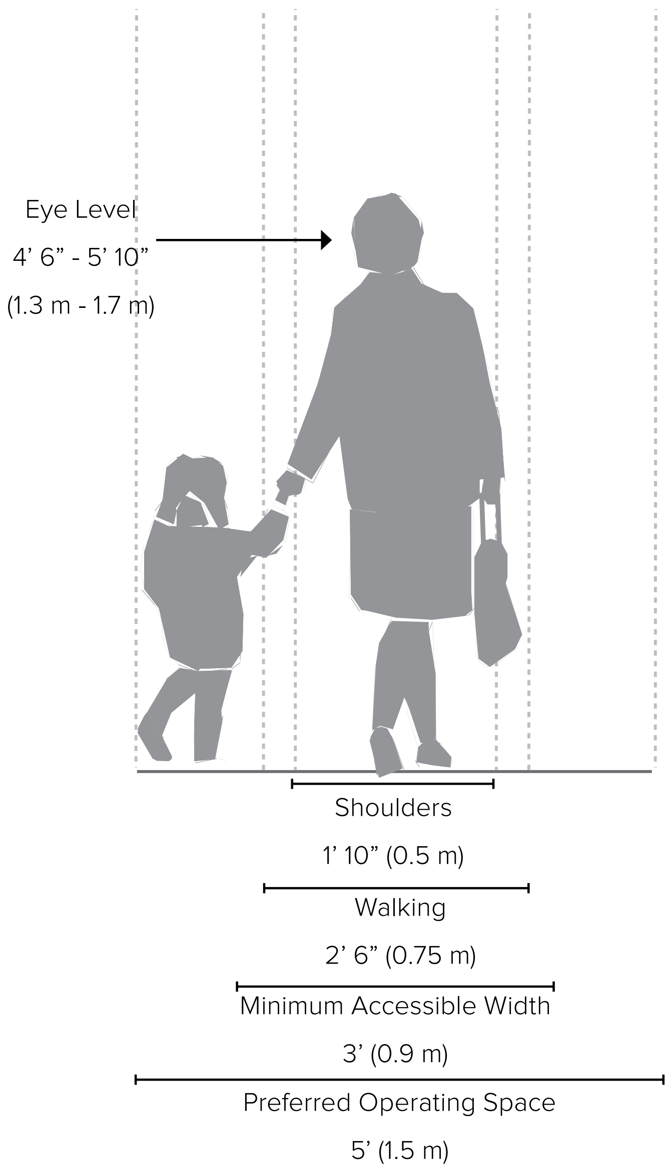
The Northbrook Bike and Pedestrian plan uses a "pedestrian first" modal hierarchy, where the most vulnerable roadway users are given priority. Implementing a modal hierarchy means making decisions according to the following prioritization:

1. Pedestrians and Transit Users
2. Bicyclists
3. Motorized Vehicles



Design Needs of Pedestrians

The MUTCD recommends a normal walking speed of three and a half feet per second when calculating the pedestrian clearance interval at traffic signals. The walking speed can drop to 3 feet per second for areas with older populations and persons with mobility impairments. While the type and degree of mobility impairment varies greatly across the population, the transportation system should accommodate these users to the greatest reasonable extent.



PEDESTRIAN CHARACTERISTICS BY AGE

0-4	Learning to walk
	Requires constant adult supervision
	Developing peripheral vision and depth perception
5-8	Increasing independence, but still requires supervision
	Poor depth perception
9-13	Susceptible to “darting out” in roadways
	Insufficient judgment
	Sense of invulnerability
14-18	Improved awareness of traffic environment
	Insufficient judgment
19-40	Active, aware of traffic environment
41-65	Slowing of reflexes
65+	Difficulty crossing street
	Vision loss
	Difficulty hearing vehicles approaching from behind

Source: AASHTO. *Guide for the Planning, Design, and Operation of Pedestrian Facilities*, Exhibit 2-1. 2004.

Types of Pedestrians

Pedestrians have a variety of characteristics and the transportation network should accommodate a variety of needs, abilities, and possible impairments. Age is one major factor that affects pedestrians' physical characteristics, walking speed, and environmental perception. Children have low eye height and walk at slower speeds than adults. They also perceive the environment differently at various stages of their cognitive development. Older adults walk more slowly and may require assistive devices for walking stability, sight, and hearing.

Disabled Pedestrian Design Considerations

The table below summarizes common physical and cognitive impairments, how they affect personal mobility, and recommendations for improved pedestrian-friendly design.

DISABLED PEDESTRIAN DESIGN CONSIDERATIONS (AASHTO PEDESTRIAN GUIDE 2004)

IMPAIRMENT	EFFECT ON MOBILITY	DESIGN SOLUTION
Physical Impairment Necessitating Wheelchair and Scooter Use	Difficulty propelling over uneven or soft surfaces.	Firm, stable surfaces and structures, including ramps or beveled edges.
	Cross-slopes cause wheelchairs to veer downhill or tip sideways.	Cross-slopes of less than two percent.
	Require wider path of travel.	Sufficient width and maneuvering space.
Physical Impairment Necessitating Walking Aid Use	Difficulty negotiating steep grades and cross slopes; decreased stability and tripping hazard.	Cross-slopes of less than two percent. Smooth, non-slippery travel surface.
	Slower walking speed and reduced endurance; reduced ability to react.	Longer pedestrian signal cycles, shorter crossing distances, median refuges, and street furniture.
Hearing Impairment	Less able to detect oncoming hazards at locations with limited sight lines (e.g. driveways, angled intersections, channelized right turn lanes) and complex intersections.	Longer pedestrian signal cycles, clear sight distances, highly visible pedestrian signals and markings.
Vision Impairment	Limited perception of path ahead and obstacles; reliance on memory; reliance on non-visual indicators (e.g. sound and texture).	Accessible text (larger print and raised text), accessible pedestrian signals (APS), guide strips and detectable warning surfaces, safety barriers, and lighting.
Cognitive Impairment	Varies greatly. Can affect ability to perceive, recognize, understand, interpret, and respond to information.	Signs with pictures, universal symbols, and colors, rather than text.

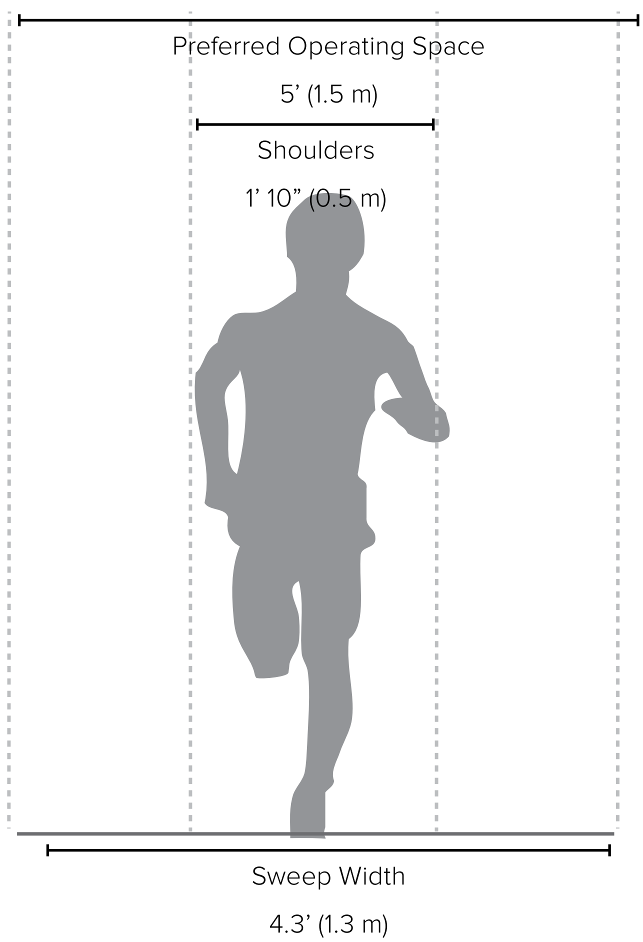
Design Needs of Runners

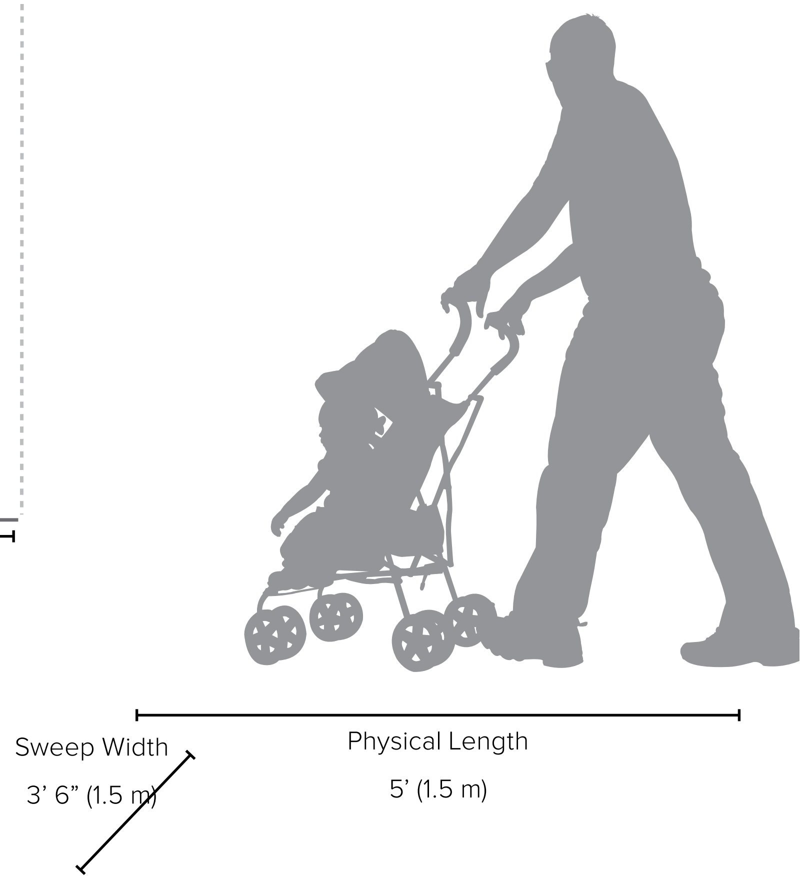
Running is an important recreation and fitness activity commonly performed on shared use paths. Many runners prefer softer surfaces (such as rubber, bare earth or crushed rock) to reduce impact. Runners can change their speed and direction frequently. If high volumes are expected, controlled interaction or separation of different types of users should be considered.

Design Needs of Strollers

Strollers are wheeled devices pushed by pedestrians to transport babies or small children. Stroller models vary greatly in their design and capacity. Some strollers are designed to accommodate a single child, others can carry three or more. Design needs of strollers depend on the wheel size, geometry and ability of the adult who is pushing the stroller.

Strollers commonly have small pivoting front wheels for easy maneuverability, but these wheels may limit their use on unpaved surfaces or rough pavement. Curb ramps are valuable to these users. Lateral overturning is one main safety concern for stroller users.





Design Needs of Wheelchair Users

As the American population ages, the number of people using mobility assistive devices (such as manual wheelchairs, powered wheelchairs) increases.

Manual wheelchairs are self-propelled devices. Users propel themselves using push rims attached to the rear wheels. Braking is done through resisting wheel movement with the hands or arm. Alternatively, a second individual can control the wheelchair using handles attached to the back of the chair.

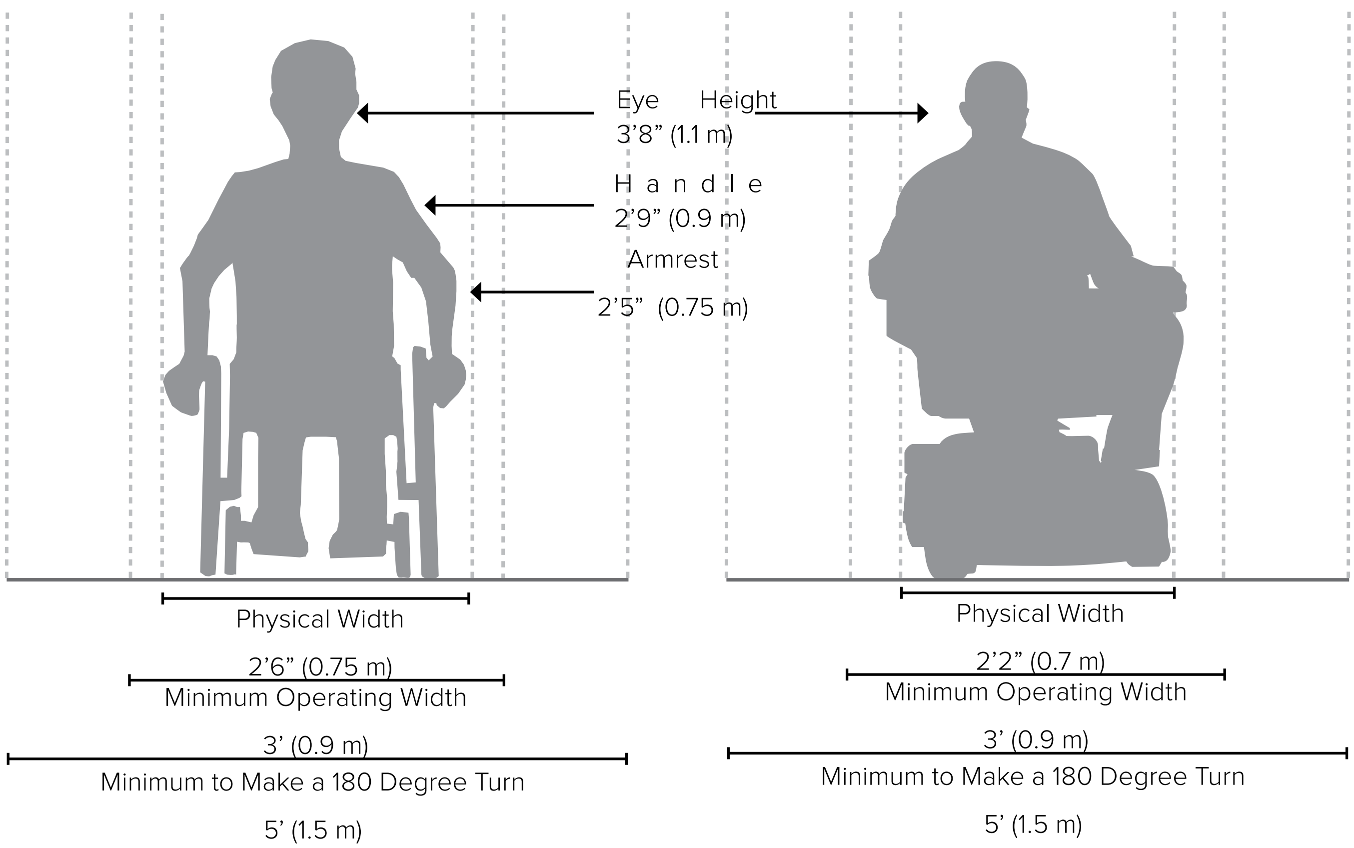
Power wheelchairs use battery power to move the wheelchair. The size and weight of power wheelchairs limit their ability to negotiate obstacles without a ramp. Various control units are available that enable users to control the wheelchair movement, based on their ability (e.g., joystick control, breath controlled, etc).

Maneuvering around a turn requires additional space for wheelchair devices. Providing adequate space for 180 degree turns at appropriate locations is an important element of accessible design.

WHEELCHAIR USER DESIGN CONSIDERATIONS

Difficulty propelling over uneven or soft surfaces.	Firm, stable surfaces and structures, including ramps or beveled edges.
Cross-slopes cause wheelchairs to veer downhill.	Cross-slopes of less than two percent.
Require wider path of travel.	Sufficient width and maneuvering space.

Wheelchair User Dimensions



Design Needs of Bicyclists

The purpose of this section is to provide the facility designer with an understanding of how bicyclists operate and how their bicycle influences that operation. Bicyclists, by nature, are much more affected by poor facility design, construction, and maintenance practices than motor vehicle drivers.

Bicyclists lack the protection from the elements and roadway hazards provided by an automobile's structure and safety features. By understanding the unique characteristics and needs of bicyclists, a facility designer can provide quality facilities and minimize user risk.

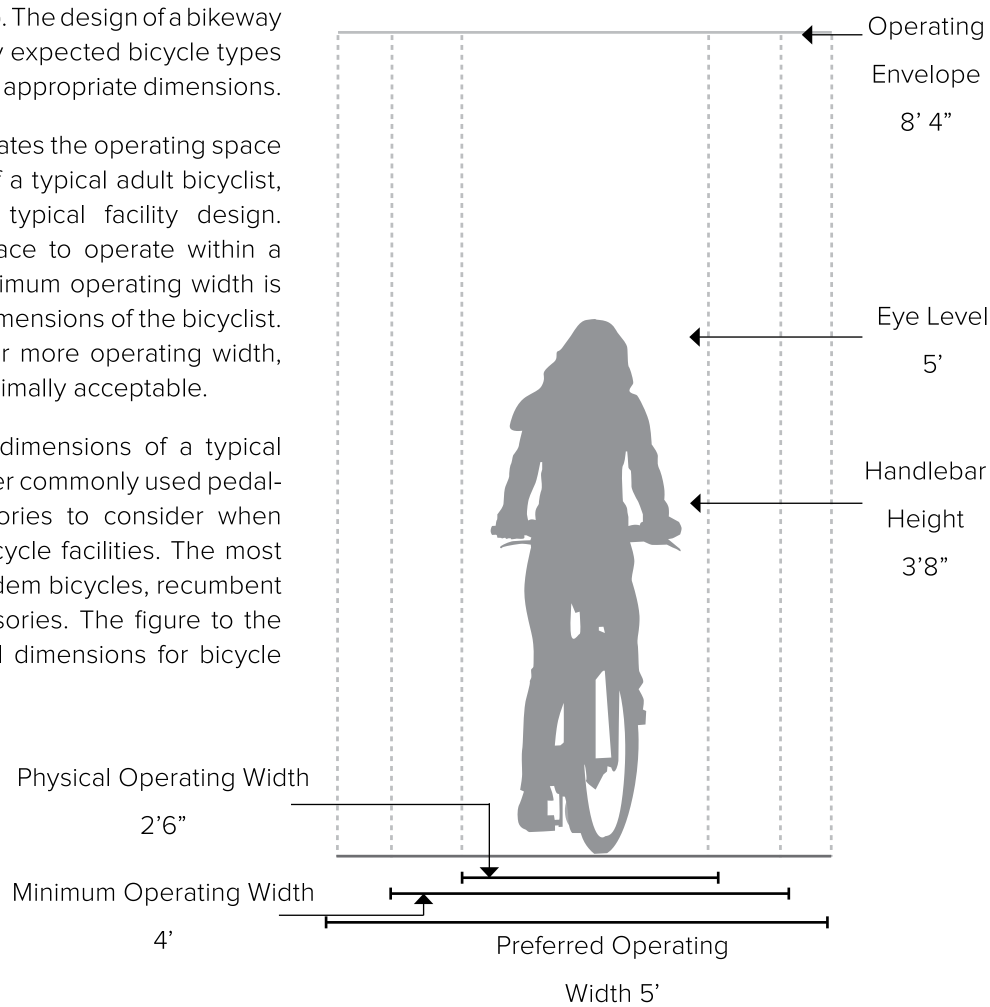
Bicycle as a Design Vehicle

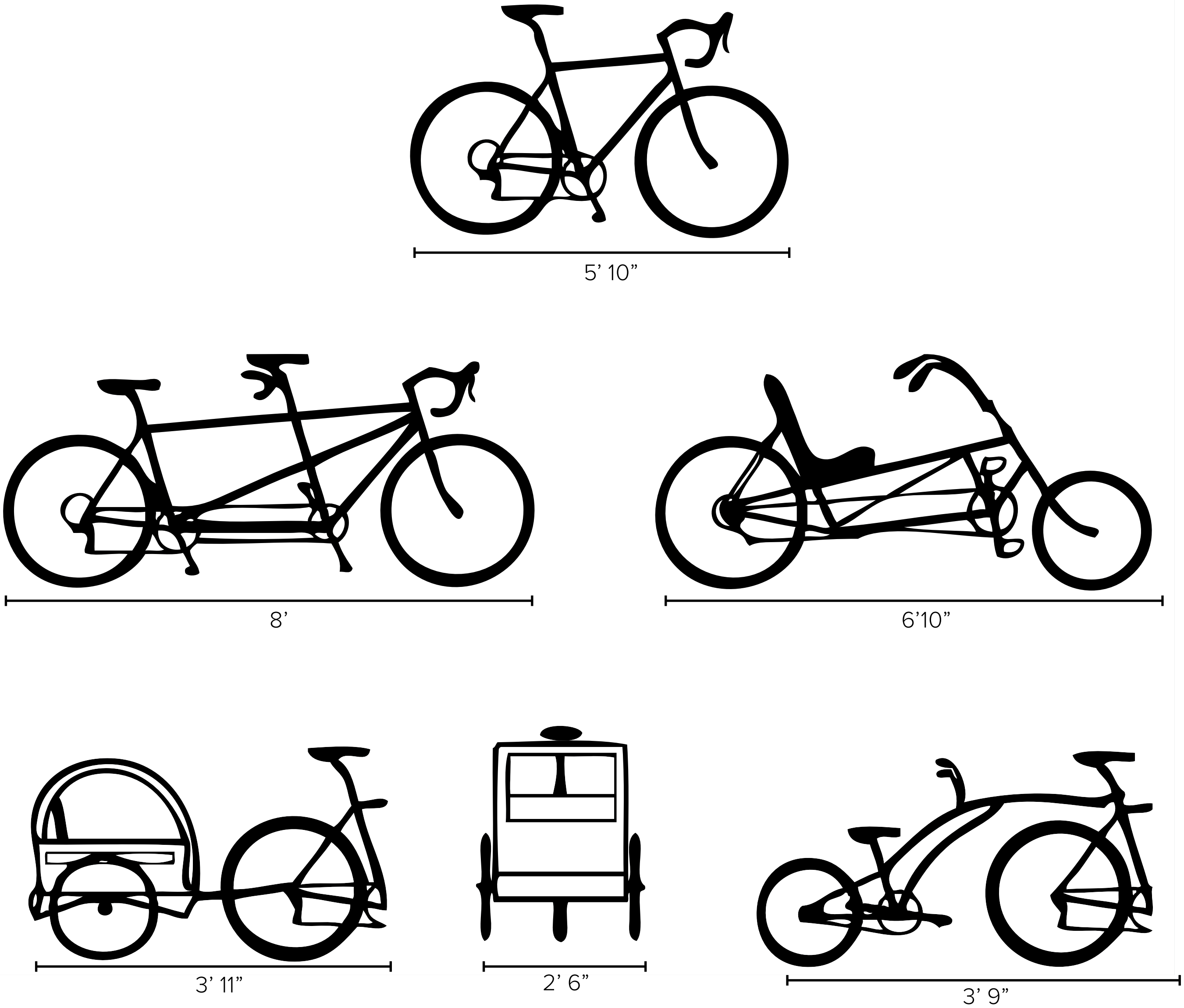
Similar to motor vehicles, bicyclists and their bicycles exist in a variety of sizes and configurations. These variations occur in the types of vehicle (such as a conventional bicycle, a recumbent bicycle or a tricycle), and behavioral characteristics (such as the comfort level of the bicyclist). The design of a bikeway should consider reasonably expected bicycle types on the facility and utilize the appropriate dimensions.

The figure to the right illustrates the operating space and physical dimensions of a typical adult bicyclist, which are the basis for typical facility design. Bicyclists require clear space to operate within a facility. This is why the minimum operating width is greater than the physical dimensions of the bicyclist. Bicyclists prefer five feet or more operating width, although four ft may be minimally acceptable.

In addition to the design dimensions of a typical bicycle, there are many other commonly used pedal-driven cycles and accessories to consider when planning and designing bicycle facilities. The most common types include tandem bicycles, recumbent bicycles, and trailer accessories. The figure to the left summarizes the typical dimensions for bicycle types.

Bicycle Rider - Typical Dimensions





Source: AASHTO Guide for the Development of Bicycle Facilities, 4th Edition

The expected speed that different types of bicyclists can maintain under various conditions also influences the design of facilities such as shared use paths. The table to the right provides typical bicyclist speeds for a variety of conditions.

BICYCLE AS DESIGN VEHICLE - DESIGN SPEED EXPECTATIONS

BICYCLE TYPE	FEATURE	TYPICAL SPEED
Upright Adult Bicyclist	Paved level surfacing	8-12 mph*
	Crossing Intersections	10 mph
	Downhill	30 mph
	Uphill	5 -12 mph
Recumbent Bicyclist	Paved level surfacing	18 mph

** Typical speed for causal riders per AASHTO 2013.*

PEDESTRIAN INFRASTRUCTURE

Pedestrian infrastructure includes any physical element that enhances the pedestrian experience. Sidewalks are the most fundamental element of the pedestrian network and should be designed not only for movement, but to provide space for commercial activities (such as cafe seating and retail displays), street trees, lighting, and other useful amenities. The streetscape can be improved with green infrastructure that enhances the aesthetic qualities of a street and also provides environmental benefits, while parklets provide additional space for seating within the public right-of-way. It is also important that pedestrians can safely navigate conflict zones, such as driveways and construction zones.

Sidewalk Zones & Widths

Sidewalks are the most fundamental element of the walking network, as they provide an area for pedestrian travel separated from vehicle traffic. Providing adequate and accessible facilities can lead to increased numbers of people walking, improved safety, and the creation of social space.

EDGE ZONE

Curbside Lane	Furnishing Zone	Pedestrian Through Zone	Frontage Zone
The furnishing zone buffers pedestrians from the adjacent roadway, and is also the area where elements such as street trees, signal poles, signs, and other street furniture are properly located.	The through zone is the area intended for pedestrian travel. This zone should be entirely free of permanent and temporary objects. Wide through zones are needed in downtown areas or where pedestrian flows are high.	The curbside lane can act as a flexible space to further buffer the sidewalk from moving traffic., and may be used for a bike lane. Curb extensions and bike corrals may occupy this space where appropriate. In the edge zone there should be a six inch wide curb.	The frontage zone allows pedestrians a comfortable “shy” distance from the building fronts. It provides opportunities for window shopping, to place signs, planters, or chairs.

Typical Application

- Sidewalks should be provided on both sides of urban commercial streets, and should be required in areas of moderate residential density. (one to four dwelling units per acre).
- When retrofitting gaps in the sidewalk network, locations near transit stops, schools, parks, public buildings, and other areas with high concentrations of pedestrians should be the highest priority.
- In rural areas, no curb and gutter is necessary to establish a sidewalk. Instead, the sidewalk should feature a wide furnishing zone, which may be configured as an open ditch for stormwater catchment and infiltration. Ditches can be retrofitted into bioswales or raingardens for filtration and water purification.

Design Features

- It is important to provide adequate width along a sidewalk corridor. A pedestrian through zone width of six feet enables two pedestrians (including wheelchair users) to walk side-by-side, or to pass each other comfortably.
- In areas of high demand, sidewalks should contain adequate width to accommodate the high volumes and different walking speeds of pedestrians.
- Appropriate placement of street trees in the furnishing zone (minimum width four feet) helps buffer pedestrians from the travel lane and increases facility comfort.

STREET CLASSIFICATION	PARKING LANE/ ENHANCEMENT ZONE	FURNISHING ZONE	PEDESTRIAN THROUGH ZONE	FRONTAGE ZONE
Local Streets	Varies	2 - 5 ft	6 ft	N/A
Downtown and Pedestrian Priority Areas	Varies	4 - 6 ft	12 ft	2.5 - 10 ft
Arterials and Collectors	Varies	2 - 6 ft	6 - 8 ft	2.5 - 5 ft

Further Considerations

- At a minimum, the Americans with Disabilities Act requires a three-foot clear width in the pedestrian zone plus five-foot passing areas every 200 feet.
- The clear width may be reduced to a minimum of 32 inches for short, constrained segments of up to 24 inches long, provided that constrained segments are separated by regular clear width segments that are a minimum of 48 inches long and 36 inches wide.
- Providing a six-foot clear width across the full corridor for all new sidewalks (and 12-foot or greater in downtown and pedestrian-priority areas) meets requirements for passing and maneuverability.
- Existing deficient-width sidewalks are to be retrofitted to meet citywide standards.

Crash Reduction

Sidewalks reduce walking along the roadway and reduce other pedestrian crashes. Roadways without sidewalks are more than twice as likely to have pedestrian crashes as roadways with sidewalks on both sides of the street.[1]

1 FHWA Investigation of Exposure-Based Pedestrian Accident Areas: Crosswalks, Sidewalks, Local Streets, and Major Arterials. Publication No. FHWA/RD87-038, FHWA, Washington, D.C., 1987.

Materials and Maintenance

Sidewalks are typically constructed out of concrete and are separated from the roadway by a curb or gutter and sometimes a landscaped boulevard. Less expensive walkways constructed of asphalt, crushed stone, or other stabilized surfaces may be appropriate. Ensure accessibility and properly maintain all surfaces regularly. Surfaces must be firm, stable, and slip resistant. Colored, patterned, or stamped concrete can add distinctive visual appeal.

Sidewalk Infill + Improvements

Due to historic development patterns, sidewalks may be missing or underbuilt for limited segments along an otherwise continuous corridor, or may be provided on only one side of the street where demand exists for access on both sides. Sidewalk infill and improvement strategies should identify and prioritize gaps in order to provide complete, accessible facilities.

Typical Application

- » Missing segments in an otherwise complete corridor
- » Missing on one side of a corridor
- » Where sidewalks are completely absent from the roadway
- » The AASHTO Pedestrian Guide states "Wherever there is developed frontage along a road or street, there will be people walking for exercise, visiting neighbors, accessing bus stops, or walking for pure enjoyment. Sidewalk or pathways are needed to safely accommodate these activities." (2004, p.25)

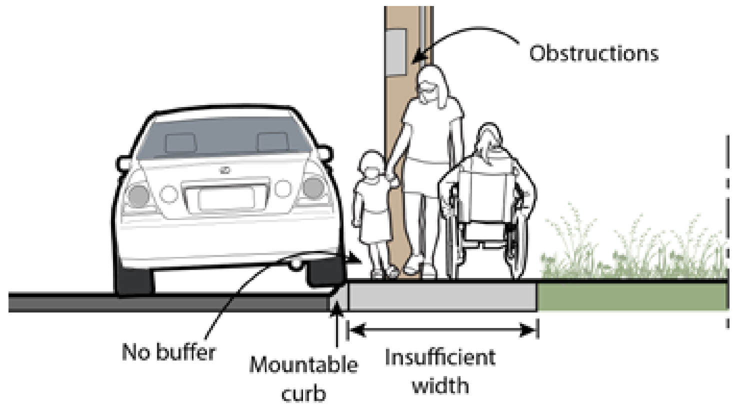
Design Features

- » Sidewalk width will vary depending on the available public right-of-way between the curb line and private property line.
- » Generally, sidewalk infill projects do not change the configuration of the roadway travel area.
- » When filling gaps in a corridor, sidewalk segments should provide adequate width and landscaped buffer. A buffer zone of four to six feet is desirable to separate pedestrians from the street.
- » Infill sidewalks may need to transition at the ends of the segments to connect to existing sidewalk alignment and design.
- » New and reconstructed sidewalks must meet accessibility guidelines. This includes the design of curb ramps and driveway curb cuts.

Sidewalk Improvements

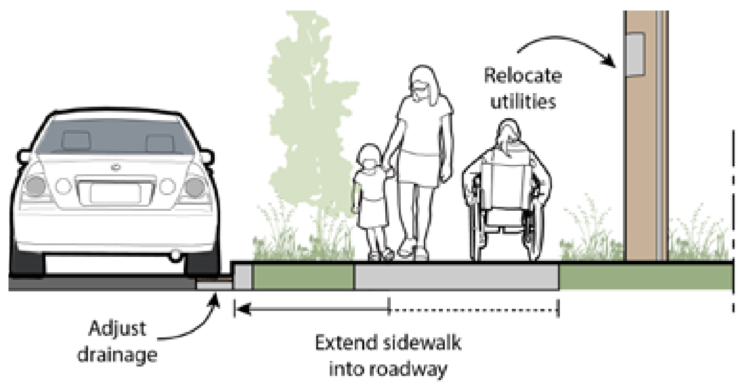
TYPICAL EXISTING CONDITIONS

A typical existing sidewalk includes a facility with insufficient width for people walking or using mobility devices, obstructions (including utility poles and boxes, fire hydrants, mailboxes, etc), and no buffer between the roadway and the sidewalk.



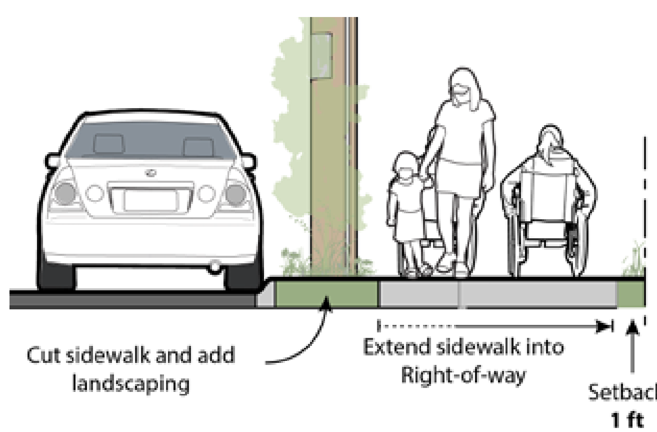
SIDEWALK IMPROVEMENTS - WIDEN OUTWARD

Widening the sidewalk outward creates additional space for a buffer between the roadway and the sidewalk, making a more comfortable facility for people walking. Relocating utilities and other sidewalk obstructions outside of the sidewalk area increases the capacity and usefulness of the sidewalk.



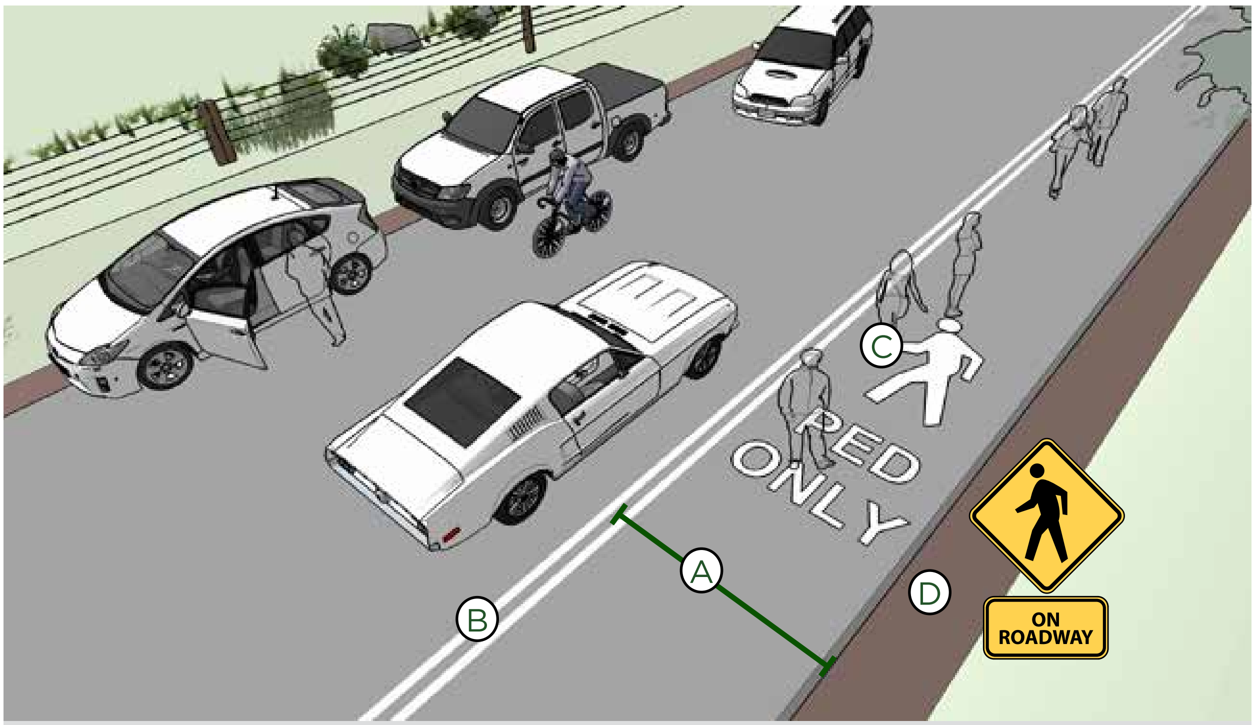
SIDEWALK IMPROVEMENTS - WIDEN INWARD

Widening the sidewalk inward into the right-of-way creates more space for a sidewalk. Existing sidewalk can be cut and creates space for landscaping and utility poles.



Pedestrian Lane

A pedestrian lane is a low-cost alternative to a separated path or sidewalk that may be appropriate on roads with moderate speeds and volumes. The lane provides a space for pedestrians to walk and separated from motor vehicle traffic by roadway striping.



Typical Application

» As an affordable alternative to a sidewalk. In some suburban and rural communities, sidewalks may not be the appropriate pedestrian facility choice, due to right of way constraints, storm water infrastructure, economic impacts, or other reasons.

» On streets with low to moderate volumes and low to moderate speeds.

» Works best inside more built up areas, such as near commercial areas.

Design Features

» Pedestrian lane width of 8 feet is preferred, five-foot minimum. Refer to location A in the figure.

» A pedestrian lane must be separated from the adjacent travel lanes with some form of lane delineation, such as a six-inch to eight-inch white line or a double 4-inch white line. A marked buffer may also be used to provide additional separation.Refer to location B in the figure.

» Pedestrian lanes should be marked with the appropriate pavement legend markings in white color, positioned laterally in the center of the lane (MUTCD, 2009, p. 415). Refer to location C in the figure.

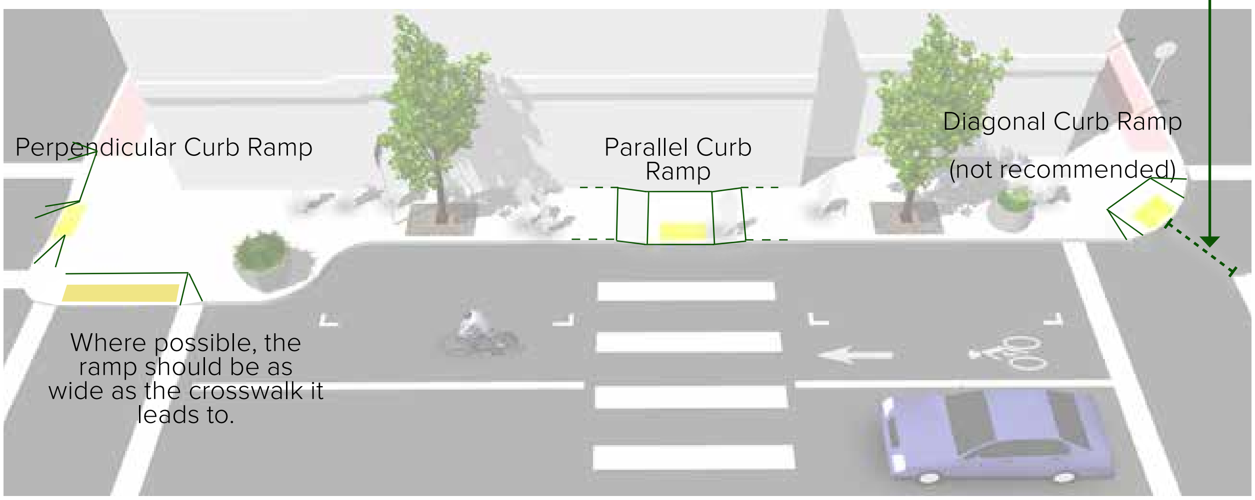
» Pedestrian Warning Sign (W11-2) paired with an "ON ROADWAY" legend sub plaque may be used to indicate to drivers to expect pedestrians within the paved road surface. Refer to location D in the figure.

ADA Accessibility

Infrastrucutre within the public right of way must be accessible and comply with the Americans with Disabilities Act (ADA) reguirements. Geometric design must accommodate users with of all abilities, including blind pedestrians and those using a mobility device.

Diagonal ramps shall include a clear space of at least 48" within the crosswalk for user maneuverability

Curb ramps shall be located so that they do not project into vehicular traffic lanes, parking spaces, or parking access aisles. Three configurations are illustrated below.



Crosswalk spacing not to scale. For illustration purposes only.

Typical Application

- » At all crossing locations, including mid-block crossings.
- » Refer to the following documents for more information on ADA accessibility:
    - » United States Access Board. Accessibility Guidelines for Buildings and Facilities. 2002
    - » United States Access Board. Proposed Accessibility Guidelines for Pedestrian Facilities in the Public-Right-of-Way. 2013
    - » USDOJ. ADA Standards for Accessible Design. 2010.

Design Features

- » The level landing at the top of a ramp shall be at least four feet long and at least the same width as the ramp itself.
- » The ramp shall slope no more than 1:12 , with a maximum cross slope of 2.0%.
- » If the ramp lands on a dropped landing within the sidewalk or corner area where someone in a wheelchair may have to change direction, the landing must be a minimum of five feet long and at least as wide as the ramp, although a width of five feet is preferred.

PEDESTRIAN CROSSING TREATMENTS

Pedestrian infrastructure includes any physical element that enhances the pedestrian experience. Sidewalks are the most fundamental element of the pedestrian network and should be designed not only for movement, but to provide space for commercial activities (such as cafe seating and retail displays), street trees, lighting, and other useful amenities. The streetscape can be improved with green infrastructure that enhances the aesthetic qualities of a street and also provides environmental benefits, while parklets provide additional space for seating within the public right-of-way. It is also important that pedestrians can safely navigate conflict zones, such as driveways and construction zones.

Pedestrian Crossing Location and Facility Selection

The specific type of treatment at a crossing may range from a simple marked crosswalk to full traffic signals or grade separated crossings. Crosswalk lines should not be used indiscriminately, and appropriate selection of crossing treatments should be evaluated in an engineering study done before a marked crosswalk is installed. The engineering study should consider the number of lanes, the presence or lack of a median, the distance from adjacent signalized intersections, the pedestrian volumes and delays, the average daily traffic (ADT), the posted or statutory speed limit or 85th-percentile speed, the geometry of the location, the possible consolidation of multiple crossing points, the availability of street lighting, and other appropriate factors.

Midblock Crossings

Midblock crossings are an important street design element for pedestrians. They can provide a legal crossing at locations where pedestrians want to travel, and can be safer than crossings at intersections because traffic is only moving in two directions. Locations where midblock crossings should be considered include:

- Blocks longer than 600 feet with destinations on both sides of the street.
- Locations with heavy pedestrian traffic, such as schools, shopping centers.
- Midblock transit stops, where transit riders must cross the street on one leg of their journey.

Crossing Treatment Selection

PEDESTRIAN CROSSING CONTEXTUAL GUIDANCE At unsignalized locations	Local Streets 15-25 mph		Collector Streets 25-30 mph			Arterial Streets 30-45 mph							
FACILITY TYPE	2 lane	3 lane	2 lane	2 lane with median refuge	3 lane	2 lane	2 lane with median refuge	3 lane	4 lane	4 lane with median refuge	5 lane	6 lane	6 lane with median refuge
Crosswalk Only (high visibility)	✓	✓	EJ	EJ	X	EJ	EJ	X	X	X	X	X	X
Crosswalk with warning signage and yield lines	EJ	✓	✓	✓	✓	EJ	EJ	EJ	X	X	X	X	X
Stop Sign Controlled	✓	✓	EJ	EJ	EJ	EJ	EJ	EJ	X	X	X	X	X
Active Warning Beacon	X	EJ	✓	✓	✓	✓	✓	✓	X	✓	X	X	X
Hybrid Beacon	X	X	EJ	EJ	EJ	EJ	✓	✓	✓	✓	✓	✓	✓
Full Traffic Signal	X	X	EJ	EJ	EJ	EJ	EJ	EJ	✓	✓	✓	✓	✓
Grade separation	X	X	EJ	EJ	EJ	X	EJ	EJ	✓	✓	✓	✓	✓

LEGEND	
Most Desirable	✓
Engineering Judgement	EJ
Not Recommended	X


1 Marked Crosswalks

5 Pedestrian Hybrid Beacon


2 Crosswalk with Warning Signage


6 Full Traffic Signal

3 Stop Sign Controlled

7 Grade Separation


4 Active Warning Beacon (RRFB)

Marked Crosswalks

A marked crosswalk signals to motorists that they must stop for pedestrians and encourages pedestrians to cross at designated locations. Installing crosswalks alone will not necessarily make crossings safer especially on multi-lane roadways. At mid-block locations, crosswalks can be marked where there is a demand for crossing and there are no nearby marked crosswalks.

Typical Application

All crosswalks should be marked at signalized intersections. At unsignalized intersections, crosswalks may be marked under the following conditions:

- At a complex intersection, to orient pedestrians in finding their way across.
- At an offset intersection, to show pedestrians the shortest route across traffic with the least exposure to vehicular traffic and traffic conflicts.
- At an intersection with visibility constraints, to position pedestrians where they can best be seen by oncoming traffic.
- At an intersection within a school zone on a walking route.

Design Features

- The crosswalk should be located to align as closely as possible with the through pedestrian zone of the sidewalk corridor.
- The landing at the top of a ramp shall be at least four feet long and at least the same width as the ramp itself.
- The ramp shall slope no more than 8.33%, with a maximum cross slope of 2.0%.
- If the ramp runs directly into a crosswalk, the landing at the bottom will be in the roadway.
- If the ramp lands on a dropped landing within the sidewalk or corner area where someone in a wheelchair may have to change direction, the landing must be a minimum of five feet long and at least as wide as the ramp itself.

Marked crosswalks are used to raise driver awareness of pedestrian and pathway crossings and help direct users to preferred crossing locations.

Further Considerations

Continental crosswalk markings should be used at crossings with high pedestrian use or where vulnerable pedestrians are expected, including: school crossings, across arterial streets for pedestrian-only signals, at mid-block crosswalks, and at intersections where there is expected high pedestrian use and the crossing is not controlled by signals or stop signs. High-visibility crosswalks are not appropriate for all locations. See intersection signalization for a discussion of enhancing pedestrian crossings.

Because the effectiveness of marked crossings depends entirely on their visibility, maintaining marked crossings should be a high priority. Thermoplastic markings offer increased durability than conventional paint.

Some cities prohibit omitting or removing a marked crosswalk at intersections in order to require a three-stage pedestrian crossing. Intersections with three-stage crossings lead to arduous and increased crossing distances, pedestrian frustration, encourages jaywalking, and exhibits modal bias favoring motor vehicle level-of-service over other modes.

Crash Reduction

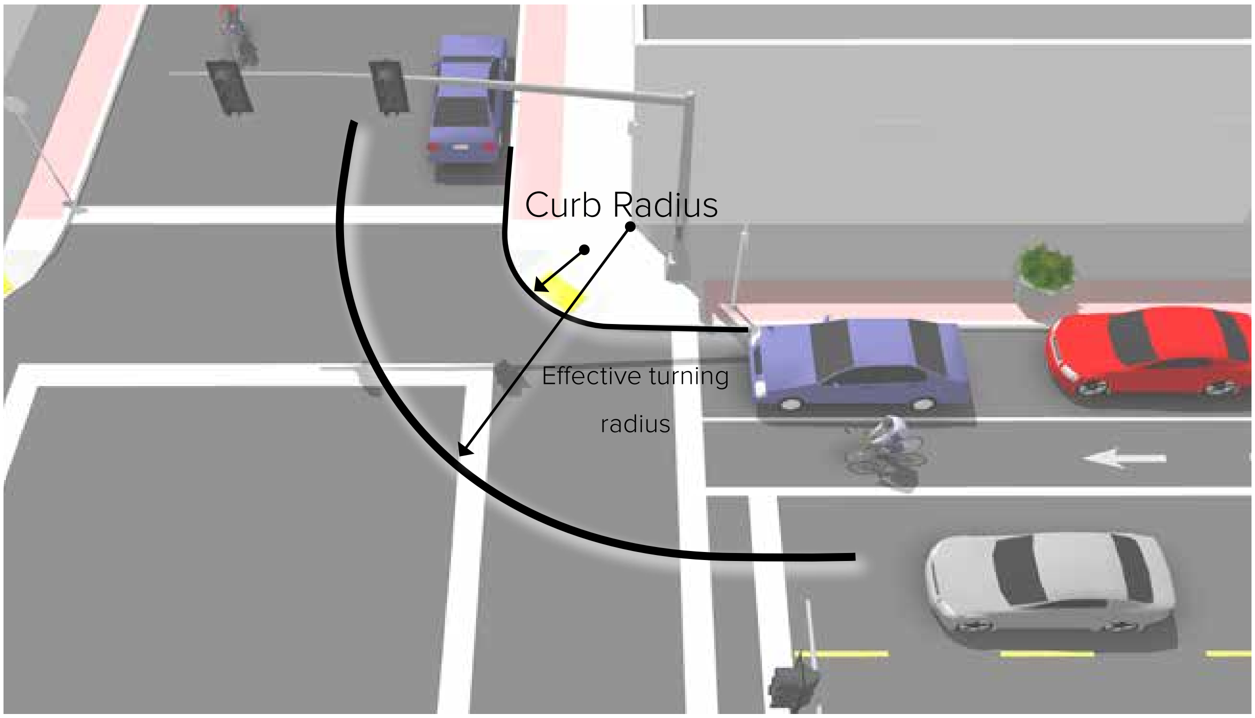
At an unsignalized four-leg intersection with no marked crosswalks and stop control for the minor street, installing markings to facilitate crossing of a major street reduced crash likelihood by 65% (CMF ID: 3019). The number of travel lanes for the major street ranged from two to eight.

Materials and Maintenance

Because the effectiveness of marked crossings depends entirely on their visibility, maintaining marked crossings should be a high priority. Thermoplastic markings offer increased durability than conventional paint.

Minimizing Curb Radii

The size of a curb's radius can have a significant impact on pedestrian comfort and safety. A smaller curb radius provides more pedestrian area at the corner, allows more flexibility in the placement of curb ramps, results in a shorter crossing distance and requires vehicles to slow more on the intersection approach. During the design phase, the chosen radius should be the smallest possible for the circumstances.



Typical Application

- Several factors govern the choice of curb radius in any given location. These include the desired pedestrian area of the corner, traffic turning movements, street classifications, design vehicle turning radius, intersection geometry, and whether there is parking or a bike lane (or both) between the travel lane and the curb.
- Improperly designed curb radii at corners may be subject to damage by large trucks.

Design Features

- The radius may be as small as three feet where there are no turning movements, or five feet where there are turning movements, adequate street width, and a larger effective turning radius created by parking or bike lanes.

Crash Reduction

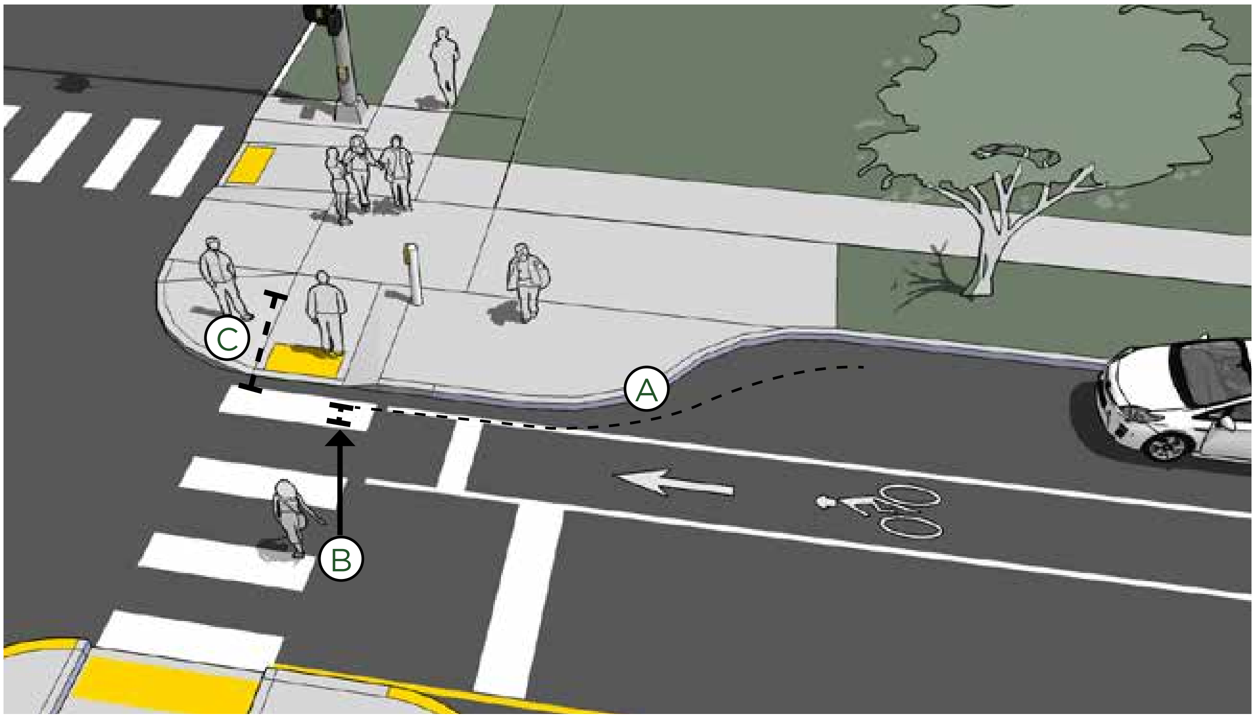
Minimizing the size of a corner radius is critical to creating compact intersections with safe turning speeds. Smaller corner radii require motor vehicles to reduce speeds when turning.

Materials and Maintenance

Improperly designed curb radii at corners may be subject to damage by large trucks.

Curb Extensions

Curb extensions minimize pedestrian exposure during crossing by shortening crossing distance and giving pedestrians a better chance to see and be seen before committing to crossing.



Typical Application

- Within parking lanes appropriate for any crosswalk where it is desirable to shorten the crossing distance and there is a parking lane adjacent to the curb.
- May be possible within non-travel areas on roadways with excess space.
- Particularly helpful at midblock crossing locations.
- Curb extensions should not impede bicycle travel in the absence of a bike lane.

Design Features

- For purposes of efficient street sweeping, the minimum radius for the reverse curves of the transition is 10 feet and the two radii should be balanced to be nearly equal. Refer to location A in the figure.
- When a bike lane is present, the curb extensions should terminate one ft short of the parking lane to maximize bicyclist safety. Refer to location B in the figure.
- Reduces pedestrian crossing distance by six to eight feet. Refer to location C in the figure.
- Planted curb extensions may be designed as a bioswale for stormwater management.

Crash Reduction

There are no Crash Modification Factors (CMFs) available for this treatment.

Materials and Maintenance

Planted curb extensions may be designed as a bioswale, a vegetated system for stormwater management.

Advance Stop Bar

Advance stop bars increase pedestrian comfort and safety by stopping motor vehicles well in advance of marked crosswalks, allowing vehicle operators a better line of sight of pedestrians and giving inner lane motor vehicle traffic time to stop for pedestrians.

Typical Application

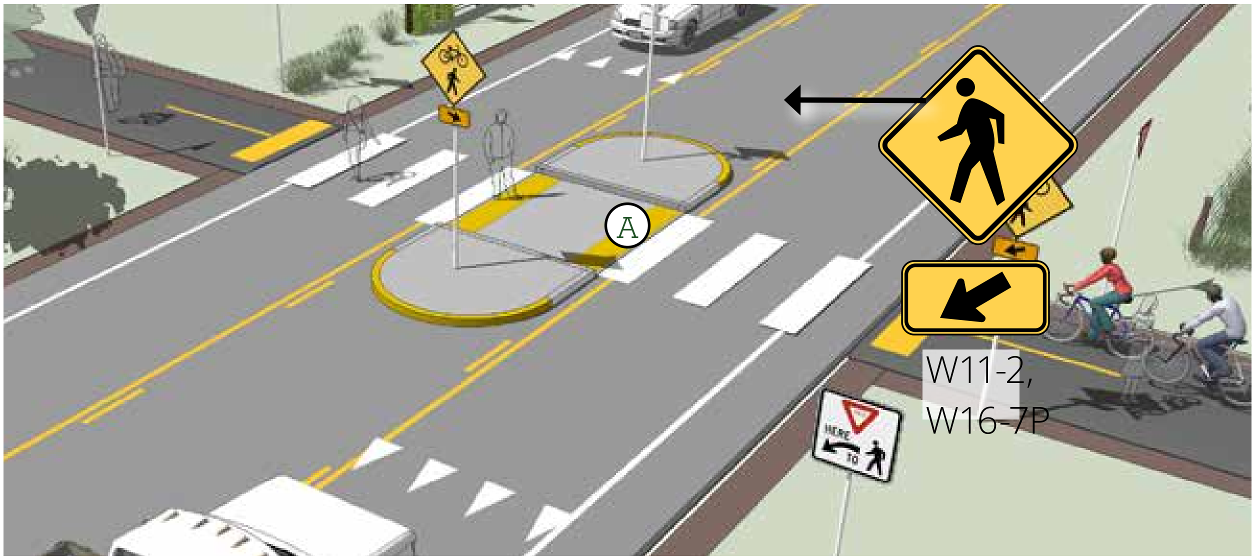
- On streets with at least two travel lanes in each direction.
- Prior to a marked crosswalk
- In one or both directions of motor vehicle travel

Design Features

- Recommended 15-50 feet or more in advance of the crosswalk
- A “Stop Here for Pedestrians” sign should accompany the advance stop bar
- If a bicycle lane is present, mark the advance stop bar to permit bicyclists to stop at the crosswalk ahead of the stop bar.
- If the State law requires drivers to YIELD to pedestrians in crosswalks, a Yield Line marking must be used rather than a stop line in these cases.

Median Refuge Island

Median refuge islands are located at the mid-point of a marked crossing and help improve pedestrian safety by allowing pedestrians to cross one direction of traffic at a time. Refuge islands minimize pedestrian exposure by shortening crossing distance and increasing the number of available gaps for crossing.



Typical Application

» Can be applied on any roadway with a center turn lane or median that is at least six feet wide.

» May be appropriate on multi-lane roadways depending on speeds and volumes. Consider configuration with active warning beacons for improved yielding compliance.

» Appropriate at signalized or unsignalized crosswalks.

Design Features

» The island must be accessible, preferably with at-grade passage through the island rather than ramps and landings. Detectable warning surfaces must be full-width and two feet deep to warn blind pedestrian. Refer to location A in the figure.

» Requires six-foot width between travel lanes (eight to ten feet preferred to accommodate bikes with trailers and wheelchair users) and 20-foot length (40-foot preferred). Clear width of four feet required, but preferably same width as crosswalk.

» On streets with speeds higher than 25 mph, there should also be double centerline marking, reflectors, and "KEEP RIGHT" signage.

Crash Reduction

Based on a comparison of crash rates on arterials with three to eight lanes and minimum 15,000 ADT, median refuge islands were found to reduce vehicle/pedestrian collisions by 46 percent at marked crosswalks (CMF ID: 75). This test controlled for pedestrian and vehicular traffic volumes.

Materials and Maintenance

Refuge islands may collect road debris and may require somewhat frequent maintenance. Refuge islands should be visible to snow plow crews and should be kept free of snow berms that block access..

Active Warning Beacons

Active warning beacons are user actuated illuminated devices designed to increase motor vehicle yielding compliance at crossings of multi lane or high volume roadways. Types of active warning beacons include conventional circular yellow flashing beacons, in-roadway warning lights, or pedestrian activated beacons.

Typical Application

» Warning beacons shall not be used at crosswalks controlled by YIELD signs, STOP signs, or traffic signals.

» Warning beacons shall initiate operation based on pedestrian or bicyclist actuation and shall cease operation at a predetermined time after actuation or, with passive detection, after the pedestrian or bicyclist clears the crosswalk. Beacons shall be unlit when not activated.

Crash Reduction

A study of the effectiveness of going from a no-beacon arrangement to a two-beacon activated flashing beacon installation increased yielding from 18 percent to 81 percent. A four-beacon arrangement raised compliance to 88 percent. Additional studies over long term installations show little to no decrease in yielding behavior over time.

Materials and Maintenance

Depending on power supply, maintenance can be minimal. Solar power is often used, so lights should run for years without issue.

Design Features

» Types of active warning beacons include conventional circular yellow flashing beacons, in-roadway warning lights, or activated flashing beacons.

» Activated flashing beacons have the most increased compliance of all the warning beacon enhancement options.

» Installations of active warning beacons on median islands improves driver yielding behavior.

» Rectangular Rapid Flashing Beacons (RRFB) have been rescinded by FHWA because the MUTCD prohibits the use of patented devices. RRFBs may not be installed after December 21, 2017.

» FHWA recommends the use of Pedestrian Activated Beacons, with two circular-shaped yellow lights that flash in an alternating pattern, with a flashrate of 50-60 times per minute and an illuminated period of each flash a minimum of ½ and maximum of 2/3 of the total cycle.

Pedestrian Hybrid Beacon

A hybrid beacon, previously known as a High-intensity Activated CrosswalK (HAWK), consists of a signal-head with two red lenses over a single yellow lens on the major street, and pedestrian and/or bicycle signal heads for the minor street. There are no signal indications for motor vehicles on the minor street approaches. The signal is only activated when a pedestrian and/or bicyclist is present, resulting in minimal delay for motor vehicle traffic.

Typical Application

- Hybrid beacons are used to improve non-motorized crossings of major streets in locations where side-street volumes do not support installation of a conventional traffic signal (or where there are concerns that a conventional signal will encourage additional motor vehicle traffic on the minor street).
- May also be used at mid-block crossing locations.
- May be used at shared use path and trail crossings.

Design Features

May be installed without meeting traffic signal control warrants if roadway speed and volumes are excessive for comfortable user crossing.

- If installed within a signal system, signal engineers should evaluate the need for the hybrid signal to be coordinated with other signals.
- Parking and other sight obstructions should be prohibited for at least 100 feet in advance of and at least 20 feet beyond the marked crosswalk to provide adequate sight distance.

Crash Reduction

A 2010 FHWA before-and-after study found that pedestrian hybrid beacons led to a 29% reduction in total crashes, a 69% reduction in pedestrian crashes, and a 15% reduction in severe crashes.

http://www.fhwa.dot.gov/publications/research/safety/10042/10042.pdf

Materials and Maintenance

Hybrid beacons are subject to the same maintenance needs and requirements as standard traffic signals. Signing and striping need to be maintained to help users understand any unfamiliar traffic control.

BICYCLE FACILITY SELECTION

Bicycle facilities provide a dedicated place for people to bicycle. Facilities include on street facilities, as well as intersections and crossing locations, which should be located in convenient and safe places for bike access. Providing bicycle facilities that meet the needs of people of all ages and abilities is an important part of creating a multi-modal network for the community.

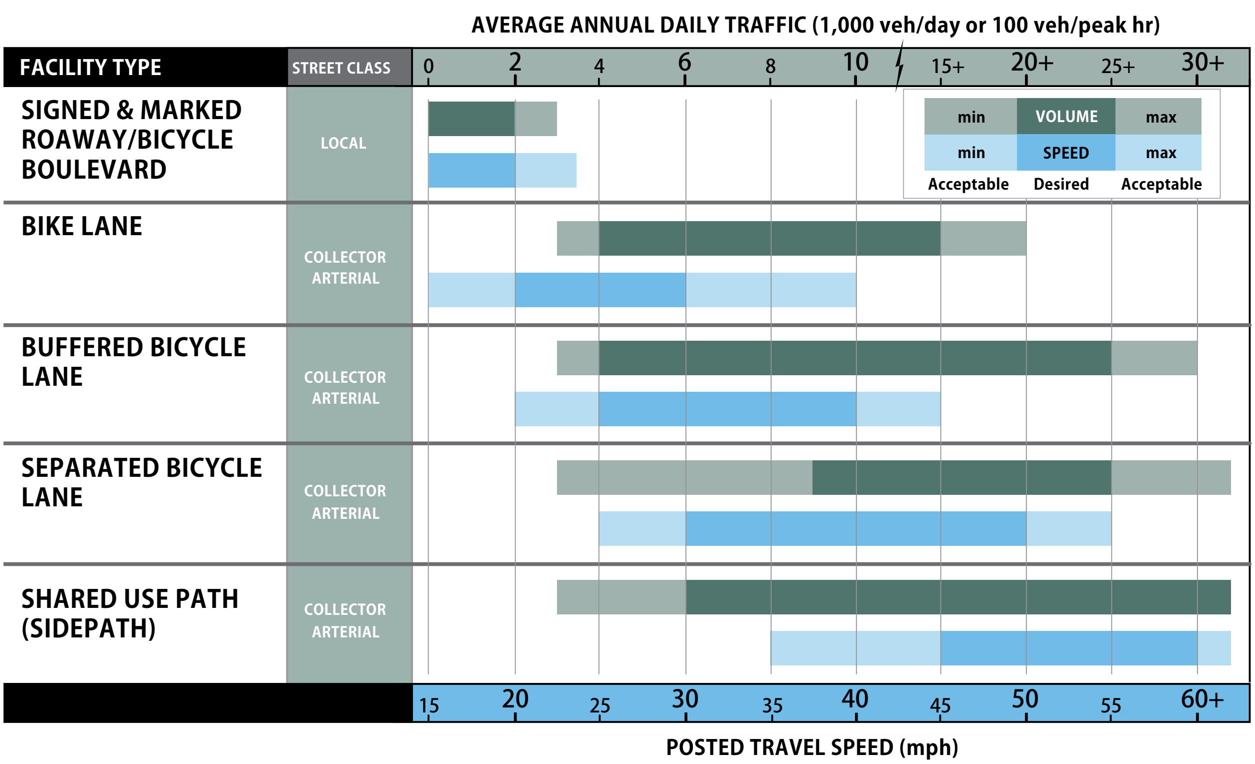
Facility Selection

Selecting the best bikeway facility type for a given roadway can be challenging, due to the range of factors that influence bicycle users' comfort and safety. There is a significant impact on cycling comfort when the speed differential between bicyclists and motor vehicle traffic is high and motor vehicle traffic volumes are high.

Facility Selection Table

As a starting point to identify a preferred facility, the chart below can be used to determine the recommended type of bikeway to be provided in particular roadway speed and volume situations. To use this chart, identify the appropriate daily traffic volume and travel speed on or the existing or proposed roadway, and locate the facility types indicated by those key variables.

Other factors beyond speed and volume which affect facility selection include traffic mix of automobiles and heavy vehicles, the presence of on-street parking, intersection density, surrounding land use, and roadway sight distance. These factors are not included in the facility selection chart below, but should always be considered in the facility selection and design process.



Facility Classification

Consistent with bicycle facility classifications throughout the nation, these Bicycle Facility Design Guidelines identify the following classes of facilities by degree of separation from motor vehicle traffic.

Shared roadways are bikeways where bicyclists and cars operate within the same travel lane, either side by side or in single file depending on roadway configuration. The most basic type of bikeway is a signed shared roadway. This facility provides continuity with other bicycle facilities (usually bike lanes), or designates preferred routes through high-demand corridors.

Shared roadways may also be designated by pavement markings, signage and other treatments including directional signage, traffic diverters, chicanes, chokers and /or other traffic calming devices to reduce vehicle speeds or volumes. Such treatments often are associated with **Bicycle Boulevards**.

On-Street Bikeways, such as conventional or buffered bike lanes, use signage and striping to delineate the right-of-way assigned to bicyclists and motorists. Bike lanes encourage predictable movements by both bicyclists and motorists.

Another variant of on-street bikeway is **Separated Bike Lanes** which are exclusive bike facilities that combine the user experience of a separated path with the on-street infrastructure of conventional bike lanes.

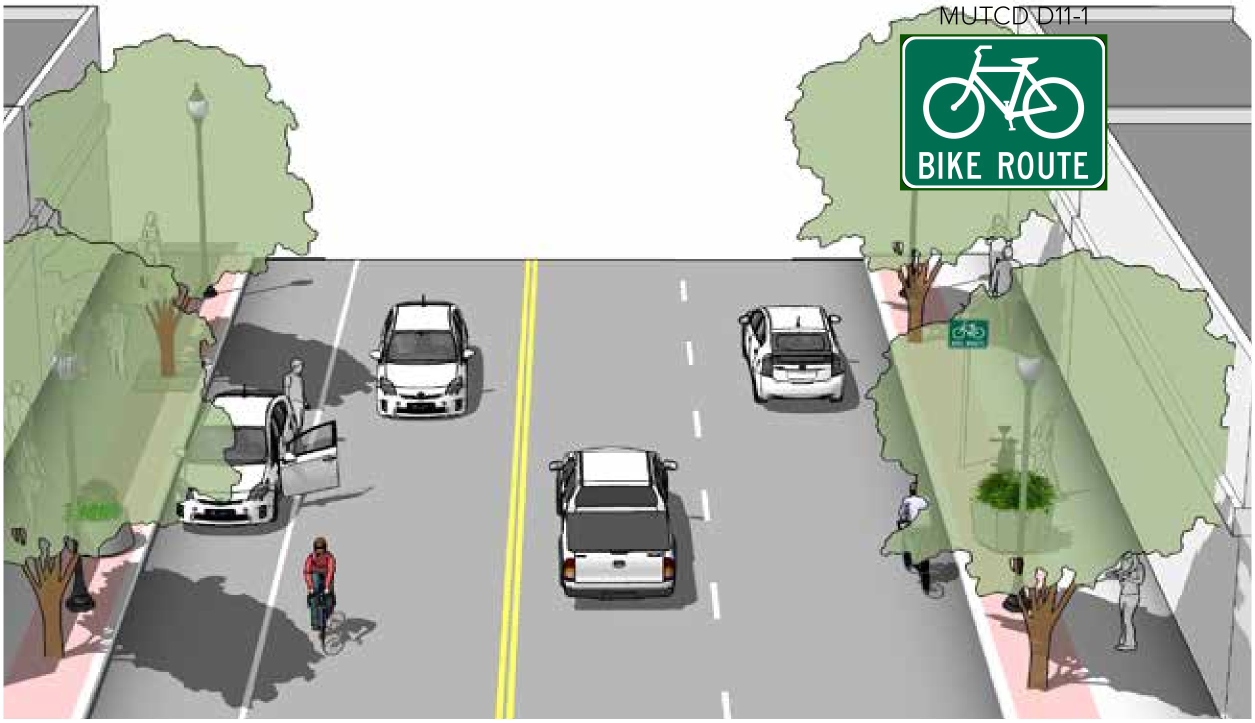
Shared Use Paths are facilities separated from roadways for use by bicyclists and pedestrians.

SHARED ROADWAYS

On shared roadways, bicyclists and motor vehicles use the same roadway space. These facilities are typically used on roads with low speeds and traffic volumes, however they can be used on higher volume roads with wide outside lanes or shoulders. A motor vehicle driver will usually have to cross over into the adjacent travel lane to pass a bicyclist, unless a wide outside lane or shoulder is provided.

Signed Shared Roadways

Signed shared roadways are facilities shared with motor vehicles. They are typically used on roads with low speeds and traffic volumes, however can be used on higher volume roads with wide outside lanes or shoulders. A motor vehicle driver will usually have to cross over into the adjacent travel lane to pass a bicyclist, unless a wide outside lane or shoulder is provided.



Typical Application

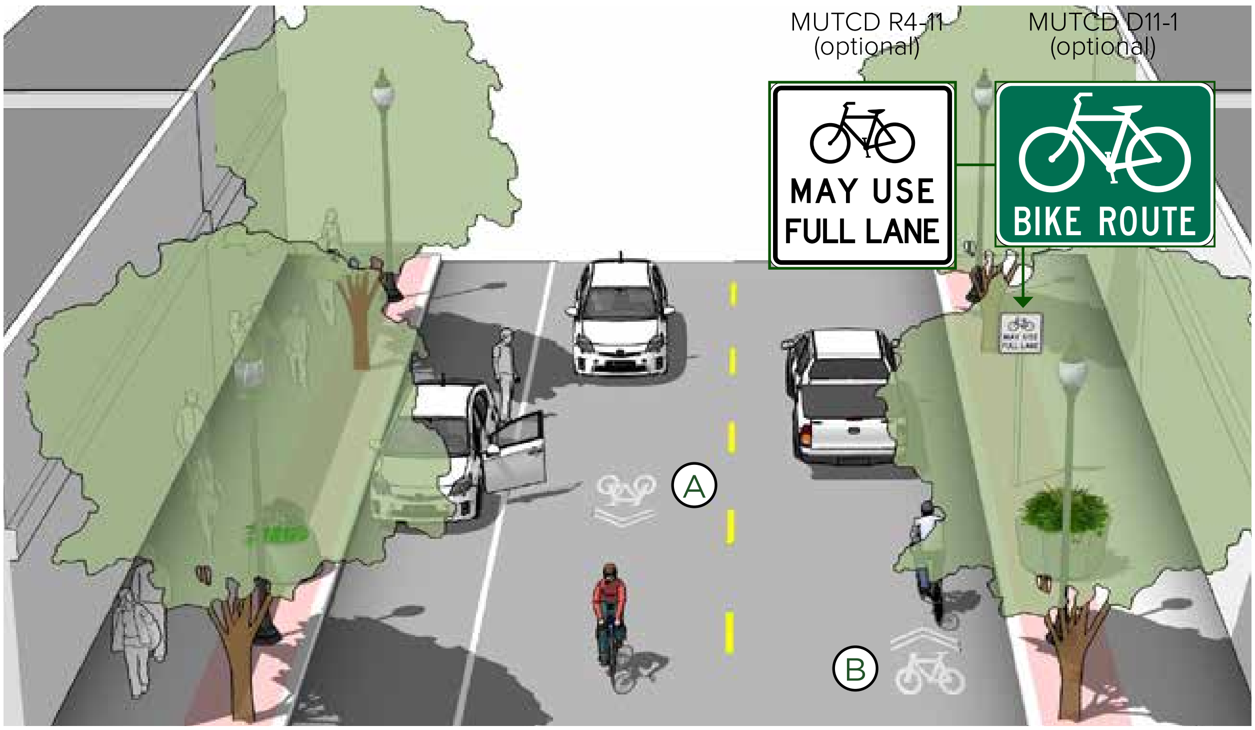
- » Signed Shared Roadways serve either to provide continuity with other bicycle facilities (usually bike lanes) or to designate preferred routes through high-demand corridors.
- » This configuration differs from a bike boulevard due to a lack of traffic calming, wayfinding, pavement markings and other enhancements designed to provide a higher level of comfort for a broad spectrum of users.

Design Features

- » Lane width varies depending on roadway configuration.
- » Bike route signage (D11-1) should be applied at intervals frequent enough to keep bicyclists informed of changes in route direction and to remind motorists of the presence of bicyclists. Commonly, this includes placement at:
    - » Beginning or end of Bicycle Route.
    - » At major changes in direction or at intersections with other bicycle routes.
    - » At intervals along bicycle routes not to exceed ½ mile.

Marked Shared Roadway

A marked shared roadway is a general purpose travel lane marked with shared lane markings (SLM) used to encourage bicycle travel and proper positioning within the lane.



Typical Application

» In constrained conditions, the SLMs are placed in the middle of the lane. On a wide outside lane, the SLMs can be used to promote bicycle travel to the right of motor vehicles.

» In all conditions, SLMs should be placed outside of the door zone of parked cars.

Design Features

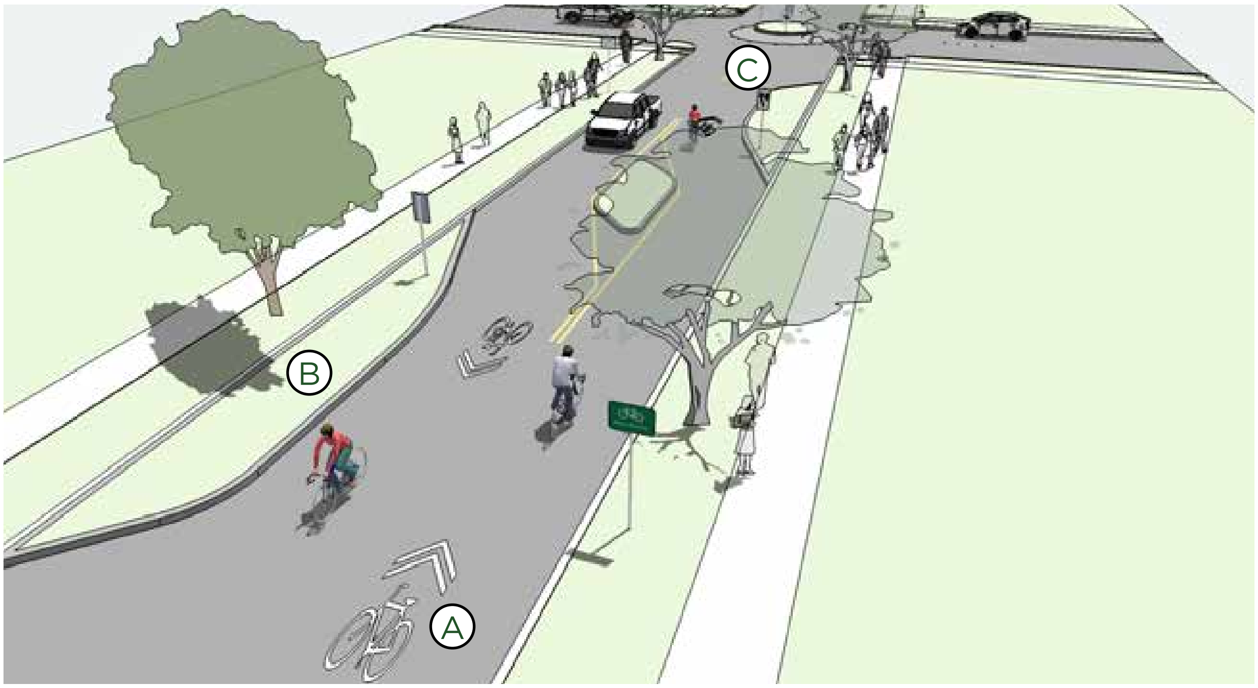
» May be used on streets with a speed limit of 35 mph or under. Lower than 30 mph speed limit preferred.

» In constrained conditions, preferred placement is in the center of the travel lane to minimize wear and promote single file travel. Refer to location A in the figure.

» Minimum placement of SLM marking centerline is 11 feet from edge of curb where on-street parking is present, four feet from edge of curb with no parking. If parking lane is wider than seven and a half feet, the SLM should be moved further out accordingly. Refer to location B in the figure.

Bicycle Boulevards

Bicycle boulevards are low-volume, low-speed streets modified to enhance bicyclist comfort by using treatments such as signage, pavement markings, traffic calming and/or traffic reduction, and intersection modifications. These treatments allow through movements of bicyclists while discouraging similar through-trips by non-local motorized traffic.



Typical Application

- Parallel with and in close proximity to major thoroughfares (1/4 mile or less).
- Follow a desire line for bicycle travel that is ideally long and relatively continuous (two to five miles).
- Avoid alignments with excessive zigzag or circuitous routing. The bikeway should have less than 10 percent out of direction travel compared to shortest path of primary corridor.
- Streets with travel speeds at 25 mph or less and with traffic volumes of fewer than 3,000 vehicles per day.

Design Features

- Signs and pavement markings are the minimum treatments necessary to designate a street as a bicycle boulevard. Refer to location A in the figure.
- Implement volume control treatments based on the context of the bicycle boulevard, using engineering judgment. Target motor vehicle volumes range from 1,000 to 3,000 vehicles per day. Refer to location B in the figure.
- Intersection crossings should be designed to enhance safety and minimize delay for bicyclists. Refer to location C in the figure.

BICYCLE BOULEVARDS

Bicycle boulevards are established on streets that improve connectivity to key destinations and provide a direct, low-stress route for bicyclists, with low motorized traffic volumes and speeds, designated and designed to give bicycle travel priority over other modes.

TRAFFIC CALMING

Streets along classified neighborhood bikeways may require additional traffic calming measures to discourage through trips by motor vehicles.

Further Considerations

Bicycle boulevard retrofits to local streets are typically located on streets without existing signalized accommodation at crossings of collector and arterial roadways. Without treatments for bicyclists, these intersections can become major barriers along the bicycle boulevard and compromise safety.

Traffic calming can deter motorists from driving on a street. Anticipate and monitor vehicle volumes on adjacent streets to determine whether traffic calming results in inappropriate volumes. Traffic calming can be implemented on a trial basis.

Crash Reduction

In a comparison of vehicle/cyclist collision rates on traffic-calmed side streets signed and improved for cyclist use, compared to parallel and adjacent arterials with higher speeds and volumes, the bicycle boulevard as found to have a crash reduction factor of 63 percent, with rates two to eight times lower when controlling for volume (CMF ID: 3092).

Construction Costs

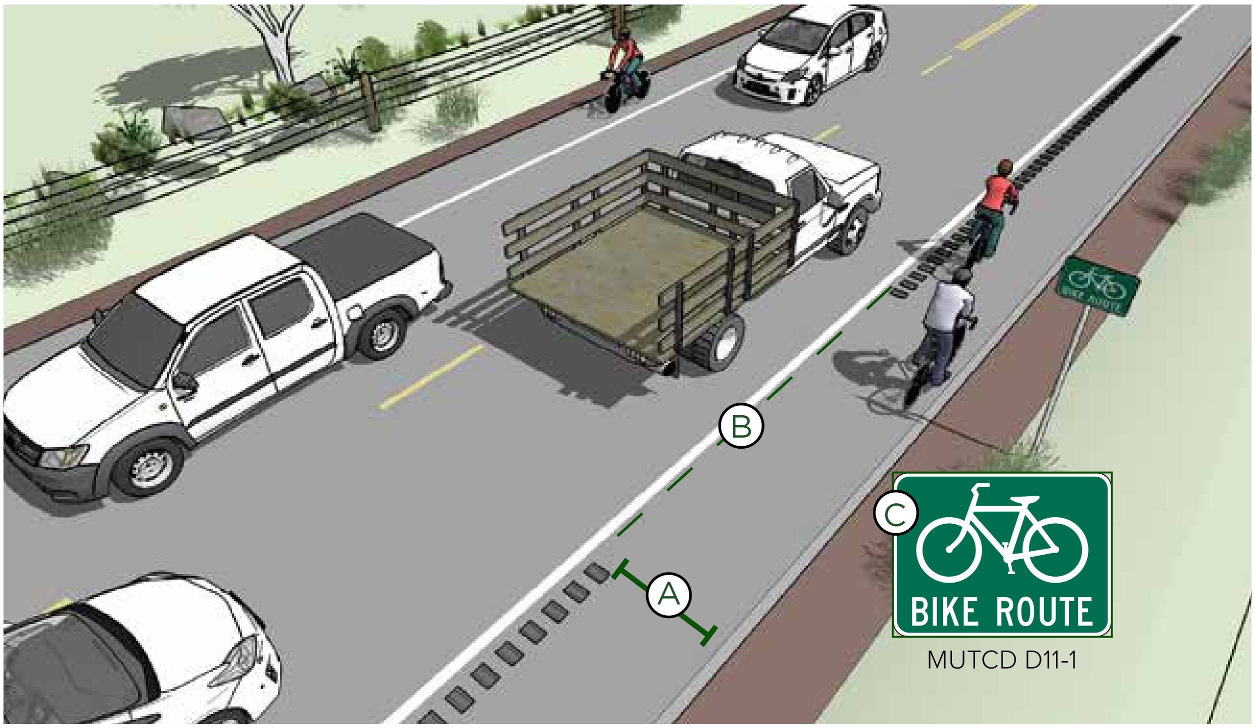
Costs vary depending on the type of treatments proposed for the corridor. Simple treatments such as wayfinding signage and markings are most cost-effective, but more intensive treatments will have greater impact at lowering speeds and volumes, at a higher cost.

ON-STREET BIKEWAYS

Designated for bicycle travel, on-street bikeways are separated from vehicle travel lanes by striping, and can include pavement stencils and other treatments. On-street bikeways may be most appropriate on collector streets with single-lane of traffic in each direction where moderate traffic volumes and speeds are too high for shared-roadway use

Shoulder Bikeways

Typically found in less-dense areas, shoulder bikeways are paved roadways with striped shoulders (4'+) wide enough for bicycle travel. Shoulder bikeways often, but not always, include signage alerting motorists to expect bicycle travel along the roadway.



Typical Application

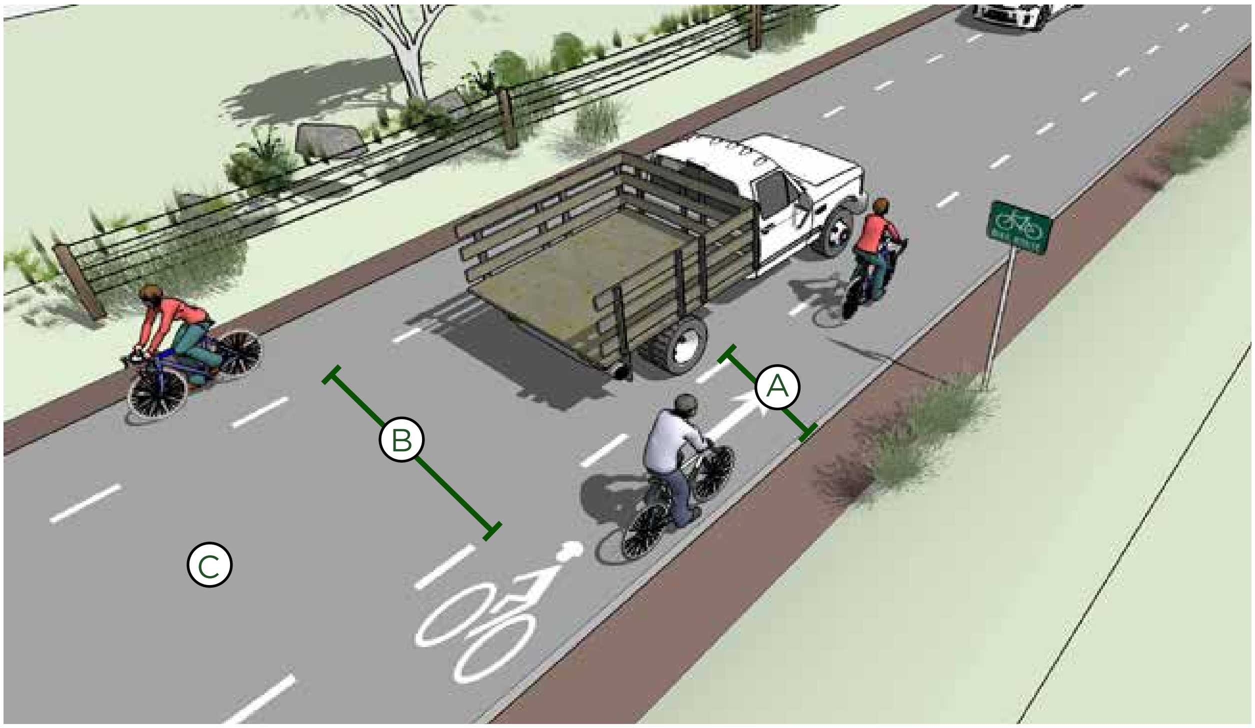
- Located in more rural environments where there are no curbs or gutters.
- Suitable for roadways with higher speeds and lower bicycle volumes.
- Shoulder bikeways should be considered a temporary treatment, with full bike lanes planned for construction when the roadway is widened or completed with curb and gutter.
- Shoulder bikeways are different from bike lanes, as bike lanes are for the exclusive use of cyclists. Shoulder bikeways, while intended for bicycle use, may also be used for a variety of safety and maintenance needs, such as a place for stopped vehicles and for storm water discharge.

Design Features

- A minimum of four feet of ridable surface should be available for bicycle travel (AASHTO 2012) . Refer to location A in the figure.
- Rumble strips are not recommended on shoulders used by bicyclists unless there is a minimum four-foot clear path. Twelve-foot gaps every 40-60 feet should be provided to allow access as needed. Refer to location B in the figure.
- MUTCD D11-1 "Bike Route" wayfinding signage is optional. Refer to location C in the figure.

Advisory Bike Lanes

Advisory bike lanes are bicycle priority areas delineated by broken white lines, separate from a center one-lane two-way travel area. Motorists may only enter the bicycle zone when no bicycles are present. Motorists must overtake bicyclists with caution due to potential oncoming traffic.



Typical Application

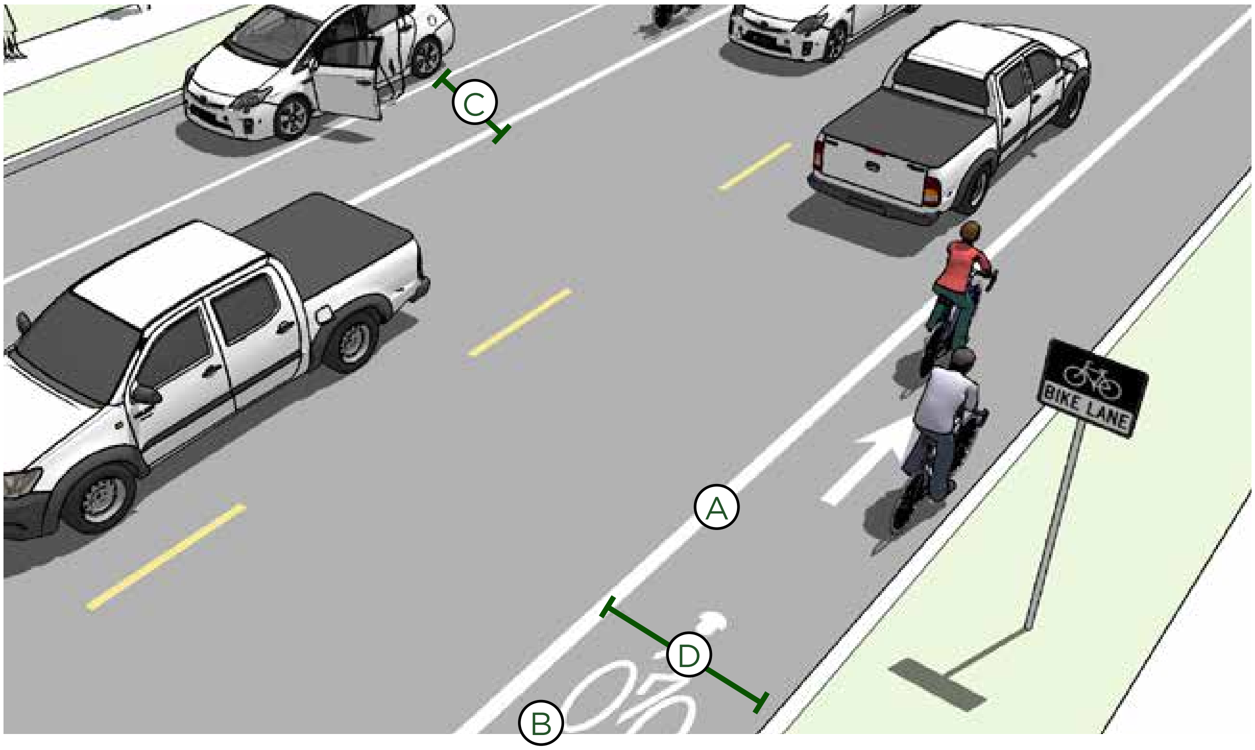
- Most appropriate on streets where motor vehicle traffic volumes are low-moderate (1,500-4,500 ADT), and where there is insufficient room for conventional bicycle lanes.
- If on-street parking is present, parking lanes should be highly utilized or occupied with curb extensions to separate the parking lane from the advisory bike lane.
- This treatment may be appropriate on roadways with low volumes if the road is straight with few bends, inclines or sightline obstructions.

Design Features

- Advisory bike lane width of six feet, five feet minimum. Refer to location A in the figure.
- The automobile zone should be configured narrowly enough so that two cars cannot pass each other in both directions without crossing the advisory lane line. Minimum two-way motor vehicle travel lane width of 16 feet. Refer to location B in the figure.
- No centerline on roadway. Refer to location C in the figure.

Bicycle Lanes

On-street bike lanes designate an exclusive space for bicyclists through the use of pavement markings and signs. The bike lane is located directly adjacent to motor vehicle travel lanes and is used in the same direction as motor vehicle traffic. Bike lanes are typically on the right side of the street, between the adjacent travel lane and curb, road edge or parking lane.



Typical Application

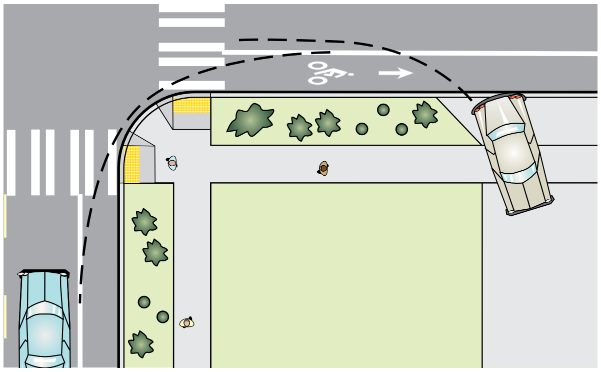
- » Bike lanes may be used on any street with adequate space, but are most effective on streets with moderate traffic volumes ≥ 6,000 ADT (≥ 3,000 preferred).
- » Bike lanes are most appropriate on streets with moderate speeds ≥ 25 mph.
- » Appropriate for skilled adult riders on most streets.
- » May be appropriate for children when configured as six-foot wide lanes or greater on lower-speed, lower-volume streets with one lane in each direction.

Design Features

- » Mark inside line with six-inch stripe. Mark four-inch parking lane line or "Ts".[1] Refer to location A in the figure.
- » Include a bicycle lane marking (MUTCD Figure 9C-3) at the beginning of blocks and at regular intervals along the route (MUTCD 9C.04). Refer to location B in the figure.
- » Six-foot width preferred adjacent to on-street parking (five-foot min.). Refer to location C in the figure.
- » Five to six feet preferred adjacent to curb and gutter (four feet min.) or four feet more than the gutter pan width. Refer to location D in the figure.

1 Studies have shown that marking the parking lane encourages people to park closer to the curb. FHWA. Bicycle Countermeasure Selection System. 2006.

PLACE BIKE LANE SYMBOLS TO REDUCE WEAR



Bike lane word, symbol, and/or arrow markings (MUTCD Figure 9C-3) shall be placed outside of the motor vehicle tread path in order to minimize wear from the motor vehicle path (NACTO 2012).

BICYCLE LANE

Bicycle lanes provide an exclusive space, but may be subject to unwanted encroachment by motor vehicles.

Further Considerations

On high speed streets (≥ 40 mph) the minimum bike lane should be six feet**.**

On streets where bicyclists passing each other is to be expected, where high volumes of bicyclists are present, or where added comfort is desired, consider providing extra wide bike lanes up to seven feet wide, or configure as a buffered bicycle lane.

It may be desirable to reduce the width of general purpose travel lanes in order to add or widen bicycle lanes.

On multi-lane and/or high speed streets, the most appropriate bicycle facility to provide for user comfort may be buffered bicycle lanes or physically separated bicycle lanes.

MANHOLE COVERS AND GRATES:

Manhole surfaces should be manufactured with a shallow surface texture in the form of a tight, nonlinear pattern

If manholes or other utility access boxes are to be located in bike lanes within 50 feet of intersections or within 20 feet of driveways or other bicycle access points, special manufactured permanent nonstick surfaces will be required to ensure a controlled travel surface for cyclists breaking or turning.

Manholes, drainage grates, or other obstacles should be set flush with the paved roadway. Roadway surface inconsistencies pose a threat to safe riding conditions for bicyclists. Construction of manholes, access panels or other drainage elements will be constructed with no variation in the surface. The maximum allowable tolerance in vertical roadway surface will be 1/4 of an inch.

Crash Reduction

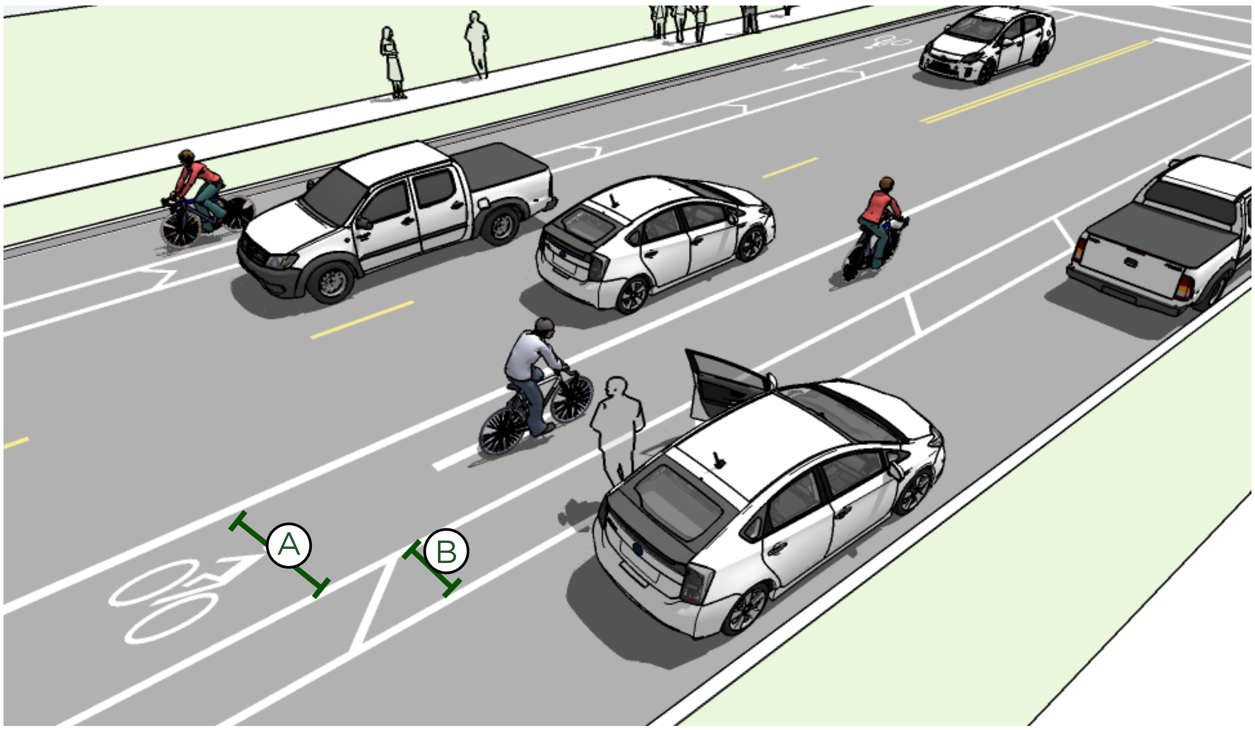
Before and after studies of bicycle lane installations show a wide range of crash reduction factors. Some studies show a crash reduction of 35 percent (CMF ID: 1719) for vehicle/bicycle collisions after bike lane installation.

Construction Costs

The cost for installing bicycle lanes will depend on the implementation approach.

Buffered Bicycle Lanes

Buffered bike lanes are conventional bicycle lanes paired with a designated buffer space, separating the bicycle lane from the adjacent motor vehicle travel lane and/or parking lane.



Typical Application

- Anywhere a conventional bike lane is being considered.
- On streets with high speeds and high volumes or high truck volumes.
- On streets with extra lanes or lane width.
- Appropriate for skilled adult riders on most streets.

Design Features

- The minimum bicycle travel area (not including buffer) is five feet wide. Refer to location A in the figure.
- Buffers should be at least two feet wide. If buffer area is four feet or wider, white chevron or diagonal markings should be used. Refer to location B in the figure.
- For clarity at driveways or minor street crossings, consider a dotted line.
- There is no standard for whether the buffer is configured on the parking side, the travel side, or a combination of both.

BUFFERED BICYCLE LANE

The use of pavement markings delineates space for cyclists to ride in a comfortable facility.

BUFFERED BICYCLE LANE

The use of pavement markings delineates space for cyclists to ride in a comfortable facility.

Further Considerations

- » Color may be used within the lane to discourage motorists from entering the buffered lane.
- » A study of buffered bicycle lanes found that, in order to make the facilities successful, there needs to also be driver education, improved signage and proper pavement markings.[1]
- » On multi-lane streets with high vehicles speeds, the most appropriate bicycle facility to provide for user comfort may be physically separated bike lanes.
- » NCHRP Report #766 recommends, when space in limited, installing a buffer space between the parking lane and bicycle lane where on-street parking is permitted rather than between the bicycle lane and vehicle travel lane.[2]

1 Monsere, C.; McNeil, N.; and Dill, J., "Evaluation of Innovative Bicycle Facilities: SW Broadway Cycle Track and SW Stark/Oak Street Buffered Bike Lanes. Final Report" (2011).Urban Studies and Planning Faculty Publications and Presentations.
2 National Cooperative Highway Research Program. Report #766: Recommended Bicycle Lane Widths for Various Roadway Characteristics.

Crash Reduction

A before and after study of buffered bicycle lane installation in Portland, OR found an overwhelmingly positive response from bicyclists, with 89 percent of bicyclists feeling safer riding after installation and 91 percent expressing that the facility made bicycling easier.[3]

3 National Cooperative Highway Research Program. Report #766: Recommended Bicycle Lane Widths for Various Roadway Characteristics.

Construction Costs

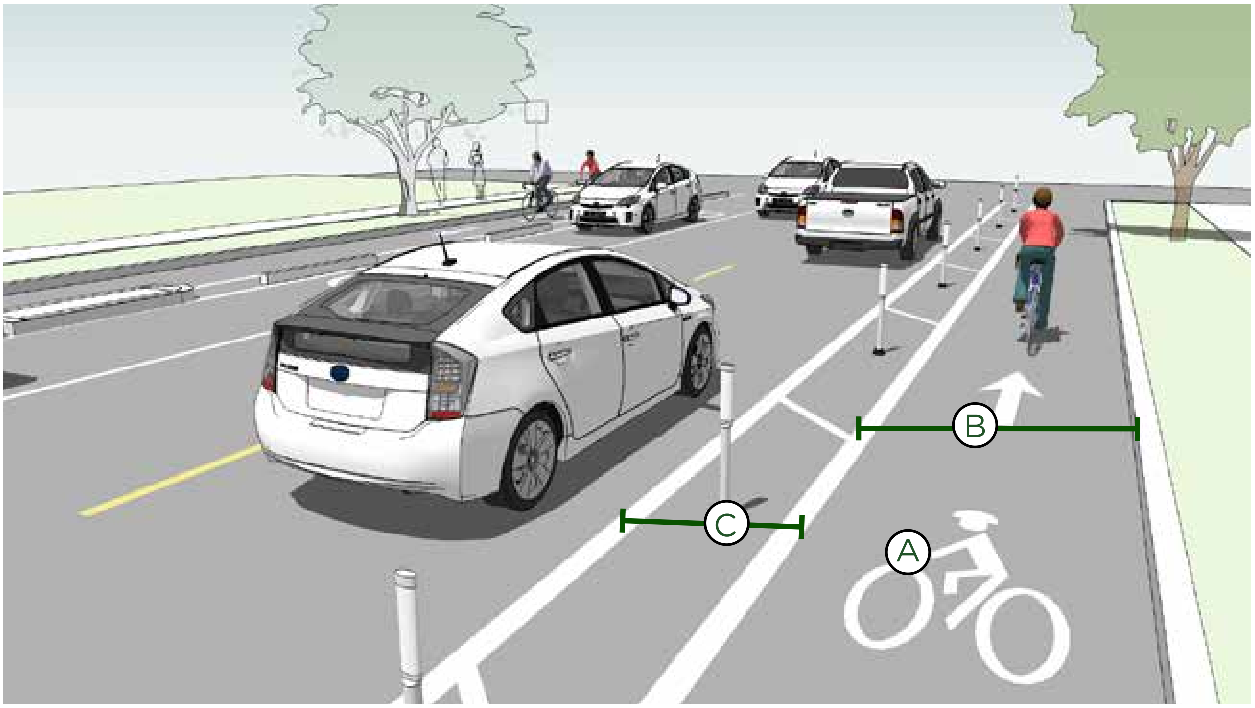
The cost for installing buffered bicycle lanes will depend on the implementation approach. The cost of large-scale bicycle treatments will vary greatly due to differences in project specifications and the scale and length of the treatment.

SEPARATED BIKE LANES

A physically separated bicycle lane (SBL) is an exclusive bike facility that combines the user experience of a separated path with the on-street infrastructure of a on-street bike lane. A separated bicycle lane is physically separated from motor traffic by a vertical element and distinct from the sidewalk. In situations where on-street parking is allowed, separated bicycle lanes are located between the parking and the sidewalk.

One-Way Separated Bicycle Lanes

When retrofitting separated bike lanes onto existing streets, a one-way street-level design may be most appropriate. This design provides protection through physical barriers and can include flexible delineators, curbs, on-street parking or other barriers. A street level separated bike lane shares the same elevation as adjacent travel lanes.



Typical Application

- » Street retrofit projects with limited funds for relating curbs and drainage.
- » Streets with high motor vehicle volumes and/or speeds and high bicycle volumes.
- » Streets for which conflicts at intersections can be effectively mitigated using parking lane setbacks, bicycle markings through the intersection, and other signalized intersection treatments.
- » Appropriate for most riders on most streets.

Design Features

- » Pavement markings, symbols and/or arrow markings must be placed at the beginning of the separated bike lane and at intervals along the facility (MUTCD 9C.04). Refer to location A in the figure.
- » Seven-foot width preferred (five-foot minimum). Refer to location B in the figure.
- » Three-foot minimum buffer width adjacent to parking. 18 inch minimum adjacent to travel lanes (NACTO, 2012). Channelizing devices should be placed in the buffer area. Refer to location C in the figure.
- » If buffer area is four feet or wider, white chevron or diagonal markings should be used.

STREET LEVEL SEPARATED BICYCLE LANES

Street Level Separated Bicycle Lanes can be separated from the street with parking, planters, bollards, or other design elements.

Further Considerations

- » Separated bike lane buffers and barriers are covered in the MUTCD as preferential lane markings (section 3D.01) and channelizing devices (section 3H.01). Curbs may be used as a channeling device, see the section on islands (section 3I.01).
- » A retrofit separated bike lane has a relatively low implementation cost compared to road reconstruction by making use of existing pavement and drainage and by using parking lane as a barrier.
- » Gutters, drainage outlets and utility covers should be designed and configured as not to impact bicycle travel.
- » Special consideration should be given at transit stops to manage bicycle & pedestrian interactions.

Crash Reduction

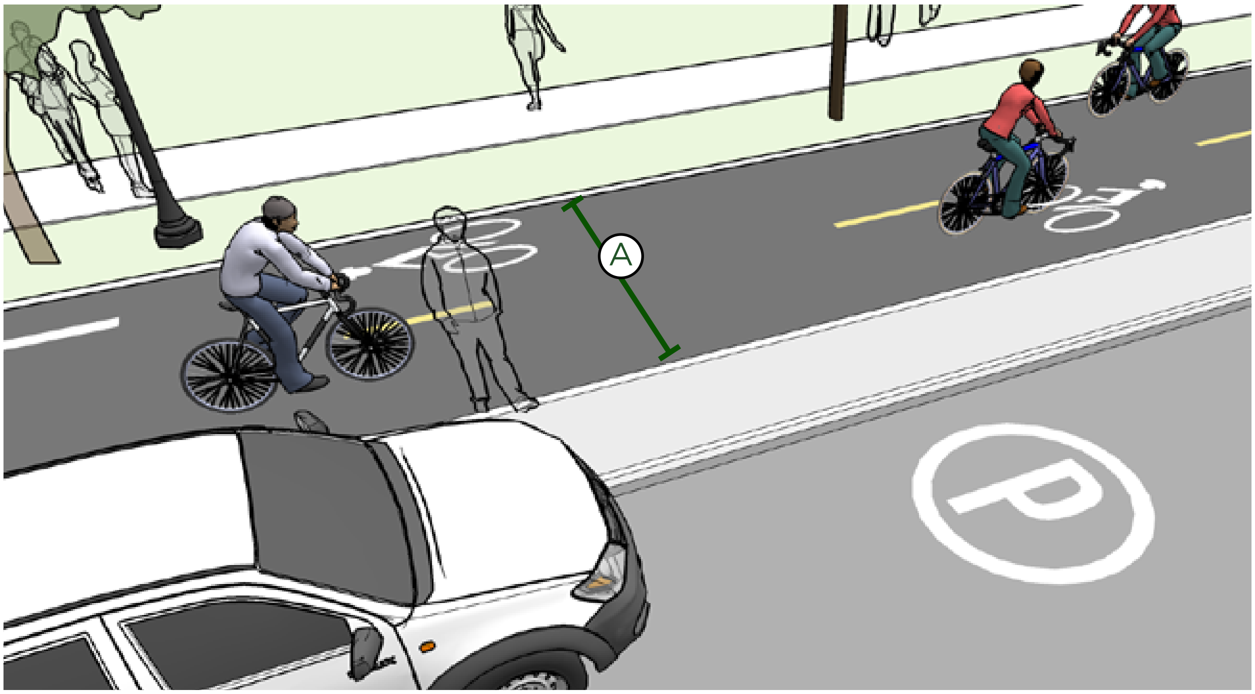
A before and after study in Montreal of physically separated bicycle lanes shows that this type of facility can result in a crash reduction of 74 percent for collisions between bicyclists and vehicles. (CMF ID: 4097) In this study, there was a parking buffer between the bike facility and vehicle travel lanes. Other studies have found a range in crash reductions due to SBL, from 8 percent (CMF ID: 4094) to 94 percent (CMF ID: 4101).

Construction Costs

The implementation cost is low if the project uses existing pavement and drainage, but the cost significantly increases if curb lines need to be moved. A parking lane is the low-cost option for providing a barrier. Other barriers might include concrete medians, bollards, tubular markers, or planters.

Two-Way Separated Bicycle Lanes

Two-Way Separated Bicycle Lanes are bicycle facilities that allow bicycle movement in both directions on one side of the road. Two-way separated bicycle lanes share some of the same design characteristics as one-way separated bicycle lanes, but may require additional considerations at driveway and side-street crossings.



Typical Application

- » Works best on the left side of one-way streets.
- » Streets with high motor vehicle volumes and/or speeds.
- » Streets with high bicycle volumes.
- » Streets with a high incidence of wrong-way bicycle riding.
- » Streets with few conflicts such as driveways or cross-streets on one side of the street.
- » Streets that connect to shared use paths.

Design Features

- » Twelve-foot operating width preferred (10-foot minimum) width for two-way facility. Refer to location A in the figure.
- » In constrained situations, an eight-foot minimum operating width may be considered.
- » Adjacent to on-street parking a three-foot minimum width channelized buffer or island shall be provided to accommodate opening doors (NACTO, 2012) (MUTCD 3H.01, 3I.01).
- » A separation narrower than five feet may be permitted if a physical barrier is present (AASHTO, 2013).
- » Additional signalization and signs may be necessary to manage conflicts.

TWO-WAY SEPARATED BICYCLE LANES

A two-way facility can accommodate cyclists in two directions of travel.

Further Considerations

- » On-street bike lane buffers and barriers are covered in the MUTCD as preferential lane markings (section 3D.01) and channelizing devices, including flexible delineators (section 3H.01). Curbs may be used as a channeling device, see the section on islands (section 3I.01).
- » A two-way separated bike lane on one way street should be located on the left side.
- » A two-way separated bike lane may be configured at street level or as a raised separated bicycle lane with vertical separation from the adjacent travel lane.
- » Two-way separated bike lanes should ideally be placed along streets with long blocks and few driveways or mid-block access points for motor vehicles.

Crash Reduction

A study of bicyclists in two-way separated facilities found that accident probability decreased by 45 percent at intersections where the separated facility approach was detected between two and five meters from the side of the main road and when bicyclists had crossing priority at intersections. (CMF ID: 3034) Installation of a two-way separated bike lane zero to two meters from the side of the main road resulted in an increase in collisions at intersections by three percent (CMF ID: 4033).

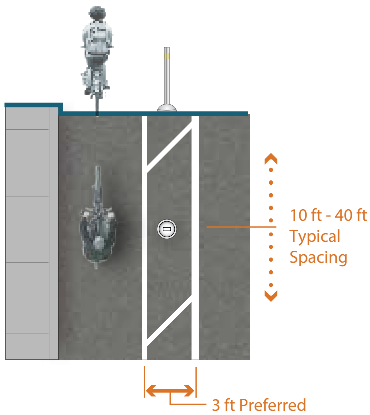
Construction Costs

The implementation cost is low if the project uses existing pavement and drainage, but the cost significantly increases if curb lines need to be moved. A parking lane is the low-cost option for providing a barrier. Other barriers might include concrete medians, bollards, tubular markers, or planters.

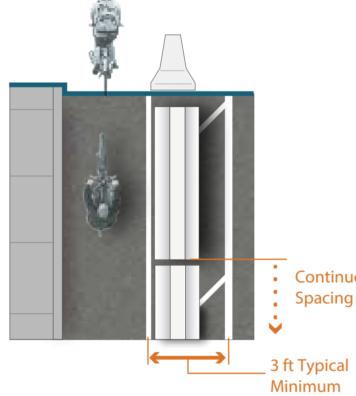
Separation Methods

Separated bikeways may use a variety of vertical elements to physically separate the bikeway from adjacent travel lanes. Barriers may be robust constructed elements such as curbs, or may be more interim in nature, such as flexible delineator posts.

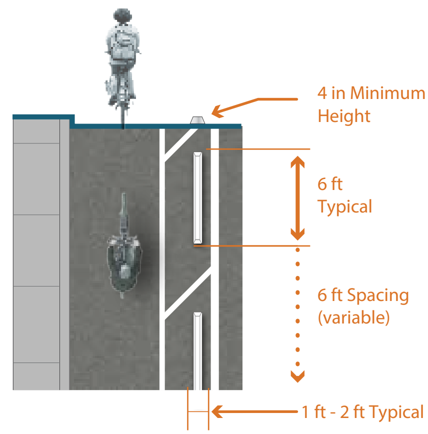
Delineator Posts



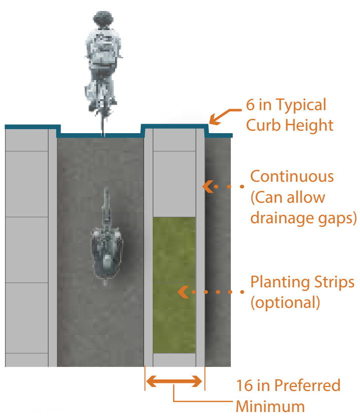
Concrete Barrier



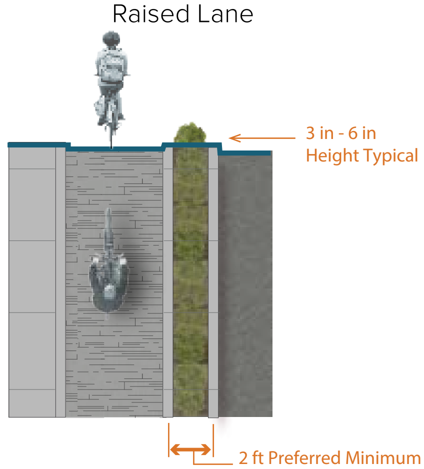
Parking Stops



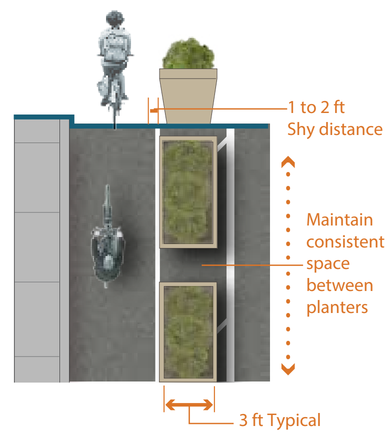
Raised Media



Raised Lane



Planters



Typical Application

Appropriate barriers for retrofit projects:

- » Parked Cars
- » Flexible delineators
- » Bollards
- » Planters
- » Parking stops

Appropriate barriers for reconstruction projects:

- » Curb separation
- » Medians
- » Landscaped Medians
- » Raised separated bike lane with vertical or mountable curb
- » Pedestrian Safety Islands

Raised separated bikeways are bicycle facilities that are vertically separated from motor vehicle traffic.

Design Features

- Maximize effective operating space by placing curbs or delineator posts as far from the through bikeway space as practicable.
- Allow for adequate shy distance of one to two feet from vertical elements to maximize useful space.
- When next to parking allow for three feet of space in the buffer space to allow for opening doors and passenger unloading.
- The presences of landscaping in medians, planters and safety islands increases comfort for users and enhances the streetscape environment.

Further Considerations

- Separated bikeway buffers and barriers are covered in the MUTCD as preferential lane markings (section 3D.01) and channelizing devices (section 3H.01). Curbs may be used as a channeling device, see the section on islands (section 3I.01).
- With new roadway construction a raised separated bikeway can be less expensive to construct than a wide or buffered bicycle lane because of shallower trenching and sub base requirements.
- Parking should be prohibited within 30 feet of the intersection to improve visibility.

Crash Reduction

A before and after study in Montreal of separated bikeways shows that this type of facility can result in a crash reduction of 74 percent for collisions between bicyclists and vehicles. (CMF ID: 4097) In this study, there was a parking buffer between the bike facility and vehicle travel lanes. Other studies have found a range in crash reductions due to SBL, from eight percent (CMF ID: 4094) to 94 percent (CMF ID: 4101).

Construction Costs

Separated bikeway costs can vary greatly, depending on the type of material, the scale, and whether it is part of a broader construction project.

BIKEWAY CROSSING TREATMENTS

Intersections are junctions at which different modes of transportation meet and facilities overlap. An intersection facilitates the interchange between bicyclists, motorists, pedestrians, and other modes in order to advance traffic flow in a safe and efficient manner. Designs for intersections with bicycle facilities should reduce conflict between bicyclists and motor vehicles by heightening the level of visibility, denoting clear right-of-way, and facilitating eye contact and awareness with other modes.

Intersection Crossing Markings

Bicycle pavement markings through intersections guide bicyclists on a safe and direct path through the intersection and provide a clear boundary between the paths of through bicyclists and vehicles in the adjacent lane.

Typical Application

» Streets with conventional, buffered, or separated bike lanes.

» At direct paths through intersections.

» Streets with high volumes of adjacent traffic.

» Where potential conflicts exist between through bicyclist and adjacent traffic.

Design Features

» Intersection markings should be the same width and in line with leading bike lane.

» Dotted lines should be a minimum of six inches wide and four feet long, spaced every 12 feet. Refer to location A in the figure.

» All markings should be white, skid resistant and retro reflective (MUTCD 9C.02.02).

» Green pavement markings may also be used. Refer to location B in the figure.

INTERSECTION CROSSING MARKINGS

Intersection crossing markings can be used at signalized intersections or high volume minor street and driveway crossings, as illustrated above.

Further Considerations

The National Committee on Uniform Traffic Control Devices has submitted a request to include additional options bicycle lanes extensions through intersections as a part of future MUTCD updates[1]. Their proposal includes the following options for striping elements within the crossing:

- » Bicycle lane markings
- » Double chevron markings, indicating the direction of travel.
- » Green colored pavement.

1 *Letter to FHWA from the Bicycle Technical Committee for the MUTCD. Bicycle Lane Extensions through Intersections. June 2014.*

Crash Reduction

A study on the safety effects of intersection crossing markings found a reduction in accidents by 10 percent and injuries by 19 percent.[2]

A study in Portland, OR found that significantly more motorists yielded to bicyclists after the colored pavement had been installed (92 percent in the after period versus 72 percent in the before period).[3]

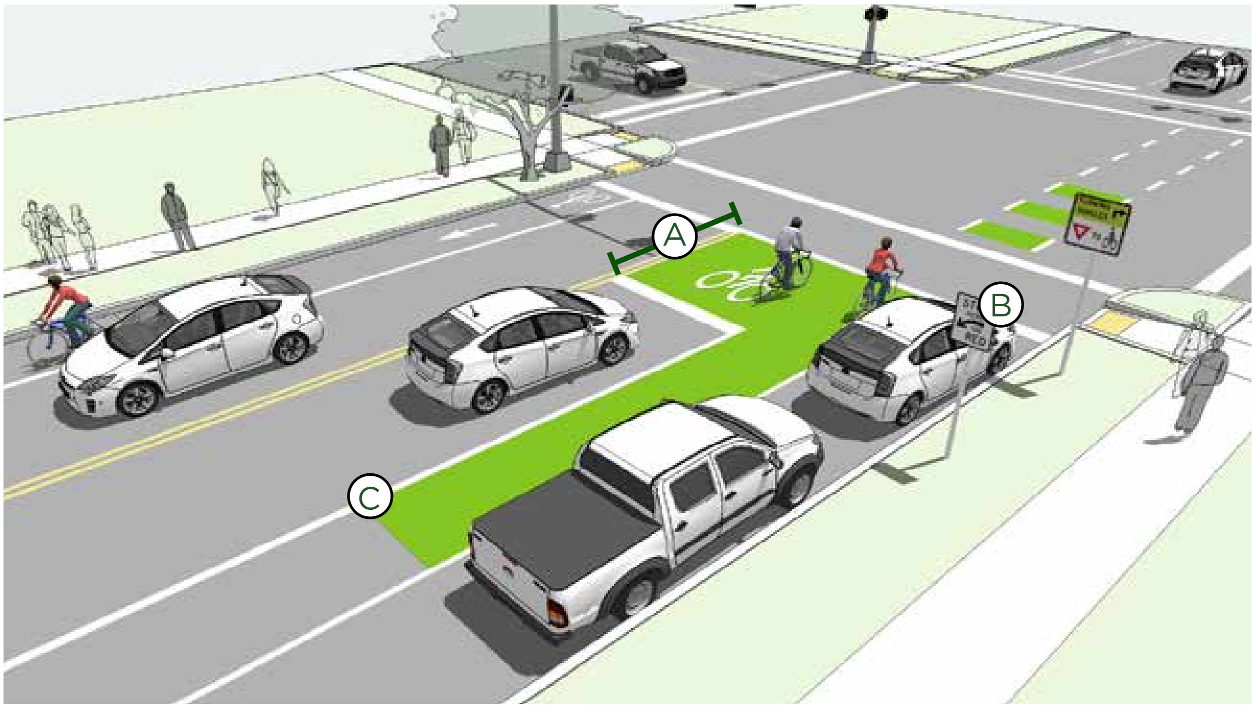
2 *Jensen, S.U. (2008). Safety effects of blue cycle crossings: A before-after study. Accident Analysis & Prevention, 40(2), 742-750.*
3 *Hunter, W.W. et al. (2000). Evaluation of Blue Bike-Lane Treatment in Portland, Oregon. Transportation Research Record, 1705, 107-115.*

Construction Costs

The cost for installing intersection crossing markings will depend on the implementation approach. On roadways with adequate width for reconfiguration or restriping, costs may be negligible when provided as part of routine overlay or repaving projects.

Bike Box

A bike box is a designated area located at the head of a traffic lane at a signalized intersection that provides bicyclists with a safe and visible space to get in front of queuing traffic during the red signal phase. Motor vehicles must queue behind the white stop line at the rear of the bike box. On a green signal, all bicyclists can quickly clear the intersection.



Typical Application

- At potential areas of conflict between bicyclists and turning vehicles, such as a right or left turn locations.
- At signalized intersections with high bicycle volumes.
- At signalized intersections with high vehicle volumes.

Design Features

- Fourteen-foot minimum depth from back of crosswalk to motor vehicle stop bar (NACTO, 2012). Refer to location A in the figure.
- A "No Turn on Red" (MUTCD R10-11) sign shall be installed overhead to prevent vehicles from entering the Bike Box. A "Stop Here on Red" (MUTCD R10-6) sign should be post mounted at the stop line to reinforce observance of the stop line. Refer to location B in the figure.
- A 50-foot ingress lane should be used to provide access to the box. Refer to location C in the figure.
- Use of green colored pavement is optional.

A bike box allows for cyclists to wait in front of queuing traffic, providing high visibility, and a head start over motor vehicle traffic.

Further Considerations

- This treatment positions bicycles together and on a green signal, all bicyclists can quickly clear the intersection, minimizing conflict and delay to transit or other traffic.
- Pedestrians also benefit from bike boxes, as they experience reduced vehicle encroachment into the crosswalk.

Crash Reduction

A study of motorist/bicyclist conflicts at bike boxes indicate a 35 percent decrease in conflicts (CMF ID: 1718). A study done in Portland in 2010 found that 77 percent of bicyclists felt bicycling through intersections was safer with the bike boxes.[1]

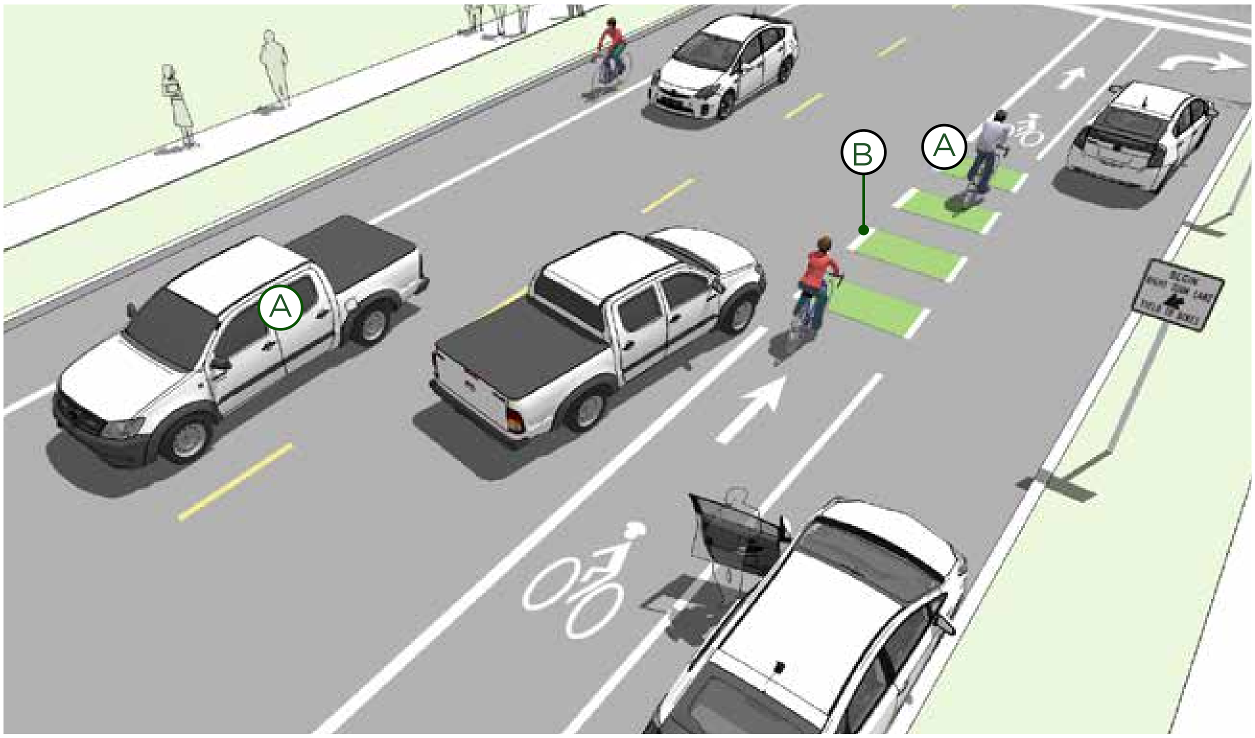
Construction Costs

Costs will vary due to the type of paint used and the size of the bike box, as well as whether the treatment is added at the same time as other road treatments.

1 Monsere, C. & Dill, J. (2010). Evaluation of Bike Boxes at Signalized Intersections. Final Draft. Oregon Transportation Research and education Consortium.

Colored Bicycle Lanes

Colored pavement within a bicycle lane may be used to increase the visibility of the bicycle facility, raise awareness of the potential to encounter bicyclists and reinforce priority of bicyclists in conflict areas.



Typical Application

- Within a weaving or conflict area to identify the potential for bicyclist and motorist interactions and assert bicyclist priority.
- Across intersections, driveways and Stop or Yield-controlled cross-streets.

Design Features

- Typical white bike lanes (solid or dotted six-inch stripe) are used to outline the green colored pavement. Refer to location A in the figure.
- In weaving or turning conflict areas, preferred striping is dashed, to match the bicycle lane line extensions. Refer to location B in the figure.
- The colored surface should be skid resistant and retro-reflective (MUTCD 9C.02.02).
- In exclusive use areas, such as bike boxes, color application should be solid green.

A colored bicycle lane on Laurel Street in Santa Cruz, CA alterts users to potential merging in advance of an intersection. Photo by Richard Masoner via Flickr (CC BY-SA 2.0).

Further Considerations

- Green colored pavement shall be used in compliance with FHWA Interim Approval (FHWA IA-14.10).[1]
- While other colors have been used (red, blue, yellow), green is the recommended color in the US.
- The application of green colored pavement within bicycle lanes is an emerging practice. The guidance recommended here is based on best practices in cities around the county.

1 *FHWA. Interim Approval for Optional Use of Green Colored Pavement for Bike Lanes (IA-14). 2011.*

Crash Reduction

Before and after studies of colored bicycle lane installations have found a reduction in bicycle/vehicle collisions by 38 percent and a reduction in serious injuries and fatalities of bicyclists by 71 percent.[2] A study in Portland, OR found a 38 percent decrease in the rate of conflict between bicyclists and motorists after colored lanes were installed.[3]

2 *Jensen, S.U., et. al., "The Marking of Bicycle Crossings at Signalized Intersections," Nordic Road and Transport Research No. 1, 1997, pg. 27.*

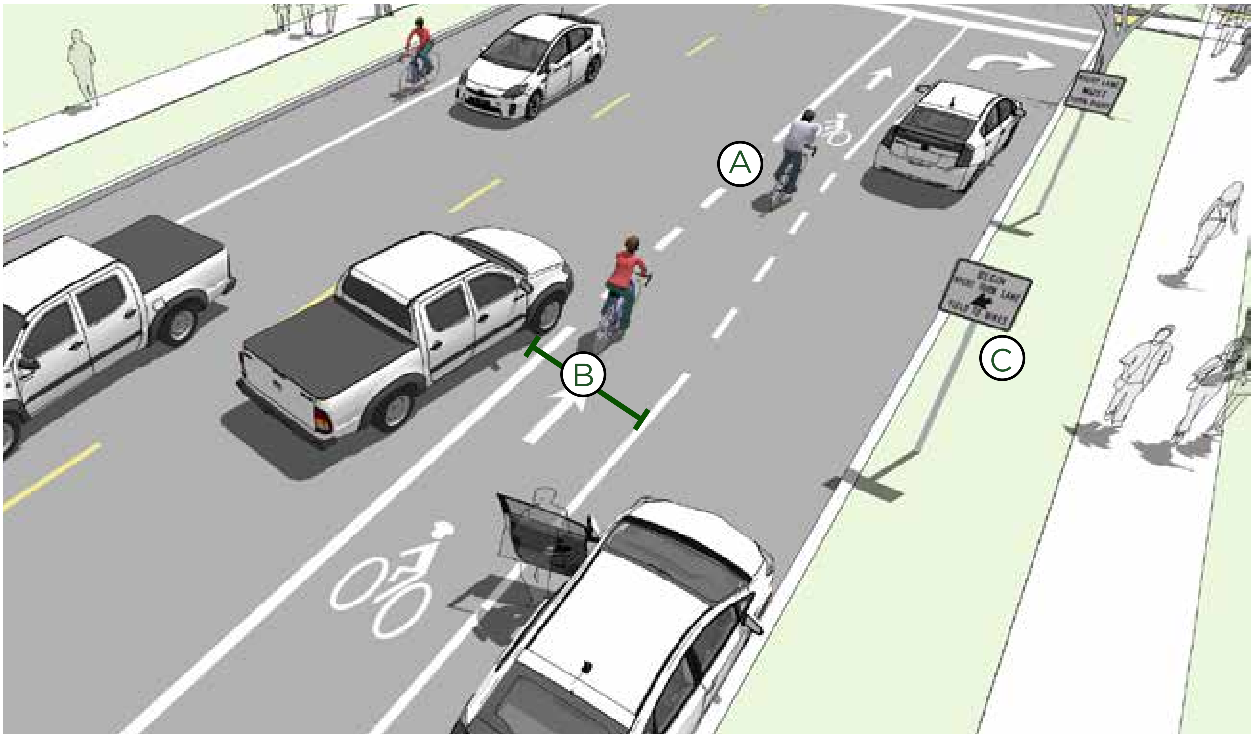
3 *Hunter, W. W., et. al., Evaluation of the Blue Bike-Lane Treatment Used in Bicycle/Motor Vehicle Conflict Areas in Portland, Oregon, McLean, VA: FHWA, 2000, pg. 25.*

Construction Costs

The cost for installing colored bicycle lanes will depend on the materials selected and implementation approach. Colored pavement is more expensive than standard asphalt installation, costing 30-50 percent more than non-colored asphalt.

Bike Lanes at Added Right Turn Lanes

The appropriate treatment at right turn only lanes is to introduce an added turn lane to the outside of the bicycle lane. The area where people driving must weave across the bicycle lane should be marked with dotted lines to identify the potential conflict areas. Signage should indicate that motorists must yield to bicyclists through the conflict area.



Typical Application

- » Streets with right-turn lanes and right side bike lanes.
- » Streets with left-turn lanes and left side bike lanes.

Design Features

- » Mark inside line with six-inch stripe. Refer to location A in the figure.
- » Continue existing bike lane width; standard width of five to six feet (four feet in constrained locations). Refer to location B in the figure.
- » A "Begin Right Turn Lane Yield To Bikes" (MUTCD R4-4) signs indicates that motorists should yield to bicyclists through the conflict area. Refer to location C in the figure.
- » Consider using colored in the conflict areas to promote visibility of the dashed weaving area.

THROUGH BICYCLE LANE TO THE LEFT OF A RIGHT TURN ONLY LANE

Drivers wishing to enter the right turn lane must transition across the bicycle lane in advance of the turn.

Further Considerations

- The bicycle lane maintains a straight path, and drivers must weave across, providing clear right-of-way priority to bicyclists.
- Maintaining a straight bicycle path reinforces the priority of bicyclists over turning cars. Drivers must yield to bicyclists before crossing the bike lane to enter the turn only lane.
- Through lanes that become turn only lanes are difficult for bicyclists to navigate and should be avoided.
- The use of dual right-turn-only lanes should be avoided on streets with bike lanes (AASHTO, 2013). Where there are dual right-turn-only lanes, the bike lane should be placed to the left of both right-turn lanes, in the same manner as where there is just one right-turn-only lane.

Crash Reduction

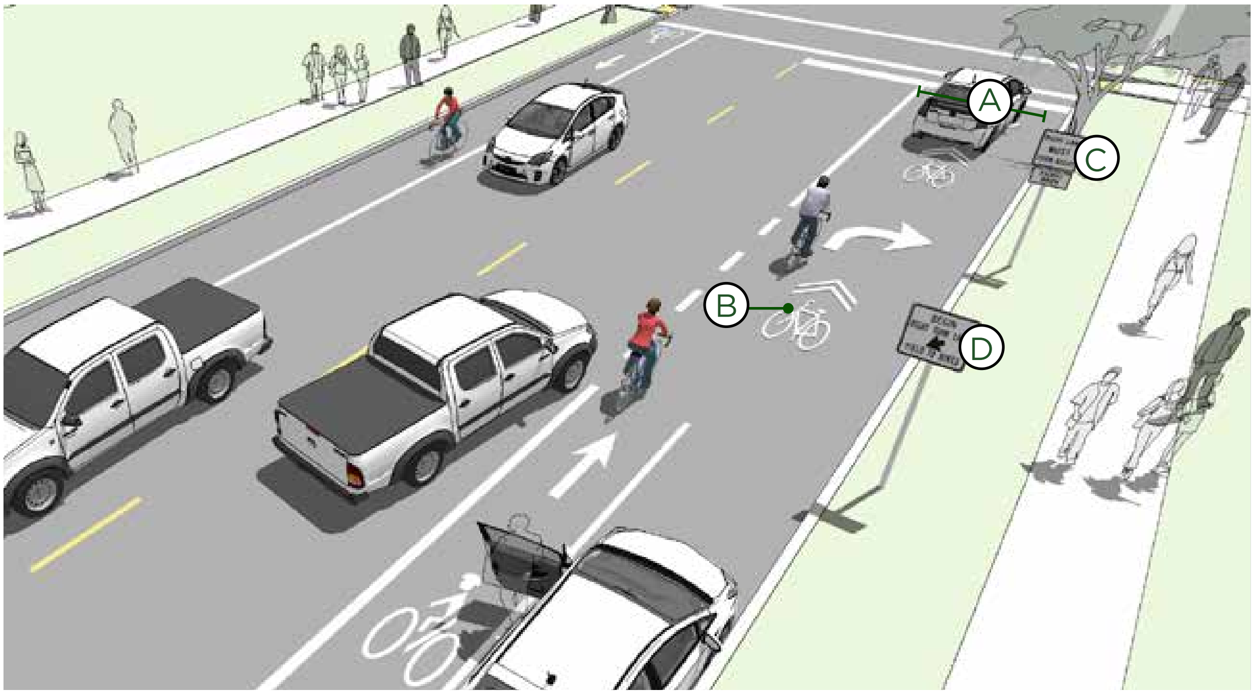
Studies have shown a three percent decrease in crashes at signalized intersections with exclusive right turn lanes when compared to sharing the roadway with motor vehicles (CMF ID: 3257).

Construction Costs

The cost for installing bicycle lanes will depend on the implementation approach. On roadways with adequate width for reconfiguration or restriping, costs may be negligible when provided as part of routine overlay or repaving projects.

Combined Bike Lane/Turn Lane

Where there isn't room for a conventional bicycle lane and turn lane a combined bike lane/turn lane creates a shared lane where bicyclists can ride and turning motor vehicles yield to through traveling bicyclists. The combined bicycle lane/turn lane places shared lane markings within a right turn only lane.



Typical Application

- Most appropriate in areas with lower posted speeds (30 MPH or less) and with lower traffic volumes (10,000 ADT or less).
- May not be appropriate for high speed arterials or intersections with long right turn lanes.
- May not be appropriate for intersections with large percentages of right-turning heavy vehicles.

Design Features

- Maximum shared turn lane width is 13 feet; narrower is preferable (NACTO, 2012). Refer to location A in the figure.
- Shared Lane Markings should indicate preferred positioning of bicyclists within the combine lane. Refer to location B in the figure.
- A "Right Lane Must Turn Right" (MUTCD R3-7R) sign with an "EXCEPT BIKES" plaque may be needed to permit through bicyclists to use a right turn lane. Refer to location C in the figure.
- Use "Begin Right Turn Lane Yield To Bikes" signage (MUTCD R4-4) to indicate that motorists should yield to bicyclists through the conflict area. Refer to location D in the figure.

COMBINED BIKE LANE/TURN LANE (BILLINGS, MT)

Shared lane markings and signs indicate that bicyclists should right in the left side of this right turn only lane.

Further Considerations

- This treatment is recommended at intersections lacking sufficient space to accommodate both a standard through bike lane and right turn lane.
- Not recommended at intersections with high peak motor vehicle right turn movements.
- Combined bike lane/turn lane creates safety and comfort benefits by negotiating conflicts upstream of the intersection area.

Crash Reduction

A survey in Eugene, OR found that more than 17 percent of the surveyed bicyclists using the combined turn lane felt that it was safer than the comparison location with a standard-width right-turn lane, and another 55 percent felt that the combined-lane site was no different safety-wise than the standard-width location.[1]

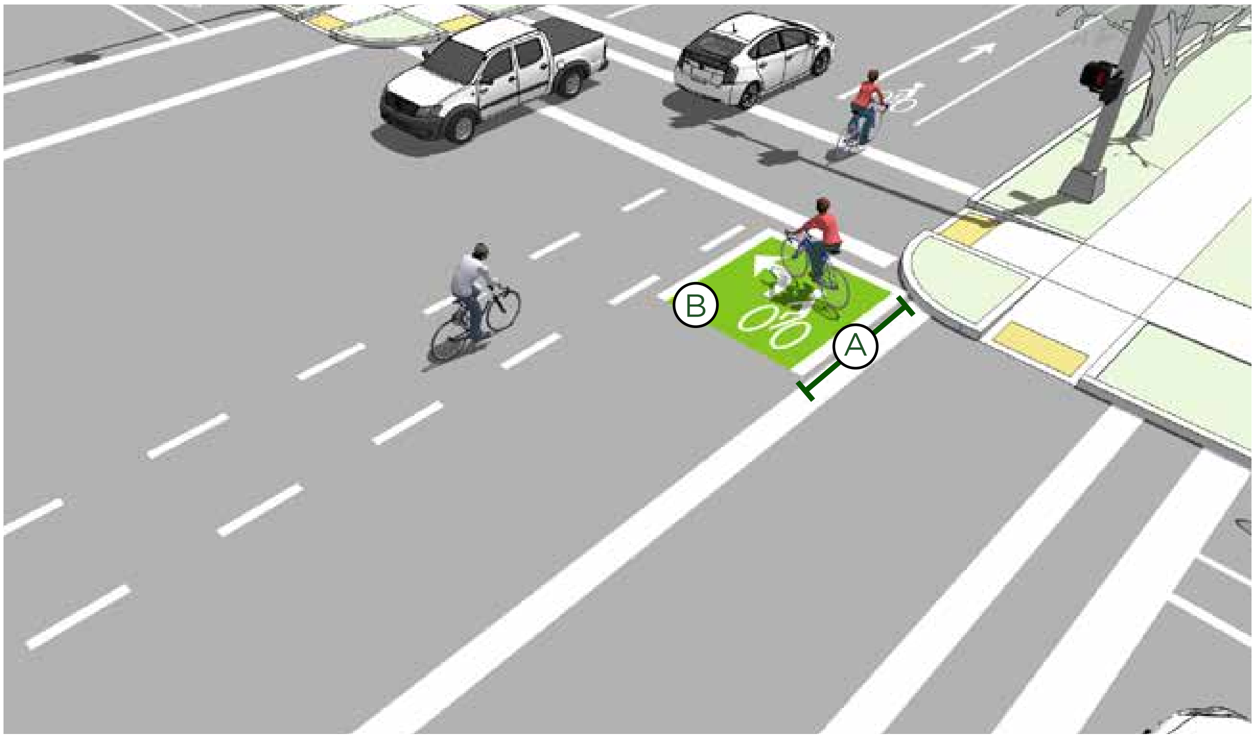
Construction Costs

The cost for installing a combined turn lane will depend on the implementation approach. On roadways with adequate width for reconfiguration or restriping, costs may be negligible when provided as part of routine overlay or repaving projects.

1 Hunter, W.W. (2000). Evaluation of a Combined Bicycle Lane/ Right-Turn Lane in Eugene, Oregon. Publication No. FHWA-RD-00-151, Federal Highway Administration, Washington, DC.

Two-Stage Turn Boxes

Two- stage turn boxes offer bicyclists a safe way to make turns at multi-lane signalized intersections from a physically separated or conventional bike lane. On physically separated bike lanes, bicyclists are often unable to merge into traffic to turn due to physical separation, making the provision of two-stage turn boxes critical.



Typical Application

- Streets with high vehicle speeds and/or traffic volumes.
- At intersections locations of multi-lane roads with signalized intersections.
- At signalized intersections with a high number of bicyclists making a left turn from a right side facility.

Design Features

- The two-stage turn box shall be placed in a protected area. Typically this is within the shadow of an on-street parking lane or separated bike lane buffer area and should be placed in front of the crosswalk to avoid conflict with pedestrians.
- Eight feet by six feet preferred depth of bicycle storage area (six feet by three feet minimum). Refer to location A in the figure.
- Bicycle stencil and turn arrow pavement markings shall be used to indicate proper bicycle direction and positioning (NACTO, 2012). Refer to location B in the figure.

JUGHANDLE TURN BOX

This MUTCD compliant design carves a jughandle out of the sidewalk to provide space for waiting bicyclists.

SEPARATED BIKE LANE TURN BOX

On separated bike lanes, the two-stage turn box can be located in the protected buffer/parking area.

Further Considerations

- » Consider providing a "No Turn on Red" (MUTCD R10-11) on the cross street to prevent motor vehicles from entering the turn box.
- » This design formalizes a maneuver called a "box turn" or "pedestrian style turn."
- » Some two-stage turn box designs are considered experimental by FHWA.
- » Design guidance for two-stage turns apply to both bike lanes and separated bike lanes.
- » Two-stage turn boxes reduce conflicts in multiple ways; from keeping bicyclists from queuing in a bike lane or crosswalk and by separating turning bicyclists from through bicyclists.
- » Bicyclist capacity of a two-stage turn box is influenced by physical dimension (how many bicyclists it can contain) and signal phasing (how frequently the box clears).

Crash Reduction

There are no Crash Modification Factors (CMFs) available for this treatment.

Construction Costs

Costs will vary due to the type of paint used and the size of the two-stage turn box, as well as whether the treatment is added at the same time as other road treatments.

Bicyclists at Single Lane Roundabouts

Roundabouts are circular intersection designed with yield control for all entering traffic, channelized approaches and geometry to induce desirable speeds. They are used as an alternative to intersection signalization.

Typical Application

» On bicycle routes a roundabout or neighborhood traffic circle is preferable to stop control as bicyclists do not like to lose their momentum due to physical effort required. At intersections of multi-use paths, pedestrian and bicycle only roundabouts are an excellent form of non-motorized user traffic control.

Design Features

It is important to indicate to motorists, bicyclists and pedestrians the right-of-way rules and correct way for them to circulate, using appropriately designed signage, pavement markings, and geometric design elements.

» 25 mph maximum circulating design speed.

» Design approaches/exits to the lowest speeds possible.

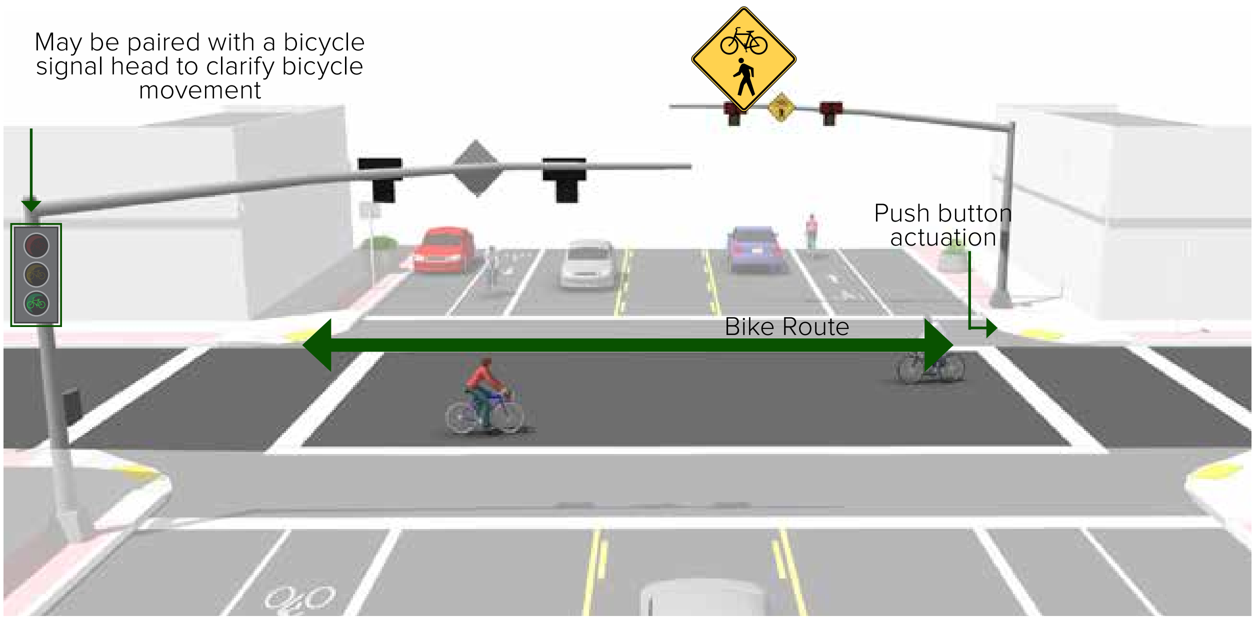
» Encourage bicyclists navigating the roundabout like motor vehicles to "take the lane."

» Maximize yielding rate of motorists to pedestrians and bicyclists at crosswalks.

» Provide separated facilities for bicyclists who prefer not to navigate the roundabout on the roadway.

Hybrid Beacon for Bicycle Route Crossing

A hybrid beacon, previously known as a High-intensity Activated Crosswalk (HAWK), consists of a signal-head with two red lenses over a single yellow lens on the major street, and pedestrian and/or bicycle signal heads for the minor street. There are no signal indications for motor vehicles on the minor street approaches.



Typical Application

- » Hybrid beacons are used to improve non-motorized crossings of major streets in locations where side-street volumes do not support installation of a conventional traffic signal (or where there are concerns that a conventional signal will encourage additional motor vehicle traffic on the minor street).
- » Hybrid beacons may also be used at mid-block crossing locations.
- » Each crossing, regardless of traffic speed or volume, requires additional review by a registered engineer to identify sight lines, potential impacts on traffic progression, timing with adjacent signals, capacity, and safety.

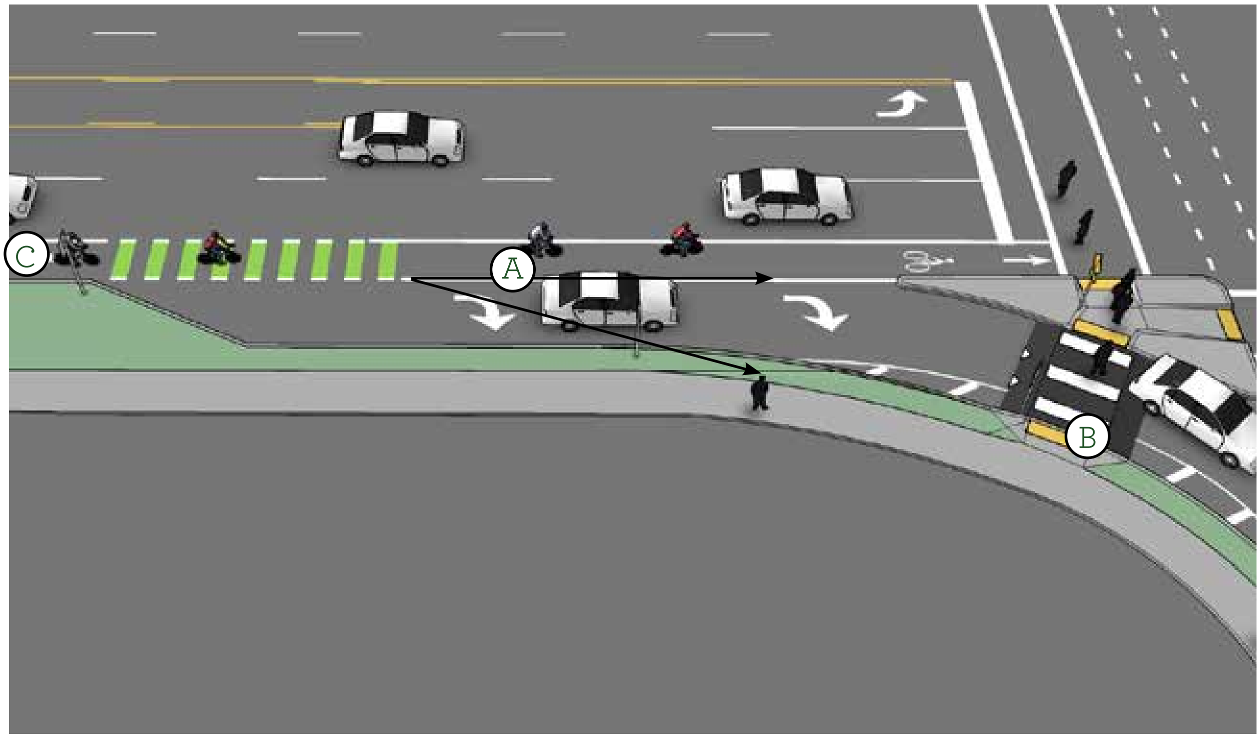
Design Features

Hybrid beacons may be installed without meeting traffic signal control warrants if roadway speed and volumes are excessive for comfortable user crossing.

- » If installed within a signal system, signal engineers should evaluate the need for the hybrid signal to be coordinated with other signals.
- » Parking and other sight obstructions should be prohibited for at least 100 feet in advance of and at least 20 feet beyond the marked crosswalk to provide adequate sight distance.

Bike Lanes at Channelized Turn Lanes

Bicycle friendly channelized turn lanes can reduce the risk of potential conflicts between bicyclists and turning vehicles by improves sight lines of turning vehicles, slows turning vehicle speed, and reminding users of bicycle priority in weave areas



Typical Application

» At signalized intersections.

» Intersections with high right turn traffic volumes, and very low levels of pedestrian activity.

» Increase intersection efficiency and reduce unnecessary delay at areas with high right-turn traffic volumes.

» Wide streets with long crossing distances.

» As an improvement to intersections with an existing traditional channelized right-turn lane.

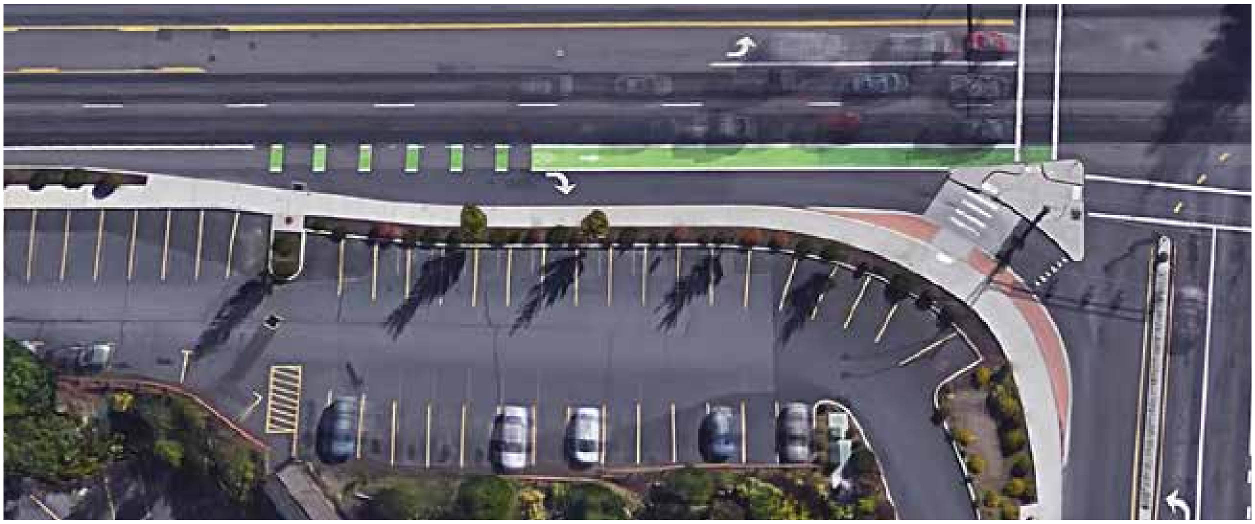
Design Features

» The preferred angle of approach is no more than 15-30 degrees[1]. Refer to location A in the figure.

» Design the right turn lane to encourage appropriate deceleration in preparation for yielding to crossing pedestrians. Refer to location B in the figure.

» Colored pavement should be used at locations where motor vehicles are directed to weave across bicycle lanes. **(NACTO, 2012)** Refer to location C in the figure.

1 *FHWA. Pedestrian Facilities User Guide. 2002.*



This example uses a raise, mountable apron at the corner to define a tight corner radius for passenger cars.

Further Considerations

- In locations where large curb radius is necessary to accommodate large vehicles, use a painted or raised apron to define a secondary curb radius for passenger cars.
- High-speed channelized right turn lanes resulted in the greatest pedestrian delay and risk. High Speed is categorized as a design speed or average observed speed at the crosswalk greater than 20 mph. These locations are good candidates for additional interventions to increase yielding.
- A raised pedestrian crossing may be used to slow driver speeds, encourage yielding, and prioritize crossing pedestrians over turning vehicles. A raised crossing is recommended if the posted speed is 50km/hour or less and turn volumes are 6,000 ADT or less.
- If further yielding compliance is needed, active warning beacons may be used.[1]

1 *TRB. NCHRP 674: Crossing Solutions at Roundabouts and Channelized Turn Lanes for Pedestrians with Vision Disabilities. 2011.*

Crash Reduction

There are no Crash Modification Factors (CMFs) for this treatment.

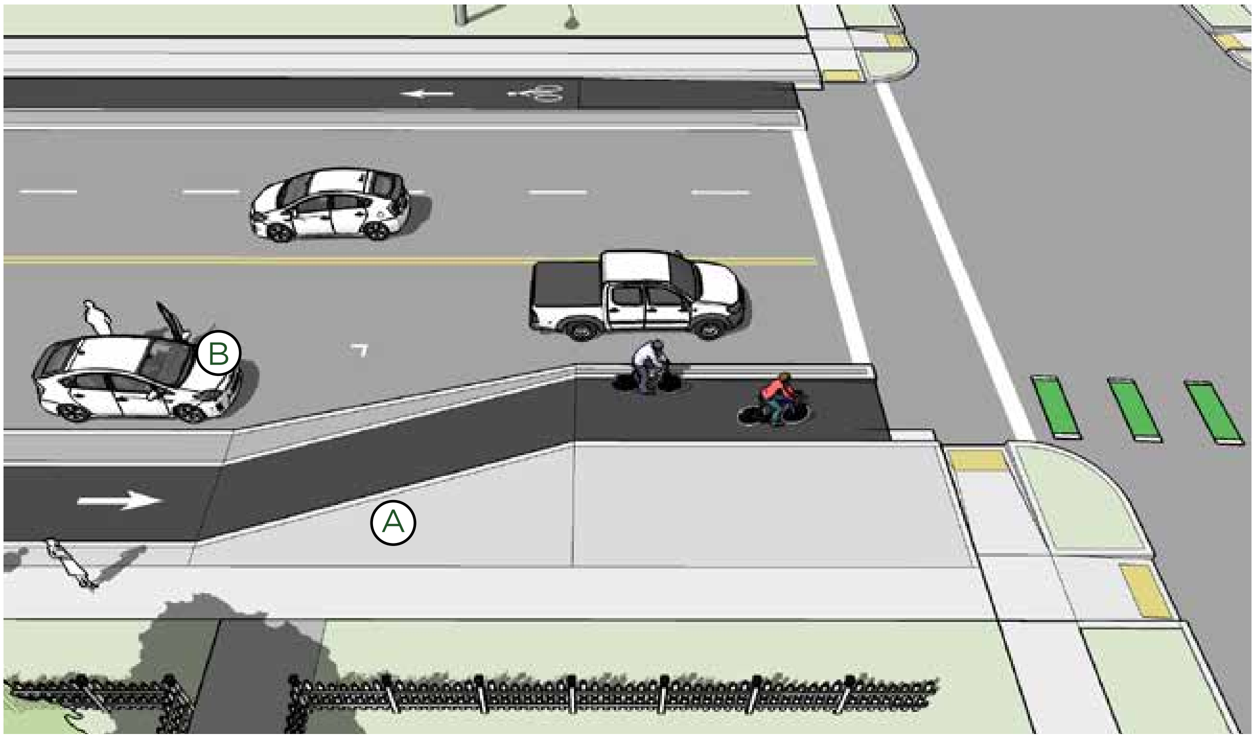
NCHRP 562 identifies raised crosswalks, sound strips and rapid flash beacons as methods to improve conditions for pedestrians.

Materials and Maintenance

Locate crossing markings out of wheel tread when possible to minimize wear and maintenance costs. Because the effectiveness of markings depends entirely on their visibility, maintaining markings should be a high priority.

Bend In

At intersection crossings, a separated bike lane may transition to a "bend-in" configuration. To increase the visibility of bicyclists for turning motorists, a bend-in intersection approach laterally shifts the separated bikeway immediately adjacent to the turning lane.



Typical Application

» Bikeways separated by a visually intensive buffer or on-street parking.

» Where it is desirable to create a curb extension at intersections to reduce pedestrian crossing distance.

» Where space is not available to bend-out the bikeway prior to the intersection.

Design Features

» At least 20 feet prior to an intersection, provide between 20 – 40 feet of length to shift the bikeway closer to motor vehicle traffic. Refer to location A in the figure.

» Where the separated bikeway uses parked cars within the buffer zone, parking must be prohibited at the start of the transition. Refer to location B in the figure.

» Place a "Turning Vehicles Yield to Bikes" sign (modified MUTCD R10-15) prior to the intersection.

» Optional - Provide a narrow buffer with vertical delineators between the travel and lane and bikeway to increase comfort for bicycle riders and slow driver turning speed.

A bend in intersection in Missoula, Montana

A bend in intersection in Vancouver, British Columbia

Further Considerations

» The design creates an opportunity for a curb extension, to reduce pedestrian crossing distance. This curb extension can also create public space which can be used bike parking corrals, bikeshare stations, parklets, public art exhibits, and/or stormwater features such as bioswales.

» Can be paired with intersection crossing markings such as green colored pavement to raise awareness of conflict points.

Crash Reduction

Separated bikeways with "bend-in" approaches create geometry similar to that of conventional on-street bike lanes and should offer a similar safety performance to those designs.

Materials and Maintenance

Because the effectiveness of markings depends entirely on their visibility, maintaining markings should be a high priority.

Bend Out

A protected intersection (or "bend out" intersection) maintains physical separation within the intersection to define the turning paths of motor vehicles, slow vehicle turning speed, and offer a comfortable place for people bicycling to wait at a red signal.

Typical Application

- » Streets with separated bikeway protected by wide buffer or on-street parking.
- » Where two separated bikeways intersect and two-stage left-turn movements must be provided for bicycle riders.
- » Helps reduce conflicts between right-turning motorists and bicycle riders by reducing turning speeds and providing space for vehicles to queue out of the way of through traffic and before the separated bikeway.
- » Where it is desirable to create a safety island at intersections to reduce pedestrian crossing distance.

Design Features

- » Setback bicycle crossing of 16.5 feet allows for one passenger car to queue while yielding. Smaller setback distance is possible in slow-speed, space constrained conditions. A reduced separation width as low as six and a half feet may be used in low-speed environments. Refer to location A in the figure.
- » Corner safety island with a 15-20 foot corner radius slows motor vehicle speeds. Larger radius designs may be possible when paired with a deeper setback or a protected signal phase, or small mountable aprons. Two-stage turning boxes are provided for queuing bicyclists adjacent to corner islands. Refer to location B in the figure.
- » Intersection crossing markings should be used.

A bend out intersection in Davis, California

A bend out intersection in Salt Lake City, Utah

Further Considerations

- » Pedestrian crosswalks may need to be set back from intersections in order to make room for two-stage turning queue boxes.
- » Colored pavement may be used within the corner refuge area to clarify use by people bicycling and discourage use by people walking or driving.
- » Intersection approaches with high volumes of right turning vehicles should provide a dedicated right turn only lane paired with a protected signal phase. Protected signal phasing may allow different design dimensions than are described here.
- » Additional information available through FHWA's "Separated Bike Lane Planning and Design Guide".

Crash Reduction

Studies of "bend out" intersection approaches find that separation distance of 6.5 – 16.5 feet offer the greatest safety benefit, with a better safety record than conventional bike lane designs. (Schepers 2011).

Materials and Maintenance

Because the effectiveness of markings depends entirely on their visibility, maintaining markings should be a high priority.

BIKEWAY AMENITIES

The ability to navigate through a city is informed by wayfinding signage and pavement markings, the availability of bicycle parking, and the provision of well-maintained bicycle facilities. Integrating bicycling and public transportation extends the catchment area for both modes and creates greater opportunity for active transportation.

Wayfinding Sign Types

The ability to navigate through a city is informed by landmarks, natural features, and other visual cues. Signs throughout the city should indicate to bicyclists the direction of travel, the locations of destinations and the travel time/distance to those destinations. A bicycle wayfinding system consists of comprehensive signing and/or pavement markings to guide bicyclists to their destinations along preferred bicycle routes.

D11-1c

D1-1

D11-1/D1-3a

Typical Application

» Wayfinding signs will increase users' comfort and accessibility to the bicycle network.

» Signage can serve both wayfinding and safety purposes including:

- Helping to familiarize users with the bicycle network
- Helping users identify the best routes to destinations
- Helping to address misperceptions about time and distance
- Helping overcome a "barrier to entry" for people who are not frequent bicyclists (e.g., "interested but concerned" bicyclists)

Design Features

» Confirmation signs indicate to bicyclists that they are on a designated bikeway. Make motorists aware of the bicycle route. Can include destinations and distance/time but do not include arrows. Refer to location A in the figure.

» Turn signs indicate where a bikeway turns from one street onto another street. These can be used with pavement markings and include destinations and arrows. Refer to location B in the figure.

» Decisions signs indicate the junction of two or more bikeways and inform bicyclists of the designated bike route to access key destinations. These include destinations, arrows and distances. Travel times are optional but recommended. Refer to location C in the figure.

COMMUNITY LOGOS ON SIGNS

Wayfinding signs can include a local community identification logo, as this example from Oakland, CA.

CUSTOM STREET SIGNS (BERKELEY, CA)

Custom street signs can also act as a type of confirmation sign, to let all users know the street is prioritized for bicyclists.

Further Considerations

» Bicycle wayfinding signs also visually cue motorists that they are driving along a bicycle route and should use caution. Signs are typically placed at key locations leading to and along bicycle routes, including the intersection of multiple routes.

» Too many road signs tend to clutter the right-of-way, and it is recommended that these signs be posted at a level most visible to bicyclists rather than per vehicle signage standards.

» A community-wide bicycle wayfinding signage plan would identify:

- Sign locations
- Sign type – what information should be included and design features
- Destinations to be highlighted on each sign – key destinations for bicyclists
- Approximate distance and travel time to each destination

» Green is the color used for directional guidance and is the most common color of bicycle wayfinding signage in the US, including those in the MUTCD.

» Check wayfinding signage along bikeways for signs of vandalism, graffiti, or normal wear and replace signage along the bikeway network as-needed.

Crash Reduction

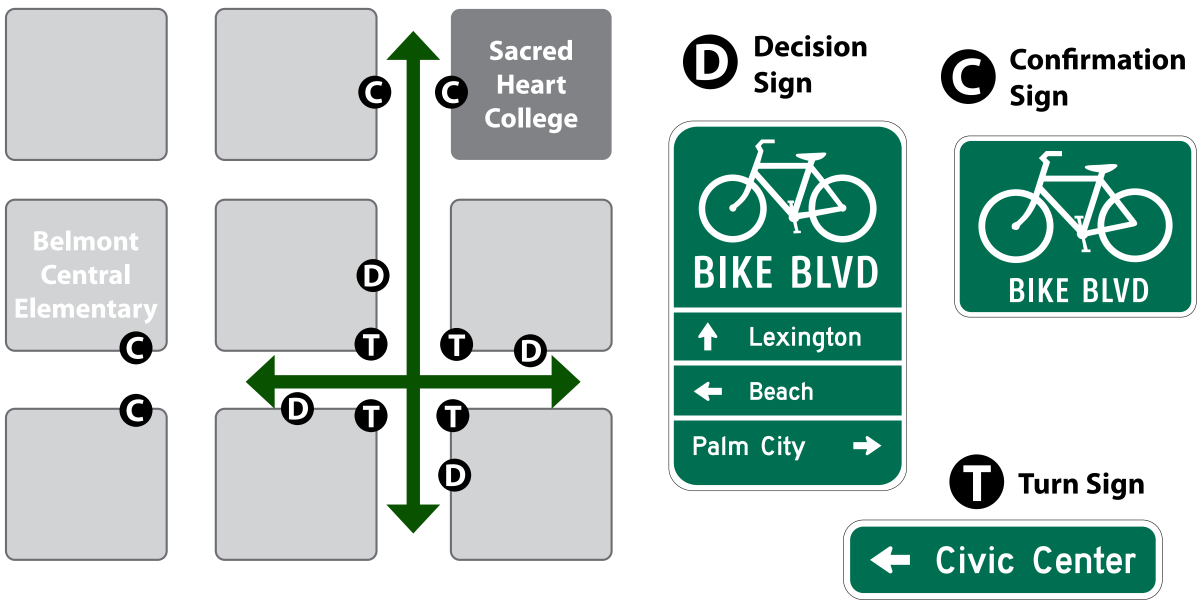
There is no evidence that wayfinding signs have any impact on crash reduction or user safety.

Construction Costs

Wayfinding signs vary based on material, size, and other characteristics.

Wayfinding Sign Placement

Signs are placed at decision points along bicycle routes – typically at the intersection of two or more bikeways and at other key locations leading to and along bicycle routes.



Typical Application

Confirmation Signs

» Placed every ¼ to ½ mile on off-street facilities and every two to three blocks along on-street bicycle facilities, unless another type of sign is used (e.g., within 150 ft of a turn or decision sign).

» Should be placed soon after turns to confirm destination(s). Pavement markings can also act as confirmation that a bicyclist is on a preferred route.

Turn Signs

» Near-side of intersections where bike routes turn (e.g., where the street ceases to be a bicycle route or does not go through).

» Pavement markings can also indicate the need to turn to the bicyclist.

Decision Signs

» Near-side of intersections in advance of a junction with another bicycle route.

» Along a route to indicate a nearby destination.

Design Features

» MUTCD guidelines should be followed for wayfinding sign placement, which includes mounting height and lateral placement from edge of path or roadway.

» Pavement markings can be used to reinforce routes and directional signage.

WAYFINDING PAVEMENT MARKINGS

Some cities use pavement markings to indicate required turns or jogs along the bicycle route.

Further Considerations

It can be useful to classify a list of destinations for inclusion on the signs based on their relative importance to users throughout the area. A particular destination's ranking in the hierarchy can be used to determine the physical distance from which the locations are signed. For example, primary destinations (such as the downtown area) may be included on signage up to five miles away. Secondary destinations (such as a transit station) may be included on signage up to two miles away. Tertiary destinations (such as a park) may be included on signage up to one mile away.

Crash Reduction

There is no evidence that wayfinding signs have any impact on crash reduction or user safety.

Construction Costs

The cost of a wayfinding sign placement plan depends on the scale and scope of the approach.

Bike Parking

Bicyclists expect a safe, convenient place to secure their bicycle when they reach their destination. This may be short-term parking of two hours or less, or long-term parking for employees, students, residents, and commuters.

Typical Application

- Bicycle parking facilities shall be located in highly visible well-lighted areas. In order to maximize security, whenever possible short-term bicycle parking facilities shall be located in areas highly visible from the street and from the interior of the building they serve (i.e., placed adjacent to windows).
- Bike racks provide short-term bicycle parking and is meant to accommodate visitors, customers, and others expected to depart within two hours. It should be an approved standard rack, appropriate location and placement, and weather protection.
- On-street bike corrals (also known as on-street bicycle parking) consist of bicycle racks grouped together in a common area within the street traditionally used for automobile parking. Bicycle corrals are reserved exclusively for bicycle parking and provide a relatively inexpensive solution to providing high-volume bicycle parking. Bicycle corrals can be implemented by converting one or two on-street motor vehicle parking spaces into on-street bicycle parking. Each motor vehicle parking space can be replaced with approximately 6-10 bicycle parking spaces.

Design Features

- All bicycle facilities shall provide a minimum four-foot aisle to allow for unobstructed access to the designated bicycle parking area. Refer to location A in the figure.
- Bicycle parking facilities within auto parking facilities shall be protected from damage by cars by a physical barrier such as curbs, wheel stops, poles, bollards, or other similar features capable of preventing automobiles from entering the designated bicycle parking area.
- Bicycle parking facilities should be securely anchored so they cannot be easily removed and shall be of sufficient strength and design to resist vandalism and theft.

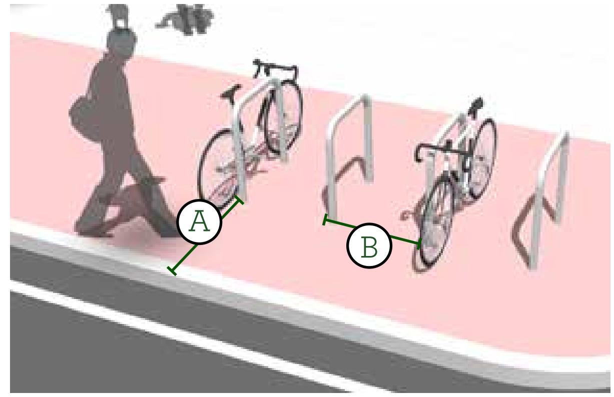
BIKE RACKS

- Two feet minimum from the curb face to avoid 'dooring.'
- Four feet between racks to provide maneuvering room. Refer to location B in the figure.
- Locate close to destinations; 50-foot maximum distance from main building entrance.
- Minimum clear distance of six feet should be provided between the bicycle rack and the property line.

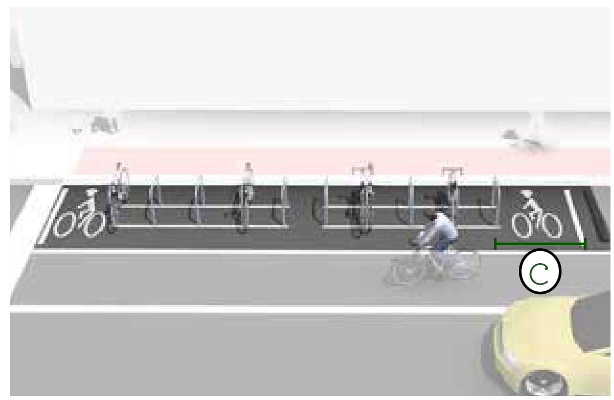
BIKE CORRALS

- Bicyclists should have an entrance width from the roadway of five to six feet for on-street corrals. Refer to location C in the figure.
- Can be used with parallel or angled parking.
- Parking stalls adjacent to curb extensions are good candidates for on-street bicycle corrals since the concrete extension serves as delimitation on one side.
- Off-street bike corrals are appropriate where there is a wide sidewalk furnishing zone (seven feet or greater), or as part of a curb extension.

PERPENDICULAR BIKE RACKS



BIKE CORRAL



Construction Costs

Costs can vary based on the design and materials used. Bicycle rack costs can range from approximately $60 to $3,600, depending on design and materials used. On average the cost is approximately $660. Bicycle lockers costs range from $1,280 to $2,680.

Bicycle Access to Transit

Safe and easy access to transit stations and secure bicycle parking facilities is necessary to encourage commuters to access transit via bicycle. Bicycling to transit reduces the need to provide expensive and space consuming car parking spaces.

Design Features

Many people who ride to a transit stop will want to bring their bicycle with them on the transit portion of their trip, so buses and other transit vehicles should be equipped accordingly.

ACCESS

» Provide direct and convenient access to transit stations and stops from the bicycle and pedestrian networks.

» Provide maps at major stops and stations showing nearby bicycle routes.

» Provide wayfinding signage and pavement markings from the bicycle network to transit stations.

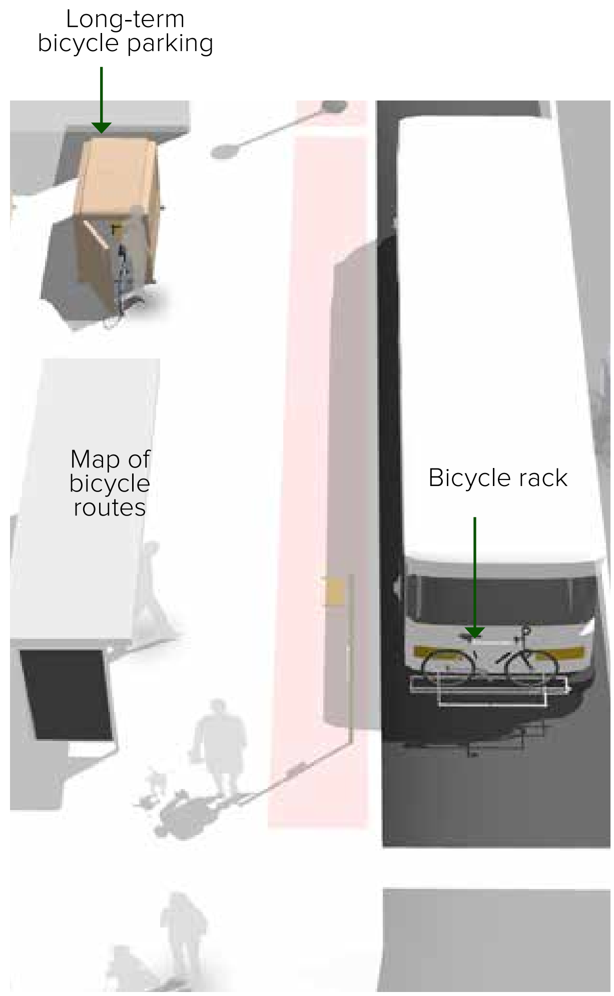
» Ensure that connecting bikeways offer proper bicycle actuation and detection.

BICYCLE PARKING

» The route from bicycle parking locations to station/stop platforms should be well-lit and visible.

» Signing should note the location of bicycle parking, rules for use, and instructions as needed.

» Provide safe and secure long-term parking such as bicycle lockers at transit hubs. Parking should be easy to use and well maintained.



Winter Maintenance

A heavy snowfall will typically require the initial removal of snow from the bikeway to restore the functionality of the facility. A proactive and reactive de-icing and traction maintenance program (discussed in the following section) in conjunction with scheduled snow removal is necessary to help maintain good riding conditions along bikeways in the winter. There are many considerations that factor into how to best remove snow from bikeways in the winter. These factors are the bikeway type, the storage of snow on or off the roadway and the presence and type of vertical protection or separation along a bikeway.

Operation Standards

A good winter maintenance program is a plan that prioritizes roadways for snow removal and storage, establishes a maintenance schedule for frequent clearing, and sets operational standards for winter maintenance relating to roadway design, equipment, and materials.

Major bikeways prioritized for plowing provide direct, predictable, connections for people on bike.

Snow Storage and Roadway Design

One of the best ways to facilitate the removal of snow from bikeways is thoughtful roadway design. While in some cases, snow is removed from the roadway and relocated to a storage site (such as a nearby commercial parking lot), most roadway maintenance programs plow snow off the main portion of the road to the shoulder (if one exists), as close to the roadway edge as possible, or along a sidewalk buffer (if one exists). Unfortunately, with roadways that include typical, unprotected bike lanes at the edge of the roadway, the bike lane often becomes the area for snow storage on the roadway. This practice leaves bicyclists either trying to share the vehicular lane or riding to the edge of the roadway while trying to avoid piled-up snow and stay clear of the vehicular path – both are unsafe and uncomfortable conditions for bicyclists on roadways with designated bike lanes. There are several roadway planning and design considerations that can be taken to avoid this situation.

WINTER MAINTENANCE IN OTTAWA, CANADA

WINTER MAINTENANCE IN VANCOUVER, BC

Protected cycletrack in Salt Lake City, UT after small truck plow snow removal. Photo Credit: Travis Jensen

PLAN ROADWAYS WITH SUFFICIENT ROW

On new roadways or in roadway reconstruction projects that include bike lanes, provide enough right of way for preferably a six-foot bike lane and a six-foot storage space on the side of the road or in the buffer space between the road and the sidewalk. This will allow typical truck-mounted snow plows to plow snow into the designated storage space rather than the bike lane. The six-foot width of the bike lane will also allow for some narrowing of the bike lane due to snow while still maintaining its functionality.

PROVIDE A WIDE BIKE LANE BUFFER

Where it is possible to provide one, such as in some “road diet” projects, a wide protected or unprotected bike lane buffer can provide ample storage space for snow. A minimum five-foot buffer is preferable to accommodate moderate snowfall with minimum encroachment upon the bike lane. This design will require the use of a smaller bike lane snow plow to clear this portion of the roadway.

RESTRICT ON-STREET PARKING DURING SNOW EVENTS

Where a bike lane is located between on-street parking and the vehicular lane, parking along the roadway can be restricted during snow events to allow this space to become snow storage space. While this isn’t an option for all roadways, it could be utilized along priority bicycle routes in the winter.

PROVIDE OFF-STREET OR PARALLEL FACILITIES

Where off-street facilities or bicycle boulevards are provided parallel to major routes, the clearing of bikeways on the main route may be unnecessary so long as these alternate snow routes are clearly marked, well-maintained, and bikeway network connectivity isn’t affected.

Sidewalk snow plow truck in Canada.

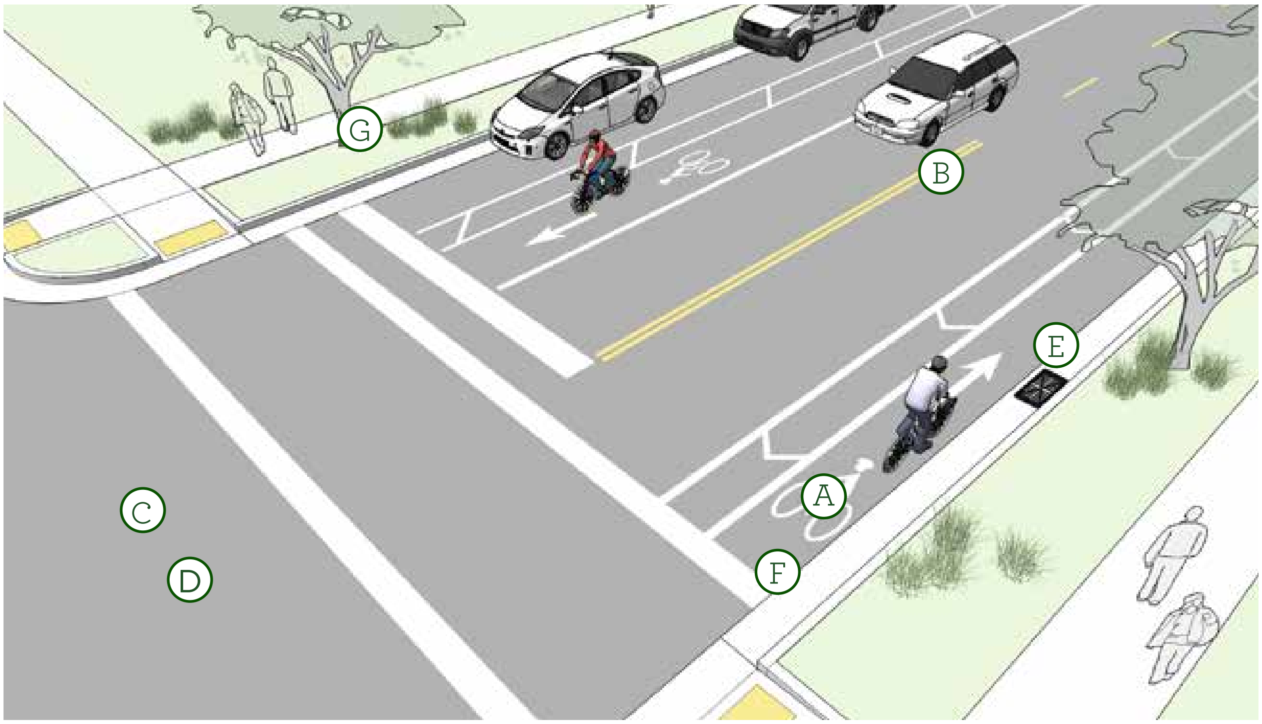
PROVIDE ENOUGH WIDTH FOR SMALL SNOW PLOW VEHICLES

There are small, specialized snow removal vehicles that are used to remove snow where typical snow removal vehicles are too wide to pass. Many large cities with harsh winter climates such as Chicago have a fleet of these specialized vehicles and ATV mounted snow plows primarily for the purpose of clearing sidewalks. While most cycletracks in Chicago can be cleared with typical pickup truck mounted snow plows, ATV mounted snow plows and bombardier snow plows are used along the protected cycletracks that are too narrow for pickup trucks.

In many towns and cities, sidewalk snow removal is contracted out, meaning that the city does not own these specialized vehicles. Utilizing existing maintenance vehicles such as pickup trucks with mounted snow blades can prove to be much more cost-effective and time-efficient than purchasing or using smaller vehicles which operate at slower speeds and have smaller plow blades. Access for snow removal vehicles should also be a consideration when designing shared-use paths and greenways.

Bikeway Maintenance

Regular bicycle facility maintenance includes sweeping, maintaining a smooth roadway, ensuring that the gutter-to-pavement transition remains relatively flush, and installing bicycle-friendly drainage grates. Pavement overlays are a good opportunity to improve bicycle facilities. The following recommendations provide a menu of options to consider to enhance a maintenance regimen.



Maintenance

Sweeping (Location A in the figure)

» Establish a seasonal sweeping schedule that prioritizes roadways with major bicycle routes.

» Sweep walkways and bikeways whenever there is an accumulation of debris on the facility.

» In curbed sections, sweepers should pick up debris; on open shoulders, debris can be swept onto gravel shoulders.

Signage (Location B in the figure)

» Check regulatory and wayfinding signage along bikeways for signs of vandalism, graffiti, or normal wear.

» Replace signage along the bikeway network as-needed.

» Perform a regularly-scheduled check on the status of signage with follow-up as necessary.

» Create a Maintenance Management Plan.

Roadway Surface (Location C in the figure)

» Maintain a smooth pothole-free surface.

» Ensure that on new roadway construction, the finished surface on bikeways does not vary more than ¼".

» Maintain pavement so ridge buildup does not occur at the gutter-to-pavement transition or adjacent to railway crossings.

» Inspect the pavement two to four months after trenching construction activities are completed to ensure that excessive settlement has not occurred.

Pavement Overlays (Location D in the figure)

» Extend the overlay over the entire roadway surface to avoid leaving an abrupt edge.

» If the shoulder or bike lane pavement is of good quality, it may be appropriate to end the overlay at the shoulder or bike lane stripe provided no abrupt ridge remains.

» Ensure that inlet grates, manhole and valve covers are within ¼ inch of the finished pavement surface and are made or treated with slip resistant materials.

Drainage Grates (Location E in the figure)

» Require all new drainage grates be bicycle-friendly, including grates that have horizontal slats on them so that bicycle tires and assistive devices do not fall through the vertical slats.

» Create a program to inventory all existing drainage grates, and replace hazardous grates as necessary – temporary modifications such as installing rebar horizontally across the grate should not be an acceptable alternative to replacement.

Gutter to Pavement Transition (Location F in the figure)

» Ensure that gutter-to-pavement transitions have no more than a ¼ inch vertical transition.

» Examine pavement transitions during every roadway project for new construction, maintenance activities, and construction project activities that occur in streets.

Landscaping (Location G in the figure)

» Ensure that shoulder plants do not hang into or impede passage along bikeways

» After major damage incidents, remove fallen trees or other debris from bikeways as quickly as possible

Maintenance Management Plan

» Provide fire and police departments with map of system, along with access points to gates/bollards

» Enforce speed limits and other rules of the road

» Enforce all trespassing laws for people attempting to enter adjacent private properties

RECOMMENDED WALKWAY AND BIKEWAY MAINTENANCE ACTIVITIES

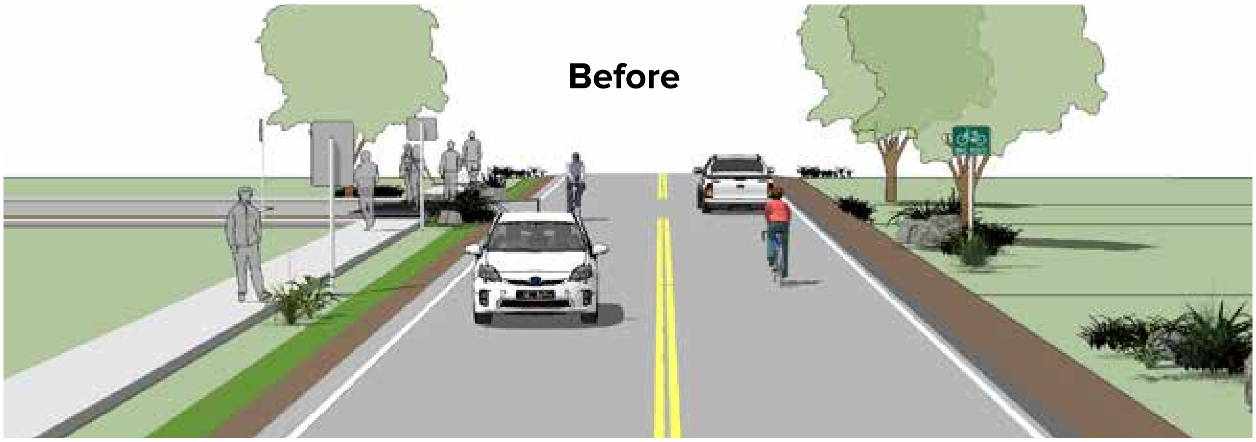
Inspections	Seasonal – at beginning and end of Summer
Pavement sweeping/ blowing	As needed, with higher frequency in the early Spring and Fall
Pavement sealing	5 - 15 years
Pothole repair	1 week – 1 month after report
Culvert and drainage grate inspection	Before Winter and after major storms
Pavement markings replacement	As needed
Signage replacement	As needed
Shoulder plant trimming (weeds, trees, brambles)	Twice a year; middle of growing season and early Fall
Tree and shrub plantings, trimming	1 – 3 years
Major damage response (washouts, fallen trees, flooding)	As soon as possible

RETROFITTING STREETS

Retrofitting existing streets to add bikeways requires reallocating existing street width through striping modifications. The reallocation of space, through lane narrowing and lane reconfiguration, can provide enough space to add bicycle accommodations. Roadways can also be widened, when necessary, to provide additional space.

Roadway Widening

Bike lanes can be accommodated on streets with excess right-of-way through shoulder widening. Although roadway widening incurs higher expenses compared with re-striping projects, bike lanes can be added to streets currently lacking curbs, gutters and sidewalks without the high costs of major infrastructure reconstruction.



Typical Application

» Roadway widening is most appropriate on roads lacking curbs, gutters and sidewalks.

» If it is not possible to meet minimum bicycle lane dimensions, a reduced width paved shoulder can still improve conditions for bicyclists on constrained roadways. In these situations, a minimum of three feet of operating space should be provided.

Design Features

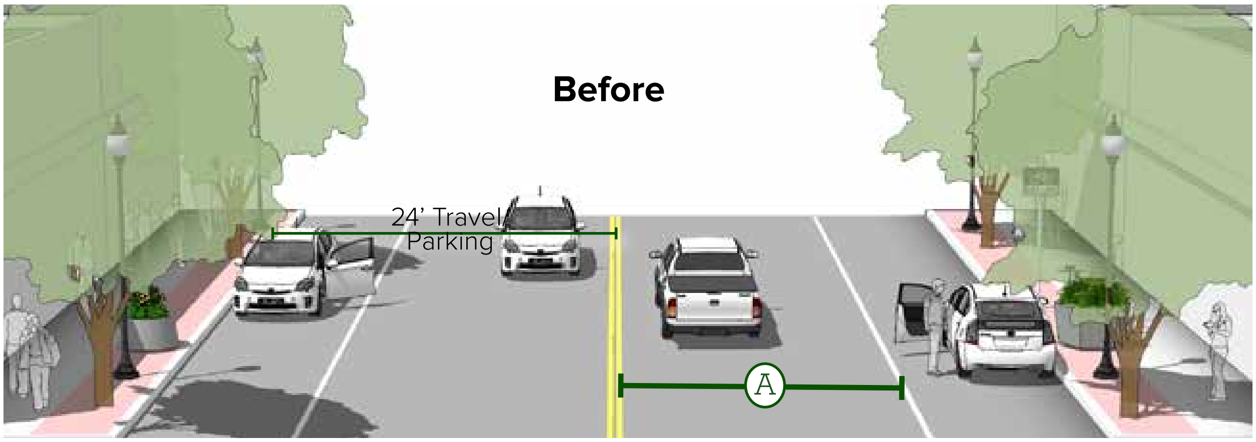
» Guidance on bicycle lanes applies to this treatment.

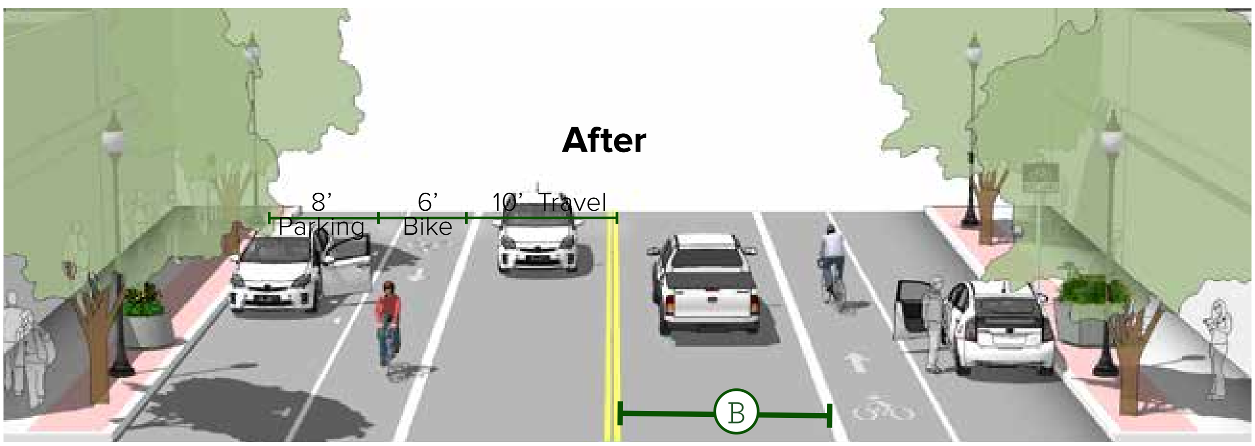
» Four-foot minimum width when no curb and gutter is present.

» Six-foot width preferred. Refer to location A in the figure.

Lane Narrowing

Lane narrowing utilizes roadway space that exceeds minimum standards to provide the needed space for bike lanes. Many roadways have existing travel lanes that are wider than those prescribed in local and national roadway design standards, or which are not marked.





Typical Application

- » On roadways with wide lane widths. Most standards allow for the use of 11-foot and sometimes 10-foot wide travel lanes to create space for bike lanes.
- » Special consideration should be given to the amount of heavy vehicle traffic and horizontal curvature before the decision is made to narrow travel lanes. Center turn lanes can also be narrowed in some situations to free up pavement space for bike lanes.

Design Features

VEHICLE LANE WIDTH:

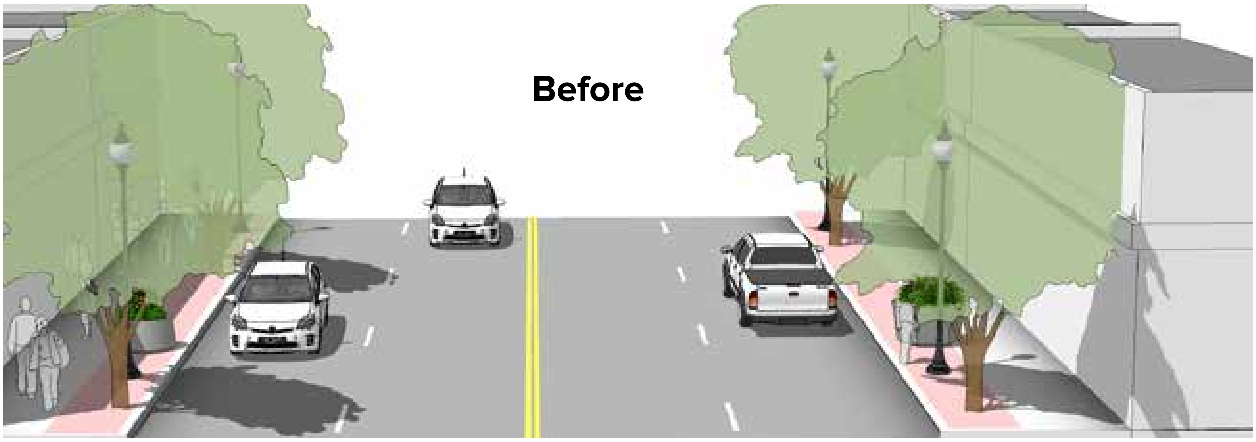
- » Before: 10-15 feet. Refer to location A in the figure.
- » After: 10-11 feet. Refer to location B in the figure.

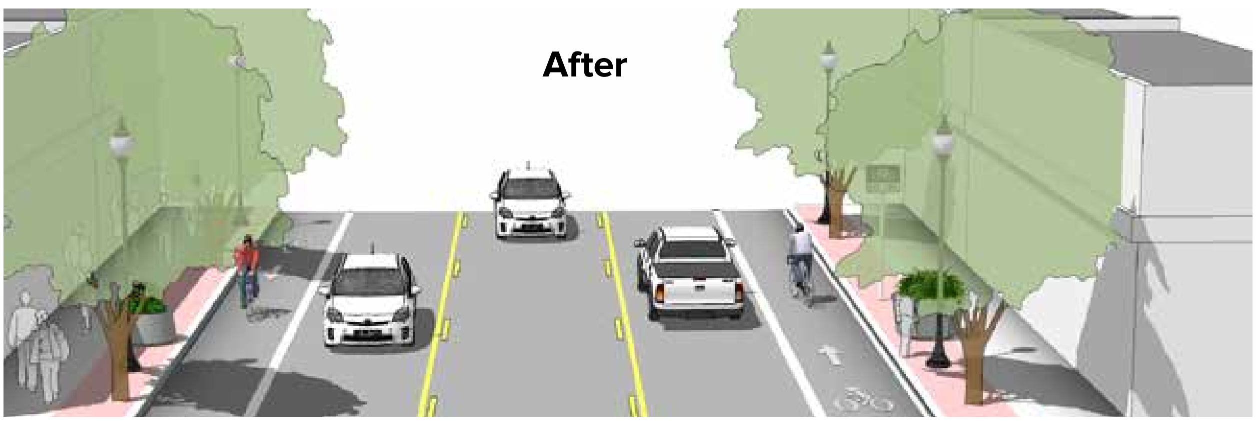
BICYCLE LANE WIDTH:

- » Guidance on bicycle lanes applies to this treatment.

Lane Reconfiguration

The removal of a single travel lane will generally provide sufficient space for bike lanes on both sides of a street. Streets with excess vehicle capacity provide opportunities for bike lane retrofit projects.





Typical Application

Depending on a street's existing configuration, traffic operations, user needs and safety concerns, various lane reduction configurations may apply. For instance, a four-lane street (with two travel lanes in each direction) could be modified to provide one travel lane in each direction, a center turn lane, and bike lanes. Prior to implementing this measure, a traffic analysis should identify potential impacts.

Design Features

VEHICLE LANE WIDTH:

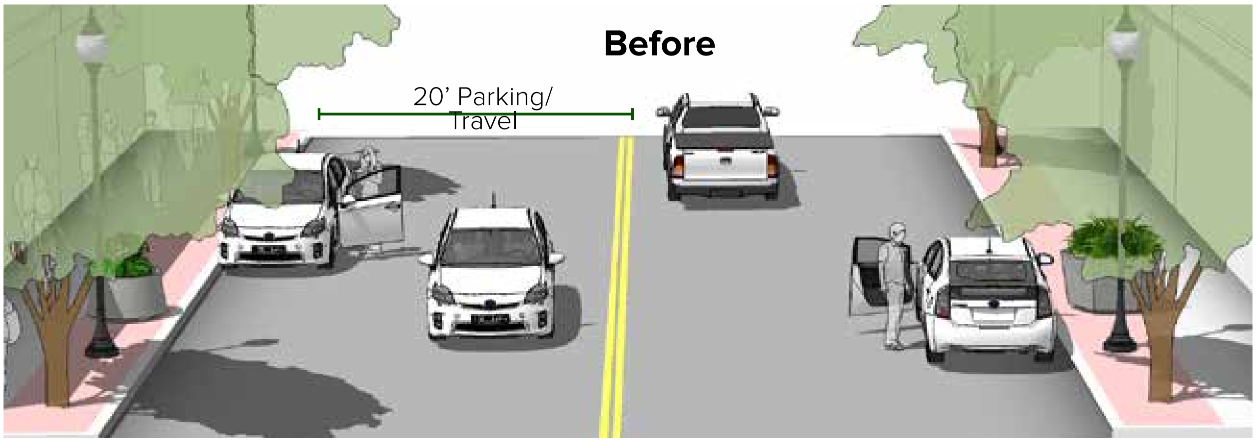
» Width depends on project. No narrowing may be needed if a lane is removed.

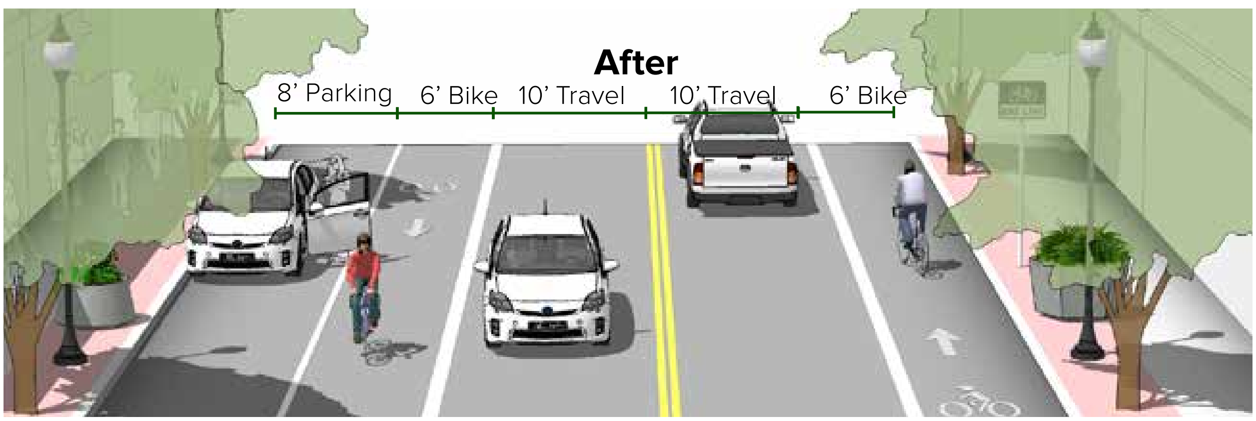
BICYCLE LANE WIDTH:

» Guidance on bicycle lanes applies to this treatment.

Parking Reduction

Bike lanes can replace one or more on-street parking lanes on streets where excess parking exists and/or the importance of bike lanes outweighs parking needs. For example, parking may be needed on only one side of a street. Eliminating or reducing on-street parking also improves sight distance for bicyclists in bike lanes and for motorists on approaching side streets and driveways.





Typical Application

Removing or reducing on-street parking to install bike lanes requires comprehensive outreach to the affected businesses and residents. Prior to reallocating on-street parking for other uses, a parking study should be performed to gauge demand and to evaluate impacts to people with disabilities.

Design Features

VEHICLE LANE WIDTH:

» Parking lane width depends on project. No travel lane narrowing may be required depending on the width of the parking lanes.

BICYCLE LANE WIDTH:

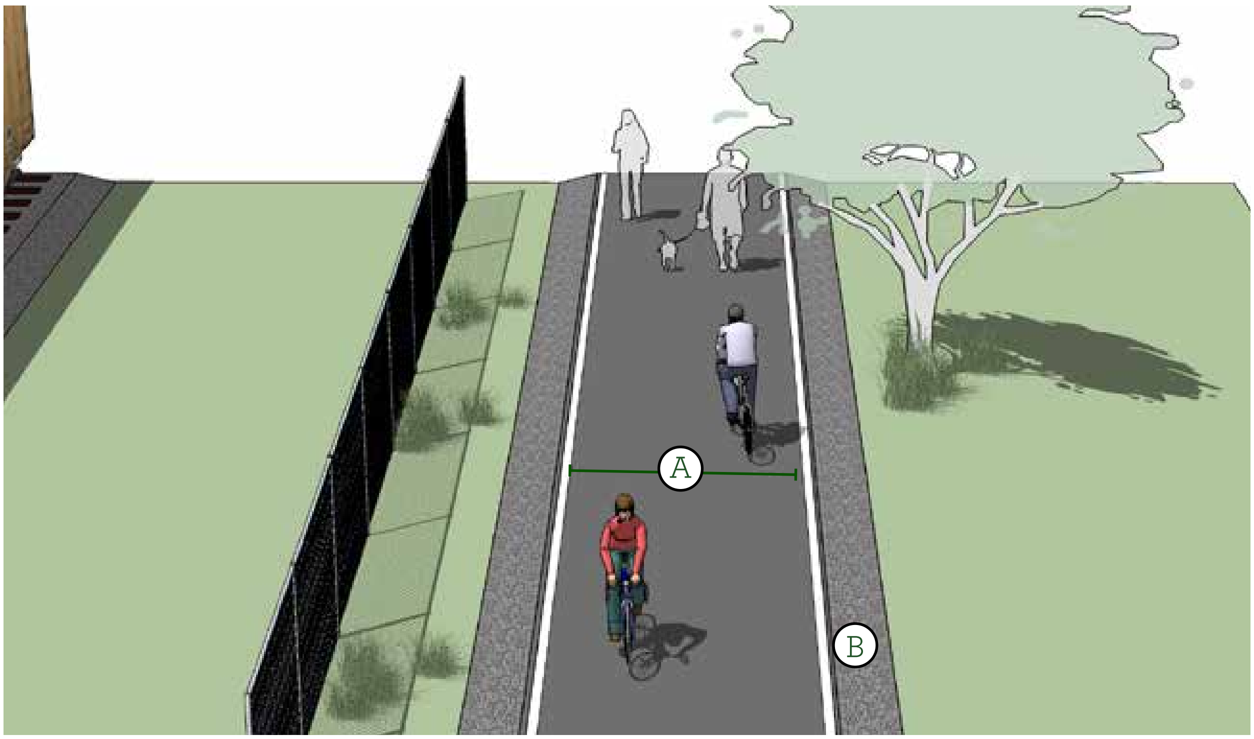
» Guidance on bicycle lanes applies to this treatment.

OFF-STREET FACILITIES

Off-street facilities provide places for walking and bicycling that are separated from motor vehicle traffic. These facilities are frequently found in parks, along rivers, beaches, and in greenbelts or utility corridors where there are few conflicts with motorized vehicles. Off-street facilities can also include amenities such as lighting, signage, and fencing.

Shared Use Path

Shared use paths can provide a desirable facility, particularly for recreation, and users of all skill levels preferring separation from traffic. Bicycle paths should generally provide directional travel opportunities not provided by existing roadways.



Typical Application

- » In abandoned rail corridors (commonly referred to as Rails-to-Trails or Rail-Trails.
- » In active rail corridors, trails can be built adjacent to active railroads (referred to as Rails-with-Trails.
- » In utility corridors, such as powerline and sewer corridors.
- » In waterway corridors, such as along canals, drainage ditches, rives and beaches.
- » Along roadways.

Design Features

WIDTH

» Eight feet is the minimum allowed for a two-way bicycle path and is only recommended for low traffic situations. Refer to location A in the figure

» Ten feet is recommended in most situations and will be adequate for moderate to heavy use.

» Twelve feet is recommended for heavy use situations with high concentrations of multiple users. A separate track (five-foot minimum) can be provided for pedestrian use.

LATERAL CLEARANCE

» A two-foot or greater shoulder on both sides of the path should be provided. An additional foot of lateral clearance (total of three feet) is required by the MUTCD for the installation of signage or other furnishings. Refer to location B in the figure

» If bollards are used at intersections and access points, they should be colored brightly and/or supplemented with reflective materials to be visible at night.

OVERHEAD CLEARANCE

» Clearance to overhead obstructions should be eight feet minimum, with 10 feet recommended.

STRIPING

» When striping is required, use a four inch dashed yellow centerline stripe with four inch solid white edge lines.

» Solid centerlines can be provided on tight or blind corners, and on the approaches to roadway crossings.

Further Considerations

The provision of a shared use path adjacent to a road is not a substitute for the provision of on-road accommodation such as paved shoulders or bike lanes, but may be considered in some locations in addition to on-road bicycle facilities.

To reduce potential conflicts in some situations, it may be better to place one-way sidepaths on both sides of the street.

Crash Reduction

Shared use paths reduce injury rates for cyclists, pedestrians, and other nonmotorized modes by 60 percent compared with on street facilities.[1]

Construction Costs

The cost of a shared use path can vary substantially based on design characteristics like surface type, width, depth, grading, and retaining walls.

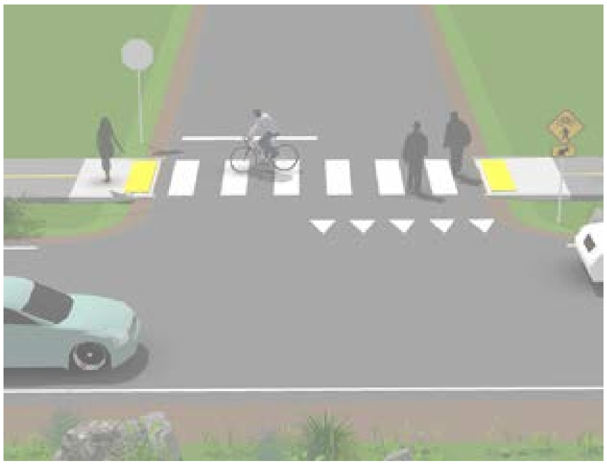
1Teschke, Kay. Route Infrastructure and the Risk of Injuries to Bicyclists. American Public Health Association. December 2012.

Sidepaths

Shared Use Paths within road right-of-way, also called sidepaths, are a type of path that run adjacent to a street. Sidepaths are for both bicycle and pedestrian travel.

Because of operational concerns it is generally preferable to place paths within independent rights-of-way away from roadways. However, there are situations where existing roads provide the only corridors available.

Adjacent Crossing - A separation of six feet emphasizes the conspicuity of riders at the approach to the crossing.



Setback Crossing - A set back of 25 feet separates the path crossing from merging/turning movements that may be competing for a driver's attention.

Typical Application

» Along one or both sides of roadways

» To reduce potential conflicts in some situations, it may be better to place one-way sidepaths on both sides of the street.

Design Features

» Guidance for sidepaths should follow that for general design practices of shared use paths.

» A high number of driveway crossings and intersections create potential conflicts with turning traffic. Consider alternatives to sidepaths on streets with a high frequency of intersections or heavily used driveways.

» Where a sidepath terminates special consideration should be given to transitions so as not to encourage unsafe wrong-way riding by bicyclists.

» Crossing design should emphasize visibility of users and clarity of expected yielding behavior. Crossings may be STOP or YIELD controlled depending on sight lines and bicycle motor vehicle volumes and speeds.

A sidepath is a facility for both pedestrians and bicyclists that is physically separated from motor vehicle traffic but located within the road right-of-way. Sidepaths are appropriate in a variety of contexts, including both urban and rural communities.

Further Considerations

The provision of a shared use path adjacent to a road is not a substitute for the provision of on-road accommodation such as paved shoulders or bike lanes, but may be considered in some locations in addition to on-road bicycle facilities.

RETROFITTING

Where space is available, it may be appropriate to retrofit an existing five-foot sidewalk into a 10-foot concrete sidepath. While sidewalks typically do not allow for bicycle traffic, sidepaths are wider and allow for bidirectional bicycle travel. This may be appropriate where high volumes of bicyclists and pedestrians are expected to be present, and/or when motor vehicle speeds and volumes create unsafe conditions for on-street bike lanes.

Crash Reduction

Sidepaths reduce injury rates for cyclists, pedestrians, and other nonmotorized modes by 60 percent compared with on street facilities.[1]

Materials and Maintenance

Asphalt is the most common surface for bicycle paths. The use of concrete for paths has proven to be more durable over the long term. Saw cut concrete joints rather than troweled improve the experience of path users.

1Teschke, Kay. Route Infrastructure and the Risk of Injuries to Bicyclists. American Public Health Association. December 2012.

Local Neighborhood Accessways

Neighborhood accessways provide residential areas with direct bicycle and pedestrian access to parks, trails, greenspaces, and other recreational areas. They most often serve as small trail connections to and from the larger trail network, typically having their own rights-of-way and easements.

Typical Application

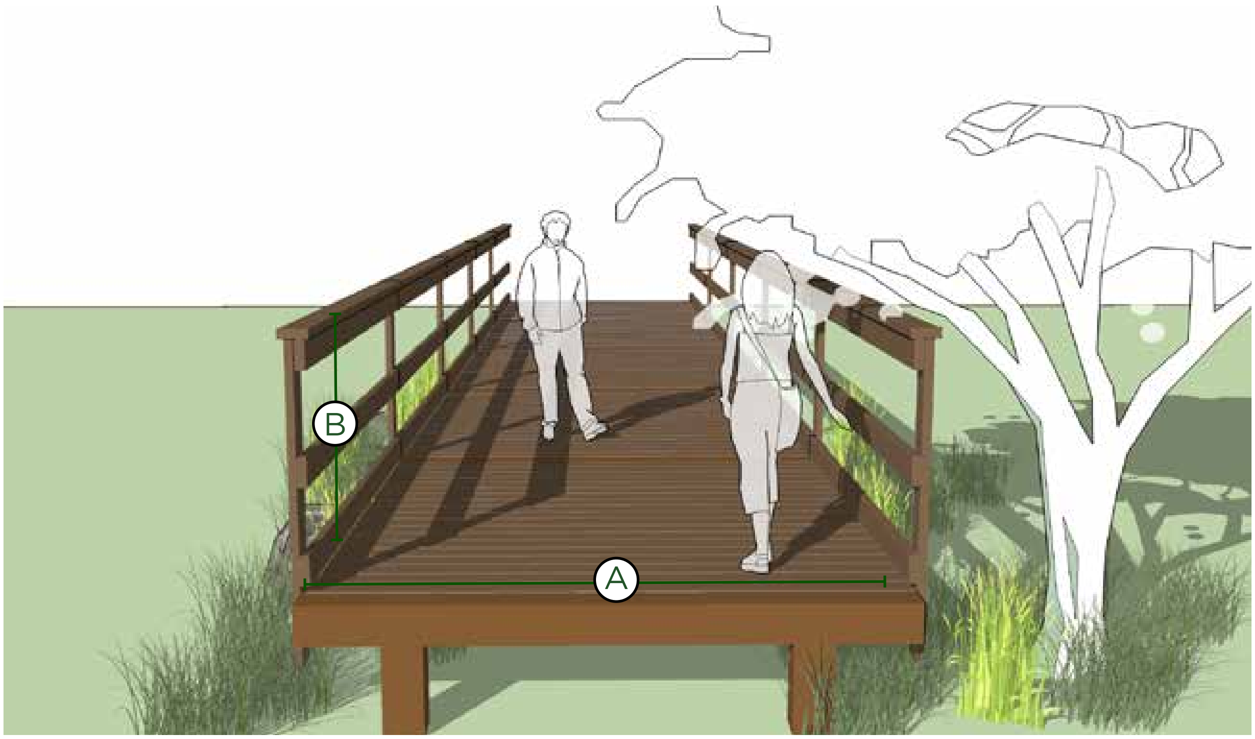
- » Neighborhood accessways should be designed into new subdivisions at every opportunity and should be required by City/County subdivision regulations.
- » For existing subdivisions, neighborhood and homeowner association groups are encouraged to identify locations where such connects would be desirable. Nearby residents and adjacent property owners should be invited to provide landscape design input.

Design Features

- » Neighborhood accessways should remain open to the public.
- » Trail pavement shall be at least eight feet wide to accommodate emergency and maintenance vehicles, meet ADA requirements and be considered suitable for multi-use. Refer to location A in the figure
- » Trail widths should be designed to be less than eight feet wide only when necessary to protect large mature native trees over 18 inches in caliper, wetlands or other ecologically sensitive areas.
- » Access trails should slightly meander whenever possible.

Boardwalks

Boardwalks are typically required when crossing wetlands or other sensitive natural areas. A number of low-impact support systems are also available that reduce the disturbance within wetland areas to the greatest extent possible.



Typical Application

» Boardwalks are usually constructed of wooden planks or recycled material planks that form the top layer of the boardwalk. The recycled material has gained popularity in recent years since it lasts much longer than wood, especially in wet conditions.

» In general, building in wetlands is subject to regulations and should be avoided.

Design Features

» A boardwalk width should be a minimum of 10 feet when no rail is used. A 12-foot width is preferred in areas with average anticipated use and whenever rails are used. Refer to location A in the figure.

» When the height of a boardwalk exceeds 30 inches, railings are required. Refer to location B in the figure.

» If access by vehicles is desired, boardwalks should be designed to structurally support the weight of a small truck or a light-weight vehicle.

STREET CROSSING TREATMENTS FOR OFF-STREET FACILITIES

Careful consideration should be given when designing and implementing trail intersection treatments, to ensure safe and convenient trail crossings for people walking and biking. Trail intersection treatments may be simple marked crosswalks on low volume, low speed roadways or may require more intensive treatments, such as signalization.

Marked Crossing

A marked/unsignalized crossing typically consists of a marked crossing area, signage, and other markings to slow or stop traffic. The approach to designing crossings at mid-block locations depends on an evaluation of vehicular traffic, line of sight, pathway traffic, use patterns, vehicle speed, road type, road width, and other safety issues such as proximity to major attractions.

Typical Application

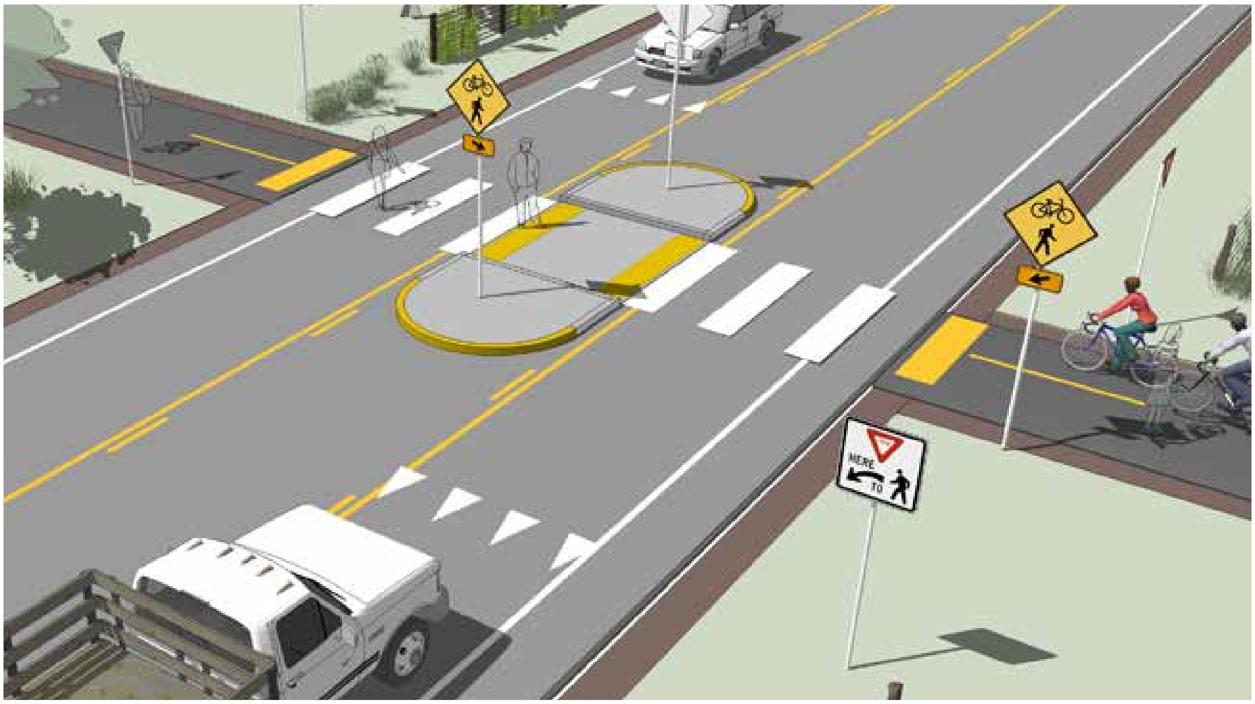
- Maximum Traffic Volumes
    - ≤9,000-12,000 Average Daily Traffic (ADT) volume
- Maximum travel speed of 35 MPH
- Minimum Sight Lines
    - 25 MPH zone: 155 feet
    - 35 MPH zone: 250 feet
    - 45 MPH zone: 360 feet

Design Features

- On roadways with low to moderate traffic volumes (<12,000 ADT) and a need to control traffic speeds, a raised crosswalk may be the most appropriate crossing design to improve pedestrian visibility and safety.

Median Crossing

On roadways with higher volumes, higher speeds and multi-lanes of vehicular traffic, a median crossing is preferred. A median refuge island can improve user safety by providing pedestrians and bicyclists space to perform the safe crossing of one side of the street at a time.



Typical Application

- Maximum Traffic Volumes
  - Up to 15,000 ADT on two-lane roads, preferably with a median
  - Up to 12,000 ADT on four-lane roads with median

Design Features

- Unsignalized crossings of multi-lane arterials over 15,000 ADT may be possible with features such as sufficient crossing gaps (more than 60 per hour), median refuges, and/or active warning devices like rectangular rapid flash beacons or in-pavement flashers, and excellent sight distance. For more information see the discussion of active warning beacons.

Active Warning Beacons

Active warning beacons are user actuated illuminated devices designed to increase motor vehicle yielding compliance at crossings of multi lane or high volume roadways. Types of active warning beacons include conventional circular yellow flashing beacons, in-roadway warning lights, or pedestrian activated beacons.

Typical Application

- Warning beacons shall not be used at crosswalks controlled by YIELD signs, STOP signs, or traffic signals.
- Warning beacons shall initiate operation based on pedestrian or bicyclist actuation and shall cease operation at a predetermined time after actuation or, with passive detection, after the pedestrian or bicyclist clears the crosswalk. Beacons shall be unlit when not activated.

Design Features

- Types of active warning beacons include conventional circular yellow flashing beacons, in-roadway warning lights, or activated flashing beacons.
- Activated flashing beacons have the most increased compliance of all the warning beacon enhancement options.
- Installations of active warning beacons on median islands improves driver yielding behavior.
- Rectangular Rapid Flashing Beacons (RRFB) have been rescinded by FHWA because the MUTCD prohibits the use of patented devices. RRFBs may not be installed after December 21, 2017.
- FHWA recommends the use of Pedestrian Activated Beacons, with two circular-shaped yellow lights that flash in an alternating pattern, with a flashrate of 50-60 times per minute and an illuminated period of each flash a minimum of ½ and maximum of 2/3 of the total cycle.

Route Users to Signalized Crossing

Path crossings within approximately 400 ft of an existing signalized intersection with pedestrian crosswalks are typically diverted to the signalized intersection to avoid traffic operation problems when located so close to an existing signal.

Typical Application

- For this restriction to be effective, barriers and signing may be needed to direct path users to the signalized crossing. If no pedestrian crossing exists at the signal, modifications should be made.
- Path crossings should not be provided within approximately 400 feet of an existing signalized intersection. If possible, route path directly to the signal.

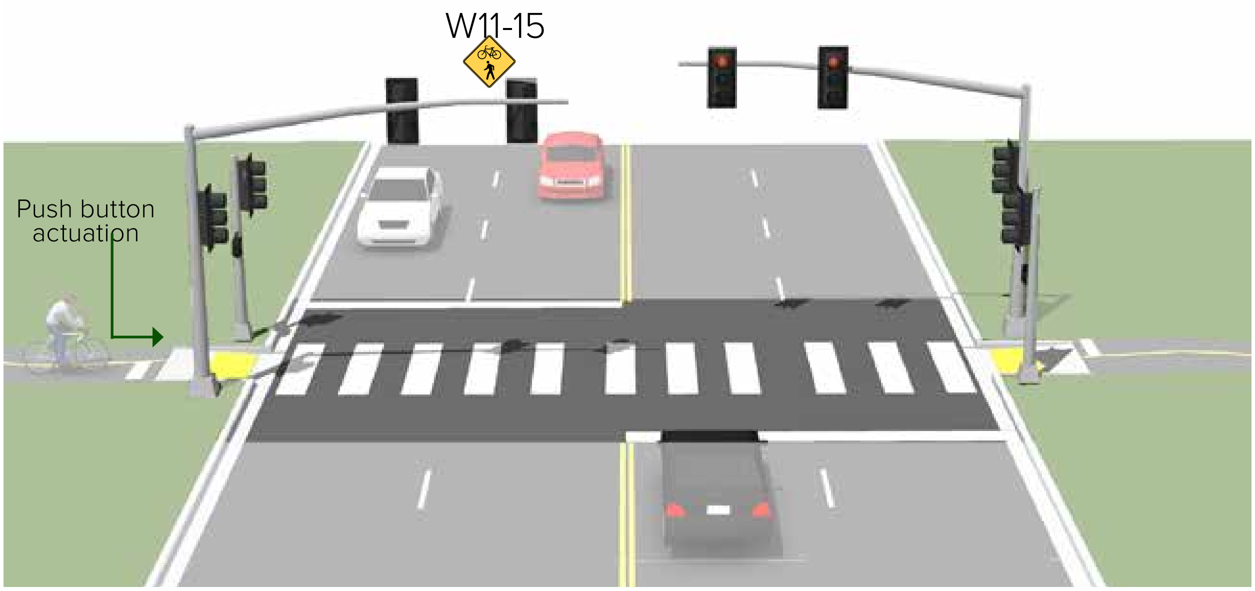
Design Features

- In the US, the minimum distance a marked crossing can be from an existing signalized intersection varies from approximately 250 to 660 feet.
- Engineering judgment and the context of the location should be taken into account when choosing the appropriate allowable setback. Pedestrians are particularly sensitive to out of direction travel and undesired mid-block crossing may become prevalent if the distance is too great.

Full Traffic Signal Crossings

Signalized crossings provide the most protection for crossing path users through the use of a red-signal indication to stop conflicting motor vehicle traffic.

A full traffic signal installation treats the path crossing as a conventional four-way intersection and provides standard red-yellow-green traffic signal heads for all legs of the intersection.



Typical Application

Full traffic signal installations must meet MUTCD pedestrian, school or modified warrants. Additional guidance for signalized crossings:

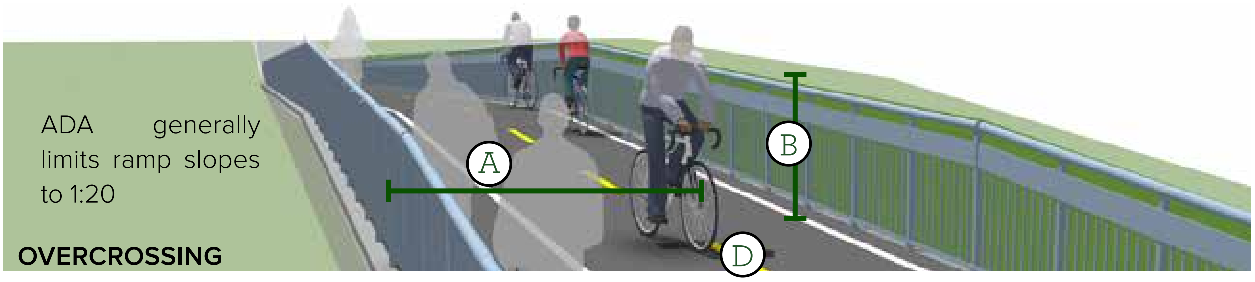
- » Located more than 300 feet from an existing signalized intersection
- » Roadway travel speeds of 40 MPH and above
- » Roadway ADT exceeds 15,000 vehicles

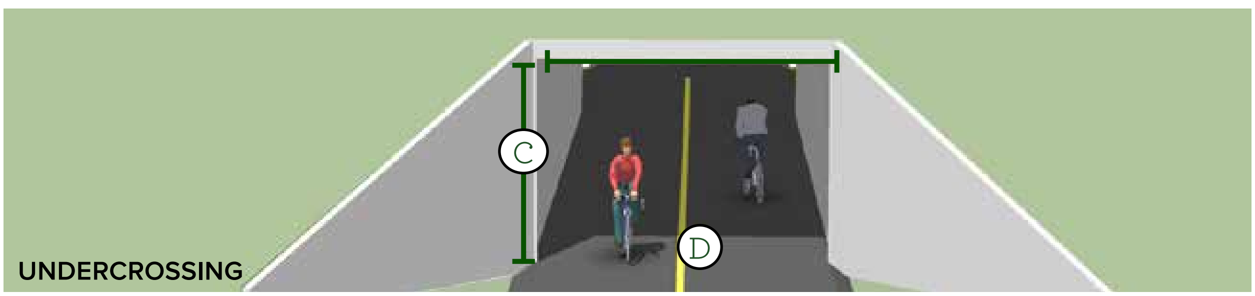
Design Features

- » Shared use path signals are normally activated by push buttons but may also be triggered by embedded loop, infrared, microwave or video detectors. The maximum delay for activation of the signal should be two minutes, with minimum crossing times determined by the width of the street.
- » Each crossing, regardless of traffic speed or volume, requires additional review by a registered engineer to identify sight lines, potential impacts on traffic progression, timing with adjacent signals, capacity and safety.

Grade-Separated Crossings

Grade-separated crossings provide critical non-motorized system links by joining areas separated by barriers such as railroads, waterways, and highway corridors. In most cases, these structures are built in response to user demand for safe crossings where they previously did not exist. There are no minimum roadway characteristics for considering grade separation.





Typical Application

- Where shared-use paths cross high-speed and high-volume roadways where an at-grade signalized crossing is not feasible or desired, or where crossing railways or waterways.
- Depending on the type of facility or the desired user group, grade separation may be considered in many types of projects.

Design Features

- Overcrossings should be at least 8 feet wide with 14 feet preferred and additional width provided at scenic viewpoints. Refer to location A in the figure.
- Railing height must be a minimum of 42 inches for overcrossings. Refer to location B in the figure.
- Undercrossings should be designed at minimum 10-foot height and 14-foot width, with greater widths preferred for lengths over 60 feet. Refer to location C in the figure.
- Centerline stripe is recommended for grade-separated facility. Refer to location D in the figure.