Appendix 8 Bend Bikeway Design Guide

BIKEWAY DESIGN GUIDE 2019

CITY OF BEND

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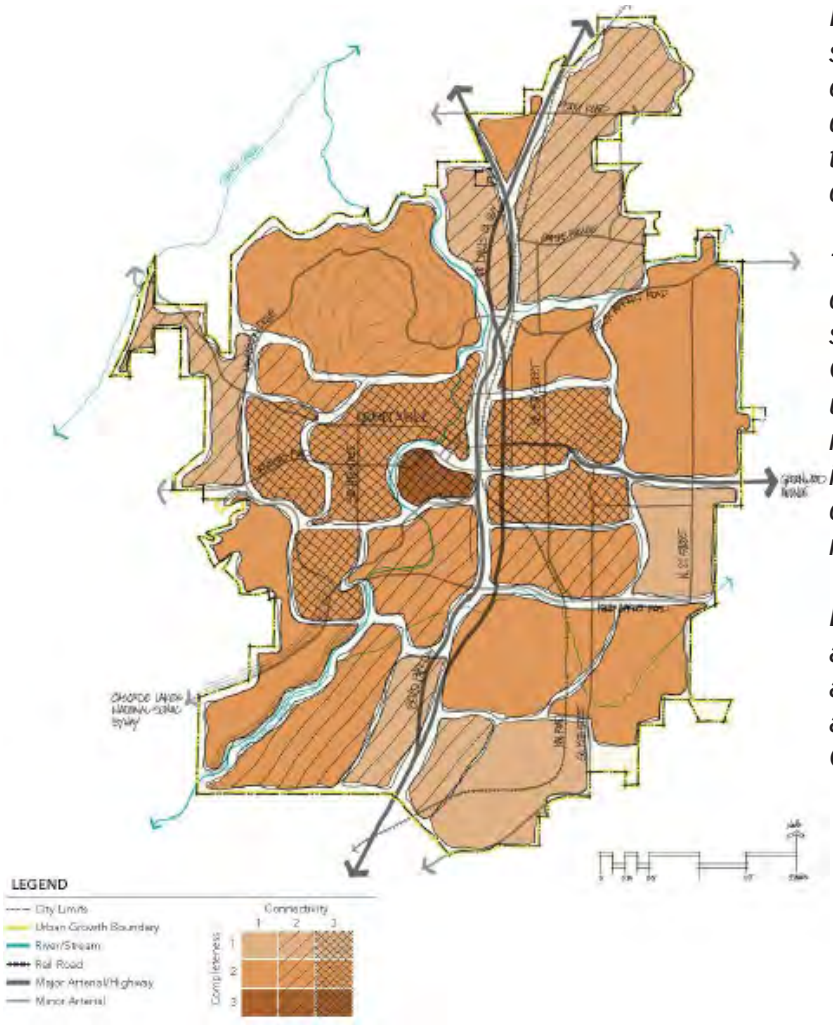
Chapter 1

Bicycle Planning: Low-Stress Network Development in Bend

Bend Bicycling Goals and Policies

The City's Transportation System Plan (TSP) requires a coordinated network of transportation facilities (reflecting requirements of Oregon's Administrative Rules (OAR 660-012-0020). The TSP also identifies key goals and policies of the Comprehensive Plan such as: serve complete neighborhoods; create a balanced transportation system; increase transportation choices; provide complete streets; and improve the safety and quality of walking and biking facilities. This Guide implements these key goals and policies of the TSP.

The Guide outlines a network approach to create critical connectivity and illustrates Bend's best practices to safely and comfortably serve people of all ages and abilities. The designs and guidance in this document are adapted from the Oregon Department of Transportation (ODOT) to allow facilities to be built in Bend with new construction, reconstruction and with pavement preservation projects when the potential to do so exists. This Guide identifies resources necessary to adequately operate and maintain these facilities.



In planning for growth, urban form studies were used to illustrate and examine relationships between density, connectivity, access to destinations, neighborhood completeness and access to transit.

This graphic shows neighborhood completeness and connectivity was strongest in the core. The City's Comprehensive Plan amended land use designations to achieve greater neighborhood completeness and increased transportation quality and connectivity to serve the completed neighborhoods.

By ensuring bikeways provide adequate coverage, connectivity, and service levels for all ages and abilities, the City can implement the Comprehensive Plan.

Bicycling in Bend

Bend has a supportive land use pattern, which translates into short distances traveled for transportation needs. The City's transportation system already has several high-quality bike facilities, such as trails and short segments of protected bikeways. These are the foundation for a safe, well-used bicycling transportation system.

Supportive Land Use Patterns

In 2017, the City of Bend adopted an Integrated Land Use Transportation Plan (ILUTP) within the Comprehensive Plan. The Plan established a Growth Boundary that accommodates projected population forecasts. The plan creates mixed-use, complete neighborhoods, that allow families to travel short distances for their everyday needs. Complete neighborhoods provide a wide variety of home styles along with schools, parks, and commercial services for everyday needs closer to home.

Short Distances

Further complementing the city's complete neighborhood zoning system, Bend itself is compact. The City of Bend is only 5 miles wide and 8 miles long. Most trips cover distances many people could bike if there were routes people considered safe.

High Quality Bike Facilities

Since 2000, national design guidelines have evolved to create safer, more efficient facilities for all modes of travel. New traffic signal controllers allow better detection and more efficient operations. Modern roundabout designs prevent serious injury and fatal crashes and efficiently handle high volumes of traffic. Bike facility design, particularly in the past 10 years, has evolved to create safer, more efficient and comfortable bike facilities. Research and science have been applied to create a strong suite of state of the practice bike facility designs. This guideline incorporates these into Bend's transportation system in a cohesive manner to create bicycling infrastructure that is more accessible to a larger percentage of the population.

This strategy will create a network of low-stress bikeways in Bend by providing facilities for people who want to travel by bike with an easy-to-find, easy-to-follow, well-connected network, while also enhancing the safety and operations within the network for all road users.

Bend Bicycling Vision

Bend is accessible for people of all ages and abilities to travel by bike to work, school, shopping and recreation. Within a short distance of their home, people can access a network of low-stress bikeways. This network of low-stress bikeways is easy for people to understand and navigate. Many of these routes are on low volume local streets and trails, and clear way-finding signs help people navigate these routes to get around town. Where key connections are planned to utilize busy streets, greater separation or protection is provided between bike riders and motor vehicles.

IMPLEMENTATION

This guide sets forth an effective implementation plan by identifying design standards and resources needed to construct, operate and maintain low-stress bikeway facilities. The new standards will apply to new road construction as well as targeted bike specific infrastructure projects. When feasible, low-stress bikeways will be retrofit during annual pavement preservation projects.

Bicycling Trip Growth

Since the adoption of the Oregon Bike Bill in the 1970s bike lanes have been required on all arterial and collector roadways. A 2018 assessment of Bend's bikeways showed the network was almost complete but there were many gaps where a bike lane ended abruptly. Additionally, bike lanes and road crossings were predominantly high stress and crash types typically fell into common categories such as right turn hooks and crossing crashes of wide, busy roadways.

The American Community Survey (ACS) reported Bend's bike ridership for trips to and from work as 2.40% in 2009 and 3.65%[1] in 2016. This increase is attributed to construction projects which closed gaps in routes, added safer crosswalks and built roundabouts.

For anyone to ride a bike for everyday transportation, the route needs to be convenient, safe, and comfortable and maintained year-round. Bike riding rates can be greatly increased by adopting low-stress designs which are proven, cost-effective techniques to better serve people's needs[2].For example, the City of Portland's bicycling to work trips increased to 7.2%[3] while Boulder Colorado now has 10.7% bike to work trips made by bike.

Northern cities such as Minneapolis, Denver, and Madison, Wisconsin have strong bicycle ridership throughout the year because they prioritize winter maintenance. This Guide identifies resources needed to support the construction, operation and maintenance of a low-stress bikeway network in Bend.

1 American Community Survey - Census Bureau

2 Portland State University Transportation Research Center, "Lessons from the Green Lanes: Evaluating Protected Bike Lanes in the U.S., Chris Monsere.

3 American Community Survey - Census Bureau

DISCUSSION

2012 American Community Survey Questionnaire

31 **How did this person usually get to work LAST WEEK?** *If this person usually used more than one method of transportation during the trip, mark (X) the box of the one used for most of the distance.*

- ☐ Car, truck, or van
- ☐ Bus or trolley bus
- ☐ Streetcar or trolley car
- ☐ Subway or elevated
- ☐ Railroad
- ☐ Ferryboat
- ☐ Taxicab
- ☐ Motorcycle
- ☐ Bicycle
- ☐ Walked
- ☐ Worked at home → *SKIP to question 39a*
- ☐ Other method

Source: U.S. Census Bureau, 2012 American Community Survey Questionnaire.

The ACS question is a poor measure of bicycling. It asks only for bike to work trips, negating any other trip purposes; surveys only 'the previous week'; and ignores the bike portion of a combined-mode trip. The data identifying which single week was surveyed is not available. Yet it is critical to measure bike ridership in any community. In 2018, the city began a walking and biking count program to provide accurate field counts year-round. With this data the city will be able to quantify ridership over time, calculate crash rates and support investment needs.

Increasing Bicycle Facility Safety and Ridership

This section provides an overview of the state of bicycle facilities in Bend in 2018 and how current design affects safety and ridership. Techniques to address each shortcoming are introduced.

Traffic Speeds

Bend's existing network is placed exclusively on the busiest, fastest roadways in town, yet most people are uncomfortable adjacent to any traffic moving faster than 30 mph. Higher speeds result in more frequent and more severe crashes. Bend will accommodate a greater number of riders by reducing exposure to fast-moving traffic:

1) Use low-speed streets and shared-use paths.

2) Provide separation and protection from traffic.

3) Design roads to self-enforce posted speeds.

4) Enforce posted speed limits.

Intersections

Existing stop- and signal-controlled intersection designs are such that auto and bicycle paths of travel cross (conflict). Bend will increase safety by reducing and better managing conflicts:

1) Add or upgrade illumination.

2) Provide separate paths of travel through intersections.

3) Create right-angle approaches to conflict points; increase sight lines; and increase awareness through signing, pavement markings, and control techniques.

4) Prevent right- and left-turn hook crashes.

Network and Connectivity

In many locations, bike lanes end abruptly with no accommodation to continue; crosswalks across wide, busy streets are infrequent and require significant out-of-direction travel to make it safely across the street. Bend will close gaps and disconnections:

1) Create adequately spaced safe crossings of busy streets.

2) Prioritize and construct missing bikeway segments such as canal crossings.

3) Require bike facilities to be accommodated up to and across intersections.

4) Create a connected network.

Facility Design

Most bikeways in Bend rely on an 8" painted bike lane stripe to separate adjacent motor-vehicle traffic from people on bikes. Yet, most people desire and require more physical separation from traffic to allow them to choose bicycling. Bend will provide greater separation by:

1) Buffer bike lanes to increase separation to moving traffic. Buffered bike lanes and parking protected bike lanes are cost-effective and the least expensive ways to provide separation.

2) Create a system of neighborhood greenways. These provide separation by using a parallel low-volume/low-speed street. Taking advantage of existing low-traffic streets is cost-efficient.

3) Incorporate shared-use paths. Shared-use paths provide an exclusive travel space away from motor vehicles.

Safety

Fatal and serious injury crashes have occurred involving bicyclists. The City has identified crash countermeasures. Minor changes such as adding a basic, buffered, or protected bike lane reduces crashes by 36%, 47% and 59%[1], respectively. Bend will update intersection design to decrease intersection crashes[2]:

1) Provide separation from traffic.

2) Better manage conflicting traffic flows through speed management, approach angle adjustments through intersections, and signal operations.

3) Create adequately spaced safe crossings of busy street

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1 https://www.oregon.gov/ODOT/Engineering/DOCS_TrafficEng/CRF-Appendix.pdf

2 Lessons from the Green Lanes: Evaluating Protected Bike Lanes in the U.S., 2014

Understanding Bicycle User Types

The LTS approach to bike facility design requires an understanding of what people need, and then providing a network designed around those needs. Planners in Portland, Oregon[1] developed a classification approach. Based on this research[2], bicycle facility designers now categorize community members who will use a bicycle as a means of transportation (rather than recreation) into four levels. This framework is now adopted at the national level and by the Oregon Department of Transportation. Categorization into one particular rider type is fluid. Furthermore, providing a low-stress bicycle transportation system can influence a rider's skill level as time allows people to practice riding and gain experience.

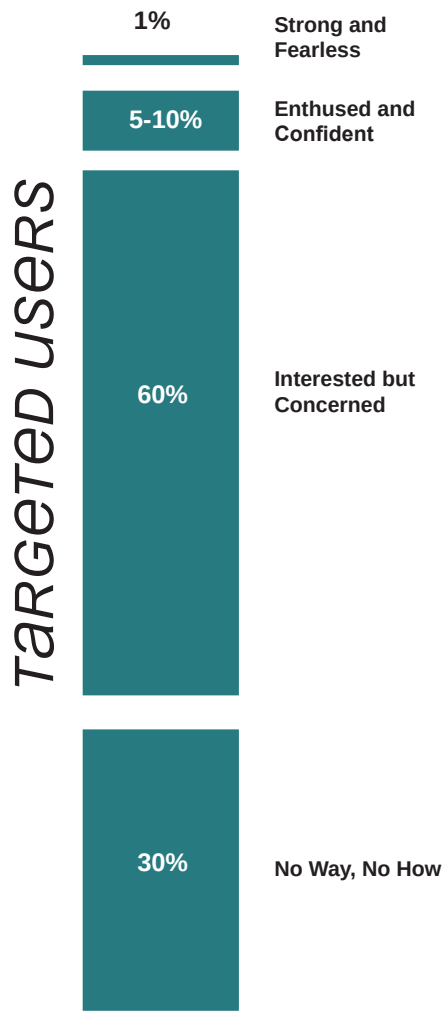
Strong and Fearless – an advanced rider that is comfortable on any urban street, regardless of bikeway. In any community, there are typically few advanced riders, often less than 1%. As experience and skills increase, however, basic riders become advanced riders. Portland currently estimates they have 7% advanced riders.

Enthused and Confident - a basic bike rider that is comfortable with bike lanes on lower speed streets. In most communities, about 10% of the population are basic bike riders. This percentage can increase as interested but concerned riders gain experience.

Interested but Concerned - the concerned rider is not comfortable in a bike lane and is particularly sensitive to speed of traffic. These riders will bike on separated facilities, such as trails or paths, or on their own neighborhood streets. This is the largest segment of transportation riders and comprises up to 60% of a community. Most new riders start out as concerned riders. Similar to alpine skiing where bunny hills and green routes create opportunities for beginners to gain exposure, experience and skills, low-stress bikeways allow concerned riders the opportunity to ride.

No Way, No How - this category captures everyone else within the community. These residents or visitors currently do not ride for many reasons. While some are not interested, many simply do not have experience or do not have access to either a bicycle or a route that meets their needs. This category can represent 25 to 37% of a community. This category can be influenced by culture as well as facility types.

Typical Distribution of People Bicycling

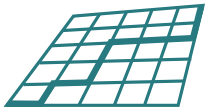


1 Roger Geller, City of Portland Bureau of Transportation. Four Types of Cyclists. http://www.portlandonline.com/transportation/index.cfm?&a=237507. 2009.

2 Dill, J., McNeil, N. Four Types of Cyclists? Testing a Typology to Better Understand Bicycling Behavior and Potential. 2012.

SYSTEM APPROACH TO SERVE MOST RIDER TYPES

By understanding riders and providing designs to serve everyone's needs, communities can increase how many people ride for transportation purposes. This next section provides the framework for applying a system approach to serve our residents and visitors needs.



Safe - The City designs its bikeways to prevent documented crash types and reduce the likelihood of crashes.

Accessible - The City will deploy a network approach to enable people on bikes to conveniently access facilities and local destinations, regardless of age or ability.

Comfortable - The City will provide bike facilities that accommodate people of all ages and abilities, and for all trip purposes.

Cohesive - The City will create a network that is easy to navigate for visitors and residents alike. It will connect to major origins and destinations.

Direct - The City will provide routes that connect people and their destinations while minimizing out-of-direction travel.

Alternatives - There will be redundancy in the network to provide people with multiple route options wherever possible.

Understandable - Maps, signs, routes, and web applications work to show people easier, lower-stress ways to get to their destinations.

The Low-Stress Bicycling Network in Bend

The City of Bend's low-stress bike network provides a variety of connected bicycle facilities across the city. The facility types that make up the City's low-stress network include:

- **Local Streets**
- **Neighborhood Greenways**
- **Shared-Use Paths**
- **Bicycle Lanes**
- **Buffered Bike Lanes**
- **Separated Bike Lanes**

Local Streets

Local streets connect homes to the bikeway network and have slow speeds and lower traffic volumes than arterial and collector roadways.

Neighborhood Greenways

These are select local streets that are identified to provide longer routes of low-stress travel throughout the community. They often are the direct connection to schools, parks and trails. They retain their local street characteristics such as slow speeds, low traffic volumes and on-street parking. In order to connect neighborhood greenways to the rest of the low-stress network, they provide help crossing busy streets. They are typically located parallel to busy roadways.

Neighborhood greenway routes typically require speed and volume management with traffic calming devices such as speed humps and traffic circles. Traffic calming can increase livability by removing traffic intrusion from cut-through[1] traffic and allowing speeds compatible with the residential nature of the underlying local street.

1 Definition of cut-through-traffic: Traffic through a neighborhood that does not begin, have an intermediate stop, nor end within the neighborhood. It is caused by drivers seeking to avoid a traffic control device or congestion and using the neighborhood streets as a cut-through.

Arterial and Collector Roadways

New, reconstructed roadways designated as part of the City's adopted low-stress network will provide low-stress bikeways. The City's Standards will utilize the following minimum widths for low-stress bike facilities:

Basic Bicycle Lanes

Basic bike lanes (defined by an 8" white stripe and bike lane markings) are 6.5' wide.

Buffered Bike Lanes

These facilities are basic bike lanes paired with a designated buffer space, separating the bicycle lane from the adjacent motor vehicle lane and/or parking lane. Buffer space width is typically 2.5' wide. The buffer is created with paint and readily allows street sweeping and snow plowing operations. Riding further from traffic, and outside of on-street parking car door-opening zone creates a safer, more comfortable experience.

Separated (Protected) Bike Lanes

These facilities are physically separated from motor vehicle traffic. The separation is provided by on-street parking or other physical barriers. They are typically one-way but can be designed as two-way.

Shared-Use Paths

Shared-use paths are bidirectional multi-use facilities for walking, biking, and other activities. They may be considered trails when located away from roads, but when placed along roadways, they are known as sidepaths. Sidepaths are often the only way to achieve LTS 1 facilities (suitable for all ages, including young students and senior citizens). Standard widths for shared-use paths are 12'. Narrower widths may be allowed at the discretion of the city engineer when right-of-way is constrained and other alterations have already been accommodated.

Design Needs of People on Bicycles

People on bicycles are affected by facility design, construction and maintenance practices because they do not have protection from roadway hazards. Low-stress bikeway designs in Bend serve all community members, under all weather conditions.

Bicycle as a Design Vehicle

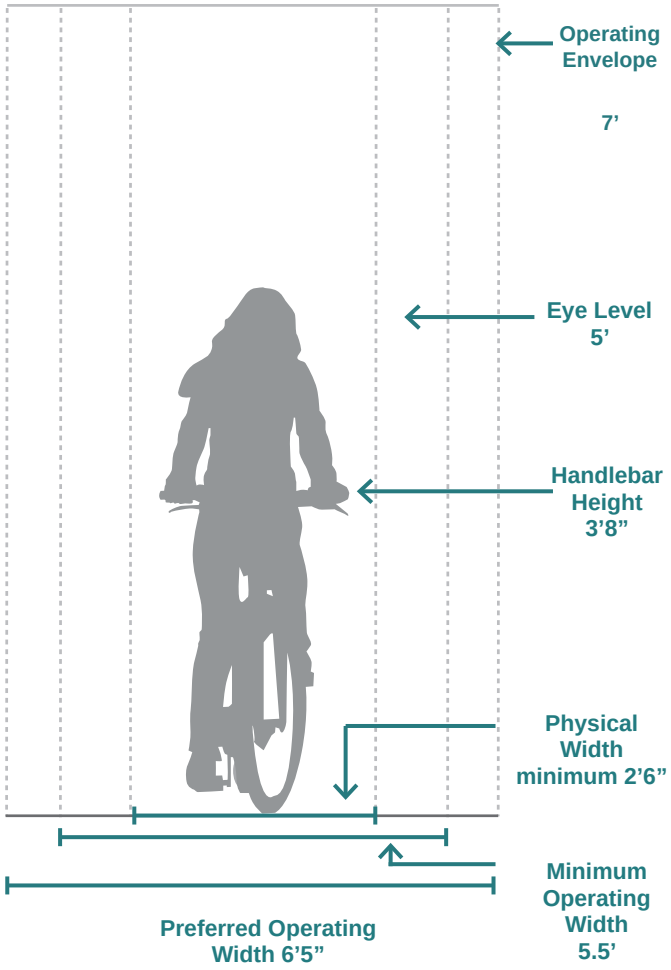
Bicycles (and their riders) come in a variety of sizes and configurations. Designers need to design for not only conventional bicycles but recumbent, tricycle, cargo-carrying or child -carrying bicycles.

Designers need to provide appropriate facility types and dimensions to accommodate appropriate elbow room, differences in rider speeds, slower start-up times, longer braking distances; and other physical needs such as accommodating guide dogs, service animals, or a rider's need for assistance by another person (in the case of those with vision impairments, etc.).

People on bicycles require clear space to operate within a facility, therefore the minimum operating width is greater than the physical dimensions of their bike. In general, providing 6.5' or more operating width is acceptable. In areas of constrained width less than 6.5' will affect level of traffic stress. Minimum basic bike lane widths in Bend will be 5.5'.

Dimension	Design Consideration
Operating envelope	Overall preferred design envelope (single rider, one-way)
Eye-level	Sight lines, vegetation, signage
Handlebar height	Railings, doors, bike parking, two-way riding, push buttons
Physical width	Parking accommodation
Minimum operating width	Minimum design envelope for facilities in constrained environments
Preferred operating width	Preferred facility width for bike facilities

Bicycle Rider - Typical Dimensions



Low-stress bike facilities accommodate different types of wheeled and pedal-driven cycles and accessories to ensure community-wide accessibility and equity. A service dog, as shown above, demonstrates how designs influence accessibility.

Accommodating ADA

The City's low-stress network of bike facilities accommodates everyone's needs by accommodating for ADA needs. Designing for LTS by accommodating ADA users allows everyone greater safety and comfort.

In the images above, a basic bike lane does not provide sufficient operating width for the person riding a bike alongside his service dog. The delivery truck approaching from behind takes a wider berth to avoid passing too close to the rider.

In the City, one of the largest demographics of bike riders are children. Young children riding solo can be sheltered from traffic by riding nearer the curb but alongside their guardian or parent. Providing adequate operating width accomodates side-by-side tandem bicycle and tri-shaws, as well.

Low-stress facilities will not impede road users whether they are driving, riding bikes, or walking.

Wider adult tricycles provide added cargo space as well as added stability for seniors or those with a balance disability.

Long boards and other skateboards, tandem and recumbent bikes, scooters, and trailer accessories are commonly seen in bike lanes and will be accommodated.

Tandem bicycles include both side-by-side and front-to-back are less commonly seen, but accommodating for both types of tandems will provide access to bicycling for those with disabilities including vision impairments, cognitive disabilities, or other physical disabilities.

Bicycling Programs

Privately organized and funded programs can encourage riding such as bicycle safety education in schools, adaptive sports programs, and programs for seniors.

Bicycle safety education can be provided in schools to expose students to bicycle riding, teach them basic safety skills, bike handling skills, and rules of the road. Programs that provide hands-on riding throughout the community provide training for specific design features found in Bend.

Adaptive sports in Bend provide opportunities for community members with different abilities to ski and bike. Adapted bicycles and tricycles are increasingly available at lower price points. Hand cycles are just one example of an adapted bicycle.

Programs for seniors specifically target the city's older population to facilitate social health. Bicycling Without Age is one program that utilizes an adapted tri-shaw bike and pairs volunteers with seniors for social outings and builds community.

Programs targeting youth, people with disabilities, and seniors can benefit from a low-stress network of fully interconnected shared-use paths, neighborhood greenways and lower stress bike lane designs.

Likewise, these programs can increase the number of people riding within Bend which increases the demand for low-stress designs and a low-stress network of easy to use bikeways that accommodate anyone within our community.

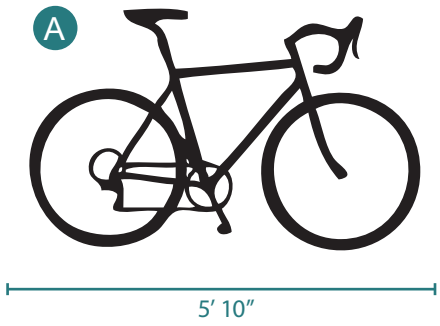
Example of a tri-shaw bicycle that can extend bike riding to seniors. Bike lane widths, bike ramp configurations, bollard placement, and turning radii are critical design components in ensuring the City's network is accessible to everyone.

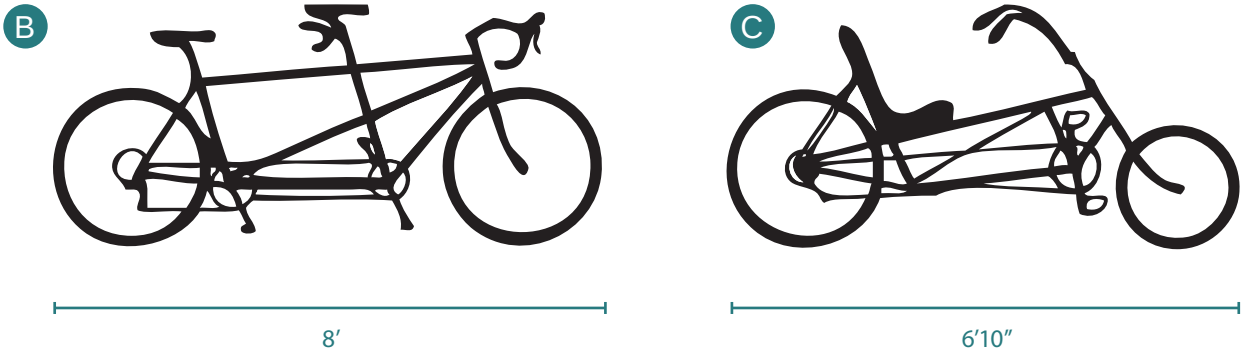
Cycling adaptations exist for people with disabilities. This man is riding a hand cycle that allows propulsion using arms rather than legs. The tricycle format is more stable and requires a little extra room on bikeways and at bicycle parking areas. Designs will take into consideration the lower stance of recumbent riders in calculating sight line needs.

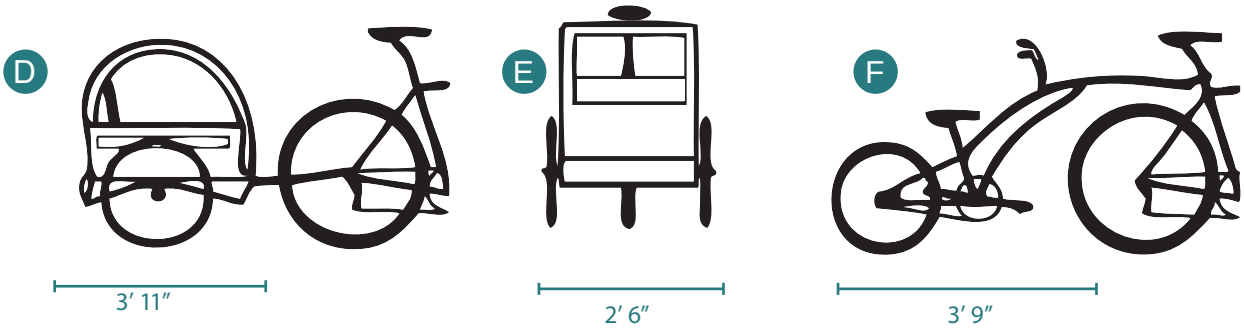
Bicycle Design Vehicle - Typical Dimensions

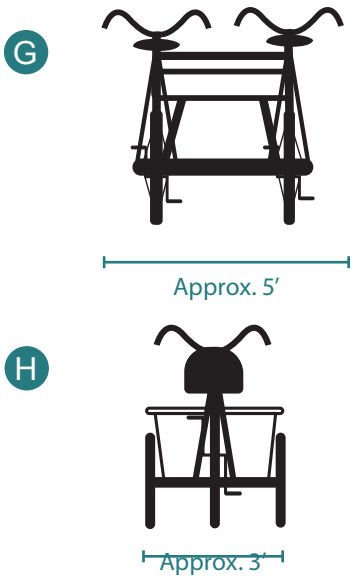
A: Adult Basic Bicycle
B: Adult Tandem Bicycle
C: Adult Recumbent Bicycle
D: Child Trailer Length
E: Child Trailer Width
F: Trailer Bike Length

G: Tandem (side-by-side)
H: Adult Tricycle









Bicycle as Design Vehicle - Design Speed Expectations

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

* Typical speed for causal riders per AASHTO 2013.

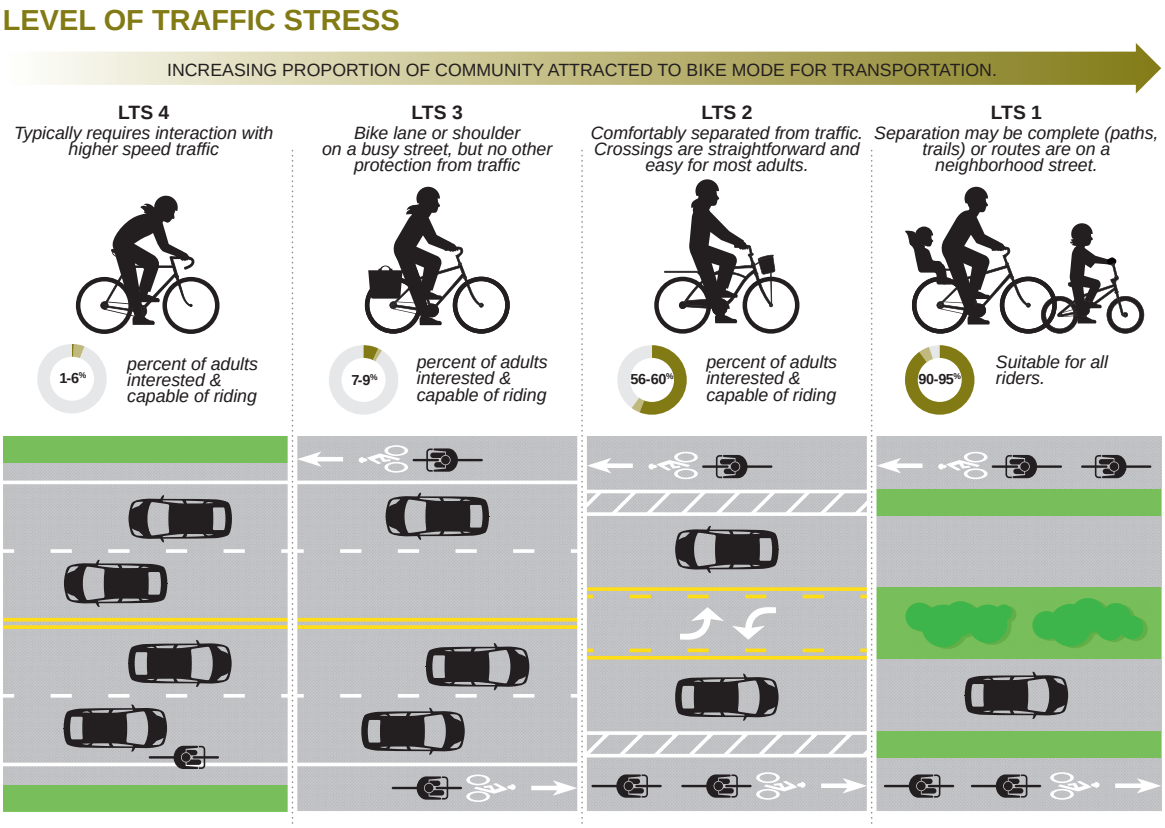
Bicycle Facility Design Accommodation

The goal in selecting a bicycle facility type is to provide a facility that supports potential "Interested but Concerned" bike riders, who are typically concerned about safety, comfort, and/or other issues stemming from general inexperience. Designing for this demographic ensures the most people in the community are served, including those in more confident and experienced rider-type categories such as "Enthused and Confident" or "Strong and Fearless" groups.

LTS is a measure of the quality of the bicycle facility, i.e. a rider's comfort level, based on roadway characteristics and conditions. These conditions include vehicle speeds, the number of travel lanes, turn lane configurations, bike lanes, parking, and other enhanced crossing treatments. The graphic below depicts an assortment of roadway configurations, LTS ratings, and corresponding bicycle user types.

The City of Bend is using ODOT's LTS methodology as the basis for quantifying facility level of traffic stress.

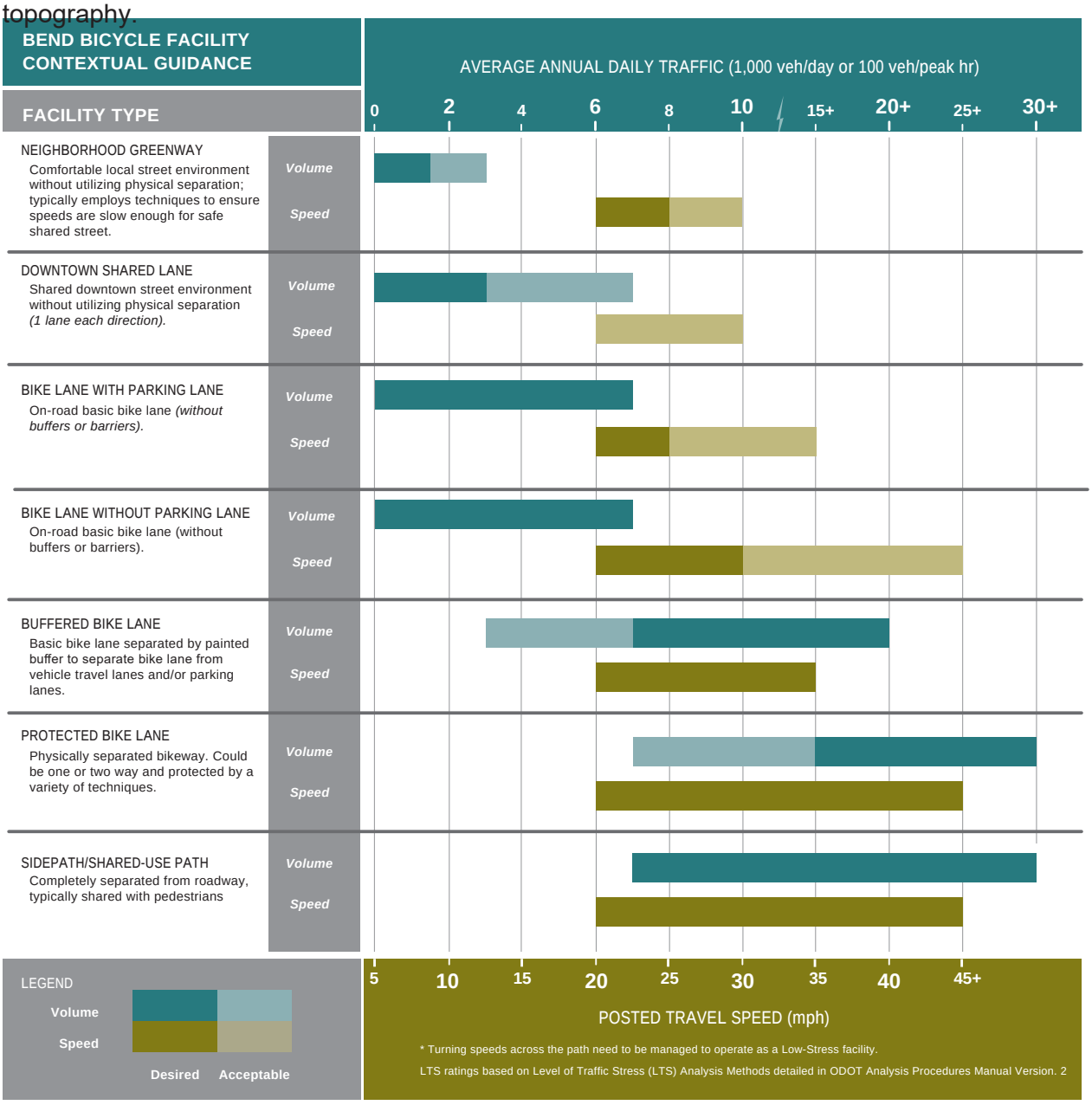
The City uses these Bikeway Design Guidelines, the City's low-stress bicycle network map, implementing policies and standard drawings, to create a community that is accessible to everyone by bike.



Note: Although this graphic shows roadways with a single-lane per direction as LTS 1 and LTS 2, multi-lane roadways can also achieve LTS 1 or 2 with different treatments.

Bicycle Facility Contextual Guidance

These tables are used within the City to identify specific treatments required for the bicycling facility to achieve LTS 1 or 2. These tables are based on ODOT's Analysis Procedures Manual, Version 2, 2018. The City will provide Desired bikeways on all new and reconstructed roadways on the low-stress network map. It may be necessary to provide Acceptable bikeways for the road and Desired bikeways on an adjacent shared-use path, parallel neighborhood greenway, or trail in areas with constrained right-of-way or topography.



Bicycle Facility Intersection Crossing Guidance

If a crosswalk serves a low-stress bikeway, it shall provide the same LTS as the facility it serves. As the motor vehicle speed and number of lanes of the roadway increase, crossing treatment protection also is required to increase in order to meet the LTS service level. LTS scores can be improved by providing a combination of crosswalk treatments, such as marked crosswalk, safety island, and RRFB. The City limits the provision of certain features to ensure safety. For example, marking a crosswalk alone is not sufficient to provide a low-stress crosswalk treatment when the roadway is wide or too fast. Similarly, providing a Rectangular Rapid Flashing Beacon (RRFB) is restricted to use on roadways that are wide and/or fast.

This table provides guidance for crosswalk safety provisions that are typically necessary to achieve targeted low-stress designations. For low-speed and/or low-volume streets, the crosswalk might only need illumination to meet an LTS 1 designation and would not require any markings or other safety provisions at all.

CROSSING SAFETY PROVISIONS	CROSSING VEHICLE POSTED SPEEDS & WIDTH OF ROADWAY *(NUMBER OF LANES)*							
	20-25 mph		30 mph		35 mph		40-45 mph	
	1-3 Lanes	4-5 Lanes	1-3 Lanes	4-5 Lanes	1-3 Lanes	4-5 Lanes	1-3 Lanes	4-5 Lanes
Marked Crosswalk	LTS 1	N/A	LTS 1	N/A	LTS 2	N/A	N/A	N/A
Median Safety Island	LTS 1	LTS 1	LTS 1	LTS 2	LTS 2	N/A	N/A	N/A
Bike Signal/RRFB/PHB	N/A	N/A	N/A	LTS 1	N/A	LTS 2	LTS 2	LTS 3
Grade Separation	N/A	LTS 1	N/A	LTS 1	LTS 1	LTS 1	LTS 1	LTS 1

* In this table a 1-lane road refers to a road with a single lane of motor-vehicle traffic in each direction; a 3-lane road refers to a 1-lane road with an added left-turn lane (either two-way left-turn lane or turn-lane pocket); a 4-lane road refers to a road with two lanes of motor-vehicle traffic in each direction; and a 5-lane road refers to a 4-lane road with an added left-turn lane (either two-way left-turn lane or turn-lane pocket).

Volumes are not included in this table for simplicity, but the City Engineer may identify very low traffic volumes, very high traffic volumes, or specially targeted populations (such as students) as justification for requiring more or fewer safety provisions.

Costs

Here are planning level costs for typical low-stress bicycle facilities found in Bend using 2018 costs. Costs for any particular project will be refined as details about each project become better defined, including project delivery such as contracted versus in-house work and size and scope of project.

Bike Facility	Planning Level Construction Costs (per road centerline mile)
Buffered Bike Lane	$4,000
Parking Protected Bike Lane	$110,000
Neighborhood greenway	$300,000
Sidepaths w/road construction	$840,000
Sidepaths as retrofit	$2,000,000

Buffered Bike Lanes The cost of painting buffered bike lane stripes on an arterial or collector roadway includes the striping of two 8" white lines for each bike lane (both sides of the road). The cost identified here is for a center line mile (buffered both sides) and includes material costs, striping machine costs, and labor. Buffered bike lanes can be LTS 1 at posted speeds of 20, 25 and 30 mph and LTS 2 at 35 mph posted speeds.

Parking Protected Bike Lanes The cost of painting parking protected bike lanes includes more manual labor to mark individual parking stalls, installation of ADA parking stall (legend, sign and ADA ramp), typically one ADA stall per block perimeter). Parking protected bike lanes have an LTS 1 stress level rating at speeds below 30 mph and LTS 2 at 35 mph. On roadways posted 35 mph two sets of buffers are required for car door opening zones (passenger side and driver side). On roadways posted 30 mph or less the buffer is required on the passenger side (bike lane side).

If curbing or other physical protection, other than on-street parking, is used to create the bike lane protection, costs to construct, operate and maintain a protected bike lane will be greater than *"sidepaths as retrofit"* category costs because of curb and stormwater management costs. Additional equipment could be necessary depending on design.

Neighborhood Greenway Costs will vary based on the operating speeds and volumes of the underlying local street. Typical treatments include traffic calming devices such as speed humps and neighborhood traffic circles; crosswalk enhancements for crossing busy streets; and can include minor traffic control to ensure safety in a mixed traffic situation. Neighborhood Greenways are required to target LTS 1 stress level rating. The crossing of any busy arterial/collector roadways also needs to provide an LTS 1 experience. Crosswalk treatments may require crosswalk markings, high visibility signage, illumination, safety islands and flashing beacons if the speed and volume warrants are met.

Sidepaths Costs in this table generally include 12' wide concrete sidepaths on both sides of the road with some signing, striping, and crossing enhancements at arterials and major crossings. Sidepaths may also be asphalt (example SW Brookswood Boulevard between Montrose and Oceanspray) which would be less expensive than the concrete material priced herein. Additionally, the prices provided here separate out the impacts of constructing the sidepath *"with road construction"* (either brand new road, or complete road modernization/complete streets project) versus *"as retrofit."* Retrofit costs are geater because of standalone mobilization and traffic control costs and added utility, irrigation/ landscaping rework. Sidepaths can achieve an LTS 1 stress level rating.

On-Going Maintenance Costs

Any new asset needs on-going maintenance. Operations costs include striping, street-sweeping, snow-plowing and ice management. Preservation costs include crack sealing or pavement preservation. Here are maintenance costs, using 2018 costs) per road centerline mile listed for typical low-stress bicycle facilities prescribed in this Guide.

Bike Facility	Annual Operations (per centerline mile)	Annual Preservation (per centerline mile)
Buffered	Annual Striping: $2,000 refresh	with adjacent roadway
Parking Protected	Annual Striping: $54,600 refresh	with adjacent roadway
Neighborhood greenway	Annual Striping: $5,256 refresh Annual Signing: $500 Sweeping quarterly $1200 Snow and Ice Management $1200	Crack seal Slurry/Carbon seal Repave
Sidepaths	Sweeping annually $300 Snow and Ice Management $1200	Crack seal Slurry/Carbon seal Repave

Buffered Bike Lanes The cost provided in this table includes re-painting buffered bike lane stripes, bike lane decals and updating signs on an annualized basis. There are no additional costs associated with street sweeping or snow plowing as these are performed for the roadway curb to curb to facilitate stormwater management in winter conditions.

Parking Protected Bike Lanes The cost provided in this table includes re-painting parking Ts, buffers, bike lane and parking lane decals and updating signs on an annualized basis. There are no additional costs associated with street sweeping or snow plowing as these are performed for the roadway curb to curb to facilitate stormwater management in winter conditions.

If curbing is used to create the bike lane protection, on-going operations and preservation costs of the protected bike lane will be greater because operations will require a separate pass for plowing and sweeping for each curb protected bike lane. Preservation will also be more expensive as the pavement preservation will be separate from the adjacent roadway and require its own schedule.

Neighborhood Greenway The cost provided in this table includes re-painting sharrows and speed hump markings, and updating signs on an annualized basis. In order to be usable after snow or ice events, neighborhood greenways require winter operations such as snow-plowing and de-icing.

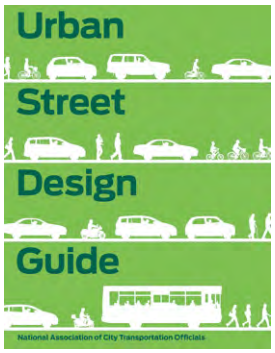
Sidepaths The cost provided in this table include sweeping and snow-plowing as well as de-icing treatments. They require pavement preservation.

Guidance Basis

The sections that follow serve as a toolbox of bicycle design treatments and provide guidelines for their implementation. These treatments and design guidelines have been tailored to the Bend community from various national guidelines. Many urban situations are complex, particularly when retrofitting these design techniques into an already built environment. Each of the designs presented here can be tailored to the unique situation by using engineering judgement based on low-stress bicycle facility design principles. The City of Bend Bikeway Design Guide utilized these foundational documents to incorporate crash reduction findings and adapt proven treatments to reflect Bend's needs and current resources.

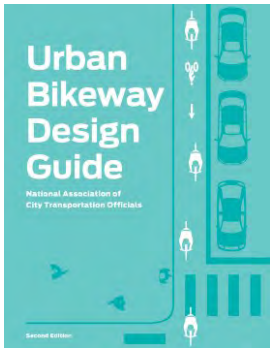
Impact on Safety and Crashes

Walking and biking facilities can have a significant influence on user safety. The Federal Highway Administration's (FHWA) **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.



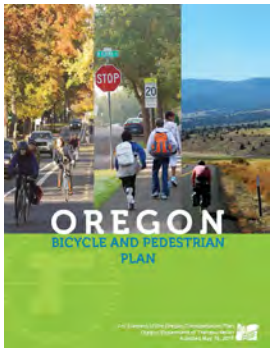
The National Association of City Transportation Officials' **(NACTO) Urban Street Design Guide (2013)** is a collection of nationally recognized street design standards, and offers guidance on the current state-of-the-practice designs.

Separated Bike Lane Planning and Design Guide (2015) is the latest national guidance on the planning and design of separated bike lane facilities released by the Federal Highway Administration (FHWA). The resource documents best practices as demonstrated around the U.S., and offers ideas on future areas of research, evaluation and design flexibility.

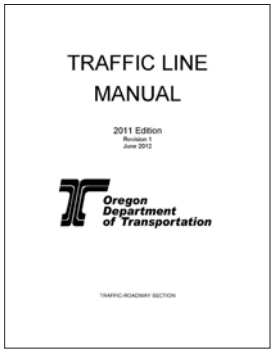


The National Association of City Transportation Officials' (NACTO) **Urban Bikeway Design Guide (2012)** provides cities with state-of-the-practice solutions that can help create complete streets that are safe and enjoyable for bicyclists. The designs in this document were developed by cities for cities, since unique urban streets require innovative solutions. In August 2013, the Federal Highway Administration issued a memorandum officially supporting use of the document.

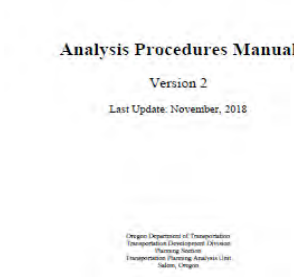
The Massachusetts Department of Transportation's **Separated Bike Lane Planning & Design Guide** presents considerations and strategies for the development of separated bike lanes. The Guide establishes a framework for determining when separated bike lanes are appropriate and feasible; and presents design guidance for separation strategies, bike lane configuration, and considerations for transit stops, loading zones, utilities, drainage, parking, and landscaping.



The Oregon Department of Transportation (ODOT) **Bicycle and Pedestrian Plan (May 2016).** This plan represents the bicycle and pedestrian elements of the Oregon Transportation Plan, and serves as the guiding statewide policy plan for project and program prioritization and evaluation, and facility design guidance. A stategic 5-year work plan was also developed to implement critical action items identified during the planning process.



The Oregon Department of Transportation (ODOT) **Traffic Line Manual (2018).** This manual establishes the standards for uniform traffic lines and pavement markings on ODOT roadways.



The Oregon Department of Transportation (ODOT) **Analysis Procedures Manual, Version 2 (2018).** This manual establishes the standards for quantifying the level of traffic stress given various operational and design elements such as posted speed, width of bike facility, separation from traffic, left- and right-turn treatments, crosswalk treatments and intersection control, etc.

Chapter 2

Design of Neighborhood Greenways

Neighborhood Greenways Overview

Neighborhood greenways are the foundation of Bend's low-stress bikeways network. They are used in conjunction with off-street trails, side-paths, and select bike lanes on busier streets. The City's low-stress bicycling network map identifies the neighborhood greenway routes. These streets were chosen to connect the community because of their ability to deliver a continuous and direct route along low-traffic streets. The planned routes are typically residential streets which will be prioritized to create safe and convenient routes for people on bikes. They create an easy-going way to access services, parks, schools and jobs. Neighborhood greenways reduce crashes by up to 63%[1] compared to basic bike lanes on the arterial/collector network.

Typical Application

- Parallel with, and in close proximity to, arterials and collectors for easy connections to key destinations.
- Provide straightforward routes - avoid zigzag or circuitous routing. Aim for less than 10% out of direction travel compared to shortest path of primary corridor.
- Use local streets with fewer than 2,000 cars per day. Use traffic calming and controls to discourage cut through and speeding.
- The accessible path of travel may be the roadway when sidewalks are not present.

1 Oregon Department of Transportation Crash Reduction Factors; https://www.oregon.gov/ODOT/Engineering/DOCS_TrafficEng/CRF-supplemental.xlsx; BP23

Neighborhood greenways improve connectivity to key destinations and provide a direct, low-stress route for people riding bicycles, with low motorized traffic volumes and speeds.

Streets along classified neighborhood greenways may require additional traffic calming measures to discourage cut-through trips by motor vehicles and maintain shared-road speeds.

Design Features

- Signs and pavement markings
- Traffic calming and minor control to facilitate 20 mph posted speed and fewer than 1,500 cars per day (up to 3,000 is acceptable)
- Access for emergency vehicles.
- Home and business access by car or truck.

Further Considerations

Neighborhood greenways may be retrofit onto older neighborhood streets that may have limited built-in speed management. Speeding negatively affects neighborhood livability and safety of shared roadways.

The neighborhood greenway should be given priority at most intersections with minor streets in order to optimize efficiency and safety. Traffic calming can provide local access while deterring drivers taking short cuts through the neighborhood (cut through traffic).

The intersections of local streets with collectors and arterials are not typically controlled with roundabouts or signals. Create safe crossings for anyone walking or biking on the neighborhood greenway across the arterial/collector.

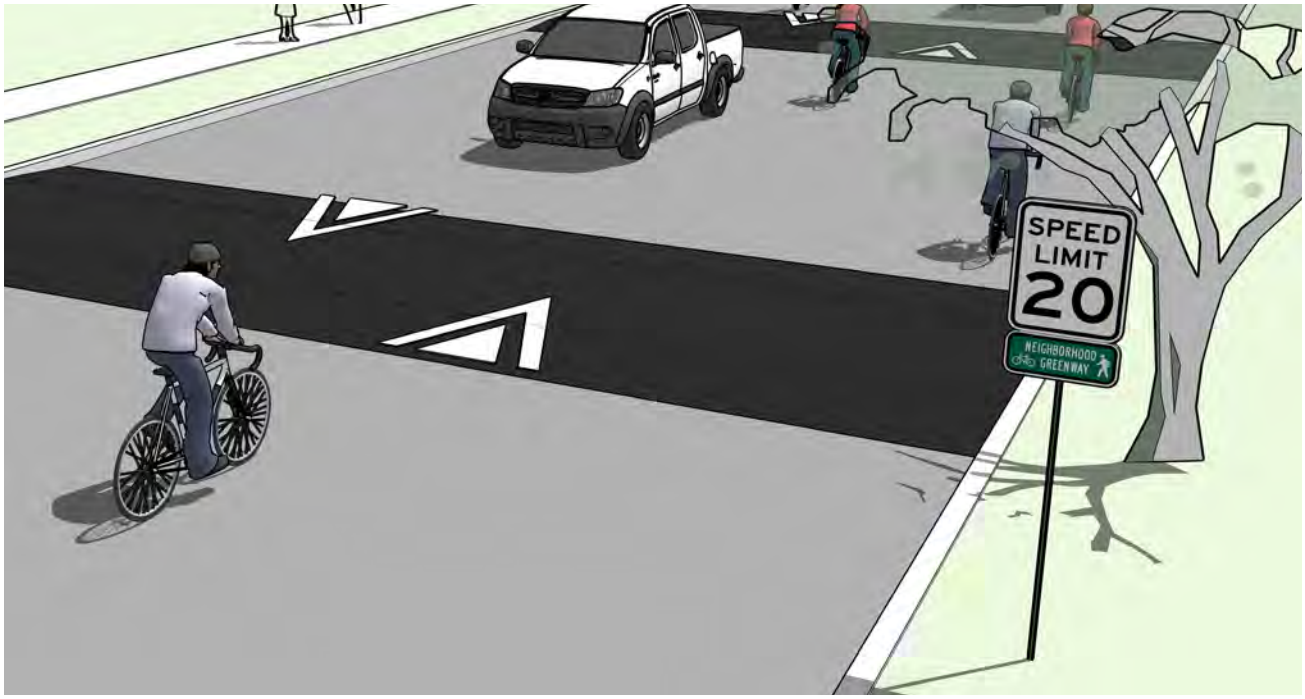
Crash Reduction

Neighborhood Greenways make streets safer for everyone. Neighborhood greenways have a crash reduction factor of 63%[1] (crash rate reductions ranged from two to eight times lower when controlling for volume) in a comparison of vehicle/bicycle collision rates on parallel and adjacent arterials with higher speeds and volumes.

DISCUSSION

The targeted rider type for neighborhood greenways is the "Interested but Concerned" category of rider and therefore slow operating speeds and low traffic volumes are critical to successful operation of the neighborhood greenway.

1 https://www.oregon.gov/ODOT/Engineering/Docs_TrafficEng/CRF-Supplemental.xlsx; Oregon Department of Transportation Crash Modification Factor 3092



Speed Management Tools

Slower speeds make it easier for everyone to see each other and create safety for the shared road. Ideally, operating speeds are 20 to 25 mph. Use traffic calming features to create the desirable operating speeds.

Neighborhood greenway maximum posted speed is 20 mph; maintain 85th percentile speed below 25 mph.

Vertical Traffic Calming

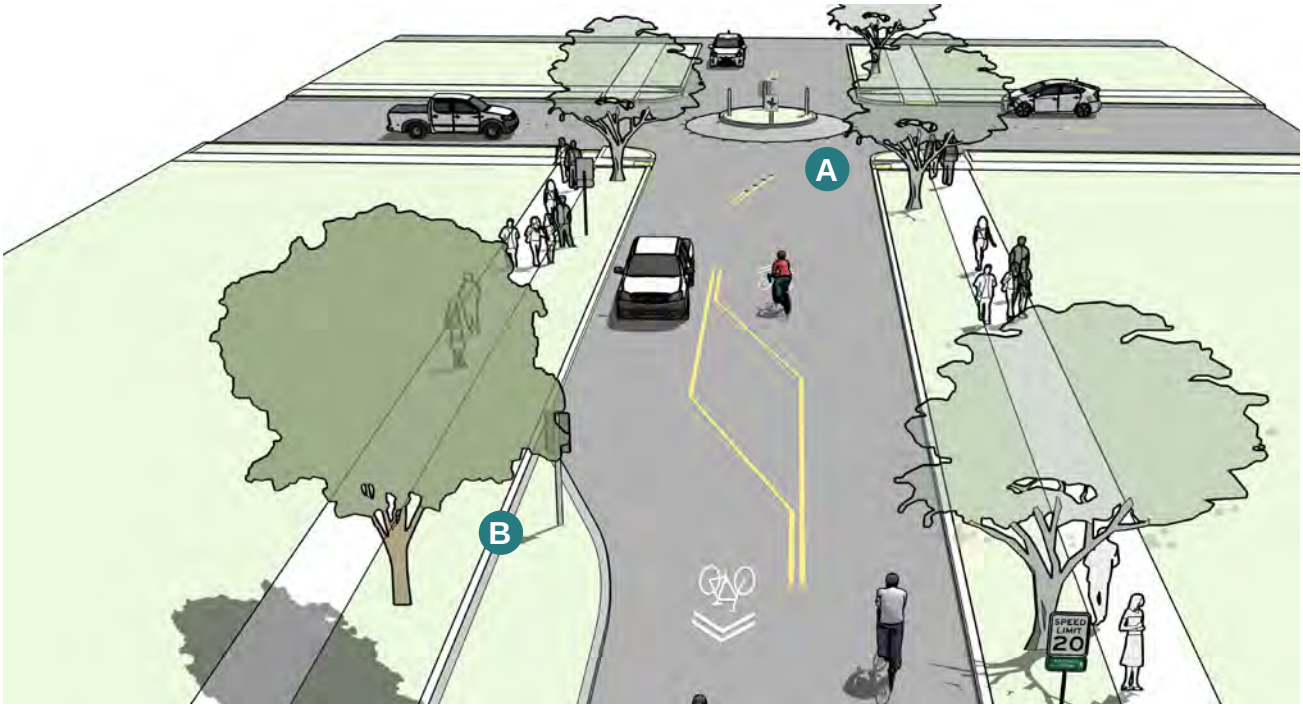
Vertical traffic calming is a cost-effective speed management device for neighborhood greenways. Speed tables are the City's preferred vertical traffic calming device to accommodate Emergency Service Vehicles. Vertical traffic calming will be sited and designed to ensure emergency service responders, as well as maintenance operations, such as sweeping and plowing are accommodated.

Design Features

- Speed tables are raised areas across the road. Speed tables have a longer, slower rate of rise than speed humps. They reduce impacts to emergency vehicles and maintenance operations such as sweeping and plowing because of their flat top.
- Speed tables should be installed in succession to be most effective.

Further Considerations

- Speed tables can be configured as raised crosswalks at intersections or mid-block crossings.
- While gaps can be provided by the curb to facilitate drainage, these features make it more difficult to clear snow and debris.



Horizontal Traffic Calming

Horizontal traffic calming devices reduce speeds by requiring more careful maneuvering. With landscaping they can reduce long views down corridors. This focuses everyone's attention.

Horizontal traffic calming will be sited and designed to ensure emergency service responders, as well as maintenance operations, such as sweeping and plowing are accommodated.

Design Features

- The City's preferred horizontal traffic calming devices are traffic circles, chicanes, and curb extensions.
- A Traffic circles can be used at minor street intersections. Neighborhood traffic circles can be landscaped to terminate sight lines along a corridor while maintaining sight lines at the intersection.
- B Chicanes are an edge treatment that requires lateral shifts along the roadway. In snowy climates they work best without a gap between the island and the curb line.
- Curb extensions make crossings shorter and increase visibility for everyone. Studies show they improve driver yielding at the crosswalk.

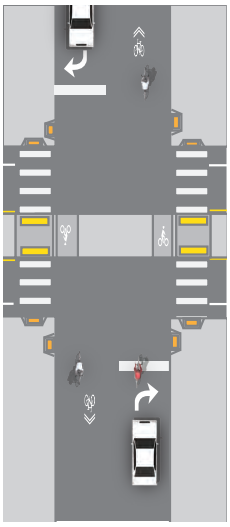
Further Considerations

- Horizontal speed control measures should not infringe on bicycle space.
- Traffic calming can also deter short cut or cut-through traffic.
- Street trees narrow a driver's visual field and create a desirable place to ride during warm weather. Because of these two impacts they facilitate place making by increasing the number of people biking on the neighborhood greenway and increasing the comfort of the facility for them.

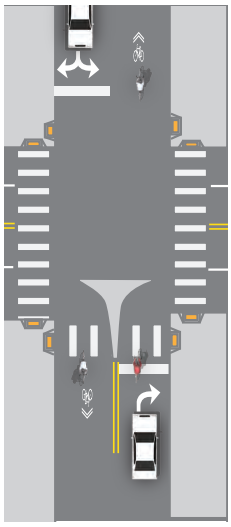
Minor Operations and Safety Enhancement Tools

The design rider for neighborhood greenways is Interested but Concerned. They are sensitive to both speed and volume of traffic. At speeds above 25 mph and/or volumes above 1,500 motor-vehicles per day, studies show people riding are more likely to try to hug the curb line. This causes safety issues such as weaving in and out of parked cars; greater number of passing situations per segment; and unpredictable paths of travel. These issues decrease the comfort and desirability as a neighborhood greenway for many folks. Therefore, neighborhood greenways should be designed to achieve the 20 mph operating speed, and low traffic volumes. The minor traffic management tools identified here can improve intersection safety for the arterial, collector, and neighborhood greenway networks.

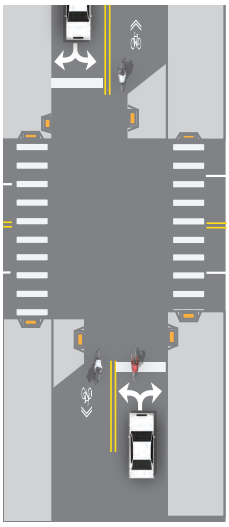
Minor traffic management tools are effective and have been successfully used throughout Bend to correct operations issues or safety deficiencies. These minor traffic management tools include safety islands, right-in-right-out controls, partial turning-movement controls, and cul-de-sacs. *Note: Stop bars may or may not be necessary on the neighborhood greenway approach to the arterial/collector.*



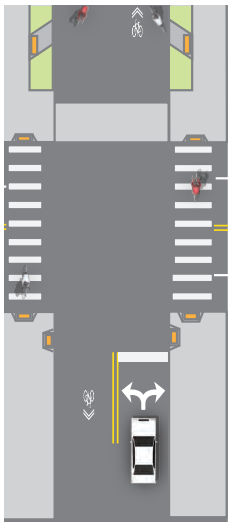
Safety Island



Right-In/Right-Out Control



Partial Turning Movement Control



Cul-de-sac

Guidance

- Safety islands are commonly required to facilitate crossings of wide, fast roadways. They reduce complexity and increase visibility.
- Right-in/right-out controls are most commonly used to better manage the operations and safety of the arterial and collector roadway, such as the turn restrictions at NE 4th Street and Greenwood Avenue. When placed on neighborhood greenways at intersections with arterials or collectors, the right-in/right-out controls allow neighborhood traffic to still access the major roadway while discouraging cut-through traffic.
- Partial turning movement control

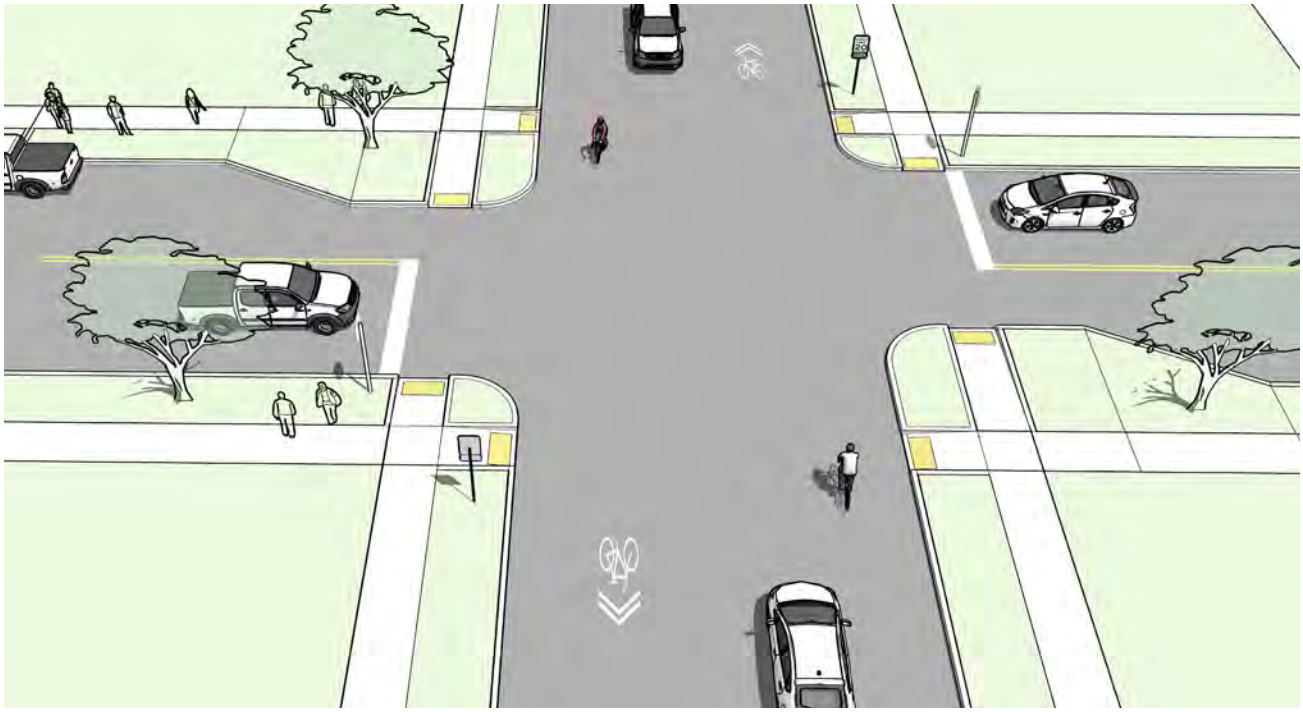
is typically used to protect the local residential street from short-cuts or cut-through traffic.

- Often the shortcut is sought to avoid downstream congestion. As such, system management treatments at the downstream congested location paired with speed management on the neighborhood greenway are also effective treatments.
- Roadway closures create a low cost cul-de-sac. This would typically only be used as part of a larger network flow management system to facilitate crash reduction at intersections with high crossing crashes or to facilitate a more desirable motor-vehicle route into a neighborhood.

Further Considerations

The City has successfully used each of these techniques to increase intersection safety. The City takes an incremental approach to minor traffic management tools and uses the least restrictive devices prior to implementing more restrictive devices.

Each minor operations and safety enhancement device will be sited and designed to facilitate the necessary operations and deployment of emergency service responders as well as maintenance operations such as sweeping and plowing. For example, minor operations and safety devices should ensure snow plows and street sweepers are able to navigate through and around devices while performing their operations.



Neighborhood Greenway Crossings at Minor Intersections

The neighborhood greenway should have priority over minor cross streets. Treatments at minor roadway intersections are designed to improve the visibility at the intersection, raise awareness and enhance safety for all users.

Guidance

If the cross street is another neighborhood greenway, or other special considerations exist, such as limited sight lines, or a history of cross-traffic crashes, an all-way stop or traffic circle can be considered.

Further Considerations

- Curb extensions move people on bikes closer to the centerline to improve visibility and encourage drivers to let them cross.
- Curb extensions reduce right-turn hook crashes between right turning traffic and people riding bikes (applicable where sidewalks exist).
- Stop signs on neighborhood greenways need to be coordinated for consistency within the neighborhood.
- Stop signs have been proven to deter cut-through traffic, but they can increase travel time for people on bicycles.
- If several stop signs exist along a potential neighborhood greenway route, the interaction and interdependency of the stop signs, speed management needs, cut-through traffic management, and delays to people on bikes should be considered systematically.

Neighborhood Greenway Crossings at Major Intersections

The quality of treatments at major street crossings can significantly affect the safety and use of the neighborhood greenway.

Crossings need to meet or exceed the Level of Traffic Stress rating of the overall bikeway corridor that the crossing serves. If the Level of Traffic Stress of the crossing of the busy street is more stressful, then the usefulness of the entire bikeway corridor it serves is greatly diminished.

Guidance

Getting people across busy, high speed arterial or collector streets is critical to the safety and ridership of a neighborhood greenway. There are several tools to help make these crossings safe for everyone.

- Marked crosswalks
- Bike boxes
- Safety islands
- Rectangular Rapid Flashing Beacons (RRFB)
- Pedestrian Hybrid Beacon (HAWK)

Further Considerations

This Guide in Chapter 1, page 19, has guidance to select treatments based on traffic volumes, speeds, and number of lanes to cross.

Further guidance can be found in the National Cooperative Highway Research Program[1].

Treatments are designed to improve visibility and safety by creating facilities that maximize driver compliance and yielding.

1 NCHRP Report # 562 Improving Pedestrian Safety at Unsignalized Crossings (2006) and ODOT Evaluation of Alternative Pedestrian Control Devices, SPR 721

Neighborhood Greenway Route Selection

Neighborhood greenways should improve connectivity to key destinations and provide a direct route for people on bikes. Local streets with existing traffic calming, traffic management tools, or safe crossings of major streets are good candidates, as they tend to be existing bicycle routes and have low motor vehicle speeds and volumes. Streets where residents have expressed a desire for traffic calming to address cut-through traffic are also good opportunities. See the City of Bend low-stress bicycle network map for neighborhood greenway routes.

Neighborhood greenways parallel to commercial streets, improve access for "interested but concerned" bicycling community, and complement bike lanes on major roadways.

Selecting the Route

When selecting routes, the city aims to target routes with the following characteristics:

- low traffic volumes (less than 3,000 vehicles per day).
- parallel to major streets to provide good access to key destinations in a low-stress environment.
- relatively continuous for people on bikes and/or where treatments can provide wayfinding and improve crossing opportunities at offset intersections.
- also provide ADA paths of travel.
- streets that also have alternative routes available for motor-vehicle traffic to minimize the challenge of keeping volumes and speeds low on the neighborood greenway.

DISCUSSION

Neighborhood greenways should form a continuous network of streets or off-street facilities that accommodate people on bikes who are less willing to ride on busier streets.

Most neighborhood greenways are located on residential streets, though they can also be on commercial or industrial streets.

Due to the presence of trucks and commercial vehicles, neighborhood greenways on commercial or industrial streets may use separated facilities such as buffered bike lanes or separated bike lanes to increase safety and comfort for everyone.

Vertical traffic calming devices may have less impact on large vehicles than horizontal traffic calming.

Neighborhood Greenway Wayfinding

The low-stress network is formed primarily using shared-use paths and neighborhood greenways. These facilities are less visible to motor-vehicle drivers and their passengers so it is important to let people know that these safer, quieter routes are available. Mobile phone applications as well as signing and striping help with directions as well as awareness of available low-stress routes.

Typical Application

Wayfinding is typically used along designated bikeway routes to provide a cohesive local wayfinding system to road users, including people walking.

Design Features

Shared narrow lane pavement markings and speed limit 20 neighborhood greenway signs designate a street as a neighborhood greenway.

Pavement marking symbols are recommended after every intersection. If there are long blocks, or where roadway curvature prevents the ability to see the markings, mid-block markings may also be needed.

On local streets typically used to create the neighborhood greenway route centerline markings do not exist. Place shared narrow lane stencils in the center of the roadway to designate the queuing nature of the street and identify the safest riding position to discourage passing.

The sharrow may be double headed rather than using two separate directional marks.

Further Considerations

Wayfinding can be stylized to provide identity and placemaking through color, font, graphics and logos.

Wayfinding can provide information about distances or routes to use to access key destinations that would enable a low-stress environment. Wayfinding can alert riders that a facility is high stress.

Wayfinding Examples

The style of Bend's low-stress bikeway network wayfinding signage has not yet been defined. These are example wayfinding and route information signs from other communities.

Chapter 3

Design of Bike Lanes and Separated Bike Lanes

Arterial and Collector Bikeways

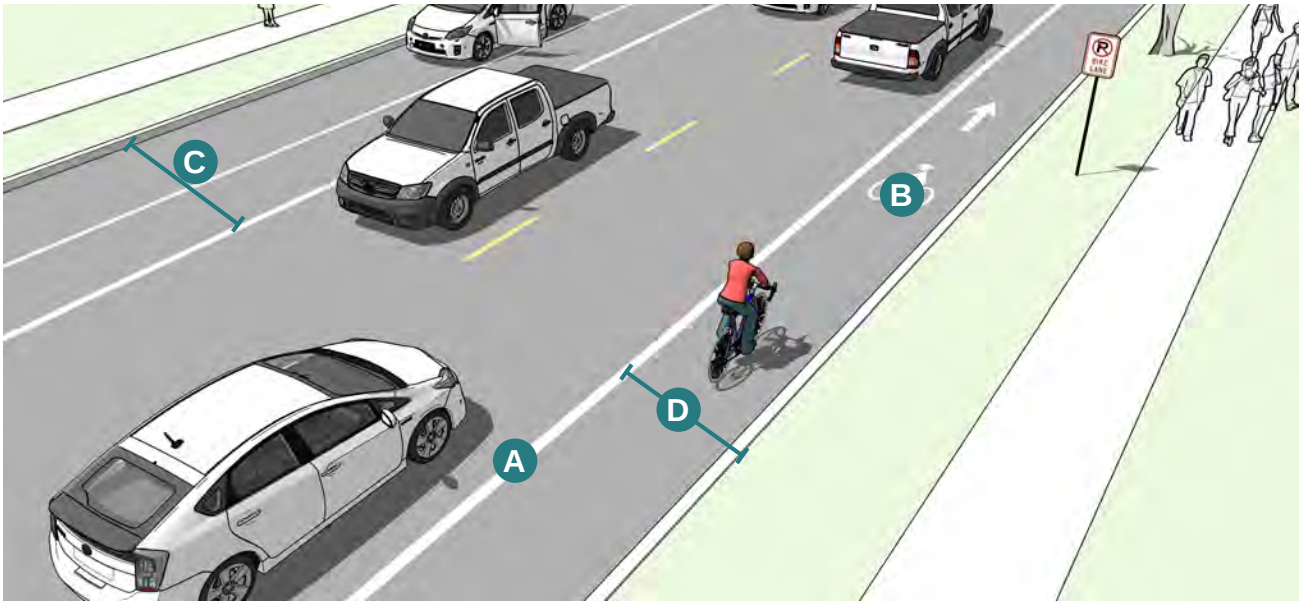
As noted in Chapter 1, providing a network of low-stress bikeways ensures bicycling is a viable transportation option. Isolated, low-stress bikeways can only serve potential bike riders who have access to those isolated segments and who simultaneously have destinations along those isolated segments. Furthermore, high-stress routes eliminate the viability of bicycling along or across those routes for transportation purposes and therefore prevent route connectivity. It is only when low-stress routes are connected to form a network that accessibility via a bicycle exists for transportation purposes.

The city's foundation of low-stress bikeways are shared-use paths and neighborhood greenways. These routes are the most universally usable and serve the broadest set of riders. But there are many arterial and collector roadways in Bend that are slow speed, either commercial or residential in nature, that create key segments on the city's low-stress network.

Key destinations are also located directly on arterial and collector roadways, making key segments of arterials and collectors critical to completing a trip to a likely destination. Because route continuity, coverage, and connectivity are crucial to maximize the number of origin-destination pairings that are viably reached by a bike, key segments of the low-stress network need to be accommodated on the arterial and collector roadway system.

Therefore, bikeway facility designs on arterials and collectors also need to be designed and operated as low-stress. The City's cross-section standard is 52' for new/reconstructed arterial and collector roadways. For speeds 35 mph and less, buffered bike lanes are standard and can provide LTS 1 and LTS 2 facilities at a very low price point. For higher speed arterials and collectors, low-stress bikeway standard is achieved with sidepaths (separated wide sidewalks facilitate biking and walking).

There are many existing arterial and collector roadways that cannot readily provide low-stress bikeways due to width and/or speeds. This chapter provides guidelines on techniques to convert existing high-stress bikeways to low-stress bikeways, as feasible without requiring re-construction. Designs that produce the lowest stress level LTS designation should be applied.



Bike Lane

A basic bike lane is one that is located directly adjacent to motor vehicle travel lanes on an arterial or collector roadway. Basic bike lanes are designated through pavement markings and signs and are typically on the right side of the street, and operate in the same direction as traffic. Designs that produce the lowest stress LTS level should be utilized.

Typical Application

- Basic bike lanes are 6.5’ wide and are typically provided on all arterial and collector roadways.
- LTS 1 or LTS 2 can be achieved with basic bike lanes on 2- or 3-lane roadways with speeds 30 mph or lower when the bike lane is wide enough.
- In environments where only an LTS 3 or 4 can be achieved, the roadway cannot be part of the low-stress network, but is still necessary to provide route coverage for Strong and Fearless as well as Enthused and Confident rider types. In these situations, 6.5’ bike lanes are standard, but may be reduced to 5.5’ in constrained rights-of-way.

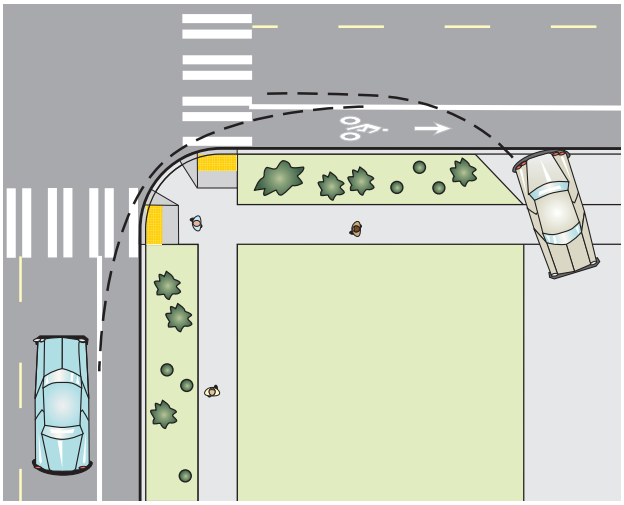
Design Features

- A Use 8” white line pavement marking to designate bike lane.
- B Put bike lane pavement marking at the beginning of each block and at regular intervals along route.
- C LTS 1 or 2 can be achieved with at least 15’ combined width of on-street parking and bike lane if speeds are 30 mph or lower.
- D 6.5’ bike lane width is the Bend standard bike lane width.

Further Considerations

- Wider bike lane widths facilitate bike passing maneuvers to better accommodate a range of bike rider travel speeds.

Bicycle lanes provide a delineated space, but may be subject to unwanted encroachment by motor vehicles, and therefore provide a lower level of comfort for many people on bikes.



Bike lane word, symbol, and 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)

- The City's standard practice is to optimize general purpose travel lane number and travel lane width in order to achieve overall corridor operations and safety goals, including the provision of the low-stress bicycle network density and coverage.
- AASHTO motor vehicle travel lane widths range from 9' to 12' as standard widths, depending on land use context, traffic speeds, number of travel lanes, and mix of traffic.
- Local classified streets do not have lanes. Their roadway surface is undefined (no striping to define lanes) and is therefore a shared space allowing travel in two directions and typically also has on-street parking.
- When travel lanes are created with lane lines on arterial and collector roadways, their widths should be set according to the following lane width guidance:
    - 11' travel lanes are standard.
    - 10' travel lanes can enhance speed compliance on roadways posted 30 mph or less. These lane widths may also provide greater flexibilty for other pavement uses such as on-street parking, pedestrian safety islands, or bike lanes. There are several miles of existing arterial and collector roadways in the city that successfully operate with 10' travel lanes. These include Newport Avenue, Greenwood Avenue and even a short segment of 3rd Street. Each of these roadway examples have a strong commercial context and operate with slow speeds. Although 10' is not a city standard lane width, the City Engineer may consider a 10' lane based on the context of the roadway.
    - 12' travel lanes are standard on higher speed roadways (40 mph+), or where other considerations exist such as heavy haul routes or roadway curvature.
    - 9' travel lanes may be considered by the City Engineer at low speeds.
- When parking T's are used to mark parking ADA requirements trigger accessible parking requirements.
- Safety and comfort for the low-stress route requires issues such as lane encroachment to be considered during route design. Low-noise producing rumble strips can be considered on the inside of horizontal curves to improve compliance with posted travel speeds, decrease the incidence of people driving into the buffer, and maintain the separation between motor vehicles and

people riding their bikes.

- The City has successfully used low-noise producing rumbles since 2014 along Riverside Boulevard for exactly this purpose.
- Roadway surface inconsistencies pose a threat to safe riding conditions for people on bicycles. Construct manholes, access panels, drainage elements, trenching, and construction joints to ensure surface smoothness tolerances are met and appropriate tire traction is provided.

Crash Reduction

Before-and-after studies of bicycle lane installations show a 58 to 60%[1] crash reduction. for vehicle/bicycle collisions after bike lane installation.

6.5' bike lane widths have 7.7% fewer crashes than 6' bike lanes.[2]

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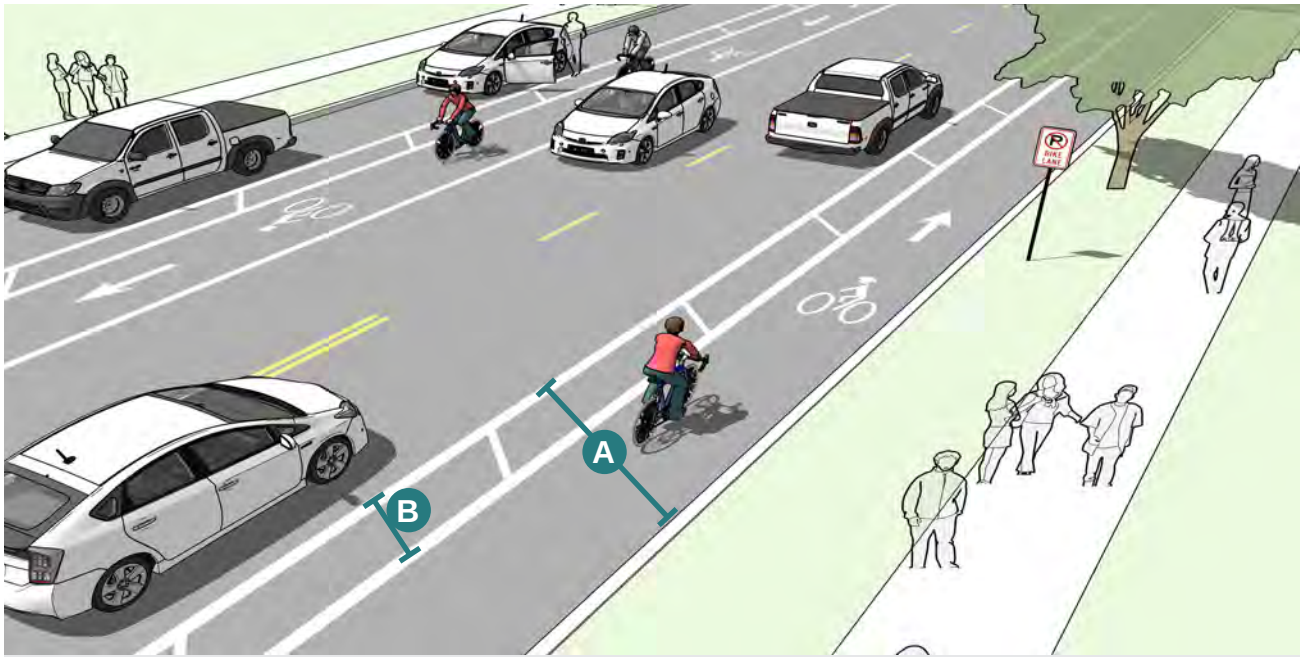
1 www.cmfclearinghouse.org/detail.cfm?facid=7840; Validation and Application of Highway Safety Manual (Part D) in Florida, Abdel-Aty et al, 2014

2 www.cmfclearinghouse.org/detail.cfm?facid=8692; Evaluation of Safety Effectiveness of Multiple Cross Sectional Features on Urban Arterials, Park and Abdel, 2016



Buffered Bike Lanes

Buffered bike lanes are basic bicycle lanes paired with a designated buffer space, separating the bicycle lane from the adjacent motor vehicle travel lane and/or parking lane. 88%[1] of Interested but Concerned potential bike riders noted they would be more likely to ride a bicycle if there was separation to motor vehicle traffic.

Typical Application

- Buffered bike lanes are the City standard on streets with posted speeds 35 mph and lower to achieve low-stress facilities as well as provide the lowest stress bikeway feasible.
- Buffers encourage drivers to comply with posted speeds, particularly on streets with several travel lanes or lane widths wider than city standards.
- Buffered bike lanes can achieve an LTS 1 when they are at least 7 feet wide (total overall width) and are located on 30 mph or lower posted roadways.
- Buffered bike lanes can achieve an LTS 2 when they are at least 7 feet wide and are located on 35 mph roadways.

Design Features

- Standard buffered width is 2.5' without diagonal cross-hatching.
- A 6.5' bike lane width plus the 2.5' buffer is considered standard for City of Bend.
- B Diagonal markings are required when buffer area is 3' or wider.
- Buffers can be configured on the parking side, the travel side or a combination of both.
- Minimum buffer widths are 2'.

1 McNeil, Monsere and Dill; "The Influence of Bike Lane Buffer Types on Perceived Comfort and Safety of Bicyclists and Potential Bicyclists"

The use of pavement markings to create a buffer space between travel lanes and bike lanes increases separation and comfort. Buffered bike lanes provide a lower-stress facility.

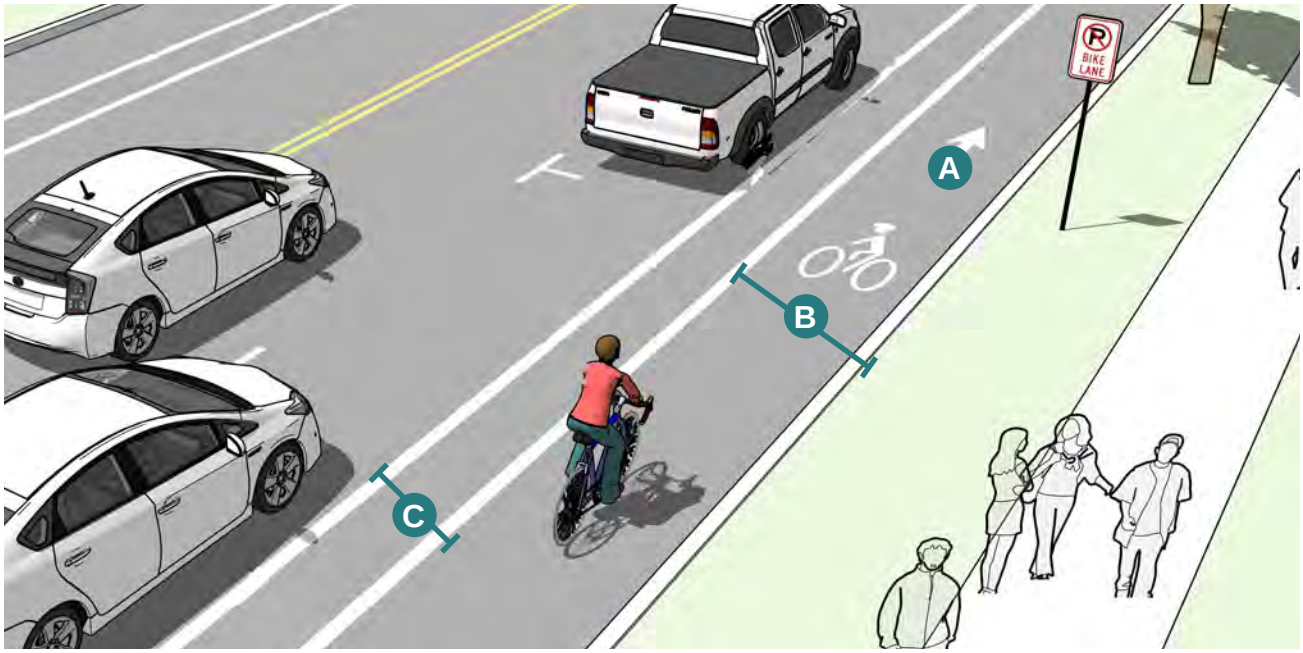
Further Considerations

- Low-noise producing rumble strips can be considered on the inside of horizontal curves to improve compliance with posted travel speeds, decrease the incidence of people driving into the buffer, and maintain the separation between motor vehicles and people riding their bikes. Safety and comfort for the low-stress route requires issues such as speeding and lane encroachment to be considered during route design.
- Buffered bike lane standard overall width is 9' in Bend and doubles as a fully functioning shoulder to allow stalled or disabled vehicles a place outside of travel lanes. This area can also be used to facilitate police enforcement of travel speeds by providing a place for vehicles to be pulled over.

Crash Reduction

A before and after study of buffered bicycle lane installation in Portland, Oregon found a positive response from people bicycling, with 89% of people bicycling feeling safer riding in the buffered bike lane. Also 91%[1] expressed that the facility made bicycling easier.

1 2015 Nathan McNeil, Christopher Monsere, Jennifer Dill; "The Influence of Bike Lane Buffer Types on Perceived Comfort and Safety of Bicyclists and Potential Bicyclists"



One-Way Separated Bike Lane Design

Separated bike lanes provide additional protection to moving traffic beyond painted buffers. The City of Bend has adopted parking separated bike lanes as its standard for protection to facilitate street sweeping and snow plowing.

Typical Application

- Streets posted 35 mph or less with on-street parking.
- Parking protected bike lanes are LTS 1.

Design Features

- A Pavement markings, symbols, and/or arrow markings must be placed at the beginning of the parking potected bike lane and at intervals along the facility based on engineering judgment to define the bike direction.
- B 6.5’ bike lane is standard width.
- C 2.5’ buffer is standard width.

Further Considerations

- Barred green may be used to highlight driveway or intersection conflict zones. Green coloration should be consistently used to prompt habit-forming responses to the conflict zones, but remain limited in scope to ensure it does not become ordinary.
- Where curb-extensions are required, the parking ends, and the bike lane shifts to curb tight along the curb-extension. See page 76 of this Guide for more details (Bike Lanes Adjacent to Through-Right Lanes).
- Special consideration should be given at transit stops and for access to and from parked cars to manage interactions between people walking and bicycling.

Raised bike lane along Reed Market Road in SW Bend operates as a one-way curb-separated bike lane. The City found difficulty in sweeping and snow plowing with the partially raised curb design, which was too narrow to accommodate basic plow and sweeping equipment. This style of curb-separated bike lane is not standard in the city.

Crash Reduction

A before-and-after study in Montreal of tow-way separated bicycle lanes showed a crash reduction of 74%[1]. In this study, there was a parking buffer, concrete curbs or painted lines with delimiting posts between the bike facility and vehicle travel lanes. Other studies have found a range in crash reductions due to parking separated bike lane, from 8%[2] to 94%[3].

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1 www.cmfclearinghouse.org/detail.cfm?facid= 4097; Cycle-tracks, bicycle lanes & on-street cycling in Montreal: a preliminary comparison of the cyclist injury risk, Nosal and Miranda-Moreno, 2012

2 www.cmfclearinghouse.org/detail.cfm?facid=4094; Cycle-tracks, bicycle lanes & on-street cycling in Montreal: a preliminary comparison of the cyclist injury risk, Nosal and Miranda-Moreno, 2012

3 www.cmfclearinghouse.org/detail.cfm?facid=4101; Cycle-tracks, bicycle lanes & on-street cycling in Montreal: a preliminary comparison of the cyclist injury risk, Nosal and Miranda-Moreno, 2012

Two-Way Separated Bike Lane Design

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

Typical Applications

- On the left side of one-way streets.
- To connect neighborhood greenways or shared-use paths jogged onto an arterial or collector roadway for a short distance to ensure low-stress connectivity and route continuity.
- 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

- 12’ operating width standard (10’ acceptable in constrained areas) for two-way facility. At the approval of the City Engineer, 8’ operating width may be considered. *(Highway Design Manual 1003.1(1))*
- Adjacent to on-street parking a 2.5’ minimum width buffer stripe shall be provided to accommodate opening doors. *(National Association of City Transportation Officials, Bikeway Design Guide, 2012).*
- Green may be used to highlight high volume driveway or intersection conflict zones. Green coloration should be consistently used to prompt habit-forming responses to the conflict zones, but its use limited in scope to ensure it does not become ordinary.

Further Considerations

- Ensure adequate separation, sight lines, and operational right-of-way is provided at driveways and intersections to reduce crash potential.
- Consult FHWA Separated Bike Lane Planning and Design Guide; and the NACTO Urban Bikeway Design Guide for more information.

Crash Reduction

A before-and-after study in Montreal of tow-way separated bicycle lanes showed a crash reduction of 74%[1]. In this study, there was a parking buffer, concrete curbs or painted lines with delimiting posts between the bike facility and vehicle travel lanes.

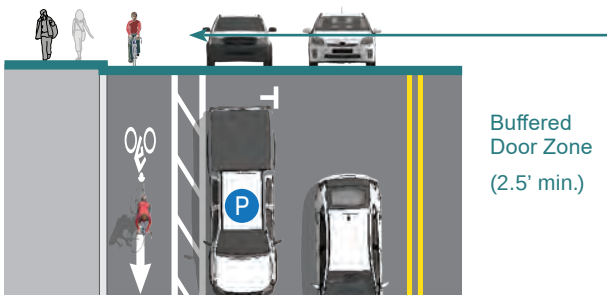
Other studies have found a range in crash reductions due to parking separated bike lane, from 8%[2] to 94%[3].

1 www.cmfclearinghouse.org/detail.cfm?facid= 4097; Cycle-tracks, bicycle lanes & on-street cycling in Montreal: a preliminary comparison of the cyclist injury risk, Nosal and Miranda-Moreno, 2012

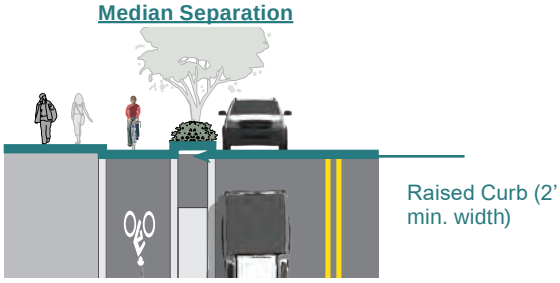
2 www.cmfclearinghouse.org/detail.cfm?facid=4094; Cycle-tracks, bicycle lanes & on-street cycling in Montreal: a preliminary comparison of the cyclist injury risk, Nosal and Miranda-Moreno, 2012

3 www.cmfclearinghouse.org/detail.cfm?facid=4101; Cycle-tracks, bicycle lanes & on-street cycling in Montreal: a preliminary comparison of the cyclist injury risk, Nosal and Miranda-Moreno, 2012

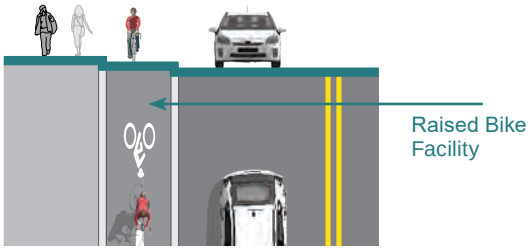
Parking Separation



Median Separation



Grade Separation



Separation Methods

While separated bikeways may use a variety of vertical elements to physically separate the bikeway from adjacent travel lanes, the City of Bend has standardized parking as the vertical element as that allows more lane miles to be deployed at a lower price point. Using parking as the separation method also allows straightforward street sweeping and plowing techniques to be used. This section provides further information when considering vertical separation alternatives.

Parking Separation

Parking separation is the city's standard vertical separation technique. The buffer space is required to allow for opening doors and passenger unloading. Buffer space standard width is 2.5'. Parking should be prohibited a distance back from intersections and driveways to improve visibility. Setback distance will depend on speed.

Median Separation

The City Engineer may consider the use of a concrete median to separate the bikeway from motor-vehicle travel lanes. Design features such as bikeway width are critical to accommodating bike demand and maintenance activities such as sweeping and plowing. Bikeway width shall be a minimum of 10' wide for standard plow and sweeper widths. Narrower bikeway widths will require specialized sweeper and plow equipment. When driveways exist along the bikeway the curbed median will need to be broken to facilitate roadway movements into and out of the driveway. Barred green conflict markings can be considered to provide adequate safety and awareness at each driveway.

Parking separated bike lanes are bicycle facilities that physically separate people riding bikes from the vehicle travel lane using parked cars.

Raised separated bike lanes are bicycle facilities that are vertically separated from motor vehicle traffic. This style of vertical separation requires a detectable zone between the sidewalk and bikeway.

Landscaping is not typically used on the curbed median, but its use can be considered at the discretion of the City Engineer. The presence of landscaping increases the visibility of the island and increases comfort for users as well as contributes to the streetscape environment. The median width should be at least 4' wide if landscaped to support vegetation and allow maintenance crew activities. Irrigation should be configured as drip irrigation to eliminate chances of overspray.

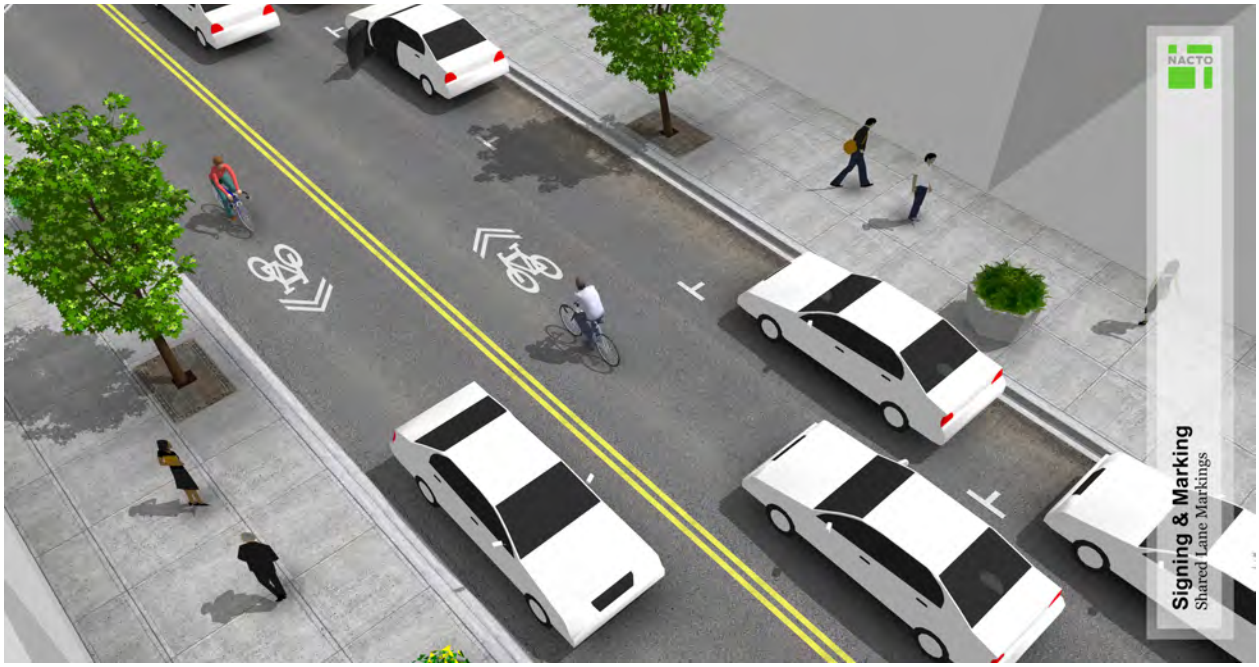
Grade Separation

The City Engineer may consider this style of vertical separation during new roadway construction or complete roadway modernization projects. The amount the bike lane is raised impacts its width requirements and on-going maintenance requirements. The City used a 5' bike lane width with a 1.5' mountable curb on the Reed Market extension project (between Mt. Washington Drive and Bond Street). The mountable curb raised the bike lane up 3", an intermediate height between the road grade and the sidewalk grade. The bike lane width, however, was found to be too narrow to allow standard street sweeping machines or snow plow machines as only the passenger side wheels could be mounted on the raised section and extendable brooms could not reach the full width of the bike lane. To prevent these issues, there are options for designers to consider.

One option is to widen the bike lane to a minimum of 10' to allow standard street sweepers and snowplows to operate on top of the bike lane.

Alternatively, another option is purchasing and operating specialized equipment for street-sweeping and snow-plowing to allow narrower width grade separated bikeways to be considered.

Another option is to raise the bikeway all the way to match the elevation of the sidewalk. This allows maintenance operations to be completed along with sidewalk maintenance operations. However, to meet Public Rights of Way Accessibility Guidelines for ADA compliance, this option also requires detectable separation between the sidewalk and the bikeway. Transitions at intersections are critical to ensure ADA compliance. This style of bikeway complicates intersection crossings because of ADA detection and separation issues as well as state law that defines crosswalks. Designs could utilize a single, shared crosswalk to negate these issues. A more standard approach to a fully grade separated bikeway would be to use the city's standard sidepath design. Sidepaths are widened sidewalks that create a combined multi-use pathway adjacent to the roadway. Sidepaths do not introduce additional ADA issues.



Typical example of a shared lane bikeway in an urban scenario. Source: NACTO Urban Bikeway Design Guide.

Urban Shared Lanes

Shared lane bikeways require motor-vehicles and bikes to share a single travel lane. The use of shared lanes in Bend is limited to select urban streets. While neighborhood greenways use the shared lane markings, they are not categorized as urban shared lane bikeways for the purposes of this guide. Neighborhood greenways are detailed in Chapter 2 of this Guide.

Typical Applications

- Downtown and commercial urban streets with insufficient width to provide any bike lane.

Design Features

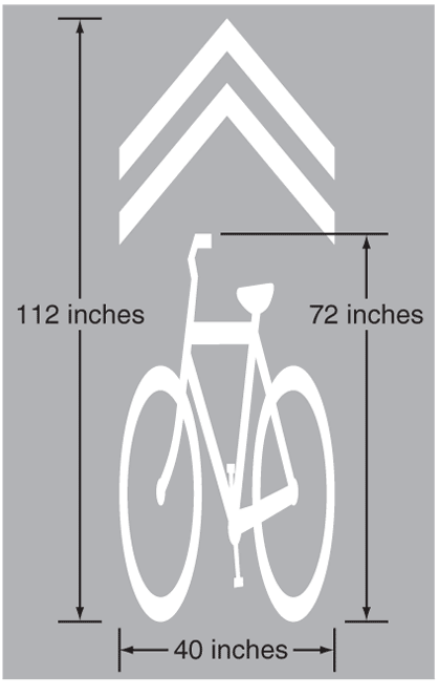
- Shared lane marking located in the center of the travel lane. The travel lane is defined as the width of roadway between the centerline marking and the parking marking. This position directs bike riders to take the lane and positions them in the most visible portion of the lane.
- Shared lane marking located outside of the parked car door zone. Placing the shared lane marking just outside of the door zone puts the sharrow about 11’ to 12’ from the curb when parallel curb-tight parking exists.

Further Considerations

Bike lanes are required on all arterial and collector roadways in Oregon as directed in ORS 366.514. Because of width restrictions on downtown streets, or higher priorities placed on sidewalk widths or on-street parking widths in commercial areas, shared lane roadways may be considered at the discretion of the City Engineer. For the most part, shared road bikeways can achieve an LTS 2 rating when speeds are 25 mph or lower, but are less desirable than bike lane treatments that also achieve LTS 2 because they mix bike riders with traffic.

Shared lane bikeways may also be utilized under certain construction scenarios as set forth in Chapter 8 of this Guide when speeds are 30 mph or slower.

Figure 9C-9. Shared Lane Marking



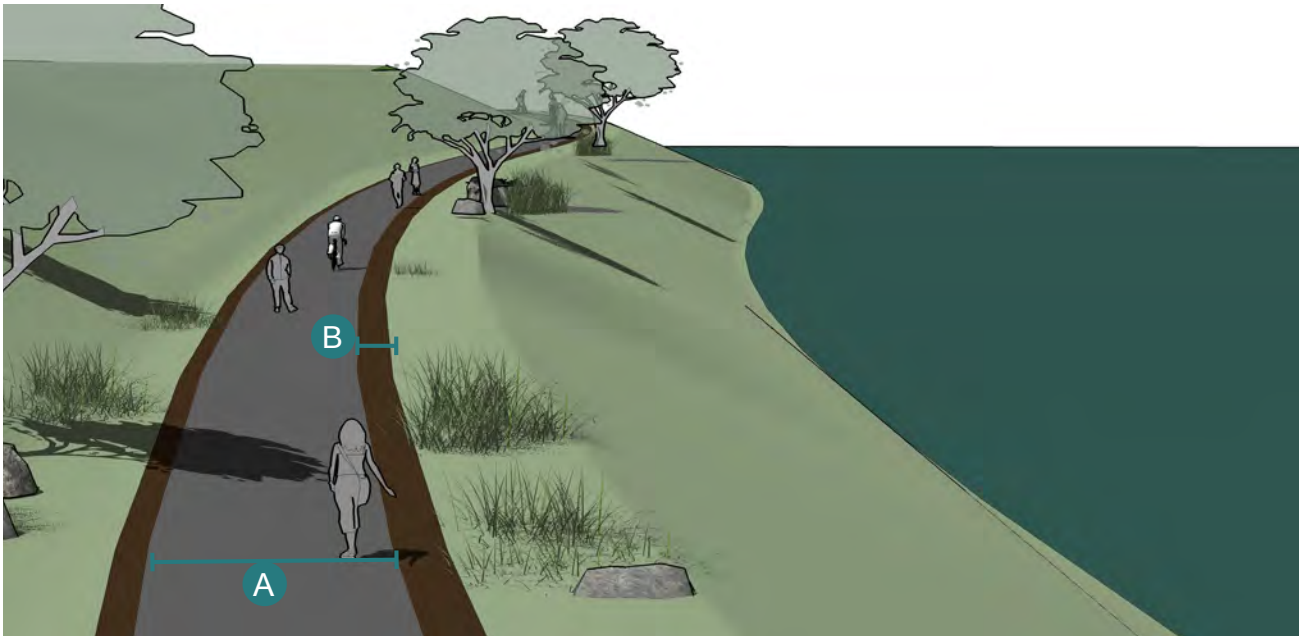
Crash Reduction

Research indicates that shared lane bikeways may contribute to increased riding when included as part of a network, but have no impacts on safety[1].

1 Transportation Reseach Board, 2016 Annual Meeting, N. Ferenchak, W. Marshall

Chapter 4

Design of Shared-Use Paths



Shared-Use Path Design

Shared-use paths are separated from motor vehicle traffic by an open space or barrier and are either within the highway right of way or within an independent right of way or easement. The Architectural and Transportation Barriers Compliance Board has published a Proposed Rulemaking in the Federal Register (36 CFR Part 1190) that covers shared-use paths.

Typical Application

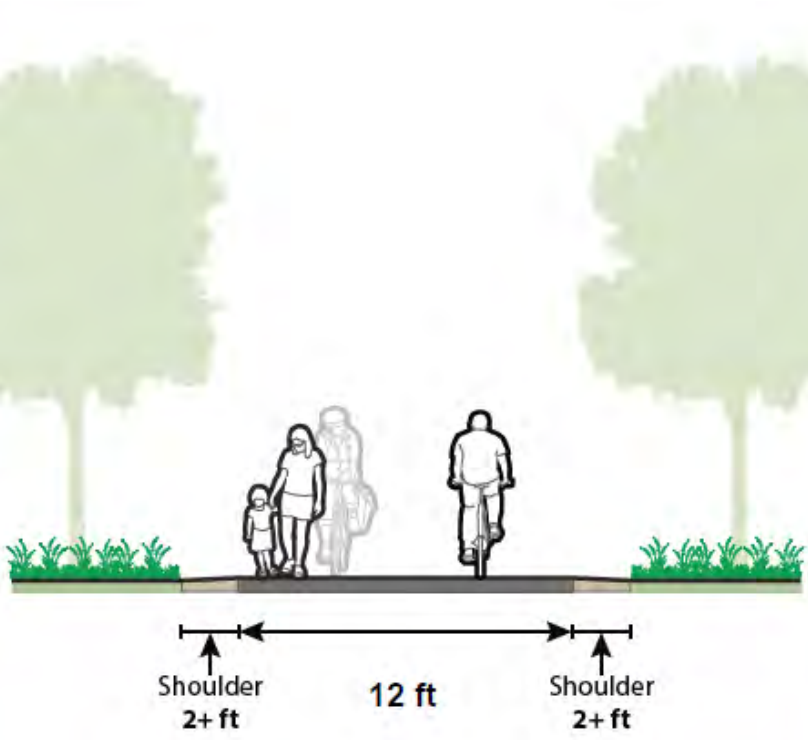
- Within unimproved public rights of way.
- As primary or connector trails within trail rights of way or utility rights of way.
- As short passageways to connect to cul-de-sacs, dead-end streets, or mid-way along long block lengths to decrease out of direction travel.
- As sidepaths, along roadways in lieu of a sidewalk to supplement on-street riding. Sidepaths are the City's standard, low-stress biking facility on arterial and collector roadways posted 40 and 45 mph as well as adjacent to schools, parks and leading to schools and parks.
- As temporary connections when future streets are not yet completed, to keep people moving, while development phases build out.

Design Features

- A Widths will vary depending on the circumstances but should be wide enough to serve a variety of users and accommodate variations in speeds.

  Standard widths of all shared use pathways are 12' wide. Narrower widths may be allowed by the City Engineer in the course of balancing competing needs for right of way or easement width allocation. Site context, user type, and competing features such as parkstrip width and snow storage needs can be considered in their determination of shared use path width.

- B Minimum 2' shoulder. Provide lateral clearance for signs and other furnishings.
- Vertical Clearance: Standard clearance to overhead obstructions is 8'.
- Cross Slope: 2%



- Grade: Typically required to be 5% maximum running grade to avoid use of handrails. Allowances exist for shared-use paths adjacent to a roadway (ADA requirements require the shared-use path follows the grade of road) or for exclusive rights of way and in steep areas.

  Where not practicable due to existing terrain or infrastructure, right of way, notable natural feature, etc., ADA compliance allows these grades to be met to the greatest extent practicable. Therefore, on steep hillsides (terrain slopes greater than 5%) the following guidelines are provided: 8% maximum grade for 30 feet; otherwise, 8.3% grade may be used for a maximum of 200 feet and 10% grade may be used for a maximum of 30 feet.

  Additionally, if switchbacks are used: the switchback shall accommodate the minimum turning radii of a bicycle of 15 feet, and the path shall be widened through the turn to 15' (10' minimum) to accommodate two-way operations, and dismounted riders pushing their bikes up the hill.

- Lighting at roadway crossings is required to accommodate safe crossings at night. Lighting is also required for daytime use in tunnels and underpasses. Lighting may be warranted along the shared-use path to increase safety and comfort for night-time riding. All lighting within Bend is required to be shielded and dark sky compliant.

Further Considerations

- Centerline striping is not generally necessary, although horizontal or vertical curves may warrant pavement marking such as a solid yellow line with white directional arrows.
- If used, signs in path environments should be small scale (MUTCD 9B.02) and should be retroreflective for night time travel.
- Terminate the path where it is easily accessible to and from the street system, preferably at a trailhead or controlled intersection to accommodate access to the path.

Sidepath Design

A sidepath is a bidirectional shared-use path located parallel to the roadway, typically within the same right-of-way, or immediately adjacent to right-of-way in an adjacent easement. Sidepaths can offer a high-quality experience for users of all ages and abilities.

Typical Application

Sidepaths are considered where one or more of the following conditions exist:

- The adjacent roadway has high-speed motor vehicle traffic that discourages most people from riding in a basic bike lane on the roadway. Sidepaths achieve low-stress LTS 1 ratings. Sidepaths do not preclude the installation or maintenance of bike lanes.
- To provide continuity between existing segments of shared-use paths.
- For use near schools, neighborhoods, and mixed-use commercial areas, where increased separation from motor vehicles is desired, and there are few roadway and driveway crossings.

Design Features

- Asphalt is standard sidepath paving material. Concrete may be required depending on the land-use context.
- Standard width is 12’ but minimums of 7’ to 10’ are allowed in constrained areas to maintain a minimum 6.5’ parkstrip and snow storage area.
- (A) The preferred minimum roadway separation is 6.5 - 16.5’ (2.0 - 5.0 m) (Schepers, 2011). Absolute minimum separation width is 5’ (1.5 m) (AASHTO Bike Guide 2012, p. 5-11).
- Separation should increase as volumes and speed of adjacent roadway increase (AASHTO Bike Guide 2012, p. 5-11).
- Lateral clearance to landscaping, street furnishings and signs is required. Signs and other street furniture should be placed outside of the minimum path width.

A sidepath provides a continuous path of travel along roadway corridors with few driveways or intersections. Depending on the anticipated volumes and context, the sidepath can be constructed in lieu of sidewalk.

- Standard clearance to overhead obstructions is 8' minimum. Greater clearance makes tunnels or longer confined spaces more comfortable and approachable and the tallest clearance possible should be attained.
- As sidepaths are typically located within public rights of way, their designs are governed by PROWAG guidelines. Grades are required to generally match the grade of the road.
- Sight Lines: It is important to keep approaches to intersections and major driveways clear of obstructions due to parked vehicles, shrubs, and signs on public or private property.

Crash Reduction

A study of crashes on two-way separated facilities found that accident probability decreased by 45%[1] at intersections where the separated facility approach was detected between 2-5 meters from the side of the main road and when the sidepath had crossing priority at intersections.

Intersection treatment is critical for sidepath designs particularly when the two-way separated bike lane or shared-use path is located between 0-2 meters from the side of the main road. Paths at this minimal separation are shown to have a slight increase in collisions at intersections of 3%[2].

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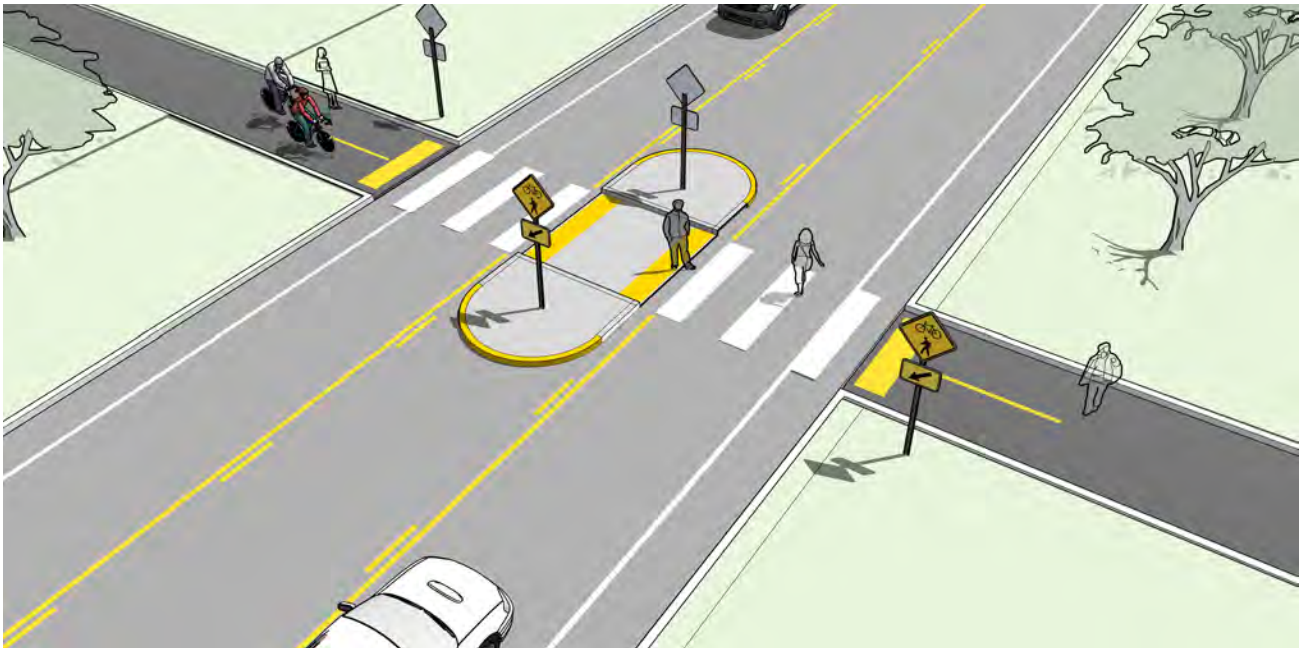
1 www.cmfclearinghouse.org/detail.cfm?facid=3034

2 www.cmfclearinghouse.org/detail.cfm?facid=4033



Path Crossings of Arterial and Collector Roadways

Enhanced crossing treatments such as marked crosswalks, safety islands, and other horizontal and vertical speed management tools help improve visibility, predictability, and safety for shared use paths and trails that cross busy arterial and collector roadways.

Typical Application

- Create a safe crossing where paths cross arterial and collector roadways.

Design Features

- Shared-use path users are prioritized over roadway users.
- The LTS rating of the roadway crossing should match the LTS rating of the shared-use path (LTS 1).
- Basic features typically include ADA ramps, crosswalk markings, crosswalk warning signs, and illumination placed in advance of each approach.
- Crossing treatment designs will accommodate emergency service vehicle passage, and maintenance needs such as brooming, and plowing.
- Crossing safety treatments, thresholds for when they are required, and any other safety treatments are established in Chapter 1 of this Guide.

Further Considerations

- A central safety island should allow shared-use path users to cross one direction of traffic at a time. The waiting area should be deep enough to allow for bikes as well as people pushing strollers or wheelchairs to fit and provide adequate separation from traffic.

  City standards for safety island depths are 9’ for all roadways. When placed within a 12’ width (two-way left turn area), this provides a 1.5’ shy distance and allows adequate curb-to-curb width between the safety island and the edge of the roadway to meet Emergency Service Vehicle width requirements.

  ODOT LTS methodology requires safety and splitter (roundabout) islands to be at least 10’ for an LTS 1 rating.

A raised crossing provides a continuous at-grade path of travel for people walking and bicycling.

- Where possible, geometric design on the arterial and collector roadway should promote a high degree of yielding to path users through horizontal deflection, signing, striping, etc.
- Typically raised crossings will not be used across arterial and collector roadways, although in urban areas such as downtown, raised crossings are allowed based on City Engineer approval. Raised elevation changes may be considered on locally designated streets (non-arterial/collector) and on arterial/collector streets under special circumstances.
- When protected crosswalks exist nearby, such as at a traffic signal, roundabout or other enhanced crosswalk, it may be desirable to direct the shared-use path to the existing protected crossing. In these situations the requirement for wrong-way riding to get to the protected crossing needs to be considered. If there is out-of-direction travel that is too great, shared-use path users will continue to cross in the unaccommodated crossing location due to convenience. This may lead to unsafe crossings of vulnerable users.

Crash Reduction

Studies have shown a 45%[1] decrease in vehicle/pedestrian crashes after a raised crosswalk is installed where none existed previously.

A study of the effectiveness of high-visibility marked crosswalks found that they were associated with an 18%[2] decrease in crashes involving pedestrians and vehicles at signalized and unsignalized intersections.

Based on a comparison of crash rates on arterials with 3 to 8 lanes and minimum 15,000 ADT, safety islands were found to reduce crosswalk collisions by 46%[3] at marked crosswalks. This test controlled for crosswalk and roadway traffic volumes.

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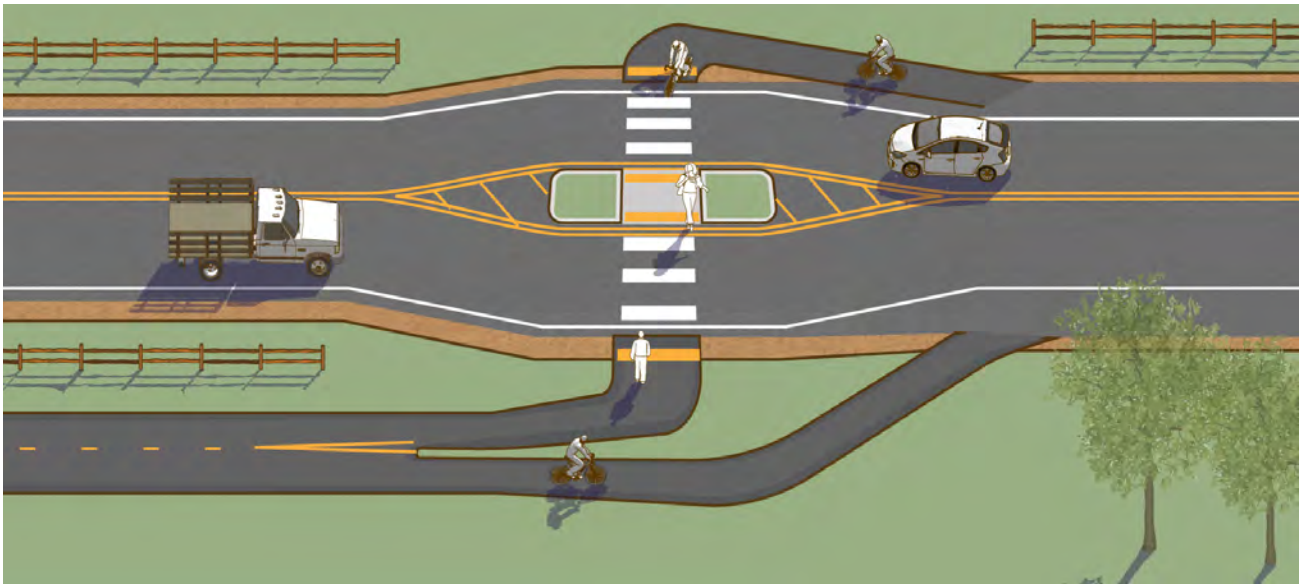
1 www.cmfclearinghouse.org/detail.cfm?facid=136
2 www.cmfclearinghouse.org/detail.cfm?facid=4123
3 www.cmfclearinghouse.org/detail.cfm?facid=75



Transitions to Directional Facilities

At locations where the shared-use path ends and meets another directional bikeway facility, such as a bike lane or neighborhood greenway, the design should consider the needs of path users when transitioning from one facility to the next. Where the sidepath ends, crossings and connections should be designed to safely and conveniently connect users with the receiving facility.

Typical Application

- Transitions are necessary where shared use paths connect to on-street bike facilities. Ideally, these transitions occur at intersections, or other established mid-block crossings along with other enhanced crossing treatments, such as median refuge islands, and marked crosswalks.
- Where a sidepath terminates, it may be necessary for path users to transition to a facility on the opposite side of the road. Designs should consider the desire for natural directional flows, and the potential for conflicts with adjacent traffic.
- For use near schools, neighborhoods, and mixed use commercial areas, where increased separation from motor vehicles is desired, and there are few roadway and driveway crossings.

Design Features

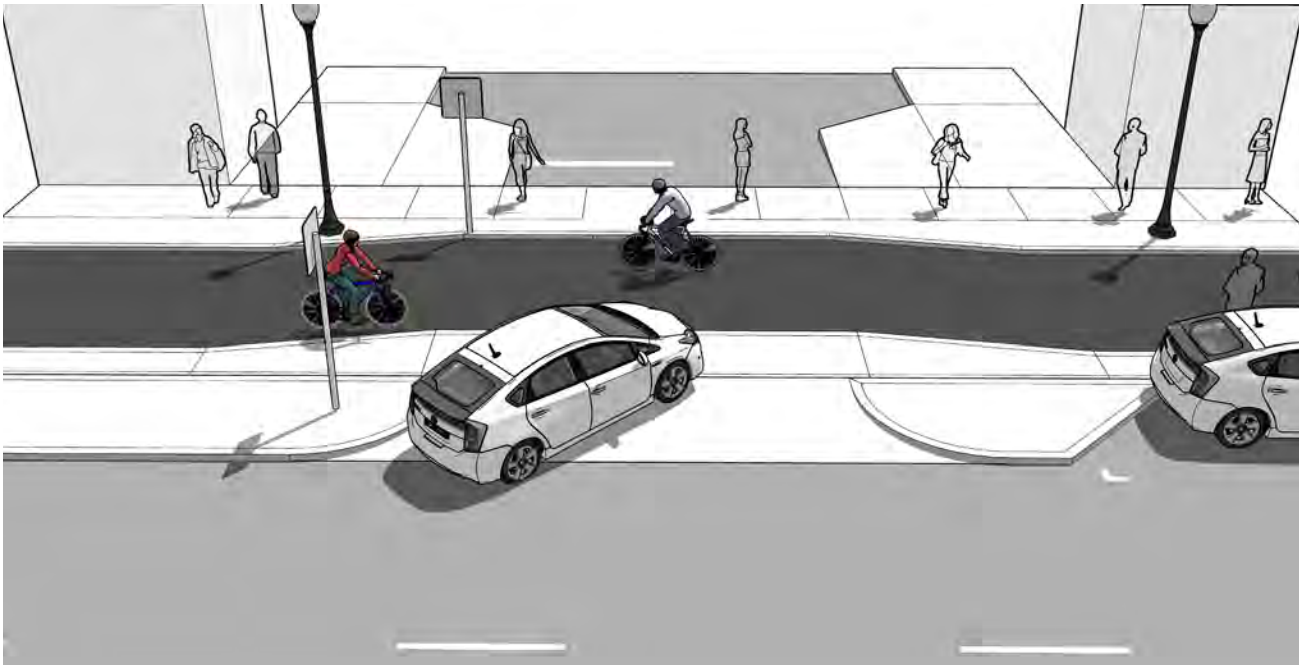
- Allow for storage of path users outside of the through travel paths of others where users transition from one path to another. Width of storage area depends on user volumes but at a minimum should accommodate anticipated bicycle design lengths and turning movements.
- Wayfinding is necessary to direct path users to nearby destinations, the transition from the trail to the next bike facility, and the trail itself.
- Minimum crosswalk features, and consideration of enhanced features, is necessary to ensure crossing safety. Chapter 1 of this Guide provides requirements for crosswalk safety treatments for given speed and roadway width requirements.

Transition from neighborhood greenway to shared -use path, including wayfinding signage.

Transitions to directional facilities at intersections helps to improve connections, and tie into existing crossing enhancements.

Further Considerations

- The design of the transition from the path and the on-street facility should meet the same LTS level as the shared-use path, so as to provide a consistent level of comfort for trail users. If the shared-use path transitions from LTS 1 to higher LTS facility, then the on-street facility should be targeted for improvements to LTS 2 or LTS 1 to provide low-stress connectivity.
- Transitions to directional facilities are important to facilitate local access. The bikeway network should be screened and transition projects prioritized to provide citywide and regional connectivity.
- Particular consideration should be given to areas where the shared-use path transitions to exclusive bike and pedestrian travelways, such as bike lanes and sidewalks. The design of the transition should aim to minimize pedestrian conflicts at these locations with the use of signs, pavement markings, and ramp alignments.
- When protected crosswalks exist nearby, such as at a traffic signal, roundabout or other enhanced crosswalk, it may be desirable to direct the shared-use path to the existing protected crossing. In these situations the requirement for wrong-way riding to get to the protected crossing needs to be considered. If there is out-of-direction travel that is too great, shared-use path users will continue to cross in the unaccommodated crossing location due to convenience. This may lead to unsafe crossings of vulnerable users.



Managing Conflicts Across Separated Bikeways, Shared-Use Paths, or Sidepaths

Shared-use paths, separated bikeways, and sidepaths that run parallel to and within a roadway right of way will be crossed at minor crossings such as driveways or streets. Minor crossings of the bikeway should provide visibility for everyone, manage turning movement speeds, and establish clear right-of-way priority.

Typical Application

- Aprons at driveways and small curb radii at local street intersections are used to maintain safe turning speeds.
- On-street parking is managed at driveway and intersections to provide sight lines for all movements and conflicts.
- Bikeways parallel to the roadway are not stopped unless the parallel roadway is also stopped.

Design Features

When checking for sight lines, use a range of eye heights to accommodate the lower eye heights of bikeway users such as children, hand cyclists, and recumbent cyclists (2.6') as well as the higher eye heights of motor-vehicle drivers in autos (3.5') and delivery trucks (9.8').

When sight lines are restricted due to zero lot line buildings, or other conditions that have been evaluated but prioritized to keep (large trees, for example), other countermeasures should be added such as barred green pavement markings through the conflict zone, signing, etc., to increase awareness.

Important features at high volume driveway and minor street crossings include good sight lines for visibility, and tighter turning radii to facilitate slower turning movements. This photo shows an example of a retrofit shared use path within an older roadway.

Further Considerations

- Removing obstructions and providing clear sight distance at crossings increases visibility of bicyclists.
- Treatments designed to constrain and slow turning motor vehicle traffic will slow drivers to bicycle-compatible travel speeds prior to crossing the separated bikeway.
- The location of street furniture and maintenance of landscaping are critical, in denser urban areas that generally have more limited sight lines.
- Garbage pick-up, freight loading, and drop-off hours should be restricted to hours of the day when less bicycle traffic is expected, to minimize potential interactions.
- The City can provide guidance to both waste management operators and customers on desirable recycling/trash can and bin placement with respect to both walkways and bikeways to improve safety and use of these facilities.

Crash Reduction

Raised crossings at driveways and intersections physically indicate priority of path travel over turning or crossing traffic, and reduce conflict risk by 51%[1].

A passenger loading zone allows pedestrians to cross the separated bike lane to access the loading island. The crossing can be raised to increase awareness of the crossing and increase bike yielding.

1 Schepers, et al. Road factors and bicycle-motor vehicle crashes at unsignalized priority intersections. Accident Analysis & Prevention. Volume 43, Issue 2, 2011.

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Chapter 5

Design at Intersections and Interchanges

Principles of Intersection and Interchange Design

Intersections and interchanges that create safe and comfortable street crossings for everyone is an essential aspect of a low-stress bikeway network. A well-connected network includes clear and direct paths of travel through the intersection that allow successful and comfortable navigation across the street. Key principles of design for bikeway navigation across intersections and interchanges include:

- **Adequate sight lines**
- **Minimal exposure to conflicts**
- **Safe speeds at conflict points**
- **Accommodating all ages and abilities**
- **Predictable movements at conflict points**
- **Clear right-of-way priority and straightforward decision-making across the intersection and through any conflict points**

All intersection design elements will accommodate maintenance operations such as street sweeping and snow plowing, and efficiently accommodate on-going upkeep such as restriping. Designs must manage stormwater to avoid puddles.

This Chapter presents techniques to connect bikeway facilities across the intersection; provides signal phasing and timing techniques; provides guidance on how to accommodate safe turning movements; and provides guidance for interchange design layouts.

Marked Crosswalks

Crosswalks exist at the intersection of roadways, and can be marked or unmarked. In Oregon, drivers must stop when anyone is in the crosswalk (ORS 811.028). This law covers people using mobility devices or riding their bike across the street in a crosswalk (ORS 814.410). Bike riders have the responsibility under this law to approach and enter the crosswalk at the speed of an ordinary walk in order to provide drivers adequate time to observe the intent of the rider to cross.

Typical Application

- The City will typically mark crosswalks to increase awareness of neighborhood greenways as well as trails when crossings of arterials and collectors are necessary and these are part of the low-stress network. The speed, volume of traffic, number of lanes, etc. will dictate whether further safety treatments are required such as safety islands, signing, beacons, etc.
- Parallel sidepaths cross the stopped control approach to an intersection, and typically would not require crosswalk markings, however, there may be situations and contexts that would warrant marking these crosswalks, such as student, elderly, or other sensitive population usage.
- Additional safety features are required with greater volumes, speeds, and roadway width as detailed in Chapter 1 of this Guide.

Design Features

- High-visibility crosswalk markings are the preferred marking type at uncontrolled marked crossings[1].
- The crosswalk should provide access for those on bicycles such as full ADA ramps or bike-only ramps.
- Street lighting should be provided at all enhanced crosswalks to ensure adequate safety under night time and adverse lighting conditions.

1 FHWA 2013 Pedestrian Safety Guide and Countermeasure Selection System.

Crosswalk pavement markingswill wear at a faster rate in areas with high turning movement volumes and heavy vehicles, such as buses or freight trucks and will require more frequent maintenance.

Marked crosswalks are used to raise driver awareness of neighborhood greenway crossings.

Further Considerations

- On roadways with high speeds or multiple lanes, crosswalk markings alone are often not a viable safety measure and more robust safety features are required[1]. This includes: measures designed to reduce traffic speeds and shorten crossing distances to enhance everyone's awareness of the crossing, and increase yielding for crosswalk users. Chapter 1 of this Guide provides crosswalk safety treatment requirements based on speed and number of lanes.
- On roadways with more than two consecutive lanes without a safety island, a marked crosswalk alone is not a viable safety measure. Continuous center turn lanes with no safety islands are not considered adequate refuge areas[2].
- Studies have shown that people driving were statistically more likely to yield right-of-way to a person in a marked crosswalk than an unmarked crosswalk[3].
- People decrease their driving speed in the vicinity of marked crosswalks, indicating an increased awareness of the potential need to stop. Crosswalk usage increases with the installations of crosswalk markings[4].
- People on bikes in crosswalks are required to travel at walking speed when anyone walking is also present. When bike riders ride faster than walking speed, the time to accommodate a driver's perception and reaction times is reduced and may cause safety issues.

Crash Reduction

A study of the effectiveness of high-visibility marked crosswalks found that they were associated with an 18%[5] decrease in crashes involving pedestrians and vehicles at signalized and unsignalized intersections.

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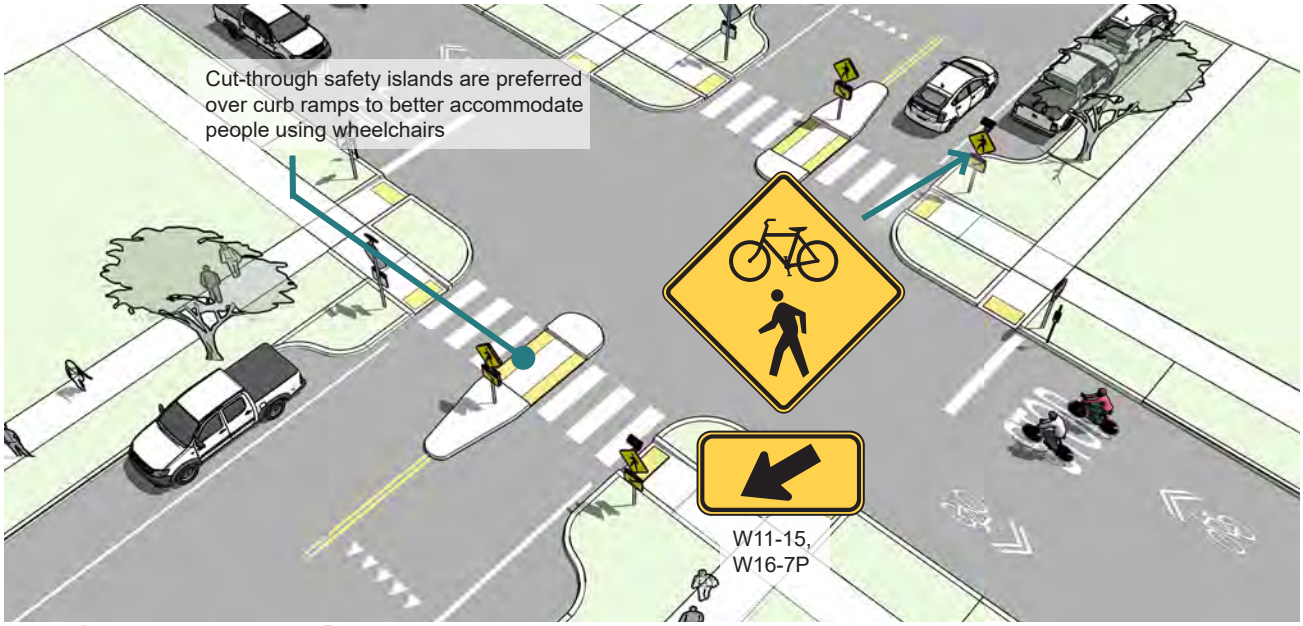
1 Zegeer 2001 Safety Effects of Marked Versus Unmarked Crosswalks at Uncontrolled Locations

2 Zegeer 2005 Safety Effects of Marked Versus Unmarked Crosswalks at Uncontrolled Locations

3 Mitman 2013 An Overview and Recommendations of High-Visibility Crosswalk Marking Styles

4 Knoblauch 2000, 2001 Crosswalk Marking Field Visibility Study

5 www.cmfclearinghouse.org/detail.cfm?facid=4123



Safety Islands

Safety islands are raised concrete islands located in the middle of the crosswalk. They can be added at an intersection crosswalk or a mid-block crosswalk. Safety islands are effective because they make everyone more visible and offer a place for the pedestrian to find gaps in traffic for each direction of travel separately.

From a traffic operations perspective, safety islands reduce exposure of people to traffic by reducing crossing distances, minimize delay for traffic on the street because of shortened crossing times. They also increase the number of available gaps in traffic for crossing opportunities by allowing a person to cross one direction of traffic at a time. This reduces the temptation to try to cross during a gap in traffic that is too small to allow a safe crossing.

Typical Application

- Multi-lane crossings.
- Speeds of 30 mph or higher.
- As splitter islands on the approaches to roundabouts.
- At right turn lanes.

Design Features

- The island must be ADA accessible; the City will use at-grade passage through the island (as opposed to ramps and landings).
- Safety islands will be sited and designed to accommodate emergency service vehicles and maintenance operations such as sweeping and plowing.
- On longer crossings, where pushbuttons are used, an additional pushbutton will be placed at safety islands to reduce delay to roadway traffic.
- Safety islands may also be offset or angled to direct users to face oncoming traffic.
- Safety island standard width is 10’ wide to achieve LTS 1. In constrained rights-of-way the width can be reduced to 8’ but may impact LTS, depending on context.

Offset or diagonal safety islands re-direct people in the crosswalk so that they are facing the direction of approaching traffic before crossing the second crosswalk leg.

Safety islands provide a place to mount a second pedestrian crossing warning sign and Rectangular Rapid Flashing Beacon, resulting in enhanced visibility of the unit and increased driver yielding compliance.

Further Considerations

- If a safety island is landscaped, the landscaping should not compromise the visibility of people crossing in the crosswalk. Shrubs and ground plantings should be no higher than 1.5'.
- On multi-lane roadways, active warning beacons may also be required for improved motor vehicle yielding compliance.
- Safety islands can be applied on any roadway with a left center turn lane; existing median that is at least 6' wide; or by narrowing travel lanes to create the safety island space.
- Safety islands may be necessary even on narrow, low-speed crosswalks if traffic volumes reduce the number of acceptable gaps in traffic available to accommodate crosswalk users.
- On higher speed approaches, safety islands alone will not be adequate to facility safe crossings. Additional treatments such as RRFBs will also be necessary.
- Designing a horizontal shift across the safety island will enhance visibility by orienting the user towards conflicting traffic.

Crash Reduction

Based on a comparison of crash rates on arterials with 3 to 8 lanes and minimum 15,000 ADT, safety islands were found to reduce crosswalk collisions by 46%[1] at marked crosswalks. This test controlled for crosswalk and roadway traffic volumes.

1 www.cmfclearinghouse.org/detail.cfm?facid=75

Crosswalk Flashing Beacon

Crosswalk flashing beacons use Rectangular Rapid Flashing Beacons (RRFB) - a type of active warning beacon, and are user-actuated illuminated devices designed to increase awareness of the crosswalk. With user-activated beacons, drivers are more likely to stop, especially on high volume multi-lane roadways. RRFB flashing beacons have been found to elicit the highest increase in compliance of all the active warning beacon options.

Typical Application

- Chapter 1 of this Guide provides guidance for when RRFBs are required based on speed and number of travel lanes.
- Typically, RRFBs are required for key crossings of multi-lane collector and arterial streets where posted speeds are 35-45 mph. They are typically paired with safety islands.
- RRFBs are typically doubled (left and right hand mounting) to increase conspicuity and maximize driver yielding.
- RRFBs are typically activated by manually pressing a push-button at the crosswalk. They can also be actuated automatically via passive detection systems.
- Flashing beacons cannot be used for crosswalks that are also controlled by traffic signals, yield signs or stop signs.

Further Considerations

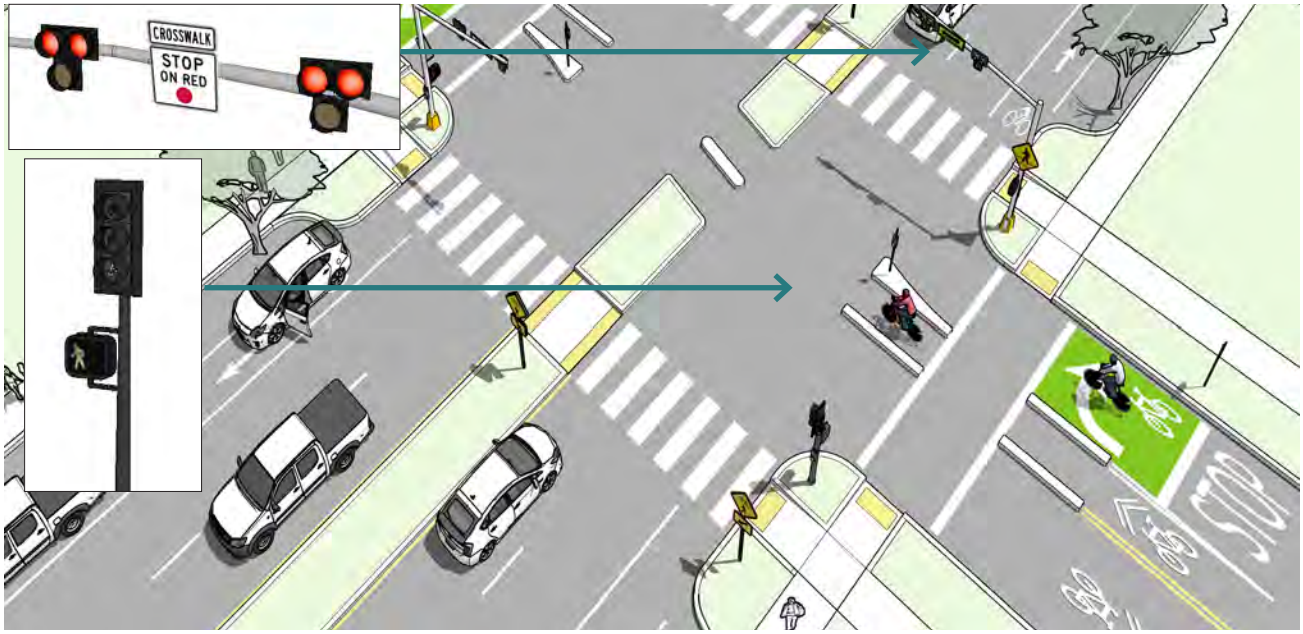
- Walk times can be increased when the crossing serves people who require more time to cross the street.
- Pushbuttons should accommodate the latest ADA and bike detection requirements. The designs shall not require the rider to dismount their bicycle to reach the push button.
- RRFBs may not be suitable in locations with close proximity to a traffic signal. Hybrid beacons may be more applicable in those situations.

Crash Reduction

Federal Highways Administration has compiled research showing high rates of yielding for RRFB devices. Each of the study sites had posted speed limits of 35 mph, safety islands, 3-4 lanes of traffic, and AADT ranges of 8,600-19,200.

The studies showed that two-beacon RRFB installations increased driver yielding rates at crosswalks to 81% and that four-beacon installations (RRFB units added on safety islands) raised compliance to 88%[1].

1 https://safety.fhwa.dot.gov/intersection/conventional/unsignalized/tech_sum/fhwasa09009/fhwasa09009.pdf



Pedestrian Hybrid Beacon

A hybrid beacon 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.

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 cut-through traffic on the minor street. Hybrid beacons may also be used at mid-block crossing locations. While Bend has standardized on the Rectangular Rapid Flashing Beacon, pedestrian hybrid beacons may be required by the City Engineer as follows.

Typical Application

- Multi-lane crossings of arterial streets where speeds are 35-45 mph. They shall not be used on slower speed crossings or on narrower roadways.

Design Features

- Hybrid beacons may be considered without meeting traffic signal control warrants if roadway speed and volumes are excessive for comfortable pedestrian crossings.
- 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 on all approaches to provide adequate sight distance.

Further Considerations

- At the crosswalk, anyone walking or biking can activate the hybrid signal. Passive detection technology should be considered, but if push buttons are used they should be located within easy reach of the crosswalk including those located within the bike path of travel.
- Once the signal has been activated, the

hybrid signal can delay a response if necessary to coordinate with adjacent traffic signals. In determining the mean response time, consider how delays affect people waiting to cross. Long wait times will make people impatient and increase darting across the street. Engineering review should focus on sight lines, traffic progression, and safety.

- At this time, hybrid beacons and dedicated bicycle signals are not allowed to be co-located.
- Hybrid beacons could be considered for crosswalks where there are 4 or more travel lanes to cross but safety islands are infeasible.
- Whenever the City begins to utilize a new traffic control treatment, such as would be in the case of hybrid beacons, a community-wide education program should also be developed and employed to educate road users on how they operate.

Crash Reduction

Pedestrian hybrid beacons have shown a crash reduction of 29%[1] for all crash types and 15%[2] for fatal or serious injury crashes.

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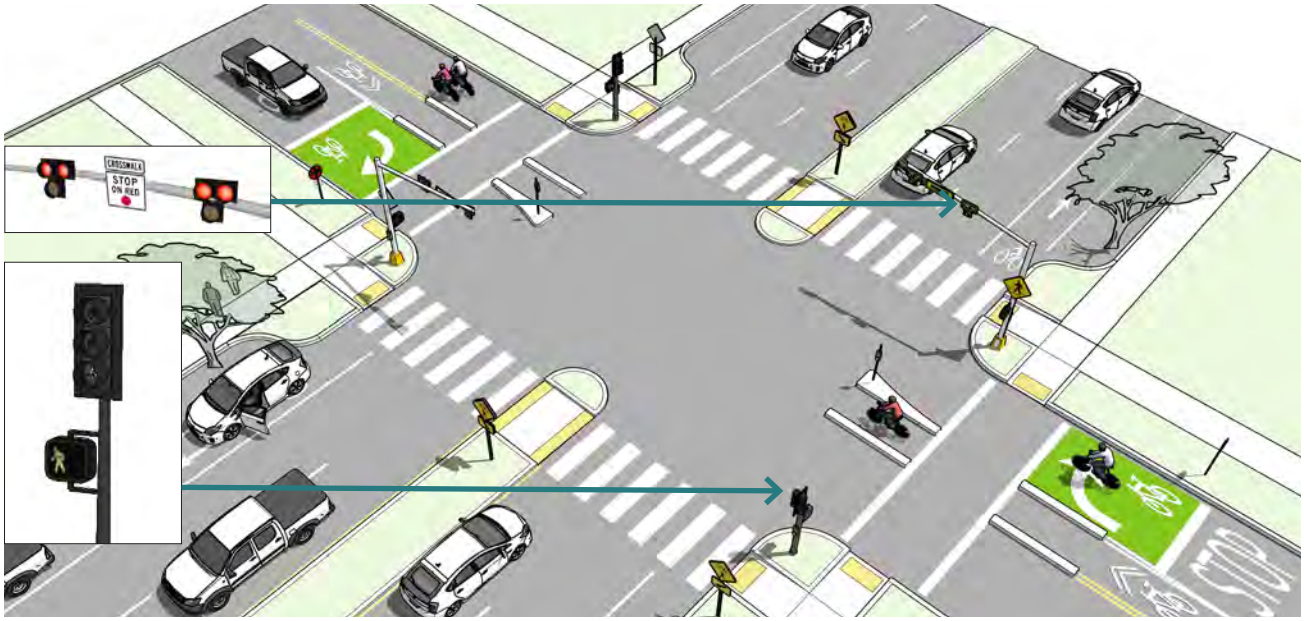
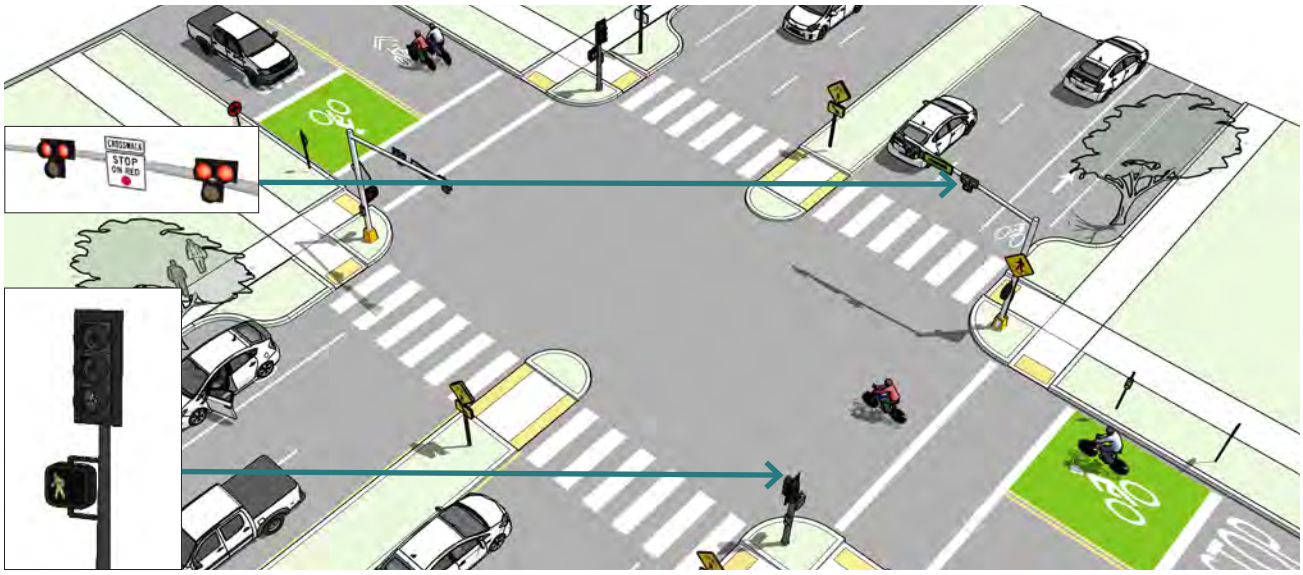
1 www.cmfclearinghouse.org/detail.cfm?facid=2911

2 www.cmfclearinghouse.org/detail.cfm?facid=2917



Enhanced Pedestrian Hybrid Beacon (HAWK) configuration with channelization and median islands on a neighborhood greenway.



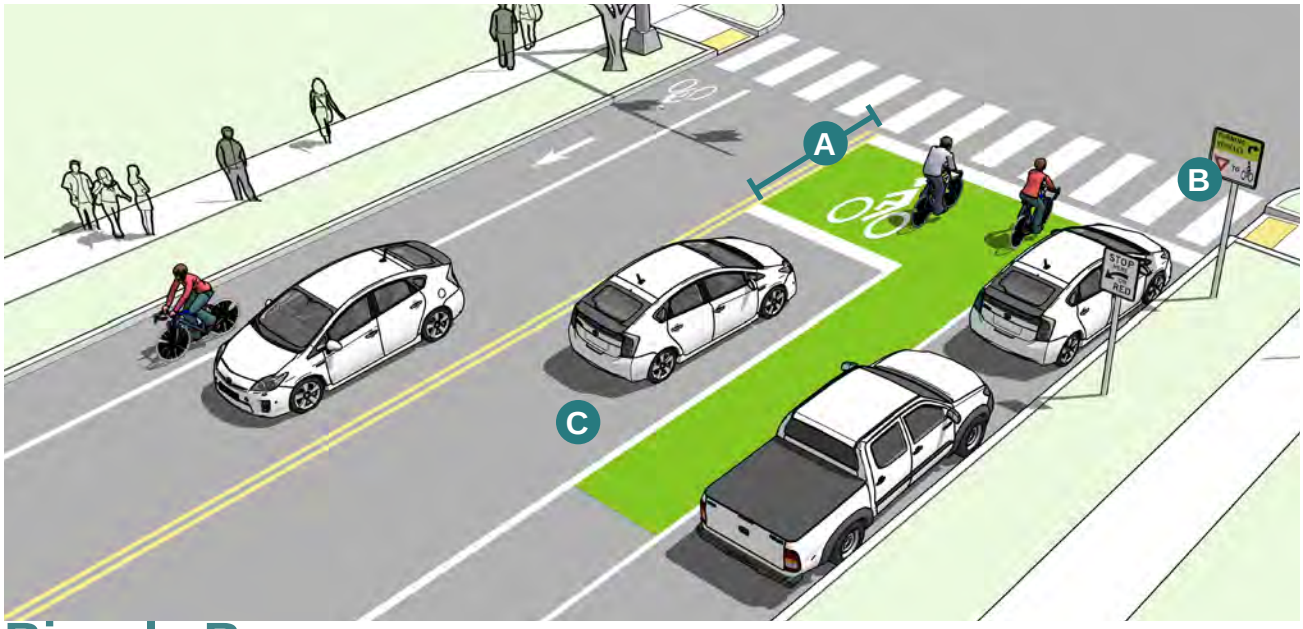
Pedestrian Hybrid Beacon (HAWK) configuration with channelization and safety enhancements on a neighborhood greenway.

Additional Bikeway Intersection Treatments

Bike box

Adjacent to through-right crossings

Protected intersections



Bicycle Boxes

Bicycle boxes provide increased visibility of bike riders at intersections and can be used to eliminate right-turning crashes with bike riders traveling straight-through an intersection. The box allows bike riders to ensure they are visible and outside of the risk zone. Risk zones exist with a basic bike lane approach at an intersection because the bike rider is located outside of the right-turning driver's field of vision. The bike box also reduces clearance intervals required to get bike riders through an intersection to provide more green time available to accommodate turning motor-vehicle traffic.

Typical Application

Bike boxes are a tool that may be applicable in the following situations. Their use requires approval by the City Engineer.

- On signalized intersection approaches with high volumes of bikes or motor-vehicles and lower speeds (30 mph and less).
- At transitions between bike lanes and shared roadways.
- At signalized or stop sign controlled intersections with high volumes of vehicles and bicycles to prevent right-turning crashes.

Design Features

- A The box depth is adequate to maneuver into and store the anticipated number of bikes.
- B For operations and safety requirements, turning movements at the traffic signal are restricted with no-turn-on-red.
- C The bicycle lane is required to have adequate length on the approach to establish a clear path of travel into the bicycle box.
- Green colored pavement within the bicycle box and for at least 30' of the approach bicycle lane is required by the Oregon Department of Transportation's acceptance of the Federal Highway Administration's interim approval for bike boxes.

A bicycle 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 to quickly clear the intersection, minimizing conflict and delay to transit or other traffic.
- People walking also benefit from bike boxes, as they experience reduced vehicle encroachment into the crosswalk.
- Bicycle boxes have been granted interim approval by FHWA (IA-18). This interim approval is the result of an official request to experiment process outlined in section IA-10 of the MUTCD.
- The Oregon Department of Transportation submitted a proposed Policy to FHWA and received blanket approval for all road authorities within Oregon to utilize bicycle boxes without further approvals from the FHWA (ODOT TR17-02(B)).
- Bike boxes alone on downward approaches to signalized intersections are insufficient to reduce crashes with right-turning motor-vehicles and requires additional treatments.
- Bike boxes require right-turn on red restrictions which may cause increased delays to right-turning vehicles. This can lead to right-turn-on-red turn restriction violations unless enforcement can be consistently provided. When there are few bike riders on the approach, bike boxes may not be the best solution as a result of these violations.

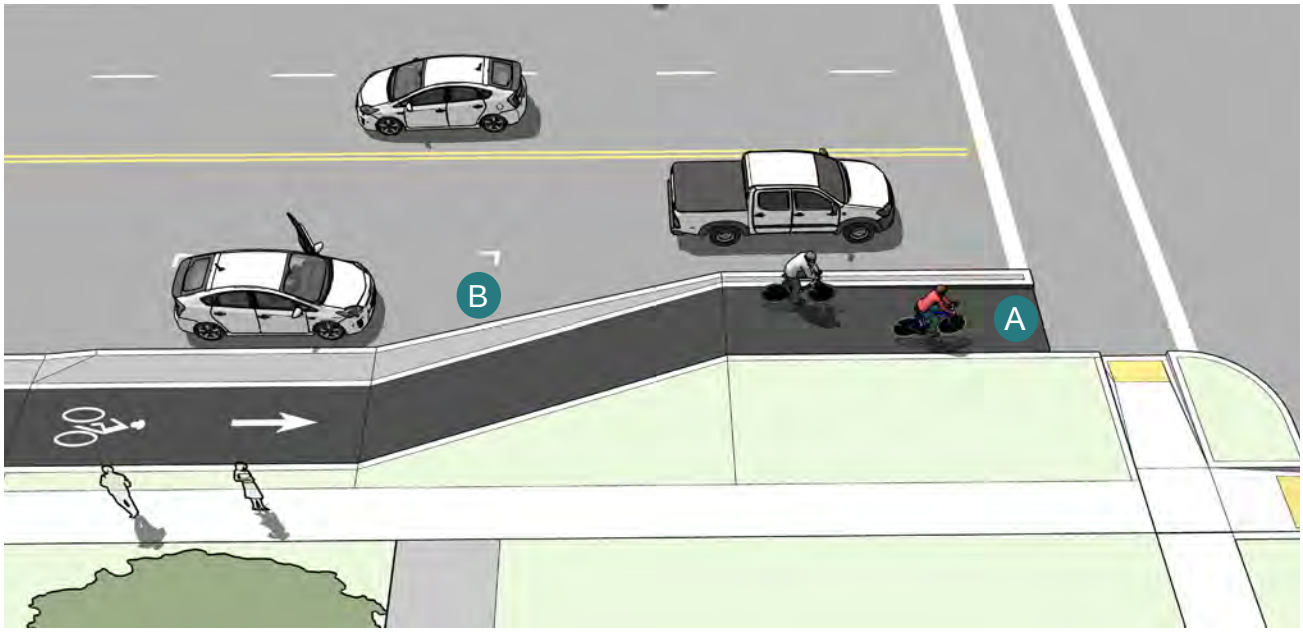
Crash Reduction

A study of motorist/bicyclist conflicts at bicycle boxes indicate a 35%[1] decrease in conflicts.

A study completed in Portland in 2010 found that 77%[2] of surveyed users felt bicycling through intersections was safer with the bicycle boxes.

1 www.cmfclearinghouse.org/detail.cfm?facid= 1718

2 Evaluation of Bike Boxes at Signalized Intersections, J. Dill, C. Monsere, N. McNeil, Oregon Transportatin Research and Education Consortium



Bicycle Lanes Adjacent to Through-Right Lanes

To increase visibility to turning traffic, a lateral shift-in or "bend-in" intersection approach laterally shifts the separated bikeway immediately adjacent to the turning lane. With parking separated bike lane, the parking lane ends and the bike lane transitions to be adjacent to the travel lane with no separation for the intersection approach.

Typical Application

- Where it is desirable to create a curb extension at intersections to reduce crosswalk length.
- Where space is not available to bend-out the bikeway prior to the intersection.

Design Features

- A Provide between 20 – 40' of length to shift the bikeway closer to travel lanes.
- B Where the separated bikeway uses parked cars within the buffer zone, parking must be prohibited at the start of the transition.
- Paint green within the bike lane for 15' on the approach to the intersection to increase visibility of the bike lane and highlight turning movement.

Further Considerations

It is important to note that the increased safety afforded by this treatment is due to the shift in alignment which allows the bicycle path of travel to cross into the driver's field of vision during the shift. However, this treatment does not eliminate the physical risk of right-turn crashes because the position of the bike still remains outside the driver's field of vision at the stop bar.

To prevent right-turning crashes, this treatment should be paired with other prevention tools such as a bicycle phase interval at traffic signals. Leading bicycle intervals are a traffic signal treatment that gets people in the bike lane moving first on the aproach, allowing them to move into the driver's field of vision (ahead and to the right) prior to the driver receiving a green signal.

This photo shows the transition from separated to adjacent bike lane at the approach to an intersection.

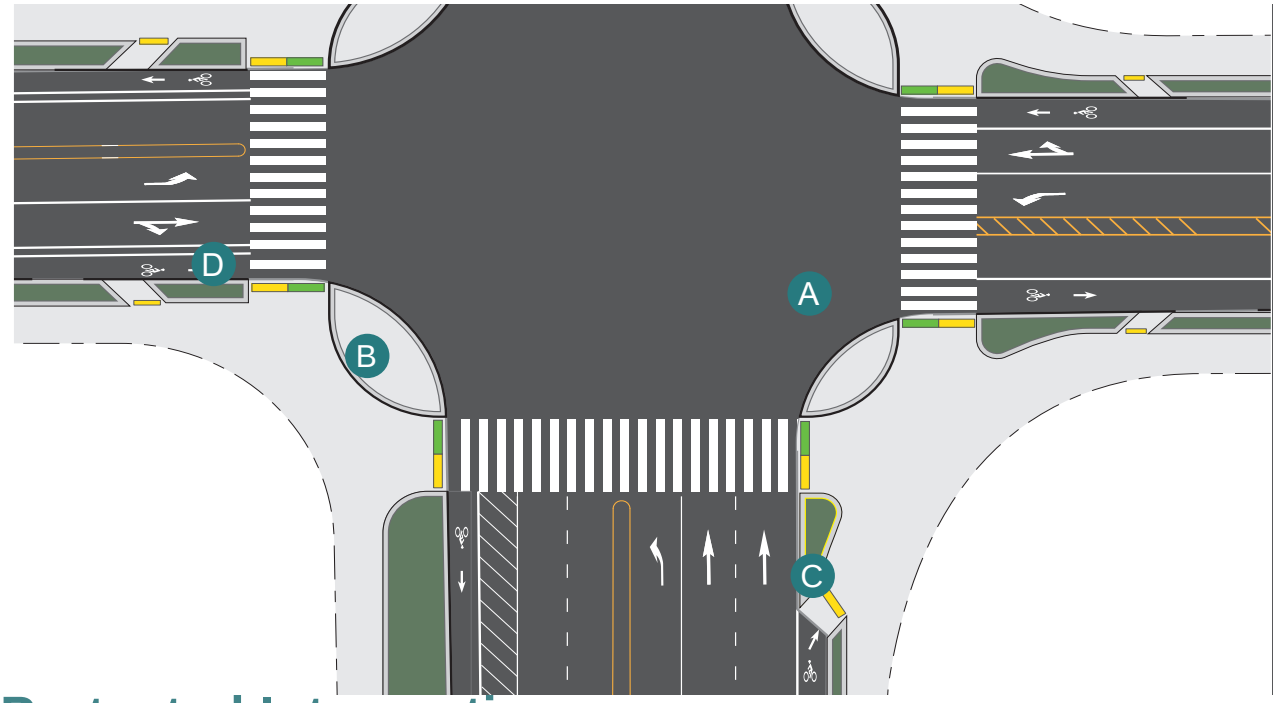
This photo shows the transition from separated to adjacent bike lane at the approach to an intersection in Vancouver, BC.

Further Considerations

- The design creates an opportunity for a curb extension to reduce crosswalk length and increase crosswalk visibility. This curb extension can also create public space which can be used for bike parking corrals, bikeshare stations, parklets, public art exhibits, and/or stormwater features such as bioswales, as long as intersection sight lines are kept clear.
- Introducing a shift in the bikeway path of travel improves awareness of the intersection by those bicycling.
- This configuration of the bike lane adjacent to a through-right turning lane does not eliminate right-turn/bike conflicts and should be used only in combination with other treatments that provide crash countermeasures such as the addition of “Turning Vehicles Yield to Bikes” signs, painted green conflict zones, and bike signals. Protected intersections and bike signals are the only design treatments that prevent this type of crash by design.

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.



Protected Intersections

A protected intersection design relocates the conflict point of straight-through bike riders and right turning drivers so that right-turning drivers can see conflicting straight-through bike riders in their primary field of vision. Protected intersections (also called “bend out,” or “separated crossing”) use roundabout-style bike exit and entry ramps to facilitate straight-through bike crossings as well as two-stage left turns. For new, or reconstructed intersections, protected intersections will be used to eliminate right-turning vehicle-bicycle crashes at signalized and all-way stop intersections when bike lanes are present on the low-stress network.

Typical Application

- Traffic signal intersections.

Design Features

- A Setback crosswalk 16.5’ to allow for one passenger car to queue while yielding. Smaller setback distance is possible in slow speed, space constrained conditions.
- B Corner safety island with a 15-20’ corner radius controls motor vehicle speeds to ensure crosswalk safety. Larger radius designs are possible when paired with a deeper setback or a protected signal phase, or small mountable truck aprons. The corner safety island creates two-stage turning for bike riders and and provides bike rider storage when waiting for the signal to turn.
- C Bike ramps are not required to have detectable warning (truncated domes). Locate away from the intersection to differentiate from intersection crosswalk ramps. Design ramp with an angle to require a change of direction for added conspicuity for pedestrians with sight disabilities.
- D This example shows bike lane being maintained through the intersection while also allowing bike riders to exit onto the shared use sidewalk. This design may be warranted to still facilitate two-stage left

Protected intersections feature a corner safety island and intersection crossing markings. In Oregon, marked crosswalks are defined by white lines. Any additional color is only used for emphasis. In this photo, the bike crosswalk has white transverse lines while the pedestrian crosswalk has continental style crosswalk markings. In Bend, only a single crosswalk would be used (combined) for accessibility.

Protected intersections incorporate queuing areas for two-stage left turns. In this photo the corner island radii readily accommodate left turns on bikes. In Bend, a single crosswalk would be used (combined) for accessibility.

turns, but allow the bike/right-turn conflict to be managed by a separate traffic signal phase for bikes.

Further Considerations

- At intersection approaches with high volumes of right turning vehicles designers 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.
- At signalized intersections, time-based separation may take the form of bicycle-only signal phases or a “leading bicycle interval.” These applications typically necessitate additional features including bicycle-specific signals (with bicycle signal heads) and supplemental signage aimed at bicyclists (e.g, “Bike Signal”) and motorists (e.g., “No Turn on Red”).
- Can be considered on multi-lane all-way stop approaches where it is difficult for riders to access the left turn lane.

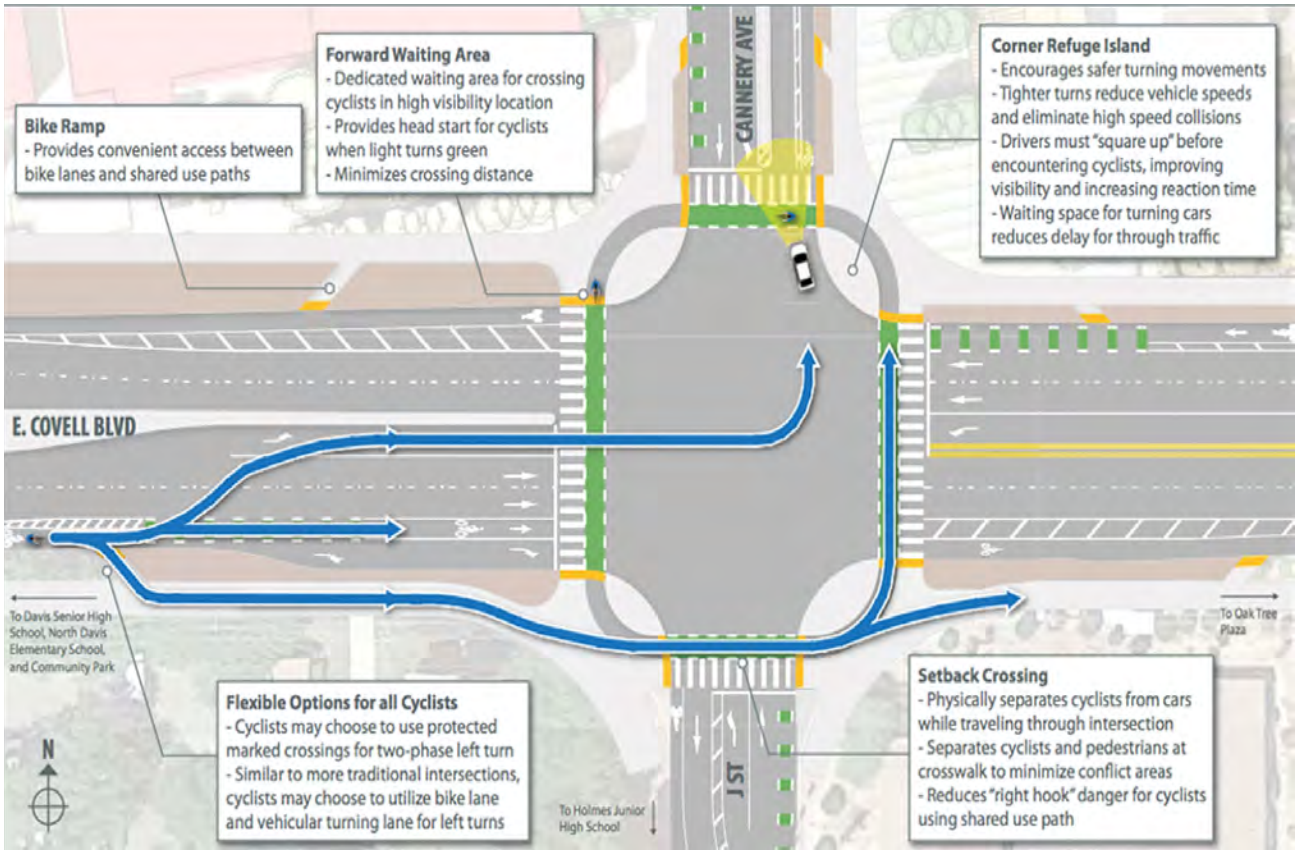
Crash Reduction

ODOT research identified bike lanes to the right of a through motor vehicle lane as the most common causation of right turning vehicle-bicycle crashes.

The City of Bend’s Arterial and Collector Multimodal Safety Study identified right turnng vehicle-bicycle crashes as the most common serious injury crash at intersections for bike riders.

Studies of protected intersection designs have shown reductions in potential high risk incidents due to a 15% turning movement speed reduction and greater visibility of the conflicting movements. The crosswalk offsets for these studies ranged between 6.5 – 16.5’. These protected intersections offered the greatest safety benefit and had a better safety record than conventional bike lane designs[1]).

1 Schepers et al. Road Factors and Bicycle-Motor Vehicle Crashes at Unsignalized Priority Intersections. 2011.



City of Davis brochure identifying design features that improve intersection safety. (Note the City of Bend Bikeway Design Guide has a stated preference for combined crosswalks rather than side by side crosswalks for walk/bike travel.) The combined crosswalk matches Bend's roundabout designs and is simpler and more straightforward. This allows focus and concentration on the crosswalk. Public Rights of Way Accessibility Guidelines for blind, low vision, etc. requires truncated dome detection at the curbline of the crosswalk. Oregon state law defines crosswalks, when painted, as white, not green.

Traffic Signal Detection and Actuation

Traffic signal detection and actuation

Separated bicycle signal phase

Leading bicycle interval

Detection, timing and phasing at traffic signals can maximize everyone's safety.

Typical Application

- To trigger actuation of the signal:
  - Provide adequate green time before the signal turns yellow.
  - Detect bikes and run a ".NOT_BIKE." script which allows permitted left-turns and other conflicts only when there are no bikes detected on the approach.

Design Features

- Locate detection where people on bicycles are intended to travel and/or wait.
- Use sufficiently sensitive detection to detect anyone using the bike lane (could be a longboarder) - accuracy should be 97% or better.
- Locate pushbuttons for use without dismounting; do not route bikes onto the sidewalk to activate the phase, unless at a combined crosswalk, such as at a protected intersection or sidepath crossing.
- Place advanced detection 100-200' upstream of the intersection ot provide an early trigger to the signal system and reduce delay for everyone.

Further Considerations

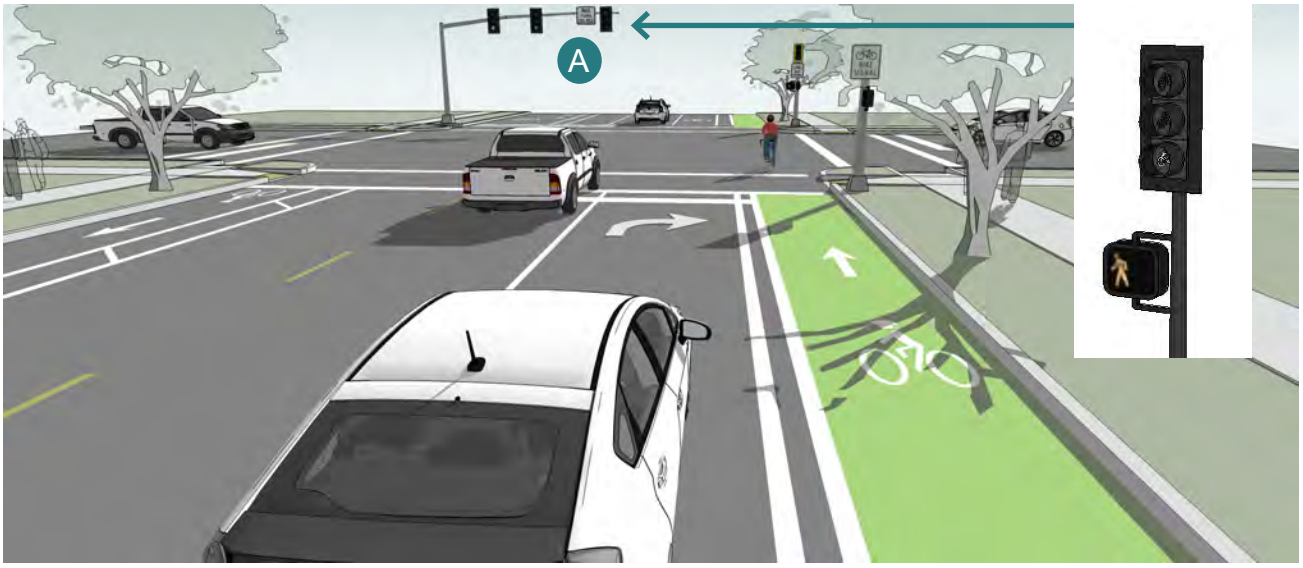
- People on bikes typically need more time to travel through an intersection than motor vehicles. Green light times should be determined by including the start up time from a standing position and should consider all ages and abilities of bike riders.
- Signage and pavement markings should help communicate what to do to call for and prompt the green phase.

- Additionally, new technologies are being developed to provide feedback to people riding bicycles once they have been detected to decrease uncertainty of detection.
- Bicycle detection and actuation systems are improving. The most accurate technology that has proven durability should be required for all new and modernized signal projects.
- Bicycle detection currently consists of user-activated buttons mounted on a pole facing the street, in-pavement loop detectors that trigger a change in the traffic signal when a bicycle is detected, video detection cameras that use digital image processing to detect a change in the image at a location, and/or Remote Traffic Microwave Sensor Detection (RTMS) which uses frequency modulated continuous wave radio signals to detect objects in the roadway. Video detection can also be used to detect bicycles.
- Remote Traffic Microwave Sensor Detection (RTMS) is unaffected by temperature and lighting which can affect standard video detection.

Crash Reduction

Properly designed bicycle detection can prevent red-light running[1].

1 Smart Red Clearance Extensions to Reduce Red-Light Running Crashes, Final Report ODOT SPR 773, D. Hurwitz, M. Abadi, S. McCrea, S. Quayle, P. Marnell, 2016



Separated Bicycle Signal Phasing

Separated bicycle lane crossings of signalized intersections can be accomplished through the use of a bicycle signal phase increases safety by separating conflicting/ crossing paths of travel through signal control. Bicycle signals are traditional three lens signal heads with green, yellow and red bicycle stenciled lenses.

Typical Application

- Two-way separated bike lanes warrant protected signal operation.
- Approaches with conflicting straight-through bike and right-turning motor-vehicle traffic.

Design Features

- A An additional “Bicycle Signal” sign should be installed with the bicycle signal head.
- Designs for bicycles at signalized crossings should allow bicyclists to trigger signals and safely maneuver the crossing.
- Signal timing and actuation shall be reviewed and adjusted to optimize safety and operations.
- Bike green or bike yellow signal indications shall not be in conflict with any simultaneous motor vehicle movement at the signalized location. Right (or left) turns on red should be prohibited in locations where such operation would conflict with a green bicycle signal indication. Permitted left turns should be prohibited in locations where such operation would conflict with a green bicycle signal indication.

Further Considerations

Traffic signal warrants are listed in the national guidance document “Manual on Uniform Traffic Control Devices” in Chapter 4C. These signal warrants, however, do not explicitly warrant the use of bicycle signal heads and separate phasing for bicycle movements through a traffic signal.

The National Association of City Traffic Official’s Urban Bikeway Design Guide, also does not provide specific warrants for a bicycle signal phase at a traffic signal[1].

In 2018, California was the only state that provided bicycle signal warrants.[1] These warrants are volume, collision, or geometric. The

1 Bicycle-Specific Traffic Signals Results from a State-of-the-Practice Review, 2013, S. Thompson, C. Monsere, M. Figliozzi, P. Koonce, G. Obery

A bicycle signal head at a signalized crossing creates a protected phase for cyclists to safely navigate an intersection.


A bicycle detection system triggers a change in the traffic signal when a bicycle is detected.

California volume warrant is at least 50 bikes in the peak hour. The California collision warrant is two or more bicycle-vehicle collisions of types that might have been prevented by a bicycle signal, that occurred over a 12-month period, and that a public works official finds would have been prevented with the bicycle signal. The California geometric warrant is defined as a path connection or a path of travel permission given to the bicycle to make a move that is not permitted by a motor-vehicle.

Crash data in the City, and in the US in general, shows right-turning motor-vehicles and straight-through bike movements, when operated without separate signal phases, cause injury and fatal crashes. Engineering judgement, and the goal of reducing these crashes, is required to initiate the consideration for using separate signal phasing to manage these conflicting flows.

FHWA has approved bicycle signals for use. Once the City Engineer makes the decision to operate the signal to manage the bike movement through the intersection, FHWA approval includes specific operations and equipment requirements (Interim Approval for Optional Use of a Bicycle Signal Face (IA-16).

Bicycle Signals are not approved for use in conjunction with Pedestrian Hybrid Beacons.

People biking typically need more time to travel through an intersection than motor vehicles. Green light times should be determined using the bicycle crossing time for standing bicycles.

Bicycle detection and actuation systems include user-activated buttons mounted on a pole, loop detectors that trigger a change in the traffic signal when a bicycle is detected and video detection cameras, that use digital image processing to detect a change in the image at a location.

Crash Reduction

The *S. Thompson, et al, 2013 Review*, identified 27 intersections in the US that had bicycle-only signal phasing and identified a research need to perform crash-reduction effectiveness for these bike signals.

Research has assessed user opinons: 92% of respondents agreed with the statement “I generally feel safe when bicycling through the intersections” when asked about an intersection with a protected bicycle signal phase[1].

1 National Institute for Transportation and Communities, Lessons from the Green Lanes, 2014.

Leading Bicycle Interval

Leading Bicycle Interval (LBI) is a relatively low-tech traffic signal detection and traffic signal phasing treatment that is used to increase visibility and protection of people on bikes to get them through an intersection more safely. Using LBI helps prevent bike crashes with both left- and right-turning vehicles that are permitted to cross the bike rider's straight-through path of travel across the intersection.

Typical Application

- Leading bicycle intervals can be used at any bicycle signal location.

Design Features

- The straight-through bicycle interval is initiated first, in advance of the concurrent and conflicting left-, straight-through, and right-turning permissive phase interval by 3-10 seconds.
- LBI can also be paired with a ".NOT_BIKE." script which allows permitted left-turns and other conflicts only when there are no bikes detected on the approach.
- Can be paired with Leading Pedestrian Intervals (LPI).
- If paired with an LPI, bicycle detection can be configured to provide additional crossing time when bicyclists arrive at the crossing during the concurrent flashing don't walk (FDW) interval. The Manual on Uniform Traffic Control Devices (MUTCD) requires signage indicating the walk time extension at or adjacent to the push button (R10-32P).
- Actuation may be achieved with either a push-button or passive detection devices.

People on bikes receive a green bike signal indication in advance of the adjacent travel lane. This clears conflicting traffic and prevents turning movement crashes.

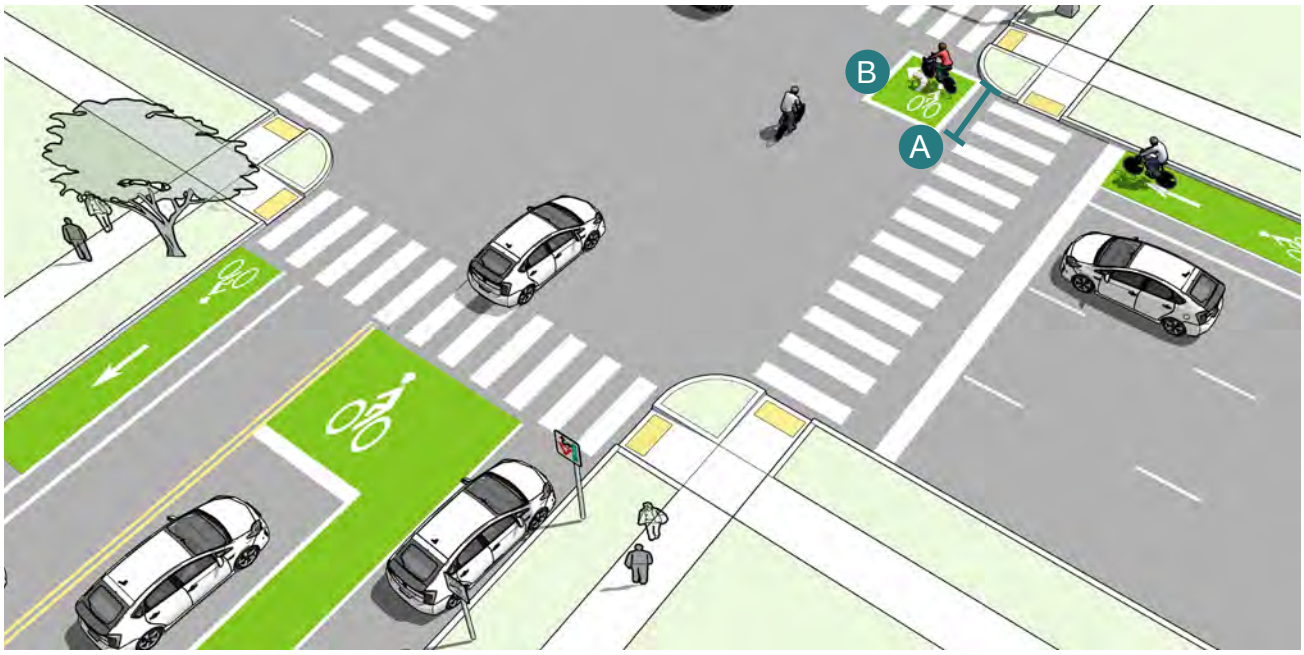
Limited-visibility signal faces have louvers that reduce the likelihood of motorists in adjacent travel lanes mistaking the bike signal indication with their own travel lane's signal indication.

Further Considerations

- These signal enhancements facilitate safer, more predictable crossing conditions. The LBI provides additional time for people on bicycles who may need more time to cross the street.
- The LBI is allowable under the Federal Highway Administration's Interim Approval for Optional Use of Bicycle Signal Faces (IA-16).
- See the MUTCD's Traffic Signal Detection and Actuation guidance for more information on detection and actuation devices.

Crash Reduction

An LBI provides a form of temporal separation from other movements and can reduce vehicle-bicycle conflicts by reducing exposure to conflicting traffic and increasing visibility of bicycle traffic.



Two-Stage Turn Boxes

Two-stage turn boxes offer a safe way for bike riders to make left-turns from a right -hand-side bikeway facility. Few people on bikes have the skills or confidence to make a lane-changing weave through multiple approach lanes or through high-speed traffic to stage into the motor-vehicle left turn lane to make left-turns. The provision of the two-stage turn boxes offers greater protection, particularly at traffic signals, where the movements into and out of the two-stage turn box are made during protected signal phasing. The two-stage left-turn box design is efficient because it does not require additional traffic signal phases; and can be more readily retrofit at existing signals.

Typical Applications

- Intersections with heavier bike left turns, where either motor vehicle volume or speed makes maneuvering into the left turn lane difficult for everyday bike riders.
- To gain an LTS 1 rating for bike left turns.

Design Features

The two-stage turn box is a colored green box with a bike stencil and left-turn arrow.

The two-stage turn box shall be placed in a protected area. Typically this is within the shadow of an on-street parking lane, a protected bike lane buffer area, or a wide-turning radius.

The two-stage turn box should be placed downstream of the crosswalk to avoid conflict with pedestrians.

- A 8’ long x 6’ wide preferred minimum dimensions of bicycle storage area (the city’s standard 6.5’ bike lane width accommodates this minimum; while the 8’ length accommodates most bikes). In this example 8’ is the width of on-street parking.
- B Bicycle stencil and turn arrow pavement markings shall be used to indicate proper bicycle direction and positioning[1].

1 National Association of City Transportation Officials, Bikeway Design Guide, 2012

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

Further Considerations

- Evaluate traffic operations and alternatives to ensure right-turning paths of travel would not cross the box. No-turn on red is a typical design treatment.
- Federal Highway Administration has provided interim approval for optional use of two-stage bicycle turn boxes. The interim approval design and operations requirements shall be met.[1]
- Bicyclist capacity of a two-stage turn box is influenced by physical dimension (how many bicycles it can contain) and signal phasing (how frequently the box clears).
- Two-stage left-turn boxes can allow the left-turn to be rated LTS 1 when used with 30 mph and lower speed roadways.

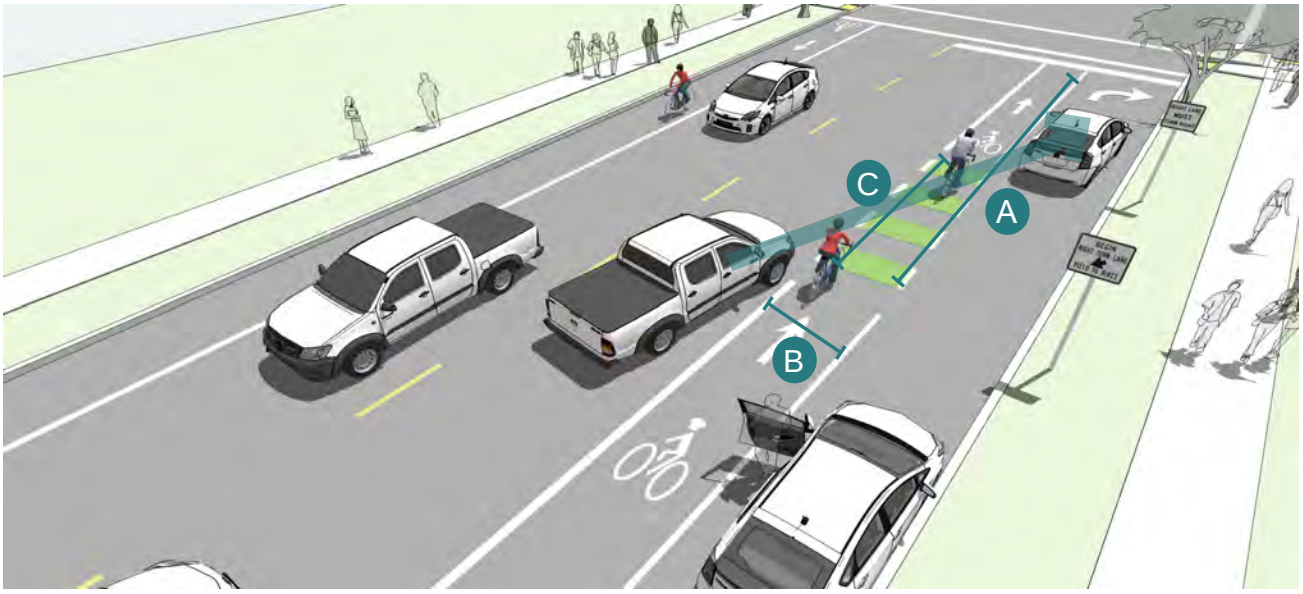
Crash Reduction

Preliminary results of an evaluation underway by the City of Columbus has observed a reduction in conflicts between bikes and motor vehicles after installing two-stage turn boxes at several intersections. In other places, two-stage turn boxes improve consistency of left turn maneuvers[2].

Two-Stage Turn Box

1 Federal Highway Administration IA-20, interim Approval for Optional Use of Two-Stage Bicycle Turn Boxes, July 13, 2017.

2 Federal Highway Administration IA-20, interim Approval for Optional Use of Two-Stage Bicycle Turn Boxes, July 13, 2017.



Conflict Markings at the Beginning of Right Turn Lanes

Where right turn lanes are added at intersections, and motor vehicles must cross through bike lanes to access the right turn lane, conflict markings clearly identify the conflict zone to focus lane changes, highlight the conflict, and improve awareness for everyone.

Typical Application

- On streets with added right turn lanes and bike lanes located on the right-hand side of the road.
- For channelized right turn lanes and interchange ramp designs see, “Channelized Right-Turn Lanes and Intersection Design Layouts” in this Guide.

Design Features

- To enable the right-turn interaction on the approach to retain an LTS 2 rating, the length of the right-turn lane adjacent to the bike lane shall be less than 150’ long; the right-turn speeds (controlled by the curb radius) shall be 15 mph or lower; and the width of the sandwiched portion of the bike lane shall be 5.5’ to 7’ for 30 mph or slower or 7’ (buffered) for 35 mph approach speeds.
- To enable the right-turn interaction on the approach to retain an LTS 1 rating, the length of the right-turn lane adjacent to the bike lane shall be less than 75’ long; the right-turn speeds (controlled by the curb radius) shall be 15 mph or lower; and the width of the sandwiched portion of the bike lane shall be 7’ (buffered) for 30 mph and lower speeds.
- The conflict zone should begin at the beginning of the right turn lane and run a minimum of 50’.

High visibility pavement markings help to increase visibility in a shared right turn lane at Franklin Blvd and Wall Street in Bend.

Further Considerations

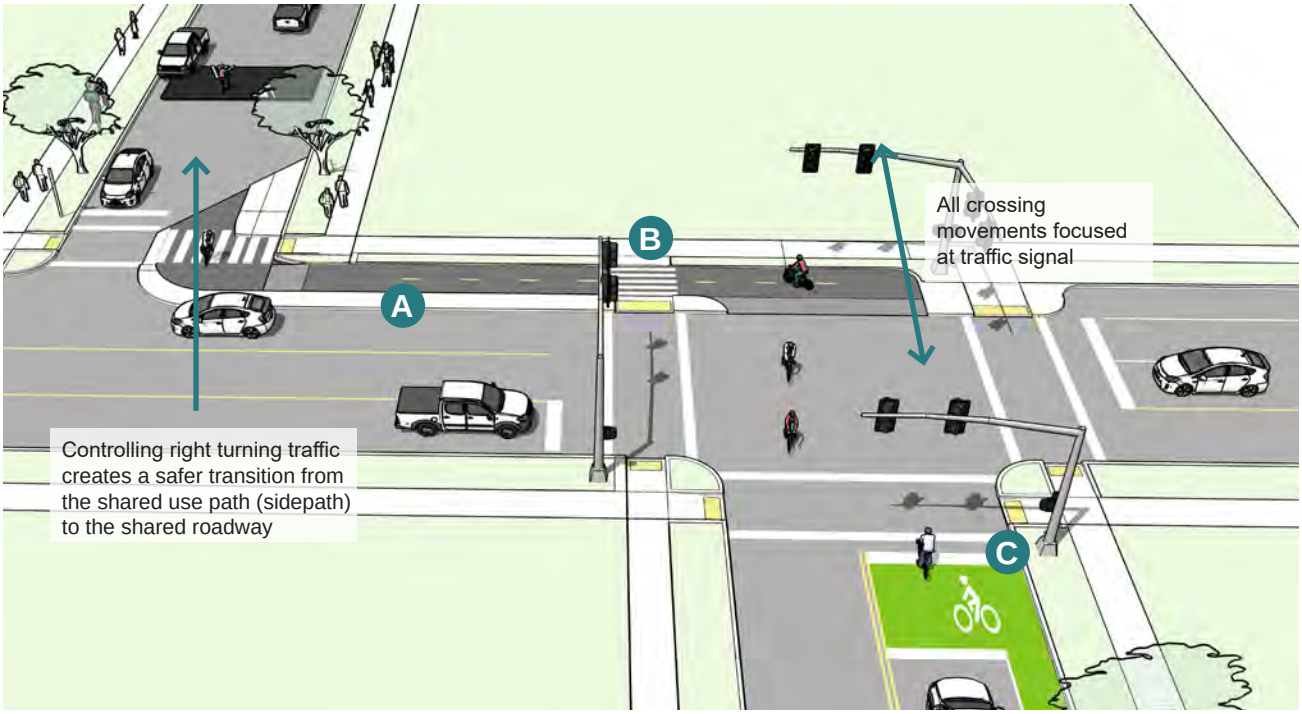
- The consideration for a right-turn lane requires an engineering analysis incuding crash history and crash causation; design speed and prevailing speed; pedestrian volumes; pedestrian crossing times; bicycle volumes; right-turning volumes; targeted bicycle LTS; and an operations assessment with and without the right-turn lane. Intersection approaches need to provide the targeted LTS while providing for the lowest crash projections and best traffic operations for all modes of travel.[1]

- In a study in Eugene, Oregon, 17% of people on bicycles surveyed preferred a combined turn lane to a standard bike lane (pocket) sandwiched between a through-lane and right-turn lane[2]. This study indicates there is added stress by having moving traffic on both sides of the bike rider.

- Interested but Concerned rider types, targeted to be served by low-stress bike facilities, are sensitive to traffic and speeds. As noted in the Design Features section of this document, the width of the sandwiched portion, speed of the right turning traffic, and length of the right turn lane each play a role in the resultant stress level for the right-turn interaction.

1 ODOT Traffic Manual 2018 Edition, Section 6.39.3 Right-Turn Lanes

2 Evaluation of a Combined Bicycle Lane/ Right Turn Lane in Eugene, Oregon, Publication No. FHWA-RD-00-151, August, 2000.



Offset Intersection Crossing

Local streets may be offset at arterial and collector roadways to make it safer to cross the busy road with the installation a safety island and reduce cut-through traffic.

When two arterial/collector roadways intersect in a T and when the terminated roadway provides low-stress bikeway facilities, it may be desirable to continue the low-stress route on an offset street. Sometimes, the offset streets together comprise the neighborhood greenway. In either case, low-stress bikeway facilities need to be provided on the short segment of the arterial/collector roadway for route continuity to facilitate the brief travel along the busier major cross street.

Off-set left intersections work best as the safety island can be provided between the two intersections while accommodating room for left turn space from the arterial onto the local street.

Offset right intersections work best when left-turn lanes are not included but a safety island is constructed instead, or when left-turns from the main road are light enough to operate safely in a two-way shared left-turn lane as opposing lefts occupy the same space on the main road. Special consideration and design treatments may be necessary to accommodate the low-stress bikeway continuity.

Offset Intersection Crossing

Pavement markings provide clear delineation between bi-directional bicycle traffic.

If located at an unsignalized location, bicycle crossing should align with existing pedestrian crossing locations.

Typical Application

- Can be constructed to connect multiple facility types, including neighborhood greenways, bike lanes, crosswalks, or separated bikeways.
- Appropriate treatments depend on volume of traffic including turning volumes and traffic speeds.

Design Features

- A Curbs or landscape strips can provide enhanced protection for people walking and bicycling, and also help facilitate maintenance by ensuring snow plowing and street sweeping operations are readily accommodated.
- B Pavement markings provide clear delineation between travel spaces designated for people walking and bicycling.
- C At signalized crossings, people on bikes should be able to trigger signals and safely maneuver the crossing.

Further Considerations

- Wayfinding signage and pavement markings provide navigation to positively guide people along the route.

Overcrossings

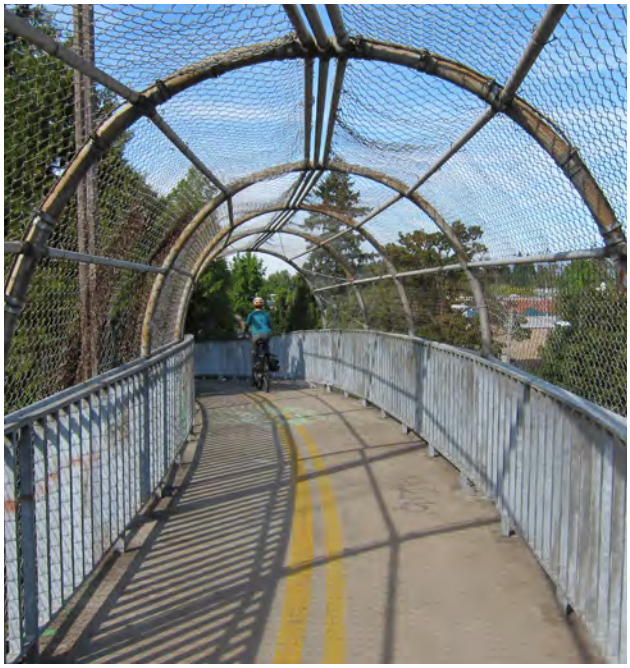
Bicycle/pedestrian overcrossings provide critical non-motorized system links by joining areas separated by barriers such as heavy railways, waterways, or major transportation corridors. In most cases, these structures are built in response to user demand for safe crossings where they previously did not exist.

Typical Application

- There are no minimum roadway characteristics for considering grade separation. Depending on the type of facility or the desired user group grade separation may be considered in many types of projects.
- Specific design and construction specifications will vary for each bridge and can be determined only after all site-specific criteria are known.

Design Features

- Width: 12’ preferred. If overcrossing has any scenic vistas additional width should be provided to allow for stopping.
- Vertical Path Clearance: 10’ headroom on overcrossing
- Vertical Clearance Below: clearance below will vary depending on feature being crossed: Overcrossing clearance to a road below should be 17’; to a freeway 18.5’ and to a freight rail line 23’.
- The overcrossing should have a centerline striping even if the rest of the path does not have one.



Centerlane markings clarify the path of travel for people walking and bicycling in opposite directions in the physically constrained environment.

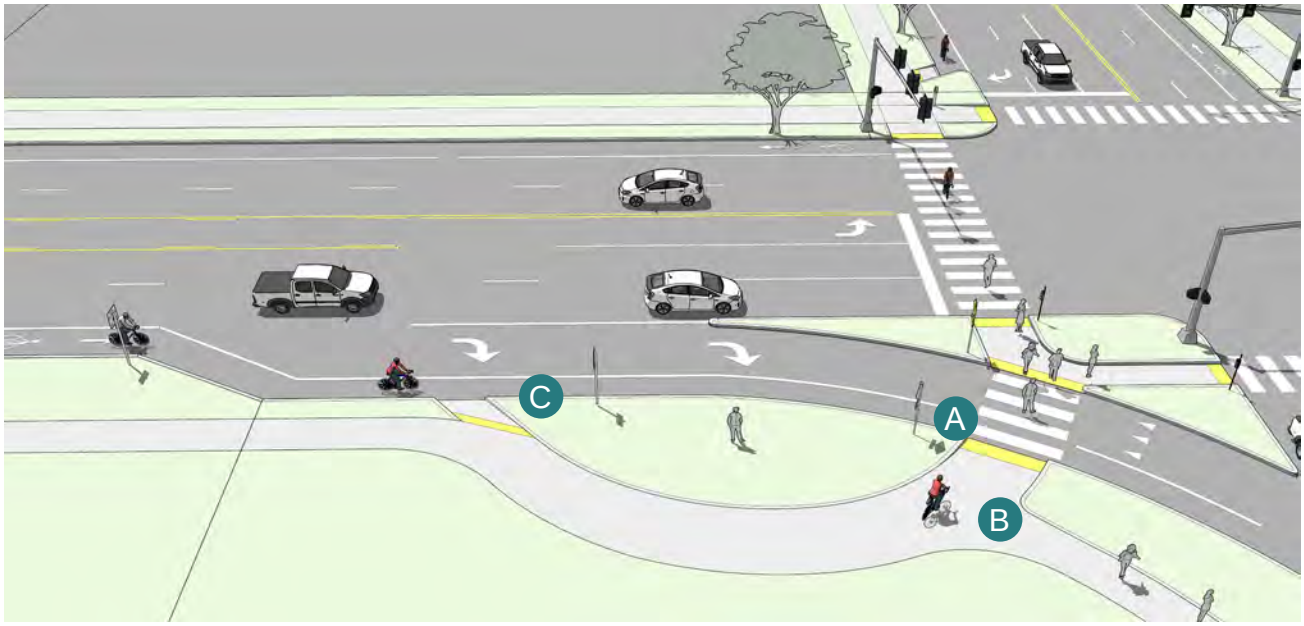
Further Considerations

Follow Public Rights of Way Accessibility Guidelines.

Designs typically require additional room for slopes or landings to meet ADA requirements.

Vertical woven wire curved fencing can be installed to protect both users and motorists below.

Channelized Right-turn Lanes and Intersection Design Layouts



Channelized Lane Crossings - Entrances

Channelized turn lanes in urban areas need to be designed to prevent crossing crashes. Provide clear right-of-way priority and straightforward decision making. Ensure crossings are perpendicular to ramps, clearly signed and marked, and ramp speeds are managed. Raised truck aprons can help accommodate trucks while managing car speeds.

Typical Application

- Streets with channelized right turn lanes.
- Freeway style merge or diverge lanes.

Design Features

- A Use crosswalk markings and signs to define priority at crossing location for those in the crosswalk to meet state crosswalk laws.
- B Angle the bike lane to cross perpendicular to the road traffic. Position the crossing before the drivers' attention is focused on the upcoming merge.
- C Design the bike ramp away from the intersection and use angles to ensure sidewalk shared use path users do not enter the bike ramp the wrong way.

In constrained conditions, bicyclists may exit onto the sidewalk and complete the maneuver with pedestrians in the crosswalk, as in this example from Portland, OR. Bicyclists may choose to exit the bike lane and make a vehicular style transition if they prefer.

Further Considerations

The crosswalk should be assessed for enhancements such as high visibility markings, signing, raised crosswalk, etc. to ensure crosswalk yielding and safety is facilitated. Significant safety risks exist at routed crossings of sidewalks and bikeways across free flowing ramps and the crossings should be reconfigured to reduce risk. (Caltrans Complete Intersections, 2010)

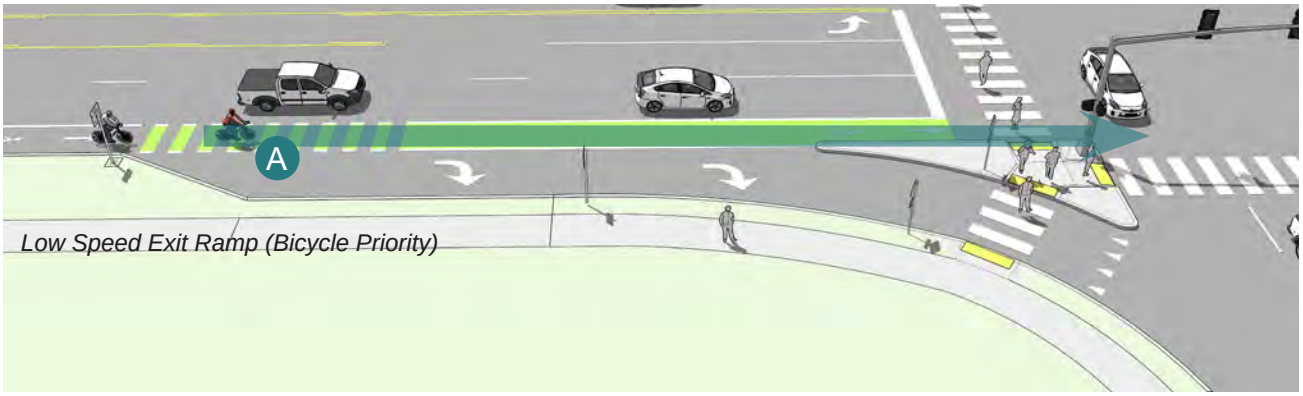
Free flow right turns should not be considered at intersections that have sidewalk and bikeway crossings. Design treatments need to include speed management, conflict positioning, and enhanced yielding clarity.

Crash Reduction

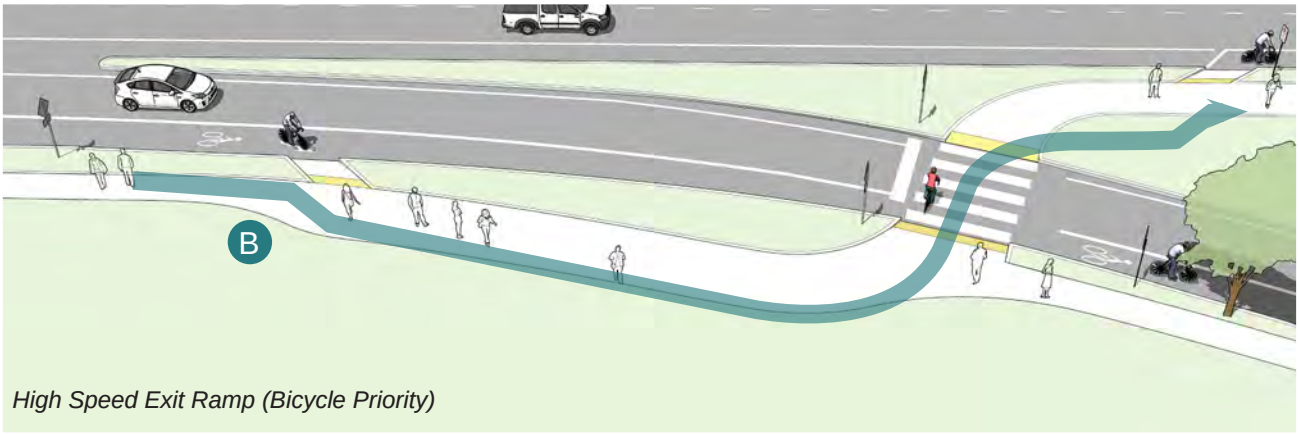
Crashes are prevented by managing the speed, angle, sight lines, and visibility of the crossing. Crashes are prevented by managing the speed, angle, sight lines and visibility of the turn lane's merge.

Crash modification factors for channelized turn lanes with raised median[1] (ODOT H6 CRF) decreases all injury crashes by 35%. Installing continental crosswalk markings at uncontrolled crossings[2] (ODOT BP 11) reduces all crashes by 15%. Improving the angle of channelized right turn lane to improve sight lines, visibility and speed decreases all crashes[3] by 55.8%.

1 https://www.oregon.gov/ODOT/Engineering/Docs_TrafficEng/CRF-Appendix.pdf
2 https://www.oregon.gov/ODOT/Engineering/Docs_TrafficEng/CRF-Appendix.pdf
3 http://www.cmfclearinghouse.org



Low Speed Exit Ramp (Bicycle Priority)



High Speed Exit Ramp (Bicycle Priority)

Channelized Lane Crossings - Exits

Arterials with freeway-style exit ramps create high risk conflict points for routed bikeways (and sidewalks) which must cross the ramp. Exit lanes typically have design-induced visibility problems because of low approach angles and feature high speed differentials between anyone on a bike and motor vehicles. There are easy ways to improve safety, visibility, and comfort for ramp terminals to accommodate the bikeway.

Typical Application

- Streets with on-street bicycle lanes.
- Streets that interface with off-ramps.

Design Features

A On low-speed exit ramps (≤ 35 mph), the bike lane should travel straight through the diverge area. Ramp design shall utilize smaller radius returns, using truck aprons if necessary, to manage speed of turns and improve yielding.

Use dashed lines, colored pavement, and signs to define the priority of the bike lane over the right-turn lane.

B On high-speed ramps (≥ 40 mph), use a jug handle turn to bring bicyclists to a visible location with exiting traffic.

Use crosswalk warning signs for ramp crosswalks.

Further Considerations

If speeds cannot be managed, or there are multiple high speed lanes, the crossings should controlled with signalization, or flashing beacons or should be grade separated.

Grade separation designs utilizing a bicycle path could be used if the approach ramp elevations are appropriate, and if bicycle volumes are fairly high and motor traffic volumes are high.

The exit ramp shown here should be improved by reducing the corner radii. This increases the driver's sight lines to conflicting traffic to prevent crashes. The desire is a more perpendicular turn onto the arterial. The bike crossing of the ramp should be aligned and combined with the pedestrian crossing, to increase visibility of crosswalk traffic across the exit ramp.

Exit Ramp Lane Crossings

Crash Reduction

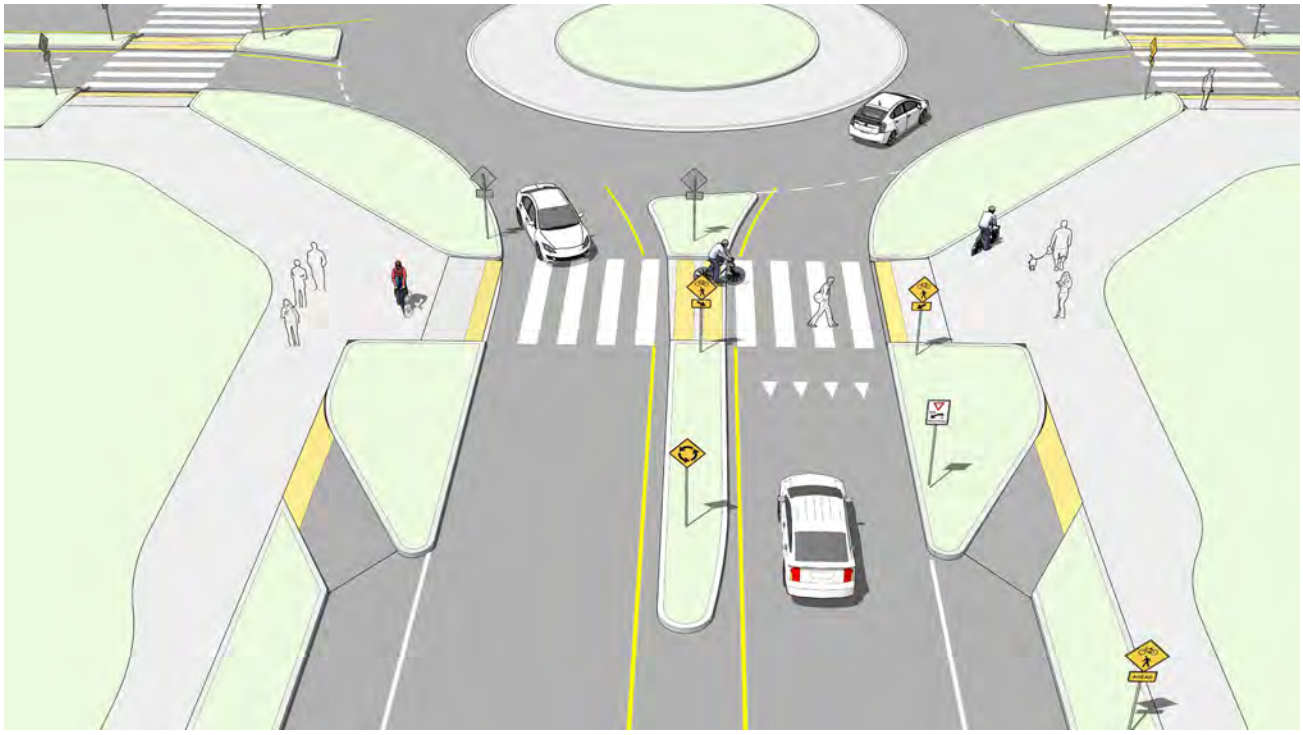
Crashes are prevented by managing the speed, angle, sight lines, and visibility of the crossing. Crashes are prevented by managing the speed, angle, sight lines and visibility of the turn lane's merge.

Crash Modification Factors for Channelized Turn Lanes with Raised Median[1] (ODOT H6 CRF) decreases all injury crashes by 35%. Installing continental crosswalk markings at uncontrolled crossings[2] (ODOT BP 11) reduces all crashes by 15%. Improving the angle of channelized right turn lane to improve sight lines, visibility and speed decreases all crashes[3] by 55.8%

1 https://www.oregon.gov/ODOT/Engineering/Docs_TrafficEng/CRF-Appendix.pdf
2 https://www.oregon.gov/ODOT/Engineering/Docs_TrafficEng/CRF-Appendix.pdf
3 http://www.cmfclearinghouse.org

Chapter 6

Design of Bikeways at Roundabouts



Roundabouts

The City will install roundabouts over traffic signals for all new, or reconstructed intersections, unless topography will not accommodate the roundabout. By design, roundabouts reduce crashes by managing speeds, angles of approach, and locations of conflicts. They have been shown to have significantly less fatal and serious injury crashes than a traffic signal because of simplified decision-making, optimal approach angle for entering circulating traffic flow and slower speeds[1]. Single lane roundabouts have been proven effective at crash prevention while providing high capacity for operations. Single lane roundabouts provide an LTS 1 crossing.

Multilane roundabouts also provide safety benefits and operations benefits but because they have more lanes, there are more conflict points and require additional attention to design features. When the bike lane ramps are used in combination with the shared use paths, the best a multilane roundabout can achieve is an LTS 2. Multilane crosswalks on the exits need special care to ensure driver yielding[2].

Typical Application

- The bikeway system at roundabouts consist of the bike lane to shared-use path entry and exit ramps and the crosswalks at roundabouts.

Design Features

- The crosswalk location needs to facilitate the shortest crossing distance, with visibility, away from the circulating lanes to allow drivers to focus on crosswalks.
- Bike on-off ramps and a shared-use path around the roundabout are critical to allow

1 https://safety.fhwa.dot.gov/provencountermeasures/roundabouts
2 National Highway Cooperative Highway Research Program Report 562

This roundabout features designated ramps that transition people on bicycles from the bike lane on to a shared use path or wide sidewalk. People on bikes are then directed back on to the roadway, or across a marked crosswalk. Crossings are set back from the circulatory lane and orient people walking and on bikes so that they are better able to see oncoming cars.

people bicycling to exit the roadway onto the shared-use path and to crosswalks.

- Provide lighting at a point immediately upstream of the crosswalk so that drivers on both approaches to the crosswalk have ample time to see and react to those in the crosswalk.
- Use mountable aprons at roundabout entries, exits and the central island to accommodate larger vehicles while managing passenger vehicle speeds. The speed of the roundabout at the crosswalk is critical to crosswalk yielding and safety. Keep crosswalk speeds below 25 mph.

Further Considerations

- Raised crosswalks at multilane roundabout exits can be used to increase yielding. A study of one multilane roundabout in Bend indicated high yielding at entry crosswalks, but only fair yielding at exit crosswalks.
- Federal Highways recommends constructing roundabouts single lane roundabouts and operating those until traffic volumes warrant the added capacity of a multilane roundabout[1]. (NCHRP 2010 p 6-71). The purpose of this is to prevent crashes in the interim time period. When intersections have more lanes and are wider than necessary to safely and comfortably accommodate near term traffic, a higher crash rate and more frequent injury crashes occur.
- Multilane roundabouts support higher traffic volumes but they add multilane threat type crash potential for crosswalk users. Multilane threat type crashes are when one travel lane yields but the second travel lane driver collides with the person crossing the street in the crosswalk. Decreasing speeds at the crosswalk is an important crash countermeasure.
- At multilane crosswalks, the splitter island can have a jog in the median to improve angle of crosswalk approach.
- Pedestrian hybrid beacons and rectangular rapid flashing beacons may be warranted on multilane exit crosswalks.

1 Federal Highway Administration Research and Technology, Publication Number: FHWAA-RD-00-067, Roundabouts: An Informational Guide.

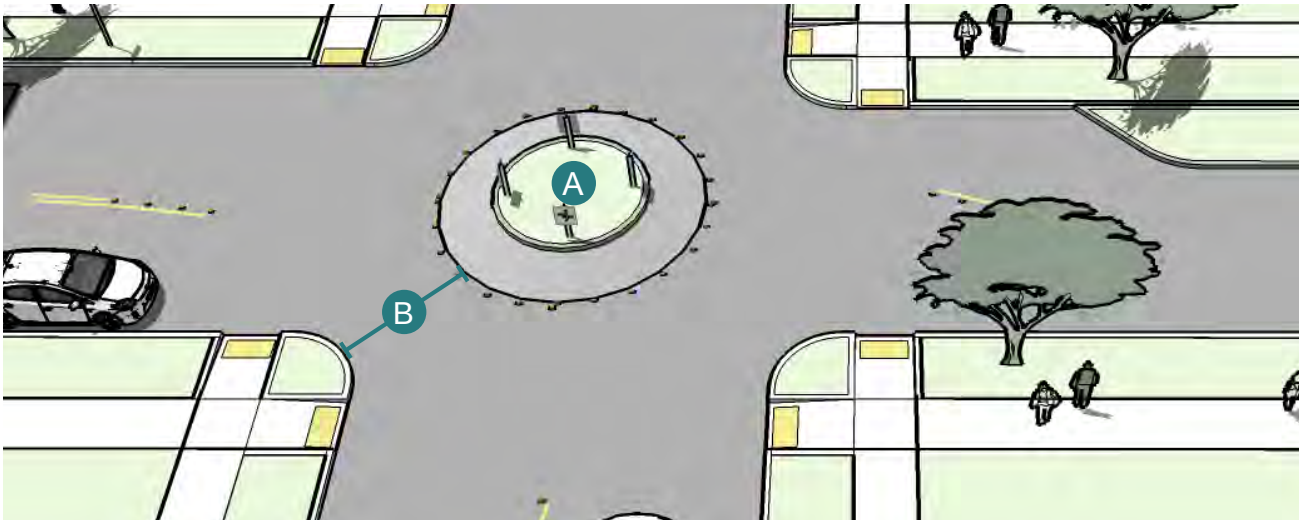
Crash Reduction

Research proves single-lane roundabouts benefit people bicycling and people walking by slowing traffic.

Crosswalks across multiple traffic lanes have decreased yielding; and greater crashes regardless of whether the multilane crosswalk is at a signalized intersection, unsignalized intersection, mid-block location, or at a multilane roundabout. The extent and severity of the injury is determined by the speed of impact and frailty of the person in the crosswalk.

The City of Bend strives to provide safe crosswalks for all users and prioritizes single lane roundabouts over other intersection forms to maximize injury prevention and optimize intersection operations.

Multilane roundabout designs target low speeds for all movements, entry, exit and circulating speeds, good sight lines, etc. to manage operations and prevent crashes.



Neighborhood Traffic Circles

Traffic circles are a type of horizontal speed management typically installed along low speed, low volume streets and neighborhood greenways. They are raised islands located in the center of intersections that shorten the view down a corridor ("terminate the vista") which encourages travel speeds compatible with residential neighborhoods. The circle also ensures a safer intersection operation as approach flows no longer intersect at right angles. The circular flow ensures all users operate at a compatible speed in order to navigate through the intersection.

Typical Application

- Traffic circles are effective safety and intersection operations devices on neighborhood greenways and other low speed, low volume bicycle routes with less than 2,000 AADT.
- Place traffic circles at the intersection of two neighborhood greenways to enhance operations and safety while also increasing the visibility and wayfinding needs of the neighborhood greenways. They can also be used as place making tools.
- Traffic circles benefit the operations of neighborhood greenways by slowing traffic. This enhances the attractiveness of the neighborhood greenway as a travel route option to people on bikes.
- Should be installed in consultation with neighborhood residents and emergency vehicle operators. The City of Bend uses a traffic circle design approved by local emergency service providers and streets operations crews.

Design Features

- A The radius of a traffic circle depends on the roadway width and curb radii. It is designed to provide adequate horizontal deflection and prevent a person driving from overtaking a person on a bike in the intersection.
- B Distance from traffic circle to curb edge should be approximately 15' to provide sufficient emergency vehicle access. At the same time, it is important to provide quality designs that prevent high speeds and overtaking within the intersection.
- At intersections with a minor street, stop signs should be placed on the minor street approaches.
- Traffic circles feature raised curbs and/

Planted neighborhood traffic circles like this one on Daggett Lane in Bend, can also enhance the attractiveness of the neighborhood greenway while having a traffic calming effect.

or mountable aprons to provide access for emergency vehicles.

Further Considerations

- Approaches can feature miniature channelization islands or pavement markings to delineate the correct direction of flow. The visual footprint of the traffic circle can be expanded in the intersection with integral colored pavement, or visually patterned surface treatments.
- The visual footprint of the traffic circle can be expanded in the intersection with integral colored pavement, or visually patterned surface treatment. The small curbed collar prevents short-cutting the curvature, and allowing for street maintenance operations.
- At 3-way intersections sufficient horizontal deflection should be provided for all directions of traffic approaches. This encourages more consistent and predictable speeds for everyone.
- Designs should discourage left-turns in front of the circle.

Chapter 7

Bikeway Wayfinding & Other Signage

Neighborhood Greenway - Speed Signs and Low-Stress Bikeway Wayfinding Signage

State law (ORS 810.180) provides that the City may post neighborhood greenway streets at 20 mph. Pavement markings accompany the 20 mph signs to indicate the presence of people biking in the road.

Bikeway wayfinding signs provide important information about time and distance while increasing security that new riders are on the correct route. Wayfinding signs often display destinations, distances, and “riding time.” Wayfinding signs increase access to the neighborhood greenway network.

Neighborhood Greenways frequently include offset intersections or ‘jog’ onto another street. Signs and pavement markings can help people on bikes remain on the route. In addition, signs inform people of the direction to key destinations, including commercial districts, transit hubs, schools and universities, and other low-stress bikeways.

Typical Application

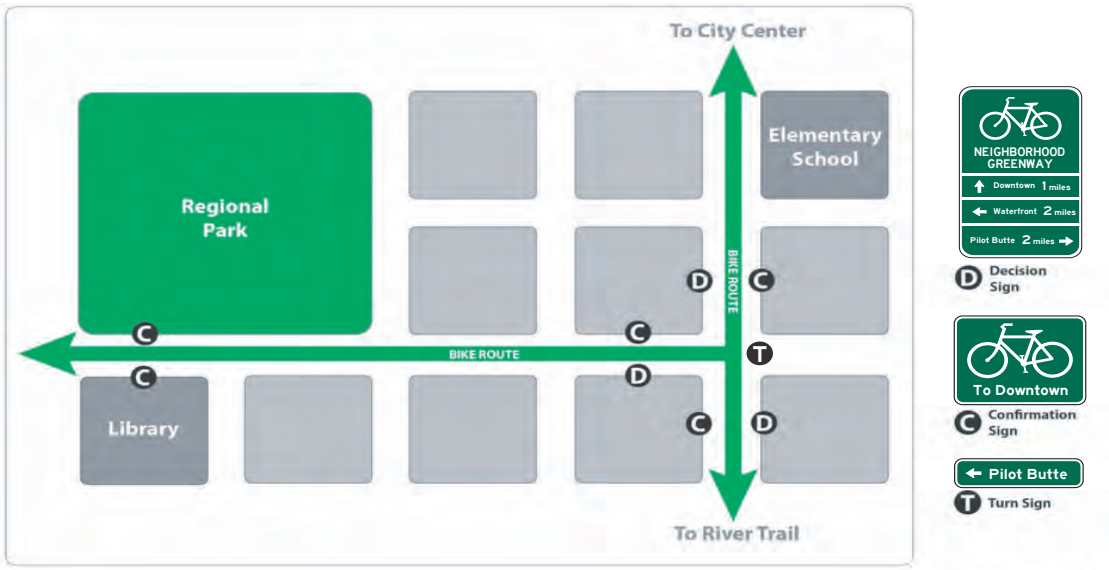
- Signs designating a 20 mph speed limit on neighborhood greenways shall be installed at the beginning of the route, and after key intermediate cross-streets to encourage safe shared road travel speeds.
- Wayfinding signs should be placed along the length of neighborhood greenways, shared use paths, or other separated or low-stress bikeways.
- As part of a community-wide signing program for way-finding on all types of bikeway facilities (bike lanes, shared use paths, neighborhood greenways, etc.).

Design Features

- Bikeway wayfinding guide signs should provide distances in miles and riding time in minutes, and comply with MUTCD requirements for destinations, colors and fonts.

Further Considerations

- Some cities have developed unique logos or colors for the tops of their wayfinding signs to help brand their neighborhood greenways.
- Graphics that specifically identify the bikeway wayfinding system, including enhancement markers and can be used on the sign assembly. Up to 20% of the sign blade may be used for identity graphics and logos.
- Recommend including neighborhood greenways and other LSN routes in the priority plowing routes to facilitate year round use. Target key routes to schools and employment.



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. Wayfinding signs are not used for individual business identification or marketing.

Typical Application

Turn Signs

Turn signs should be used to identify where bike routes turn and are placed in advance of the turn. Because they provide important information, turn signs should always be part of the way-finding scheme.

Confirmation Signs

When used, confirmation signs are placed on the far-side of intersections. They provide redundant information and are not required to be part of the way-finding scheme. Consider the need for these only when the route is difficult to follow or less straight-forward, or when there could be a significant number of riders who are unfamiliar with the area.

Decision Signs

When used, place on the near-side of intersections in advance of a junction with another bicycle route. Decision signs provide supplemental information. They are helpful to increase knowledge of low-stress routes and key destinations that can be accessed via the low-stress bikeways. These are not required as part of the way-finding scheme, but are useful tools in increasing knowledge of the low-stress network. There is flexibility in their placement and deference should be given to required traffic control signs.

Design Features

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

Further Considerations

Communities can increase ridership by using wayfinding signs that meet MUTCD requirements for both motor-vehicle and bicycle rider visibility to identify nearby destinations.

Pavement markings may be obscured by snow. Signing should be visible year round.

Excessive signing can create visual clutter and distract from warning or regulatory signs. Wayfinding signs are secondary signs and warning and regulatory signs are provided a higher priority in placement.

Turning signs can be smaller as they are targeted primarily to people walking or bicycling.

Chapter 8

Bikeway Operations and Maintenance

Bike Facility Maintenance

Regular bicycle facility maintenance elements include: sweeping, snow-plowing, maintaining a smooth roadway, trimming encroaching vegetation, ensuring that the gutter-to-pavement transition remains relatively flush, and maintaining a smooth, level transition over stormwater grates. Bike facilities that are located on-street are generally maintained in conjunction with street maintenance. The City will create a program to routinely maintain Low-Stress Network routes, prioritizing Key Routes established in the City's TSP. Pavement preservation projects are a good opportunity to improve the complete street, including bicycle facilities. The following recommendations provide a menu of options to consider to enhance a maintenance regimen.

Sweeping

The City of Bend Sweeping Operations Plan will identify debris management to ensure safe surface conditions in bikeways. Debris that is allowed to accumulate can become a hazard due to loss of control, inner tube blow outs, and service dogs working with their bike riding handler.

The following are recommended items to include in the City's Sweeping Operations Plan.

- Both on-road and off-road bikeways under the jurisdiction of the City can establish a seasonal sweeping schedule that allows for prioritization of routes. The schedule should prioritize facilities designated as major bikeways, before routes designated as minor bikeways.
- Identify winter traction material removal methods to ensure traction materials do not become hazards themselves.

Signage

Include bikeway regulatory and wayfinding signing as part of the roadway sign maintenance program, regularly checking for vandalism, graffiti, and wear.

Roadway Surface

- Smooth pothole-free surfaces are especially critical for people on bikes.
- The finished surface on bikeways do not

vary more than 1/4" for new roadway construction.

- Coordinate with railroad companies to maintain railway crossings.
- Ensure pavement inspections occur after trenching activities and require mitigation prior to the expiration of the project's warranty period.
- To the extent possible, pavement markings and green-colored areas should be placed out of the motor-vehicle path of travel to minimize wear.

Drainage Grates

- New drainage grates should be bicycle-friendly. Grates should have horizontal slats so that bicycle tires and assistive devices do not fall through any 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

- Gutter-to-pavement transitions should have no more than a 1/4" vertical transition.
- Pavement transitions should be examined during every roadway project for new construction, maintenance activities, and construction project activities that occur in streets.

Landscaping

- Vegetation on the edge of the roadway should not hang into or impede passage along bikeways.
- After storm events, remove fallen trees or other debris from bikeways as quickly as possible.

Coordination With Emergency Responders

- General roadway maintenance should be coordinated and prioritized on emergency response routes that overlap with major and minor bikeways.
- Provide Emergency-Medical Service responders with a map of major and minor bikeway routes.

Recommended Bikeway Maintenance Activites

The following table summarizes maintenance activities. In order to facilitate the safety of the bikeway network and encourage bike riding amongst the Interested but Concerned rider type category, it is recommended that the City develop a maintenance and emergency operations plan that includes maintaining bikeways along with the streets. Activities listed below should be done in a timely manner to keep bikeways usable and safe.

Maintenance Activity
Inspections
Pavement sweeping/blowing
Pavement sealing, pothole repair, pavement preservation
Winter maintenance, snow-plowing, de-icing
Culvert and drainage grate inspection
Pavement markings replacement
Signage replacement
Shoulder plant trimming (weeds, trees, brambles)
Tree and shrub plantings, trimming
Major damage response (washouts, fallen trees, flooding)

Maintenance Prioritization

The City of Bend's current pavement preservation and snow-plowing programs include three priority levels: 1) major collectors and arterials, 2) selected collectors and arterials, and 3) residential streets. The tier system works to maintain emergency routes, high volume streets followed by routes to medical facilities, schools, major employment centers, and streets requiring special attention such as steep hills or curves. Some of the on-street low-stress bicycling network is included in this existing priority system.

TSP policies require that the city's maintenance program be expanded to include the low-stress bikeway network. The low-stress bikeway network is designated with Key Routes, which are primarily arterial and collector roadways. Given existing priority levels, these Key Routes will be given priority. The City's maintenance program will need to establish treatment protocols for the non-roadway bikeway elements (such as shared use paths). Similar to the tiered priority levels for streets, this optimizes allocation of maintenance program funding and serves the most community members while efficiently deploying resources.

Within the City's roadway operations and maintenance program, neighborhood greenways and other major connecting routes will be identified as a high priority within the residential street network. By their nature, neighborhood greenways are located on those local streets that carry the most amount of traffic of any of the neighborhood streets. They are typically long, and straight, and create great connections to where people are trying to go. By plowing neighborhood greenways as the highest priority residential street, the city gets more people moving, by more modes of travel, more quickly after snow events. By keeping neighborhood greenway pavements in good condition, the majority of neighborhood traffic will be safely accommodated.

To keep key bikeways safely operating, priority plowing of the low-stress network is recommended for the City's plowing plan. It is recommended that the plan and funding include all bikeway elements on Key Routes and neighborhood greenways on residential streets. Low-stress network routes will be served in as high of plowing priority as feasible to continue to provide bicycle routes throughout the winter.

Bicycle Access Through Construction Areas

When construction work zones include work in the right of way, or extend into a low-stress on- or off-street bicycle facility, the City will provide a low-stress bikeway through or around the work zone. If the work zone obstructs an existing bike facility, the City will provide a facility of the same level of access, LTS, and safety through the area as prior to the construction activity. It is unsafe to route people who are cycling into a shared lane situation, even during temporary operations, unless posted speeds are 30 mph or lower. At higher speeds, the risk for injury and fatal crashes is high.

Typical Applications

- People on bicycles should not be led into conflicts with work site vehicles, equipment, moving vehicles, open trenches, or temporary construction signage.
- Whenever people are allowed to ride bikes through an exclusive work zone area, measures should be taken to provide a continuous path of travel for bikes.
- Construction warning signage guides people on bikes through construction work zones, and/or along route detours.
- Debris should be swept to maintain a reasonably clean riding surface in the provisional bike facility.
- A Allow temporary use of sidewalk in suburban areas (lower walk/bike volumes) by requiring temporary ramps up to sidewalk and down from sidewalk for short zones. Proper shared use signs on sidewalk are needed as well as “bikes yield to people walking” signs.

Safety & Warning Signs

Signs may be used to raise awareness of shared road operations and may reduce conflict between roadway users.

Design Features

- Advanced signage alerts people on bicycles to the changes ahead. Construction warning signage at the site should be located in the furnishing zone of the sidewalk, or in a location that does not obstruct the designated path of travel for people walking and bicycling. Signage mounts and footings should not pose a hazard for bicycle wheels nor a tripping hazard for anyone walking, caning, or traveling in a wheelchair.
- B Steel plates used to cover trenches tend to have a 1”-2” vertical raised lip over the roadway surface. Because the plate is not flush, it can cause a person on a bicycle to lose control as they come into contact with it. Require temporary asphalt (cold mix) around steel plates to create a smooth transition.
- Use steel plates only as a temporary measure during construction, not for extended periods.

Typical Application

- The bicycle warning sign (W11-1) with legend plaque “ON ROADWAY” may be considered during construction in the following limited situations: the shared roadway condition matches the LTS of the roadway under normal operations and posted speeds are 25 mph or lower, or a construction speed of 25 mph is posted.
- The “Bikes May Use Full Lane” (BMUFL) (R4-11) sign may be considered in shared roadway conditions when posted speeds are 25 mph or lower.

Design Features

- R4-11 Sign: Bikes May Use Full Lane.Use with travel lanes too narrow for safe passing within the lane.
- Place signs at regular intervals along construction and detour routes.

In this bike accommodation at a construction area, the existing bike lane ends abruptly and merges bikes into the adjacent vehicle travel lane without warning or proper merge signage. The existing bike lane is covered in gravel and debris, increasing the likelihood of crashes.

Options for accommodating bike riding through the construction zone include: strictly limiting the encroachment into the bike lane so it can still be used; requiring daily sweeping; narrowing the travel lanes so the bike lane can continue. If the posted speeds are 25 mph or lower, another option is to create a shared lane by providing merge pavement markings and signage, shared lane pavement markings, and signage.

In this example, the existing bike lane was repurposed as a pedestrian travelway, which then requires people riding to merge into the adjacent travel lane. Options for accommodating bike riding through the area could include: widening the pedestrian travelway sufficiently (8-10', depending on the number of expected users) to create a shared use path of travel; tapering to a single travel travel lane while providing a bike lane; providing a well-routed bike only detour. If the roadway travel lanes are posted 25 mph or lower, another option would be to add proper merge areas, signing, and temporary retro-reflective sharrows. Setting a construction speed limit is required when posted speeds are 30 mph or higher to reduce roadway travel speeds and create a safer situation.

Further Considerations

- Contractors should be trained in how to safely route bicyclists through or around work zones.
- Detour paths of travel and routing, detour signage, and path of travel and closure signage should be included on all bikeways where construction activities occur.
- Require both temporary and final repaving to provide a smooth surface without abrupt edges.
- Although it is common to use steel plates during non-construction hours, these plates can be dangerously slippery, particularly when wet. Applying traction to the surface of the plate can reduce the likelihood of slips.

Best Designs to Facilitate Winter Riding

To provide safe, ridable bikeway surface conditions in the winter, designs shall consider bikeway type (basic, buffered, shared use sidepath, parking protected bike lane, etc.); presence and type of vertical protection that might affect equipment size and deployment; and width of buffer space/separation. Snow storage spaces should be designed to accommodate snow without blocking sight lines.

Design Roadways with Snow Storage in Mind

Require buffered sidewalks and sufficient right of way for snow storage

In areas where snow is likely, such as central Oregon, the City will design streets to provide space within the right of way for snow storage. Ensure that the snow storage space is of adequate width to accommodate typical snowfall accumulations, allows plows to clear the roadway and bike lane of snow, and allows sidewalks to also be kept clear of snow storage.

The City standard is to provide a minimum 6.5 foot landscape/snow storage strip between sidewalk and curb. This has been identified as adequate for most snowfall conditions, but can depend on width of roadway and cumulative snowfall conditions.

Curb tight sidewalks do not provide snow storage space for either the roadway snow or the sidewalk snow. The snow needs to be accommodated in one of the following ways:

Use on-street parking

If roadway designs include on-street parking but do not include a parkstrip/snow-storage area, the on-street parking area may be used for snow storage. Plows may be able to direct snow within the roadway where there would normally be parked cars.

Because the sidewalk and bikeway and travel lanes are part of the transportation system, they are prioritized over on-street parking. Some on-street parking accommodation should be considered and provided to the greatest extent practical to accommodate commercial businesses.

A parking protected bike lane in Salt Lake City, UT after a snow plow operation. Photo Credit: Travis Jensen

Manage cross-slope for snowmelt

Standard roadway design in Bend includes stormwater flows to the outside curb line and snow storage is provided in the parkstrip/snow-storage area between the curb and the sidewalk.

For areas where there is curb-tight sidewalks there isn't snow-storage space provided in the cross-section.

In the case where there is no snow-storage space but parking protected bike lanes, using the parking lane for snow storage may lead to icy surface conditions in the the bike lane.

Through a design exception, designers may seek to design a parking protected bike lane with an inverted crown would mitigate the snow melt issues. In this case, the roadway would have a typical cross-slope towards the edge of the roadway (right) but the bike lane would have a counter cross-slope to the left. Where these two cross-slopes meet could have a pan-style gutter and stormwater catchbasins.

Design porous or pervious pavement for parking and/or bike lane

The City does not have a standard developed for pervious pavement. Research has identified water quality benefits as well as fewer potholes caused by freeze-thaw because of the voids in the pavement structure[1]. Snow and ice melted more quickly, including in low ambient and freezing sub-surface temperatures, which can lead to reduced sanding and salt usage[2].

The City may find ways to implement pervious pavement and there may be benefits to not only the bike facility's winter maintenance, but appears to lead to reduced winter maintenance needs on roadways overall, including de-icing operations and needs.

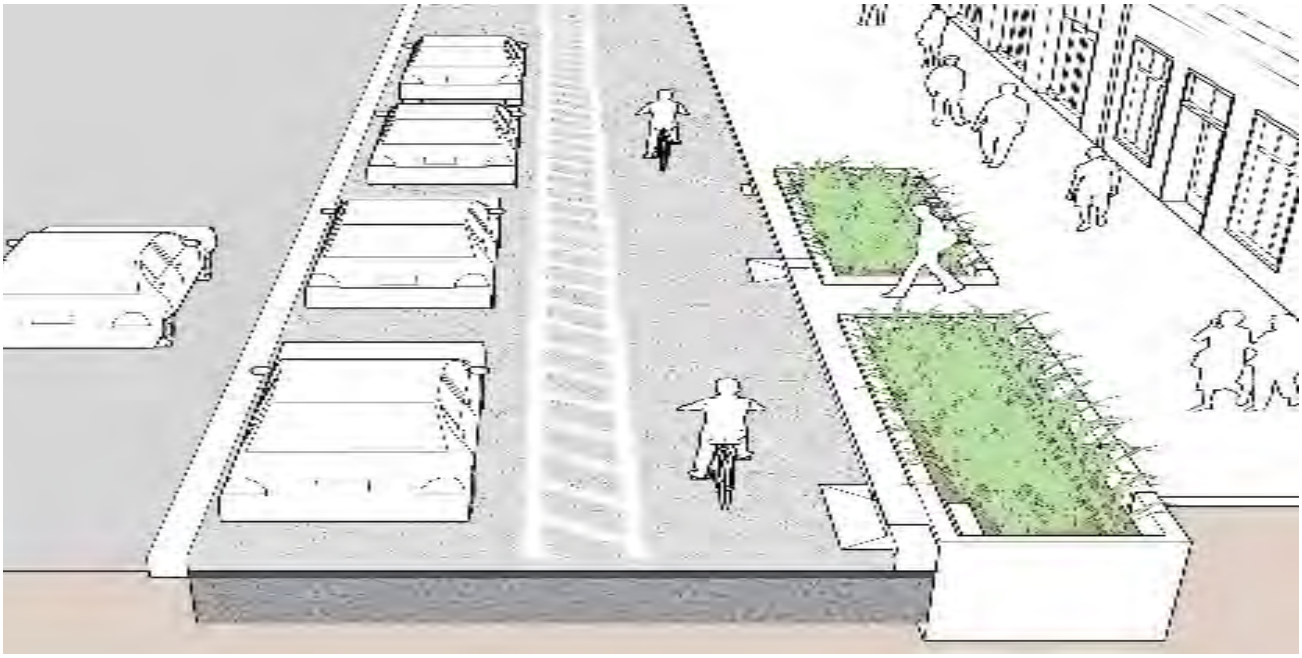
Truck snow to remote sites

In cases of curb tight sidewalk, particularly in urban areas where there is high demand for on-street parking, snow storage may be located in a remote site. This will require snow to be loaded and trucked which is tedious and can be costly. Urban streetscape designs should accommodate snow storage. Trucking snow should be considered as a last resort.

1 Pavement that can clean water, Dr. Katie Holzer, Watershed Scientist, City of Gresham Oregon.

2 Permeable Pavements in Cold Climates: State of the Art and Cold Climate Case Studies, John S. Gulliver, University of Minnesota, June 2015 Final Report 2015-30.

Slush gathers and refreezes on traditional asphalt whereas porous asphalt leads to slush free pavement: Case Study (photos taken January 17, 2010), Permeable Pavements in Cold Climates, John Gulliver, 2015.



Using porous pavement in conjunction with parking protected bike lanes has provided convenient snow storage alternatives and better winter surface conditions in cold weather climates for several communities. Photo Credit: NACTO Urban Street Stormwater Guide.

Ensure bikeway designs accommodate snow plow and street sweeper equipment

Bikeways that are separated, but too narrow to accommodate standard snow plow widths will require specialized plows. These specialized plows are becoming particularly important for bikeways that have confined widths, such as separated bike lanes and trails.

Many large cities with harsh winter climates, such as Chicago, and Minneapolis, have a fleet of these specialized vehicles and ATV-mounted snow plows primarily for the purpose of clearing sidewalks and bikeways. While most separated bikeways in Chicago can be cleared with typical pickup truck mounted snow plows, ATV-mounted snow plows and Bombardier snow plows are also used for separated bikeways such as Kinzie Street in Chicago, Illinois that are too narrow for pickup trucks.

Where bike facility widths permit, utilizing existing maintenance vehicles (such as pickup trucks with mounted snow blades) can be more cost-effective and time-efficient than the smaller vehicles which operate at slower speeds, have smaller plow blades and need to be hauled, rather than driven, to the site.

Design of shared use paths and bicycle facilities will consider how the snow removal vehicles will access the facility. Sometimes there are driveways conveniently located, other times a wide pedestrian crossing ramp will be needed to accommodate the width of the maintenance vehicle to access the bikeway.

A small snow plow vehicle clears sidewalks in Vancouver, BC.

Provide adequate width for snow storage. Photo Salt Lake City, Utah

Kinzie Street Protected Bike Lane after winter maintenance to clear snow. Chicago, IL, Photo Credit: Alta Planning and Design

DISCUSSION

Salt Lake City, UT, has designed protected bikeways specifically to accommodate snowplows. Protective, flexible bollards are located at a far enough distance from the curb to allow a small truck-mounted snowplow to clear the bikeway. Separated bikeways, medians, and bulb-outs in Salt Lake City are designed with tapered front ends and vertical delineators at obstacles to help prevent snowplow blade collisions along these facilities.

A recessed thermoplastic bike lane marking in Minneapolis, MN.

Vertical delineators help inform snow plow drivers of obstacles such as cycletracks, raised medians and bulb-outs in Salt Lake City, UT

Recessed thermoplastic pavement markings

Milling the pavement 3mm in depth where thermoplastic pavement markings are applied has shown to be effective in reducing pavement damage as a result of snowplows in a 2010 study.[1] Minneapolis, MN, mills the pavement where thermoplastic bike lane indicators are placed to help reduce damage as a result of snowplows. While this method increases the cost of installation, it may save in long-term maintenance costs (and help preserve safety conditions along the roadway).

[1] Development of Recessed Pavement Markings that Incorporate Rumble Strips. http://www.easts.info/publications/journal_proceedings/journal2010/100292.pdf

Edge-of-roadway visual cues

Pavement markings, striping, sidewalks curbs, and other types of travel delineators installed at ground-level serve as good indicators of the bicycle travel way when the ground is clear, but after a snow event, these lose their utility.

For this reason it is important to provide other visual cues to indicate the bicycle travelway for those riding and snow plow vehicles. This becomes especially critical when the bike facility bends in or out around curb extensions, median islands or other transitions. At these locations, flexible tubular delineators or other post delineators are necessary.

Chapter 9

Bicycle Parking

Bike corral on Minnesota Ave in Bend, OR provides group bike parking in a convenient location. Bike corrals improve the accessible path of travel on the sidewalk to ensure compliance with the Americans with Disabilities Act.

Bike Parking

The Bend Development Code requires safe, convenient bicycle parking with site development. Short-term bike parking serves quick customer trips, long-term bicycle parking serves employees, and covered bicycle parking serves longer visits (such as events, theatrical and musical venues). Group bike parking is also critical to businesses that attract families and groups of customers. Each type of bicycle parking provides an important service at the end of a bike trip.

Within the Central Business District there is a special allowance that allows short term (customer) bike parking to be located within the public right-of-way rather than on the individual lot.

Strategic Placement

Bike parking and other street furniture can be used to help define and enhance the walking environment in a mixed use urban area.

Channelize pedestrians

Bare curb extensions may be temporarily used for bike parking until other street amenities such as street trees and benches can be added. This ensures those walking are channelized into a clear path of travel, and directed to the crosswalk.

Repurpose right-turn lanes

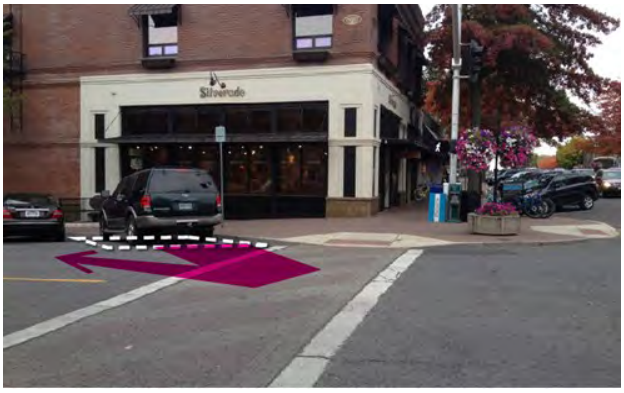
Depending on priorities, right turn lanes in mixed use urban areas can be repurposed to shorten crosswalk lengths, shorten traffic signal phase, and enhance the pedestrian environment by adding curbside amenities such as high-turnover on-street parking (pick-up, delivery, or drop-off parking), outdoor cafe or parklet seating, landscaping, and bike parking or a combination of these for a complete urban streetscape amenity.

Reallocate unused roadway space

Unused roadway space can cause operations issues with poor lane integrity and sloppy turns as well as increased impervious surface area and stormwater run-off. The space makes the roadway appear wider than it is, and can encourage speeding and high speed turns in or out of driveways. Similar to the guidance on right turn lanes, this unused space can benefit the urban environment with landscaping, stormwater retention, art, and/or bike parking.

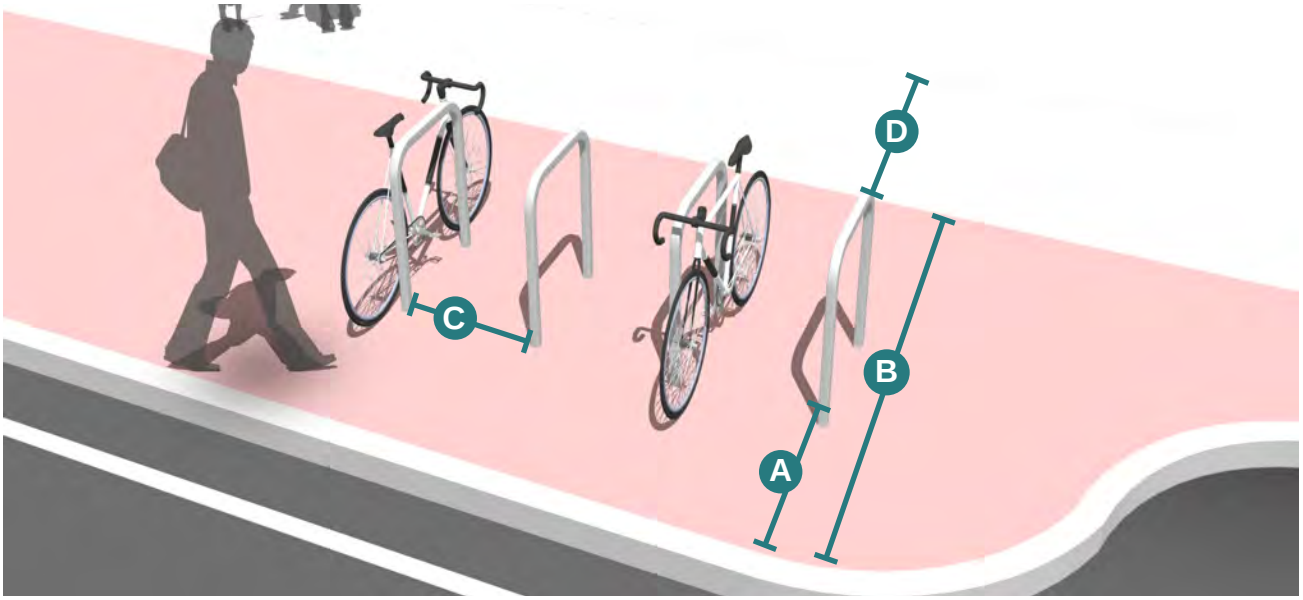
Remove angled parking conflicts with crosswalks

When head-in angled parking is located too close to intersections, the backing maneuver backs over the crosswalk. This safety issue can be corrected by replacing the parking stall with motorcycle parking, police only parking, ADA access aisles or bike corrals.



Define pedestrian path of travel

In urban areas there can be shared zones that provide places to walk, park, drive, and load/unload. By using strategically placed trees and other street furniture designers can define accessible paths of travel and separation between conflicts. Strategically placing bike parking in line with a row of street trees can enhance the separation and protection.



Perpendicular short-term bike parking in right of way

Bike Parking Design Elements

Short-term bicycle parking

Short term bicycle parking serves customers and visitors who need a secure location to park a bicycle for a shorter duration. Locate short -term parking near front doors and do not block accessible paths of travel on the sidewalk.

Take care to develop paths of travel between the bikeway and the bike parking. Parkstrips and furnishing zones are common locations for short-term bike parking. For bike parking located near intersections, bike riders typically access the space using the crosswalk pedestrian ramp. Allocate a space to the side of the bikeway that allows riders to dismount outside of the path of traffic to gain access to this ramp. For mid-block bike parking, add a bike ramp mid-block to allow access.

Maneuvering and other Dimensions

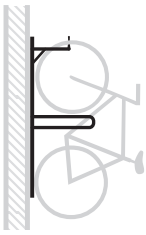
- A Provide at least 2' minimum space from either end of the rack to accommodate basic bike lengths. However, strive for longer to accommodate a wide variety of bike lengths.
- B Maximize total length of bike parking footprint to accommodate cargo bikes, bikes with trailers, and bikes with tagalongs. 6' accommodates basic adult bikes while tandems and most cargo bikes require 8' and 10' is needed for bikes with trailers, tag alongs, etc
- Ways to provide the necessary "B" dimension include angling the bike racks, placing them parallel to the sidewalk, or locating them on curb-extensions.
- C 4' between racks provides maneuvering room when accommodating typical adult bikes. Tricycles, side-by-side tandem bikes and bikes with cargo space, trailers, etc. will require additional space. In a group of bike racks, the end racks might be sufficient to accommodate over-dimensional bikes. Provide as much room as possible to provide the most flexibility.
- D Minimum clear distance of 2' should be provided between the parking area and the sidewalk. In some special districts the sidewalks are required to be 11' to 15' wide. In those situations, bike parking may be allowed to reduce the sidewalk width, but that allowance will need to be made by the City Engineer on a case by case basis. The sidewalk width should be maximized and not typically allowed to be reduced to accommodate bike parking.

Preferred Bike Rack Types

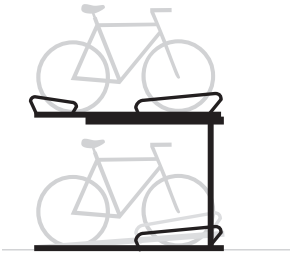
INVERTED U-STYLE

POST & RING

In higher capacity secure parking areas, the following rack styles may be appropriate:



VERTICAL



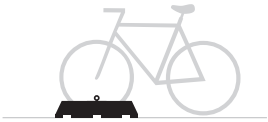
TWO-TIER

Racks to Avoid

WAVE

SCHOOLYARD

COATHANGER



WHEELWELL

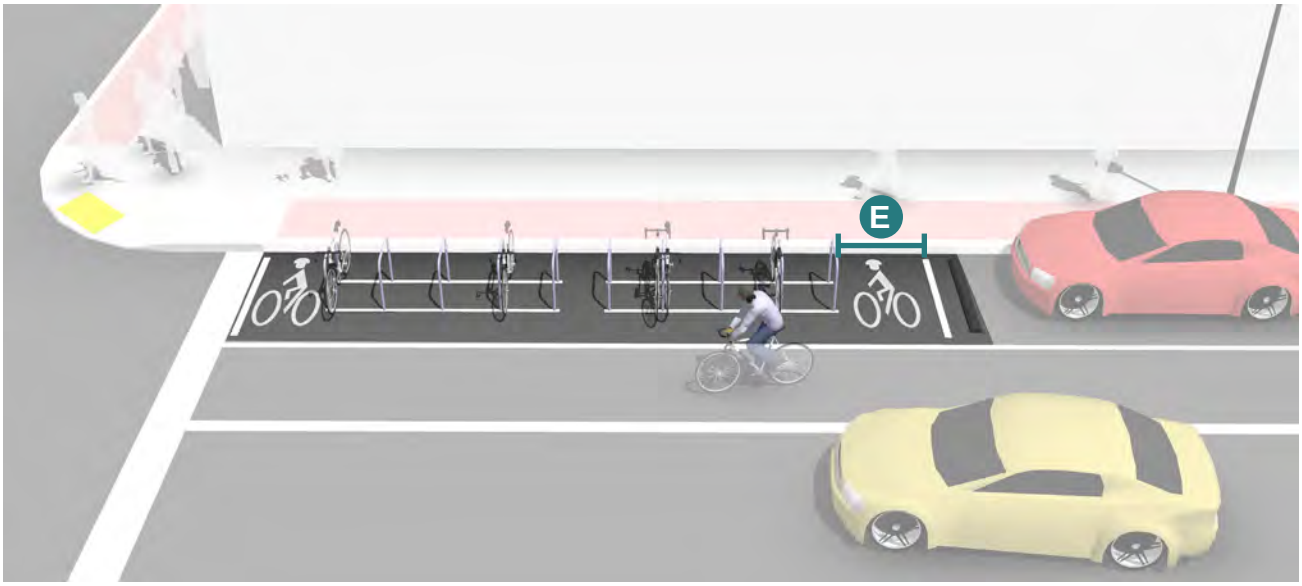
BOLLARD

SPIRAL

SWING ARM SECURE

WHEELWELL

Diagrams from the Association of Pedestrian and Bicycle Professionals (APBP), Essentials of Bike Parking, 2015.



Bike Corral

When bike racks are placed adjacent to walls or curbs, or other street furniture, users need space to maneuver and position their bicycle. Racks should be placed a minimum of 36" from the nearest wall. When placed in rows, bike racks should provide a clearance aisle for people to access their bikes through.

Group bike parking

Provide group bike parking for restaurants, event sites, schools, parks, and any other site that will attract groups of people arriving together.

For downtown Bend, group bike parking can be located in curb extensions, parallel and angled parking stalls, and parkstrips/furnishing zones. The first several feet of right turn lanes may also be considered depending on the length of the turn pocket.

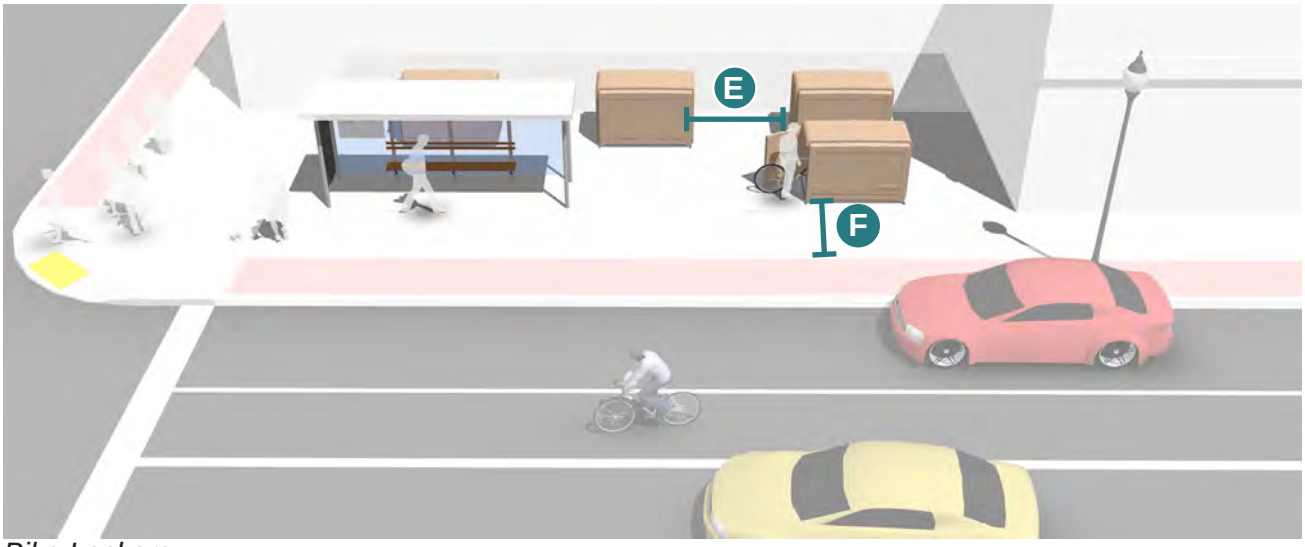
A bike corral is a common form of group bike parking. Bike corrals are warranted in high demand bike parking areas, where families and friends meet to shop, dine, or attend an event. They can free up space for pedestrian walkway features, outdoor seating, or other pedestrian amenities when located within the roadway.

- Bike corrals consist of bicycle racks grouped together in a common area within the street or within the furnishing zone as space allows, e.g. on a curb extension.
- When adding bike corrals within an on-street parking space, approximately 6-10 bike parking spaces can be provided.
- E The corral should allow 6' for a person to enter with their bike directly from the bikeway. This allows width for a bike parked on the end rack and maneuvering into the corral.
- Can be placed in 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.
- Bike corrals can be considered in roadway space currently designated for right turn lanes, or where there is a wide enough landscape strip/furnishing zone (7'or greater), or as part of a curb extension.

Further Considerations

It is recommended that bike corrals are installed by private sponsors who enter into a development agreement with the city. Bike parking within the roadway can impact winter maintenance and seasonal sweeping. Development agreements should cover maintenance obligations and accommodations.

Group bike parking signage that is taller can aid riders in locating the group bike parking.



Bike Lockers

Long-Term Bicycle Parking

Long-term bicycle parking provides a secure and weather-protected place to park bicycles for more than roughly two hours on the project site. Long-term bicycle parking typically serves employees, students and residents, but it is also needed for anyone who needs a secure location to park a bicycle for a longer duration. Theatrical and musical venues, and special events can be supported with long-term bicycle parking.

Long-term bicycle parking must:

- Provide cover such that bicycles are protected from inclement weather
- Be accessible 24 hours a day, 365 days a year, except by notice.

Bike lockers

- Bike lockers provide long-term bicycle storage for employees, students, residents, commuters, and others expected to park more than two hours. Lockers protect the entire bicycle, its components, and accessories against theft and inclement weather, including snow and wind-driven rain. Lockers should be placed in visible, easily accessible locations.
- Minimum dimensions: width (opening) 2.5'; height 4'; depth 6'.
- F 4' side clearance and 6' end clearance.
- E 7' minimum distance between facing lockers.

Secure Parking Areas

- A secure bike parking area is an enclosed space offering a higher level of security than ordinary short-term bike parking.
- Increased security measures are often necessary to allow riders to feel comfortable enough to leave their bicycle: dedicated access control, electronic key-card, combination locks or keys, secure parking areas, closed circuit monitoring with secure access for users.
- Two-tier high capacity racks and cargo bike spaces.
- Bike repair station with bench and bike tube and maintenance item vending machine.
- Bike lock "hitching post" allows people to leave bike locks.

Bike Rack Form and Function

Bike racks come in a wide variety of shapes and styles. In general, bike racks shall meet the

following specifications:

- 1.5” to 1.75” gauge, ASTM A53 Grade B Standard Weight Steel Pipe.
- The bike frame and one wheel can be locked to the rack with a high security, U-shaped shackle lock if both wheels are left on the bike.
- A basic adult bike 6’ long can be securely held with its frame supported in two locations so that the bike cannot be pushed or fall in a manner that will damage the wheels or components.
- The rack must be securely anchored with security hardware.

Short-term bike racks installed in City right of way shall be one of three styles:

Inverted-U style

- Racks shall be constructed of 1.5” diameter wall square pipe, galvanized or stainless steel.
- Racks shall be 32” tall by 30” wide.
- Flanges for surface mounted racks must be 3/8” thick and drilled with 9/16” holes to admit 1/2” fasteners.
- For installation of multiple racks side-by-side, rail mounted inverted U-racks can be used.
- The capacity of each inverted U-rack is two bicycles, locked parallel to the rack.
- A lower cross bar and internal cable provide additional security in the event that the rack is successfully unbolted or cut.

Circle style

- Racks shall be constructed of 1.5” diameter wall square pipe, galvanized or stainless steel.
- Racks shall be approximately 32” tall.
- Flanges for surface mounted racks must be 3/8” thick and drilled with 9/16” holes to admit 1/2” fasteners.
- The capacity of each circle rack is two bicycles, locked parallel to the rack.
- A lower cross bar and internal cable provide additional security in the event that the rack is successfully unbolted or cut.

Post-and-Ring style

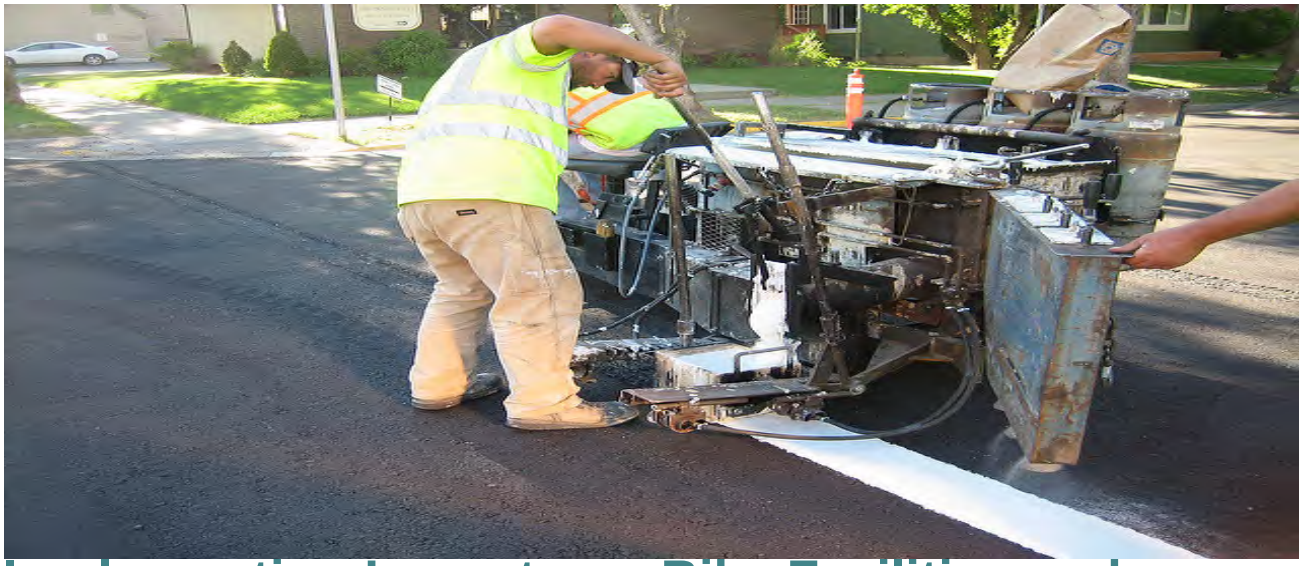
- Racks consist of two components: a vertical pipe sleeve and two halfcircle locking loop elements welded to either side of the sleeve.
- The vertical sleeve shall be constructed of 2 1/2” I.D. Schedule 40 pipe.
- The half-circle locking loops shall be constructed of 2”x2”x.188” wall square pipe.
- All materials galvanized or stainless steel to prevent corrosion.
- Racks shall be 37 3/8” tall or as specified by City to fit height of existing parking meter poles.
- Locking loop elements shall be 18” tall and 8” wide, attached at a height of 12” from the bottom of the sleeve, measured to the bottom edge of locking loop.
- Sleeve must be drilled with hole for 3/8” security bolt to affix rack to existing parking meter pole.
- The capacity of each post-and-ring rack is two bicycles, one on either side.
- Post-and-Ring style racks are sleeved onto existing parking meter poles and secured using a fastening wedge and 3/8” mushroom head stainless steel bolt with security nut in top of rack.

Mounting

- Inverted U-racks and circle racks installed on concrete should be surface flange mount style.
- Fasteners for use in flange mounting must be 1/2” x 3” mushroom head stainless steel.

Chapter 10

Implementation Plan & Performance Measures



Implementing Low-stress Bike Facilities and Tracking Performance

TheTraffic Level of Stress approach to planning bicycle facilities and the Low-stress Network of bicycle facilities were adopted into the Bend Transportation System Plan in 2020. There are a variety of ways the City can implement the policies and build the network such as updating Standard Drawings and the Bend Development Code to allow construction of low-stress bike facilities with new construction.

There are several performance measures to track the success of implementation over time such as LTS of the overall system, miles of bikeways, miles of system gaps, crash reduction and ridership increases that this chapter also discusses.

The low-stress bicycling network was adopted as part of the Transportation System Plan's transportation framework to facilitate coverage and connectivity for accessibility by bike to jobs, services, schools, and parks.

Standards and Specifications

The City will adopt low-stress bike facility designs as standard practice and adopt this Guide as part of the City's Standards & Specifications so that all new, and reconstructed roadway arterial and collector roadways, and roadways on the low-stress network will be built to include low-stress bikeways. This would affect public capital improvement projects as well as private development projects.

Pavement Preservation Projects

The City will utilize pavement preservation projects as opportunities to implement low-stress bikeways, but this process will remain within the scope of a pavement preservation project. Pavement overlays and chip seals allow the City to create buffered bike lanes, add parking protected bike lanes and correct intersection safety deficiencies through cost-effective, minor striping changes when there is adequate width to accommodate these changes.

This section identifies activities to consider to ensure maximum use of overlay opportunities to reduce crashes and facilitate the City's low-stress bikeway network deployment.

- Most riders will have difficulty with rough surfaces, particularly young riders or older riders. Because of this, and the need to preserve pavement integrity where stormwater intrusion is most likely, most surface treatments cover curb-to-curb in order which ensures smooth riding surfaces in bike facilities.
- If the shoulder or bikeway pavement is of good quality, it may be appropriate to end the overlay at the shoulder or bikeway stripe provided no abrupt edge remains as people riding bikes do move in and out of the bike lane to facilitate turning movements. Traversing a rough joint can result in loss of control and crashes.
- Inlet grates and manhole and valve covers should be within 1/4" of the finished pavement surface and made or treated with slip resistant materials.
- The City of Bend publishes pavement preservation streets and their limits on a 3- to 5-year schedule. An early peek at projects allows staff time to identify safety needs, ADA facility elements, and low-stress bikeway network needs.
- Sometimes the roadway space can be optimized to enhance safety and operations for everyone. It is recommended that staff review the safety and operations of left-turn lanes, right-turn lanes, lane widths, bike lane widths and buffer widths for pavement preservation projects.

Develop a Low-Stress Bicycle Network Program

This program would be similar to programs developed for traffic signal modernization, bridge modernization, citywide safety program, multi-modal count program, and citywide sidewalk infill program. These programs allow annual investments in a prioritized list of key facilities.

Low-stress bikeways will be implemented as part of the City's annual CIP program for major roadway construction or reconstruction; as part of the pavement preservation program; and as part of private development transportation facility construction. By adding an annual low-stress bicycle program, discrete projects can be built such as reconstruction of footbridges over the Deschutes River, construction of sidewalks/bikeways over key irrigation canals, key crosswalks across wide-busy streets, and construction of neighborhood greenways.

It is possible that deploying neighborhood greenways might lead to strong ties into the city's traffic calming program to enhance neighborhood livability and reduce the impacts of cut-through traffic in neighborhoods. Many neighborhood greenways are also likely candidates for needed neighborhood traffic calming.

GIS Geo-Database

The low-stress bikeways project created new GIS geo-database elements. The assigned level of traffic stress for each roadway segment is a calculation based upon attributes such as number of roadway lanes, bike lane width, left- and right-turn lane treatments, intersection control, crossing treatments, and posted speed limits. When the City updates its GIS management plan, the City will develop an on-going GIS attribute management plan for the level of traffic stress elements.

The GIS geo-database elements will also track the construction of crosswalk treatments, bike boxes, two-stage left turn boxes, etc. to support asset management and operations funding.

Performance Measures

The level of traffic stress quantified for each segment can be used as a performance measure in future transportation system planning efforts and periodic reviews of the transportation system. Performance measures can include overall bicycle system level of traffic stress, completeness of the low-stress network, bike involved crashes, and bike counts.

Periodic review of these performance measures allows the city to tailor the low-stress bicycle network program to advance implementation of key low-stress bikeway elements to increase ridership and reduce crashes.