

Bend, Oregon
A Complete and Attractive System of Bikeways
Tool Box
2014

Bend residents are asking for improved walking and biking systems. The city is currently rated as a Bike Friendly Community (silver rating) and the League of American Cyclists have provided quantitative as well as qualitative guidance on how to improve the attractiveness and safety of the system to increase the number of people biking. Staff also receives frequent requests for traffic calming on local streets, streets where many families initiate each and every bike trip and where new riders begin to perfect their riding skills. The city has an Arterial and Collector Safety Program focusing on busier streets which aims to improve safety for all modes of travel by implementing countermeasures for specific crash patterns and types, including bike crashes.

Rather than an ad hoc manner of responding to citizen input and crashes, the city of Bend has utilized the input of citizens, crash data and league feedback to develop a Strategic Implementation Plan for a system of walkways and bikeways that will increase usage and increase safety of all users. The Strategic Implementation Plan goals include: meet statewide planning rules for reduction of Single Occupancy Vehicle travel, vehicle miles traveled, greenhouse gases; develop a list of projects for the 5-Year CIP (capital infrastructure program); increase ridership; and increase safety.

While the Strategic Implementation Plan provides the framework, it is important to note that just implementing bike lanes will not achieve the goals of the Program. To do that, people need to not only have a bikeway route to use, but that route must be “**S-A-F-E**” (Safe, Accessible, Fun and Easy) to use. Routes must appeal to a broad range of skills and demographics. Several important national initiatives have been undertaken recently that allowed the city to develop this toolbox which is aimed at creating a “**S-A-F-E**” system of bikeways.

In 2009, the National Association of City Transportation Officials (NACTO)¹ Cities for Cycling initiative began. One of their cornerstone projects was the development of the Urban Bikeway Design Guide. This Guide was created by cities for cities and documents state-of-the-practice solutions that can help create complete streets that are safe and enjoyable for people on bikes. The designs in the guide are based on the experiences of those cities throughout the world that have the highest ridership. In 2013, the Federal Highway Administration issued a memorandum officially supporting use of the Urban Bikeway Design Guide.

In 2011, the Oregon Department of Transportation published the Oregon Bicycle and Pedestrian Design Guide, which also provides guidance to implement safe and effective walking and biking solutions.

¹ National Association of City Transportation Officials, NACTO, www.nacto.org.

In 2012, the Green Lane Project² began implementing the Urban Bikeway Design Guide's best practices in six U.S. Cities (Austin, Chicago, Memphis, Portland, San Francisco, and Washington D.C). The Green Lane Project is the brainchild of an industry coalition of bicycling suppliers and retailers to provide technical, financial and strategic resources to each of these communities to create inviting, safe and innovative systems to increase people biking.

In 2012, the Federal Highways Administration³ published a series of best practices aimed at improving safety for people walking and biking and driving. Out of the nine best practices, five of them (roundabouts, medians/pedestrian crossing islands, road diets, and pedestrian hybrid beacons) are already being implemented in Bend.

In 2014, the Oregon Department of Transportation published the Oregon Pedestrian and Bicycle Safety Implementation Plan. This plan uses a systemic approach to safety and thus identifies potential areas needing safety countermeasures based on the presense of proven factors that contribute to walking or biking crashes.

The Growth Management Department of the City of Bend is charged with planning, design and construction of a safe, efficient multimodal transportation system for the community. This toolbox outlines transportation system elements that are proposed in Bend to increase ridership and safety and allow the city to achieve our system goals. The results of updating the city's transportation system with state of the practice safety and multimodal features will be:

- people walking and biking more in their community (lower vehicle miles traveled)
- higher land values,
- increased safety, and
- more productive workers.

² People for Bikes Foundation and People for Bikes Coalition, www.peopleforbikes.org, (established 1999).

³ Federal Highway Administration (FHWA), "safety.fhwa.dot.gov/provencountermeasures."

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BUFFERED BIKE LANES

Buffered bike lanes are considered a low-stress bike facility. The buffer separates bicycle traffic from motor vehicle traffic. Buffers are created with pavement markings.



Figure 1 Buffered Bike Lane

Buffered bike lanes provide increased comfort and security for people using the bike lanes. In Bend, they might be able to be retrofitted onto roadways that are unusually wide.

Buffers can be utilized to increase comfort by reallocating the pavement width to yield greater distance between moving traffic.

The following calculations assume a 10.5' truck and a 2' bicyclist width:

- No Buffer = $12' + 6' = 2.8'$ space between bicyclist and moving traffic
- 2' buffer = $11' + 2' + 5' = 3.8'$ space between bicyclist and moving traffic
- 3' buffer = $10' + 3' + 5' = 4.3'$ space between bicyclist and moving traffic

Buffered Bike Lane Effectiveness:

- Increase bicycle ridership by increasing the demographic attracted to the corridor.⁴ Ridership on buffered bike lane corridors have been shown to increase between 77% and 271%.
- Demonstrated increase in distance between bicyclist and moving traffic
- Reduced motor vehicle travel speeds

Buffered Bike Lane Maintenance:

- May require annual maintenance similar to longitudinal lane line striping

⁴ "Evaluation of Innovative Bicycle Facilities: SW Broadway Cycle Track & SW Stark/Oak Street Buffered Bike Lanes," Final Report, Portland Bureau of Transportation, (2011).

CYCLE TRACKS

A cycle track is considered another low stress bike facility type that increases separation of the bicyclist from moving traffic. Cycle tracks are a hybrid between a buffered bike lane and a separated path. They are located within the roadway, but can be separated from traffic through curbing, on-street parking, or bollards. Cycle tracks can be one-way or two-way and can be implemented in a contra-flow manner on one-way streets.

Bend installed one of the first cycle tracks in the U.S. in 2003 with the new road construction project which created the Southern River Crossing. The Reed Market Road Cycle Track consists of a 4" raised bike lane separated from motor vehicle traffic by an 18" wide mountable curb. The mountable curb is designed to allow people riding their bike to easily and safely enter or exit the bike lane. The cycle track is highlighted with red color along its length. This cycle track is 5' wide.

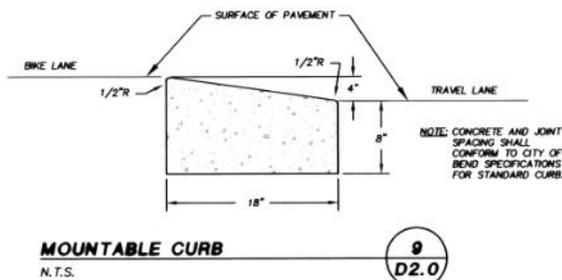


Figure 3 Cycle Track Mountable Curb



Figure 2 Reed Market Cycle Track

The purpose of the raised feature of this cycle track was to prevent straightening of the many curves in the road, which keeps vehicle speeds close to the posted speed of 25 mph which increases the attractiveness of this facility to riders of all comfort levels.



Figure 4 Franklin Ave Cycle Track

Another local example of a cycle track is on Franklin Avenue between Broadway Avenue and Wall Street, where on-street parking has been moved away from the curb to protect a bike way located at the curb. Door zone protection areas were incorporated into the parking bays to increase safety of the cycle track.

Cycle track design for sight line availability as well as transitions into intersections is critical to safety outcomes. Designs that remove on-street parking increase turning conflicts for bicyclists as vehicles need to turn onto side streets to access on-street parking. Designs that provide poor sight lines between a driver executing a turn and a bicyclist can result in an increase in crashes. Bend has utilized an open sight line design for its cycle tracks which have resulted in safe designs. The cycle track on Franklin Avenue does not have turning conflicts and has been ended at the approach to the signalized intersection to provide maximum sight lines for conflicting turns.

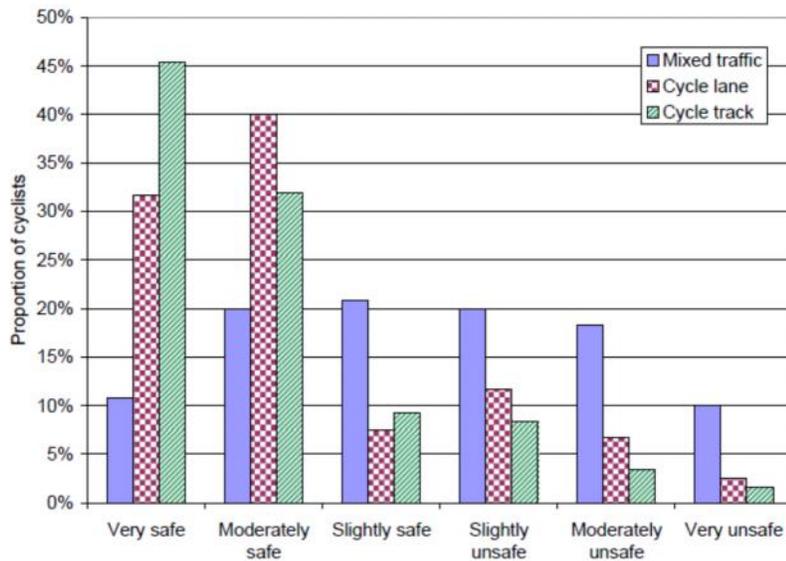


Figure 3. Division of answers to questions put to cyclists about their feelings of safety on roads with mixed traffic, cycle lanes and cycle tracks.

Figure 5 Reported Cyclist Perception of Safety

Benefits of Cycle Tracks:

- People on bicycles feel most secure on roads with cycle tracks and most at risk on roads with mixed traffic⁵
- Cycle tracks have been shown to decrease injury rates by 28%⁶ over roadways with mixed traffic.

Maintenance of Cycle Tracks:

- Street sweeping and plowing may need special equipment narrow enough to effectively operate within the cycle track
- Color pavement may need to be refreshed every 5 to 8 years
- Periodic maintenance of signs and markings.

⁵ "Road Safety and Perceived Risk for Bicycling on Cycle Tracks Versus in the Street," Jensen, S.U., Rosenkilde, C., Jensen, N., (2007).

⁶ "Risk of Injury for Bicycling on Cycle Tracks Versus in the Street," Lusk, A., Furth, P., Morency, P.

GREEN BIKE ELEMENTS

Conflict Areas (right turn lane add, right turn movement conflicts)

Bike Boxes (at signals for right turn hook mitigation, queue jump)

Two Stage Left Turn Boxes (at key route intersections)

Intersection crossing guidance (for wide intersections or where heavy turns exist)

Green color is now reserved for bicycle facilities by the Manual of Uniform Traffic Control Devices (MUTCD). The purpose is to increase visibility of a conflict area to improve safety and operations through the conflict zone. Solid color is usually reserved to highlight the position of the bike facility while dashed color is used through the conflict zone itself or as guidance through larger intersections.

Green Bike Lane Effectiveness:

- More effective at keeping parked cars out of the bike lane⁷
- Improved driver yielding to bicyclists
 - Before/After comparisons = 92%/72%⁸
 - Before/After comparisons = 98.5%/86.7%⁹
- Improved turn signal usage before crossing the conflict zone
 - Before/After comparison = 38%/74%¹⁰
- Improved safety¹¹
 - Reduction of 10% in accidents
 - Reduction of 19% in injuries

Green Bike Lane Maintenance:

- Refresh conflict areas every 3 to 5 years due to tire wear
- Refresh bike and turn boxes every 3 to 5 years due to tire wear



⁷ "Evaluation of Solid Green Bicycle Lanes, to Increase Compliance and Bicycle Safety," New York City Department of Transportation (2011).

⁸ "Evaluation of Blue Bike-Lane Treatment in Portland Oregon," Hunter, W.W. et al. (2000).

⁹ "Evaluation of a Green Bike Lane Weaving Area in St. Petersburg, Florida," University of North Carolina Highway Safety Research Center, (2008).

¹⁰ "Effects of Colored Lane Markings on Bicyclist and Motorist Behavior at Conflict Areas," City of Austin Texas, (2010).

¹¹ "Safety Effects of Blue Cycle Crossings: A Before-After Study," Accident Analysis & Prevention, (2008).

RED BIKE LANES

Red bike lanes have traditionally been used in Bend on higher speed, multi-lane roadways.

4 and 5 Lane Higher Speed Roadways - Problem Parking Encroachment Areas

Bend has found minor issues with motor vehicle encroachment (standing, parking, driving upon) in designated curb tight bike lanes. Standing vehicles use bike lanes as a location to dwell while taking/making a cell phone call while in the process of driving. This issue has increased since Oregon passed laws prohibiting driving and hand held cell phone use.



Figure 6 Greenwood Avenue

Parking in bike lanes is an issue on certain corridors adjacent to programmed playing fields, such as Mt. Washington Drive adjacent to the Skyline Sports Complex, SE 15th Street next to Ponderosa Park and NE 27th Street adjacent to Mtn. View High School. Driving upon bike lanes occurs along curves and at approaches to intersections.

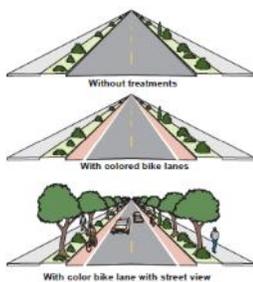


Figure 7 Colored Bike Lanes "Narrow" the Roadway

The use of red bike lane is proposed to be limited to 5 lane corridors, but may have limited use in other situations, such as on cycle tracks, or locations such as those described above near ball fields. Five-lane corridors in town typically have limited width and curb tight sidewalk. The visual contrast of a red bike lane can highlight the space for bicyclists as well as increase the sense of buffer for curb tight sidewalk next to higher speed and/or truck traffic.

Red Bike Lane Effectiveness:

- Reduces driver encroachment in the bike lane¹²
 - With Color/Without Color Comparison=7%/16%
- Fewer instances of driving in the bike lane¹³
 - With Color/Without Color Comparison=4%/7%
- Increases rider comfort and safety by reducing encroachments by motor vehicle traffic into the bike lane.

Red Bike Lane Maintenance:

- For maximum effectiveness refresh every 5 to 7 years.

¹² "Evaluation of Solid Green Bicycle Lanes, to Increase Compliance and Bicycle Safety," New York City Department of Transportation, (2011).

¹³ "Evaluation of Solid Green Bicycle Lanes, to Increase Compliance and Bicycle Safety," New York City Department of Transportation, (2011).

SEPARATED TRAILS

Trails are used for commuting, recreation and fitness and are an important part of a low-stress bicycling network. Roadway crossing treatments and accesses to the trail from the on-street bicycling facility network are key elements to a seamless integration.

Bend has a planned system of urban trails incorporated as part of the city's Transportation System Plan and includes rails with trails. The city has partnered with the Bend Park and Recreation District to implement and maintain these trails through an intergovernmental agreement.

Trails are implemented as land development occurs or along ditch rider roads along canals as agreements with the canal companies can be completed. The parks district periodically publishes the "Bend Urban Trails Map."

Here is a link to the Urban Trails Master Plan:

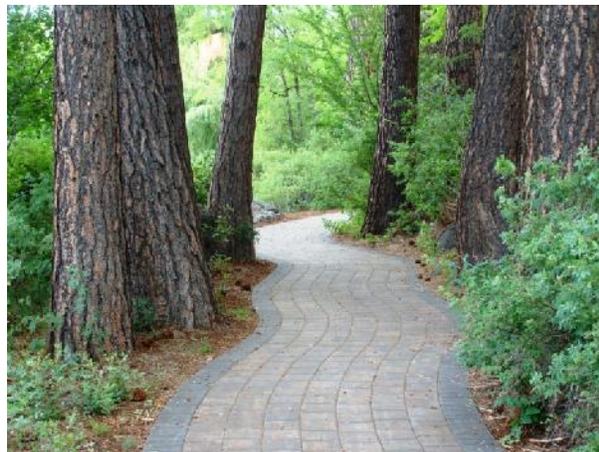
http://bendparksandrec.org/info/About_Us/Planning__Development/Bend_Urban_Trails_Plan/

Benefits of trails and trail crossings:

- Provides the lowest stress facility
- Increases bicycling ridership by providing ways for families and children to develop strong riding skills
- Attracts a broad range of riders
- Increase property values¹⁴
- Key to economic development as tourists are attracted to communities with strong urban trail systems.

Maintenance of trails and trail crossings:

- periodic surface conditioning
- periodic pavement marking and signing
- annual equipment maintenance for active warning beacons.



¹⁴ <http://www.uc.edu/news/nr.aspx?id=14300>, University of Cincinnati, "Little Miami Scenic Trail and property values in Hamilton County, Ranier Vom Hofe, Oliviere Parent, (2011).
<http://www.americantrails.org/resources/adjacent/sumadjacent.html>,
<http://128.175.63.72/projects/DOCUMENTS/bikepathfinal.pdf>

ROADWAY, RIVER/CANAL CROSSINGS

Crossing Treatments

Bike facility crossings of roadways range from very simple at grade crossings to fully controlled crossings depending on traffic volumes and speed as well as available sight lines. Other times, it is not possible to simply cross the roadway at the immediate bike facility intersection with the roadway. In these situations, it may be necessary to route the bike facility along the roadway until there is a safe crossing.

Many traffic signals throughout the community have dropped the bike facility on the approach and departure side of the traffic signal, leaving a gap in the network and only serving the boldest of people riding bicycles who are required to merge into the moving traffic stream and act as a motor vehicle. Updating these signalized intersections to create low stress connections will expand the bicycling network and ridership.

What is the risk? Walking or biking along a roadway does not represent much risk as few crashes have occurred when traffic is moving parallel to each other. Crash data show that intersections and multi-lane roadway crossings present areas where crashes could occur and they occur most often on 3rd Street and Greenwood Avenue where multi-lane roadway crossings exist. At unmarked crossings national data and local data confirm that only 5 to 25% of drivers stop for a pedestrian at an uncontrolled/unenhanced crossing. Yielding rates are lowest on multi-lane roadways and lowest on higher speed facilities (35 mph or greater). There are tools that can be used to increase the yielding rate of drivers to the person crossing the roadway which are presented in the following sections.

In 2012, the Federal Highways Administration¹⁵ published a series of best practices aimed at improving safety for people walking and biking and driving. These best practices provide improved operations and safety of the facility and allow roadway crossings to be more readily performed by people on bikes or walking.

Additionally, the city has planned grade separated crossings on the Transportation System Plan of major roadways such as Hwy 20, Hwy 97, and Empire Avenue.

This section of Roadway/River/Canal Crossings covers the broad range of crossing types the city can use to facilitate safe and efficient crossings:

- ADA Ramps
- Pavement Markings and High Visibility Signage
- Medians/pedestrian crossing islands
- Beacons
- roundabouts
- treatments at traffic signals (bike boxes, dutch bike lanes, bike signal)
- routing out of direction to a nearby crossing

¹⁵ Federal Highway Administration (FHWA), "[safety.fhwa.dot.gov/provencountermeasures.](https://safety.fhwa.dot.gov/provencountermeasures/)"

- road diets
- grade separated over or under crossings.

Curb Ramps

Curb ramps provide a transition from sidewalk level to roadway level and are used at each roadway crossing. Ramps are legally required at intersections by the Americans with Disabilities Act. The ramps therefore have very specific design features such as running grade, cross slope, detectable warning devices, and landings as detailed in the Public Rights of Way Accessibility Guidelines. Additionally, it is important to note that these ramps are used by everyone that crosses a street including people with bicycles, strollers, or skateboards. A set of curb ramps is the minimum feature every street crossing will have in common.

Benefits of Curb Ramps:

- facilitates the transition from sidewalk grade to street grade
- meets ADA requirements
- expands the use of the system to a broad range of users

Maintenance of Curb Ramps:

- initial installation costs range from \$2,500 to \$3,500 depending on the complexity
- detectable warnings need to be replaced every 7 to 10 years at a cost of \$1,000 depending on installation technique
- periodic review of compliance to the technical requirements of grade, slope, etc. due to pavement heaving and/or sidewalk cracking.

High Visibility Pavement Markings and Signage

Sometimes it is necessary to further delineate a roadway crossing with pavement markings and signage. Factors considered are speed, volume and number of lanes on the roadway, sight lines to the crossing, how expected the crossing is to the driver, as well as volume of people crossing the roadway. Depending on conditions, it may not be safe to just implement pavement markings and signage – certain volume and roadway characteristics require markings and signage to be paired with median refuge and/or active beacons.

Illumination is an important factor in reducing crashes during low light conditions. Installing illumination on either approach to the crossing allows the pedestrian to be front lit and more visible to the driver.

Benefits of Markings and Signage:

- Yielding rates of motorists to pedestrian is 17%¹⁶ for posted speeds of 35 mph
- Yielding rates of motorists to pedestrian is 61%¹⁷ for posted speeds of 25 mph

¹⁶ *“Improving Pedestrian Safety at Unsignalized Crossings,”* Transit Cooperative Research Program, Report 112, Federal Transit Agency (2006)

¹⁷ *“Improving Pedestrian Safety at Unsignalized Crossings,”* Transit Cooperative Research Program, Report 112, Federal Transit Agency (2006)

- Attracts people to a particular crossing.

Maintenance of Markings and Signage:

- Initial marking and signing installation costs¹⁸ are approximately \$2,000 to \$5,000.
- Periodic refreshing of pavement markings due to weather and tire wear and wear from maintenance operations (street sweeping/snow plowing), typically every 2 to 3 years.
- Periodic sign upgrade for reflectivity, typically every 15 to 20 years.
- Illumination costs will depend on the proximity to the power source and need for transformers but generally cost \$12,500 per luminaire (\$25,000 per crossing)¹⁹.

Medians/pedestrian crossing islands



Medians can be used when there are limited gaps in traffic or when there are multiple lanes of traffic to cross in each direction. Oregon Bicycle and Pedestrian Guide notes that medians should be considered the first option on multi-lane, two way roadways²⁰.

Safety is greatly enhanced with the addition of medians and the FHWA has identified medians as a proven countermeasure to crashes on multi-lane roadways. FHWA strongly encourages the use of raised medians in curbed sections of multi-lane roadways in urban and suburban areas, particularly in areas where there are mixtures of a significant

number of pedestrians, high volumes of traffic (more than 12,000 vehicles per day) and intermediate or high travel speeds.

Benefits of Medians/pedestrian crossing islands:

- Allow crossing of one direction of traffic at a time
- minor reduction in vehicle speeds on the roadway²¹
- Yielding rates range from 7% to 75% (depending on speed and number of lanes)²²
- Pedestrian safety is enhanced 39% for unmarked crossings with medians over those without medians²³
- Pedestrian safety is enhanced 46% for marked crossings with medians over those without medians²⁴.
- Mid-block medians enhance pedestrian safety 25%²⁵

¹⁸ Oregon Pedestrian and Bicycle Safety Implementation Plan, ODOT, (2014)

¹⁹ Oregon Pedestrian and Bicycle Safety Implementation Plan, ODOT, (2014)

²⁰ "Oregon Bicycle and Pedestrian Guide," ODOT, (2011)

²¹ "xxx," King, et al. (2003)

²² "Improving Pedestrian Safety at Unsignalized Crossings," Transit Cooperative Research Program, Report 112, Federal Transit Agency (2006)

²³ "xxx," Lindley, (2008)

²⁴ "xxx," Lindley, (2008)

²⁵ ODOT Pedestrian and Bicycle Safety Implementation Plan, (2014)

- Lighting is anticipated to improve safety 25% for all nighttime crashes²⁶

Maintenance of Medians/Pedestrian Crossing Islands:

- Initial median installation costs²⁷ are approximately \$5,000 to \$30,000
- Periodic cleaning with hand brooms to remove accumulated debris

Active Beacons

There are two state of the practice devices that have been demonstrated to increase safety of roadway crossings and increase driver yielding rates into the upper 90 percentile range. These are the LED Rectangular Rapid Flashing Beacon (RRFB) and the Hybrid Beacon (sometimes called a HAWK for High Intensity Activated CrossWalk Beacon).



Figure 8 RRFB with LED Stutter Flash

The RRFB uses a yellow/amber LED Stutter flash in a wig wag pattern. The city and ODOT have installed this device on the Parkway at Reed Lane and Badger Road and on Greenwood Avenue at 12th Street. There is no Walk-Don't Walk signal and an audible messages states that vehicles may not stop.

The Hybrid Beacon uses a signal layout in the Mickey Mouse Head and utilizes both and red phases. The Hybrid Beacon is paired Walk pedestrian signal and provides more pedestrian. Both of these devices are active (and are dark until an activation occurs).

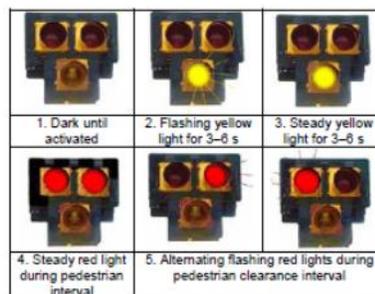


Figure 9 Hybrid Beacon Operating Sequence

shape of a yellow/amber with Walk-Don't guidance to the when present

Benefits of Active Beacons:

- Yielding rates of motorists to pedestrians for LED RRFB Beacon was 82.9%²⁸
- Yielding rates of motorists to pedestrians for Hybrid Beacons was 97%²⁹

Maintenance of Active Beacons:

- Initial costs are approximately \$26,000 for Rectangular Rapid Flash Beacons and \$100,000 for Hybrid Beacons
- Periodic maintenance includes annual electronic equipment review and maintenance which requires a specialized technician. ODOT is under contract for annual maintenance as the city of Bend does not have certified technicians at this time.
- Period maintenance of signs and pavement markings.

²⁶ Oregon Pedestrian and Bicycle Safety Implementation Plan, ODOT, (2014)

²⁷ Oregon Pedestrian and Bicycle Safety Implementation Plan, ODOT, (2014)

²⁸ "Assessment of Driver Yielding Rates Pre- and Post-RRFB Installation, Bend, Oregon," Ross, June, Serpico, Daniel, Lewis, Robin, ODOT, (2011)

²⁹ "Improving Pedestrian Safety at Unsignalized Crossings," Transit Cooperative Research Program, Report 112, Federal Transit Agency (2006)

Roundabouts³⁰

Roundabouts in Bend Oregon have been successful at creating safe, attractive multimodal crossings of arterial and collector roadways. The Federal Highways Administration has identified roundabouts as one of 9 safety countermeasures for their ability to increase safety of all users. Bend has identified roundabout pedestrian crossings as the safest crossing in the community.

Roundabouts simplify crossings by incorporating median pedestrian refuges to allow each direction of traffic to be crossed separately. Crash data indicate that roundabouts have little to no crash experiences between vehicles and people walking or biking. Bend has been installing roundabouts since 1999 and there are currently more than 25 in place. The city of Bend typically considers roundabouts at the intersection of an arterial/collector intersection and does not usually place a roundabout at a local street intersection with an arterial/collector roadway due to the initial and on-going maintenance costs as well as the potential for induced cut-through traffic on the local street attracted to the route because of the roundabout.

The FHWA has included roundabouts as one of their proven crash countermeasures for increasing safety at intersections for all modes of traffic.

FHWA is currently studying the operational and safety effects of mini-roundabouts. These circular intersection forms have similar geometric features of the roundabout, same operational platform, except that large vehicles may traverse over the entire central island to maneuver through the intersection. Preliminary safety and operations review indicates high safety and twice the capacity of an all-way stop controlled intersection (approaching similar capacities of standard modern roundabouts) when there are few semi-tractor trailers. Mini-roundabouts have the advantage of being installed in shorter time (9 to 20 days) and can be readily retro-fit into existing intersections.

Benefits of Roundabouts:

- Driver yielding rate to people crossing 83%³¹
- Slower speeds
- Safe and efficient movement of people

Maintenance of Roundabouts:

- initial roundabout costs can be expensive ranging upwards of \$1 to \$2 million (mini roundabouts \$20,000 to \$120,000).
- periodic maintenance of crosswalk pavement markings and signage

Treatments at Traffic Signals³²

Traffic signals themselves can be used to facilitate roadway crossings. Signals in Bend Oregon have been successful at creating safe multimodal crossings of arterial and collector roadways. Signals simplify crossings by incorporating Walk-Don't Walk signaling for the

³⁰ City of Bend, Multimodal Traffic Safety Program Report 2006-2010 Crash Data Assessment (2012).

³¹ Evaluating Pedestrian and Bicyclist Risk in Minnesota Roundabouts, (2012).

³² City of Bend, Multimodal Traffic Safety Program Report 2006-2010 Crash Data Assessment (2012).

pedestrian. Crash data indicate that signals in Bend, however, do have more crash experiences between vehicles and people walking or biking than roundabouts. There are just a couple of distinct crash types including: pedestrians crossing during the Walk phase while there is a programmed conflicting green phase for a right or left turning vehicle; and straight bicycle movements conflicting with right or left turning vehicle movements (primarily right hook crashes were noted at a few locations). Crash numbers were relatively low for even these crash types with a handful occurring throughout the community over the course of a 5 year data study.

There are currently more than 50 traffic signals in place in Bend. The city of Bend typically considers traffic signals at the intersection of an arterial/collector intersection and does not usually place a traffic signal at a local street intersection with an arterial/collector roadway due to the initial and on-going maintenance costs as well as the potential for induced cut-through traffic on the local street attracted to the route because of the traffic signal.

Older signals in Bend, however, are often without bike lanes or bike facilities to allow safe, accessible usage by people on bicycle. Retro-fitting these facilities with the following devices will be important as the city implements the Strategic Implementation Plan for bikeways to be Safe, Accessible, Fun and Easy.

Benefits of Traffic Signals:

- Provides a controlled crossing
- Turning drivers yielding to pedestrians range from 50 to 82%³³

Maintenance of Traffic Signals:

- Annual maintenance of electronic components
- Periodic maintenance of signage and pavement markings

Bike Boxes

A bike box is a designated area at the head of a traffic lane at a signalized intersection that provides bicyclists with a safe and visible way to get ahead of queuing traffic during a red signal phase.

The Bike Box is not currently an allowed traffic control device in the FHWA Manual of Uniform Traffic Control Devices. FHWA has allowed a handful of cities to experiment with this device under their guidance in a controlled experiment³⁴. Portland, Oregon is one city participating in the experiment. Bike boxes may be created with white retroreflective striping and can be colored green for added emphasis. Color can enhance the effectiveness of the box.

Bike boxes are aimed at reducing right turn hook crashes for people on bike at traffic signals by providing a location at the top of a queue that a person on a bike could occupy during the

³³ "Pedestrian Safety Engineering and ITS-Based Countermeasures Program for Reducing Pedestrian Fatalities, Injury Conflicts, and Other Surrogate Measures Final System Impact Report," FHWA, (2001).

³⁴ Experiment No. 9-105(E), Colored Bike Lanes and Bike Boxes, Office of Transportation Operations, FHWA, (2008).

red phase. Experiment results indicate that crashes during the red phase (right turn on red) and at the startup of the green phase have been reduced.

Benefits of Bike Boxes:

- Provides a safe location for bicyclists to occupy during the red phase of a traffic signal, placing the person directly at the head of the queue, in front of motor vehicles.
- Reduces right hook crashes during startup of green phase.
- 98% of motorists yield to cyclists even while being overtaken by bicyclists³⁵



Figure 10 Bike Box

Maintenance of Bike Boxes:

- Initial installations are approximately \$10,000 per location depending on materials
- Periodic pavement marking and signing maintenance.

Intersection Painted Conflict Areas and Crossing Islands

Some intersections have difficult geometry due to number of traffic lanes, number of intersecting streets, or width of crossing. It is possible to enhance safety by delineating the path of travel desired for the bicyclist to utilize to maneuver through the intersection.

Maintenance of Painted Conflict Areas:

- Installations are approximately \$10,000 per location depending on materials
- periodic pavement marking maintenance.

Benefits of Painted Conflict Areas:

- user comfort and predictability
- reduced crashes at conflict points by 39%³⁶

³⁵ "Progress Report: Request to Experiment 9-105(E) Colored Bike Lanes and Bike Boxes," Portland, Oregon, (2012).

³⁶ Oregon Pedestrian and Bicycle Safety Implementation Plan, ODOT, (2014).

Dutch Bike Lane/Right Turn Lane at an Intersection

This is a geometric solution to requiring bicyclists to traverse across an added right turn lane. In this countermeasure, the bike lane is allowed to remain to the right of a right turn lane, while the right turning motorist is directed around an island for their right turn. The result is that the bicyclist and the motorist conflict point is now a 90 degree perpendicular crossing. The desire is to allow a face to face conflict, so that both the bicyclist and the motorist can communicate. The dutch style may result in a more comfortable bike facility because it eliminates the weaving movement of a person on a bike with a motorist entering the right turn lane.



Figure 11 Dutch bike lane/right turn lane

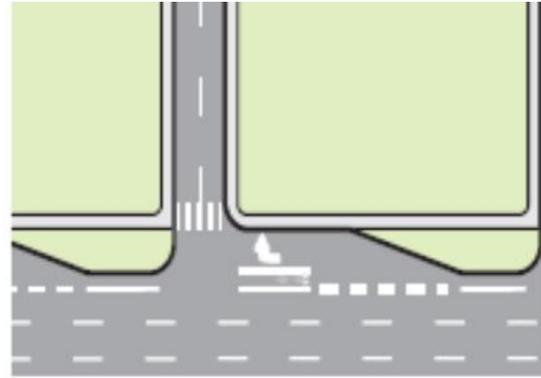


Figure 12 Traditional US bike lane/right turn lane weave

Benefits of Dutch Bike Lane/Right Turn Lane:

- Improved comfort for bicyclist
- Provides better visibility of the conflicting maneuver
- May enhance safety

Maintenance of Dutch Bike Lane/Right Turn Lane:

- Periodic maintenance of pavement markings

Two Stage Turn Queue Box

Two-stage turn queue boxes offer people on bikes a safe way to make left turns at multi-lane signalized intersections from a right side bikeway. May also be used at mid-block crossing locations to get bicyclists properly oriented for a safe crossing.



Figure 13 Two-Stage Turn Queue Box

Benefits:

- Creates a comfortable left turn in situations where it is difficult to maneuver from a right-hand-side bike lane across faster, heavier traffic or multiple lanes to the left turn lane.

Maintenance of Two-Stage Turn Queue Box

- Periodic maintenance of pavement markings.

Bike Phase at Signal

At a traffic signal with high volume conflicting flow, straight-through bike and right turn traffic needs to be separated by time with a phase of a traffic signal assigned to each movement. This is an efficient way of handling very high volumes. The signal head is typically a 3 section head with green, yellow, and red lenses each having a bike outline over the lens. There is typically bike signal signs associated with the signal head. Along contra-flow bike lanes on one-way streets, the bike signal head is necessary to control flow when there would not normally be a signal head. At times, bicycle crossings of arterial streets may be co-located with pedestrian crossings. Rather than providing information to the bicyclist via the pedestrian Walk-Don't Walk signal head, a bike signal head can improve visibility and understanding.

Benefits of a separate bike phase at a traffic signal:

- Provides separate movements for conflicting flows.
- can provide leading bicycle intervals.
- Allows simplification of complex bike movements.

Routing Out of Direction to a Nearby Crossing

At times, trails or other facilities intersection with busier arterial or collector roadways in close proximity to an existing enhanced crossing. Depending on traffic conditions, sight lines and distance, it can be beneficial to provide a route diversion of the trail up to the enhanced crossing and back to the trail alignment. Traffic conditions may be speed, volume or number of lanes to cross or vehicle queuing. Safety and compliance are two elements that need to be considered as the design is being implemented.

Benefits of routing out of direction to a Nearby Crossing:

- Safety
- Connectivity

Road Space Optimization

The most common space optimization takes a 4-lane undivided roadway and redistributes the roadway to one travel lane in each direction, a center turn lane, and two bike lanes. Space optimizations have safety, operational and livability benefits. FHWA has identified space optimization as a proven countermeasure to improve the safety of a road for all users including abutting property owners. In many cases, the road carries as much traffic with fewer lanes, but does so with better performance considering business owners, people on bikes, and people crossing the roadway. A person attempting to cross a four lane roadway must receive a gap from four separate traffic streams, concentrate on potential lane changes, and be aware that one lane of stopped traffic will block the view to the second lane of moving traffic. Because left

turn lanes do not exist, a driver turning left may cause through movement delay as advancing vehicles wait to proceed.

When the city examined crash data on Greenwood Avenue between Bond and 2nd Street common crash types included:

- rear end crashes (for those attempting to turn left)
- sideswipe crashes
- left turn crashes
- sidestreet crossing Greenwood Avenue crashes
- pedestrian street crossing crashes
- wrong-way bike riding crashes (typically on the sidewalk due to no bike lane).

These were the only crashes noted on this roadway. Each of these crash types can be counteracted with a road diet. Rear end crashes and sideswipe crashes are counteracted with the center left turn lane. Left turn crashes were occurring when a vehicle turned left across the first of two traffic lanes and was hit in the second traffic lane. With only a single opposing traffic lane, left turns are easier to judge and execute. Sidestreet crossing crashes would be counteracted by fewer traffic streams to judge and a narrower roadway crossing. Pedestrians would be able to cross one lane of traffic at a time, possibly with the benefit of a median being able to be constructed. With a bike lane, wrong way sidewalk ridership will decrease.

Livability benefits of a space optimization include:

- Greater separation from moving traffic for pedestrians
- Enhanced room for street furniture and landscaping with curb extensions around on-street parking
- on-street parking can remain or be implemented
- increased bike ridership
- Reduces bicycle crashes 41%³⁷

Grade Separated Over or Under Crossings

Depending on traffic volumes, speeds, and the number of travel lanes, it may not be practical or safe to require the arterial or highway to stop to accommodate people crossing at a bikeway or walkway.

The city's transportation system plan identifies grade separated over or under crossings.

³⁷ Oregon Pedestrian and Bicycle Safety Implementation Plan, ODOT, (2014)

BIKE SIGNALS

Active Warning Beacons for bike route crossings of busy streets

Hybrid Beacons for bike route crossings of busy streets

Bicycle Signal Heads and separated Phases at a signalized intersection

Signal Detection and Actuation

These devices usually are implemented when speeds and/or volumes are such that conflicting movements need more active control or guidance to facilitate adequate safety or convenience.

Active Warning Beacons

These beacons warn traffic of crossing activity but do not control traffic. Their beacons flash yellow in a rapid flash, wig-wag, strobe pattern and are activated by a user. They are not static flashing devices.

The city of Bend has utilized Active Warning Beacons at locations where walking and biking facilities cross 4 and 5 lane high speed arterial roadways or highways. Beacons are currently installed on Greenwood at NE 12th Street, Hwy 97/Parkway at Reed Lane, Hwy 97/Parkway at Badger Lane.

Benefits of Active Warning Beacons:

- Typically less expensive than the Hybrid Beacon and other full signals³⁸
- Driver yielding increases up to 93 to 97%.³⁹

Active Warning Beacon maintenance:

- Annual maintenance of power, equipment.
- Periodic maintenance of markings and signage.

Hybrid Beacons

This beacon is different than warning beacons in that they actually control traffic by utilizing red traffic signals. They are activated by a user and are not static devices. The device is set up as two red lenses over a single yellow lens. The signal head directs and faces only the busy street. Side street traffic is unable to be controlled or operated by this device. The side street user must be a person walking or biking who activates the device. The person walking or biking sees a walk/bike signal indication. Their operations pattern includes a flashing yellow phase a flashing red phase, and a steady red phase. The device rests in dark (no signal indication).

Benefits of a Hybrid Beacon

- Since there is no signal to help side street motor vehicle traffic access the arterial street, there is no induced cut-through traffic.
- Creates gaps for a person on a bike or walking to cross a busy street.

³⁸ "Interim Approval for Optional Use of Rectangular Rapid Flashing Beacons," Federal Highway Administration, (2008).

³⁹ "Efficacy of Rectangular-shaped Rapid Flash LED Beacons," Houten, R.V., Malenfant, L., (undated).

- Does not need to be activated if adequate gaps in traffic exist, such as at off-peak time periods.
- High compliance rates, exceeding 94%⁴⁰
- Reduces crossing crashes by 69%⁴¹

Hybrid Beacon Maintenance:

- Annual signal equipment and power maintenance.
- Periodic maintenance of signage and markings.

Bicycle Signal Heads

A bicycle signal is typically a separate phase of a traffic signal that separates a conflict in time rather than space. This allows bike lanes to remain to the right of a heavy right turn lane, and eliminate the need to weave the bike lane across the right turn traffic.

Portland Oregon has installed several bicycle phases on their traffic signals. Designs are available and have been reviewed and approved by the Oregon Traffic Control Devices Committee.

Bike Signal benefits:

- Simplifies bicycle movements through complex intersections
- Accommodates contra-flow movements that otherwise would have no signal indication (contra-flow bike lanes on one way streets).
- Improves comfort of bicyclist by eliminating difficult weaving movements.

Signal Detection and Actuation

At traffic signals, active warning beacons, or hybrid beacons, calls for service need to be provided to the controller. Activation is usually push button or passive detection. Passive detection can be in the form of video, inductive loop detectors, micro-wave, or other forms. Zones sensitive enough to identify a bicyclist are necessary. Notifying the bicyclist where the detection zone is located can be done through pavement markings.



Figure 14 Bike Detection Zone at Signal

⁴⁰ "Improving Pedestrian Safety at Unsignalized Crossings," National Cooperative Highway Research Program Report 112/562, Transportation Research Board, Washington, D.C., (2006).

⁴¹ "Safety Effectiveness of the HAWK Pedestrian Crossing Treatment," Federal Highway Administration Publication No. FHWA-HRT-10-042, (2010).

Benefits of Bike Detection/Activation:

- Improves efficiency and reduces delay,
- Discourages red light running for people on bikes,
- Can be used to prolong green phase or other priority phasing programs.

Maintenance of Detection/Actuation:

- equipment maintenance is typically performed with annual signal maintenance
- periodic pavement marking or sign maintenance.

SHARROWS

Use when traffic is designed to mix with motor vehicle traffic in a shared lane.



Figure 15 Sharrow with On-Street Parking

Shared narrow lane markings indicate a shared space in the roadway, where both motor vehicles and bicycles share the lane. Their use is typically limited to low speed (20 to 30 mph) arterial and collector roadways that are required to have bikeways on them but have limited width. Typical applications are in narrow tunnels where there is insufficient width to have side by side facilities. Other examples include roadways with on-street parking, when the on-street parking is not able to be removed for bike lanes.

For roadways with parallel on-street parking sharrows are placed so that people riding bikes are encouraged to ride outside of the door zone for parked vehicles. They have been shown to encourage an additional 1' spacing of bicycle positioning to parked cars. This positioning typically also results in long durability for the marking which are outside of the wheel path of motor vehicle traffic.

For roadways with head in/back out angle on-street parking, and for tunnels or narrow bridges, sharrows are typically placed in the center of the travel lane to allow backing vehicles greater sight distance to see conflicting bicyclists. This placement is outside of the wheel paths and results in long durability of marking.

It is desirable not to use sharrows for unfinished roadways that do not have their bike lanes constructed. These roadways are typically those the city inherited from the county that have limited roadway paved width and are striped for narrow auto lanes only. Examples include portions of Brosterhous and Simpson Avenue.

Sharrow Benefits:

- Reduced the incidence of wrong way riding 80%⁴²
- Reduced sidewalk riding 6%⁴³
- Motorists provide up to 2' more space for bicyclists⁴⁴

Maintenance of Sharrows:

- most likely as often as bike lane symbols, depending on wear due to placement and wheel positioning.

⁴² "San Francisco's Shared Lane Pavement Markings: Improving Bicycling Safety," San Francisco Department of Parking and Traffic, (2004).

⁴³ "Evaluation of the Shared Use Arrow," Florida Department of Transportation," (1999).

⁴⁴ "San Francisco's Shared Lane Pavement Markings: Improving Bicycling Safety," San Francisco Department of Parking and Traffic, (2004).

BIKE BOULEVARDS

A Bike Boulevard is a local street, typically residential, that is enhanced to improve bicycling conditions. Key features which make these facilities attractive to a broad range of users are their slow speeds, continuous flow, and safe/comfortable crossings of busier streets. The objective of implementing a network of bike-friendly local streets is to increase accessibility of the bicycling network to more citizens of Bend.

The main feature of a Bike Boulevard is a formal and systematic implementation of speed and volume management. To this end, these roadways typically have frequently spaced traffic calming devices to regulate motor vehicle speeds and reduce cut through traffic; no stop signs (in order to keep people moving on their bicycles); and enhanced crossings of busier streets. Speed management devices need to be developed with emergency service provider input.



Figure 16 Raised Pedestrian Crossing/Speed Table

Oregon has adopted a statutory speed of 20 mph for residential streets with volumes less than 2,000 vehicles per day, and an 85th percentile speed less than 30 mph when they are enhanced as bicycle boulevards.

Bike Boulevard Benefits:

- decreases motor vehicle speeds up to 8.9 mph⁴⁵
- increases people on bikes up to 87%⁴⁶
- increases safety by increasing driver response time available to avoid collisions
- lower collision rates⁴⁷
- minimizes the number of automobiles which overtake a bicycle
- decreases the likelihood of injury⁴⁸
- increases livability on local residential streets by discouraging through vehicle traffic.

Bike Boulevard Maintenance:

- impacts to street sweeping and snow plow operations,
- typical periodic signing and striping maintenance.



Figure 17 Raised Intersection+Mini Roundabout Speed Management

⁴⁵ "U.S. Traffic Calming Manual," Ewing (2009)

⁴⁶ "Traffic Calming: State of the Practice," Baoouina and Robinson, (1990, 1999).

⁴⁷ "Cyclist Safety on Bicycle Boulevards and Parallel Arterial Routes in Berkely, California," Minikel, E. (2011).

⁴⁸ "Impact Speed and a Pedestrian's Risk of Severe Injury or Death," AAA Foundation for Traffic Safety (2011).

WAY FINDING

Way finding signs identify routes and route choices to cultural or civic sites. The signs usually identify distance and time in minutes, can be used for branding a route or series of routes with a name/logo rather than a very generic “bike route” identifier.

Way finding signs provide an outreach tool to help new users, teach best routes and increase comfort for tourists unfamiliar with the area. Advances in smart phone technology may allow signs to be virtual.

A rating system for the route may be incorporated to indicate stress level or physical challenges. Similar to ski trail green, blue and black rating system, busier streets or steeper routes may be rated differently than neighborhood bike boulevards or shared use paths.

Way finding signage would be appropriate along roadway bikeways and neighborhood bicycle boulevards in Bend.



Figure 18 Example Way Finding Signs

Way Finding Sign Benefits:

- Increases rider comfort by providing route information
- Identifies best routes to destinations
- Overcomes a ‘barrier to entry’ for infrequent riders
- Helps drivers remember people on bikes may be present
- Promotes route to potential users by branding the route, and identifying how quickly the destination can be reached by bike

Maintenance of Way Finding Sign Benefits:

- Periodic maintenance of signs and markings
- Periodic review and update of destinations.

BIKE CORRAL PARKING

End of trip amenities such as bicycle parking complete the attractiveness and comfort of the system. While individual businesses are typically required to provide on-site bicycle parking, the nature of any individual business or group of businesses may lead to more group parking needs.

Areas such as downtown, Old Mill District, or individual restaurants, amphitheaters, etc. usually attract larger groups traveling together. It is usually more difficult to find several bike parking stalls together. For example, if a family of 5 bikes to downtown there is a need for five separate bike parking stalls. If the family needs to split up to find secure parking, the fun of the trip may be dampened.

Bike Corral parking may be located in underutilized public areas, on private property, or within the roadway. The key will be to find available space that will meet security and convenience factors. The city has cataloged and mapped existing bike parking locations throughout the downtown district. Next steps will be the identification of additional demand and opportunity locations to install additional parking.



Figure 19 Bike Corral Thump Coffee

Benefits of Bike Corral Parking:

- increases convenience of individual and group parking,
- efficiently uses public and private space,
- maximizes parking available to customers.
-

Maintenance of Bike Corral Parking:

- winter maintenance to keep parking clear may require agreements with private entities,
- periodic pavement marking or signing maintenance.

