APPENDIX B:
INFRASTRUCTURE TOOLKIT

Appendix B - Infrastructure Toolkit

This chapter contains guidance on the following:

Introduction

This toolkit includes a description of best practices for the development of bicycling infrastructure. The tools and approaches included are based on a survey of national applications and case studies, and provide guidance for improvements to street cross sections, intersections, and signals. This toolkit should not be the only resource to determine appropriate measures or infrastructure. Rather, it is part of an overall planning and engineering toolbox that includes the requirements and guidelines of state and local best-practices.

The following is a list of resources for bicycle and pedestrian infrastructure design and planning:

- Wisconsin Traffic Engineering, Operations and Safety Manual
- Wisconsin Manual on Uniform Traffic Control Devices (WMUTCD)
- Wisconsin Bicycle Facility Design Handbook
- Wisconsin Bicycle Planning Guidance
- Wisconsin Guide to Pedestrian Best Practices
- NACTO (National Association of City Transportation Officials)
- AASHTO (American Association of State Highway and Transportation Officials)

Facility Design and Selection Tables

Tables B.1-3 and Figures B.1-2 may be referenced when investigating new routes and crossing improvements in Lannon related to bicycle facilities. The following Bikeways Design Selection Tables were developed using a combination of reference with best-practice standards presented by MnDOT, WisDOT, NACTO, and AASHTO, as well as direct guidance from the Village of Lannon Engineer. Widths specified below are *minimum* recommended widths. Buffered bicycle lanes and protected bicycle lanes are recommended along primary routes whenever space permits. In addition, four lane roads with fewer than 25,000 ADT are ideal candidates for road diets: four-to-three lane conversion with potential bicycle lanes added.

Table B.1 - Bikeways Design Selection for Rural (Shoulder/Ditch) Cross Section - Adapted from multiple sources* for Lannon, WI****

Motor Vehicle ADT (2 Lane)		<500	500-1,000	1,000-2,000	2,000-5,000	5,000-10,000	>10,000
Motor Vehicle ADT (4 Lane)		N/A	N/A	2,000-4,000	4,000-10,000	10,000-20,000	>20,000
Motor Vehicle Speed	25 MPH	4' PS or SLM	4' PS or SLM	4' PS	4' PS	5' PS or SUP	5' PS or SUP
	30 MPH	4' PS or SLM	4' PS	4' PS	4' PS	5' PS or SUP	5' PS or SUP
	35-40 MPH	5' PS or SLM	5' PS	5' PS	5' PS min.; 6' PS preferred	6' PS or SUP	6' PS or SUP
	45 MPH and greater	5' PS	5' PS	5' PS	5' PS min.; 6' PS preferred	6' PS or SUP	SUP

PS= Paved Shoulder; SUP= Shared Use Path; SLM = Shared Lane Marking

Table B.2 - Bikeways Design Selection for Urban (Curb/Gutter) Cross Section - Adapted from multiple sources* for Lannon, WI****

Motor Vehicle ADT (2 Lane)		<500	500-1,000	1,000-2,000	2,000-5,000	5,000-10,000	>10,000
Motor Vehicle ADT (4 Lane)		N/A	N/A	2,000-4,000	4,000-10,000	10,000-20,000	>20,000
Motor Vehicle Speed	25 MPH	NSS or SLM	SLM	SLM	NSS or 5' BL	5' BL	SUP
	30 MPH	NSS or SLM	NSS	NSS	5' BL	5' BL	6' BL or 5' BL + 2' BuL
	35-40 MPH	5' BL	5' BL	5' BL	5' BL	5' BL + 2' BuL or PBL	6' BL + 2' BuL and SUP or PBL
	45 MPH and greater	5' BL	5' BL	5' BL	5' BL + 2' BuL	5' BL + 2' BuL or PBL	SUP or PBL

NSS=Neighborhood Slow Street***; BL=Bicycle Lane**; BuL=Buffer Lane*****; PS= Paved Shoulder; SUP= Shared Use Path; SLM = Shared Lane Marking; PBL=Protected Bicycle Lane*****

*Adapted from MnDOT Bikeways Facility Design Manual, Wisconsin Bicycle Facility Design Handbook, AASHTO, and NACTO guides, as well as through direct guidance from the Village of Lannon Engineer.

** Bicycle lane widths do not include the width of adjacent gutter pan.

***Preferred ADT for neighborhood slow streets is below 3,000. Neighborhood slow streets are not recommended for 4 lane roadways.

****While bicycle lanes with minimum widths are presented here as recommendations, consideration should be made about whether an on-street facility with greater protection/separation from vehicles (such as buffered or protected bicycle lanes) is warranted based on local road conditions, destinations, and expected and desired bicycle ridership. Where possible, the highest level of separation between bicyclists and motor vehicles is preferred; the dimensions and facilities shown in this table are suggested minimum widths and facilities.

*****Where possible, protected bicycle lanes should be integrated with a buffer. See page B-8 for a description of protected bicycle lanes

Table A.3 - Criteria for Crossing Treatments at Uncontrolled Locations*

Roadway Configuration	# of lanes crossed to reach a refuge (1)	# of multiple threat lanes per crossing (2)	Roadway ADT and Posted Speed															
			1,500 – 9,000 vpd				9,000 – 12,000 vpd				12,000 – 15,000 vpd				>15,000 vpd			
			≤ 30 mph	35 mph	40 mph	≥ 45 mph	≤ 30 mph	35 mph	40 mph	≥ 45 mph	≤ 30 mph	35 mph	40 mph	≥ 45 mph	≤ 30 mph	35 mph	40 mph	≥ 45 mph
2 Lanes (two way street, no median)	2	0	A	B	C	E	A	B	C	E	B	B	C	E	B	C	C	E
2 Lanes w/ Raised Median	1 or 2	0 to 1	A	B	C	E	A	C	D	E	B	C	D	E	C	D	D	E
3 Lanes w/ Striped Median	3	0 to 1	C	C	D	E	C	C	D	E	C	C	D	E	C	D	D	E
4 Lanes (two way street, no median)	4	2	A	D	D	E	B	D	D	E	B	D	D	E	D	D	D	E
4 Lanes w/ Raised Median (5 Lanes w/ turn lanes)	2 to 3	2	A	B	D	E	B	C	D	E	B	C	D	E	C	C	D	E
6 Lanes (two way street with or without median)	3 to 6	4	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F

NOTES: Painted medians shall not be considered a refuge for a crossing pedestrian. Similarly, a four-foot wide raised median next to a left turn lane can only be considered a refuge for pedestrians if the left turning volume is less than twenty vehicles per hour (meaning that in most cases the left turn lane is not occupied while the pedestrian is crossing). A multiple threat lane is defined as a through lane where it is possible for a pedestrian to step out in front of a stopped vehicle in the adjacent travel lane (either through or turn lane).

Treatment Descriptions

A Install marked crosswalk
Specific Guidance: Install marked crosswalk with standard (W11–2) advance pedestrian warning signs; use S1–1 signs for School Crossing locations.

B Install marked crosswalk with enhanced road-side and in-roadway (bollard mounted) signs
Specific Guidance: Install marked crosswalk "State Law - Yield to Pedestrian" signs mounted on in-roadway bollards; use standard (W11-2) advance pedestrian warning signs; use S1-1 signs for School Crossing locations.

C Install marked crosswalk with enhanced signs and geometric improvements to increase pedestrian visibility and reduce exposure
Specific Guidance: For 2 or 3-lane roadways, install marked crosswalk with "State Law – Yield to Pedestrian" signs mounted on in-roadway bollards or median mounted signs or overhead (R1–9) signs; use standard (W11–2) advance pedestrian warning signs; use S1–1 signs for School Crossing locations. Add neckdowns or median refuge islands to shorten the pedestrian crossing distance and increase pedestrian visibility to motorists.

D Install marked crosswalk with enhanced signs, user activated RRFBs, and geometric improvements to increase pedestrian visibility and reduce exposure.
Specific Guidance: Install raised median refuge island (unless it is a one-way street or one already exists) to shorten the pedestrian crossing distance and increase pedestrian visibility to motorists. [If a median refuge cannot be constructed on a two-way street, go to Scenario F]. Install marked crosswalk with "State Law - Yield to Pedestrian" signs WITH pedestrian activated RRFBs mounted on the side of the roadway and on median mounted signs; use standard (W11-2) advance pedestrian warning signs; use S1-1 signs for School Crossing locations. Consider adding neckdowns at the crossing if on-street parking exists on the roadway and storm drain considerations will allow. [Note: Implement when pedestrian volume is a minimum of 20 pedestrians in a single hour (young, elderly, and disabled peds count as 2x's the volume thresholds.) If pedestrian volume falls above the RRFB limit line in 5.2.2.b and 5.2.2.c, consider pedestrian hybrid beacon, pedestrian traffic signal, or grade-separated crossing.]

E Do not install marked crosswalk at uncontrolled crossing. Determine if the speed limit can be effectively reduced to 40 mph AND a raised refuge median can be installed. If so, utilize Scenario D criteria above. If this is not possible, or if pedestrian volume falls above the RRFB limit line on 5.2.2.b and 5.2.2.c, consider pedestrian hybrid beacon, pedestrian traffic signal, or grade-separated crossing.
Specific Guidance: Consider pedestrian hybrid beacon, pedestrian traffic signal or grade-separated crossing; application of these treatments will consider corridor signal progression, existing grades, physical constraints, and other engineering factors.

F Do not install marked crosswalk at uncontrolled crossing with 3 or more THROUGH lanes per direction or where the speed limit is 45 mph and/or there is not a median refuge on a 5-lane crossing. Consider pedestrian hybrid beacon, pedestrian traffic signal, or grade-separated crossing.
Specific Guidance: Consider pedestrian hybrid beacon, pedestrian traffic signal or grade-separated crossing; application of these treatments will consider corridor signal progression, existing grades, physical constraints, and other engineering factors.

*Adapted from the 2011 City of Boulder, CO Pedestrian Crossing Treatment Installation Guidelines (updated in 2025)

Figure B.I - Guidelines for the Installation of Pedestrian Hybrid Beacons (PHB), Pedestrian Signals, or Rectangular Rapid Flash Beacon (RRFB) Signs on Low-Speed Roadways*

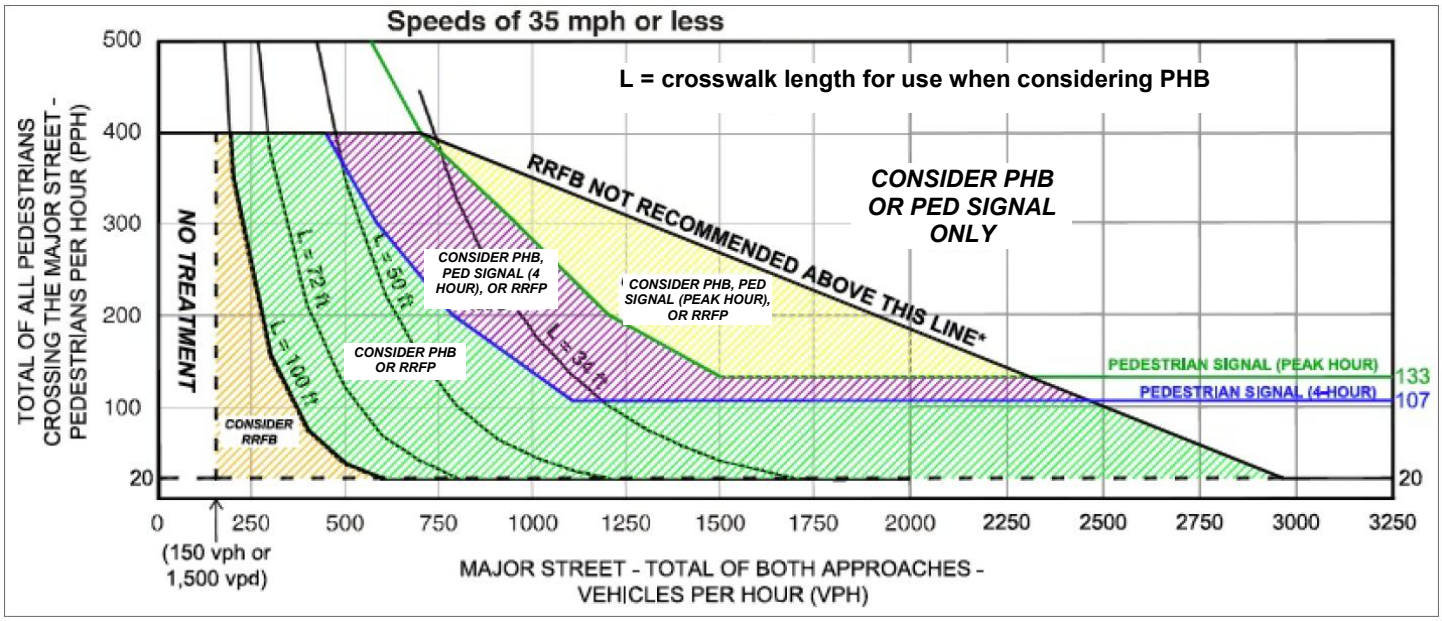
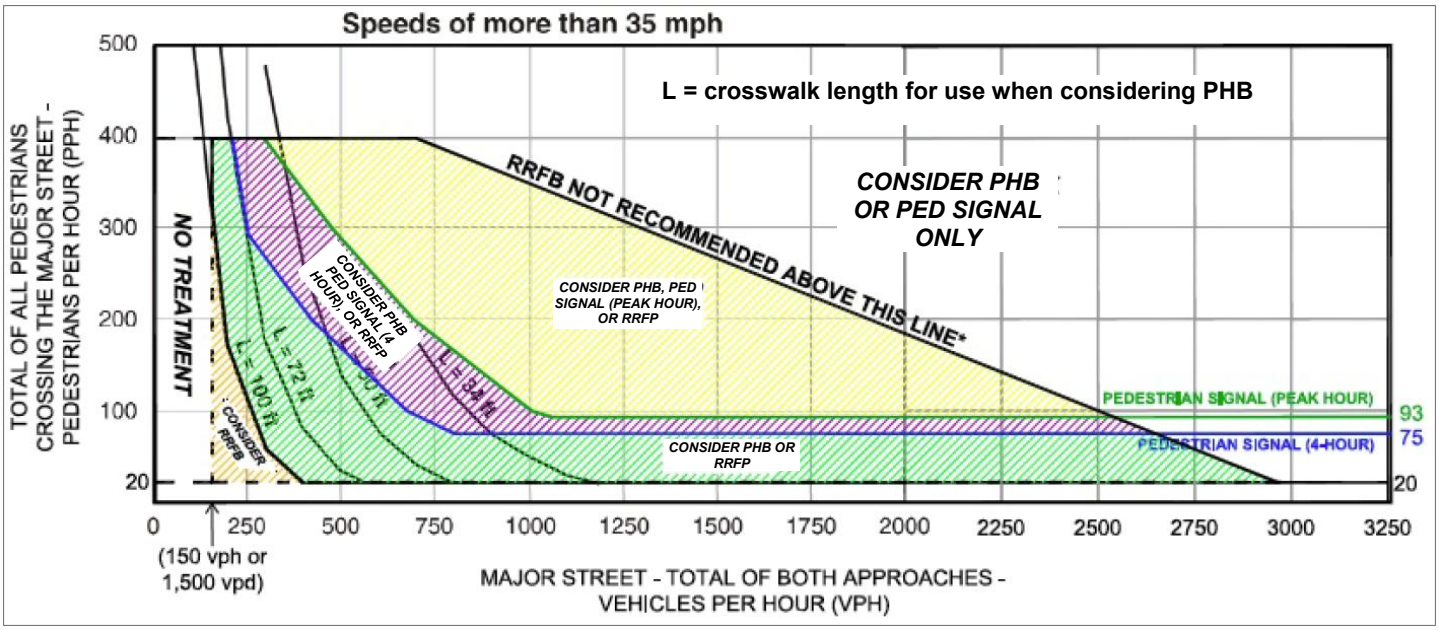


Figure B.2 - Guidelines for the Installation of Pedestrian Hybrid Beacons (PHB), Pedestrian Signals, or Rectangular Rapid Flash Beacon (RRFB) Signs on High-Speed Roadways*



*Adapted from the 2011 City of Boulder, CO *Pedestrian Crossing Treatment Installation Guidelines*

Figure B.3 - Levels of Separation for Bicycle Facilities

Off-Street Bicycle Facilities (Shared-Use Facilities Shared with Pedestrians)

Shared-use path (no lane markings)

Shared-use trail (separated lanes)

On-Street Bicycle Facilities Not Shared with Motor Vehicles

Paved shoulder

Bicycle lane

Buffered bicycle lane

Protected bicycle lane

On-Street Bicycle Facilities Shared with Motor Vehicles

Sharrow (shared-lane arrow)

Neighborhood Slow Street

Increasing Separation from Motor Vehicles

Increasing Separation from Motor Vehicles

Note on application of facilities

In general, bicycle routes where higher motor vehicle traffic speeds and volumes are present should offer riders greater separation from motor vehicles. This will result in facilities that offer greater perception of safety and comfort to current and potential bicycle riders and will invite use by larger number of riders and through a greater range of ages and abilities.

Pedestrian and Bicycle Facilities

Conventional Bicycle Lane

Description

Bicycle lanes designate a portion of the roadway for preferential use by bicyclists. Lanes are defined by striping, pavement markings and signage. Bicycle lanes create separation between bicycling and driving and increase comfort and visibility of people bicycling. On some roads, space availability may be a constraint; however, implementing a "road diet" (for example, by converting a four-lane roadway to three-lanes), or decreasing the width of travel lanes (down to 11 ft or 10 ft in urban settings) can often free up additional roadway space and provide a solution to this issue.

A conventional bicycle lane in Milwaukee, WI with striping and pavement marking

Application of Facility

- Bicycle lanes should be considered for streets that exceed 3,000 or higher motor vehicle average daily traffic (ADT); and
- Bicycle lanes should be paired with shared-use path on roads with speeds of 45 mph or greater and the following ADTs:
  - 2-Lane Road with ADT greater than 10,000; and
  - 4-Lane Road with ADT greater than 20,000.

Design guidance

- Provide door zone clearance when bicycle lanes are located adjacent to parked vehicles.
- Apply bicycle symbol markings frequently to indicate that the space is a bicycle lane.
- Place pavement markings out of the path of turning vehicles to minimize wear.
- Minimum total width of 5' (including gutter). Example:
  - 4' bicycle lane + 1' gutter
- Preferred total width of 6' (including gutter). Examples:
  - 4' bicycle lane + 2' gutter
  - 5' bicycle lane + 1' gutter

Buffered Bicycle Lane

Description

Buffered bicycle lanes provide cyclists with extra space between bicycles and traffic, increasing comfort for bicycle riders. Buffers can provide cyclists with room to pass slower riders without having to merge into motor vehicle traffic. Buffered bicycle lanes also separate people from motor vehicle traffic as they exit and enter parked cars.

Application of Facility

- All locations where a bicycle lane is considered;
- On streets with higher travel speeds and/or higher travel volumes;
- On streets that provide additional lane width; and
- Buffered bicycle lanes may provide a safer and more comfortable designated bicycling space for parents with schoolchildren than conventional bicycle lanes and should be considered for routes serving school locations.

A buffered bicycle lane. This example has a buffer on the left for separation from moving vehicles and a buffer on the right for separation from parked cars (Park Avenue, Minneapolis).

A painted buffer provides extra distance between the bicycle lane and motor vehicle travel lanes on Portland Avenue in Minneapolis.

Design guidance

- Apply pavement markings frequently to identify that the space is designated for people bicycling.
- Color may be used at the beginning of each block to clearly indicate to motorists that the space is a buffered bicycle lane.
- Buffer is typically marked with 2 solid white lines with optional diagonal hatching of 3'.

Protected Bicycle Lane

Description

A protected bicycle lane (also known as a separated bicycle lane or cycletrack) is an exclusive space for bicycles separated from motor vehicle traffic by a painted buffer and a physical barrier (such as a curb, parked cars, or bollards). Protected bicycle lanes are separated and distinct from the sidewalk. Protected bicycle lanes significantly increase bicycle ridership for people of all ages and experience levels because the distinct separation from motorized vehicles greatly increases rider comfort.

Protected bicycle lanes also increase safety by reducing the likelihood of dooring crashes and potential conflicts from passing motor vehicles. They require more space and infrastructure than conventional bicycle lanes, and require special design attention at intersections. Separated bicycle lanes are the preferred on-street bicycle accommodation where the right-of-way space allows for its installation.

Removable bollards (also known as "candlesticks") can be used seasonally as a method for protecting bicycle lanes during the spring, summer, and fall. Removing the bollards during the winter months can alleviate conflicts with snow plow methods.

Application of Facility

- Along roadways with few cross streets, longer blocks, and limited driveways;
- Major roadways with medium to high motor vehicle traffic speeds and volumes; and
- Streets with parking lanes.

A painted buffer and bollards physically separate bicyclists using the two-way protected bicycle lane from motor vehicle traffic.

A protected bicycle lane in Missoula, Montana is physically separated from motor vehicle traffic by a curb and parallel parking. Image courtesy of bicycleleague.org.

Design guidance

- Design with consideration for intersections and driveways.
- Colored pavement may be used to define the lane.
- One-way protected bicycle lane width: 6' min. (not including buffer space).
- Two-way protected bicycle lane or cycletrack: 10' min. (not including buffer space).

Neighborhood Slow Street

Description

A neighborhood slow street (also sometimes known as a bicycle boulevard, neighborhood greenway, or shared street) is a lower volume, lower speed residential street designed to prioritize bicycle travel while encouraging motor vehicles to use other routes and maintaining relatively low motor vehicle speeds.

Application of Facility

- Residential streets where traffic calming is desired;
- Residential streets a block or two away from a major thoroughfare with high traffic volumes;
- Target speed for motor vehicle traffic on a bicycle boulevard should be no higher than 20 to 25 mph; and
- Motor Vehicle traffic volumes on a bicycle boulevard should be no higher than 3,000 ADT.

A traffic circle helps to calm traffic along a Neighborhood Slow Street.

The Riverlake Greenway Bicycle Boulevard in Minneapolis, MN includes traffic diverters to reduce motor vehicle cut-through traffic.

Design guidance

- Traffic calming devices (traffic circles, speed tables) will reduce motor vehicle speeds and create a safer environment for people walking and bicycling.
- Roadway markings should be used to designate the roadway as a bikeways and remind motorists to be mindful of people walking and bicycling.
- Wayfinding markers should be used to direct people bicycling to neighborhood slow streets from major thoroughfares and to alert motorists to the presence of bicycle riders.
- Signals, roundabouts, and/or median refuges should be used at major intersections when necessary to calm and/or redirect through traffic.

Shared-Use Path/ Trail

Description

Off-road shared-use paths (SUPs), also known as shared-use trails, provide separated space away from the street for non-motorized transportation users. These paths often link parks and other recreation destinations, and some serve broader regional connection purposes. Shared-use paths may run parallel to roadways, or away from streets in parks, along railways, and in wetland areas. Shared-use paths are generally very comfortable for users of all ages and abilities.

Application of Facility

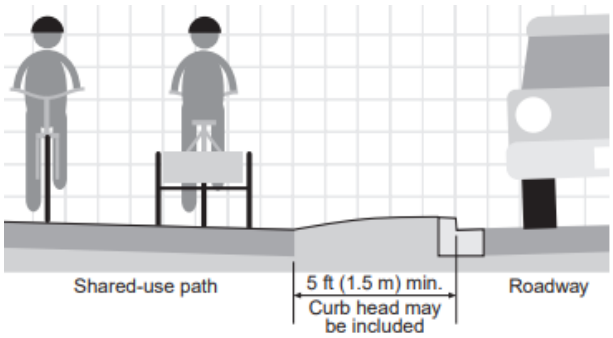
- Along corridors where there is a sufficient width of continuous right-of-way and limited or controlled access
- Along roads with speeds of 45 mph or greater with the following traffic volumes:
  - 2-Lane Road with ADT greater than 10,000
  - 4-Lane Road with ADT greater than 20,000

Design guidance

- Minimum width should be 10'.
- Dual paths recommended along high speed/ volume roadways, or roadways with limited crossing opportunities to minimize unsafe crossing behavior.
- Minimum separation of 5 ft between the edge of the paved roadway shoulder and the path, preferably outside of the roadway clear zone.
- Maintain adequate shoulders and clearance between the path and obstacles.

A shared-use path (SUP) in Eden Prairie, MN is separated from traffic with a wide vegetative buffer, and accommodates several types of users.

A shared-use path in Saint Paul, Minnesota offers separate lanes for people walking and bicycling.



Guidance for share-use path in the Wisconsin Bicycle Facility Design Handbook

Shared-Lane Markings

Description

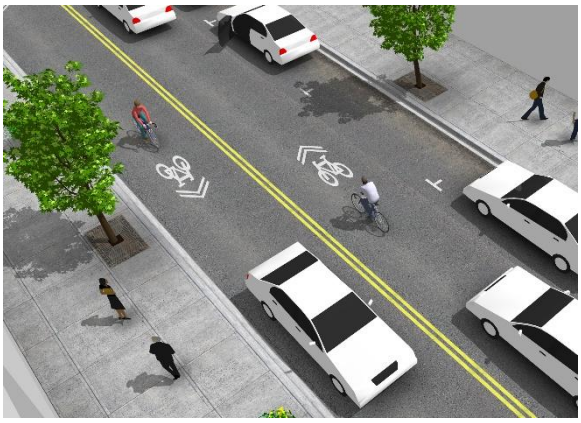
Shared-lane markings (often called sharrows) are pavement markings used to communicate bicyclists' right to use the full roadway space for their travel. Sharrows help bicycle riders position themselves safely in travel lanes that cannot accommodate a bicycle lane or other facility. Sharrows may also be used to mark Neighborhood Slow Streets.

Priority shared-lane markings include additional paint or striping to bring further attention to the facility and highlight a bicyclist's placement and presence in the roadway.

Priority shared-lane markings include additional striping to further establish the route as a bikeways. Image courtesy of Boston.com

Application of Facility

- Streets with fewer than 3,000 motor vehicles per day, and where right-of-way width does not allow a bicycle lane or protected bicycle facility;
- If right-of-way width allows room for a bicycle lane on only one side of the street, a sharrow may be used in downhill direction, with a bicycle lane in the "climbing" direction;
- Can be used to clarify bicyclist movement and positioning in challenging environments such as intersections and at a combined turn/bicycle lane; and
- May be used as a treatment for streets identified as Neighborhood Slow Streets.



Guidance for Shared Lane Markings from NACTO

Design guidance

- Typical bicycle-and-chevron symbol dimensions are 9'3" by 3'3".
- High frequency of markings indicate shared lane environment.
- Markings should be placed in the center of travel lanes and out of turning vehicles' paths to minimize wear from automobiles.
- Should not be used as a substitute for bicycle lanes where space allows.

Painted Bicycle Facilities

Description

Bicycle lanes are made more visible by painted pavement. This treatment distinguishes the lane from the rest of the roadway, making bicycle riders more visible. It is recommended that high-friction surfacing be used over standard paint because it is more slip-resistant and it doesn't have to be reapplied as often (standard paint has to be reapplied every year or two).

Green painted lanes through an intersection on the University of Minnesota campus in Minneapolis, MN.

Application of Facility

- Within conventional, buffered, and protected bicycle lanes;
- Corridors with heavy auto and bicycle traffic;
- Through busy and/or complex intersections and at conflict points, such as driveways;
- Use thermoplastic treatment with anti-slip characteristics - has a 7-8 year life expectancy; and
- Areas where illegal motor vehicle parking in the bicycle lane is common.

Green painted lanes approaching an intersection in Minneapolis, MN. At this location, motor vehicles travel across the bicycle lane to turn right.

Color recommendation

PMS 375

Design guidance

- Provide signage to accompany pavement markings.
- Use green high-friction surfacing rather than paint.
- Consistency in coloring bicycle facilities is important. Green is standard in U.S. applications.
- Color can be provided in conflict areas alone, or throughout the facility.
- White border lines should be provided along the edges of the colored lane to maintain consistency with other bicycle facilities.

As stated in the MUTCD, Green-colored pavement shall not be:

- Incorporated into electric-vehicle parking stations or parking stalls
- Incorporated into crosswalks
- Used as a background for shared-lane markings
- Used instead of the required markings for bicycle facilities

Intersection Treatments

Bicycle Box

Description

A bicycle box is a designated area for bicycle riders at the head of an intersection. Pavement markings guide motorists to stop a greater distance ahead of an intersection, allowing bicycle riders to move forward and stop in the bicycle box, increasing visibility and decreasing the risk of "right hook" crashes. This treatment also gives bicycle riders priority at a green light by allowing them to be the first to begin movement when a traffic signal turns from red to green. Ideally, bicycle boxes are paired with bicycle specific traffic signals.

An example of a bicycle box implemented in the City of Wauwatosa, WI

Bicycle boxes enhance the visibility of bicyclists and allow them to get out in front of motor vehicles at intersections. Image courtesy of streetwise.kittelson.com.

Application of Facility

- Signalized intersections with high volumes of bicycles and/or motor vehicles, especially those with frequent bicyclist left-turns and/or motorist right-turns.

Design guidance

- Box may be ineffective without application of surface color.
- The box may be disregarded by motorists if it is not commonly filled by bicyclists.
- Box depth: 10' to 16'.
- Ingress bicycle lane should be used to define bicycle space and allow people bicycling to bypass stopped motor vehicles.
- High-visibility pavement markings and green-colored pavement surfacing should be used.
- "WAIT HERE" marking should be used to guide motorists to stop before the box.

Bicycle Detection Systems

Description

Bicycle detection systems allow people bicycling to make movements through intersections in a timely way without requiring the detection of a motorized vehicle or push button. Detection systems include in-pavement loop detectors and mounted camera detectors.

Loop detectors detect the presence of bicycles on the roadway. Detectors should be installed to cover areas of the road where people bicycling are likely to ride, including the right edge of travel lanes and the center of bicycle lanes. Pavement markings may be used to direct riders to the proper spot where their presence will be detected.

Cameras can be used to detect roadway users, including people bicycling. Once detected, a signal change is initiated to allow users to travel through the intersection.

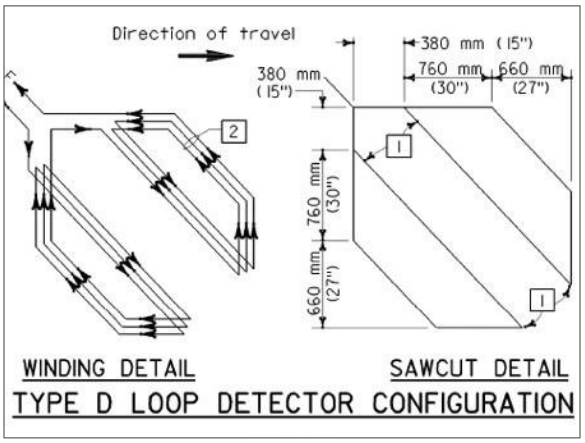
Various technologies are available, some of which are in use in surrounding communities, including loops, buttons and camera technology

Application of Facility

- Implement appropriate detection whenever traffic signals are added or significantly upgraded;
- At intersections with traffic control;
- At intersections that require vehicle detection to initiate a signal change; and
- Crossings with traffic signals for bicycles.

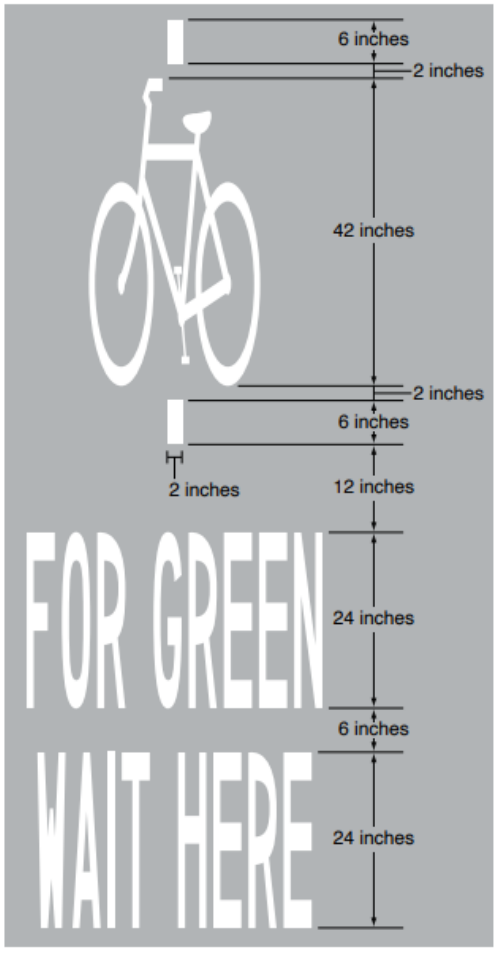
Design guidance

- The most effective loop detection design is a Type D Loop, also known as a diagonal quadrupole pattern. This loop is sensitive over its entire width with a quick drop off in sensitivity outside its perimeter to avoid detection of vehicles in adjoining lanes.
- Sensitivity setting for the loop amplifier should be tested and adjusted to ensure that the detector can be activated by using only a bicycle wheel.



Diagonal quadrupole pattern. Image courtesy of California DOT.

Figure 9E-16. Bicycle Detector Pavement Marking



Note: The word pavement markings are optional.

Pavement marking recommended to encourage proper positioning of bicycles at loop detectors (Source: FHWA).

Bicycle Traffic Signals

Description

Traffic signals for bicycles are traffic control devices used to provide guidance specific to people bicycling at intersections. Bicycle signals are coordinated with motor vehicle signals to provide a protected crossing for bicycle riders at intersections, reducing stress and delays, and increasing safety and comfort. They also discourage illegal and unsafe crossing maneuvers.

Traffic signals for bicycles include:

- Bicycle Signal Heads and supplemental "Bicycle Signal" sign, clearly visible to oncoming bicycle riders (and motorists, if applicable);
- Signal detection and actuation; and
- Intersection crossing markings.

A bicycle traffic signal in Minneapolis, MN helps people bicycling to safely cross a busy street.

Application of Facility

- Intersections where high volumes of bicycle riders have to travel across roadways with high motor vehicle traffic volumes and/or speeds.

Push buttons for bicycle signals should be located at the edge of the curb facing the roadway so they can be easily accessed and activated by people bicycling.

Design guidance

- Identify which signal treatment is appropriate by analyzing the factors involved: speed limit, average daily traffic, anticipated bicycle crossing traffic.
- Determine a clearance interval appropriate for the specific intersection.
- The bicycle clearance interval should be sufficient to accommodate at least 85% of bicyclists at their normal travel speed, including reaction time and acceleration from a stop.

High-Visibility Crosswalks

Description

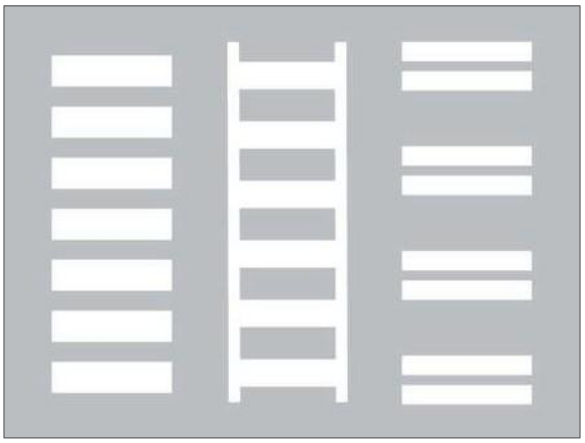
Marked crosswalks help to create a continuous route network for people walking and bicycling by alerting motorists to their potential presence at crossings and intersections.

Application of Facility

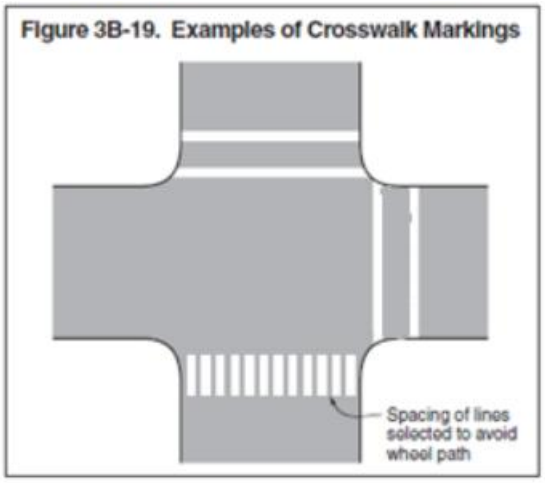
- Should be used at fully-controlled intersections where sidewalks exist (all-way stop signs, traffic lights, or user-activated crossing beacons);
- Should be used where bicycle trails or shared-use paths cross a roadway; and
- Should not be used at uncontrolled crossings as a stand-alone device when speeds exceed 40 mph, to discourage unsafe crossings.

Design guidance

- Advanced stop bars should be considered when multiple motor vehicle travel lanes per direction are present in order to minimize risk of "hidden threat" crashes.
- Crossings marked with pavers are discouraged as they can be difficult for those with mobility impairments.
- High-visibility marked crossings are preferred because they are easier for motorists to see.
- Minimum markings consist of solid white lines between 6-24" in width (MUTCD).



Different types of high-visibility crosswalk markings.



Wisconsin Standards prefer Two 6" Transverse Lines or 24" Ladder Pattern

Median Refuge Island

Description

Median crossing islands make crossings safer and easier by dividing them into two stages so that pedestrians and bicyclists only have to worry about crossing one direction of traffic at a time. Median crossing islands make high-volume roads safer and easier to cross, especially for slower walkers such as children and the elderly who might otherwise get stranded in the middle of the roadway. Space can sometimes be a constraint as crossing islands require the provision of a median in the center of the road.

Median crossing island on Bainbridge Island in Washington State. Image courtesy of FHWA.

Application of Facility

- Two-way, multi-lane roads;
- Roads with high traffic speeds and/or volumes; and
- Near schools, transit hubs, trails, shopping centers and employment centers.

A median refuge at the intersection of Franklin Avenue Wand Bryant Avenue S (a Neighborhood Slow Street) in Minneapolis makes it easier for people walking and bicycling to cross Franklin Avenue W.

Design guidance

- In addition to signage, trees and low ground cover increase visibility to alert drivers of the presence of the median island.
- Minimum width of 6'.
- Adequate lighting should be provided.
- Refuge area in the median should be angled so that users face traffic before crossing, while still allowing bicycle riders (when present) to navigate without dismounting.

Pedestrian Hybrid Beacon (PHB)

Description

A Pedestrian Hybrid Beacon (formerly known as HAWK or High-Intensity Activated crossWalK beacon) is a pedestrian-activated red-indication signal designed for locations where a standard traffic light does not meet traffic engineering warrants. The PHB gives pedestrians and bicyclists a chance to comfortably cross busy roads at intersections or mid-block locations protected by an enforceable, red-indication signal for motorists.

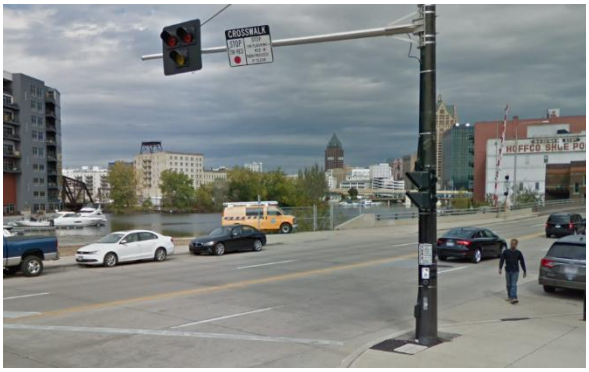
The PHB remains dark until activated by a pedestrian or bicyclist pressing the crossing button. Once activated, the signal responds immediately with a flashing yellow pattern that changes to a solid red light providing unequivocal "Stop" guidance to motorists. PHB signals have been shown to elicit very high rates of motorist compliance. Cost for installation of a PHB typically ranges from $75,000 to $100,000.

Application of Facility

- At crosswalks where no traffic signal is present;
- At mid-block or intersection locations; and
- The MUTCD (Chapter 4J) has guidance for applying a PHB based on motor vehicle speeds and volumes, crossing length, and pedestrian volumes. Bicyclists are not specifically considered, however bicycle crossing volumes may be added to pedestrian crossing volumes for evaluation purposes.

Design guidance

- Should include installation of a high-visibility crosswalk and advanced stop bar ahead of crosswalk.
- When used to facilitate bicycle movements, a bicycle signal head should be installed in addition to pedestrian signal heads. The bicycle signal head should display a flashing red to bicyclists when the hybrid is dark, allowing bicyclists to treat the intersection as a "stop" when the beacon is not activated.
- The MUTCD provides guidance on establishing the length of signal phasing.



A PHB in Milwaukee, Wisconsin makes it easier for pedestrians and bicyclists to cross a busy street.

Pedestrian Hybrid Beacon Operation

	DRIVERS		PEDESTRIANS	
	Will See ...	Will Do ...	Will See ...	Will Do ...
1		Proceed with caution.		Push the button to activate the system.
2	 FLASHING	Proceed with caution. A pedestrian has activated the system.		Wait.
3		Stop if safe to do so.		Continue to wait.
4		STOP. A pedestrian is in the crosswalk.		Start crossing when all vehicles are stopped.
5	 FLASHING	STOP. Proceed with caution if the crosswalk is clear.		Continue crossing; the signal will count down.
6		Proceed if the cross-walk is clear.		Push the button to activate the system.

Operation of a PHB from perspective of drivers and pedestrians. (Source: WisDOT)

Rectangular Rapid Flashing Beacon (RRFB)

Description

The Rectangular Rapid Flash Beacon (RRFB) is a high-intensity flashing sign assembly that is placed ahead of a crosswalk. The RRFB is user-activated, and uses an irregular "stutter" flash pattern with very bright amber lights (similar to those on emergency vehicles) to alert drivers to yield to pedestrians who wish to cross.

The RRFB offers a higher level of driver compliance than other flashing yellow beacons, but lower than the PHB signal. Installation cost ranges from $8,000 to $13,000 for two assemblies (for installation on each side of the street).

Application of Facility

- At crosswalks where no traffic signal is present;
- Suitable for two-lane roads (one assembly on each side of the street) and four-lane roads (one assembly on each side of the street and in the median or center island);
- Implemented when a minimum of 20 pedestrians in a single hour (young, elderly, and disabled peds count as 2x's the volume thresholds);
- Not compatible with three-lane approaches if roadside-mounted signs are used (due to potential line of sight issues / obstruction of signs); and
- FHWA permits the overhead placement of RRFBs, when it is not possible to achieve clear visibility of roadside signs; for placement, FHWA directs: "Only a minimum of one such sign per approach is required and it should be located over the approximate center of the lanes of the approach or where optimum visibility can be achieved."

An RRFB at a mid-block crossing alerts drivers when a pedestrian or bicyclist is crossing. Image courtesy of Michael Frederic.

Design guidance

- Employ RRFBs at crossing problem areas, school routes, or high volume routes.
- A beacon should be placed between the pedestrian crossing sign and the attached arrow plaque.
- For overhead signs, no arrow plaque is required.
- A maximum of 4 lanes to be crossed, unless there is a raised median, in which case it can be six lanes.
- RRFPs need adequate stopping sight distance, to be reviewed by qualified engineer.

Design Concepts for Protected Trail Crossings

Description

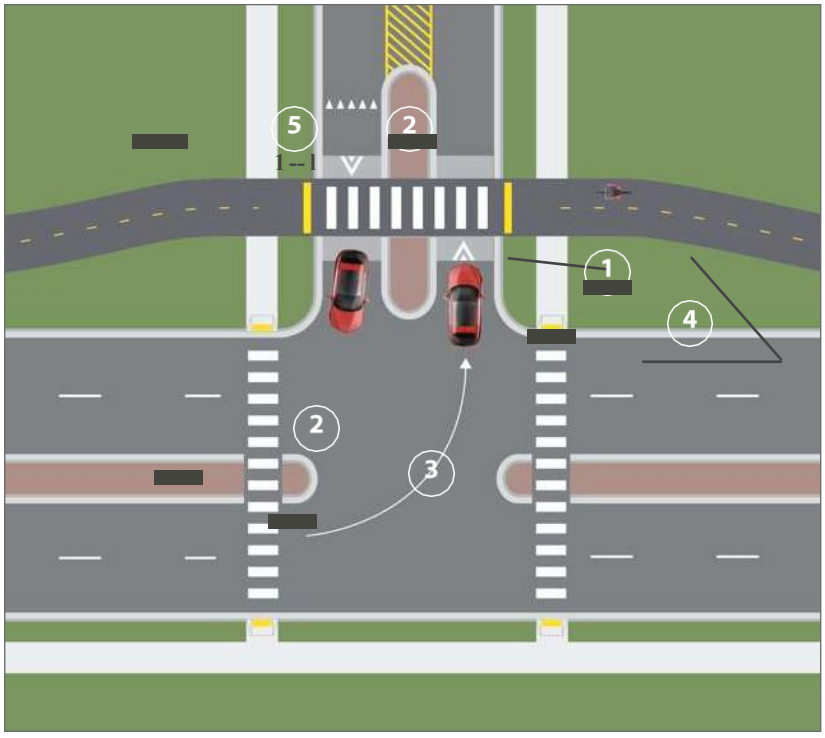
Common problems at trail crossings include:

- People walking and bicycling are blocked by motor vehicles which have inched forward and are preparing to turn onto the main road;
- Elevation changes at curb ramps and through the intersection affect walking and bicycling conditions; and
- High motor vehicle speeds as they turn from the main road and travel across the path crossings.

The concepts shown here address these issues by identifying measures that can, when used in combination, mitigate challenges for users. At a T-intersection, this concept sets trail crossings about 20 feet back from the parallel street (to provide space for motorists to queue up outside of the crossing when waiting for a gap in traffic), and provides a continuous path at a constant elevation for people walking and bicycling.

Additional components and configuration elements (including turning radius, medians, signs and markings) reduce the probability of drivers blocking the path of pedestrians and bicyclists, and provide traffic-calming benefits near the trail crossing.

Figure A.4 - Protected Trail Crossing Concept



Protected trail crossings are set back from parallel streets to provide room for motorists to queue up outside of the crossing

Additional design elements include:

1. *Speed table for the crossing*
2. *Medians and median extensions*
3. *Reduced turning radius*
4. *Clear sight triangle between motorists and trail users*
5. *6-foot waiting zone*

Design Considerations

Crossing is pulled back 20 feet from parallel street

- Allows room for one vehicle to queue up, without blocking pedestrian or bicycle travel, to wait for a gap in traffic; and
- Allows sufficient distance for motor vehicles turning from the parallel roadway to see pedestrians or bicyclists using the crossing and to react and stop if needed.

Crossing is raised

- Addresses the issues of elevation changes affecting wheelchair users, pedestrians and bicycle riders at crossings;
- Calms traffic by functioning as a speed table, giving motorists more time to notice approaching pedestrians or bicyclists; and
- Discourages motorists from stopping on the crossing, maintaining a clear travel-way for trail users.

Medians and islands are provided, and include mountable curbs

- Channelize and calm motor vehicle traffic while allowing access for freight trucks and emergency vehicles.

Crossing is visible and legible

- Crossing location is visible and understood by all users of the road and path (appropriate pavement markings and signs are used); and
- Maintains clear and unobstructed sight lines at corners.

Turning radius is reduced

- Tightens corner radii and includes installation of median extensions to slow motor vehicles turning into and out of the intersection to/ from all directions; and
- Accommodates freight vehicles and emergency vehicles with mountable curbs.

Additional Design Considerations

Additional design considerations for improved safety and functioning of crossings include:

- Speed table slope should be 1:10 except on emergency or freight routes when it can be lowered to 1:25;
- 6 feet waiting zone for path users between perpendicular path and curb; and
- Maintain a clear sight triangle between motorists and trail users at crossing approach.

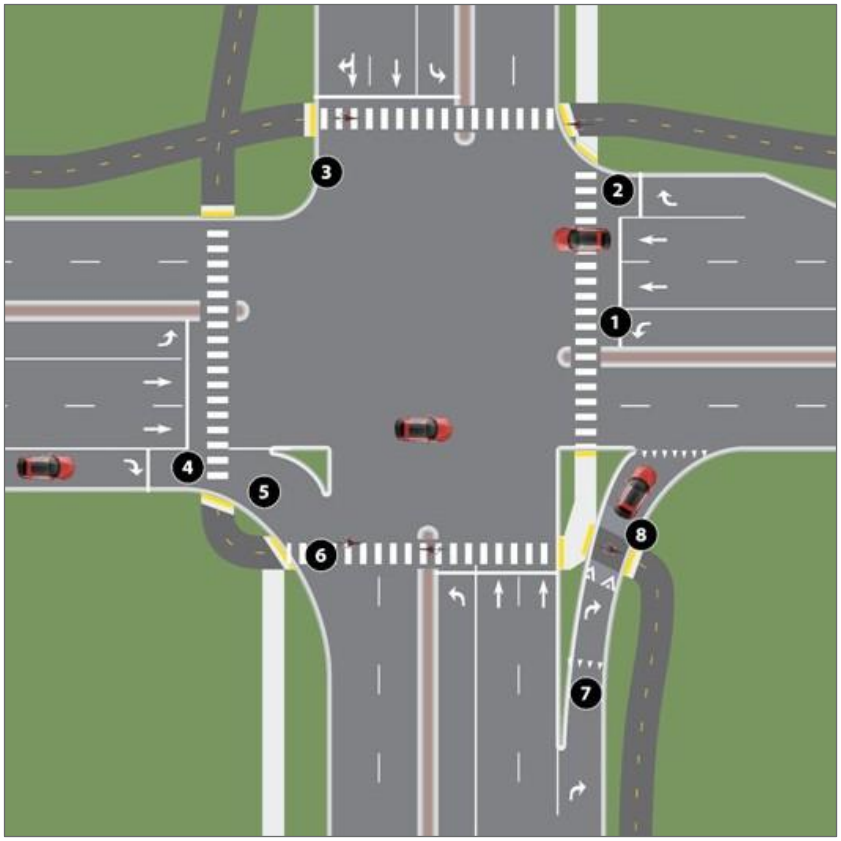
Design Concepts for Arterial Intersections

Description

Arterial intersections carry large volumes of motor vehicle traffic. Conventional geometric design for arterials, which focused on optimizing traffic flow for motor vehicles and did not fully consider the needs of other users, has negative implications for the safety, comfort and experience of people walking or bicycling through an intersection.

At locations where high numbers of people are expected to walk or bicycle, the roadway designer should strive to eliminate conflicts completely if possible, or to modify roadway designs to reduce motor vehicle speeds and make them more compatible speeds of people walking and bicycling (10-15 mph) at locations where conflicts cannot be avoided.

Figure A.5 - Components of Arterial Intersection Design



Design components:

1. *Protected-Only Left Turn Signal Phase*
2. *Conventional Turn Lanes*
3. *Shared Right/Through Lane and Slow Speed Geometry*
4. *Protected Right Turn Signals*
5. *No Turn on Red*
6. *Leading Pedestrian Interval (LP/)*
7. *Pedestrian-Friendly Channelizing Islands*
8. *Other Channelized Turn Lane Enhancements*

Design Considerations

Refer to Figure B.5 for illustration of each of the numbered characteristics below.

1) Protected-Only Left Turn Signal Phase

Exclusive left turn lanes should use protected-only signal phasing at intersections with trail crossings. This type of operation is recognized to provide the safest left-turn operation. Permitted-only or protected/ permitted left turn phasing should not be allowed at crossings of high-priority bicycle and pedestrian routes.

2) Conventional Turn Lanes

Channelized turn lanes generally offer larger radius, higher speed turns than conventional turn lanes, which may pose a pedestrian and bicyclist safety issue (FHWA 2013). Conventional right turn lanes with smaller curb radii will reduce vehicular turning speeds, minimize pedestrian crossing distances, and reduce the potential severity of vehicle-pedestrian collisions. In situations where a right-turn lane is necessary, preference should be given to a narrow conventional turn lane with a small corner radii over a channelized turn lane.

3) Shared Right/Through Lane and Slow Speed Geometry

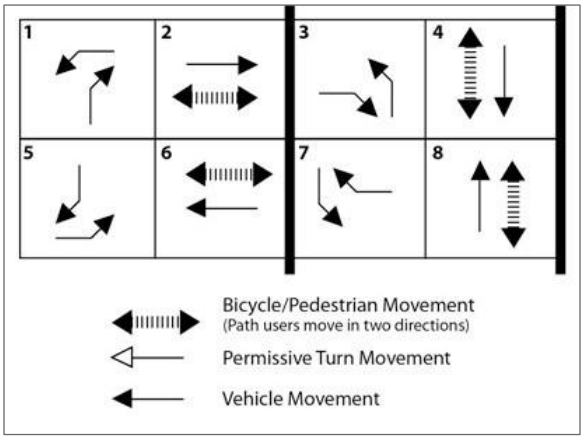
In areas with lower right turn volumes and lower speeds, a right turn only lane may not be warranted. By using a shared right/through lane in place of an exclusive right turn only lane, pedestrian crossing distance is decreased and turning speeds are reduced. The pedestrian signal commonly runs concurrently with the adjacent right/through lane. Because this creates a potential conflict between right turning vehicles and crossing path users, it is essential to use geometric design to create a slow speed turning movement. To design for slow speed turning movements, use a very small corner radius and narrow receiving lanes. Like intersections at T-intersections and minor streets, the crossing should be setback around 20 ft from the intersection.

A note on arterial intersection design recommendations

Please note that signalization, lane configuration and user volumes all have an effect on vehicle throughput, delay and safety. All intersections are unique, and there is no single typical design that can serve all needs. Each intersection requires review by a registered Professional Engineer to identify sight lines, potential impacts on traffic progression, timing with adjacent signals, capacity and safety for all users.

Notes and references

- FHWA Signalized Intersections: An Informational Guide, 2013
- TRB NCHRP 780: Design Guidance for Intersection Auxiliary Lanes, 2014
- TRB NCHRP 674: Crossing Solutions at Roundabouts and Channelized Turn Lanes for Pedestrians with Vision Disabilities, 2010



Simple Ring/Barrier Diagram for Protected but Concurrent Phasing.

4) Protected Right Turn Signals

At signalized intersections, right turn lanes are commonly served the circular green signal of the adjacent through lane. Assuming pedestrian signal phase occurs at this time, right turning vehicles are expected to yield for crossing pedestrians and bicyclists in the crosswalk.

Reconfiguring the signals to offer a protected right-turn phase may allow a fully protected pedestrian signal phase, allowing efficient and safe mobility for path users. Protected right-turn signalization may be established concurrently with the left-turn signal phase of the cross street, while the pedestrian signal phase is provided concurrently with the adjacent through movement. This type of "protected but concurrent" phasing provides the benefits of protected signalization without adding additional delay to the intersection that comes with exclusive phase operation (please see diagram on previous page).

5) No Turn on Red

The Minnesota Manual on Uniform Traffic Control Devices (WI-MUTCD 2B.54) states that a No Turn on Red (NTOR) sign should be considered when an engineering study finds "an unacceptable number of pedestrian conflicts with right-turn-on-red maneuvers, especially involving children, older pedestrians, or persons with disabilities."

Given the likelihood and desire to support high volumes of bicycle and pedestrians along priority paths, an engineering study should be performed to evaluate the potential benefits of NTOR prohibitions at path crossings.

When right-turn-on-red is prohibited, there may be more right-turn-on-green conflicts between motor vehicles and pedestrians when both the right turning motorists have a green light and the pedestrian has the walk signal on the adjacent crosswalk. The use of leading pedestrian intervals can reduce this effect, and the use of protected signal phasing can eliminate it. Alternatives to NTOR prohibitions include "Yield to Pedestrian in Crosswalk," "Turning Vehicles Yield to Pedestrians," and "No Turn on Red When Pedestrians are Present."

6) Leading Pedestrian Interval (LPI)

At intersections with high pedestrian volumes and high conflicting turning vehicle volumes, a brief leading pedestrian interval, during which an advance WALKING PERSON (symbolizing WALK) indication is displayed for the crosswalk while red indications continue to be displayed to parallel through and/or turning traffic, may be used to reduce conflicts between pedestrians and turning vehicles. All path crossings at signalized intersections should be evaluated for leading pedestrian interval use where there is a desire to support high volumes of bicycle and pedestrian travel.

7) Pedestrian-Friendly Channelizing Islands

Whenever possible, channelized turn lanes should be avoided in pedestrian- and bicycle-oriented areas. If their use cannot be avoided, efforts should be made to mitigate their negative effects on these users.

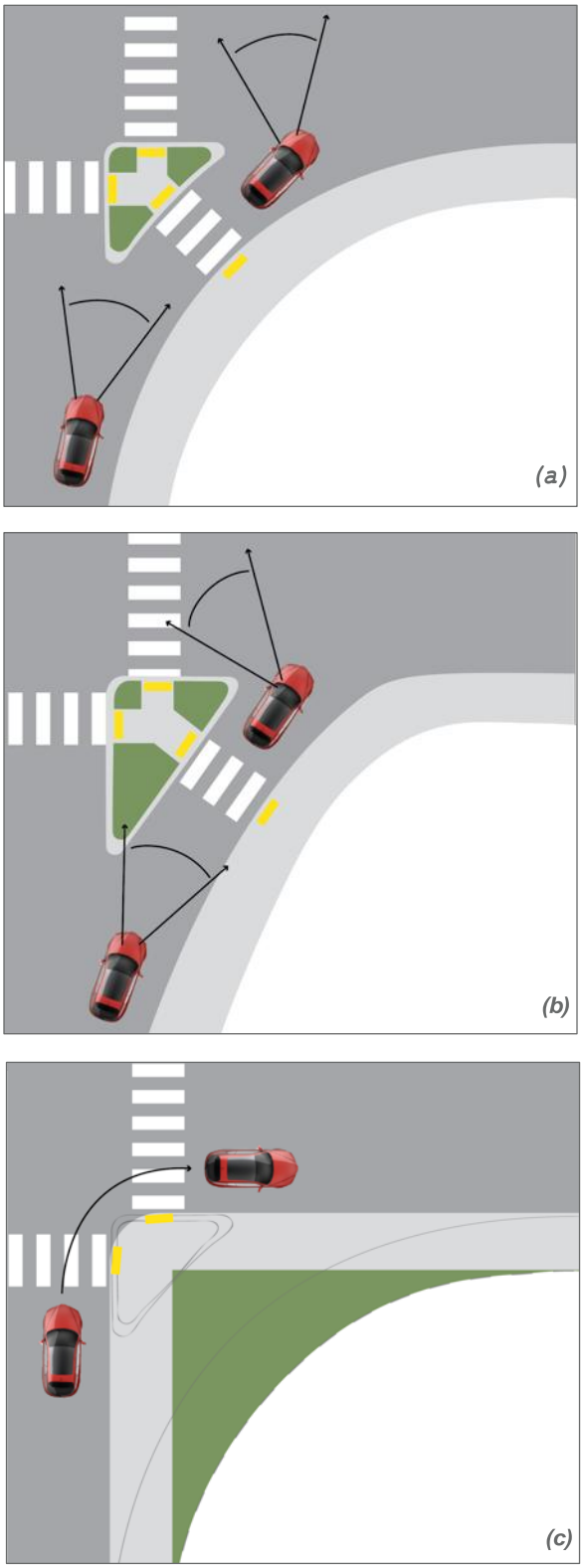
If channelized turn lanes and yield or free-flow operation is necessary, pedestrian-friendly geometry should be used to promote slow driver speed through the channelized turn lane and promote yielding of motor vehicles to people crossing the street.

Channelizing island geometry should promote clear visibility of people in the crosswalk, and provide space for safe yielding to people walking, bicycling, or driving (TRB 2014). The alignment of the turn lane should be a nearly right-angle entry to the cross street, giving the channelizing island a shape like an acute right triangle. There should be adequate length of the turn lane to store yielding motor vehicles both before and after the crosswalk area.

8) Other Channelized Turn Lane Enhancements

Channelized turn lanes can be particularly challenging to navigate for pedestrians with vision impairments (TRB 2010). Recommended strategies to assist these users include the use of raised crossings through the channelized turn lane to slow driver turning speeds and/or use of Rectangular Rapid Flash Beacons (RRFB) to improve yielding rates. These improvements also greatly benefit sighted users and should be considered where possible.

Each intersection/ crossing has its own unique challenges. Concepts should be considered and implemented on a case by case basis.



(a) Vehicle speed is prioritized; (b) Pedestrian safety is improved as well as driver sight lines; (c) Removing channelized turns maximizes pedestrian space and minimizes turning speeds.

Wayfinding & Signage

Description

A bicycle wayfinding system is a comprehensive network of signing and pavement markings indicating destinations along preferred bicycle routes. Wayfinding signage encourages cycling by familiarizing riders with the bicycle network and by making it easier for cyclists to reach preferred destinations.

Confirmation Signs

Confirmation signs reassure bicycle riders that they are on a designated bikeways, and make motorists aware that they are driving on a route where they can expect to encounter bicyclists. They can include destinations, and possibly distance or time. They don't typically include directional arrows.

Confirmation signs are placed every quarter to every half mile on off-street facilities, and every 2 to 3 blocks along on-street facilities, unless another types of sign is used (for example a turn or decision sign). Confirmation signs should be placed soon after turns to confirm destinations still ahead. Pavement markings also act as confirmation to bicyclists that they are on a designated route.

Turn Signs

Turn signs indicate where a bikeways turns onto a new street, or when a bicyclists should turn to reach a particular destination. Pavement markings can also be used for this purpose. Turn signs typically include destinations and arrows.

Turn signs are placed on the near-side of an intersection where a bicycle route turns. Pavement markings can also be used to indicate the need to turn.

Wayfinding signs should include clear destination, direction and distance information (in both time and miles). Image courtesy of bicyclemichiana.org.

Confirmation signage reassures bicyclists that they are on a designated route, and helps to make motorists aware of the route.

Turn signs indicate to bicyclists when they need to turn to reach a particular destination or stay on a designated route.

Decision Signs

Decision signs inform bicyclists of the designated bicycle routes that provide access to key destinations. Decision signs include destinations and directional arrows. Distances and travel time should also be included.

Three main components are needed for useful decision signs. They can be thought of as the 3 "Ds":

Destination

The destination is the main element, and communicates where things are that a bicycle rider may not have already known.

Direction

The direction component guides riders to their destination. The direction is indicated simply by using an arrow on the sign that directs users to proceed forward or to prepare to turn. Directional signage also gives motorists warning to expect cyclists on the road, and to anticipate cyclists' turning or crossing movements.

Distance

The distance and time component informs riders how long their trips will be, adding a measure of certainty and convenience when planning trips. Distance should be communicated in miles and time, calculated at a bicycling speed of 10 miles per hour.

Decision signs are located at the intersection of one or more bikeways, and inform bicyclists of the designated routes that provide access to important destinations.

Decision signs should be placed on the near-side of intersection in advance of a junction with another bicycle route, or along a route to indicate a nearby destination.

Pavement markings reinforce routes and direction signage. Image courtesy of share.america.gov.

Types of Destinations

Destinations that may be signed as part of a network wayfinding system include:

- On-street bikeways
- Commercial areas
- Schools
- Civic/community destinations
- Transit centers
- Local or regional parks and trails
- Hospitals

Before developing a wayfinding system, it is useful to classify a list of destinations for inclusion based on the relative importance to users in the area. A destination's place in the hierarchy may be used to determine the physical appearance of signs, as well as how far destinations are signed from their location.

In Lannon, primary destinations may be signed throughout the Village (or even outside Village limits), while secondary or tertiary destinations may be signed within a mile or two of the destination.

Pavement Markings

Pavement markings installed along dedicated routes help to reinforce routes and directional signage, and help bicyclists position themselves in the roadway. In many areas, pavement markings are more visible than signs to bicycle users, and can be especially helpful in areas where signage would be difficult to see including areas with parking or vegetation. They can also help to assist bicyclists in positioning themselves in difficult turning situations.

Pavement markings can also serve as confirmation and directional wayfinding. The use of stencils within bicycle lanes and along bicycle boulevards reinforces the designation of the route as a bicycle corridor. The chevron symbol for shared-lane markings can also be applied at an angle to indicate to bicyclists when they need to turn to stay on a designated route.

Pavement markings can also be used to indicate to bicyclists when and where they should turn. Green turn boxes help bicyclists position themselves during two-stage turns.

Design Guidance

- Provide information on destination, direction and distance (in miles and in minutes, calculated at speed of 10 mph).
- Decision signage should be placed in advance of all decision points.
- A consistent font, such as ClearviewHwy, is recommended for maintaining consistency with other road signs.
- The frequency of wayfinding signs is important. Confirmation signs should be placed every 1/4 to 1/2 mile along off-street bicycle routes and every 2 to 3 blocks along on-street routes.

Route signage along the Monona Lake Loop in Madison, WI.

Bicycle Parking Guide

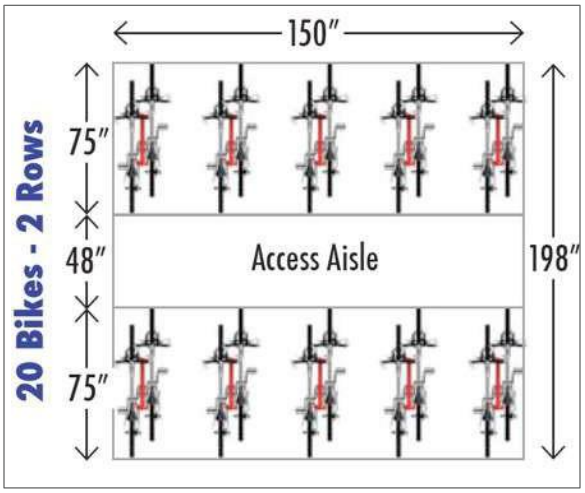
Bicycle parking is an end of trip facility that makes it more convenient and inviting for people to arrive by bicycle to a destination.

Provision of adequate bicycle parking cannot be overlooked: if bicycle parking spots are inadequate or if finding them is enough of an inconvenience, cyclists will next time choose a different mode for arriving or may choose another destination altogether, even if the provided bicycle routes are perfectly safe and convenient.

Two of the preferred types of bicycle rack: the "Inverted U" (left) and the "Post and Loop" (right).

Application of Facility

- Choose a style that allows secure locking of the bicycle (frame and front wheel) to the rack without need of lifting the bicycle. The "Inverted U" and "Post and Loop" style bicycle racks are preferred.
- Locate bicycle parking with consideration for the rack's proximity to the building entrance it serves, its placement along the natural path used by cyclists to approach the building, and its visibility from both the interior and exterior of the building.
- Provide an adequate number of racks to meet the needs of people visiting the area.



Arrangement of a bicycle parking area with parking for 20 bicycles and a central aisle for circulation. Image courtesy of Dero Bicycle Racks.

Additional Details

Generally, there are three components to bicycle parking:

1) The type or design of the bicycle rack itself, which supports the bicycle;
2) The location of the rack area, including its relationship to the building entrance it serves and the cyclists' approach to that entrance; and
3) The design of the rack area (the "bicycle parking lot"), which may include several individual bicycle racks.

The Bicycle Rack

The rack should support the bicycle upright by its frame in two places, enabling the frame and one or both wheels to be secured while preventing the bicycle from tipping over. Additionally, it should not require a cyclist to lift their bicycle to be able to lock it securely - a useful rack design should allow a cyclist to roll-in or back-in their bicycle to lock it.

The Rack Area

The rack area is the "bicycle parking lot" defined by the racks and the space needed to access the racks. To be functional and useful, certain minimum clearances and access rules should be observed:

- Individual racks should be located no closer than 30 inches to each other in order to allow sufficient space for easy entry and removal of bicycles on either side.
- No rack element should be closer than 24 inches to a wall or other obstruction in order to allow full usability and easy access to perimeter racks.
- Large rack areas, or rack areas with high turnover, should provide more than one entrance to ease circulation of cyclists and pedestrians.
- Rack areas should preferably offer protection from rain and snow in order to ease loading and unloading of bicycles and to keep bicycle saddles dry.
- When multiple rows of bicycle racks are provided, the circulation space provided from the wheel of a bicycle on one row to the closest wheel of a bicycle on the next row should be a minimum of 48 inches.

Location of the Rack Area

One of the most important considerations in providing useful and functional bicycle parking is the location of the rack area in relation to the building it serves. Some guidelines for locating the rack area include:

- The recommended location for a bicycle parking area is immediately adjacent to the entrance it serves, preferably within 50 feet. It should be located as close as possible without blocking the entrance or hindering pedestrian movement to or from the building.
- The rack area should be clearly visible from the entrance it serves and from the building's approach line.
- Bicycle rack areas should be as close or closer than the nearest car parking space.
- Buildings with multiple active entrances should include bicycle rack areas at each entrance.
- Racks that are hard to find, are far from principal entrances, or perceived to be unsafe will not be used by cyclists.

Minimum Parking Guidelines

The following table provides guidance regarding the number of bicycle parking spaces that should be provided in areas of Lannon.

Table B.4 - Non-Smart Code Bicycle Parking Guidelines

Type of use	Short term parking	Long term parking
Commercial	Office: 1 space for each 15,000 ft^2; minimum 2 spaces	1 space for each 10,000 ft^2; minimum 2 spaces
	Retail: 1 space for each 8,000 ft^2; minimum 2 spaces	
Multifamily residential	0.05 spaces for each bedroom; minimum 2 spaces	0.5 spaces for each bedroom
Institutional/ public uses (libraries, hospitals, parks, religious uses, etc.)	1 per 8,000 ft^2; minimum 6 spaces	1 space per 25 employees; minimum 2 spaces
Institutional Assembly (Auditoriums, Religious Gathering Spaces)	Spaces to equal 2% of assembly seating capacity; minimum 2 spaces	1 space per 20 employees; minimum 2 spaces
Parks and Recreational Space	1 space per 10 automobile stalls; minimum 4 spaces	None required; consider minimum 2 spaces at facility offices or public building entrance
Manufacturing, industrial	None required; consider minimum 2 spaces at public building entrance	1 space for each 25,000 ft^2; minimum 2 spaces