Minnesota's Best Practices for Pedestrian and Bicycle Safety

January 2021

DEPARTMENT OF TRANSPORTATION

Document Information and Disclaimer

Purpose of this Guide

This guide is intended to assist practitioners in their efforts to improve bicycle and pedestrian safety on their roadway networks. The strategies included in this handbook include a mix of treatments that have been used widely across the state and are considered proven strategies, along with emerging treatments that are considered experimental. This guide is not intended to supersede other existing design guidance or rules, and practitioners should always consult the appropriate design guidance when using these treatments, including, but not limited to:

Minnesota Manual of Uniform Traffic Control Devices (MnMUTCD) - https://www.dot.state.mn.us/trafficeng/publ/mutcd/

- Signs and pavement markings are governed by the MnMUTCD

Federal Highway Administration (FHWA) Interim Approvals - https://mutcd.fhwa.dot.gov/res-interim_approvals.htm

- Some markings and signs included in this Guide are not included in the MnMUTCD, and are allowed instead by an FHWA Interim Approval. When using a device allowed under interim approval, practitioners should follow the requirements of the Interim Approval carefully, and provide the location of any installed elements to the MnDOT Traffic Standards Engineer at 651-234-7388. See MnMUTCD Section 1A.104 for more information on Interim Approvals.

MnDOT Bicycle Facility Design Manual - http://www.dot.state.mn.us/bike/bicycle-facility-design-manual.html

Other MnDOT, State Aid, FHWA, and/or American Associate of Highway Transportation Officials (AASHTO) Manuals/Guidance/Rules. Refer to the Appendix for a list of potential resources.

Each best practice contained within this document includes the following information, to help practitioners answer common questions about these practices and provide tools to help use them.

- What is its purpose?
  - A description of the purpose of the strategy.
- Is it a proven strategy?
  - Refer to the following text on determining the efficacy of a certain treatment.
- Where would we use it?
  - A description of where this strategy is typically used. It's important to note that strategies may still be used in other situations not listed within this guide, however their efficacy may vary from what's noted in the guide. Practitioners should use judgement when applying treatments in other situations.
- What are the maintenance impacts?
  - A summary of the maintenance impacts associated with the strategy.
- What are the advantages?
  - Advantages associated with implementing the strategy.
- What are the challenges?
  - Challenges associated with implementing the strategy.
- Best Practices
  - The best practices for implementing the strategy.
- Design Features
  - Typical design features of the strategy.
- Resources
  - List of resources for more information on the strategy.

Determining the Efficacy of a Certain Treatment

This guide includes information on the crash reduction associated with certain treatments, as well as notes about whether a treatment is proven, tried, or experimental., based on research conducted on previous installations. Note that any information provided on the efficacy of a given treatment is particular to the context noted within the strategy – for example, a treatment that is proven effective on low-speed roadways may not be effective at all on high speed roadways.

Treatments within this document are noted as **PROVEN** when they have been widely deployed and properly designed evaluations have shown them to be effective when used under certain conditions. Any treatment that has been granted FHWA Interim Approval is considered **PROVEN** because FHWA has reviewed the efficacy of those treatments through the experimentation process.

Treatments within this document are noted as **TRIED** when they have been implemented in a number of locations where the results of the evaluations have not been fully evaluated or are inconsistent.

Treatments within this document are noted as **EXPERIMENTAL** when they have been suggested and at least one agency has considered sufficiently promising to try on a small scale in at least one location. Note that some experimental treatments are not included in either the MnMUTCD or an FHWA Interim Approval, and therefore require a Request to Experiment if they are to be used. For more information on Requests to Experiment, refer to MnMUTCD Section 1A.10.2 and contact the MnDOT Traffic Standards Engineer at 651-234-7388.

In an effort to help reduce the potential exposure to claims of negligence associated with motor vehicle crashes on an agency's roadway system, the following two key points should be considered:

1. Minnesota tort law provides for discretionary immunity for decisions made by agency officials when there is documentation of the decision and evidence of consideration of social, economic, and political issues.
2. Minnesota tort law also provides for official immunity for decisions made by agency staff where there is written documentation of the thought process supporting project development and implementation.

Proven/Tried/Experimental

This document refers to treatments as "Proven", "Tried", or "Experimental". Treatments are categorized according to the definition in NCHRP Report 500:

• **Tried** (T)—Those strategies that have been implemented in a number of locations and that may even be accepted as standards or standard approaches, but for which there have not been found valid evaluations. These strategies—while in frequent or even general use—should be applied with caution, carefully considering the attributes cited in the guide and relating them to the specific conditions for which they are being considered. Implementation can proceed with some degree of assurance that there is not likely to be a negative impact on safety and very likely to be a positive one. It is intended that as the experiences of implementation of these strategies continue under the AASHTO Strategic Highway Safety Plan initiative, appropriate evaluations will be conducted so that effectiveness information can be accumulated to provide better estimating power for the user and the strategy can be upgraded to a "proven" (P) one.

• **Experimental** (E)—Those strategies that have been suggested and that at least one agency has considered sufficiently promising to try on a small scale in at least one location. These strategies should only be considered after the others have proven not to be appropriate or feasible. Even where they are considered, their implementation should initially occur using a very controlled and limited pilot study that includes a properly designed evaluation component. Only after careful testing and evaluations show the strategy to be effective should broader implementation be considered. It is intended that as the experiences of such pilot tests are accumulated from various state and local agencies, the aggregate experience can be used to further detail the attributes of this type of strategy so that it can be upgraded to a "proven" (P) one.

• **Proven** (P)—Those strategies that have been used in one or more locations and for which properly designed evaluations have been conducted that show it to be effective. These strategies may be employed with a good degree of confidence, but any application can lead to results that vary significantly from those found in previous evaluations. The attributes of the strategies that are provided will help the user judge which strategy is the most appropriate for the particular situation.

ACKNOWLEDGEMENTS

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	Strategy	Pages	Crash Modification Factor (CMF)	Evidence (Proven/Tried/ Experimental)	Candidate Locations	Construction Estimates
General Intersection Elements	**Marked Crosswalks**	4-7	Varies, Marked Crosswalks alone should not be considered a safety treatment	Tried	Signalized intersections, unsignalized locations with AADT below 15,000, school zone crossings, unsignalized locations with high pedestrian activity, and mid-block crossing locations.	$3,000
	Medians and Crossing Islands	8-10	Medians - 0.54 CMF Crossing Islands - 0.46 CMF Source: https://safety.fhwa.dot.gov/provencountermeasures/ped_medians/	Proven	Mid-block crossing locations, high-priority pedestrian crossing location such as transit stop, school and parks, and on roads with four or more, speeds greater than 35 mph and AADT greater the 9,000.	$25,000-$50,000
	Curb Extensions and Curb Radii	11-14	Curb Extensions - 0.55 CMF Source - http://www.dot.state.mn.us/stateaid/trafficsafety/county/CRSPEnhancedCrosswalks.pdf	Proven	Mid-block curb extensions or pinch points, offset curb extensions or chicanes, and bus stops.	$2,000-$3,500/ corner; $10,000-$20,000/corner with storm sewer impacts
	Crosswalk Lighting	15-17	0.55 CMF Source: http://www.cmfclearinghouse.org/detail.cfm?facid=436	Proven/Tried	Isolated intersections with crosswalks that are not along continuously lit roadways, and mid-block crosswalks.	$10,000 per intersection to over $40,000
	Raised Crosswalks	18-21	0.55 CMF Source: https://safety.fhwa.dot.gov/ped_bike/step/docs/TechSheet_RaisedCW_508compliant.pdf	Proven	Along 2-lane or 3-lane roadways with speeds 30 mph or less and with AADT of 9,000 or less, locations with high pedestrian or bicycle activity, roundabout crossing locations, and locations where shared use paths cross commercial driveways or ramps.	$7,000 to $40,000 each
	Intersection Geometric Design	22-24	Varies	Proven	Where on-street parking or bike lanes are present, where channelized right-turn lanes create more conflicts with pedestrians and bicyclists, where left turns are permitted to occur concurrent with bicycle or pedestrian movements, and at locations where the design must still accommodate turning movements by larger vehicles.	Varies depending on the specific treatment

	Strategy	Pages	Crash Modification Factor (CMF)	Evidence (Proven/Tried/ Experimental)	Candidate Locations	Construction Estimates
Controlled Intersection Elements	**Traffic Signals**	25-27	Countdown timers - 0.22 CMF Source: http:// www.cmfclearinghouse.org/ detail.cfm?facid=5272	Proven/Tried	Intersection needs additional enhancements to improve motorist yielding rates or address limited gaps in traffic, and where there is a high volume of pedestrian activity, such as transit stops, schools, and parks.	$250,000 to $500,000
	Leading and Separate Exclusive Signals	28-30	Leading Ped Signal - 0.87 CMF Source: https:// safety.fhwa.dot.gov/ provencountermeasures/ lead_ped_int/	Proven/Tried	Intersection with high crossing volumes, intersection with high turning vehicle volumes, and intersection with patterns of pedestrian or bicycle conflict with vehicles.	Varies depending on existing infrastructure
	Bicycle Signals	31-34	Bicycle Signal - 0.55 CMF Source: www.oregon.gov/ODOT/ Engineering/Docs_TrafficEng/ CRF-Appendix.pdf	Proven (Separate Bicycle Signal) Experimental (Leading Bicycle Interval)	Intersections with high motor vehicle/bicycle conflicts, Intersections with a with two-way or contraflow bicycle movement, where a bicycle facility transition requires the bicyclist to cross through a motor vehicle lane, and locations where bicyclist are required an increase level of control to facilitate unusual or unexpected movements.	Varies depending on existing infrastructure
	Right Turn on Red Prohibition	35-36	Varies	Tried	Locations that have limited sight distance and/or unusual geometry, at locations with high pedestrian activity such as schools, libraries, senior center and trasit stations, and at any crosswalk where the MnMUTCD pedestrian volume and/or school warrant is met.	$200/standard sign; $3,000/LED blank-out sign
	Roundabouts	37-39	0.40 CMF for pedestrian crashes	Tried	Intersections with a pattern of fatal, angle, turning,and head-on crashes and intersections that would benefit from platoon and gap acceptance management.	$1 million
	Bicycle Boxes	40-42	0.65 CMF Source: www.oregon.gov/ODOT/ Engineering/Docs_TrafficEng/ CRF-Appendix.pdf	Proven	Signalized intersections, roadways with bike lanes that experience a substantial volume of bicycle traffic, and at intersections with a high number of motor vehicle conflicts.	$1,000 per bicycle box
	Protected Intersections	43-45	Varies	Proven	Locations with high numbers of conflicts between bicyclists and turning vehicles	$100,000 to upgrade a signalized intersection

	Strategy	Pages	Crash Modification Factor (CMF)	Evidence (Proven/Tried/ Experimental)	Candidate Locations	Construction Estimates
Uncontrolled Intersection Elements	**Pedestrian Hybrid Beacon (PHB)**	46-48	Pedestrian Crashes - 0.45 CMF Source: https://safety.fhwa.dot.gov/provencountermeasures/ped_hybrid_beacon/	Proven	Locations with marked crosswalks, and high traffic volumes and speeds combined with high volumes of pedestrians crossing.	$100,000-$170,000
	Rectangular Rapid Flashing Beacon (RRFB)	49-51	0.53 CMF Source: https://safety.fhwa.dot.gov/ped_bike/step/docs/TechSheet_RRFB_508compliant.pdf	Proven	Locations with traffic volumes less than 12,000 vehicles per day, and speeds less than 40 MPH.	Varies; $15,000-$100,000
	Crossing Guards	52-54	Not Available	Tried	Crossing guards are commonly applied within school zones as part of MnDOT Safe Routes to School program. This program allocates funds to communities and schools to complete safety improvement projects on routes students use to walk and bike to school.	Nominal costs for training student and parent volunteers
	Grade-separated Crossings	55-57	0.13 CMF Source: https://www.dot.state.mn.us/stateaid/trafficsafety/reference/ped-bikehandbook-09.18.2013-v1.pdf	Proven	Locations with heavy volumes of pedestrian and bicycle traffic crossing a roadway with high vehicular traffic volumes, locations where pedestrian and bicyclists will want to cross the road, and locations with difficult terrain or geographic obstacles to cross the roadway	$1,800/lf + $19,000 per end section

	Strategy	Pages	Crash Modification Factor (CMF)	Evidence (Proven/Tried/ Experimental)	Candidate Locations	Construction Estimates
Linear Facilities	**Route Modifications**	59-61	Not Available	Proven	On routes that experience and encourage bicycle activity, such as a bicycle boulevards, locations where vehicle traffic is lo, and in urban settings on low-speed, low-volume local streets.	Varies depending on treatment
	Road Diets	62-64	0.53-0.81 CMF Source: FHWA	Proven	On roadways with volumes up to 20,000 ADT.	$25,000-$40,000 per mile
	Sidewalks	65-66	0.11-0.35 CMF Source: https://safety.fhwa.dot.gov/provencountermeasures/walkways/	Proven	Along all urban streets and suburban arterials and collectors, adjacent to streets that connect pedestrian origins and destinations, along high-speed and high-volume roadways without shoulder width, shoulder space should be considered on any rural or suburban roadway that cannot feasibly implement a sidewalk or walkway.	$8 per square foot of concrete sidewalk, $6,000 per curb ramp
	Shared Space /Complete Streets	67-69	Not Available	Tried	Locations with a high volume of pedestrian activity, little through motor vehicle traffic, and motor vehicle operating speeds between 5 and 15 MPH.	$50,000 per block
	On-Road and Buffered Bicycle Lanes	70-72	0.65 CMF Source: https://safety.fhwa.dot.gov/tools/crf/resources/fhwasa08011/page2.cfm#linktarget_t3	Proven	On roadways with motor vehicle speeds of 35 MPH or less. Bike lanes are likely to be comfortable for bicyclists of all ages and abilities when traffic volumes are less than 6,000 vehicles per day and speeds are 25 mph or lower.	Varies depending on type of construction project
	Paved Shoulders	73-75	Pedestrian Crashes - 0.29 CMF Source: https://safety.fhwa.dot.gov/ped_bike/tools_solve/fhwasa11018/	Proven	Any road is a suitable candidate for paved shoulders, but rural or suburban locations where motor vehicle speeds are equal to or exceed 50 mph are particularly important to improve bicyclist comfort and safety.	$60,000-$100,000 per mile

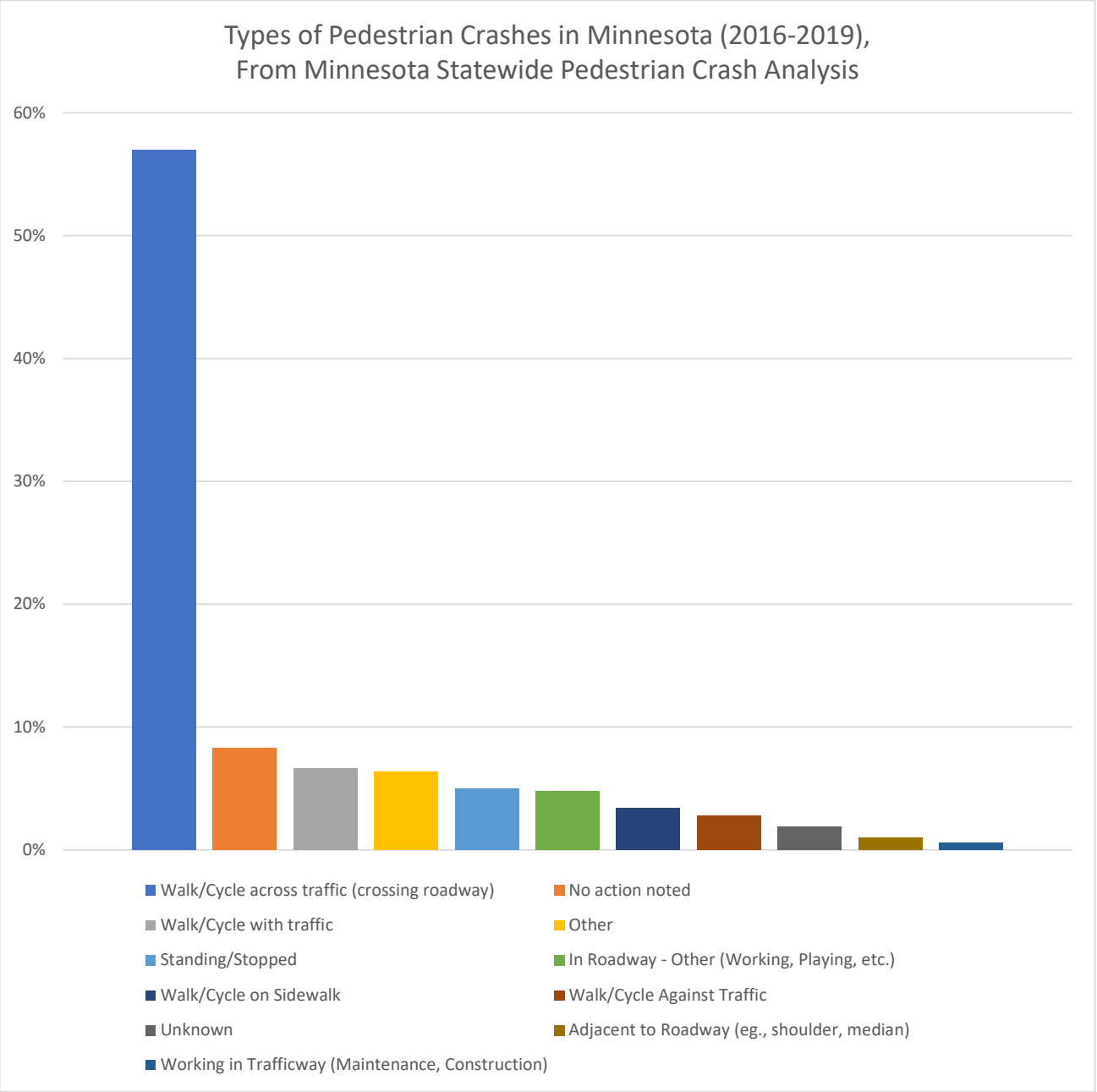
	Strategy	Pages	Crash Modification Factor (CMF)	Evidence (Proven/Tried/ Experimental)	Candidate Locations	Construction Estimates
Linear Facilities	**Bicycle Boulevards**	76-78	0.37 CMF Source: http:// www.cmfclearinghouse.org/ detail.cfm?facid=3092	Tried/Proven	On local/residential streets that are parallel to and near an arterial road or community destination, On street segments that are of sufficient length to reasonably serve long-distance bicycle trips or serve as a missing link in the bicycle network, and on local/residential streets that have less than 3,000 ADT, low operating speeds (25 mph or less), and few heavy commercial vehicles	$5,000 to $150,000 per mile, depending on the extent of traffic calming devices used
	Shared Use Paths	79-82	0.63 CMF Source:https://www.fdot.gov/ docs/default-source/ contentdocs/ roadway/qa/tools/CRF.pdf/	Proven	Where there is a greater mix of users, high user volumes, and a wide range of speeds between shared use path users, when space is limited, shared use paths can be placed in lieu of separated bike lanes, and wider paths may be necessary where there are either large numbers of people bicycling or large percentages of other nonmotorized users	$300,000 to $600,000 per mile
	Separated Bicycle Lanes	83-85	0.41 CMF Source: http://www. cmfclearinghouse.org/detail. cfm?facid=4102	Tried	In areas with traffic volumes over 6,000 ADT or high motor vehicle speeds (over 30 mph), in areas with peak hour bicycle traffic over 100 per hour, in areas with a wide range of user types and variety of speeds, in areas that connect existing or planned biking networks, and where roadways experience freight movements, delivery locations, on-street parking, accessible parking, pedestrian curb ramps,bus and transit access, and curb cuts.	$75,000 per mile for tube delineator separated, up to $1,000,000 per mile for urban, two-way, curb separated reconstruction
	Temporary On-Street Shared Use Paths	86-88	Not available	Experimental	Areas where there is limited right-of-way, areas with limited bicycle or pedestrian demand, where missing links exist in the bicycle and/or pedestrian network	vary depending on type, size and materials

Bicycle and Pedestrian Design and Planning Considerations

Pedestrian and Bicyclist Crashes and Safety Issues in Minnesota

A review of statewide pedestrian crashes in Minnesota found that the majority of crashes - 57% - occurred when the user was crossing the roadway.

More than half of all pedestrian crashes occured on minor arterials, meaning that these roadways are overrepresented as they represent only 7% of the total roadway network in Minnesota. Practitioners should focus improvement efforts on these minor arterial roadways to realize the greatest impact on reducing pedestrian crashes.



Intersection Design Techniques

Marked Crosswalks

What is their purpose?

A marked crosswalk is a type of pavement marking that both indicates to pedestrians the recommended location to cross the roadway and alerts approaching motorists as to where pedestrians may be crossing the street. Section 1A.13 of the MnMUTCD defines a crosswalk as the extension of the sidewalk or the shoulder across an intersection, regardless of whether it is marked or not. A crosswalk also includes the portion of a roadway distinctly indicated for pedestrian activity by lines or other markings on the surface, such as at mid-block crossings (MN Statute 169.011, Subd. 20).

Marked Crosswalk at Golden Valley Road and Winnetka Avenue, Golden Valley, MN

Are they a proven strategy?

Marked crosswalks alone are considered **TRIED**.

When installed with other treatments, such as curb extensions or a Rectangular Rapid Flashing Beacon, marked crosswalks have been **PROVEN** to improve safety (refer to section on Rectangular Rapid Flashing Beacons).

The efficacy of marked crosswalks, whether installed as a stand-alone treatment or in conjunction with other improvements, decreases as traffic volumes, speeds, or number of lanes increases.

An FHWA study concluded that the presence of marked crosswalks alone, without supplemental enhancements, neither improve or decrease safety.

The study also stated that these findings should not be misused as justification to do nothing to help pedestrians cross streets safely. Instead, pedestrian crossing issues and needs should be identified routinely, and appropriate solutions should be selected to improve pedestrian safety and access.

Where would we use them?

Prior to installing a marked crosswalk, an agency should always consider pedestrian volumes, vehicular volumes, stopping sight distance for drivers, the distance to adjacent crosswalks and signalized intersections, the number of driving lanes, and the operating speed of vehicles. MnDOT's Traffic Engineering Manual provides a flowchart and summary table (Table 13-1) to help communities determine appropriate application of crosswalks at a given location. Additionally, the FHWA Guide for Improving Pedestrian Safety at Uncontrolled Crossing Locations provides direction on evaluating

Marked Crosswalks

crossing locations and selecting potential crossing treatments.

Marked crosswalks with or without supplemental treatments can be installed at:

- Signalized intersections
- Unsignalized locations with vehicle volumes below 15,000 vehicles per day
- School zone crossings (whether signalized or not)
- Unsignalized locations where it is determined there is sufficient crossing activity for a marked crossing (transit stop, library, recreation center, trail, major commercial destination)
- Mid-block crossing locations

What are the maintenance impacts?

Partner with maintenance team members during design development to discuss strategies and issues related to routine maintenance. Similar to other roadway markings, crosswalk markings will require routine maintenance to sustain effectiveness and meet reflectivity standards. Ground-in poly preform or thermoplastic crosswalk markings may have higher installation costs, but these options will improve the life of crosswalk markings and reduce maintenance costs.

What are the advantages?

- A low cost way to guide pedestrians to the best location to cross.
- Help designate school zones and other high-pedestrian activity crossing locations.
- Reinforce the presence of a crossing at an intersection.
- Establish a legal mid-block crossing.

Supplemental treatments

Marked crosswalks, especially at uncontrolled intersections, are often combined with additional treatments. Reference the MnDOT Traffic Engineering Manual, Table 13-1 and Section 13-3.02, to help determine additional treatment options. Additional treatment options include:

- High-visibility crosswalk markings
- Parking restrictions on crosswalk approaches
- Improved lighting
- Advance (Stop Here For) pedestrians sign and (stop) line
- Advanced signing
- In-street pedestrian crossing sign
- Curb extensions or median islands
- Raised crosswalks (not allowed on State Aid roadways)
- RRFBs or PHBs

What are the challenges?

- FHWA study shows safety effects of marked crossings are minor; are dependent on number of lanes and vehicular volumes; and are indirectly related to speed.
- In most cases, marked crosswalks are most effective with additional treatments (e.g. roadway lighting, curb extensions, raised islands, advanced warning signs, or flashing beacons), which require a range of investment.
- Require continued maintenance.

Best practices

Marked crosswalks markings should be considered at all signalized intersections where there is pedestrian activity. Marked crosswalks at uncontrolled intersections should include additional features such as improved lighting, advance warning signs, medians, and curb extensions, whenever possible.

How much do they cost?

Depending on the material, type of crosswalk, and supplemental signing, cost per square foot of crosswalk can vary between $100 and $5,000. Supplemental features such as curb extensions, median islands, RRFBs, and lighting bring additional costs.

Marked Crosswalks

Roadway Configuration	Posted Speed Limit and AADT								
	Vehicle AADT <9,000			Vehicle AADT 9,000–15,000			Vehicle AADT >15,000		
	≤30 mph	35 mph	≥40 mph	≤30 mph	35 mph	≥40 mph	≤30 mph	35 mph	≥40 mph
2 lanes (1 lane in each direction)	❶ 2 4 5 6	❶ 5 6 7 9	① 5 6 ❼ ❾	❶ 4 5 6	❶ 5 6 7 9	① 5 6 ❼ ❾	❶ 4 5 6 7 9	① 5 6 7 9	① 5 6 ❾
3 lanes with raised median (1 lane in each direction)	❶ 2 3 4 5	❶ ❸ 5 7 9	① ❸ 5 ❼ ❾	① 3 4 5	① ❸ 5 ❼ ❾	① ❸ 5 ❼ ❾	① ❸ 4 5 7 9	① ❸ 5 ❼ ❾	① ❸ 5 ❾
3 lanes w/o raised median (1 lane in each direction with a two-way left-turn lane)	❶ 2 3 4 5 6 7 9	❶ ❸ 5 6 7 9	① ❸ 5 6 ❾	① 3 4 5 6 7 9	① ❸ 5 6 ❼ ❾	① ❸ 5 6 ❾	① ❸ 4 5 6 7 9	① ❸ 5 6 ❾	① ❸ 5 6 ❾
4+ lanes with raised median (2 or more lanes in each direction)	❶ ❸ 5 7 8 9	❶ ❸ 5 7 8 9	① ❸ 5 8 ❾	① ❸ 5 7 8 9	① ❸ 5 ❼ 8 ❾	① ❸ 5 8 ❾	① ❸ 5 ❼ 8 ❾	① ❸ 5 8 ❾	① ❸ 5 8 ❾
4+ lanes w/o raised median (2 or more lanes in each direction)	❶ ❸ 5 6 7 8 9	① ❸ 5 ❻ 7 8 9	① ❸ 5 ❻ 8 ❾	① ❸ 5 ❻ 7 8 9	① ❸ 5 ❻ ❼ 8 ❾	① ❸ 5 ❻ 8 ❾	① ❸ 5 ❻ ❼ 8 ❾	① ❸ 5 ❻ 8 ❾	① ❸ 5 ❻ 8 ❾

Given the set of conditions in a cell,

- # Signifies that the countermeasure is a candidate treatment at a marked uncontrolled crossing location.
- ● Signifies that the countermeasure should always be considered, but not mandated or required, based upon engineering judgment at a marked uncontrolled crossing location.
- ○ Signifies that crosswalk visibility enhancements should always occur in conjunction with other identified countermeasures.*

The absence of a number signifies that the countermeasure is generally not an appropriate treatment, but exceptions may be considered following engineering judgment.

1. High-visibility crosswalk markings, parking restrictions on crosswalk approach, adequate nighttime lighting levels, and crossing warning signs
2. Raised crosswalk
3. Advance Yield Here To (Stop Here For) Pedestrians sign and yield (stop) line
4. In-Street Pedestrian Crossing sign
5. Curb extension
6. Pedestrian refuge island
7. Rectangular Rapid-Flashing Beacon (RRFB)**
8. Road Diet
9. Pedestrian Hybrid Beacon (PHB)**

Application of pedestrian crash countermeasures by roadway feature

**Refer to Chapter 4 from the Guide for Improving Pedestrian Safety at Uncontrolled Crossing Locations, 'Using Table 1 and Table 2 to Select Countermeasures,' for more information about using multiple countermeasures.*

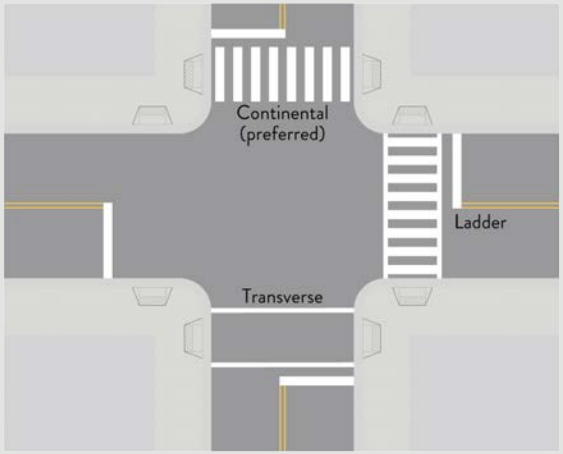
***It should be noted that the PHB and RRFB are not both installed at the same crossing location.*

This table was developed using information from: Zegeer, C.V., J.R. Stewart, H.H. Huang, P.A. Lagerwey, J. Feaganes, and B.J. Campbell. (2005). Safety effects of marked versus unmarked crosswalks at uncontrolled locations: Final report and recommended guidelines. FHWA, No. FHWA-HRT-04-100, Washington, D.C.; FHWA. Manual on Uniform Traffic Control Devices, 2009 Edition. (revised 2012). Chapter 4F, Pedestrian Hybrid Beacons. FHWA, Washington, D.C.; FHWA. Crash Modification Factors (CMF) Clearinghouse; FHWA. Pedestrian Safety Guide and Countermeasure Selection System (PEDSAFE); Zegeer, C., R. Srinivasan, B. Lan, D. Carter, S. Smith, C. Sundstrom, N.J. Thirsk, J. Zegeer, C. Lyon, E. Ferguson, and R. Van Houten. (2017). NCHRP Report 841: Development of Crash Modification Factors for Uncontrolled Pedestrian Crossing Treatments. Transportation Research Board, Washington, D.C.; Thomas, Thirsk, and Zegeer. (2016). NCHRP Synthesis 498: Application of Pedestrian Crossing Treatments for Streets and Highways. Transportation Research Board, Washington, D.C.; and personal interviews with selected pedestrian safety practitioners.

Marked Crosswalks

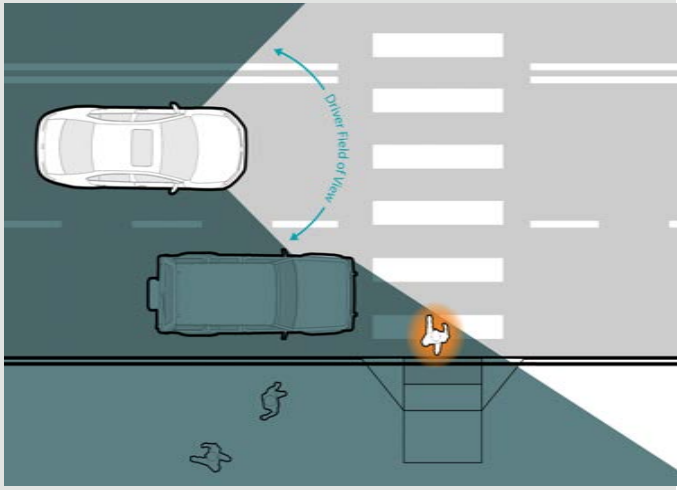
Design Features

There are a variety of marked crosswalks, such as continental, ladder, and transverse, that are more visible to motorists than traditional parallel marked crosswalks. The locations should be convenient, accessible, and aligned with pedestrian routes.



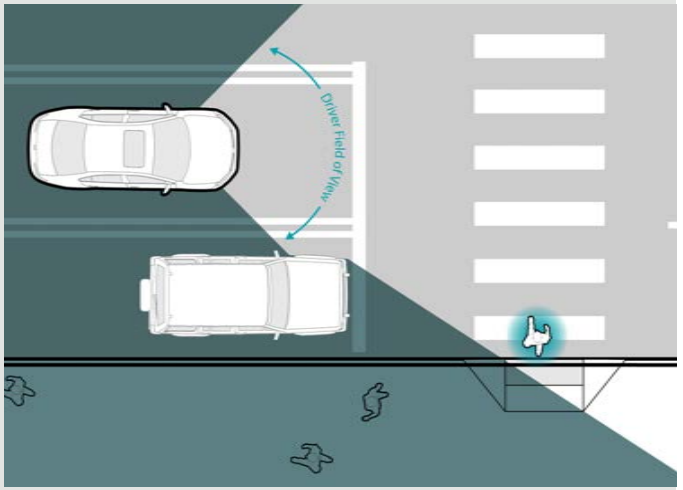
Types of crosswalk markings

Additionally, advance warning signs prior to the crossing are typically installed when signing is needed to better alert drivers of an upcoming crosswalk. Advanced stop bars can improve sight distance and reduce the risk of a "multiple-threat" pedestrian crash on multi-lane roadways, which occurs when one vehicle stops for a pedestrian at the marked crosswalk and blocks the line of sight between the crosswalk user and approaching vehicles in the adjacent lane. The advance yield line allows more time and distance for a collision to be avoided.

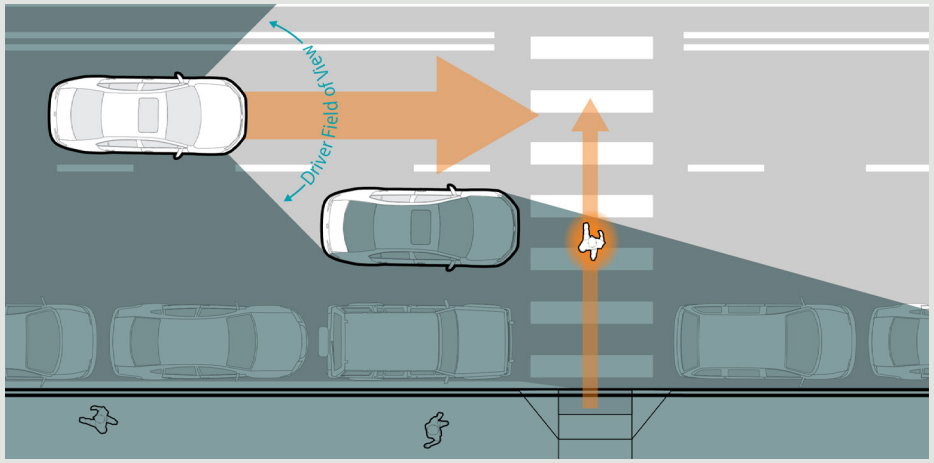


No advanced stop bar

Overhead lighting, curb extensions, and/or median islands can also be considered to improve a crossing's effectiveness. In-pavement lights are another design strategy, however they may have ongoing maintenance issues related to climate and snow plow damage.



Advanced stop bar



An image of a multiple threat situation

Medians and Crossing Islands

What is their purpose?

Medians and crossing islands (also known as refuge islands or center islands) are raised areas that are constructed in the center portion of a roadway, serving as a place of refuge for people who cross the road mid-block or at an intersection. They allow pedestrians and bicyclists to concentrate their attention on one direction of traffic at a time while crossing the roadway. After crossing to the center island, users wait for motorists to stop for an adequate gap in traffic before crossing the second half of the street. Refuge islands can drastically reduce pedestrian delay and vehicle conflicts by increasing the number of safe gaps that are available.

Median at Maryland Avenue and Greenbrier Street, Saint Paul, MN

Are they a proven strategy?

FHWA research shows that median and crossing islands are a **PROVEN** safety countermeasure.

Supporting Document: FHWA Proven Countermeasures – Pedestrian Medians

Where would we use them?

When installing a median or crossing island, an agency should develop a design that allows accessibility for all users and adheres to ADA crossing standards. 6' is the minimum median width where detectable warning surfaces are required. However, to allow storage space for a bicycle and to allow space for a level landing and truncated domes, a best practice is to construct crossing islands or medians of at least 8' in width. 10' or greater width is preferred, especially where bicycle traffic is expected. Crossing islands less than 6' are not considered pedestrian refuges since they cannot include detectable warning surfaces and may not safely serve as a refuge for all users.

Crossing islands are commonly installed at:

- Mid-block crossing locations or candidate locations
- High-priority pedestrian crossing locations such as transit stops, schools, and parks
- On roadways where marked crosswalks alone may not be sufficient, including roadways with speeds greater than 35 mph, and when annual average daily traffic (AADT) is greater than 9000. The raised medians must be accessible by all users, and should adhere to ADA crossing standards.

Medians and Crossing Islands

What are the advantages?

- Separates opposing vehicle travel lanes and allows pedestrians/bicyclists to cross the roadway in two stages rather than all at once.
- Reduces certain types of motor vehicle crashes, such as head-on crashes.
- Can help slow vehicle speeds by providing visual narrowing/traffic calming of the roadway.
- Can be implemented using low-cost, interim materials such as striping, flexible posts, and other bollards until a permanent improvement can be funded through a reconstruction project or other programming.
- Can provide area for landscaping and other visual enhancements as well as stormwater treatment.
- Studies show that a **raised median can reduce up to 46% of pedestrian crashes, and a pedestrian crossing island can reduce up to 56% of pedestrian crashes.**

What are the challenges?

- Permanent medians can be costly and are recommended to be included in larger construction projects.
- May restrict driveway access and on-street parking.
- Can introduce more significant design features and construction costs if stormwater management is impacted and additional inlets are required at locations with curb extensions.
- Require additional winter maintenance considerations.

What are the maintenance impacts?

Partner with maintenance team members during design development to discuss strategies and issues related to routine maintenance, especially during winter months, to keep the crossing island clear of snow and debris, along with the rest of the sidewalk network. Median crossings can pose an obstacle to snow plows, and to reduce plow strikes on median island curbs, designers should follow the pedestrian approach nose details in MnDOT Standard Plan 5-297.250.

Supplemental treatments

Raised medians and crossing islands are often combined with the following treatments:

- High-visibility crosswalk markings
- Advanced warning signs
- Curb extensions
- Street lighting
- Advance stop bars
- RRFBs or PHBs

A median with a refuge island

Best practices

To accommodate all users, medians must be fully accessible by ramp or cut through, and should provide tactile cues for pedestrians with visual impairments to indicate the border between the pedestrian refuge area and the motorized vehicle roadway.

How much do they cost?

The average cost for a raised island or crossing island is approximately $10/sf, and the total cost can vary widely from approximately $2,000 to $45,000. Costs depend on the design, site conditions, and whether the median can be included as part of a larger construction project.

Medians and Crossing Islands

Design Features

Continuously raised medians may not be appropriate or physically possible at all locations. They may need to be weighed against other roadway features such as wider sidewalks, bicycle lanes, landscaping buffers, or on-street parking.

At both intersections and mid-block locations, short sections of median at high-priority crossings such as schools and parks provide benefit to pedestrians. Pedestrian islands may be appropriate at unsignalized and signalized crossing locations.

Raised medians must incorporate the following:

- Fully accessible ramps.
- Tactile cues for pedestrians with visual impairments, that meet ADA standards.
- Adequate visibility between pedestrian and approaching vehicles.
- The median crossing can be angled (rather than perpendicular) to allow pedestrians easier visibility of on-coming traffic.
- Crossing islands may also be staggered (also known as a Z–crossing), which is a treatment that forces pedestrians to turn in the median and face the direction of traffic. Staggered crossings may be difficult for pedestrians with vision impairments to navigate, so it's important to provide a detectable edge along the crossing.

Pedestrian approach nose shown at a refuge island

Z-crossing treatment

Resources

- Proven countermeasure: https://safety.fhwa.dot.gov/provencountermeasures/ped_medians/
- http://pedbikesafe.org/PEDSAFE/countermeasures_detail.cfm?CM_NUM=6
- CRFs: https://safety.fhwa.dot.gov/tools/crf/resources/fhwasa08011/fhwasa08011.pdf
- https://www.dot.state.mn.us/ada/pdf/5-297-250.pdf

Curb Extensions and Curb Radii

What is their purpose?

A curb extension is an extension of the sidewalk into the roadway that reduces the crossing distance of a roadway for pedestrians and pedestrian exposure to vehicular traffic. Curb extensions can provide visual cues to drivers that encourage them to reduce speeds and be aware of pedestrians and bicyclists. Curb extensions also improve intersection sight distance for vehicles and pedestrians since they restrict parking near the intersection. They can also provide additional space to construct ADA-compliant curb ramps, making them an effective strategy on ADA retrofit projects where constructing and ADA-compliant ramp may be otherwise difficult. Curb extensions are used at intersections and at mid-block crosswalks.

A curb extension at an intersection

Are they a proven strategy?

Curb extensions are **PROVEN** safety strategies. Research shows that reducing the crossing distance, restricting the street width, and reducing wide corner radii improve pedestrian safety and enhance the sight distance between motorists and pedestrians.

Supporting Documentation: MnDOT Enhanced Crosswalks

Where would we use them?

Curb extensions are most appropriate in urban settings when there is an on-street parking lane or a shoulder where the extensions will not impede bicycle travel. The curb extension physically precludes vehicles parking near an intersection or pedestrian crossing, improving sight lines and visibility both for and of crossing pedestrians near parked vehicles. Beyond being used at intersections, curb extensions can be applied in a variety of ways depending on the roadway's needs. Examples include the following:

- Mid-block curb extensions or pinch points
- Offset curb extensions or chicanes
- Bus stops

What are the maintenance impacts?

Partner with maintenance team members during design development to discuss strategies and issues related to routine maintenance, especially during winter months. Curb extensions may increase the level of effort required to remove snow from the parking lane. This can be minimized by adding delineators or markers on the curb extension to help guide snow plows, and by flattening the taper rate of the curb extension to 1:5 so plows can maintain a limited forward speed while clearing snow adjacent to the curb extension.

Curb Extensions and Curb Radii

What are the advantages?

- May be temporarily implemented and evaluated using low-cost, interim materials such as gravel, planters, paint and striping, flexible posts, or bollards until a permanent improvement can be funded through a reconstruction project or other programming.
- Increase visibility of pedestrians and bicyclists crossing the street.
- Encourage slower turning speeds.
- Reduce crossing distance at mid-block crosswalks.
- Serve as a gateway or visual cue for drivers entering a slower, more residential area.
- May dedicate width for bus stops (bus bulbs).
- May dedicate width for on-street parking.
- Increase space for street furniture, landscaping, and stormwater treatment.
- Improve intersection sight distance (by prohibiting parking near the intersection)
- Provide additional space to construct ADA-compliant curb ramps.
- Studies show a reduction in crashes up to 45%.

What are the challenges?

- Design can be restricted by the turning radius of the larger design vehicles (trucks and buses).
- Stormwater management needs associated with the new curb alignment (e.g., catch basin locations) can bring additional design and construction costs.
- Require additional winter maintenance considerations.
- Curb extension retrofits may reduce the amount of available on-street parking

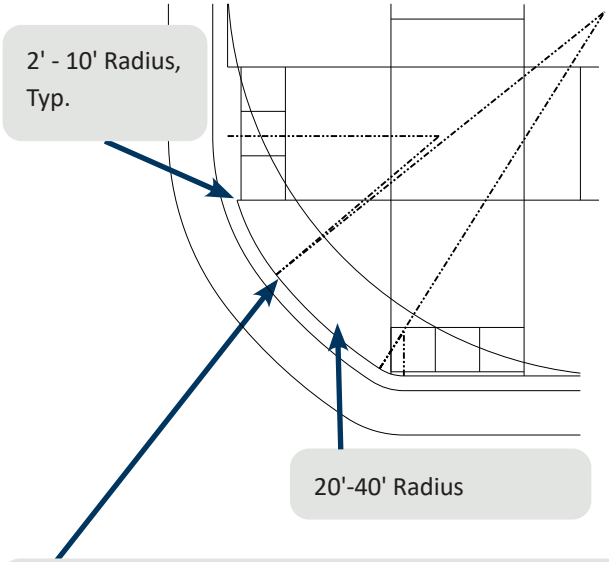
Supplemental treatments

Curb extensions and curb radii can be combined with the following treatments:

- High-visibility crosswalk markings
- Advanced warning signs
- Right turn on red restrictions at signalized intersections
- Landscaping or other aesthetic improvements

Best practices

Curb extensions can often be lengthened to provide additional space for landscaping, stormwater treatment, transit waiting areas, and bus shelters. In addition, curb extensions can create additional space to fit ADA-compliant curb ramps, improving accessibility in constrained locations where it may otherwise be difficult to do so.



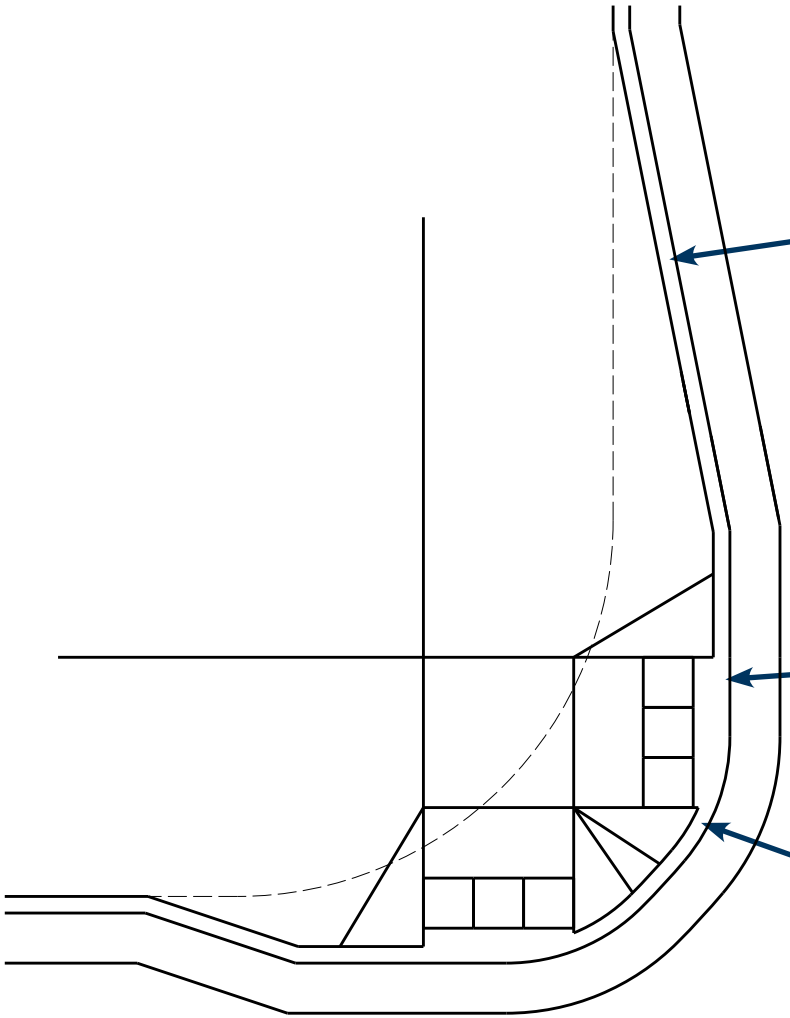
A compound radius can increase available curb extension space while still allowing large vehicles to turn, especially on multi-lane roadways.

Compound radius detail, Source: MnDOT Curb Ramp Standard Plan

How much do they cost?

Costs depend on site conditions, drainage impacts, pavement design, and ADA accommodations. Curb extension installation can range between $2,000-$3,500 per corner if it does not cause storm sewer impacts and between $10,000-$20,000 per corner if it does cause storm sewer impacts.

Curb Extensions and Curb Radii



1:3 minimum taper. Using a 1:5 taper on the upstream (plow-facing) side can improve ease of maintenance, but is so flat that vehicles may still attempt to park along the taper. Even with a 1:3 taper, signage may be needed such as "no parking here to corner".

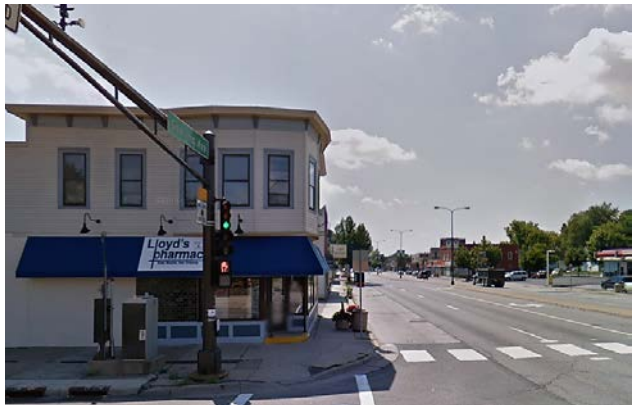
Where prohibiting parking is a primary concern, a steeper taper can be helpful (some agencies have used as steep as 1:2 taper; designers should take care to adequately delineate steep tapers).

Having at least 5' of non-zero height tangent curb helps establish the presence of the curb ramp and

With the previous curbline, it would have been difficult to construct an ADA-compliant curb ramp at this location, especially if trying to match into a doorway at the intersection. This design creates enough space to construct ADA-compliant curb ramps, while still keeping the back of the sidewalk at the existing elevation.

Curb extension detail, Source: MnDOT Curb Ramp Standard Plan

Curb Extensions and Curb Radii



Curb retrofit on Snelling Avenue, Saint Paul, MN; Source: Google

Before/after photo of curb ramp retrofit. The curb extension allowed the construction of ADA-compliant ramps on an otherwise constrained corridor. Note the upstream side of curb extension has a flatter taper than the downstream side.

Design Features

Curb extensions should be tailored to the unique characteristics of the site at which they are installed, though MnDOT's Pedestrian Curb Ramp Standard Plans has details that may be helpful. See Curb Extensions and Curb Radii section of this handbook.

Designers should also consider or incorporate the following:

- Curb extensions should extend the full width of an adjacent parking lane.
- Maintain proper sight distance between pedestrians and motorists, including street furniture and landscaping features.
- Stormwater runoff may be impacted and additional catch basins may be required as part of the design. Avoid designs that cause water to pool on the sidewalk.

Resources

- Proven: http://www.dot.state.mn.us/stateaid/trafficsafety/county/CRSP-EnhancedCrosswalks.pdf
- https://safety.fhwa.dot.gov/intersection/conventional/signalized/fhwasa13027/ch9.cfm#s911
- Minnesota DOT Roadway Design Manual, Chapter 5-1.04
- http://www.pedbikeinfo.org/cms/downloads/Countermeasure%20Costs_Report_Nov2013.pdf
- Bump Outs: http://pedbikesafe.org/PEDSAFE/countermeasures_detail.cfm?CM_NUM=5
- https://nacto.org/publication/urban-street-design-guide/street-design-elements/curb-extensions/
- Curb Radii: http://pedbikesafe.org/PEDSAFE/countermeasures_detail.cfm?CM_NUM=28
- https://safety.fhwa.dot.gov/ped_bike/step/docs/STEP_Guide_for_Improving_Ped_Safety_at_Unsig_Loc_3-2018_07_17-508compliant.pdf

Crosswalk Lighting

What is its purpose?

Crosswalk lighting is a strategy that installs street lights at and in advance of intersections and crosswalks to improve visibility, safety, and comfort, especially at night. Crosswalk lighting can contribute significantly to safety by providing an advance warning to drivers that they are approaching a point of potential conflict with pedestrians and bicyclists. Street lights can be located at individual intersections or crosswalks, or be continuous along roadway corridors.

Lighting at a midblock crosswalk

Is it a proven strategy?

Research shows that the installation of street lights at rural intersections is a **PROVEN** strategy to reduce crashes,—especially nighttime crashes, fatal and serious crashes, and vehicle-pedestrian and vehicle-bicycle crashes.

However, there is no research into the effectiveness of street lights relative to reducing pedestrian crashes at urban intersections or along urban roadways; this strategy has been **TRIED**.

Where would we use it?

Crosswalk lighting is commonly installed at:

- Isolated intersections with crosswalks that are not along continuously lit roadways
- Mid-block crosswalks

What are the maintenance impacts?

Crosswalk lighting requires routine maintenance to ensure the lighting is uniform at the intersection and all other material and fixtures are functioning appropriately. Maintenance depends on power source; for example, back-up battery packs require periodic replacement.

Supplemental treatments

Most strategies discussed in this guide would benefit from additional lighting, including mid-block crossings, marked crosswalks, curb extensions, and signalized intersections.

Crosswalk Lighting

Best practices

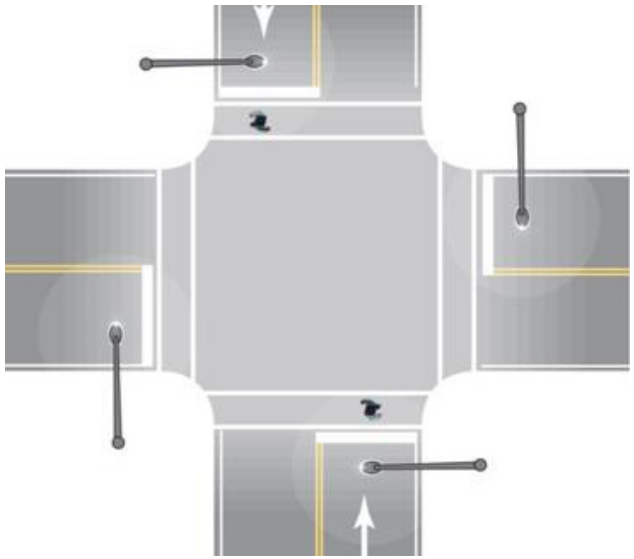
Properly designed street lights improve drivers' ability to see pedestrians during low light conditions. Crosswalk lighting should be provided on urban and suburban corridors that do not have continuous street lighting. Crosswalk lighting provides valuable visual cues for drivers, including a visual cue to pay attention for the possibility of a pedestrian in the roadway.

What are the advantages?

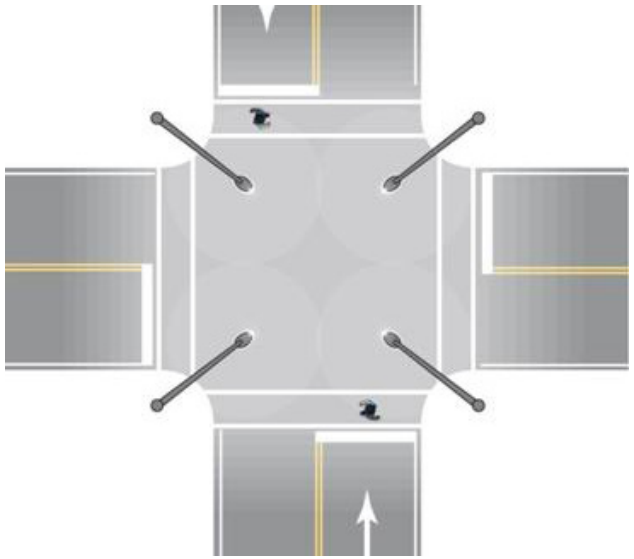
- Some construction costs may be eligible to be covered by federal and state funds.
- Solar-powered lighting can be used as an alternative to traditionally powered fixtures.
- Intersection illumination can reduce nighttime vehicle/pedestrian crashes by up to 42%.

What are the challenges?

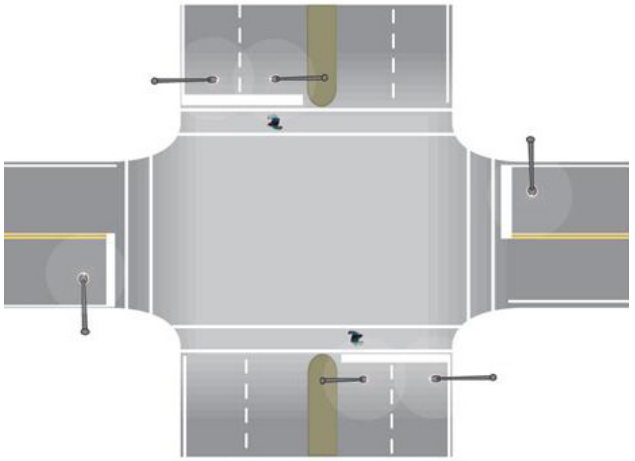
- Increased maintenance and power cost or battery costs (solar fixtures).
- Requires power source.
- Some communities are concerned about light pollution (consider full cutoff fixtures).



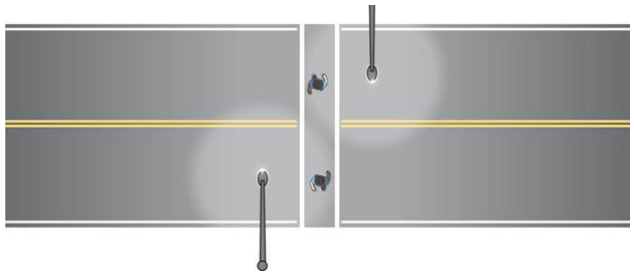
Intersection lighting over the stop bars



Intersection lighting over the center of the intersection



Intersection lighting with a four-lane divided roadway



Midblock crossing with two lights

Midblock crossing with a single light

How much does it cost?

Costs for implementation vary widely, depending on available utilities, power source, and fixture type. Typically, street light installation can range from around $10,000 per intersection to over $40,000.

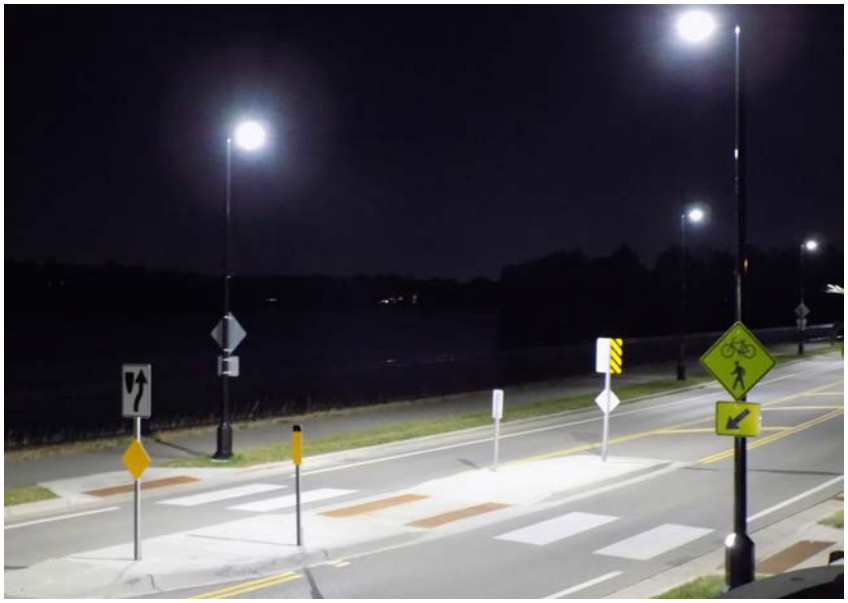
Crosswalk Lighting

Design Features

Agencies should reference MnDOT's Roadway Lighting Design Manual, AASHTO's Roadway Lighting Design Guide, and FHWA's Informational Report on Lighting Design for Midblock Crossings for information on state and federal lighting design practices.

Typical street light designs at crosswalks include the following:

- LED luminaires, davit arms that extend the luminaire out towards the roadway, and 30'-40' poles. There is a variety of options for pole material, such as aluminum, stainless steel, and fiberglass. More expensive options can include decorative luminaries and poles.
- Use breakaway poles and bases to reduce the severity of vehicle crashes involving the street lights. This is a common practice along high-speed and high-volume arterials where poles are placed in close proximity to the driving lanes.
- Ensure uniform lighting levels.
- Lights should be located in advance of crosswalks to illuminate the front of the pedestrian.
- A variety of lighting arrangements are possible at intersections or other crossing locations depending on the size and configuration of the site. For example, on wider or commercial streets, lighting should be installed on both sides.
- Consider the use of full cutoff lighting fixtures where light pollution is a concern. Full cutoff fixtures eliminate stray up-lighting.



Crosswalk lighting on Wayzata Boulevard, Long Lake, MN

Resources

- http://www.pedbikesafe.org/PEDSAFE/countermeasures_detail.cfm?CM_NUM=8
- http://www.cmfclearinghouse.org/detail.cfm?facid=436
- https://www.dot.state.mn.us/trafficeng/lighting/2010_Roadway%20Lighting_Design_Manual2.pdf

Raised Crosswalks

What is their purpose?

Raised crosswalks combine a marked crosswalk with a speed table that extends the full width of the crossing. A speed table is a mid-block traffic calming device that raises the entire wheelbase of a motor vehicle. This type of vertical deflection can have a positive effect for bicyclists and pedestrians, as it reduces motor vehicle speeds.

Raised crosswalk on Wheelock Parkway, Saint Paul, MN

Are they a proven strategy?

Based on FHWA research, raised crosswalks are a **PROVEN** strategy to reduce pedestrian crashes, and are a good candidate treatment for unsignalized intersections on roads with posted speeds 30 mph or less and AADT of 9,000 or less.

Where would we use them?

The same considerations for installing a marked crosswalk should also be made prior to installing a raised crosswalk. Reference MnDOT's Traffic Engineering Manual, Chapter 13 for more information on where a marked crosswalk is appropriate.

Typically, raised crosswalks are placed at mid-block locations where a marked crossing exists. Locations with the following characteristics are also good candidates, with examples including:

- At locations with high pedestrian or bicycle activity, such as at school crossings, park entrances, and commercial shopping districts
- At roundabout crossing locations
- At locations where shared use paths cross commercial driveways or ramps

In Minnesota, raised crosswalks have been implemented sparsely, and they may not be appropriate on major streets, truck, or transit routes. A majority of installations to date have been on minor streets, often on the stop-controlled leg of an intersection.

Raised Crosswalks

What are the maintenance impacts?

Partner with maintenance team members during design development to discuss strategies and issues related to routine maintenance, especially during winter months, to keep the raised crosswalk and its approaches clear of debris and snow. The design should ensure that the maintenance vehicles can clear the vertical deflection safely and without damaging the raised walk. One maintenance benefit of a raised crosswalk is that it can be simpler to remove snow from the pedestrian facility.

In addition, signing and markings require routine maintenance to sustain effectiveness and meet reflectivity standards.

Supplemental treatments

Similar to traditional marked crosswalks, raised crosswalks are often combined with the following treatments:

- High-visibility crosswalk markings
- Parking restriction on crosswalk approach
- Improved lighting
- Advanced stop lines and Stop Here for Pedestrians (R1-5b or R1-5c) signs
- Advanced or in-street signing
- In-street pedestrian crossing sign
- Curb extensions or median islands
- RRFBs or PHBs

What are the advantages?

- Reduced vehicle speeds at intersections can reduce bicycle and pedestrian crash severity.
- Improve driver ability to perceive and react to bicycles and pedestrians in the intersection by slowing vehicle speeds.
- May eliminate the need for separate ADA curb ramp construction, although tactile detectable warnings such as truncated domes are still necessary.
- Provide a strong gateway treatment at the entrance to a bicycle boulevard or a downtown area.
- Raised crosswalks can reduce pedestrian crashes by 45%.

Best practices

Raised crosswalks can be placed mid-block or at an intersection, and they are commonly constructed to be flush with the roadside curb. Raised crosswalks can also be constructed separate from the curb, but this requires ADA-compliant curb ramps on both sides of the crosswalk.

When considering raised crosswalks, evaluate local bus, truck, and emergency vehicle needs, and tailor the vertical design of the raised crosswalk to accommodate the appropriate design vehicles.

What are the challenges?

- Not appropriate on high-speed roadways.
- If not designed properly, may pose an obstacle to some low-clearance commercial vehicles and emergency vehicles. Coordination with fire departments, Emergency Management Services (EMS), and the trucking industry may be required.
- Modifications to existing drainage infrastructure may be required.
- Require additional winter maintenance considerations, especially related to snow removal.

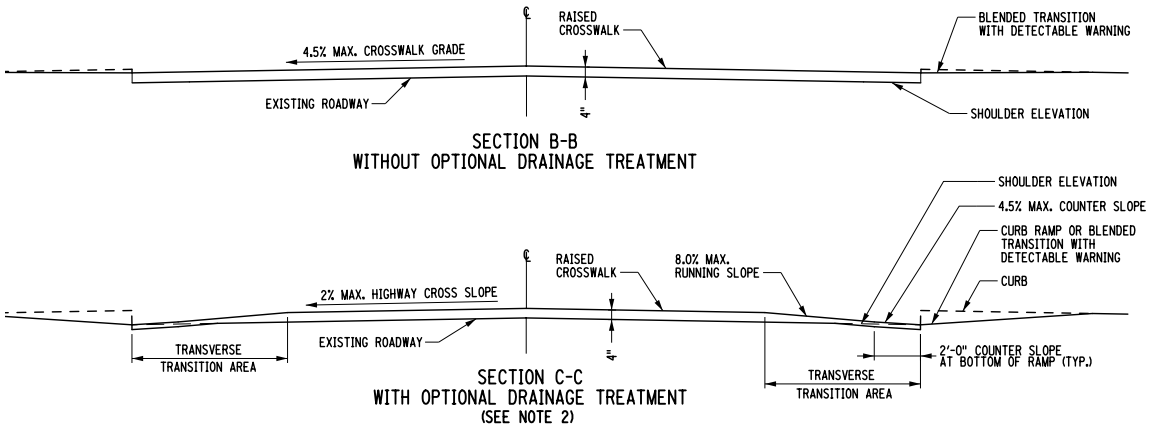
How much do they cost?

Depending on the material, stormwater impacts, and roadway type, costs for a raised crosswalk range from approximately $7,000 to $40,000 each.

Design Features

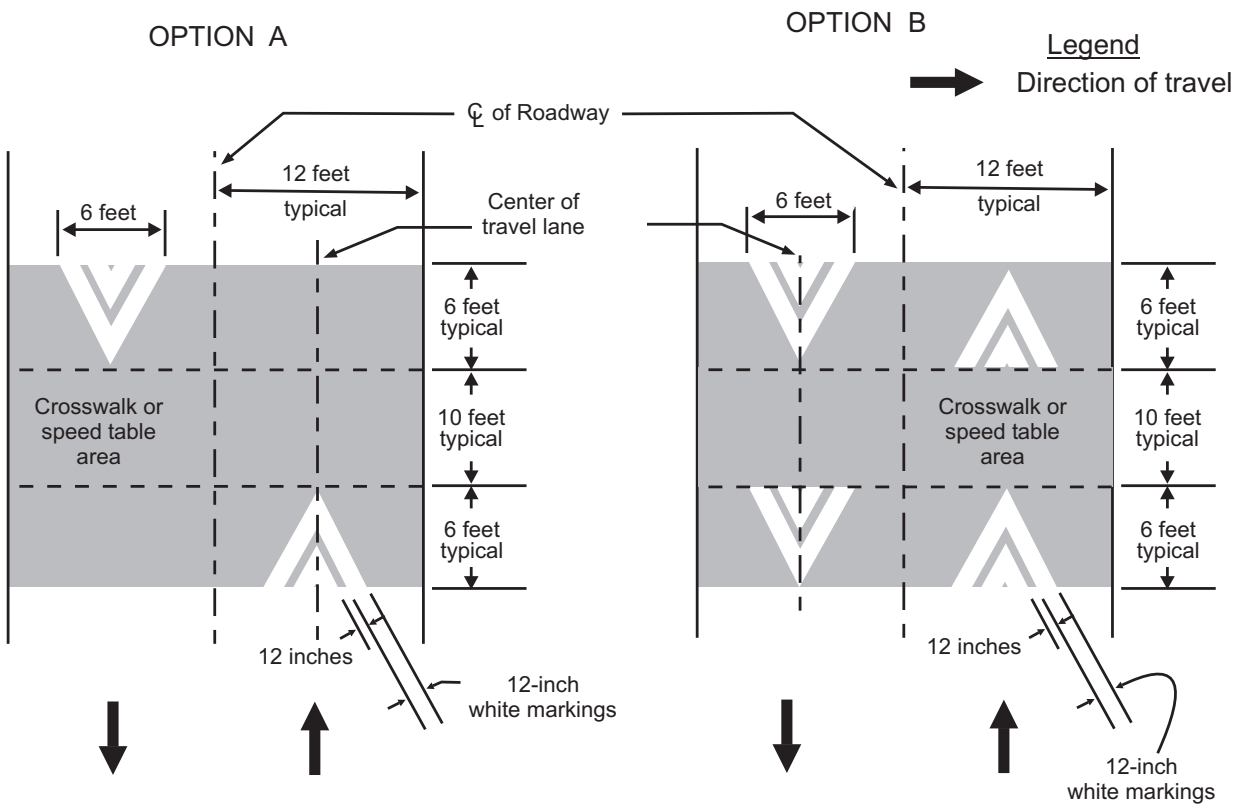
Design features can vary depending on the context of the installation. One example cited below is New York State DOT Standard Sheet 608-07 for raised crosswalk details. Several features of these details include:

- 3" -6" vertical deflection
  - New York State recommends a 4" height, so that a low-boy trailer (with a 5" clearance) can traverse the crosswalk.
  - 6" is a common height for installations that don't need to accommodate low-clearance vehicles. The width of the raised crossing is usually at least 10'.
- Typically, crosswalks are flush with the height of the sidewalk.
- ADA standards should be incorporated, including detectable warning fields and transverse transition areas.
- Approaches should have approach grades between 4% and 7%.
  - New York State recommends a 4% approach, with the rationale that a 4% grade break is no different than crossing a crowned roadway at an intersection.
  - Steeper (up to 7%) approaches are more typical at stop-controlled locations or areas unlikely to see low-clearance vehicles or higher speeds.
- The length of the approach grade varies as needed to achieve the desired approach grade break (7'-10' is common).
- A drainage channel may be provided through the raised crosswalk.
- Use pavement material that is different than the approach roadway to help draw attention to the presence of the raised crossing.
- Raised crossing pavement markings (refer to MnMUTCD Chapter 3).



Section view of raised crosswalk drainage treatment, Source: New York Department of Transportation

Raised Crosswalks



Note: optional crosswalk lines are not shown in this figure

Figure 3B-30 Pavement Markings for Speed Tables or Speed Humps with Crosswalks

Pavement markings for speed tables with crosswalks, Source: Minnesota MUTCD

Resources

- https://www.dot.ny.gov/programs/completestreets/repository/ei_13-018_raised%20crosswalks.pdf
- https://safety.fhwa.dot.gov/ped_bike/step/docs/TechSheet_RaisedCW_508compliant.pdf
- http://www.pedbikesafe.org/PEDSAFE/countermeasures_detail.cfm?CM_NUM=7

Intersection Design Standards

What is its purpose?

Intersection design should reduce conflicts between turning motor vehicles and crossing bicyclists or pedestrians. Design strategies to eliminate conflicts can include stop bar positions, channelized right-turns, and mountable truck aprons. When conflicts cannot be eliminated, intersection design should control the speed of turning vehicles to improve the visibility of bicycles and pedestrians, which force motorists to yield and ensure that if crashes do occur, they are less likely to result in injury. Intersection design elements must accommodate the design vehicle of the intersection.

Is it a proven strategy?

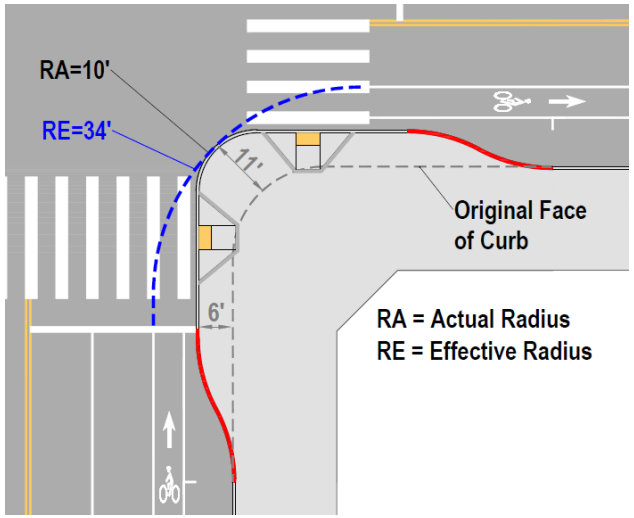
Individual intersection design strategies have been **PROVEN** to improve yielding and slow turning vehicles. For example, a study in New York City showed both pedestrian crashes and vehicles speeds reducing by 20% when hardened centerlines were implemented.

Hardened centerline

Where would we use it?

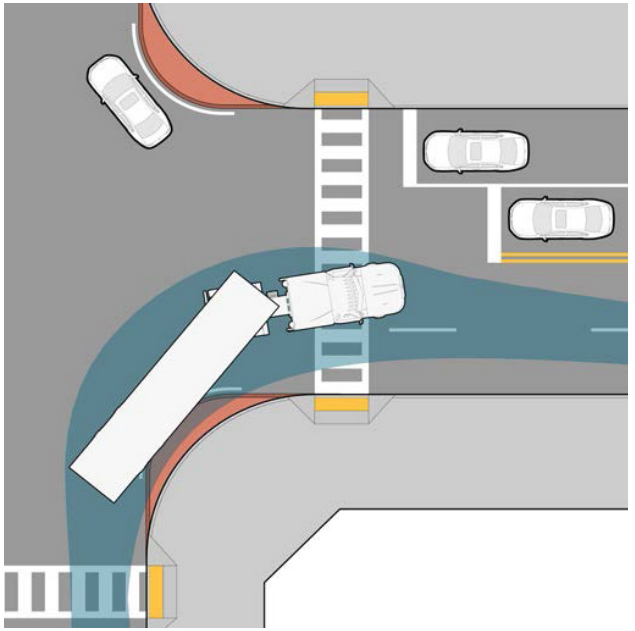
Changes to intersection design to achieve improved safety for pedestrians and bicyclists should be considered at the following locations:

- Where on-street parking or bike lanes are present, designers should examine "effective" turning radius rather than the actual curb radius. See the graphic below to compare effective turning radius with actual turning radius. Where the effective turning radius is greater than 25', consider curb extensions, mountable truck aprons, and/or hardened edge lines to create a more compact intersection that encourages slower speeds.



Effective vs. actual turning radius, Source: Los Angeles Supplemental Street Design Guide

- Where channelized right-turn lanes create higher speed conflicts with pedestrians and bicyclists at urban intersections due to the high turning speeds and large turning radii.
- Where left turns are permitted to occur concurrent with bicycle or pedestrian movements, hardened centerlines are a left-turn traffic-calming measure that may slow left-turning motorists.
- At locations where the design must still accommodate turning movements by larger vehicles, stop bars can be shifted back on the cross streets and mountable truck aprons can be implemented to reduce lane encroachments. Truck aprons are commonly used on the center island of roundabouts, but they may also be applied to intersection corners as well.



Truck turning right over a mountable curb, Source: FHWA Achieving Multimodal Networks

Intersection Design Standards

What are the advantages?

- Can reduce vehicle speeds at intersections, reducing bicycle and pedestrian crash severity.
- Can increase motorist yielding rates by improving drivers' ability to perceive and react to bicycles and pedestrians in an intersection.
- Can reduce intersection width by providing smaller curb radii and shorter crossing distance, minimizing pedestrian and bicycle exposure in the intersection.

What are the challenges?

- Reducing curb radii or removing channelized right turns can make it difficult for larger vehicles to navigate an intersection without encroachment into opposing lanes of travel.
- Adjustments to curb radii and channelized right turns may require modifications to existing drainage infrastructure.
- Removal of channelized right turns may increase motor vehicle delay at intersections.

What are the maintenance impacts?

Partner with maintenance team members during design development to discuss strategies and issues related to routine maintenance, especially during winter months. Intersections should be designed to allow proper street sweeping, snow plowing, and other routine maintenance along curb edges with curb extensions or smaller corner radii. In addition, hardened centerlines with bollards can require increased maintenance, as bollards may need to be repaired or replaced if they are struck by motor vehicles.

Supplemental treatments

- Refer to the Curb Extensions and Curb Radii section
- Refer to the Right Turn on Red Prohibition section

Resources

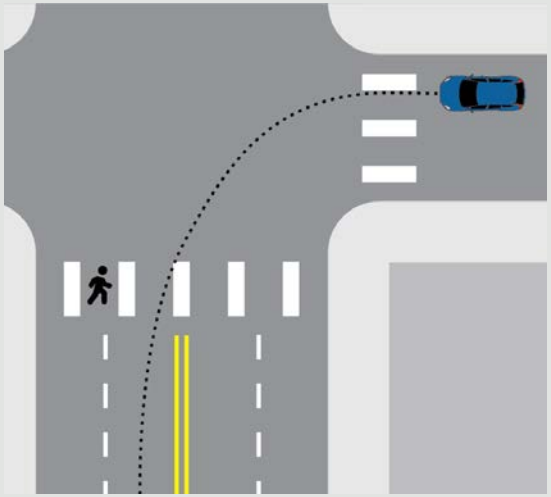
- NYC DOT study on Left Turn Traffic Calming: https://www1.nyc.gov/html/dot/html/pedestrians/left-turn-traffic-calming.shtml
- FHWA Achieving Multimodal Networks: https://www.fhwa.dot.gov/environment/bicycle_pedestrian/publications/multimodal_networks/fhwahep16055.pdf
- MnDOT Performance-Based Practical Design Process and Design Guidance: https://edocs-public.dot.state.mn.us/edocs_public/DMResultSet/download?docId=2156389
- https://www.iihs.org/news/detail/simple-infrastructure-changes-make-left-turns-safer-for-pedestrians

How much does it cost?

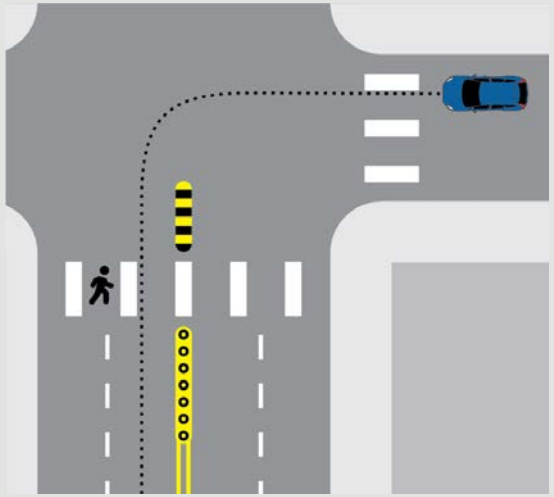
Typical costs for improvements to intersections vary depending on the specific treatment. For example, mountable truck aprons are similar in cost to standard mountable S-type curb and gutter. Hardened centerlines are approximately $5,000 per approach.

Design Features

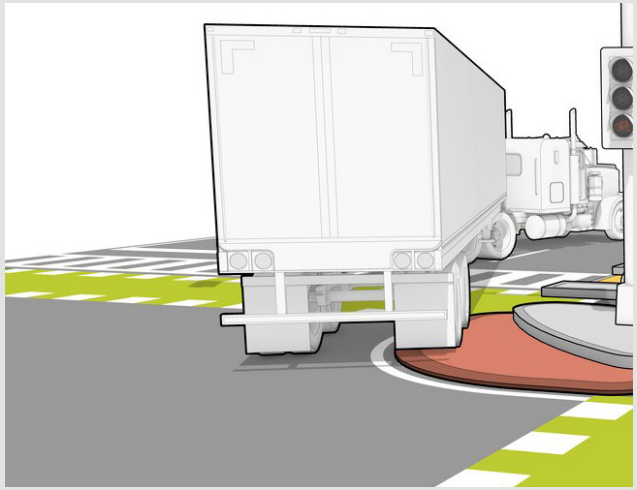
- Design vehicles - Selection of design vehicle(s) and assumptions made about their operating behavior are a major determining factor in intersection design. To achieve optimal intersection performance, the accommodation of oversized vehicles must be balanced with providing a safe, usable, and functional environment for passenger vehicles and pedestrians. Whereas “design vehicle” is defined as a frequent user of a facility, a “control vehicle” is an infrequent large user or fire apparatus which is permitted to use the entirety of the pavement area to navigate an intersection. Passenger cars and school buses are typical design vehicles on most urban streets and rural roads.
- Curb radii – Curb radii should be designed for the vehicle that turns at the intersection most frequently, typically a passenger car and a school bus. Smaller curb radii and curb extensions position vulnerable users in a more visible location, reduce crossing distances, reduce motor vehicle speeds, and provide additional space for curb ramps. Generally, for local urban streets, curb radii should be between 10' and 15' unless special circumstances require a larger radius. Curb extensions can be used to create smaller curb radii.
- Mountable truck aprons – Mountable truck aprons encourage passenger vehicles to make tighter turns while allowing oversized vehicles, such as trucks, to track over an apron. Mountable truck aprons deter passenger vehicles from making higher speed turns, but accommodate the control vehicle without encroachment or off-tracking into pedestrian waiting areas. Mountable truck aprons should be visually distinct from the adjacent travel lane and sidewalk to reduce use by most vehicles and communicate to pedestrians that it is not a safe place to stand or walk. For more details on mountable truck aprons, see the MnDOT Bicycle Facility Manual.
- Hardened Centerlines – Centerline hardening may be accomplished with rubber curbs or bollards installed on the yellow center line near an intersection and continued past the crosswalk, similar to an extended median nose, to slow turning drivers.



Before centerline hardening, Source: IIHS



After centerline hardening, Source: IIHS



Mountable outside truck apron, Source MassDOT Separated Bike Lane Planning and Design Guide

Traffic Signals

What is their purpose?

Traffic signals assign right-of-way to various traffic movements at intersections and help reduce conflict between different roadway users. Signal design typically focuses on the operating characteristics of motorized vehicles, but can also benefit pedestrians and bicyclists by creating gaps in traffic to cross. For example, in areas with pedestrian activity, traffic signals can include features such as countdown timers, leading pedestrian intervals, and exclusive pedestrian signal timings.

MnMUTCD Chapter 4C includes a list of nine warrants, which are threshold conditions that should be analyzed to help determine if signalization is appropriate for an intersection. These warrants are based on the volume of pedestrians and vehicles crossing the intersection, the presence of a school crossing, coordinated signal system, a grade crossing, and the crash experience at the intersection location. Engineering judgment should always be used when assessing traffic control change and signal warrant analysis.

Bicyclists at a traffic signal

Are they a proven strategy?

A traffic signal alone is not a proven safety countermeasure for pedestrians and bicyclists. There are a number of reasons for this, including lack of attention and failure of motorists to yield to pedestrians, lack of signal compliance by drivers and pedestrians, and speeding.

Supplemental strategies should be considered to improve pedestrian accommodations at signalized intersections. Strategies include countdown timers, which are **PROVEN** countermeasures to reduce crashes; and leading pedestrian intervals, which are **PROVEN** countermeasures. No Turn on Red restrictions, which are a **TRIED** countermeasure; and exclusive pedestrian signal timings, which are **TRIED** countermeasures.

Where would we use them?

Traffic signals serve many purposes. Before they are used, an engineering study of traffic conditions, pedestrian activity, and location characteristics should be performed. Additionally, the MnMUTCD signal warrants must be analyzed as part of the study. It should be noted that a location meeting one or more traffic signal warrant criteria does not in itself mandate the installation of a traffic signal.

Traffic signals are most effective for pedestrian and bicycle safety when:

- The intersection needs additional enhancements to improve motorist yielding rates or address limited gaps in traffic.
- There is a high volume of pedestrian activity, near transit stops, schools, and parks.

Traffic Signals

Wat are the advantages?

- Stop vehicles on red, allowing pedestrians and bicyclists to cross and create gaps in traffic flow to allow pedestrians and bicyclists to cross.
- Can be enhanced with many supplemental design features to further improve pedestrian safety.
- Widely used strategy to manage traffic
- Can reduce the severity of motor vehicle crashes.
- With countdown timers, pedestrian-vehicle crashes can be reduced up to 70% relative to signals without countdown timers.

What are the maintenance impacts?

Traffic signals require routine maintenance by properly trained technicians and ongoing funding to repair, replace, or upgrade signal controllers, detectors, and other signal hardware. It is also important to regularly assess the condition of traffic signal control equipment, including verifying that detectors are working properly, traffic signal controller timings are entered correctly, and signal displays are operational. Additionally, all traffic signal and pedestrian displays should be routinely checked to ensure they are visible to motorists and pedestrians. A maintenance management system database is typically employed to track these items.

Wat are the challenges?

- Installation of a traffic signal will increase delay and travel time for some motorists .
- Rely on driver attention and behavior to obey signals, to stop behind the stop bar, and to yield to crosswalks when turning.
- Some crash types could increase, including rear-end collisions.

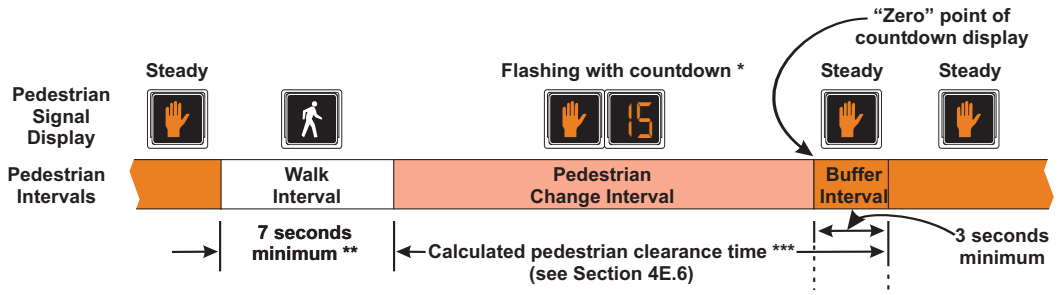
For pedestrians and bicyclists, it is especially important that all indications, push buttons, detectors, and other components are positioned and working properly.

Supplemental treatments

Traffic signals are often combined with one or more of the following treatments:

PROVEN treatments:

- Countdown pedestrian timers reduce pedestrian-vehicle crashes up to 70% after installation.
- Leading pedestrian intervals (LPI) reduce up to 60% of pedestrian-vehicle crashes at intersections.
- Backplates with retroreflective borders improve the visibility of the signal face during daytime and nighttime conditions. Research shows that the installation of retroreflective backplates can reduce total crashes by up to 15% at intersections.
- Yellow change intervals should be well-timed to reduce the number of red-light running vehicles. Red-light running vehicles cause a majority of the severe crashes at signalized intersections, and improvements to yellow change intervals can improve overall intersection safety. Research shows that optimized yellow change intervals can reduce red light running by up to 50%, reduce total crashes up to 14%, and reduce injury crashes up to 12%. Requirements and guidance about optimal yellow change interval timing can be found in the FHWA Traffic Signal Timing Manual.



Pedestrian signal display, Source: Minnesota MUTCD

Traffic Signals

Other Common Treatments:

- Fixed pedestrian phases are common at intersections with steady pedestrian activity throughout the day.
- Pedestrian push buttons are common in areas with intermittent pedestrian activity. When push buttons are installed, the design should consider implementing an Accessible Pedestrian Signal (APS). An APS is a device that communicates information about WALK and DON'T WALK intervals at signalized intersections through audible tones, speech messages, and vibrating surfaces to assist pedestrians with visual impairments.
- Implementing shorter cycle lengths (approximately 90 seconds).
- Implementing turn restrictions or left-turn phasing for vehicles.
- Ensuring that the signal has proper crossing times for pedestrians per MnMUTCD guidance.
- Exclusive pedestrian signal timings are most common in urban areas. These stop vehicles from all directions to allow pedestrians the right-of-way to cross the street in any direction (including diagonally).

Best practices

Traffic signals are used to assign right-of-way to conflicting traffic modes at intersections. There are several proven safety countermeasures that can be paired with traditional signalized intersections to enhance safety. Examples include countdown pedestrian timers, leading pedestrian intervals, backplates with retroreflective borders, and yellow change intervals.

Resources

- Crash Modification Factors
- Cost
- http://www.dot.state.mn.us/trafficeng/publ/mutcd/mnmutcd2018/mnmutcd-4.pdf
- http://guide.saferoutesinfo.org/engineering/traffic_signals.cfm
- https://www.dot.state.mn.us/trafficeng/publ/fundamentals/2015-mndot-safety-handbook-

How much do they cost?

Installing a new traffic signal can vary from approximately $250,000 to $500,000, depending on the site conditions, existing utilities, and additional enhancements. Annual maintenance costs are approximately $2,000 to $4,000 per intersection.

Design Features

Reference the MnDOT Traffic Control Signal Design Manual for a detailed review of traffic signal design elements, including signal phasing and operations, detection design, and signing and pavement markings. The goals of the design should include providing a safe and efficient operation for the intersection's unique conditions.

Key strategies for improving pedestrian accommodation at signalized intersections include the following:

- Adding accessible pedestrian push buttons where signals are pedestrian actuated.
- Implementing short cycle lengths (90 seconds maximum)
- Adding countdown timers, which are usually installed with pedestrian indication lights. These provide the number of seconds remaining during the pedestrian phase. MnMUTCD Chapter 4D.7 now requires countdown timers to be installed at signals with pedestrian signal heads at crosswalks with pedestrian change intervals greater than 7 seconds.
- Leading pedestrian intervals, which can be installed to improve the safety of the crossings by providing pedestrians 3-7 seconds to enter an intersection prior to giving the green indication to vehicles. More information can be found in the section on Leading and Separate Exclusive Signals.
- Using a fixed pedestrian phase - if pedestrian traffic is frequent, this timing strategy does not require pushing the pedestrian button to activate the WALK phase.
- Maintaining optimal sight distance and visibility of signals to pedestrians.
- Implementing MnMUTCD guidelines for creating optimal WALK and DON'T WALK times for pedestrians.

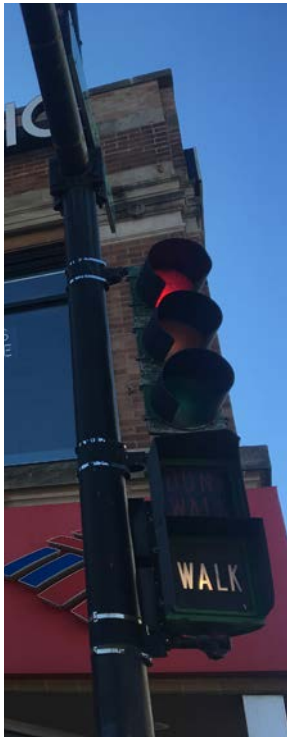
Leading and Separate Exclusive Signal Phases

What is their purpose?

A leading pedestrian interval (LPI) activates the WALK interval at least 3 to 7 seconds before drivers are given a green signal. This gives pedestrians additional time to establish their presence in the crosswalk, making them more visible to drivers, especially right- and left- turning vehicles. The effectiveness of LPIs can be seen the most at intersections with patterns of pedestrian or bicycle conflict with vehicles.

An exclusive pedestrian phase is a signal phase dedicating the right-of-way to pedestrian traffic with the WALK indication by stopping vehicular movements in all directions simultaneously. The pedestrian phase is sometimes referred to as a "pedestrian scramble" and allows pedestrians to cross streets in all directions, sometimes including diagonally. This strategy is most effective in high-density urban areas with high volumes of pedestrian and low-to-moderate volumes of vehicles since the phase can cause undesirable vehicle and pedestrian delay.

Protected walk phase with a right turn restriction



Leading pedestrian signal

Are they a proven strategy?

As a result of the FHWA Proven Safety Countermeasures initiative, leading pedestrian intervals are officially a **PROVEN** safety countermeasure. Exclusive pedestrian signal phasing is not yet a proven safety countermeasure and is considered a **TRIED** countermeasure.

Supporting Documentation: FHWA Safety Countermeasures - LPI

Where would we use them?

Leading pedestrian intervals are most effective when:

- Intersections have relatively high crossing volumes.
- Intersections have relatively high turning vehicle volumes.
- Intersections have patterns of pedestrian or bicycle conflict with vehicles.

Exclusive pedestrian phases are most effective when:

- Intersections with large concentrations of pedestrians often need to cross a busy street at the same time. This is typically in urban areas, tourist-heavy areas, college campuses, places with major shift changes.
- Intersections that experience high vehicular delay due to heavy pedestrian traffic.
- Intersections that experience patterns of vehicle-pedestrian conflicts for all movements.

Leading and Separate Exclusive Signal Phases

What are the advantages?

- Can be programmed into an existing traffic signal for a relatively low cost ($0 to $3,500) .
- Increase visibility of crossing pedestrians, especially for pedestrians who may be slower to enter the intersection.
- Improve comfort for pedestrians crossing busy intersections.
- Increase likelihood of motorists yielding to pedestrians.
- LPIs reduce pedestrian-vehicle crashes by 60% at intersections.

What are the challenges?

Leading Pedestrian Intervals

- Can increase delay for drivers.
- Older traffic signals may not support the infrastructure needed to easily and cost effectively implement this phasing. In these cases, there would be an increased cost to support the technology due to new controller and other traffic signal infrastructure.

Exclusive Pedestrian Phases

- May increase pedestrian delays by reducing amount of pedestrian crossing time during a signal cycle.
- Operations do not meet most pedestrian or driver expectations, and therefore additional educational efforts may be necessary.

Pedestrian scramble crossing at New Brighton Boulevard & Stinson Boulevard NE, Minneapolis, MN, Source: Google Earth

How much do they cost?

Depending on the existing infrastructure at the signalized intersection, timing adjustment costs can range from almost nothing to approximately $3,500. If pedestrian signals are required, the infrastructure costs can range approximately $8,000 to $75,000 per intersection. Additional costs for pedestrian countdown timers, push buttons, and other signal infrastructure components can add up to a total of approximately $150,000 per intersection.

Leading and Separate Exclusive Signal Phases

Design Features

LPIs and exclusive pedestrian phase designs can typically be programmed into an existing traffic signal. The phase can be activated by the pedestrian or with pedestrian phases that are on automatic recall.

The MnMUTCD provides guidance for LPIs. It states that if they are used, designs should include the following:

- Accessible pedestrian signals
- A minimum 3-second interval, depending on the crossing width, site location, and other factors
- Consider prohibition of turns across the crosswalk during the LPI

Supplemental treatments

LPIs and exclusive pedestrian phase designs can be enhanced with the following treatments:

- Curb extensions at the intersection to further improve pedestrian visibility.
- Marked crosswalks in all directions (including diagonally if desired for exclusive pedestrian phase).

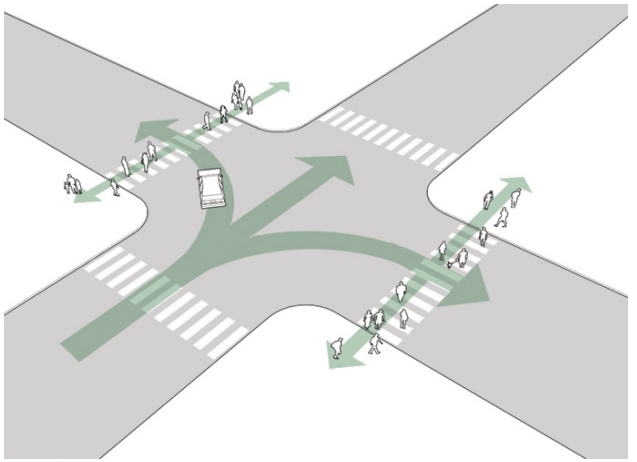
Resources

Leading Pedestrian Interval

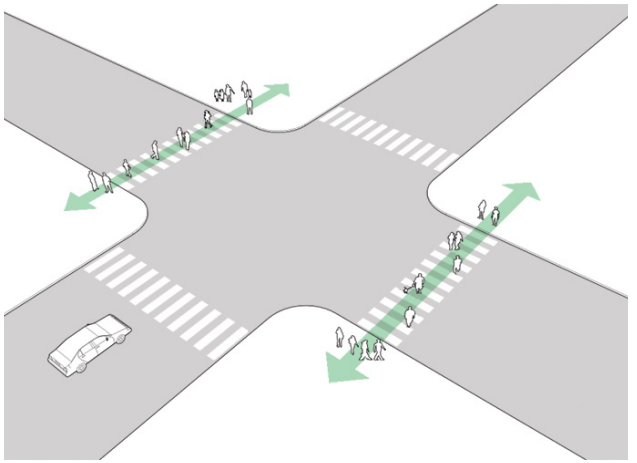
- https://safety.fhwa.dot.gov/provencountermeasures/lead_ped_int/
- http://www.pedbikesafe.org/PEDSAFE/countermeasures_detail.cfm?CM_NUM=12
- https://nacto.org/publication/urban-street-design-guide/intersection-design-elements/traffic-signals/leading-pedestrian-interval/

Exclusive Pedestrian Signal

- https://safety.fhwa.dot.gov/ped_bike/legis_guide/rpts_cngs/pedrpt_0808/chap_3.cfm
- http://www.pedbikesafe.org/pedsafe/countermeasures_detail.cfm?CM_NUM=47



Potential conflict with pedestrians without a leading pedestrian interval, Source: NACTO Urban Street Design Guide



Potential conflict with pedestrians avoided with the use of a leading pedstrian interval, Source: NACTO Urban Street Design Guide

Bicycle Signals

What is their purpose?

A separate bicycle signal can improve operations involving bicycle facilities and designate right-of-way for bicyclists at locations where their needs may differ from other roadway users and a separate bicycle facility exists. For example, bicyclists may be allowed to enter an approach leg that vehicles are restricted to turn onto. With the inclusion of bicycle signals in the MnDOT Bicycle Facility Design Manual and the Interim Approval of Bicycle Signal Faces (IA 16), there is an opportunity to use similar strategies to minimize or eliminate bicycle-motor vehicle conflicts at signalized intersections.

Similar to a leading pedestrian interval (LPI), the purpose of a leading bicycle interval (LBI) is to allocate dedicated time for bicyclists to enter the intersection prior to vehicles being given the green indication. This time reduces the risk of conflicts between bicyclists and turning vehicles. It also gives bicyclists additional time to safely make necessary turning or lane change maneuvers. An LBI is a supplemental strategy that requires bicycle signal infrastructure.

Bicycle signal lens with supplemental plaque. Note the right turn signal with a blank out sign to restrict turns across the bikeway during the bicycle signal phase. Jackson Street, Saint Paul, MN

Are they a proven strategy?

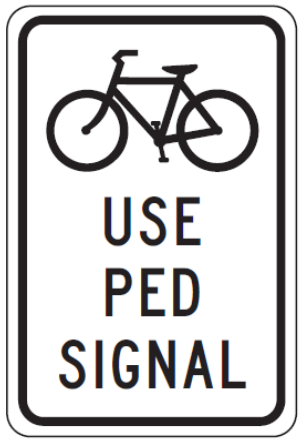
Separate Bicycle Signal

As part of the Interim Approval process, the FHWA reviewed research of bicycle lenses where bicyclists have separate signal phases. The use of a bicycle signal, in accordance with FHWA Interim Approval 16, is considered **PROVEN**.

Leading Bicycle Interval

The FHWA Interim Approval does not allow for the use of bicycle signal lenses where permissive motor vehicle movements conflict with bikeway traffic (such as a leading bicycle interval). Therefore, LBIs are considered **EXPERIMENTAL**, and a Request to Experiment to the FHWA is required when using a signal with a bicycle signal face lens.

An alternative approach for a leading bicycle interval that does not require a request to experiment is to implement a leading pedestrian interval in conjunction with a "Bikes use ped signal" sign (R9-5). R9-5 signs and leading pedestrian intervals are both included in the MnMUTCD, and there is nothing that precludes their use together. This approach has been **TRIED**, but there is no research documenting its efficacy.



R9-5

Bicycle Signals

What are the advantages?

Separate Bicycle Signal

- Separating bicycle and motor vehicle movements can reduce conflicts, and thus reduce the risk of a crash.
- Bicycle signals facilitate unusual or unexpected arrangements of the bicycle movement.

Leading Bicycle Interval

- Once bike signal infrastructure is in place, the LBI can be programmed into an existing traffic signal for a relatively low cost.
- Increase visibility of crossing bicyclists.
- Improve comfort for bicyclists crossing busy intersections.
- Increase the likelihood of motorists yielding to bicyclists.

What are the challenges?

Separate Bicycle Signal

- Older traffic signals may not support the infrastructure needed to easily and cost effectively implement this phasing. In these cases, there would be an increased cost to support the technology due to new controller and other traffic signal infrastructure.
- Can help simplify bicycle movements at complex intersections.
- Bicycle signals require bicycle detection unless located at a pre-timed signal. Options include passive detection (inductive loop detectors, video, infrared, microwave/radar) and active detection (push buttons). In Minnesota, the most common type of detection are inductive loop detectors, and video detection is sometimes used. Detection costs have a wide range, and bicycle detection equipment should be tested and calibrated under a variety of bicycle sizes, material types, and lighting and weather scenarios to confirm effectiveness.
- Bicyclists may disregard a bicycle signal if it is unnecessary or if detection is ineffective.

Leading Bicycle Interval

- Can increase delay for drivers, especially turning vehicles.
- May require additional education for drivers and bicyclists.

Where would we use them?

Separate bicycle signals are most appropriate when you have two or more of the following conditions:

- Intersections with relatively high motor vehicle/ bicycle conflicts for certain signal phases
- Intersections with a with two-way or contraflow bicycle movement that may not be expected by motor vehicles
- Bicycle facility transitions that require bicyclists to cross through a motor vehicle lane
- Intersections that permit a relatively short cycle length, and have either bicycle detection or a bicycle phase on recall, such that it comes up with each cycle
- Locations where bicyclists may require an increased level of control to facilitate unusual or unexpected arrangements of the bicycle movement through complex intersections and conflict areas. Locations where bicyclists are physically separated from motorists and pedestrians.

Separate bicycle signals are less appropriate where these conditions don't exist. Bicyclists are less likely to obey separate bicycle signals if there are few bicycle-motor vehicle conflicts and if the bicycle signal phase isn't reliably called in a timely manner.

Leading bicycle intervals should be considered at the following locations:

- Complex intersections with high bicycle demand.
- Locations where a protected phase is not operationally feasible.
- Locations where there is history of bicycle-vehicle conflict or visibility concerns.
- Reference the Interim Approval 13 for more details regarding the federal guidance.

How much do they cost?

Depending on the existing infrastructure at the signalized intersection, timing adjustment costs can range from almost nothing to approximately $3,500. If new signal equipment such as controllers, wiring, loop detectors, and bicycle signal heads is required, the cost can be up to approximately $150,000. Installing video detection would bring additional costs.

Bicycle Signals

Design Features

Prior to implementing a bicycle phase or bicycle signals, the agency should review the existing traffic volumes, existing bicycle amenities, traffic signal equipment, and signal phasing. NACTO provides design guidance for bicycle signal heads, including clearance interval calculations, signal head locations, and additional infrastructure recommendations.

In locations where leading bicycle intervals are recommended, bike signals must be provided at the intersection to designate the interval.

Bike signal designs should include:

- Signal heads placed in a location visible to approaching bicycles.
- A bicycle recall phase for each cycle, or installed detection and actuation. There is currently no standard for detection in Minnesota; inductive loop detectors and video detection have been used.
- Proper clearance interval of at least 3 seconds, based on bicycle travel speeds and crossing distance.
- Prohibited right-turn on red movements if the bicycle movements would conflict with right-turning vehicles.
- Consideration for adjacent signalized intersections to ensure the bicycle signal does not cause undesirable delay.
- The MnDOT Bicycle Facility Design Manual states that the primary bicycle signal head should be 8" or 12" in diameter; this is based on the MnMUTCD, which allows 8" diameter signals for the purpose "of controlling a bikeway or a bicycle movement."
- Supplemental, near-side bicycle signal faces may be 4" per the Interim Approval 16.

The Interim Approval only allows the use of a bicycle signal lens where there are no conflicting motor vehicle movements. If practitioners wish to use a bicycle signal in a condition where permissive motor vehicle movements conflict with the bikeway, they need to do one of the following:

- Use a traditional signal lens with a "bicycle signal" plaque in accordance with the Interim Approval;
- Instruct bicyclists to follow the pedestrian signal and program a leading pedestrian interval; or
- Obtain a "Request to Experiment" from the FHWA for the use of a bicycle signal lens in conjunction with a conflicting permissive motor vehicle movement.

What are the maintenance impacts?

Bike signal heads and leading interval timings will require similar routine maintenance as standard traffic signals.

Inductive loop detectors are used at many locations throughout the state due to their low maintenance and relatively low cost. However, these detectors do not always work for bicycles that are made of non-metal material. Video detection captures all bicycle types, but requires additional maintenance to ensure the lens is cleaned and positioned correctly.

Supplemental treatments

LBIs and separate bicycle signal designs can be enhanced with the following treatments:

- Restriction of all turn movements that would conflict with the bicycle movements
- Bicycle detection by means of inductive loop detectors or bicycle push buttons
- Bicycle boxes
- Intersections with LBIs commonly implement parallel leading pedestrian intervals

Best practices

Bicycle signals should only be used in combination with existing traffic signals or a pedestrian hybrid beacon to improve safety or operational problems that involve bicycle activities. Bicycle signals typically use standard three-lens signal heads in green, yellow, and red lenses. Design should comply with Interim Approval 16.

Bicycle Signals

Resources

- MnDOT Bicycle Facility Design Manual
- http://www.dot.state.mn.us/bike/bicycle-facility-design-manual.html
- MassDOT Separated Bike Lane Planning and Design: https://www.mass.gov/files/documents/2017/10/26/SeparatedBikeLaneChapter6_Signals_1.pdf
- https://nacto.org/publication/urban-bikeway-design-guide/bicycle-signals/bicycle-signal-heads/
- http://www.minneapolismn.gov/www/groups/public/@publicworks/documents/images/wcmsp-195582.pdf
- Cost: http://pedbikesafe.org/bikesafe/countermeasures_detail.cfm?CM_NUM=55
- https://mutcd.fhwa.dot.gov/resources/interim_approval/ia16/

A bicycle signal on Jackson Street in Saint Paul, MN

Right Turn on Red Prohibition

What is its purpose?

Prohibiting right turning movements on red at signalized intersections is an option to enhance the safety for pedestrians at the intersection. Static or dynamic signage is installed prohibiting the turning movement during the red signal, either at all times or certain times of day. This practice helps to mitigate conflicts stemming from motorists basing turning decisions on gaps in conflicting traffic rather than looking for crossing pedestrians.

Allowing right turns on red except where signs prohibited them was a policy adopted nationwide in the 1970s (with the exception of New York City) as an effort to save energy. While the law requires motorists to come to a full stop and yield to cross street traffic and pedestrians prior to turning right on red, many motorists do not fully comply with the regulations. As mentioned above, some motorists focus mainly on traffic approaching from the left and do not look for pedestrians on their right. Additionally, many motorists encroach into the crosswalk to wait for a gap in traffic, blocking pedestrian crossing movements. In some instances, motorists simply do not come to a full stop.

No turn on red blank-out sign

No turn on red static sign

Is it a proven strategy?

Prohibiting right turns on red (RTOR) can help reduce crashes that involve right-turning vehicles, drivers with limited sight distance, and pedestrians. Because of the lack of specific data for this treatment, this is a **TRIED** measure.

Where would we use it?

The RTOR restriction should be considered for improving pedestrian and bicycle safety at:

- Locations that have limited sight distance and/or unusual geometry.
- Locations within school zones (especially at school crosswalks) and near libraries, senior centers, transit stations, or other pedestrian traffic generators.
- Locations that intersect exclusive bicycle facilities (especially two-way bicycle facilities with contraflow bicycle traffic) and trail crossings.
- At any crosswalk where the MnMUTCD pedestrian volume and/or school crossing warrant is met (MnMUTCD, Section 4C, Warrants 4 and 5).

What are the maintenance impacts?

Partner with maintenance team members during design development to discuss strategies and issues related to routine maintenance, such as checks to ensure the signs meet retroreflectivity standards and that electronic signs, if used, are functioning properly.

Supplemental treatments

- Leading pedestrian interval (LPI)

Right Turn on Red Prohibition

What are the advantages?

- Protects bicyclists and pedestrians crossing with a signal from crashes with right-turning vehicles.
- Provides a way to mitigate risks of crashes when limited sight distance or contraflow bicycle movements exists at an intersection

Best practices

Restricting RTOR movements is a low-cost strategy to improve safety at intersections for crossing pedestrians. This should be implemented at intersections with consistent pedestrian activity and at intersections with limited sight distance.

Resources

- https://safety.fhwa.dot.gov/saferjourney1/library/countermeasures/44.htm
- https://nacto.org/wp-content/uploads/2016/04/1-11_nchrp500_antonucci-on-NACTO-website.pdf
- https://nacto.org/publication/transit-street-design-guide/intersections/signals-operations/turn-restrictions/
- http://pedbikesafe.org/PEDSAFE/countermeasures_detail.cfm?CM_NUM=49
- Page 114: https://www.chicago.gov/content/dam/city/depts/cdot/Complete%20Streets/CompleteStreetsGuidelines.pdf

What are the challenges?

- Drivers may fail to comply with the RTOR prohibition.
- Additional enforcement may be necessary to improve compliance, and enforcement may be more difficult with a blank out sign relative to a static sign.
- Implementation may lead to an increase in right turn on green conflicts with pedestrians. Using an LPI to establish pedestrians in the crosswalk before drivers have the green indication to turn right may be the best way to address this issue.
- Could cause intersections to experience an increase in motor vehicle delay, making it more challenging to implement where vehicle volumes are higher.
- Require additional maintenance considerations

What are the maintenance impacts?

RTOR signals require routine maintenance by properly trained technicians and ongoing funding to repair, replace, or upgrade signal controllers, detectors, and other signal hardware. Additionally, all No Turn on Red signs should be routinely checked to ensure they are visible to motorists. It is also important to regularly assess the condition of RTOR signal control equipment, including verifying that detectors are working properly, and signal displays are operational.

Design Features

Restricting right turn on red movements at a signalized intersection generally does not require physical design changes. When right-turn restrictions are implemented, the following is recommended:

- Install No Turn on Red sign – this sign can be traditional static sign posting or an electronic sign.
- Signs should be placed within proper sight lines of potentially turning drivers, ideally installed adjacent to a signal face viewed by drivers in the right lane.
- RTOR prohibitions may be signed to occur only during the peak travel times during the day.
- No Right Turn LED Blank-out signs can also be installed, and can be programmed to be activated by the pedestrian.

How much do they cost?

The cost for a static sign is approximately $200. An LED blank-out sign costs approximately $3,000.

Roundabouts

What is their purpose?

The modern roundabout is a circular intersection that helps traffic move safely and efficiently. Roundabouts include channelized approaches and a center island, and entering traffic yields to vehicles already circulating. They have lower speeds and fewer conflict points than a typical signalized intersection, which leads to improved operational performance.

Generally, there are two types of roundabouts: single-lane and multi-lane. Single-lane roundabouts are typically simpler and safer for pedestrians and bicyclists to cross. Neighborhood traffic circles and mini-roundabouts are similar strategies for streets with lower traffic volumes and speeds.

Roundabout at CSAH 15 and 7th Street, New Prague, MN

Are they a proven strategy?

Roundabouts provide substantial safety and operational benefits for motorists compared to other intersection types, most notably a reduction in severe crashes. Roundabouts are an effective strategy for reducing severe crashes involving vehicles. Comprehensive studies of both pedestrian and bicycle safety at roundabouts are limited, so they are considered **TRIED**.

Roundabouts have demonstrated improved safety performance compared to traffic signal control, especially for the most severe types of crashes. In Minnesota, the most common type of severe intersection-related crash is an angle crash. In roundabouts, angle crashes still may occur, but at lower speeds and at shallower angles.

A 2017-2018 MnDOT study of Minnesota roundabout traffic safety found that single-lane roundabouts had an 89% reduction in fatal crashes. The study also found that while some other roundabouts had an increase in total crash rates, the severity of the crashes was reduced. The study found that roundabouts do not increase the risk to pedestrians and bicyclists from collisions with motor vehicles. Further research in Minnesota found that roundabouts provide an approximate 60% Crash Reduction Factor (CRF) for pedestrian crashes after conversion from a four-legged intersection.

Supporting Documentation: FHWA Proven Safety Countermeasures, MnDOT Roundabout Study, MnDOT Roundabout Study Addendum

Roundabouts

What are the advantages?

- Crash Reduction Factor (CRF) for all crash types vary widely according to FHWA. When converting a two-way stop-controlled intersection, there is an 82% reduction in severe crashes for all crash types. When converting a signalized intersection, there is a 60% reduction in severe crashes for all crash types.
- Can reduce vehicle speeds, which benefits bicyclists and pedestrians crossing the roundabout.
- Can increase the capacity of an intersection compared to traditional stop sign or signal-controlled intersections.
- Observational studies have found that vehicles in single-lane roundabouts have higher rates of yielding to pedestrians than vehicles in multi-lane roundabouts.

What are the challenges?

- Multi-lane roundabout crosswalks can present the same multiple-threat sight line challenges as other uncontrolled crossings.
- Available right-of-way can restrict or limit the construction of a roundabout.
- Additional enhancements may be necessary for pedestrians with visual impairments or at intersections with significant pedestrian, bicycle, and vehicle traffic, particularly at multi-lane roundabouts. Supplemental treatments include raised crosswalks and RRFBs or PHBs at the splitter islands.

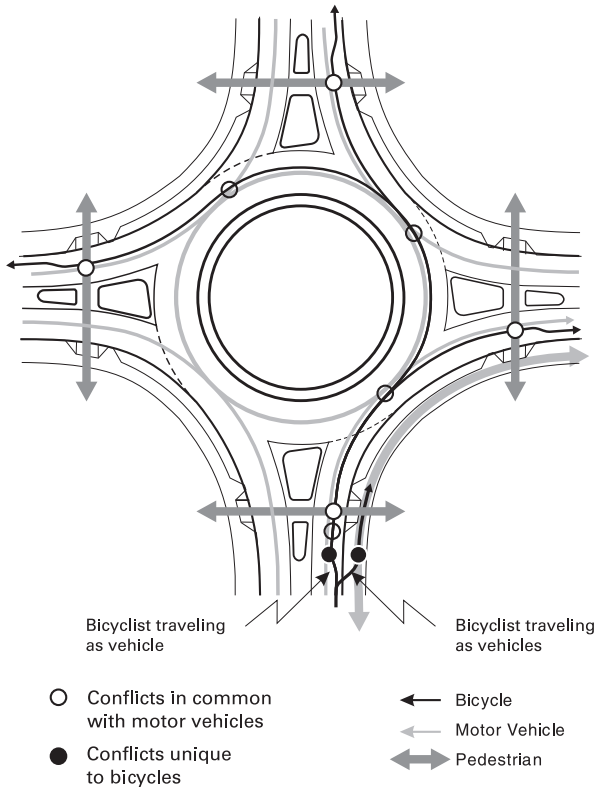
Where would we use them?

Roundabouts can be considered at the following locations:

- At intersections with a pattern of fatal, angle, turning, and head-on crashes.
- Roundabouts can be implemented in both urban and rural areas under a wide range of traffic conditions, but are commonly installed when intersections experience undesirable delay at stop-controlled or signalized intersections.
- Roundabouts are commonly installed as an alternative to all-way stop controlled or signalized intersections

What are the maintenance impacts?

Due to the lack of hardware, electric needs, and timing equipment, the costs to maintain and operate a roundabout are typically less than the maintenance costs for signal-controlled intersections.



An illustration of bicycle conflict points at a roundabout, Source: FHWA Roundabouts: An Informational Guide

How much do they cost?

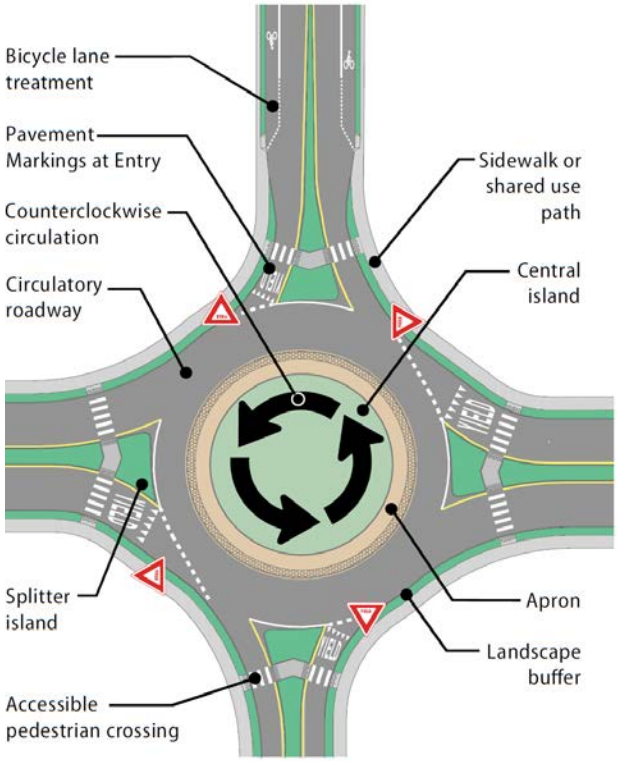
The typical cost of a basic roundabout is approximately $1 million, not including right-of-way acquisition. Costs will vary depending on location and size of the roundabout.

Roundabouts

Design Features

MnDOT specific roundabout design details can be found in Chapter 7 of MnDOT's Bicycle Facility Manual, Chapter 12 of MnDOT's Road Design Manual, and NCHRP Report 672 - Roundabouts: An Informational Guide. General roundabout design considerations to maintain or improve pedestrian/bicycle safety include the following:

- If long-term traffic projections suggest the need for a multi-lane roundabout, but the need isn't likely for several years, the roundabout can be constructed as a single-lane roundabout and designed for additional lanes to be constructed if warranted in the future.
- Designers should be cognizant of bicycle traffic when designing roundabouts, constraining design speeds to those compatible with typical bicycle speeds to promote bicyclist safety and comfort, refer to MnDOT's Bicycle Facility Manual for more information.
- Separated bike lanes can be continued through roundabouts, with crossings that are similar to, and typically adjacent to, pedestrian crosswalks. Drivers approach the bicycle crossings at a perpendicular angle, maximizing visibility of approaching bicyclists.
- Roundabouts can include truck aprons along the approaches or exits to keep entering and exiting vehicle speeds low at conflict points with pedestrians and bicyclists while still accommodating larger design vehicles.
- Proper roadway deflection angles at all entries and exits and are critical to reducing motor vehicle speeds through the intersection.
- Bicycle slip lanes or exit ramps to shared use paths are another design element that should receive detailed consideration.



An illustration of a roundabout, Source: FHWA

A pedestrian crossing at a roundabout

Resources

- https://safety.fhwa.dot.gov/provencountermeasures/roundabouts/
- http://www.dot.state.mn.us/bike/design-engineering.html
- https://safety.fhwa.dot.gov/tools/crf/resources/fhwasa08011/fhwasa08011.pdf
- http://www.dot.state.mn.us/trafficeng/safety/docs/roundaboutstudy.pdf
- http://www.dot.state.mn.us/trafficeng/safety/docs/roundaboutsafetyaddendum.pdf

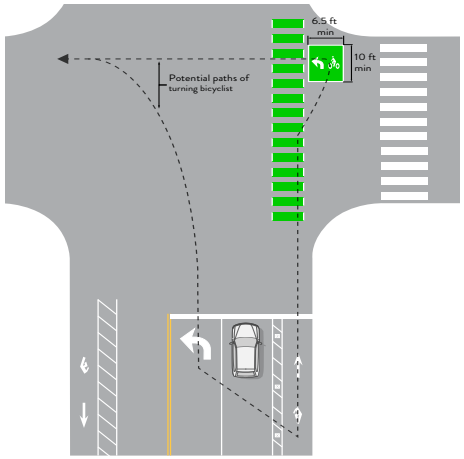
Bicycle Boxes

What is their purpose?

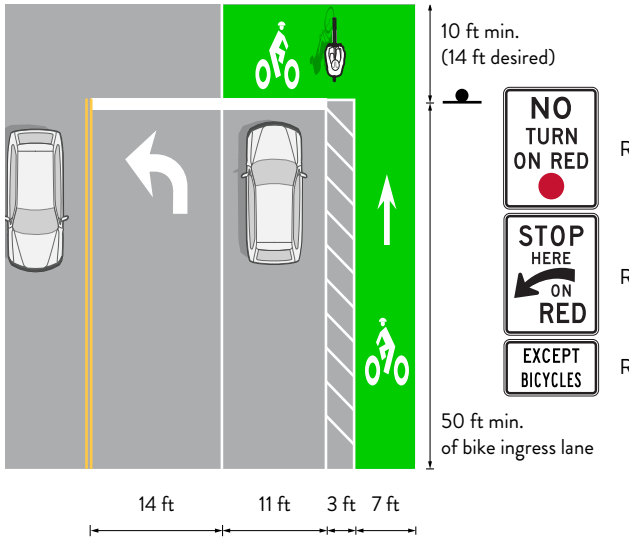
A bicycle box is a set of pavement marking elements installed at signalized intersections that allows bicyclists to pull in front of waiting traffic at a red light. This makes bicyclists more visible to motorists and gives bicyclists a head start when the light turns green, thus providing the opportunity to avoid conflicts with turning motor vehicles.

There are two types of bicycle boxes: two-stage turn boxes and intersection boxes (also referred to as simply "bicycle boxes"). Two-stage turn bicycle boxes are located adjacent to the bicyclist's direct path of travel and downstream of a crosswalk and stop line, and are typically used for facilitating bicycle left turns. Intersection bicycle boxes are located in front of the vehicle stop bar but behind the pedestrian crosswalk and are used for all bicycle turning movements.

MnDOT received statewide Interim Approval from FHWA for the use of green-colored pavement for bike lanes (IA 14), the use of bicycle boxes (IA 18), and for two-stage turn boxes (IA 20). Statewide Interim Approval allows any jurisdiction within Minnesota to use the devices, as long as the jurisdiction agrees to notify the MnDOT Traffic Standards Engineer of the location for each installation and agrees to the specific conditions outlined for Statewide Interim Approvals.



Two-stage bicycle turn box, using optional green colored pavement. This drawing also illustrates dotted bicycle lane extensions with green colored pavement.



Intersection bicycle box, using optional green colored pavement.

Are they a proven strategy?

Bicycle boxes and two-stage turn boxes have been tested through the FHWA experimentation process and are considered **PROVEN**. FHWA has concluded that bicycle intersection boxes reduce conflicts between motor vehicles and bicyclists and that motorists and bicyclists understand the purpose and proper usage of the box. FHWA has also found positive operational effects after the installation of two-stage turn boxes, including bicyclists using a two-stage turning maneuver with greater consistency.

Where would we use them?

Bicycle boxes are often installed at the following locations:

- At signalized intersections (if one is installed, it must be at a signalized intersection).
- On roadways that already have bike lanes and a substantial volume of bicycle traffic, especially bicycle traffic that primarily continues through the intersection.
- At intersections where a left turn is necessary to continue on a dedicated bicycle route or other shared use path.
- In locations where there are bicycle-motor vehicle turning conflicts.
- In locations where right turn on red prohibitions for motor vehicles can be added.
- Two-stage turn bicycle boxes can be used on roadways of any speed, but they provide a greater benefit on roadways with speeds of 35 MPH or higher.

Bicycle Boxes

What are the advantages?

- Reduce the number of conflicts between bicyclists and turning drivers, especially those turning right.
- Reduce the number of avoidance maneuvers by both bicyclists and motorists.
- Reduce the number of bicycles and motor vehicles encroaching into pedestrian crosswalks when stopped at an intersection.
- Help prioritize bicyclists at intersections with major streets.
- Reduce bicyclist delay at signalized intersections.
- Motorists and bicyclists both understand the purpose and proper usage of the bicycle box.
- 35% reduction in bicycle crashes.

Bicyclist waiting at a signal in a bicycle box with optional green colored pavement

What are the challenges?

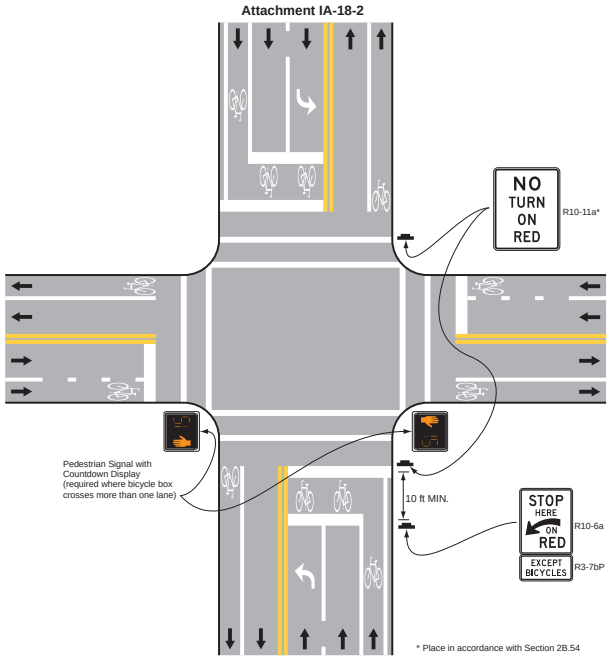
- Cars may encroach into the bicycle boxes, reducing the available space for bicycles to queue safely.
- Right turn on red movements must be prohibited to avoid conflicts between right-turning motor vehicles and waiting bicyclists.
- In cases where there are multiple travel lanes and where the bicycle box does not extend to all travel lanes, bicyclists may still have difficulty turning left.

What are the maintenance impacts?

The use of durable pavement markings will help minimize ongoing maintenance, especially when using green-colored pavement, which may be difficult for some agencies to refresh. Ground-in thermoplastic pavement markings are commonly used in Minnesota and typically have a service life of several years.

Best practices

- Place an advance stop line at least 10' from the intersection stop line.
- Prohibit right turn on red movements to avoid conflicts between right-turning motor vehicles and waiting bicyclists.
- Provide at least 50' of a bicycle lane prior to the bicycle box.



Bicycle box at an intersection, Source: FHWA Interim Approval 18

How much do they cost?

The cost for a bicycle box can vary depending on whether a bike lane already exists or needs to be added. Costs are typically about $1,000 per bicycle box.

Bicycle Boxes

Design Features

Reference FHWA Interim Approval 18 for detailed design provisions for intersection bicycle boxes. NACTO can also be referenced for additional recommended and optional design features for bicycle boxes. A summary of key design features is below:

- Place an advance stop line at least 10' from the intersection stop line.
- Countdown pedestrian signals shall be provided at adjacent crosswalks to inform bicyclists of the remaining time to cross; this is especially important at locations with multiple lanes to cross.
- A bicycle box should be paired with an approach lane as well as a lane that extends through the intersection.
- Provide at least 50' of a bicycle lane prior to the bicycle box.
- Prohibit right turn on red movements to avoid conflicts between right-turning motor vehicles and waiting bicyclists.
- Install a sign assembly of STOP HERE ON RED (R10-6 or R10-6a) and EXCEPT Bicycles (R3-7bP) in advance of the stop line for motor vehicles.
- For intersection bicycle boxes: 10'-wide bicycle boxes are the minimum, 14'-wide bicycle boxes are recommended.
- For two-stage turn bicycle boxes: 6.5'-wide bicycle boxes are the minimum, 10'-wide bicycle boxes are recommended.
- Use a high-friction pavement marking material, such as MnDOT's Enhanced Skid Resistance Thermoplastic to avoid slipping on wet markings.

Bicycle box with optional green colored pavement

Resources

- https://mutcd.fhwa.dot.gov/res-interim_approvals.htm
- https://safety.fhwa.dot.gov/tools/crf/resources/fhwasa08011/fhwasa08011.pdf
- http://www.dot.state.mn.us/bike/design-engineering.html
- https://nacto.org/publication/urban-bikeway-design-guide/intersection-treatments/bike-boxes/

Protected Intersections

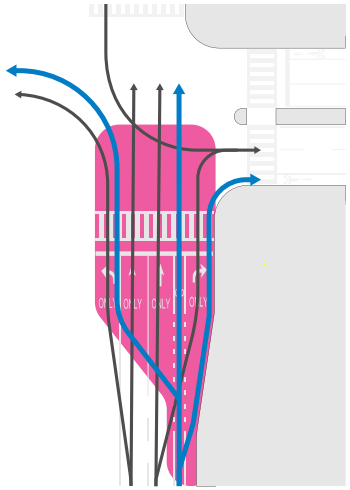
What is their purpose?

Protected intersections separate pedestrians and bicyclists from motor vehicles using physical barriers that eliminate merging and weaving movements. Well-designed protected intersections are intuitive and comfortable, provide clear right-of-way assignment, promote predictability of movement, and allow eye contact between motorists, bicyclists, and pedestrians. A comparison of conflict points at conventional (on-road) bike lanes and at protected intersections is shown in pink on the figures to the right. The single conflict point at a protected intersection can be eliminated by providing a separated signal phase for turning traffic, when used in conjunction with dedicated turn lanes..

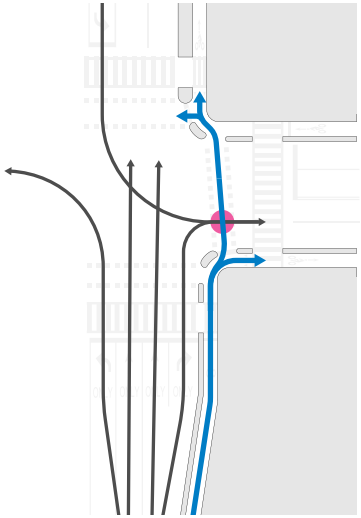
Protected intersections can also incorporate intersection design elements that reduce speeds (see Intersection Design section).

By moving the bicycle through movement further from the vehicle lane, it becomes easier for a cyclist to spot a right-turning vehicle in time to avoid a collision, and improves motorist sight lines as well.

A protected intersection



Conflict area between bicycles and motor vehicles (in pink) at a conventional intersection, Source: MassDOT Separated Bike Lane Planning and Design Guide



Conflict points with a protected intersection, Source: MassDOT Separated Bike Lane Planning and Design Guide

Protected Intersections

What are the advantages?

- Reduce motor vehicle speeds at intersections, which reduces bicycle and pedestrian crash severity.
- When combined with intersection design practices such as smaller curb radii, can reduce crossing distance, minimizing pedestrian and bicycle exposure at the intersection.
- Reduce the interaction between bicyclists and motor vehicles through an intersection, which minimizes bicycle exposure at the intersection.
- Improve the ability of drivers to perceive and react to bicyclist in the intersection, and improve ability of cyclists to recognize when a vehicle is turning right.
- Forward queuing area for bicyclists and pedestrian refuge median reduces crossing distances for both users and improves their visibility to motorists.
- Can reduce bicyclist speeds by adding deflection to the bike lane or sidepath.

What are the challenges?

- Design may require additional right-of-way depending on the existing roadway's cross-section. Existing roadway amenities, such as on-street parking lanes, may need to be removed to fit the design.
- Reducing curb radii and removing channelized right turns can make it difficult for larger vehicles to navigate an intersection without encroaching into opposing lanes of travel.
- Adjustments to curb radii and channelized right turns may require modifications to existing drainage infrastructure.
- Channelized right-turn lanes may need to be removed from an intersection in order to make the design fit, which may increase motor vehicle delay.
- If motorists and bike/pedestrian movements are concurrent or uncontrolled, sight lines on the approach must be kept clear to maintain visibility between street users.
- Significant impacts on maintenance efforts.

Are they a proven strategy?

Individual strategies to slow vehicles at intersections have been **PROVEN**. Protected intersections have **PROVEN** safety benefits at signalized and unsignalized intersections where bicycle crossings are offset from the motorist travel way by a preferable distance of between 6' and 16.5'.

Where would we use them?

Protected intersections can be considered at the following locations:

- At signalized or stop-controlled intersections to create safe, comfortable conditions for people bicycling and walking, where there are high volumes of turning motor vehicle traffic.
- They are most commonly used with separated bike lanes and sidepaths, but can be used with conventional (on-road) bike lanes, paved shoulders, or shared lanes.

What are the maintenance impacts?

Partner with maintenance team members during design development to discuss strategies and issues related to routine maintenance, especially during winter months, to keep the bike lane and small concrete islands free of snow and debris. The design should ensure that maintenance vehicles can clear snow and debris from the narrow bikeways.

How much do they cost?

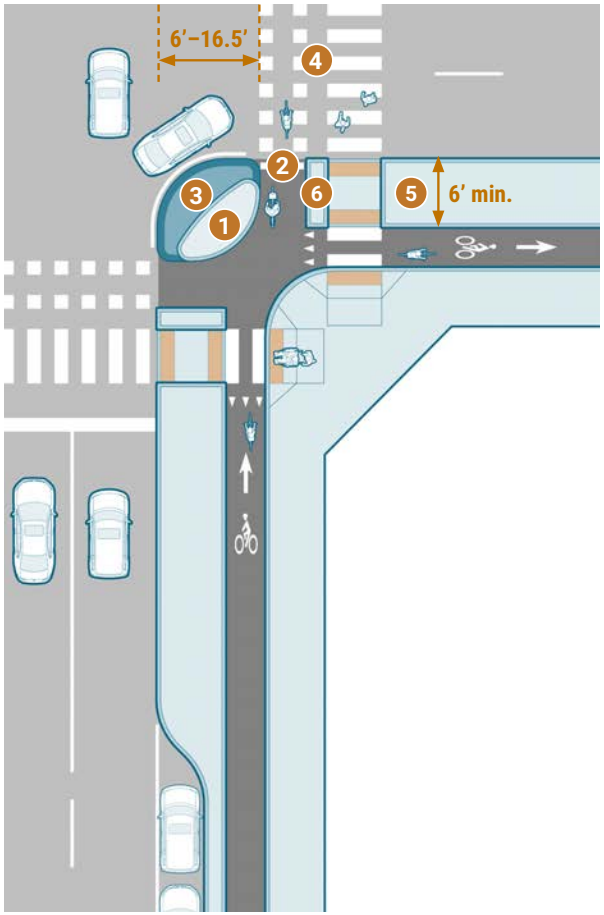
The cost for a protected intersection varies widely depending on the site conditions, drainage impacts, and existing intersection features. On average, it costs approximately $100,000 to upgrade a signalized intersection to a protected intersection with permanent features, without a separate bicycle phase. A seasonal or other short-term design (only intended for a few years) can be achieved at a much lower cost by using flexible posts.

Protected Intersections

Design Features

FHWA Achieving Multimodal Networks report and Chapter 4 of the MassDOT Separated Bicycle Lane Planning and Design Guide both provide additional detailed guidance for protected intersections. Noteworthy design features include the following (specific points in some notes are illustrated in the graphic on the right):

- Key features include a corner island, forward bicycle queuing area, driver yield zone, and pedestrian refuge median.
- Corner island – A corner island allows the bike lane to be physically separated from motor vehicle traffic up to the edge of the intersection and reduces motor vehicle turning speeds (1). Mountable truck aprons can accommodate large vehicles (3).
- Forward bicycle queuing area – Forward bicycle queuing area provides a waiting area for bicyclists that is fully within view of drivers waiting behind the pedestrian crosswalk (2).
- Driver yield zone – A driver yield zone creates a space for turning drivers to yield to bicyclists and pedestrians by setting the bicycle and pedestrian crossings back from the intersection, similar to the offset geometry recommended for sidepath crossings (4). If pedestrian and/or bicyclist movements are to be protected by signal phasing, a driver yield zone is not as critical.
- Pedestrian refuge median – A pedestrian refuge median enables pedestrians to cross bicycle and motor vehicle traffic separately and reduces the pedestrian crossing distance ((5) and (6)). Medians less than 6'-wide should not be considered refuges, and cannot include detectable warning surfaces.
- Can be constructed of curbs and more permanent features, or using flexible delineators and other rapid implementation materials.



A protected intersection. Source: FHWA Achieving Multimodal Networks

Supplemental treatments

Protected intersections include several other treatments discussed in more detail in the following sections of this handbook:

- Intersection Design
- Bicycle Boxes
- Medians and Crossing Islands
- Curb Extensions and Curb Radii
- Bicycle Signal Indications
- LPI and/or LBI

Resources

- FHWA Achieving Multimodal Networks: https://www.fhwa.dot.gov/environment/bicycle_pedestrian/publications/multimodal_networks/fhwahep16055.pdf
- MnDOT's Bicycle Facility Manual: http://www.dot.state.mn.us/bike/design-engineering.html
- MassDOT Separated Bicycle Lane Planning and Design Guide: https://www.mass.gov/lists/separated-bike-lane-planning-design-guide

Pedestrian Hybrid Beacon Systems

What is their purpose?

A pedestrian hybrid beacon (PHB) system, formerly known as a High-Intensity Activated crossWalK (HAWK), is a beacon installed at unsignalized locations to assist pedestrians in crossing a street at a marked crosswalk. The beacon warns and controls traffic with the use of two side-by-side red lenses and a single yellow below the red.

Per the Manual on Uniform Traffic Control Devices (MnMUTCD), a PHB may be considered for installation at marked crossing locations that do not meet traffic signal warrants or at locations that meet traffic signal warrants but the agency has not yet decided to install a traffic signal. The MnMUTCD, Chapter 4F, provides additional guidelines and appropriate volumes that should be reached prior to installation. The guidelines include separate criteria for low speeds (35 mph or less) and high speeds (greater than 35 mph). Consideration should also include major street volumes, pedestrian volumes, operating speeds, widths, gaps in traffic, walking speeds, and pedestrian delay.

Pedestrian Hybrid Beacon

Are they a proven strategy?

As a result of the FHWA Proven Safety Countermeasures initiative which began in 2008, PHB systems are a **PROVEN** safety countermeasure.

Supporting Document: FHWA Proven Countermeasures - PHB

Where would we use them?

Per the MnMUTCD, a PHB shall:

- Only be installed with a marked crosswalk and warning signs
- Only be installed to assist pedestrians to cross a street or highway

Additional guidance suggests that PHBs are most effective when:

- Locations need additional enhancements to improve motorist yielding rates or address limited gaps in traffic at marked crosswalks.
- There is a high volume of pedestrian traffic, such as near transit stops, schools, and multi-use trail crossings. The MnMUTCD states that the lowest pedestrian volume threshold for a PHB is 20 pedestrians/hour to cross the major street.
- Traffic signals are not yet warranted and/or are too costly to install.
- Installed at mid-block crossings. Consideration can be given to their use at minor, uncontrolled intersections, but this is not typically encouraged as it may create ambiguity for the assignment of right of way for vehicles on the minor road.

Pedestrian Hybrid Beacon Systems

What are the advantages?

- Proven countermeasure per FHWA.
- Improve visibility of pedestrians.
- Assign right-of-way for vehicles and pedestrians.
- Advantageous at mid-block crossings and uncontrolled intersections
- Effective option for crossing locations with higher speeds and vehicle volumes but not the pedestrian or vehicle volumes required to warrant a traffic signal.
- Studies have shown a 55% reduction in pedestrian crashes, 29% reduction in total crashes, 15% reduction in serious injury and fatal crashes, and over 90% compliance rate.

- Prior to installing a PHB system, an engineering study should consider the major-street volumes, speeds, sight distance, widths of the crossing, gaps in traffic, pedestrian volumes, walking speeds, and delay. The MnMUTCD provides additional guidance for the installation of PHB systems on Low-Speed Roadways and High-Speed Roadways.

What are the maintenance impacts?

PHBs typically involve similar maintenance and requirements as traditional traffic signals. Associated signing and striping also requires routine maintenance.

What are the challenges?

- Technology is not widely implemented, but agencies are becoming increasingly interested in this strategy to improve pedestrian safety.
- Educating drivers and pedestrians on PHB function and purpose is a key component to its effectiveness.
- Appropriate only for locations with moderate to high pedestrian demands.
- Challenging to install on roadways with high driveway density.
- If installing on a roadway with adjacent signals, the PHB will likely need to be programmed to work in coordination with the existing signal timing plan.
- Can increase delays.
- Require routine maintenance, similar to that of a traffic signal.
- If installed at an intersection, appropriate side street traffic control should be considered

Supplemental treatments

PHBs are often combined with the following treatments:

- Marked crosswalk and warning signs (required)
- Marked stop line on the major street approaches
- Countdown pedestrian signal heads and pedestrian pushbuttons
- Parking restrictions
- Curb extensions and ADA curb ramps
- Pedestrian refuge islands

Pedestrian Hybrid Beacon

How much do they cost?

For a two-lane roadway, the cost for a PHB system can range from approximately $100,000 to $120,000. For a four-lane roadway, the cost can range higher from approximately $100,000 to $170,000. The increase in cost accounts for a longer mast arm, a median mounted push button, and a newly constructed pedestrian refuge island.

Significant cost items include the mast arm and pole with an extension, the controller and cabinet, conduit, and signing. Total construction costs will depend on site conditions, available power sources, and curb ramp improvements.

Pedestrian Hybrid Beacon Systems

Design Features

The PHB consists of two side-by-side red lenses and a single yellow lens below the red. The assembly includes both vehicular beacons and pedestrian signals (WALK and DON'T WALK). A stop line should also be installed for each approach to the crosswalk.

The beacon rests in dark until activated manually by a pedestrian using the pushbutton or by a pedestrian detection system. Once activated, the beacon flashes a sequence consisting of six intervals: dark, flashing yellow, steady yellow, steady red, alternating flashing red, and dark. The steady red interval mandates drivers to stop for pedestrians at the crosswalk.

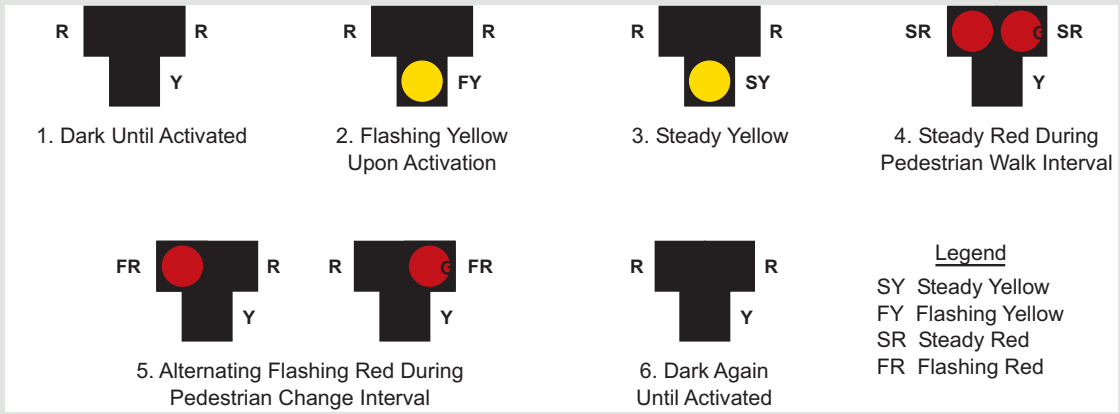
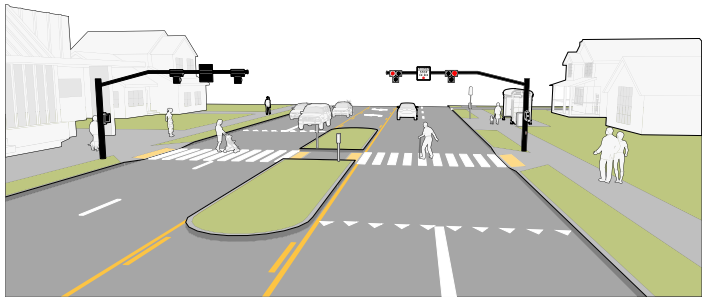


Figure 4F-3. Sequence for a Pedestrian Hybrid Beacon

Best practices

PHBs can be an effective pedestrian safety strategy when used at locations with high rates of pedestrian activity and high volumes of crossing traffic that do not allow adequate gaps for pedestrians to safely cross. They are best suited for mid-block locations.



An illustration of a pedestrian hybrid beacon

An image of a pedestrian hybrid beacon, Source: FHWA STEP

Resources

- FHWA's source for these: Zegeer, C., R. Srinivasan, B. Lan, D. Carter, S. Smith, C. Sundstrom, N.J. Thirsk, J. Zegeer, C. Lyon, E. Ferguson, and R. Van Houten. (2017). NCHRP Report 841: Development of Crash Modification Factors for Uncontrolled Pedestrian Crossing Treatments. Transportation Research Board, Washington, D.C.
- MUTCD: https://mutcd.fhwa.dot.gov
- https://www.fhwa.dot.gov/innovation/everydaycounts/edc_4/STEP-tech-sheets.pdf
- Pros/Cons: https://www.westernite.org/Sections/washington/events/2011/Quad/A-2/A-2%20Pedestrian%20Crossing%20Toolbox%20for%20High%20Speed%20Urban%20Arterials.pdf
- https://safety.fhwa.dot.gov/ped_bike/tools_solve/fhwasa14014/

Rectangular Rapid Flashing Beacons

What is their purpose?

A Rectangular Rapid Flashing Beacon (RRFB) is a crossing enhancement at uncontrolled intersections that can be activated manually by a pedestrian using a pushbutton or by a pedestrian detection system. The RRFB assembly typically includes one RRFB device on each end of a crosswalk. Each device includes two rapidly and alternatively flashing rectangular yellow indications attached to a pole supplementing the pedestrian warning sign (W11-2) or school crossing sign (S1-1) at a crosswalk. The irregular "wig-wag" flashing sequence is similar to emergency flashers on police vehicles (left light on, then right light on, etc.) with a pulsing light source.

MnDOT has received statewide Interim Approval from FHWA for the use of a pedestrian actuated RRFB (IA-21). Statewide Interim Approval allows any jurisdiction within Minnesota to use the device as long as the jurisdiction agrees to notify the MnDOT Traffic Standards Engineer of the location for each installation and agrees to the specific conditions outlined for Statewide Interim Approvals.

RRFB at Johnson Street NE & 22nd Avenue NE, Minneapolis, MN

Are they a proven strategy?

FHWA has reviewed studies related to the effectiveness of the RRFB device and have confirmed its success at uncontrolled marked crosswalks. Therefore, based on the number of successful experiments, the RRFB is a **PROVEN** safety countermeasure strategy for marked crosswalks.

Supporting Research: Evaluation of Pedestrian Hybrid Beacons and Rapid Flashing Beacons

Where would we use them?

The purpose of the RRFB is to increase driver awareness of the presence of pedestrians at crosswalks that are not across approaches controlled by YIELD signs, STOP signs, or traffic control signals. RRFBs can be used on crosswalks across the approach to and/or egress from a roundabout. Research shows that an RRFB is most effective on roadways with volumes less than 12,000 vehicles per day and with speeds less than 40 mph.

Per the IA-21 the use of an RRFB shall:

- Only be installed to function as a pedestrian-actuated enhancement
- Only be used to supplement a post-mounted or overhead-mounted W11-2 (Pedestrian), S1-1 (School), or W11-15 (Trail) crossing warning sign. A diagonal downward arrow (W16-7P) plaque shall supplement the post-mounted signs.

The IA-21 also provides information regarding sign/beacon assembly locations, beacon dimensions and placement, beacon flashing requirements, beacon operations, and accessible pedestrian features. Reference the Interim Approval-21 for more details regarding the federal guidance.

Rectangular Rapid Flashing Beacons

What are the advantages?

- RRFBs can utilize power from the existing grid network or by solar panels furnished on the devices.
- Increases driver awareness of the crosswalks and driver yielding compliance, especially at night. Compliance rates vary per site, and are generally highest on low-speed, single-lane facilities. Studies have found compliance rates from 17% to as high as 98%, which are comparable to a traffic signal or pedestrian hybrid beacon system.
- Can reduce the number of multiple-threat crashes, especially when used in combination with other strategies noted below.
- 47% reduction in vehicle-pedestrian crashes.

What are the maintenance impacts?

Maintenance for the RRFB is dependent on the power supply type. If solar power is used, the primary concern is removing nearby foliage and the amount of sun exposure throughout the day. Solar powered RRFBs typically function for several years without maintenance issues.

Solar powered RRFB systems do not require underground conduit, and would only require a push button to activate the system. The largest solar panel (55 watt) can accommodate around 1,000 activations per day. These solar panels typically can last up to 10 years or longer depending on usage. The batteries require replacement approximately every 5 years.

What are the challenges?

- RRFB effectiveness varies depending on the type of roadway, traffic volumes, and speeds. On higher-speed (40 mph or higher), multilane, or high-volume (over 12,000 vehicles per day), RRFB's are less effective, and other strategies (or a combination of strategies) should be considered.
- Additional maintenance and operating costs, depending on power source

RRFB systems that are hardwired are powered from a nearby electrical source by running wire underground. Hard wired systems are typically recommended at crossing locations that experience very high pedestrian activity. A hardwired system can ensure consistent operation, especially during the fall and winter months when the sun is low in the sky and reducing the ability to charge the batteries as frequently.

Supplemental treatments

Rectangular Rapid Flashing Beacons are often combined with the following treatments:

- Marked crosswalk (required) and Advance STOP markings and signs (recommended if multi-lane)
- Warning signs (required)
- Parking restrictions (required)
- Curb extensions and ADA curb ramps
- Pedestrian refuge island
- Speed bumps

Best practices

The RRFB offers significant safety benefits, achieving high rates of compliance for a relatively low cost. The RRFB increases yield rates at uncontrolled crosswalks, and studies show they are most effective on roadways with volumes less than 12,000 vehicles per day and with speeds less than 40 mph. Reference the Interim Approval-21 for more details regarding the federal guidance.

How much do they cost?

Costs can vary widely for the installation of two RRFB units (one on either side of the street). For an RRFB system using a solar-powered system, the cost is approximately $15,000 for materials and installation. For an RRFB system that is hardwired, the costs range between $30,000 and $50,000 depending on the proximity of a power source. RRFB systems that include overhead flashers cost between $80,000 to $100,000, which includes a mast arm and pole for each direction of traffic and hardwired power.

Rectangular Rapid Flashing Beacons

Design Features

The installation of an RRFB must include two units: one on the right-hand side and one on the left-hand side of the roadway. It is also recommended to consider placing an additional unit within a median if available. The two yellow indications shall flash in a rapidly flashing pattern ("wig-wag"), at a rate not less than 50 or more than 60 times per minute (IA 21). The lights should rest in dark until activated, and should start and stop simultaneously. Additionally, the RRFB indication should be approximately 5" wide by 2" high and aligned horizontally between the bottom of the crossing warning sign and the top of the supplemental downward diagonal arrow plaque. Pedestrian push buttons should be properly installed, in accordance with ADA design standards, and in a position where the activated lights are visible to the pedestrian.

RRFBs typically receive power from solar panel units attached to each device, but can also be hard wired to a traditional power source.

RRFB at CSAH 16, Shakopee, MN

Resources

- https://safety.fhwa.dot.gov/ped_bike/step/docs/TechSheet_RRFB_508compliant.pdf
- https://www.fhwa.dot.gov/innovation/everydaycounts/edc_4/STEP-field-guide.pdf
- http://www.dot.state.mn.us/stateaid/trafficsafety/county/CRSP-EnhancedCrosswalks.pdf
- Development of Crash Modification Factors for Uncontrolled Pedestrian Crossing Treatments: https://www.nap.edu/download/24627

School Crossing Guards

What is their purpose?

Trained school crossing guards can help stop the flow of traffic and guide students safely across the street in specific times and locations. According to the Minnesota Safe Routes to School Crossing Guard Guide, a school crossing guard can encourage safe crossing behaviors, provide education and reinforcement of safe pedestrian behavior, ensure adequate gaps in traffic, alert motorists of students in the area, and observe incidents and behaviors that create safety hazards.

Crossing guard at E 25th Street and 29th Avenue S, Minneapolis, MN

Are they a proven strategy?

Crossing guards are considered a **TRIED** safety strategy due to the lack of specific research into their effectiveness. Nationwide observations made after implementing crossing guards have shown consistent success in helping students cross roads more safely and improving vehicle compliance with school zone speed limits.

It should be noted that the FHWA Pedestrian Safety Guide and Countermeasure Selection System states that the implementation of trained adult crossing guards is one of the most effective measures for guiding children safely across streets.

2019 Minnesota State Statute, 169.21:

(c) It is unlawful for any person to drive a motor vehicle through a column of school children crossing a street or highway or past a member of a school safety patrol or adult crossing guard, while the member of the school safety patrol or adult crossing guard is directing the movement of children across a street or highway and while the school safety patrol member or adult crossing guard is holding an official signal in the stop position. A peace officer may arrest the driver of a motor vehicle if the peace officer has probable cause to believe that the driver has operated the vehicle in violation of this paragraph within the past four hours.

School Crossing Guards

What are the advantages?

- Serve as an inexpensive countermeasure. Costs vary depending on depending on the type of crossing guard (student, trained adult, or safety official) and whether the crossing guard is paid or a volunteer.
- Alert drivers to students crossing.
- Improve motorist yielding rates.
- Can monitor crossing locations, track and report unsafe incidents or events that occur in the area.
- Encourage physical activities among students by making walking more accessible.

What are the challenges?

- Those serving as guards can feel their safety is at risk depending on the environment.
- Only adult crossing guards should serve at higher speed and higher volume roadways.
- If student crossing guards are to be used, it is recommended that they work with an adult supervisor and at crossings of lower speeds and lower volume roadways.
- Difficulty recruiting paid workers for part time crossing guard work

A crossing guard at a crosswalk

Where would we use them?

Crossing guards are typically provided at crossings near schools, where the traffic flow does not provide adequate gaps for school-aged children to safely cross.

- Crossing guards are commonly applied within school zones as part of MnDOT Safe Routes to School program. This program allocates funds to communities and schools to complete safety improvement projects on routes students use to walk and bike to school.

Communities and school groups should reference the MnDOT Safe Routes to School Crossing Guard Guide and MnMUTCD Section 7D.1 prior to implementing crossing guards.

Supplemental treatments

- Marked crosswalks
- Advanced school zone/crossing signs

Best practices

The use of adult crossing guards is a common practice to improve crossing safety in school zones. At crossings of lower speed and lower volume collectors, the use of student crossing guards with adult supervision is appropriate, but adults should be employed for higher speed and higher volume arterials or at locations with unique features such as poor sight distance.

How much do they cost?

The costs of training and implementing student and parent-volunteer crossing guards at school crossings is relatively nominal. Additional costs may be required for non-volunteer adult crossing guard salaries and uniforms.

School Crossing Guards

Design Features

Crossing guards should be well trained and equipped with reflective safety vests and stop paddles. It is best practice to use student crossing guards, with adult supervision, at crossings of lower speed and lower volume collectives. Adults should be employed for higher speed and higher volume arterials. Even at signalized intersections, studies have documented that the presence of a crossing guard is still beneficial in many elementary school sites too. A successful implementation of crossing guards should also include public information and education campaigns for school-age children and their caregivers so all users are aware of pedestrian rights and safe routes to school.

Resources

- http://www.pedbikesafe.org/pedsafe/countermeasures_detail.cfm?CM_NUM=57
- https://www.dot.state.mn.us/mnsaferoutes/assets/downloads/MN_SRTS_CROSSING%20GUARD%20GUIDE.pdf
- http://guide.saferoutesinfo.org/crossing_guard/the_role_of_the_adult_school_crossing_guard.cfm
- MnMUTCD – 7D: https://www.dot.state.mn.us/trafficeng/publ/mutcd/mnmutcd2015/mnmutcd-7.pdf
- AAA School Safety Patrol Operations Manual: https://www.aaa.com/aaa/049/PublicAffairs/SSPManual.pdf
- https://www.salary.com/research/salary/benchmark/crossing-guard-salary/mn
- https://www.revisor.mn.gov/statutes/cite/169.21

Grade-Separated Crossings

What is their purpose?

A grade-separated crossing provides a vertical separation (overpass or underpass) between pedestrian/bicyclists and motor vehicles. Grade-separated crossings are effective strategies for locations with heavy pedestrian and bicycle volumes crossing a roadway with heavy or high speed traffic, such as interstates, railroad tracks, and other busy roadways. Pedestrians can rarely be convinced to use a poorly located crossing, so grade-separated crossings should be provided within the normal path of pedestrians wherever possible.

Are they a proven strategy?

A grade-separated crossing is a **PROVEN** strategy to eliminate conflicts between pedestrian/bicyclists and motor vehicles.

Where would we use them?

Prior to constructing a grade-separated crossing, agencies should research and consider the following:

- Existing or projected crossing volumes
- Roadway features, including daily volumes, speed, and geometry
- The location of adjacent crossing facilities
- The location of existing pedestrian/bicycle facilities and generators, such as regional trail networks
- Predominant type and age of persons who will use the facility
- Terrain, soil composition, and presence of conflicting utilities

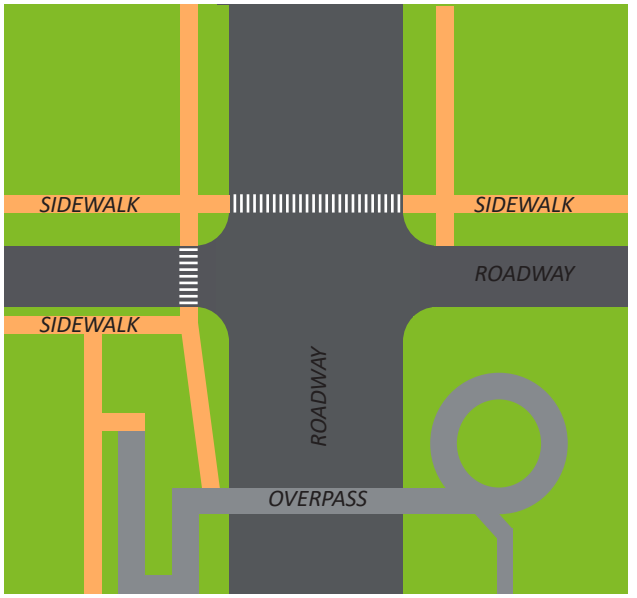
Grade-separated crossings are commonly constructed at:

- Locations with heavy volumes of pedestrian and bicycle traffic crossing a roadway with high vehicular traffic volumes
- Locations where pedestrian and bicyclists will want to cross the road
- Locations with difficult terrain or geographic obstacles to cross the roadway

Grade-separated crossings are most effective where they offer a direct route for nonmotorized users. Many pedestrians and bicyclists will not use an indirect grade-separated crossing if a more direct at-grade route is available.

What are the maintenance impacts?

Partner with maintenance team members during design development to discuss strategies and issues related to routine maintenance, especially during winter months, to keep all accesses, tunnel entries, and paths free clear of snow and debris. All structures should get routine inspection.



This grade-separated crossing may be less effective because it requires more travel distance and physical effort than crossing at-grade. Nonmotorized users are highly likely to cross at-grade instead.

This grade-separated crossing is more effective because it offers a direct route for pedestrians on the trail.

Grade-Separated Crossings

What are the advantages?

- Can help encourage walking or biking.
- Can help connect regions and trail networks separated by busy highways.
- Allow for uninterrupted flow of pedestrian and bicycle movement.
- Can be associated with 86% reduction in pedestrian crashes and 90% reduction in fatal and injury pedestrian crashes.
- Grade-separated crossings are more usable by children or others that may not be comfortable using an at-grade crossing.

Gateway Trail Bridge, Washington County, MN; Source: MnDOT

What are the challenges?

- Grade-separated crossings do not completely prohibit pedestrian or bicyclists from crossing the road at-grade. There is risk for underutilization and decreased value if not properly implemented.
- Require diligent planning and agency/public involvement to determine a location that will have the most benefit.
- Underpasses and overpasses for pedestrians and bicyclists can require right-of-way acquisition and are expensive to construct.
- Underpass design requires careful drainage design and management of underground utilities.
- Design must incorporate ADA-compliant design standards, including maintaining a maximum 5% grade, providing a 5' landing surface for every 30" of elevation change, and handrail requirements.
- Maintenance and security concerns should be considered and managed, especially with underpasses.
- Lighting design is important to mitigate personal safety concerns.

Lakewalk Trail tunnel under TH 61, Duluth, MN

How much do they cost?

Overpasses and underpasses are major construction projects, and costs depend significantly on site characteristics. For example, a recent project in the state for a 16' x 10' underpass cost approximately $1,800 per linear foot, with additional end section costs of $19,000 each. Pre-fabricated truss structures for an overpass can cost approximately $3,500 per linear foot; however, these projects require additional structural material and total project costs can reach up to $3 million.

Best practices

Grade-separated crossings are a proven safety strategy, especially when an underpass or overpass is conveniently located to achieve the most benefit. Due to the high cost of construction, grade-separated crossings should be considered where high volumes of pedestrian/bicycle traffic must cross major high-speed roadways with high volumes of traffic. Grade-separated crossings are typically seen along regional trail networks. They can be a great choice to integrate where roads cross waterways, especially if a trail follows the waterway.

Grade-Separated Crossings

Design Features

Grade-separation should only be constructed when the safe movement of pedestrians and bicyclists cannot be ensured in a simpler, more cost-efficient manner.

Designers should reference state and federal design references, including the MnDOT Bicycle Facility Design Manual, the AASHTO Guide Specifications for Design of Pedestrian Bridges, and the AASHTO Guide for the Planning, Design, and Operation of Pedestrian Facilities.

Grade-separated crossing facilities should incorporate the following design features:

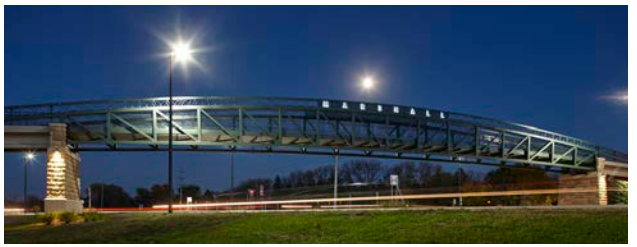
- Be positioned to be conveniently accessible by pedestrians and bicyclists in order to avoid under use.
- Good sight distance in underpasses, preferably with the open ends of the tunnel in view at all times, to improve security.
- Adequate lighting and ventilation in tunnels.
- ADA design features, especially for approach ramp design. Stairs cannot be the only access to the grade separation; an elevator or ramp that meets the ADA regulations must be provided.
- Be wide enough to allow two-way pedestrian/bicycle traffic; per the MnDOT Bikeway Facility Design Manual, the minimum recommended width is 8' for a shared pedestrian/bicyclist lane and 14' for separate pedestrian and bicyclist lanes.
- Barriers or landscaping to encourage use.
- Provide handrails on overpasses.
- Minimized grades, cross slopes, and unnecessary travel distances.

Resources

- Minnesota DOT Road Design Manual (11-3)
- MnDOT Bikeway Facility Design Manual (Updated February 2020): http://www.dot.state.mn.us/bike/bicycle-facility-design-manual.html
- http://www.mnltap.umn.edu/publications/handbooks/pedcrossingguide/documents/ped_guidebook.pdf
- http://www.minneapolismn.gov/www/groups/public/@publicworks/documents/webcontent/convert_280659.pdf
- https://safety.fhwa.dot.gov/saferjourney1/library/countermeasures/07.htm

Bridge overpass at TH 23 & Saratoga Street, Marshall, MN

Lakewalk Trail tunnel under TH 61, Duluth, MN



Bridge overpass at TH 23 & Saratoga Street, Marshall, MN

Linear Facilities

Route Modifications

What is their purpose?

Route modifications remove through access for motor vehicles with the goal of diverting traffic from and reducing volumes on key bicycling and pedestrian routes. Modifications that allow pedestrians and bicyclists to maintain access can be made through a variety of tools, including regulatory signs, major street refuge medians, diagonal diverters, forced turns, turn prohibitions, street closures, and partial closures. Such traffic management techniques and plans are most frequently implemented on low-speed streets near residential areas to manage traffic; they have been implemented in Minnesota communities such as Rochester, Moorhead, Orono, Eagan, Roseville, Minneapolis, and Blaine.

Traffic diverter at 11th Avenue S., Minneapolis, MN

Are they a proven strategy?

Route modifications have been **PROVEN** to reduce motorist volumes without affecting emergency services access when well thought out from a network approach. Thoughtful corridor access management is a **PROVEN** safety countermeasure, and route modifications are one factor in corridor access management. Similarly, median refuge islands are a proven safety strategy for crossing bicyclists and pedestrians at street crossings.

Where would we use them?

Given the variety of elements that make up route modifications, a Neighborhood Traffic Management Program is often used to determine which measures should be implemented. An area-wide approach is best, and should receive neighborhood support.

Route modifications can be considered at the following locations:

- On routes that experience and encourage bicycle activity, such as a bicycle boulevards (see Bicycle Boulevards section)
- In locations where vehicle traffic is low and re-routed vehicles can make desired maneuvers at a nearby intersection
- Often in urban settings on low-speed, low-volume local streets

What are the maintenance impacts?

Higher maintenance impacts are expected if elements such as raised medians or traffic diverters are part of implementation. For example, raised medians will impact drainage and need to be cleared of snow and other debris.

Route Modifications

What are the advantages?

- Reducing motor vehicle traffic reduces the likelihood of a crash with a bicycle or pedestrian.
- Reducing motor vehicle traffic can make a street more comfortable for bicycle or pedestrian use.
- Reduce intersection width by providing refuge medians, reducing crossing distance, and minimizing pedestrian and bicycle exposure at the intersection.

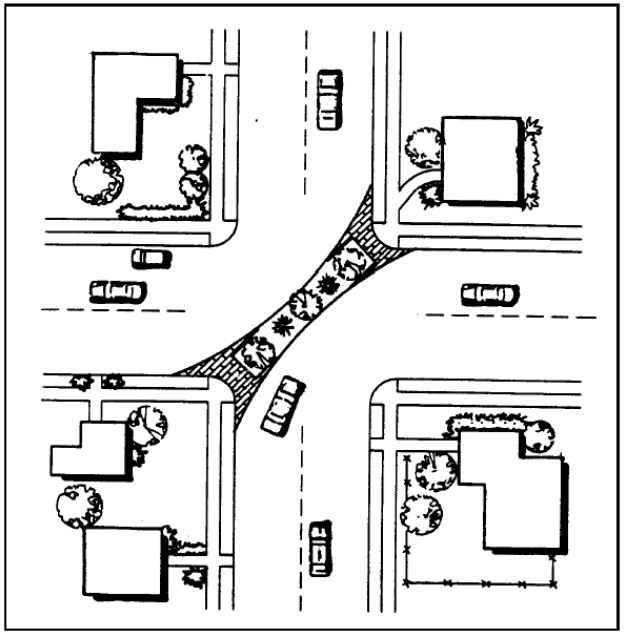
What are the challenges?

- Design should ensure that diverted motor vehicle traffic will use routes that can accommodate an increase in volume.
- Diverting motorists to other routes will increase interactions with bicyclists and pedestrians on those facilities.
- Travel time and distance can increase for local street users.
- Visitors and tourists using paper maps and wayfinding kiosk maps may be confused if maps are not up to date.
- Community engagement and buy-in on this and perhaps other treatments as well.

Traffic diverter with an opening for bicycles

Supplemental treatments

- Route modifications are often used to create bicycle boulevards. More details are included in the Bicycle Boulevards section of this handbook.



Sketch of a traffic diverter

How much do they cost?

Costs vary widely depending on the type and number of route modification elements that are installed. Regulatory signs are cheaper than diagonal diverters or refuge medians. Diverters can cost between $15,000 and $45,000 depending on the design and site conditions.

Route Modifications

Design Features

- Route modification elements combined with bicycle boulevards can improve bicyclist access to destinations. Bicycle boulevards may incorporate route modification elements such as traffic diverters, median refuges, curb extensions, or yield signs. Traffic diverters at key intersections reduce motor vehicle through traffic but permit bicycle passage and maintain local access.
- Regulatory signs such as “DO NOT ENTER” (R5-1) and mandatory turn signs should be used to restrict motor vehicle traffic. Use “EXCEPT BICYCLES” (W16-xxP) plaques to supplement signs restricting motor vehicle traffic.
- Access for emergency services can be maintained using flexible delineators, mountable curbs, signing, or other similar treatments.

A traffic circle on a bicycle boulevard.

A traffic diverter with openings for a bicycle

Resources

- FHWA Achieving Multimodal Networks: https://www.fhwa.dot.gov/environment/bicycle_pedestrian/publications/multimodal_networks/fhwahep16055.pdf
- https://safety.fhwa.dot.gov/saferjourney1/Library/countermeasures/36.htm

Road Diets

What is their purpose?

A road diet is a reconfiguration of a roadway's available width to integrate additional modes, such as bike lanes, transit lanes, pedestrian crossing islands, parking, or a combination thereof. A common form of road diet involves converting an undivided four-lane (two-way) roadway into a three-lane roadway made up of two through lanes, a center two-way left turn lane, and a shoulder or bike lane. Road diets can improve safety, mobility, and access management along a roadway.

The FHWA Road Diet FAQ provides additional information on road diets.

Road diet with RRFB on CR-101 S, Minnetonka, MN

Are they a proven strategy?

Road Diets are considered a **PROVEN** effective strategy for reducing crashes when converting from four lanes to three. In these situations, research has found a 19-47% reduction in total crashes.

Supporting Documentation: FHWA Proven Safety Countermeasures – Road Diets

Where would we use them?

Prior to implementing a road diet, the average daily traffic (ADT) volumes must be considered. Several roads in the Minneapolis/St. Paul metropolitan area with volumes as high as 20,000 vehicles per day have had successful road diet implementations.

The FHWA provides a summary of the ADT volume guidelines for four-lane to three-lane conversions:

- **Less than 10,000 ADT**: A great candidate for road diets in most instances. Capacity will most likely not be affected.
- **10,000 - 15,000 ADT**: A good candidate for a road diet in many instances. Agencies should conduct intersection analyses and consider signal re-timing in conjunction with implementation.
- **15,000 - 20,000 ADT**: A good candidate for a road diets in some instances; however, capacity may be affected depending on conditions. Agencies should conduct a corridor analysis.
- **Greater than 20,000 ADT**: Agencies should complete a feasibility study to determine whether the location is a good candidate. There are several examples across the country where road diets have been successful with ADTs as high as 26,000.

Road Diets

What are the advantages?

- Crash Reduction Factor for all crashes range from 19% to 47%.
- Reduce rear-end and left-turn crashes due to the dedicated left-turn lane.
- Reduce side swipe crashes and the likelihood of multiple-threat crashes.
- Improve left-turning vehicle visibility. Also enables dedicated left turn control at signalized intersections.
- Reduce right-angle crashes, as side street motorists cross three versus four travel lanes.
- Create fewer lanes for pedestrians to cross.
- Dedicate space for left-turns for motorists and bicyclists.
- Create opportunity to install pedestrian refuge islands, bicycle lanes, on-street parking, and/or transit stops. Also potential ability to install landscape medians for traffic calming.
- Provide traffic calming and more consistent speeds, which may reduce potential crash severities for all users.

While daily traffic volume can provide a screening measure, knowledge of the turning traffic volumes in conjunction with the potential for safety improvements along a roadway should inform the decision on whether or not to implement a road diet. Road diets, specifically four to three-lane conversions, can be implemented on many roadways where safety improvements are needed, including the following:

What are the challenges?

- Before implementing a road diet, a traffic study should be conducted to evaluate potential reductions in crash frequency and severity, to evaluate roadway capacity /level of service, and to evaluate bicycle level of service.
- Road diets may have negative impacts to roadway capacity and motor vehicle delay, including on routes with transit service where there may not be opportunities to pass buses..
- Reconfiguration of the roadway will likely require modifications to signal head placement/phasing and restriping of pavement markings at intersections.

- Roadways with high numbers of left turn crashes
- Roadways with safety concerns related to the number of lanes for pedestrians to cross
- Roadways where traffic calming is an objective
- Roadways with history of head-on crashes and rear-end crashes
- Roadways where multimodal improvements such as transit and bicycle facilities are desired

What are the maintenance impacts?

Higher maintenance impacts are expected if elements such as curb extensions or raised medians are part of the road diet implementation. Depending on the reconfiguration, there will likely be additional pavement markings to maintain.

Road diet retrofit on Larpenteur Ave, Maplewood, MN

How much do they cost?

The cost for a four-lane to three-lane road diet improvement is about $25,000 to $40,000 per mile. If done during planned resurfacing, costs are typically limited to signalization changes. Cost also depends partly on the number of lane lines that need to be re-painted. The estimated cost of curb extensions or constructing a raised median can amount to $100,000 per mile or more.

Installing bicycle facilities during roadway resurfacing projects is an efficient and cost-effective way for communities to create connected networks of bicycle facilities. See FHWA's Incorporating Bicycle Networks in Resurfacing Projects for more information, cost considerations, and case studies.

Road Diets

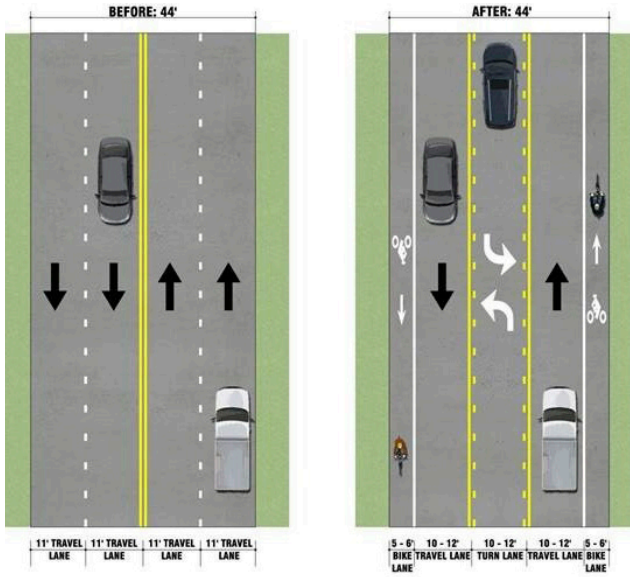
Design Features

Considerations before implementing a road diet should include driveway density, transit routes, and the number and design of intersections along the corridor, as well as operational characteristics. Changes to intersection turn lanes, signing, pavement markings, traffic control devices, signal timing and phasing, transit stops, and pedestrian and bicyclist facilities may be needed to support this concept.

See the FHWA Road Diet: Informational Guide and the NACTO Urban Street Design Guide for design details.

- Narrowing lane widths, often called a "Lane Diet," can also lead to greater safety. Narrower lanes on urban and suburban streets were generally associated with lower crash frequencies compared to wider lanes. Narrower cross-sections reduce crossing distances and have been associated with reduced travel speeds, both direct factors in the safety of pedestrians. For these reasons, lane widths on urban and suburban streets should be designed no wider than necessary to adequately accommodate the vehicular traffic volume and composition.

See Chapter 7 of MnDOT's Bicycle Facility Manual for discussion about narrow lane widths and relocation of car parking.



Before and after image of a road diet, Source: MassDOT Road Diet Guide

Resources

- https://safety.fhwa.dot.gov/provencountermeasures/road_diets/
- http://www.dot.state.mn.us/bike/design-engineering.html
- https://safety.fhwa.dot.gov/road_diets/resources/pdf/roadDiet_MythBuster.pdf
- https://safety.fhwa.dot.gov/road_diets/guidance/info_guide/

Road diet at Portland Avenue and Bischof Lane, Bloomington, MN

Sidewalks

What is their purpose?

A sidewalk is a type of walkway that defines a path for pedestrian travel placed along the side of a roadway. They are usually separated from roadway traffic lanes by curb and gutter and sometimes by a planting strip or buffer zone. Other types of walkways include shared use paths and roadway shoulders.

Are they a proven strategy?

Sidewalks are a **PROVEN** safety strategy. Sidewalks on both sides of a street have been found to significantly reduce occurrences of walking along the roadway (which is a pedestrian crash risk) compared to locations where no sidewalks or walkways exist. Sidewalks provide a 65-89% reduction in crashes involving pedestrians walking along roadways.

Supporting Documentation: FHWA Countermeasure – Walkways

Before and after images of sidewalk construction on 54th Street in Edina, MN

Where would we use them?

Planning for a network of sidewalks should include an audit of the current sidewalk system. The audit should document pedestrian access to transit stops/service, schools, public buildings, parks, etc. The audit should also include consideration of sidewalk design issues, including obstructions (e.g., fire hydrants, signposts, etc.) and compliance with Americans with Disabilities Act (ADA) Standards for Accessible Design (see PROWAG guidelines). Sidewalks can be considered at the following locations, on both sides of the roadway:

- Along all urban streets and suburban arterials and collectors
- Adjacent to streets that connect pedestrian origins and destinations. For example, segments connecting neighborhoods with schools, parks, transit locations, or retail areas
- Along high-speed and high-volume roadways without shoulder width
- Shoulder space should be considered on any rural or suburban roadway that cannot feasibly implement a sidewalk or walkway. See the section on Paved Shoulders

What are the maintenance impacts?

- Partner with maintenance team members during design development to discuss strategies and issues related to routine maintenance, especially during winter months. Snow clearance from sidewalks may be improved by a buffer zone in between the sidewalk and roadway. This buffer zone can be landscaped and allows for snow storage during winter.
- In addition, sidewalks can become damaged over time from tree roots or other reasons. Vertical lips at these locations must be ground down to avoid tripping hazards and maintain ADA compliance.

Sidewalks

Design Features

- Curb ramps – To meet ADA requirements, crosswalks along a sidewalk must include curb ramps with tactile warnings during reconstruction or resurfacing of a roadway. Curb ramps on each side of a crosswalk not only provide better orientation for pedestrians with vision disabilities, but also assist pedestrians who use wheelchairs by providing a direct connection to the roadway crossing instead of directing them toward the center of the intersection.
- Cross slope – To properly accommodate pedestrians in wheelchairs, the cross slope of sidewalks should be less than 2% percent.
- Sidewalk widths – The minimum recommended sidewalk width is 6', which allows two people to walk comfortably side-by-side or pass each other while traveling in opposite directions. Wider sidewalks are needed in urban areas and commercial districts.
- 4' wide sidewalks may be considered in constrained areas, but require 5'-wide passing areas at regular intervals.
- Continuity – Sidewalks should be continuous, installed on both sides of the roadway, and relatively free of obstacles that could cause a tripping hazard or impede travel by children, senior citizens, and people with visual or mobility impairments.
- See MnDOT's Accessibility Design Guidance for additional ADA design guidance, technical memo, and curb ramp guidelines.

What are the advantages?

- Well-designed sidewalks improve the safety and mobility of pedestrians.
- Wider sidewalk widths accommodate a larger variety and volume of users and allow for people to walk side-by-side while accommodating people going in opposite directions.
- Can encourage multimodal activity and healthier lifestyles among the community.
- Can improve transportation equity.

What are the challenges?

- Sidewalks in constrained conditions may require additional right-of-way to construct and may require costly utility relocations.
- Features like utilities, signs, and vegetation are often in similar locations as sidewalks, requiring careful design and placement.
- Additional maintenance is required.
- Property owners may oppose construction of sidewalks, especially if they will be responsible for clearing snow.

How much do they cost?

Typical costs for implementation of sidewalks vary depending on the location, amount of available right-of-way, and materials used, but are generally in the range of $4 to $5 per square foot for a concrete sidewalk, excluding costs for purchasing additional right-of-way.

The cost for adding standard curbs and gutters is approximately $20 to $35 per linear foot, although the costs will vary depending on the length of sidewalk, the type of base material, and whether curb ramps are needed. Asphalt curbs and walkways are less costly, but require more maintenance than concrete sidewalks.

Resources

- https://safety.fhwa.dot.gov/provencountermeasures/walkways/
- https://www.dot.state.mn.us/ada/design.html

Shared Streets

What is their purpose?

A shared street, also known as a commercial shared street, is a street that includes a shared zone where pedestrians, bicyclists, and motor vehicles mix in the same space. Shared streets maintain access for vehicles operating at very low speeds. A shared street can include various elements, such as curb cuts and ramps, bicycle parking, benches, lighting, signs, and special plantings.

Shared streets differ from pedestrian malls and curbless streets. Unlike pedestrian malls, shared streets maintain access for vehicles operating at very low speeds. Also, while curbless streets are designed to provide flexible and accessible space for festivals and farmers markets when the street is closed to motor vehicles, they are not intended to encourage the mixing of street users.

Are they a proven strategy?

Shared streets are designed to reduce motor vehicle speeds, but due to the lack of specific data for these treatments, they are considered **TRIED**. However, a number of communities in the United States have built or converted existing conventional streets and alleys to shared streets with success.

Where would we use them?

Shared streets can be considered at the following locations:

- Locations that would benefit from an accessible walking area but where there is insufficient room for accessible sidewalks due to limited right-of-way
- Locations that would benefit from flexible space throughout the day; this might include space for motor vehicle and bicycle delivery activity during the day and more pedestrian activity in the evening, for example
- In areas with high pedestrian activity and low vehicle speeds, such as residential streets or areas targeted for retail development
- Local examples of shared streets include:
  - 29th Street in Minneapolis
  - 8th Avenue Artery in Hopkins

Shared Street Zones, Source: FHWA Accessible Shared Streets

Shared Streets

What are the advantages?

- Reducing vehicle speeds and volumes increases pedestrian comfort and reduces bicycle and pedestrian crash severity. Shared streets are generally designed for vehicle speeds between 5 and 15 mph.
- Slower speeds and reduced vehicle volumes lend themselves to quieter, more inviting streets where sidewalk cafes and outdoor commerce is more enjoyable for customers.
- Can support flexible spaces for routine activities as well as parades, concerts, festivals, and other special events.

What are the challenges?

- Can be challenging for pedestrians with vision impairments because they often lack navigational cues such as curbs and defined crossings, which pedestrians with vision disabilities typically use when navigating the street.
- Candidate locations should be carefully reviewed and selected to avoid user confusion and conflicts.
- Due to the lower vehicle speeds, drivers may avoid the shared street and take alternative routes unless their destination is located on the shared street. Alternative routes should be reviewed before implementing a shared street.

Shared street, 29th Street, Minneapolis, MN

Design Features

Designers should consider the following:

- It is critical to ensure that tactile surfaces provide navigational information to pedestrians with vision impairments. Tactile surfaces need to be detectable, consistent, and predictable.
- Detectable warning surfaces should not be used as a guidance surface or directional indicator.
- Signage and other detectable navigation cues should be provided at the transition to the shared street to indicate the change to all users.
- Because ADA guidance does not address directional indicators to provide linear navigational guidance for pedestrians, directional indicators should conform with International Standard Organization (ISO) 23599.

How much do they cost?

Based on the 29th Street project in Minneapolis, typical costs for implementation of a shared street are approximately $50,000 per block. That project included a comfort zone on the south side, with a narrow furniture zone. There is no curb between the furniture zone and the shared zone where vehicles drive. However, there is a contrasting tactile surface that serves as the detectable edge.

Shared Streets

What are the maintenance impacts?

Proper maintenance of shared streets is critical to ensure usability and safety. Shared streets often feature non-standard paving materials and treatments, which may require more care in installation and long-term maintenance. Partner with maintenance team members to discuss strategies related to routine maintenance, especially during winter months.

Resources

- FHWA Accessible Shared Streets – Notable Practices and Considerations for Accommodating Pedestrians with Vision Disabilities: https://www.fhwa.dot.gov/environment/bicycle_pedestrian/publications/accessible_shared_streets/index.cfm
- US Access Board Proposed Guidelines for Pedestrian Facilities in the Public Right-of-Way (PROWAG): https://www.access-board.gov/guidelines-and-standards/streets-sidewalks/public-rights-of-way/proposed-rights-of-way-guidelines
- International Standard Organization (ISO) 23599: https://www.iso.org/obp/ui/#iso:std:iso:23599:ed-2:v1:en

Streetscape elements within a shared street should be organized in a way that facilitates navigation by pedestrians with vision disabilities. The defining feature of a shared street is a shared zone where pedestrians, bicyclists, and motor vehicles can safely interact in the same space. If there is sufficient right of way, shared streets may also have a pedestrian-only comfort zone.

Figure 24

Frontage Zone varies	Comfort Zone 6 min, more preferred	Furniture Zone	Shared Zone
Landscaping, front stoops, door swings, awnings, café seating, retail signage and displays	Pedestrian access route (NOTE: If there is insufficient right-of-way for a comfort zone of at least 6'-wide, consider the shared alley design shown in Figure 25.)	Lights, signs, utility poles and boxes, trees, bicycle racks, parking meters, transit stops, benches, stormwater facilities and snow storage	Shared circulation for pedestrians, bicycles, vehicles

Shared Street Elements, Source: FHWA Accessible Shared Streets

On-Road and Buffered Bicycle Lanes

What is their purpose?

On-road bike lanes use pavement markings and signs to designate exclusive space for bicyclists. They are normally provided in both directions on two-way streets or on one side of a one-way street.

Buffered bike lanes are a type of on-road bike lane that provide increased horizontal separation between bicyclist, travel lanes, and/or parking lanes. The image shown below, from the MnDOT Bicycle Facility Design Manual, incorporates a double solid white line, some agencies also use a solid line along with a broken line.

Buffered bicycle lane

Are they a proven strategy?

Bicycle lanes are a **PROVEN** safety strategy. The Crash Reduction Factor (CRF) for bicycle crashes where bicycle lanes are provided is 36. Additionally, studies have shown that the provision of a bike lane, even if located along on-street parking in the "door zone," is still safer for bicyclists than the provision of a wide shared lane. However, further research is needed to distinguish between different types of bike lane configurations and street characteristics.

Where would we use them?

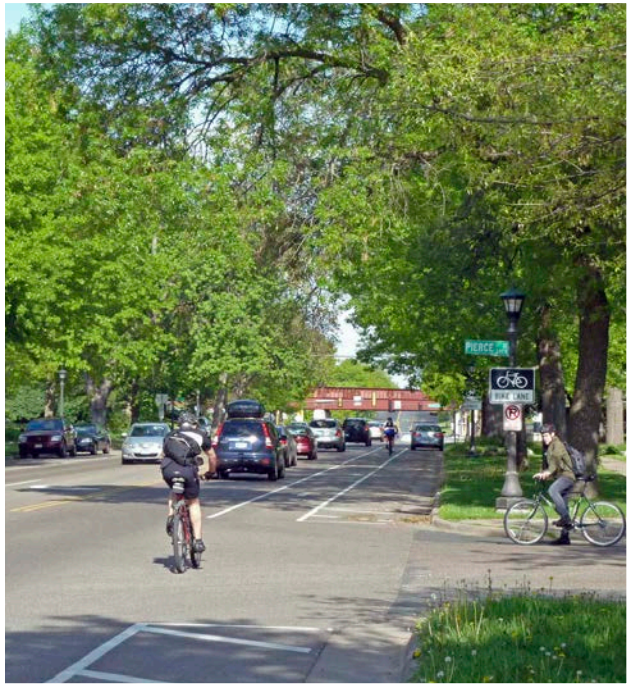
Bicycle lanes can be considered at the following locations:

- On roadways with motor vehicle speeds of 35 mph or less
- Bike lanes are likely to be comfortable for bicyclists of all ages and abilities when traffic volumes are less than 6,000 vehicles per day and speeds are 25 mph or lower.
- Greater separation, such as additional buffer width or a separated bike lane, may be considered when a roadway has any of the following critical factors:
  - Unusually high peak hour traffic volumes (greater than 10%-12% ADT)
  - Considerable volume of large trucks (5%-7% or more of daily volume)
  - On-street parking (which increases the risk of dooring collisions)
  - Concentrations of children or older adults (schools or senior centers)
  - Vehicle turn-lanes and/or high volumes of turning vehicles

On-Road and Buffered Bicycle Lanes

What are the advantages?

- Bike lanes, even those without buffers, help to separate modes of travel by their speed.
- Can improve comfort for both bicyclists and drivers.
- Can improve uniformity of speeds for drivers.
- Buffered bike lanes, with their increased horizontal separation from motor vehicles, further increase comfort for both bicyclists and drivers.



Bicycle lane on Marshall Avenue, Saint Paul, MN

What are the challenges?

- Drivers may confuse overly wide bike lanes (wider than 7') with a parking or travel lane. When space permits, consider a buffered bike lane.
- Bicycle lanes need careful design at intersections and driveways to consider interactions with bicycles and turning vehicles. Turning drivers may have difficulty seeing a cyclist approaching from behind them.
- Bike lanes may need to transition to separated bike lanes or shared use paths when vehicle speeds are not controlled at conflict points.
- Are not comfortable for all users when traffic volumes or speeds are high.
- May be located within the "door zone" of parked vehicles, which accounts for 2%-10% of bike crashes in urban areas.
- It may be challenging to maintain desirable sight distances to bike lanes.

What are the maintenance impacts?

Typically, bike lanes can be cleared along with the mainline roadway without special equipment. However, it is important to partner with maintenance team members to discuss strategies and issues related to routine maintenance since bike lanes should be maintained free of potholes, broken glass, and other debris. This is especially important for buffered bike lanes. Maintenance should also consider upholding clear and legible lane lines, in particular the buffer striping, which is not always longitudinal. Also, additional de-icing material may be needed to achieve a bare pavement condition due to the lack of vehicle traffic and to maintain smooth roadway surfaces for safe riding.

Best practices

- The portion designated for bicycle travel should not be less than 4' (5' adjacent to curbs). Buffers should be at least 2' wide.
- For buffered bike lanes, the buffer space can be provided between driving lanes and the bike lane, between the bike lane and parked motor vehicles, or both.

How much do they cost?

Typical costs range from $16,000 per mile for restriping to $500,000 per mile for overlay to $5 million per mile for reconstruction.

On-Road and Buffered Bicycle Lanes

Design Features

For state-specific design details, see Chapter 5 of the MnDOT Bicycle Facility Manual. Contraflow bike lanes, left-side bike lanes, and combination bus/bike lanes are also covered in Chapter 5. Additional contexts, such as bus stops and/or one-way streets, present other opportunities for bike lanes.

- To ensure appropriate widths of bike lanes and buffers, it is best to narrow motorized lanes as much as practicable while considering the needs of all roadway users.
- The portion designated for bicycle travel should not be less than 4' (5' adjacent to curbs). Buffers should be at least 2'-wide.
- As a bike lane approaches an intersection, solid bike lane markings can be continued, or they are typically replaced with dotted lines. Dotted lines reinforce that motor vehicles will merge into the bike lane prior to turning. Dotted lines are important where there are frequent right-turn movements or a high percentage of trucks. Refer to the MnMUTCD for details.
- For buffered bike lanes, the buffer space can be provided between driving lanes and the bike lane, between the bike lane and parked motor vehicles, or both.
- A buffer between a bike lane and on-street parking is desirable if the parking has high turnover. Dooring can be a risk when a bike lane is next to parallel parking. Dooring is when a vehicle door opening in front of the bicyclist's path of travel causes a collision. This is a serious concern and can lead to bicyclists not using a bike lane, particularly in places where there is high parking turnover. To reduce the risk of dooring, consider adding a buffer next to the parked motor vehicles.

Bike Lane	Preferred Width (ft.)	Minimum Width (ft.)
Adjacent to edge of pavement or gutter pan	5-7*	4
Between travel lanes or buffers	5-7*	4
Adjacent to parking (without buffer)	6-7*	5

Bicycle Lane Dimensions, Source: Adapted from MnDOT Bicycle Facility Design Manual

**If more than 7' are available, consider a buffered bike lane. Drivers may confuse overly wide bike lanes without a buffer or separation as a parking or travel lane.*

Resources

- http://www.dot.state.mn.us/bike/bicycle-facility-design-manual.html
- https://tooledesign.com/wp-content/uploads/2019/12/Winter-Maintenance-Resource-Guide.pdf
- http://www.ocpcrpa.org/docs/projects/bikeped/NACTO_Urban_Bikeway_Design_Guide.pdf

Bicycle lane at Rollins Avenue SE and 15th Avenue SE, Minneapolis, MN

Paved Shoulders

What is their purpose?

A paved shoulder is a multi-purpose area that is separate from but on the same level as the motor vehicle travel lanes, available for bicycle and pedestrian use and separated from vehicles by the roadway's edgeline. Paved shoulders can accommodate people walking or bicycling on or along roads. Paved shoulders can perform various other functions as well, such as reducing pavement edge deterioration, providing motor vehicle parking and space for emergency vehicles, and accommodating stopped vehicles.

Paved shoulders differ from bike lanes because they can be used for motor vehicle parking unless prohibited by local or area restrictions, whereas bike lanes cannot be used by motorists or pedestrians. Paved shoulders can be designated as bike lanes through the installation of bicycle lane symbol markings, but they must meet bike lane criteria.

Are they a proven strategy?

- Paved shoulders are a **PROVEN** safety strategy, providing a 71% reduction in crashes for pedestrians walking along roadways.
- Wider shoulders have been proven to reduce bicycle crashes.

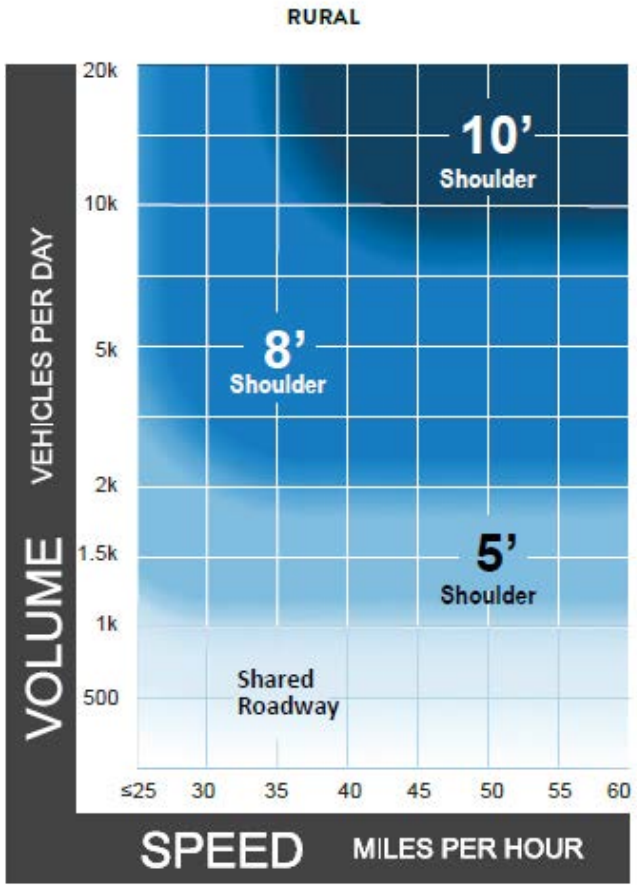
Where would we use them?

Paved shoulders can be considered at the following locations:

- Any road is a suitable candidate for paved shoulders, but rural or suburban locations where motor vehicle speeds are equal to or exceed 50 mph are particularly important to improve bicyclist comfort and safety.
- Paved shoulders are particularly important for bicyclist comfort and safety on any roadway with motorist volumes over 2,000 ADT.
- On roadways where bicycle usage is expected to be limited to higher speed recreational bicyclists.
- On roadways with higher-than-average (greater than 10%) heavy trucks, buses, or recreational vehicles.

What are the maintenance impacts?

Debris from adjacent travel lanes often accumulates in the area where people bicycle. Small rocks, branches, and other debris can deflect the wheel of a bicycle, and broken glass can puncture bicycle tires. These conditions can result in falls and injuries for bicyclists. Because bikeways that are not kept free of debris year-round may discourage bicyclists from using the facility, routine cleaning and clearing as well as more significant repairs and maintenance are necessary to keep bike facilities safe and comfortable in all seasons.



Rural bikeway selection, Source: FHWA Bikeway Selection Guide

Paved Shoulders

What are the advantages?

- Provide separated space for people walking or bicycling on roads where sidewalks, bike lanes, or shared use paths are not provided.
- Paved shoulders have several benefits for motor vehicles as well, such as reducing pavement edge deterioration, reducing run-off-road crashes, providing parking, and providing staging for maintenance activities.
- Improve comfort for both bicyclists and drivers by separating each mode by their speed.

What are the challenges?

- Generally do not accommodate biking by people of all ages and abilities, as they are not often a comfortable place to ride.
- Often collect debris that can make bicycling difficult.
- Rumble strips can create challenges for bicyclists attempting to avoid obstacles or debris in the shoulder.
- Right-of-way and wetland impacts.

Supplemental treatments

Rumble strips are an effective tool to mitigate motorist lane departure crashes, such as run-off-the-road and head-on crashes. However, edgeline or shoulder rumble strips can be difficult for bicyclists to traverse and can impact the use of a paved shoulder as a bicycle facility. See MnDOT Tech Memo 17-08-T-02 for information on the different types of rumble strips and their uses. Rumble strips should be placed in such a way as to provide at least a 4'-wide, smooth, bikeable paved path along the shoulder.

Shoulder widening along an uphill grade

How much do they cost?

On two-lane rural roadways, adding a paved shoulder ranges from $60,000 per mile for 4'-wide shoulders to more than $100,000 per mile or more for 8'-wide shoulders, depending on site conditions. For edgeline rumble strips, the implementation costs approximately $3,000 per mile.

Paved Shoulders

A bicyclist riding on a paved shoulder

Design Features

For state specific design details, including rumble strip design and recommended signage, see Chapter 5 of the MnDOT Bicycle Facility Manual. Key considerations include the following:

- To be considered a bicycle facility, a paved shoulder must be between 4' and 10'-wide, with wider shoulders intended on roadways with higher speeds and volumes.
- Provide paved shoulders on both sides of two-way roads to discourage wrong-way riding; shoulders on one side can be considered on roadways with constrained width and in uphill directions or where sight distances are limited.
- Where rumble strips are provided, they should be placed to maximize the width of the shoulder for bicycle use, should be as narrow as possible, should use a profile that is more bicycle tolerant, and should include regular gaps of sufficient length to allow bicyclist to move between the shoulder and travel lane where necessary.
- While a paved shoulder is not a designated pedestrian facility and therefore is not required to meet ADA requirements, it is a best practice to construct shoulders at a 2% or less cross slope where pedestrian use is expected.
- Paved shoulders are generally only suitable bikeways for highly confident or somewhat confident bicyclists. If connections to schools, parks, residential land uses, or employment centers are present along a roadway, consider providing shared use paths or other suitable bikeways and walkways for less experienced or confident bicyclists.
- Guide signs and wayfinding signs should be placed to inform users how to navigate conflict areas or find popular destinations.

Resources

- FHWA Proven Safety Countermeasures: https://safety.fhwa.dot.gov/provencountermeasures/long_rumble_strip/
- MnDOT Tech Memo on Rumble Strips and Stripes on Rural Trunk Highways: https://edocs-public.dot.state.mn.us/edocs_public/DMResultSet/download?docId=1966746
- FHWA Incorporating On-Road Bicycle Networks into Resurfacing Projects: https://www.fhwa.dot.gov/environment/bicycle_pedestrian/publications/resurfacing/resurfacing_workbook.pdf
- PROWAG (Proposed Accessibility Guidelines for Pedestrian Facilities in the Public Right-of-Way) Guidance: https://www.access-board.gov/guidelines-and-standards/streets-sidewalks/public-rights-of-way

Bicycle Boulevards

What is their purpose?

Bicycle boulevards are a type of shared roadway designed to prioritize bicycle traffic on low-volume, low-speed streets such as local and residential streets. They often include treatments such as signs, pavement markings, traffic calming and diversion treatments, and intersection modifications. The image below shows a median island, stop sign, and shared-lane pavement markings as part of a bicycle boulevard.

Bicycle boulevard on E 40th Street and 19th Avenue S, Minneapolis, MN

Are they a proven strategy?

Bicycle boulevards are a **TRIED** treatment since data collection on their effectiveness is difficult due the generally low frequency of conflicts on low-volume and low-speed roadways. However, higher motor vehicle speeds have been proven to lead to a higher likelihood of severe or fatal injury, and the traffic calming treatments associated with bicycle boulevards have been **PROVEN** to reduce speeds, thus reducing the potential for severe or fatal crashes.

Where would we use them?

The FHWA Bikeway Selection Guide can be used as a reference. In general, bicycle boulevards can be considered at the following locations:

- On local/residential streets that are parallel to and near an arterial road or community destination (school, library, commercial district, etc.)
- On street segments that are of sufficient length to reasonably serve long-distance bicycle trips or serve as a missing link in the bicycle network
- On local/residential streets that have less than 3,000 ADT, low operating speeds (25 mph or less), and few heavy commercial vehicles

Supplemental treatments

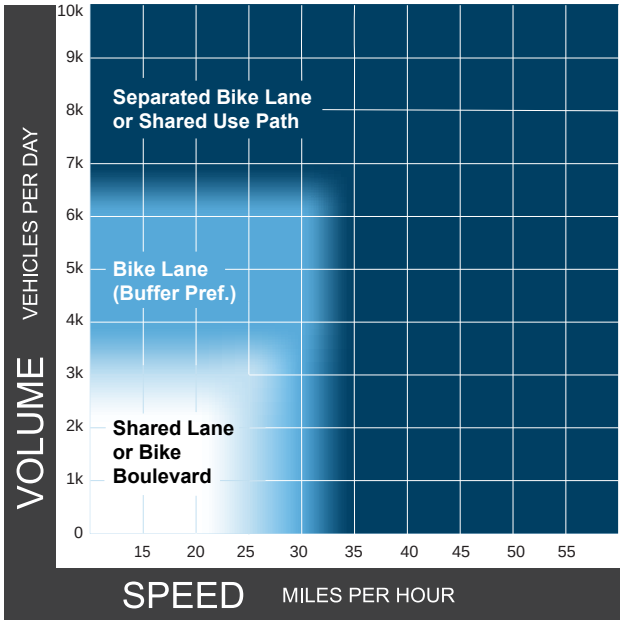
Bicycle boulevards can be enhanced with the following treatments:

- Traffic calming treatments may be appropriate to reduce motor vehicle speeds along bike boulevards. For more information on traffic calming techniques, see Chapter 7 of the MnDOT Bicycle Facility Manual.

Bicycle Boulevards

What are the advantages?

- Can be a low-cost solution to accommodating bicyclists and establishing bicycle networks
- Maintain low-stress bicycle access at busy cross streets.
- Typically allow bicyclists to share the lane with motor vehicle traffic.
- Can incorporate other traffic calming strategies to reduce roadway speeds, such as traffic circles.



Urban/suburban bikeway selection, Source: FHWA Bikeway Selection Guide

What are the challenges?

- Sometimes bicycle boulevards are associated with different type of trips, which requires balancing of transportation priorities and goals, such as an all ages and abilities bicycle network, and a full grid network for motor vehicles. This is not true of all bicycle boulevards.
- Reducing traffic volumes and speeds may require additional study to confirm that the desired street operating characteristics are achieved and maintained.
- Must ensure safe crossings at intersecting streets so that the bicycle boulevard or bicycle network can continue.

- Neighborhood traffic circles and mini-roundabouts used at minor intersections
- Crossing improvements at major streets, including traffic signals or beacons with bicycle detector/bicycle push buttons, median refuges, and curb extensions
- May incorporate shared use paths or other facilities to overcome discontinuous streets such as connecting cul-de-sacs and dead-end streets
- Traffic diverters discourage through motor vehicle traffic but still maintain local access. See Route Modifications section.

How much do they cost?

Many local/residential streets already have many of the desirable characteristics for bicycle boulevards. Revisions can involve moving STOP signs and adding guide signs, both of which could be done at very low cost. There may be some very low costs for new pavement markings. Where traffic volumes exceed the thresholds, traffic diverters can be constructed with flex posts or curbs. Where traffic speeds exceed thresholds, traffic calming techniques should be used. Other improvements may range from $15,000 to $30,000 for adding median pedestrian refuge islands, $5,000 to $10,000 for curb extensions, and $10,000 to $120,000 for RRFBs or traffic signals.

Bicycle Boulevards

Design Features

Bicycle boulevards can include the following design features:

- Improve bicycle mobility by limiting the times bicyclists are required to stop at neighborhood cross streets. Minimize use of stop signs by considering other forms of traffic control such as yield signs or mini-roundabouts in lieu of stop signs where practical.
- Wayfinding signs.
- Shared lane markings or other bicycle boulevard specific pavement markings.

Resources

- FHWA Bikeway Selection Guide: https://safety.fhwa.dot.gov/ped_bike/tools_solve/docs/fhwasa18077.pdf
- MnDOT Bicycle Facility Design Manual: http://www.dot.state.mn.us/bike/design-engineering.html
- https://nacto.org/publication/urban-bikeway-design-guide/bicycle-boulevards/

Bicyle boulevard sign, Minneapolis, MN

Bicycle boulevard, E 40th Street, Minneapolis, MN

Shared Use Paths

What is their purpose?

Shared use paths are bicycle facilities that are physically separated from motor vehicle traffic by an open space or barrier. Most shared use paths are designed for two-way travel and can serve a variety of nonmotorized users. They may be located within roadway right-of-way or an independent right-of-way. Shared use paths are sometimes referred to as trails, greenways, and sidepaths. In Minnesota, trails are facilities that may use a variety of surface materials, widths, and other standards, so although a shared use path might be called a trail, not all trails are shared use paths.

Are they a proven strategy?

Shared use paths are considered **PROVEN**. Shared use paths provide separation for pedestrians and bicyclists from motor vehicles. This separation increases road safety for all road users, particularly for pedestrians and bicyclists.

Wider shared use paths provide space to separate pedestrians and bicyclists from each other. Because of the lack of specific data for this measure, it is considered **TRIED**.

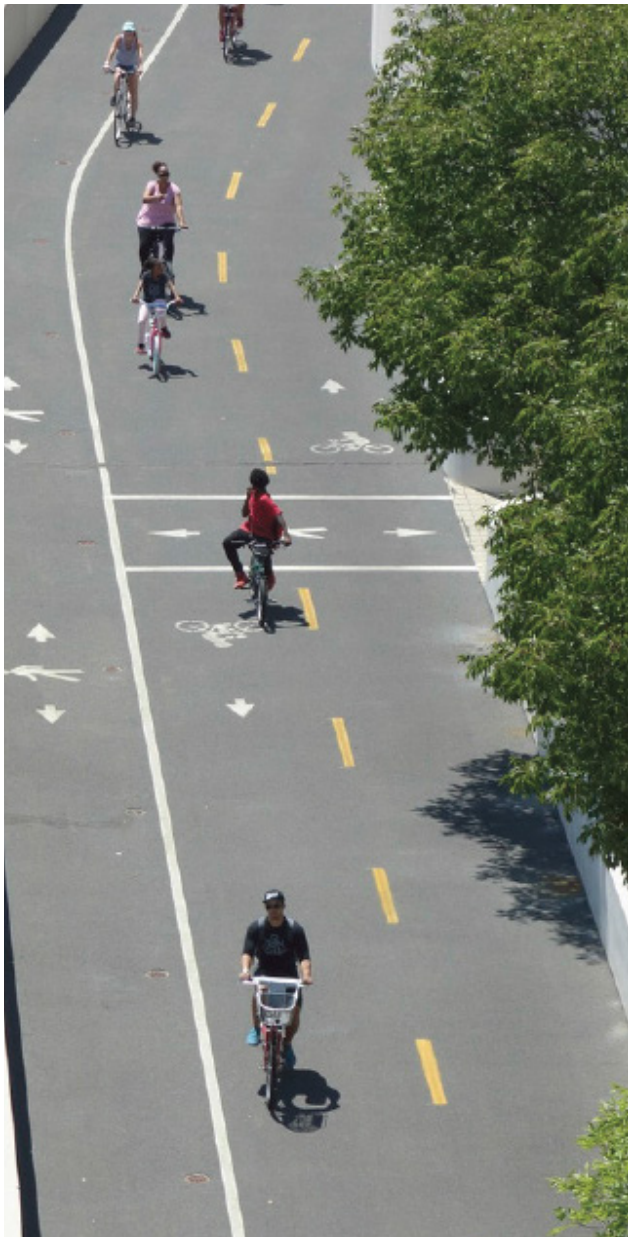
Where would we use them?

The FHWA Bikeway Selection Guide may be used as a reference. In general, shared use paths can be considered at the following locations:

- Where there is a greater mix of users, high user volumes, and a wide range of speeds between shared use path users
- When space is limited, shared use paths can be placed in lieu of separated bike lanes.
- Wider paths may be necessary where there are either large numbers of people bicycling or large percentages of other nonmotorized users that create frequent and inconsistent passing and meeting events. Crowded paths can result in delay, frustration, and collisions. Wider paths also better accommodate social cycling or walking (i.e. the ability to bike or walk side-by-side with another person)
- Geometric characteristics that may merit a wider shared use path include maintenance vehicle size, steep grades, curves, and stationary activities (such as fishing or scenic overlooks)

What are the maintenance impacts?

Partner with maintenance team members during design development to discuss strategies and issues related to routine path maintenance. For example, a wider shared use path may be necessary to better suit available snow removal equipment. Shared use paths should be clear of debris, snow, and major cracks or potholes to accommodate users year round.



Shared use path with pavement markings separating bicycles and pedestrians

Shared Use Paths

What are the advantages?

- Separating bicyclists from motor vehicles is safer and more comfortable than shared lane facilities. Separating pedestrians from motor vehicles is also safer. Shared use paths are also more comfortable as motorist volumes and speeds increase.
- Shared use paths that separate users with a range of speeds (i.e., bicyclists and pedestrians) reduce crashes between shared use path users.
- When designed along corridors with minimal road interactions, such as routes following waterways, linear parks, and railroad or transit facility rights-of-way, shared use paths can increase safety and reduce travel times.

What are the challenges?

- Widening existing shared use paths may require modifications to existing drainage infrastructure.
- May require additional lighting for safety including for personal safety.
- Activities that create distractions or obstructions may require wider shared use paths to accommodate people standing. Standing areas for scenic overlooks or fishing, or benches and wayfinding kiosks, should be located beyond the functional area of the shared use path.
- The speed differential of users on wheels and walking can present safety challenges, thus the demand and user mix must be carefully considered when selecting a width and the ability to provide separate lanes, or spaces along the path (see FHWA's Shared Use Path Level of Service Calculator).
- Shared use path intersections should be carefully designed, particularly at intersections with other shared use paths and roadways. Grade separation may be appropriate to eliminate conflicts with railroads or motor vehicle traffic entirely. See Grade-separated Crossings section.
- A limiting factor to consider when widening a shared use path (or constructing a wider shared use path) is the available right-of-way. If necessary, the shared use path may still be widened but with narrower portions provided where right-of-way is constricted.

A shared use path

How much do they cost?

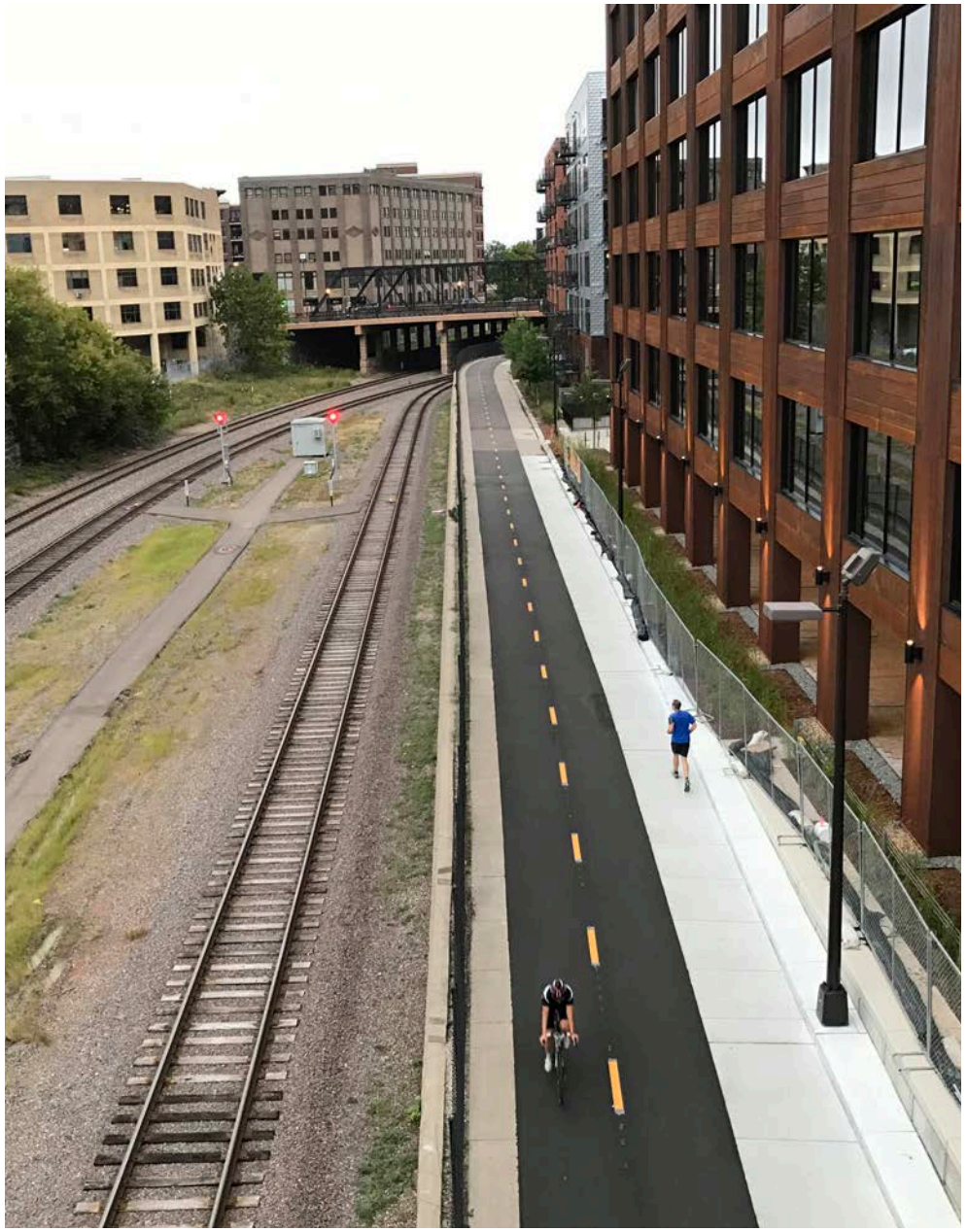
Typical costs for a shared use path range from $300,000 to $600,000 per mile.

Shared Use Paths

Shared Use Path Level of Service Look-Up Table, Typical Mode Split*											
Shared Use Path Peak Hour Volume	Shared Use Path Width (ft)										
	8	10	11	12	14	15	16	18	20	22	24
50	B	B	B	B	B	A	A	A	A	A	A
100	D	C	B	B	B	A	A	A	A	A	A
150	D	C	B	B	B	A	B	A	A	A	A
200	D	D	C	B	B	A	B	A	A	A	A
300	E	D	C	C	C	B	B	B	B	A	A
400	F	E	D	D	C	C	C	B	B	A	B
500	F	F	D	D	D	C	C	C	C	B	B
600	F	F	E	E	E	D	D	C	C	C	B
800	F	F	F	F	F	E	E	E	E	D	D
1,000	F	F	F	F	F	E	F	F	F	E	E
1,200	F	F	F	F	F	F	F	F	F	F	F
1,600	F	F	F	F	F	F	F	F	F	F	F
2,000	F	F	F	F	F	F	F	F	F	F	F

*Assumptions:

1. Mode split is 55% adult bicyclists, 20% pedestrians, 10% runners, 10% in-line skaters, and 5% child bicyclists.
2. An equal number of trail users travel in each direction (the model uses a 50% - 50% directional split).
3. Trail volume represents the actual number of users counted in the field (the model adjusts this volume based on a peak hour factor of 0.85).
4. Trail has a centerline.



Cedar Lake Trail, Minneapolis, MN

Shared Use Paths

Design Features

FHWA's Shared Use Path Level of Service Calculator can be used to determine whether a shared use path may require additional width to obtain an acceptable level of service. The calculation is based on four inputs: peak hour volumes, mode splits, shared use path width, and the presence of a centerline.

Additional information on how to use the Level of Service Calculator can be found in the FHWA Bikeway Selection Guide. MnDOT-specific design guidelines can be found in Chapter 5 of the MnDOT Bicycle Facility Design Manual. Noteworthy design features include the following:

- Typical shared use path widths range from 8' to 15', though they may be wider. A 15' shared use path is effectively a 10' bicycle path and 5' walkway, allowing for the separation of bicyclists and pedestrians.
- Shared use path users include adult bicyclists, child bicyclists, pedestrians, in-line skaters, roller skiers, runners, dog walkers, children in general, and people with disabilities.
- MnDOT requires all shared use paths that are funded by MnDOT, or within MnDOT right-of-way, to be ADA-accessible year-round. Required accessibility features include:
  - Ramps and detectable warnings at every shared use path intersection with a roadway
  - Accessibility to and from a roadway shoulder at the end of the shared use path
  - If the shared use path has a separate designated facility for walking, then it should be separated by a detectable edge.
- Walking and bicycling are inherently social activities. Designers should expect that people bicycling on shared use paths desire to ride side-by-side. Choosing an appropriate shared use path width depends on the mix of users, expected volumes, and land use context. Consider the following when determining a shared use path width:
  - User types (e.g. adult bicyclists, child bicyclists, runners, dog walkers)
  - User volumes and speeds, by type
  - Nearby land use context
  - Scenery
  - Distractions
  - Sight distance obstructions
  - Roadside hazards or conditions (fences, retaining walls, waterways)
  - Right-of-way availability
  - Maintenance, utility, or emergency services vehicle access

Resources

- FHWA Shared Use Path Level of Service Calculator: https://www.fhwa.dot.gov/publications/research/safety/pedbike/05138/
- FHWA Bikeway Selection Guide: https://safety.fhwa.dot.gov/ped_bike/tools_solve/docs/fhwasa18077.pdf
- MnDOT Bicycle Facility Design Manual
- MnDOT Land Use Context Memo: MnDOT Technical Memorandum 18-07-TS-05

Separated Bicycle Lanes

What is their purpose?

Separated bike lanes, also known as cycle tracks and protected bike lanes, are exclusive facilities for bicycling that are located within or directly adjacent to a roadway. They are physically separated from motor vehicle traffic by a vertical element such as flexible post delineators, channelizing curb, rigid bollards, raised medians, concrete barriers, parked motor vehicles, planters and landscaping, and/or other physical objects. The presence of this vertical element is what differentiates separated bike lanes from conventional and buffered bike lanes.

Unlike sidepaths and shared use paths, separated bike lanes are bike-only facilities. The buffer between the bicycle facility and the roadway is known as the street buffer; the buffer between the bicycle facility and sidewalk is known as the sidewalk buffer. Separated bike lanes can be:

- One- or two-way facilities
- On the left or right-hand side of a street
- At road-grade, at sidewalk-grade, or at an intermediate-grade between the roadway and sidewalk.

Capital City Bikeway, Jackson Street, Saint Paul, MN

Are they a proven strategy?

Physical separation of bicyclists from motor vehicle traffic promotes multimodal safety. The specific impact of separated bike lanes is not yet quantified, but has been shown to be more comfortable for people of all ages and abilities. Because of the lack of specific data for this measure, it is considered **TRIED**.

Where would we use them?

Separated bike lanes can be considered at the following locations:

- In areas with traffic volumes over 6,000 ADT or high motor vehicle speeds (over 30 mph)
- In areas with peak hour bicycle traffic over 100 per hour
- In areas with a wide range of user types and variety of speeds
- In areas that connect existing or planned biking networks
- Freight movements, delivery locations, on-street parking, accessible parking, pedestrian curb ramps, bus and transit access, and curb cuts must be carefully considered when designing separated bike lanes.

What are the maintenance impacts?

Partner with maintenance team members to discuss strategies and issues related to routine maintenance for separated bicycle lanes, in particular for debris in the spring and snow in the winter. Separated bicycle lanes typically require special equipment to remove snow. If adequate snow storage space is not provided in the buffer

Separated Bicycle Lanes

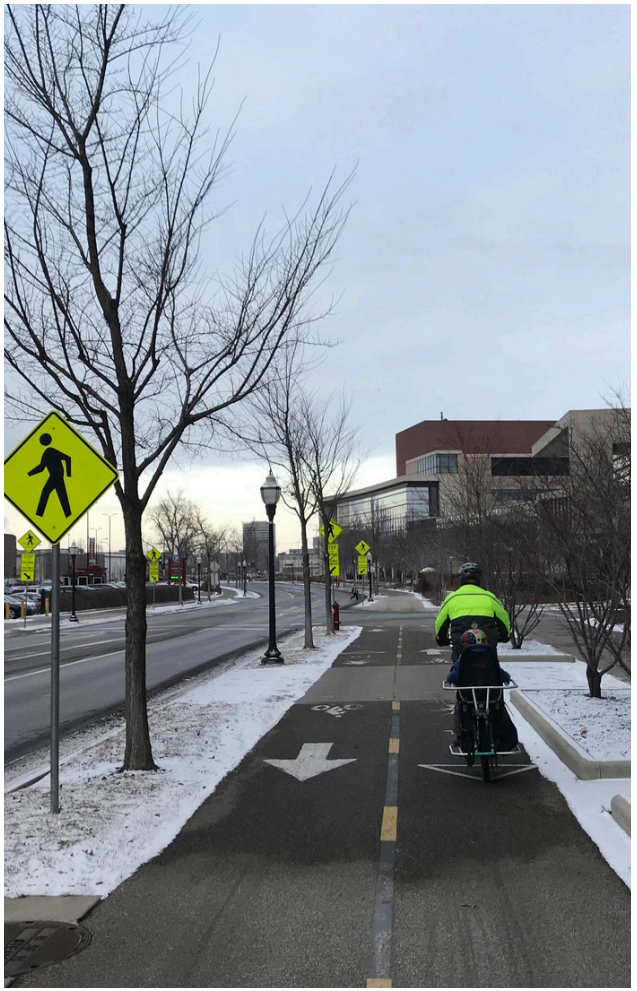
zone, snow removal may be needed. If delineator posts are used in lieu of curb separation, agencies should plan on replacing delineators that are damaged or destroyed during regular use; in high-traffic areas, this may require replacing up to 1/3 of delineators annually.

What are the advantages?

- Minimize bicyclist exposure and reduce the interaction between bicyclists and motor vehicles through the corridor.
- If a separated bike lane is at sidewalk- or intermediate-level through driveways and intersections, this design reduces the speed of motor vehicles at conflict points. This reduces bicycle crash severity.
- The street buffer provides space outside of the pedestrian accessible route space for roadway signs, utility poles, and parking meters. The street buffer can also provide space for snow storage.
- The sidewalk buffer can provide space outside of the pedestrian accessible route for trash receptacles, landscaping, benches, and/or pedestrian scale lighting.
- A buffer width of 5' or more can create the opportunity for additional landscaping or for providing stormwater best management practices.

What are the challenges?

- One-way separated bicycle lanes may attract wrong way riding if a separated bike lane is not provided in the opposite direction.
- Two-way separated bicycle lanes present unexpected conflicts between bicyclists and motorists at intersections and driveways because bicycles are riding against traffic.
- The design of the vertical separation must consider the drainage impacts.
- Consider freight movements and delivery locations when designing separated bike lanes.
- The design of the vertical separation will need to consider accessibility features, such as a space for paratransit needs since paratransit vehicles cannot park in bike lanes.



A separated bicycle lane in Minneapolis

How much do they cost?

Typical costs range from $16,000 per mile for restriping to $500,000 per mile for overlay to $5 million per mile for reconstruction.

Separated Bicycle Lanes

Design Features

- Coordinate with MnDOT ADA Group for guidance related to ADA needs and paratransit needs on roadways where separated bicycle lanes are proposed.
- For state specific design details, including preferred and minimum bike lane widths, see Chapter 5 of the MnDOT Bicycle Facility Manual.
- If a separated bike lane is at sidewalk-level, the design should allow the bicycle facility to continue at grade and while motor vehicles change grade to cross the facility.
- On two-way roadways, one-way separated bike lanes on each side of the roadway are typically preferred over a two-way separated bike lane on one side of the roadway.
- If motorists and bike/pedestrian movements are concurrent or uncontrolled at conflict points, sight lines on the intersection or driveway approach must be kept clear to maintain visibility between street users.
- Separated bike lanes can present some specific accessibility challenges that must be carefully thought through during the initial planning process.
- Protected intersections are commonly used with separated bike lanes. Refer to Separated Bicycle Lanes section.
- The MassDOT Separated Bicycle Lane Planning and Design Guide provides additional detailed guidance for Separated Bicycle Lanes.

A separated bicycle lane along Minnesota Avenue, Glenwood, MN

Resources

- FHWA Separated Bike Lane Planning and Design Guide: https://www.fhwa.dot.gov/environment/bicycle_pedestrian/publications/separated_bikelane_pdg/separatedbikelane_pdg.pdf
- MnDOT Bicycle Facility Design Manual, Chapter 5
- MassDOT Separated Bicycle Lane Planning and Design Guide: https://www.mass.gov/lists/separated-bike-lane-planning-design-guide

A separated bicycle lane along Minnesota Avenue, Glenwood, MN

Temporary On-Street Shared Use Paths

What is their purpose?

A temporary on-street shared use path discourages vehicles from entering into the shoulder space for bicyclists and pedestrians. These facilities are typically considered a temporary measure since the design retrofits the existing street width to provide an accessible route for pedestrians and bicyclists where a conventional sidewalk is not provided. These are not a recommended best practice and should be carefully designed to minimize the potential drawbacks.

Temporary on-street shared use paths may use delineator posts to separate the area from the roadway. There is often no curb, concrete barrier, or other continuous vertical element separating the space for bicycles or pedestrians from the space for motor vehicles. However, vertical elements can be provided to improve the detectability of the shared use path.

A temporary on-street shared use path

Are they a proven strategy?

There is little research or documentation on the efficacy of temporary on-street pedestrian accommodations. A variety of treatments have been tried in several locations across the country, including in Minneapolis, but are generally viewed as an interim solution until a more permanent bicycle/pedestrian facility is constructed. Therefore, this treatment is considered **EXPERIMENTAL**.

Where would we use them?

Temporary on-street shared use paths can be considered at the following locations:

- Areas where there is limited right-of-way
- Areas with limited bicycle or pedestrian demand
- Where missing links exist in the bicycle and/or pedestrian network

What are the maintenance impacts?

Partner with maintenance team members during design development to discuss strategies and issues related to maintenance, especially regarding snow clearance. Since on-street shared use paths are retrofitted and temporary, they may have slopes that require additional maintenance to prevent melt and re-freeze. This is similar to retrofitted on-road bicycle lanes.

In addition, temporary shared use paths often repurpose space from existing shoulders, which may have been used for snow storage. Snow removal and storage must be carefully considered in the design.

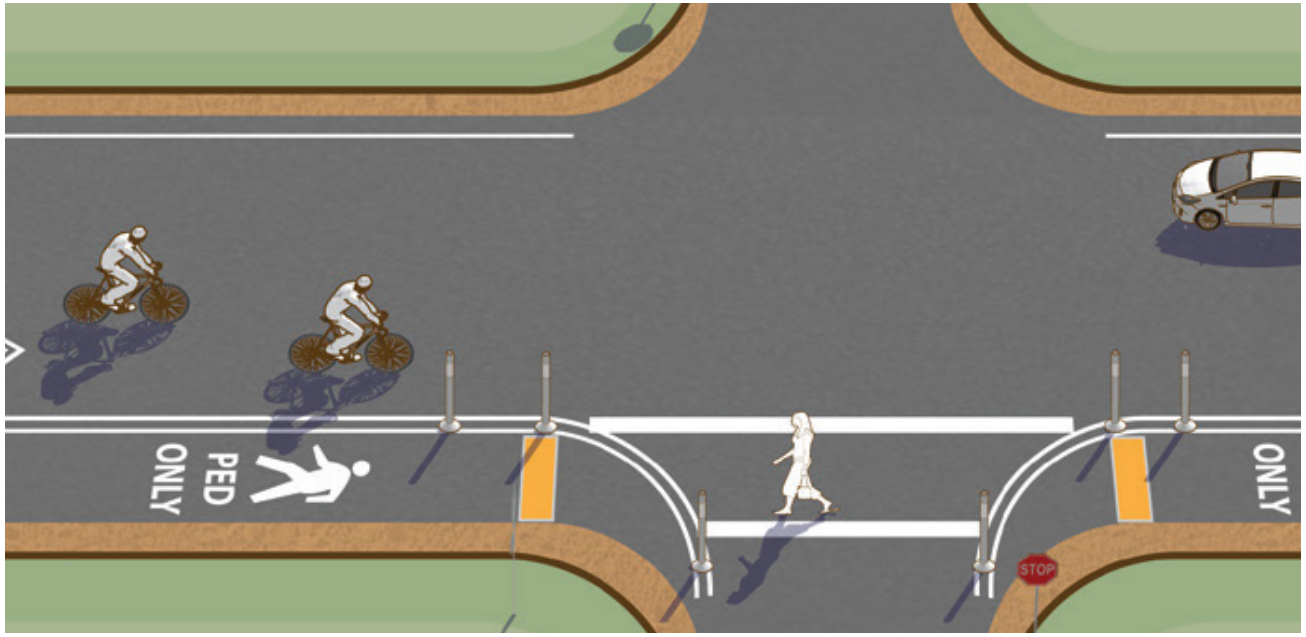
Temporary On-Street Shared Use Paths

What are the advantages?

- Can be implemented for a low cost.
- Can be used in areas where there is a desire to provide pedestrian and bicycle connections and separation from motor vehicle traffic but there is not enough space and/or resources to accommodate significant construction of a dedicated facility.

What are the challenges?

- Can present unique accessibility challenges because accessible routes typically have defined characteristics such as cross slopes of 2% or less.
- Should include detectable warning fields at intersections/ramps.
- Agencies should document any deficiencies with the on-street shared use paths and identify a plan to correct them in an ADA Transition Plan once a more permanent facility is constructed.



Pedestrian lane, Source: FHWA Small Town and Rural Multimodal Networks

A temporary on-street shared use path on 36th St, Minneapolis, MN

How much do they cost?

The cost of temporary on-street shared use paths will vary depending on the type, size and materials used.

Temporary On-Street Shared Use Paths

Design Features

Temporary on-street facilities should include a detectible edge whenever possible, such as the examples shown at right. If a dectectible edge is not provided, the installation should be for temporary use only until a long-term installation can be completed.

Examples constructed to date in Minnesota include truncated domes at intersections, and tube delineators to separate the path from the roadway.

Best practices

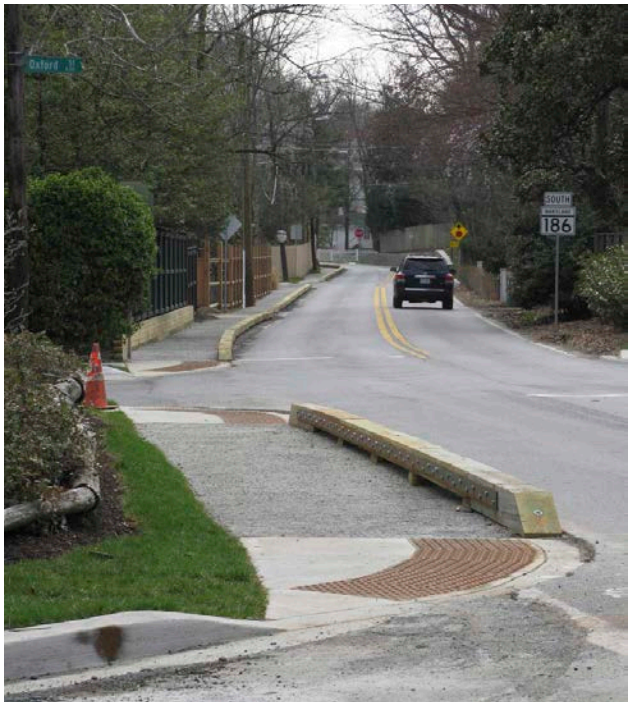
Important design features include the following:

- In cases where it is not possible to provide an ADA-compliant facility, ensuring the cross slope matches the mainline may be acceptable as a temporary treatment. In rural situations, cross slopes greater than 2% but less than 4% may be acceptable.
- Temporary installation is defined as 5 years or less. Shorter durations for the installation are preferred.
- Proposed Accessibility Guidelines for Pedestrian Facilities in the Public Right-of-Way (PROWAG) Guidance can be helpful when designing this type of facility for pedestrians. See Paved Shoulders section for more information.

Resources

- FHWA Small Town and Rural Multimodal Network Guide: https://www.fhwa.dot.gov/environment/bicycle_pedestrian/publications/small_towns/fhwahep17024_lg.pdf
- PROWAG (Proposed Accessibility Guidelines for Pedestrian Facilities in the Public Right-of-Way) Guidance: https://www.access-board.gov/guidelines-and-standards/streets-sidewalks/public-rights-of-way

A temporary on-street shared use path



A temporary on-street shared use path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