Best Design Practices for

Walking and Bicycling

in Michigan

Michigan Department of Transportation

Acknowlegements

These best design practices were prepared by **T.Y. Lin International**
at the direction of the **Michigan Department of Transportation**.

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Cover photo source: Ann Arbor Downtown Development Authority

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Introduction

The Michigan Department of Transportation (MDOT) has undertaken a research initiative to determine how to optimize pedestrian and bicycle safety while minimizing impacts to vehicular mobility. The best practices in this document provide guidance in the design of nonmotorized improvements that have been shown to reduce crashes involving pedestrians and bicyclists. This best practices report is one of several reports prepared under this research initiative. Other reports prepared include:

- *Pedestrian and Bicycle Crash Data Analysis: 2005-2010*
- *Crash Countermeasures and Mobility Effects*
- *Case Study Report*
- *Review of National Association of City Transportation Officials (NACTO) Bicycle Facilities*

These four reports will then be assembled into one final report entitled *Sharing the Road: Optimizing Pedestrian and Bicycle Safety and Vehicle Mobility Final Report.* This report also will include a review of MDOT design guides and safety reports.

This report is organized as a toolbox for planners and designers. A summary matrix is provided that provides a general comparison of the potential crash reduction, potential mobility impacts, and cost of each best practice.

Potential crashes for each best practice is summarized as either reducing or having no difference on crashes. Potential mobility effects are shown as making mobility better, making no difference, or making mobility worse for one or more modes of transportation.

Mobility is a function of speed, access, and delay. For the purposes of this report, potential mobility impacts refer to a potential change in delay as the result of implementing a best design practice. As bicyclists are considered roadway users to the same extent as motor vehicles per State of Michigan law, the determination of mobility assumes that bicyclists are traveling in the roadway unless otherwise stated.

Cost is summarized as low (up to $20,000), medium ($20,000-$100,000), and high (over $100,000). Best practices are grouped into three categories:

1. Signalized Intersections
2. Unsignalized Pedestrian Crossing Improvements
3. Corridor Improvements

Refencences are provided at the end of the document. Where applicable, references to MDOT manuals, including the Michigan Manual on Uniform Traffic Control Devices (Michigan MUTCD), are provided.

Signalized Intersection Improvements

Best Practice	Potential Crashes			Potential Mobility Effects			Cost
	MotorVehicles	Pedestrians	Bicyclists	Motor Vehicles	Pedestrians	Bicyclists	
Proper Walking Speed	No Difference	Reduce	No Difference	Worse	Better	No Difference	Low
Fixed Time Signals/ Pedestrian Push Buttons	No Difference	No Difference	No Difference	No Difference	Better	No Difference	Low
Pedestrian Countdown Signal	Reduce	Reduce	Reduce	No Difference	Better	No Difference	Low
Leading Pedestrian Interval	No Difference	Reduce	No Difference	No Difference	Better	No Difference	Low
Pedestrian-Only Phase (Scramble)	No Difference	Reduce	No Difference	Worse	Better	Worse	Low
Exclusive Left Turn Phase (Leading/Lagging)	Reduce	Reduce	Reduce	Worse	Better	Better	Low
Flashing Yellow Arrow	Reduce	No Difference	No Difference	Better	No Difference	No Difference	Low
Prohibited Left Turns (Michigan Left)	Reduce	Reduce	Reduce	Better	Better	Better	Med/High
Prohibited Right Turn on Red	Reduce	Reduce	No Difference	Worse	Better	Better	Low
Advance Stop Bar	No Difference	Reduce	No Difference	No Difference	Better	No Difference	Low
Pork Chop Island	Reduce	Reduce	No Difference	Better	Better	No Difference	Med/High
Bulb-outs	Reduce	Reduce	No Difference	No Difference	Better	No Difference	Med/High
Roundabout	Reduce	Reduce	Reduce	Better	Better	Better	High
Bicycle Signal Detection	No Difference	No Difference	Reduce	No Difference	No Difference	Better	Low/Med
Intersection Crossing Markings	No Difference	No Difference	Reduce	No Difference	No Difference	Better	Low
Bike Box	No Difference	Reduce	Reduce	No Difference	No Difference	Better	Low
Two-Stage Bike Left Turn	No Difference	No Difference	Reduce	No Difference	No Difference	Better	Low
Combined Bike/Turn Lane	No Difference	No Difference	Reduce	No Difference	No Difference	Better	Low
Bicycle Signals	No Difference	No Difference	Reduce	No Difference	No Difference	Better	Medium

Cost: Low: up to $20K; Med: $20K-$100K; High: over $100K

Proper Walking Speed

What: Pedestrian signal timing is calculated using a walking speed of 3.5 feet/second or slower where there is a significant population of elderly pedestrians or pedestrians with disabilities using the signal.

Where: All new or rehabilitated pedestrian signals should be timed with this signal timing according to the Michigan MUTCD.

Why: Studies have shown that the previous standard walking speed of 4.0 feet/second was an average walking speed and thus was not adequate time to allow most pedestrians to cross the street.[2]

How: See Michigan MUTCD, Section 4E.05.

Image: www.pedbikeimages.org/Dan Burden

Potential Crashes			Potential Mobility Improvements			Cost
Motor Vehicles	Pedestrians	Bicyclists	Motor Vehicles	Pedestrians	Bicyclists	
No Difference	Reduce	No Difference	Worse	Better	No Difference	Low

Fixed Time Signals or Pedestrian Push-Buttons

What: Fixed time signals have an automatic pedestrian phase built in to the signal cycle. Pedestrian push-buttons allow pedestrians to call up a pedestrian signal where they do not come up automatically.

Where: Fixed time signals should be used where pedestrian traffic is routine. Pedestrian push-buttons should be used where pedestrian crossings are infrequent and pedestrian signals are not automatic.

Why: Requiring pedestrians to call for the pedestrian signal increases their delay and should only be used where pedestrian traffic is limited. Fixed-time signals increase mobility for pedestrians.

How: Traffic signals may need to be re-programmed and/or re-timed to automatically bring up the pedestrian phase.

Potential Crashes			Potential Mobility Improvements			Cost
Motor Vehicles	Pedestrians	Bicyclists	Motor Vehicles	Pedestrians	Bicyclists	
No Difference	No Difference	No Difference	No Difference	Better	No Difference	Low*

* If signal timing is maintained.

**If signal needs to be re-timed for pedestrian walking speeds, there may be a slight increase in motor vehicle delay.

Pedestrian Countdown Signal

What: Pedestrian countdown signals give pedestrians an indication of how much time is left to cross the street by accompanying the “flashing don’t walk” signal with a countdown.

Where: Pedestrian countdown signals are required anywhere a pedestrian signal is used whenever new signals are installed or existing signals are replaced per the Michigan MUTCD.

Why: Pedestrian countdown signals have been shown to reduce all crashes at signalized intersections by 25%. They also increase the incidence of pedestrians completing their crossing before the end of the “flashing don’t walk” phase.

How: Adding pedestrian countdown signals typically cost between $10,000 to $15,000 per intersection to replace all pedestrian signal heads to as little as $800 per intersection to add a countdown clock to each existing pedestrian signal head See MUTCD, Section 4E.04.

Potential Crashes			Potential Mobility Improvements			Cost
Motor Vehicles	Pedestrians	Bicyclists	Motor Vehicles	Pedestrians	Bicyclists	
Reduce	Reduce	Reduce	No Difference	Better	No Difference	Low

Leading Pedestrian Interval

What: A leading pedestrian interval (LPI) gives pedestrians a walk signal before the parallel traffic gets the green. This allows pedestrians to get into the crosswalk before turning motor vehicle traffic.

Where: LPIs should be considered where turning vehicles delay or pose a danger to pedestrians, particularly where turns have been shown to cause crashes or create a high number of conflicts with pedestrians.

Why: Where LPIs are used, pedestrians were shown to be less likely to surrender their right of way to turning vehicles and there were fewer conflicts between motorists and pedestrians crossing at the beginning of the WALK phase.[6]

How: To implement a LPI, the signal must be re-timed to allow pedestrians a WALK phase that begins in advance of the vehicular green phase. Right turn on red should be prohibited across the crosswalk where LPIs are used.

Potential Crashes			Potential Mobility Improvements			Cost
Motor Vehicles	Pedestrians	Bicyclists	Motor Vehicles	Pedestrians	Bicyclists	
No Difference	Reduce	No Difference	No Difference	Better	No Difference	Low

Pedestrian-Only Phase (Scramble)

What: A pedestrian-only phase or pedestrian scramble allows pedestrians to walk in any direction across the intersection, including diagonally, during an exclusive phase in which only pedestrian traffic has the right of way.

Where: This treatment should be limited to intersections where pedestrian volumes are higher than vehicular volumes and where a significant percentage of pedestrians would make a diagonal crossing. Pedestrian-only phases have been shown to significantly increase motor vehicle delay.[5] Engineering judgement should be used in determining locations.

Why: Pedestrian-only phases has been shown to reduce pedestrian crashes by 34%.[1]

How: A pedestrian-only phase adds a phase to the typical traffic signal sequence during which all directions of motor vehicle traffic have a red phase and all directions of pedestrian traffic have a WALK phase. The diagonal crossing sign image to the right can provide additional information to pedestrians and motorists. The MUTCD does not preclude the use of this sign. However, there is no specific MUTCD guidance for signs of this type.

Image: Oakland Chinatown Chamber of Commerce

Potential Crashes			Potential Mobility Improvements			Cost
Motor Vehicles	Pedestrians	Bicyclists	Motor Vehicles	Pedestrians	Bicyclists	
No Difference	Reduce	No Difference	Worse	Better	Worse	Low

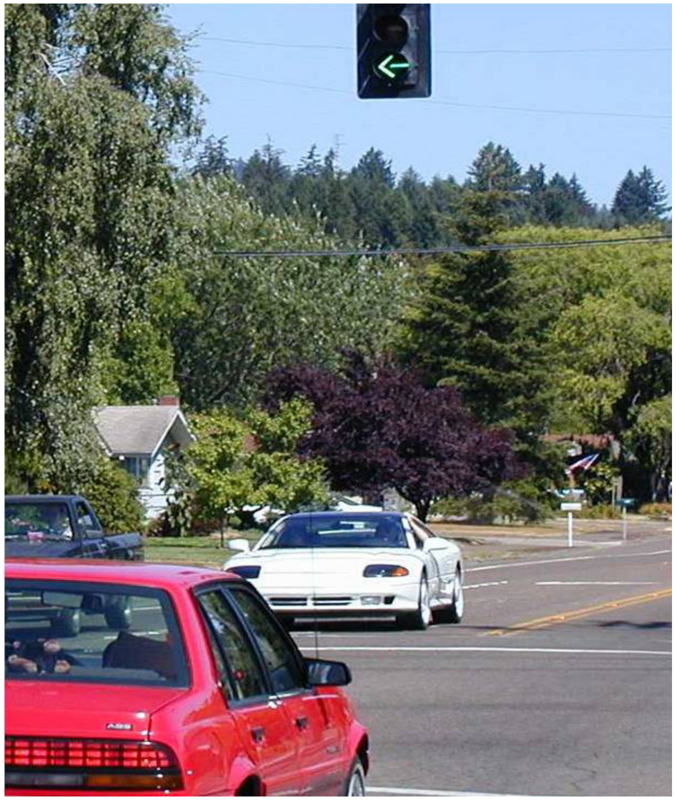
Exclusive Left Turn Phase (Leading/Lagging)

What: Left turning vehicles have an exclusive phase, indicated by a green left arrow. The phase can either be given before the green phase for through traffic (leading) or after (lagging).

Where: An exclusive left turn phase should be considered at intersections where left-turning traffic volumes are high and a Michigan Left is not feasible. A lagging left turn phase should be considered where there is a high number of conflicts between left turning vehicles and pedestrians.

Why: Exclusive left turn phases reduce conflicts between left turns and pedestrians. Pedestrians normally start to cross at the beginning of the through green interval. A lagging left-turn phase strategy allows pedestrians to clear the crossing before left-turning vehicles begin to turn.

How: The signal timing must be adjusted to allow for this exclusive phase.



Potential Crashes			Potential Mobility Improvements			Cost
Motor Vehicles	Pedestrians	Bicyclists	Motor Vehicles	Pedestrians	Bicyclists	
Reduce	Reduce	Reduce	Worse	Better	Better	Low

Flashing Yellow Arrow

What: For permitted left turns at a signalized intersection, the signal phase is displayed as a flashing yellow arrow rather than a green ball.

Where: This treatment should be considered at intersections where pedestrian crashes have been caused by motorists making a left turn and an exclusive left turn is not desired.

Why: Crash rates at intersections where the flashing yellow arrow was used were found to be lower than intersection with the conventional green ball indication.[4]

How: A three-head signal must be replaced with a four-head signal in order to provide a flashing yellow arrow. The flashing yellow is displayed during the permitted left turn phase.

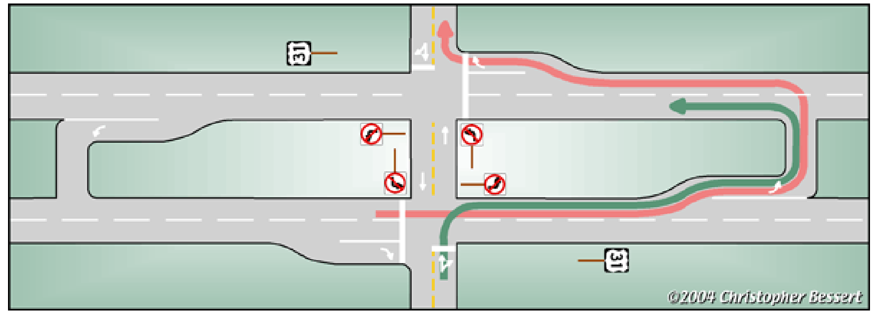
Image: www.aaroads.com

Potential Crashes			Potential Mobility Improvements			Cost
Motor Vehicles	Pedestrians	Bicyclists	Motor Vehicles	Pedestrians	Bicyclists	
Reduce	No Difference	No Difference	Better*	No Difference	No Difference	Low

* When installed to replace a protected left turn phase.

Prohibited Left Turns (Michigan Left)

What: The prohibition of left turns at signalized intersections and providing room for U-turns at median crossovers is known as a Michigan Left. The diagram to the right shows Michigan left turn movements from two approaches.



Where: Michigan Lefts can be implemented on roads with a wide center median or where the cross-street has a wide center median. Michigan Lefts should be considered where there are conflicts or crashes caused by left-turning vehicles or where improved efficiency of left turns is desired.

Why: Prohibiting left turns has been shown to reduce pedestrian intersection crashes by 10%.[3] MDOT has also found that they increase efficiency and reduce congestion and reduce the number and severity of crashes.

How: MDOT provides guidance on left-turn prohibitions in the MDOT Road Design Manual, Pavement Marking Typicals (PAVE-935-A, PAVE-990-A).

Images: www.michiganhighways.org

Image: www.michigan.gov/mdot/0,4616,7-151-9620_10694-161777--,00.html

Potential Crashes			Potential Mobility Improvements			Cost
Motor Vehicles	Pedestrians	Bicyclists	Motor Vehicles	Pedestrians	Bicyclists	
Reduce	Reduce	Reduce	Better	Better	Better*	Med/High

* This assumes that bicyclists make a two-stage left turn. The two-stage left turn is described on page 22.

Prohibited Right Turn on Red

What: Right turns on red are prohibited through the use of regulatory signs.

Where: Right turn on red restrictions should be implemented where right-turning vehicles are involved with crashes with pedestrians or rear-end or angle crashes with vehicles approaching from the left on the cross-street.

Why: Permitted right turns on red pose a threat to pedestrians crossing with the signal, as motorists wanting to turn right are looking to the left for a gap in traffic and may not see a pedestrian approaching from the right. Prohibiting right turn on red also benefits bicyclists in bike lanes, as it prevents right-turn vehicle crashes involving bicyclists.

How: Regulatory signs are posted at the intersection. See MUTCD, Section 2B.54.

Image: www.highwaytrafficsupply.com

Potential Crashes			Potential Mobility Improvements			Cost
Motor Vehicles	Pedestrians	Bicyclists	Motor Vehicles	Pedestrians	Bicyclists	
Reduce	Reduce	No Difference	Worse	Better	Better	Low

Advance Stop Bar

What: An advance stop bar is a stop bar that is marked 15 or more feet in advance of the crosswalk at a signalized intersection, as opposed to the minimum 4-foot setback.

Where: Advance stop bars should be considered where there is a high number of conflicts between vehicles turning right on red and pedestrians. They could also be used at any intersection where improved visibility is desired.

Why: Advance stop bars improve visibility of and for pedestrians. It also gives pedestrians a little more time to get into the crosswalk and establish their position before turning vehicles enter the crosswalk space. Conflicts between drivers and pedestrians were shown to be reduced by 90%[7]

How: This tool involves marking a stop line further from the crosswalk. However, there is a maximum allowable distance; guidance in Section 3B.16 of the MMUTCD suggests that the stop bar should be placed no more than 30 feet from the near edge of the intersecting roadway.

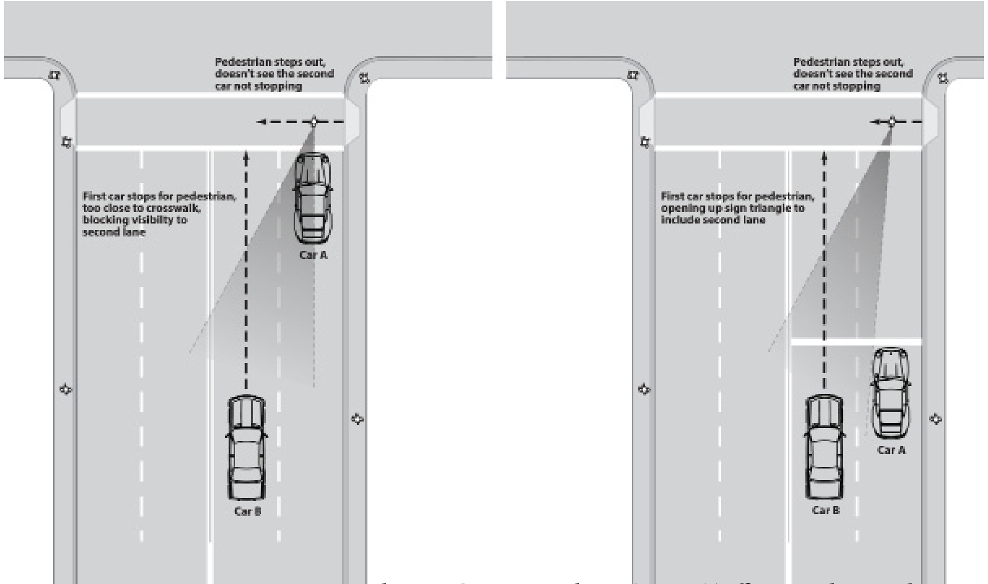


Image: Pedestrian Crossing Facilities, Ontario Traffic Manual, December 2010

Potential Crashes			Potential Mobility Improvements			Cost
Motor Vehicles	Pedestrians	Bicyclists	Motor Vehicles	Pedestrians	Bicyclists	
No Difference	Reduce	No Difference	No Difference	Better	No Difference	Low

Pork Chop Island

What: A wedge-shaped island between a right-turn lane and through lanes at an intersection.

Where: Pork chop islands should be considered at wide intersections where channelized right turn lanes are desired, or where a large turning radius would otherwise be required to prevent large, right-turning vehicles from encroaching on opposing traffic lanes.

Why: Pork chop islands break up a pedestrian crossing, making the crossing both safer and easier. They have been shown to reduce pedestrian crashes by 29%.

How: Care should be taken to design the right-turn lane to encourage slow speeds and improve visibility of crossing pedestrians by the turning vehicles. Reference *Pedestrian Facilities Users Guide - Providing Safety and Mobility,* p. 59 for more information.

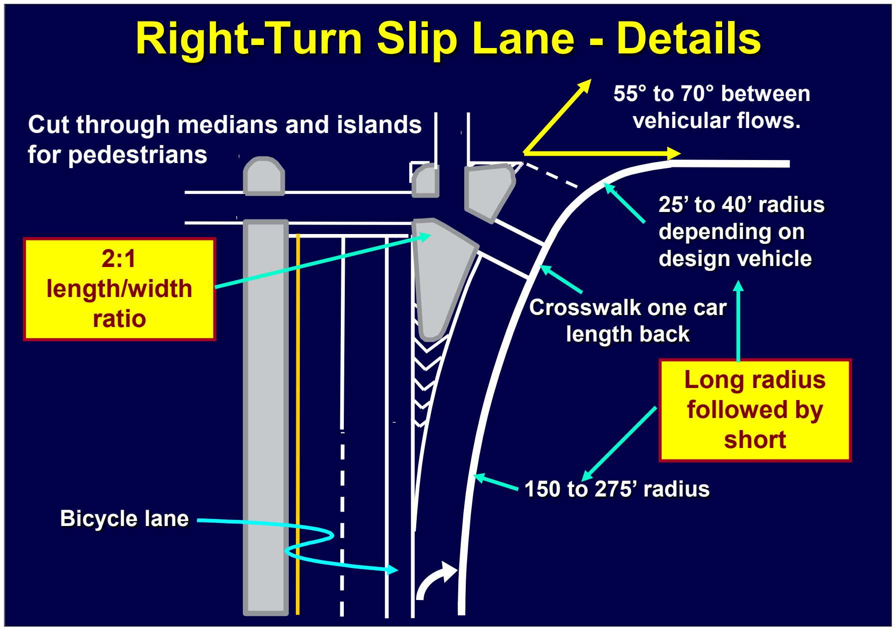


Image: AASHTO

Potential Crashes			Potential Mobility Improvements			Cost
Motor Vehicles	Pedestrians	Bicyclists	Motor Vehicles	Pedestrians	Bicyclists	
Reduce	Reduce	No Difference	Better	Better	No Difference	Med/High

Bulb-Outs

What: Bulb-outs (also known as curb extensions or bump-outs) extend the sidewalk or planting space out into the existing roadway, taking up space in a parking lane.

Where: Bulb-outs may be used anywhere with permitted on-street parallel or angle parking. They should be considered in particular where pedestrian crossings are too long.

Why: Bulb-outs increase visibility between pedestrians and motorists. They also shorten the distance a pedestrian must cross to reach the other side of the street.

How: Curbs must be reconstructed to extend the pedestrian space. The new curb line should not encroach the traveled way where bicyclists or motor vehicles may be traveling.

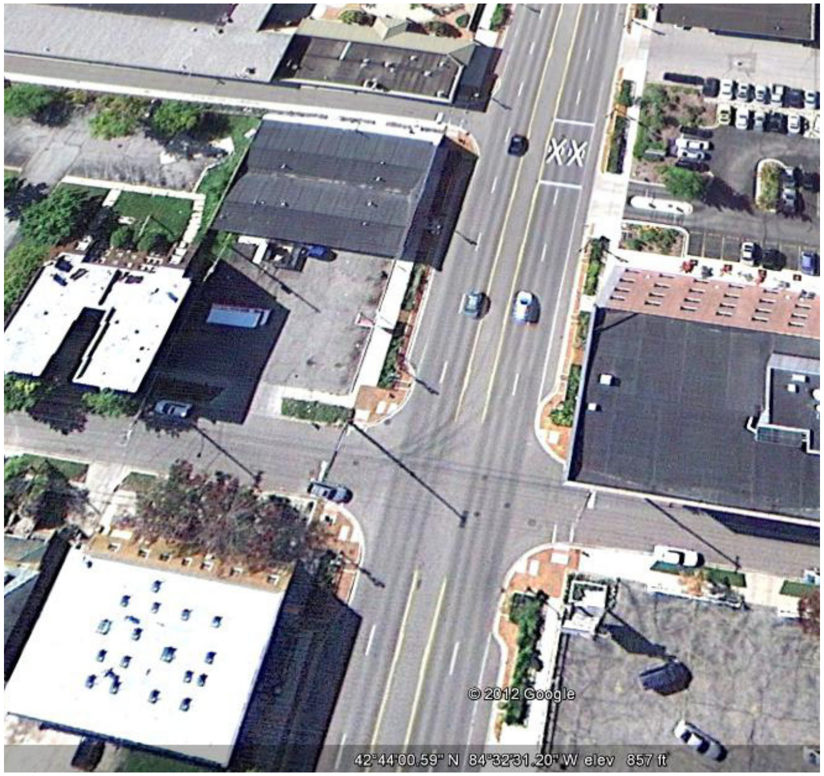


Image: Lansing, Michigan. Source: Google Earth Professional

Potential Crashes			Potential Mobility Improvements			Cost
Motor Vehicles	Pedestrians	Bicyclists	Motor Vehicles	Pedestrians	Bicyclists	
Reduce	Reduce	No Difference	No Difference	Better	No Difference	Med/High

Roundabout

What: In place of a stop-controlled or signalized intersection, a roundabout directs straight and turning traffic through a circular intersection designed to ensure yielding upon entry and slow vehicle speeds through the roundabout.

Where: Single-lane roundabouts can handle traffic volumes up to 26,000 vehicles per day. While multi-lane roundabouts can be used for traffic volumes up to 50,000 vehicles per day, they may complicate pedestrian crossings.[8]

Why: Roundabouts reduce the number of conflict points at a typical four-leg intersection and have been shown to reduce motor vehicle crashes as well as pedestrian crashes. Below the volumes listed above, roundabouts tend to improve the efficiency of the intersection.

How: If future traffic projections identify a need for a multi-lane roundabout, the roundabout should first be installed as a single lane roundabout, with right-of-way reserved to add more lanes later when they become necessary. Refer to the *FHWA Roundabout Technical Summary* and www.michigan.gov/roundabout for more information.

Okemos, MI Image: Google Earth

Potential Crashes			Potential Mobility Improvements			Cost
Motor Vehicles	Pedestrians	Bicyclists	Motor Vehicles	Pedestrians	Bicyclists	
Reduce	Reduce	Reduce	Better	Better	Better	High*

* Cost assumes a retrofit. Cost may be similar to or less than installing a signalized intersection as part of planned roadway construction.

Bicycle Signal Detection

What: Bicycle signal detection is a modification to existing loop detectors or the addition of new loop detectors to detect the presence of bicycles at actuated and semi-actuated signalized intersections. Bicycle location markings and signage is often included to make sure bicyclists are positioned to ensure that they are detected at intersections. Conveniently-located push buttons may be substituted for automatic loop detection.

Where: Bicycle signal detection may be used wherever bicycle connectivity is desired across signalized intersections.

Why: Bicycle signal detection is helpful to reduce the likelihood that a bicyclist would attempt to cross against a signal, or to minimize delay for signalized intersections where a shorter cycle length can be used when bicyclists are not present.

How: Guidance for installation of bike signal detection markings is provided in the AASHTO *Guide for the Development of Bicycle Facilities*.


San Luis Obispo, CA

Potential Crashes			Potential Mobility Improvements			Cost
Motor Vehicles	Pedestrians	Bicyclists	Motor Vehicles	Pedestrians	Bicyclists	
No Difference	No Difference	Reduce	No Difference	No Difference	Better	Low/Med

Intersection Bike Crossing Markings

What: On streets with bike lanes, pavement markings are continued through the intersection to indicate the intended position for bicyclists, as well as alert motorists that the bicycle facility is carried through the intersection.

Where: Intersection crossing markings should be considered at wide intersections or intersections where the intended direction for bicyclists is complex or unclear.

Why: The markings encourage bicyclists to ride in the most visible position on the roadway, and also raises motorist awareness of the presence of bicyclists.

How: The intended path may be marked using shared lane markings, colored pavement, dashed lines, or some combination. For additional background and design details, refer to the NACTO Urban Bikeway Design Guide: www.nacto.org

Image: Chicago, Illinois. Source: T.Y. Lin International

Potential Crashes			Potential Mobility Improvements			Cost
Motor Vehicles	Pedestrians	Bicyclists	Motor Vehicles	Pedestrians	Bicyclists	
No Difference	No Difference	Reduce	No Difference	No Difference	Better	Low

Bike Box

What: A bike box provides a space for bicyclists to wait in front of the queue of vehicles at a signalized intersection. It includes an advance stop bar with markings for bicycles in the space between the stop bar and the crosswalk. The bike box may also use colored paverment to denote the space for bicyclists.

Where: Bike boxes can be used in conjunction with bike lanes and may be considered where it may be helpful to provide additional space to separate bicyclists traveling straight or making right turns, or where there is a high number of motorists making right turns. Bike boxes are also useful at complicated intersections. No Turn On Red is required at intersections where bike boxes are used.

Why: Bike boxes improve visibility of bicyclists at intersections, where they are most vulnerable. In particular, they reduce conflicts between right-turning vehicles and bicyclists.

How: Bike bixes are not yet in the MUTCD and will require FHWA approval prior to installation. For design detail information refer to the NACTO Urban Bikeway Design Guide: www. nacto.org

Image: www.pedbikeimages.org/Laura Sandt

Potential Crashes			Potential Mobility Improvements			Cost
Motor Vehicles	Pedestrians	Bicyclists	Motor Vehicles	Pedestrians	Bicyclists	
No Difference	Reduce	Reduce	No Difference	No Difference	Better	Low

Two-Stage Bike Left Turn

What: A two-stage left turn consists of a queue box marked on the far side of at an intersection to provide a place for bicyclists to wait while making a left turn without having to move to the left-turn lane.

Where: Two-stage left turn queue boxes should be considered where a bicycle facility crosses another facility, or where the facility makes a left turn. These may be installed at intersections with or without medians. The image from NACTO to the right shows the median treatment.

Why: A two-stage left turn is helpful in providing bicyclists with flexibility in making a left turn where it may be uncomfortable or undesirable to move to the left-turn lane, or where multiple left-turn lanes exist.

How: A bicyclist enters a two-stage left turn by crossing the street on which he/she intends on making a left turn and waits in the queue box. Once across, the bicyclists waits for the green light and continues in the direction of traffic, completing the left turn in two stages. Two-stage bike left turns are not yet in the MUTCD and will require FHWA approval prior to installation.

Image: www.nacto.org

Potential Crashes			Potential Mobility Improvements			Cost
Motor Vehicles	Pedestrians	Bicyclists	Motor Vehicles	Pedestrians	Bicyclists	
No Difference	No Difference	Reduce	No Difference	No Difference	Better	Low

Combined Bike/Turn Lane

What: A combined bike/turn lane most commonly occurs at an intersection where a bike lane and a right-turn lane occupy the same space.

Where: Combined bike/turn lanes should be considered only when a right-turn lane is needed along a street with a bike lane, and there is not enough street width to provide a separate bike lane to the left of the turn lane. The bike lane transitions to a shared lane condition with the motor vehicle turn lane.

Why: Combined bike/turn lanes help to identify the presence and riding location of a bicyclist. Signs help communicate the shared lane condition and that motor vehicles shall yield to bikes in these locations.

How: Pavement markings denoting the shared lane condition and signs posted "RIGHT TURN ONLY EXCEPT BIKES" or shared lane signs are posted to clarify the shared lane condition. Current guidance in the MUTCD suggests a lane drop resulting in a shared through or turn lane. Combined bike/turn lanes are not yet in the MUTCD and will require FHWA approval prior to installation. For more information, consult NACTO *Urban Bikeway Design Guide*.

Image: www.nacto.org

Potential Crashes			Potential Mobility Improvements			Cost
Motor Vehicles	Pedestrians	Bicyclists	Motor Vehicles	Pedestrians	Bicyclists	
No Difference	No Difference	Reduce	No Difference	No Difference	Better	Low

Bicycle Signals

What: Bicycle signals are signals designated specifically for bicyclists. They may be actuated or pre-timed and may provide an exclusive signal phase for bicylists at an intersection.

Where: Bicycle signals may be used in areas where bicyclists are subject to different traffic control than vehicles, such as at trail crossings, cycle tracks, or bicycle boulevards.

Why: Bike signals are helpful to clarify the separation of bicycle and automobile traffic, to give bicyclists a head start in mixed traffic conditions, or where one bicycle facility transitions to another (e.g. when a shared use path transitions to an on-street bike lane.)

How: Guidance for installation of bike signals is provided in the NACTO *Urban Bikeway Design Guide*.

Image: www.pedbikeimages.org/Dan Burden

Potential Crashes			Potential Mobility Improvements			Cost
Motor Vehicles	Pedestrians	Bicyclists	Motor Vehicles	Pedestrians	Bicyclists	
No Difference	No Difference	Reduce	No Difference	No Difference	Better	Medium

Unsignalized Pedestrian Crossing Improvements

Best Practice	Potential Crash Reduction			Potential Mobility Effects			Cost
	MotorVehicles	Pedestrians	Bicyclists	Motor Vehicles	Pedestrians	Bicyclists	
Marked Crosswalk	No Difference	Reduce	Reduce	No Difference	Better	Better	Low
Advance Yield Markings	No Difference	Reduce	Reduce	No Difference	Better	Better	Low
In-roadway Yield Sign	No Difference	Reduce	No Difference	No Difference	Better	No Difference	Low
Pedestrian / Bicycle Refuge Island	Worse	Reduce	Reduce	No Difference	Better	Better	Low/Med
Rectangular Rapid Flashing Beacon	No Difference	Reduce	No Difference	No Difference	Better	No Difference	Medium
Pedestrian Hybrid Beacon	Reduce	Reduce	No Difference	No Difference	Better	Better	Med/High
Midblock Signal	No Difference	Reduce	Reduce	No Difference	Better	Better	Med/High
Roadway Illumination	No Difference	Reduce	Reduce	No Difference	Better	Better	Medium
Overpass/Underpass	No Difference	Reduce	Reduce	Better	Better	Better	High

Cost: Low: up to $20K; Med: $20K-$100K; High: over $100K

Marked Crosswalk

What: Marked crosswalks indicate to both pedestrians and motorists the intended or preferred crossing location. High-visibility pavement markings to denote the crosswalk, such as those shown at the right, are recommended.

Where: Crosswalks should be marked to indicate the intended path for a pedestrian. At uncontrolled (no stop sign or traffic signal) crossings, crosswalks may be marked on two lane roadways or roadways with less than 12,000 vehicles per day. Marked crosswalks alone are insufficient for roadways with four or more lanes and traffic volumes higher than 12,000 vehicles per day.

Why: Marked crosswalks suggest to pedestrians the most appropriate locations to cross the street. They also raise awareness of pedestrians by motorists.

How: Refer to Federal Highway Administration, *Safety Effects of Marked Versus Unmarked Crosswalks at Uncontrolled Locations* for additional guidance on how and where to mark crosswalks.

Image: www.pedbikeimages.org/Tom Harned

Potential Crashes			Potential Mobility Improvements			Cost
Motor Vehicles	Pedestrians	Bicyclists	Motor Vehicles	Pedestrians	Bicyclists	
No Difference	Reduce	Reduce *	No Difference	Better	Better *	Low/Med

* When used as a shared use path midblock crossing

Advance Yield Markings

What: At midblock crosswalks, advance yield markings improve visibility of pedestrians on multilane roadways, particularly by the motorist in the inside lane.

Where: Advance yield markings should be placed with pavement markings at midblock crosswalks on multilane roadways. The markings should be placed 20 to 50 feet in advance of the crosswalk.

Why: On multilane roadways, if a motorist in the outside lane yields or stops close to the crosswalk, that vehicle may block the view of crossing pedestrians by motorists in the inside lane. By advance the yield markings, visibility is improved and conflicts are reduced.

How: Advanced yield markings must be accompanied by a "Yield Here to Pedestrians" sign. See Michigan MUTCD Section 3B.16.

Image: www.walkinginfo.org

Potential Crashes			Potential Mobility Improvements			Cost
Motor Vehicles	Pedestrians	Bicyclists	Motor Vehicles	Pedestrians	Bicyclists	
No Difference	Reduce	Reduce*	No Difference	Better	Better*	Low

* When used with a shared use path midblock crossing.

In-Roadway Yield Sign

What: In-roadway yield signs are signs placed in the center of the roadway that reinforce state law for motorists to yield to pedestrians in crosswalks at unsignalized locations.

Where: To clarify the state law for yielding to pedestrians, it can be helpful to install in-roadway yield signs at unsignalized, marked crosswalk locations. Usually, they are placed in the center of roadways with only one lane in each direction and can be used as temporary signs by school crossing guards. They work well at midblock crossings as well as unsignalized intersections.

Why: In-roadway yield signs have been shown to significantly improve motorist yielding compliance and reduce pedestrian crashes[9].

How: Refer to Michigan MUTCD Section 2B.11 for guidance on the placement of in-roadway yield signs.

Image: www.fhwa.dot.gov

Potential Crashes			Potential Mobility Improvements			Cost
Motor Vehicles	Pedestrians	Bicyclists	Motor Vehicles	Pedestrians	Bicyclists	
No Difference	Reduce	No Difference	No Difference	Better	No Difference	Low

Pedestrian / Bicycle Refuge Island

What: Pedestrian / bicycle refuge islands are areas of the roadway where medians or curbs are constructed to protect pedestrians or bicyclists at crossings, allowing them to cross one direction of traffic at a time.

Where: Refuge islands should be considered at multilane pedestrian crossings, particularly where a painted or barrier median already exists or is proposed. At trail crossings, bicyclists also benefit from being able to cross one direction of traffic at a time.

Why: The placement of a refuge island on multilane roadways has been shown to reduce pedestrian crashes by 56%[1].

How: Guidance for the installation of a refuge island can be found in Michigan MUTCD Sections 3I.06 and 4B.04.

Image: www.pedbikeimages.org/Dan Burden

Potential Crashes			Potential Mobility Improvements			Cost
Motor Vehicles	Pedestrians	Bicyclists	Motor Vehicles	Pedestrians	Bicyclists	
Worse*	Reduce	Reduce	No Difference	Better	Better	Low/Med

* If the median nose is not adequately designed or delineated

Rectangular Rapid Flash Beacon

What: A rectangular rapid flashing beacon (RRFB) is a device that consists of two sets of high intensity light emitting diode (LED) lights mounted on poles on each side of an unsignalized pedestrian or bicycle trail crossing. The signals rest in the dark phase until activated by a push button and then flash in a rapid stutter flash pattern.

Where: RRFBs are recommended wherever an unsignalized crossing exists and it is necessary to provide additional notification to motorists of the presence of crossing pedestrians, or where there are insufficient gaps in vehicle traffic to provide a pedestrian crossing opportunity.

Why: RRFBs have been shown to produce an average motorist yielding compliance rate of 83% to a high of 94% for unsignalized crossings.

How: The FHWA provides guidance for the use of RRFB in conjunction with other unsignalized crossing improvements, such as advance stop or yield bars and median refuge islands.

Image: www.pedbikeimages.org/Michael Frederick

Potential Crashes			Potential Mobility Improvements			Cost
Motor Vehicles	Pedestrians	Bicyclists	Motor Vehicles	Pedestrians	Bicyclists	
No Difference	Reduce	No Difference*	No Difference	Better	No Difference	Medium

*Potential crashes may be reduced for bicyclists if RRFB is used in conjunction with a shared use path trail crossing.

Pedestrian Hybrid Beacon

What: A pedestrian hybrid beacon consists of two red lights above a yellow light. The lights remain dark unless activated by a pedestrian waiting to cross. When activated, the yellow signal flashes to warn motorists and then the red lights are illuminated, indicating that the motorist must stop.

Where: Pedestrian hybrid beacons are appropriate where it is difficult to find a gap in traffic to make a crossing and there are a significant number of pedestrians wanting to cross at a particular location. Hybrid beacons may be used at locations with lower volumes than what is required for a midblock signal.

Why: Pedestrian hybrid beacons have been shown to reduce crashes up to 69% and motorist yielding compliance rates between 94% and 99%.[9]

How: Guidance for the installation of pedestrian hybrid beacons is provided in the Michigan MUTCD.

Image: www.pedbikeimages.org/Mike Cynecki

Potential Crashes			Potential Mobility Improvements			Cost
Motor Vehicles	Pedestrians	Bicyclists	Motor Vehicles	Pedestrians	Bicyclists	
Reduce	Reduce	No Difference	No Difference	Better	Better	Med/High

Midblock Signal

What: A midblock signal is a full traffic signal for vehicles in one direction and pedestrians in the cross direction. The signal is often pedestrian actuated and therefore only interrupts traffic flow at times when pedestrians are wanting to cross.

Where: Midblock signals may be desired where large volumes of pedestrians are crossing midblock to access a particular destination, such as a transit station. The MUTCD has guidelines for the pedestrian volumes warranting a midblock signal.

Why: As a full traffic signal, a midblock signal has a very high compliance rate with motorists. The compliance rate for pedestrians decreases the longer a pedestrian has to wait for a WALK signal. The best compliance was found when pedestrians had to wait less than 30 seconds for the walk signal.

How: See Michigan MUTCD, Section 4C.05

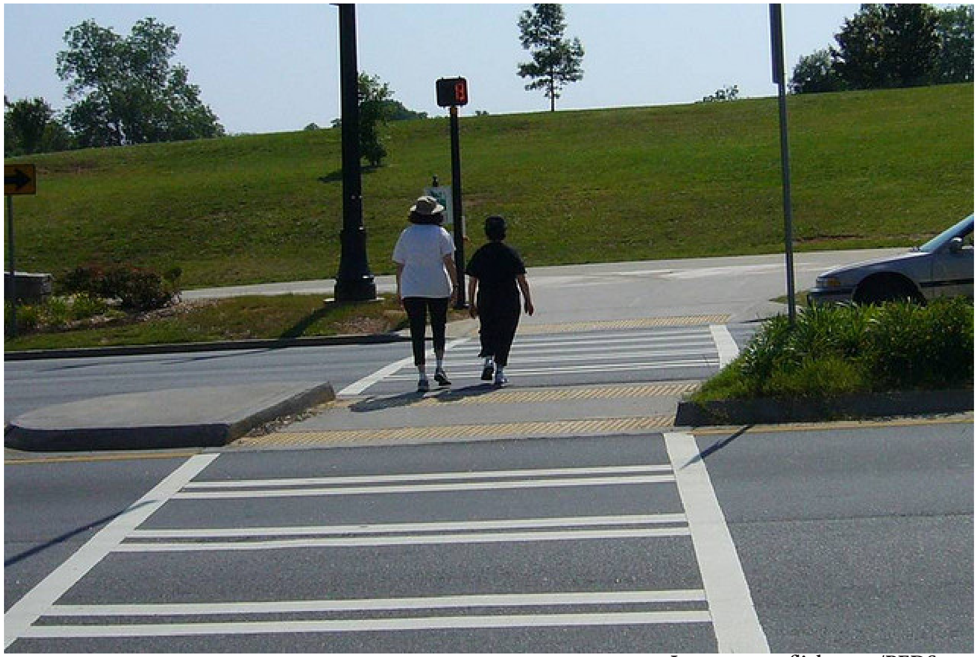


Image: www.flickr.com/PEDS.org

Potential Crashes			Potential Mobility Improvements			Cost
Motor Vehicles	Pedestrians	Bicyclists	Motor Vehicles	Pedestrians	Bicyclists	
No Difference	Reduce	Reduce*	No Difference	Better	Better*	Med/High

* When used as a shared use path midblock crossing

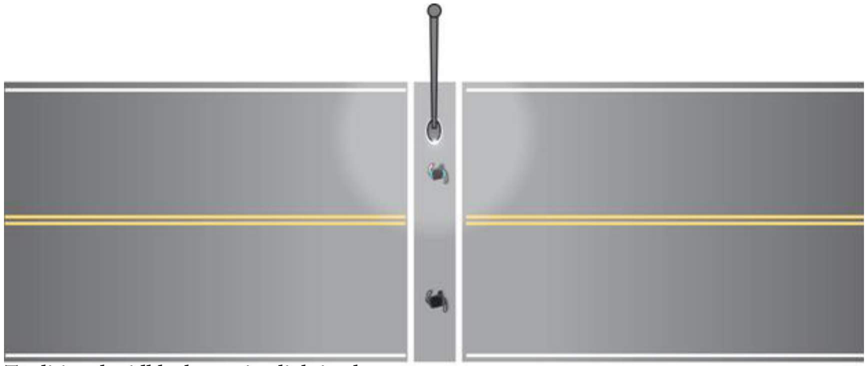
Roadway Illumination

What: Roadway illumination is the provision of sufficient overhead lighting on the roadway surface midblock crossings (as well as intersections) to make pedestrians and bicyclists more visible to motorists.

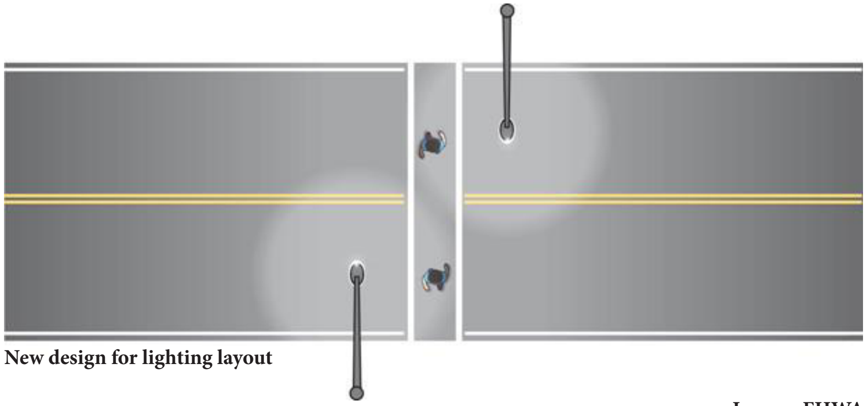
Where: Sufficient roadway illumination should be considered at all marked crossings where pedestrian and bicyclist crossing activity is observed or expected.

Why: Roadway illumination can reduce crashes associated with low light conditions and had been shown to reduce crashes at these locations by 42%-78%[1].

How: Refer to the Michigan Design Manual Section 9.03.01 for guidance on the placement of roadway lighting projects.



Traditional midblock crossing lighting layout



New design for lighting layout

Image: FHWA

Potential Crashes			Potential Mobility Improvements			Cost
Motor Vehicles	Pedestrians	Bicyclists	Motor Vehicles	Pedestrians	Bicyclists	
No Difference	Reduce	Reduce	No Difference	Better	Better	Medium

Overpass or Underpass

What: Construction of an overpass or underpass completely separates autmobile movements from bicycle and pedestrian movements.

Where: Due to their cost, overpasses and underpasses should be considered only when at-grade treatments are not feasible due to wide crossings and high automobile volumes not subject to traffic controls, such as freeway crossings.

Why: Overpasses and underpasses have been shown to reduce all crashes by 60%-95%[1]. However, if an overpass or underpass is designed in a manner that makes it inconvenient or unappealing, such as a long detour or tunnel effect, it will not be used.

How: Guidance for the placement of overpasses and underpasses can be found in the AASHTO *Guide for the Development of Bicycle Facilities*.

Images: www.pedbikeimages.org/Dan Burden, www.pedbikeimages.org/Sree Gajula

Potential Crashes			Potential Mobility Improvements			Cost
Motor Vehicles	Pedestrians	Bicyclists	Motor Vehicles	Pedestrians	Bicyclists	
No Difference	Reduce	Reduce	Better	Better*	Better*	High

* If designed to make pedestrian and bicycle usage a simpler and obvious choice.

Corridor Improvements

Best Practice	Potential Crash Reduction			Potential Mobility Effects			Cost
	MotorVehicles	Pedestrians	Bicyclists	Motor Vehicles	Pedestrians	Bicyclists	
Sidewalks and Paved Shoulders	Reduce	Reduce	Reduce	No Difference	Better	Better	Med/High
Road Diet	Reduce	Reduce	Reduce	No Difference	Better	Better	Low/Med
Raised Median	Reduce	Reduce	Reduce	Better	Better	Better	High
On-Street Parking	No Difference	Reduce	Reduce	No Difference	Better	Better	Low
Rear-In Diagonal Parking	Reduce	Reduce	Reduce	No Difference	No Difference	Better	Low/Med
Bike Lane	No Difference	No Difference	Reduce	No Difference	No Difference	Better	Medium
Shared Lane Markings	No Difference	No Difference	Reduce	No Difference	No Difference	Better	Low
Buffered Bike Lane	No Difference	No Difference	Reduce	No Difference	Better	Better	Med/High
Colored Bike Lane	No Difference	No Difference	Reduce	No Difference	No Difference	Better	Medium
Contra-flow Bike Lane	No Difference	No Difference	Reduce	No Difference	No Difference	Better	Medium
Left Side Bike Lane	No Difference	No Difference	Reduce	No Difference	No Difference	Better	Medium
Cycle Track	No Difference	No Difference	Reduce	No Difference	No Difference	Better	High

Cost: Low: up to $20K; Med: $20K-$100K; High: over $100K

Sidewalks and Paved Shoulders

What: Sidewalks are facilites separated from the roadway by a curb and sometimes a setback for the exclusive use by pedestrians. Paved shoulders are paved extensions of the roadway outside the traveled way.

Where: Sidewalks should be installed as part of every urban arterial and collector street where there is developed frontage. Paved shoulders should be considered on any roadway where sidewalk construction is not feasible due to grade or right-of-way constraints.

Why: When sidewalks are added to a roadway, pedestrian crashes are reduced by 88%[1]. When paved shoulders are added to the roadway, pedestrian crashes are reduced by 70%[1]. Additionally, paved shoulders can increase the pavement life of roadways and reduce cracking.

How: Sidewalks and shoulders are most cost effective when incorporated as part of roadway construction. If sidewalks cannot be provided at the time of roadway design, right-of-way should be secured and proper grading should be done in anticipation of sidewalks at a later date. Whenever roadway drainage goes from an open swale to a closed drainage system, sidewalk construction should be considered as a low cost addition to the project.

Images: www.pedbikeimages.org/Dan Burden

Potential Crashes			Potential Mobility Improvements			Cost
Motor Vehicles	Pedestrians	Bicyclists	Motor Vehicles	Pedestrians	Bicyclists	
Reduce	Reduce	Reduce	No Difference	Better	Better	Med/High

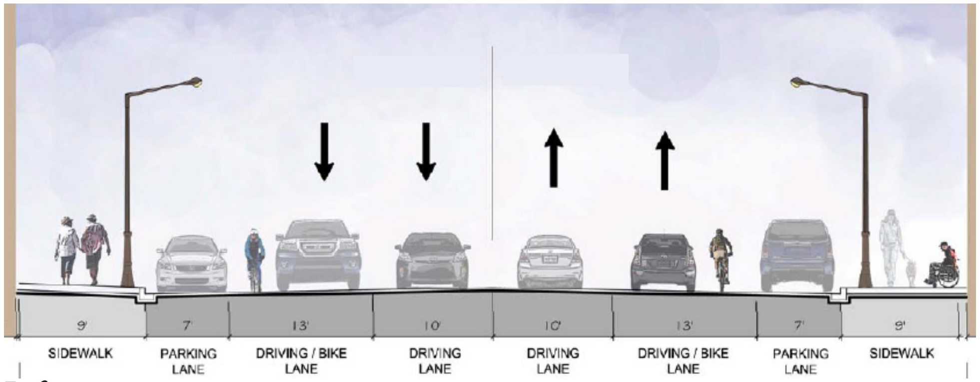
Road Diet

What: A road diet reallocates the through travel lanes of a roadway and adds a center two-way left-turn lane. A typical road diet reduces a 4-lane roadway to 3 lanes and adds bike lanes, sidewalks, or widens existing sidewalks.

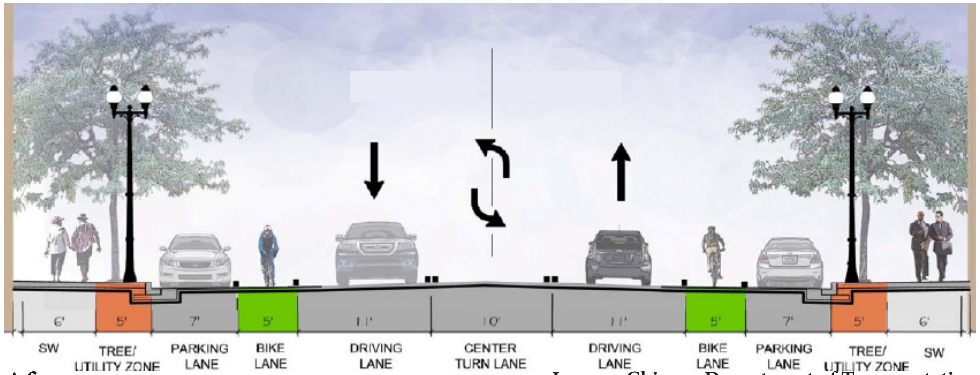
Where: Road diets can be implemented on streets with up to 20,000 vehicles per day without greatly impacting motor vehicle travel.

Why: Road diets improve safety and mobility for all users by reducing read-end, sideswipe, and left-turn crashes, and freeing up one lane in each direction for uninterrupted travel. Total crashes are reduced by 18-44%[11].

How: Because road diets are a reconfiguration of existing roadways, they are feasible on roadways with up to 15,000 ADT, and can be considered under a more detailed traffic analysis for volumes as high as 20,000 ADT.



Before



After

Images: Chicago Department of Transportation

Potential Crashes			Potential Mobility Improvements			Cost
Motor Vehicles	Pedestrians	Bicyclists	Motor Vehicles	Pedestrians	Bicyclists	
Reduce	Reduce	Reduce	No Difference	Better	Better	Low/Med*

* Minimal cost when done as part of a street resurfacing.

Raised Median

What: Raised medians provide a physical separation between lanes of opposite direction of travel. They often serve to provide a refuge in the middle of the street for pedestrians crossing.

Where: Raised medians are useful on multi-lane roadways where there is a need to improve pedestrian crossings. Medians should also be considered where there has been a history of head-on collisions or pedestrians involved in crashes while crossing.

Why: The majority of pedestrian crashes in Michigan are occurring mid-block. At unsignalized locations, raised medians were shown to reduce pedestrian crashes by 69%.

How: The design of raised medians is covered in the Michigan Design Guide Section 7.01.54 and the Michigan MUTCD Section 3I.06.

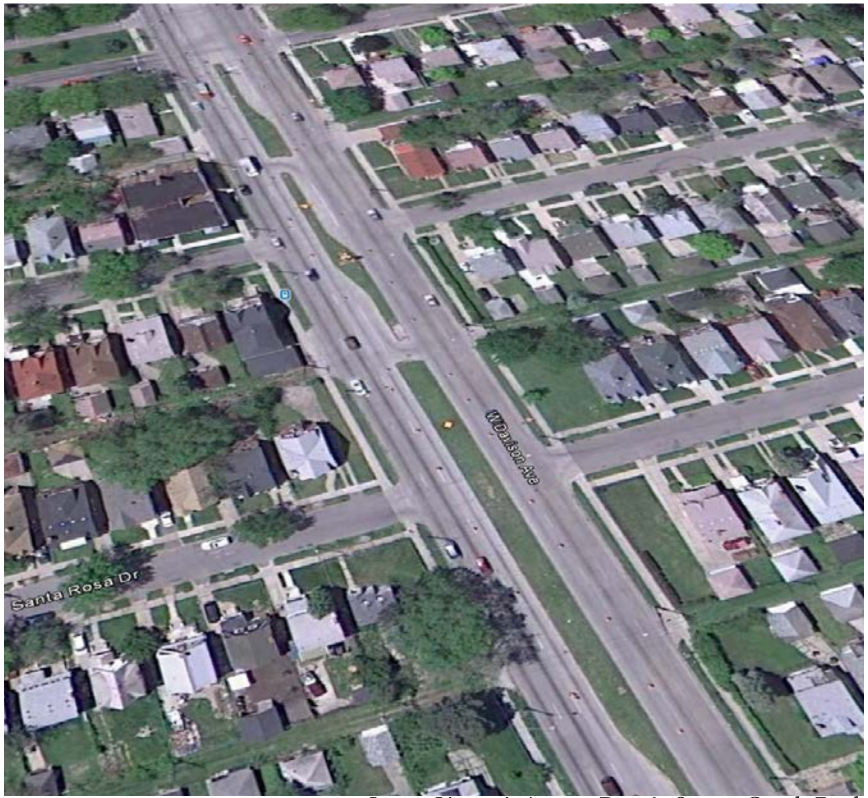


Image: Livernois Avenue, Detroit. Source: Google Earth

Potential Crashes			Potential Mobility Improvements			Cost
Motor Vehicles	Pedestrians	Bicyclists	Motor Vehicles	Pedestrians	Bicyclists	
Reduce	Reduce	Reduce	Better	Better	Better	High

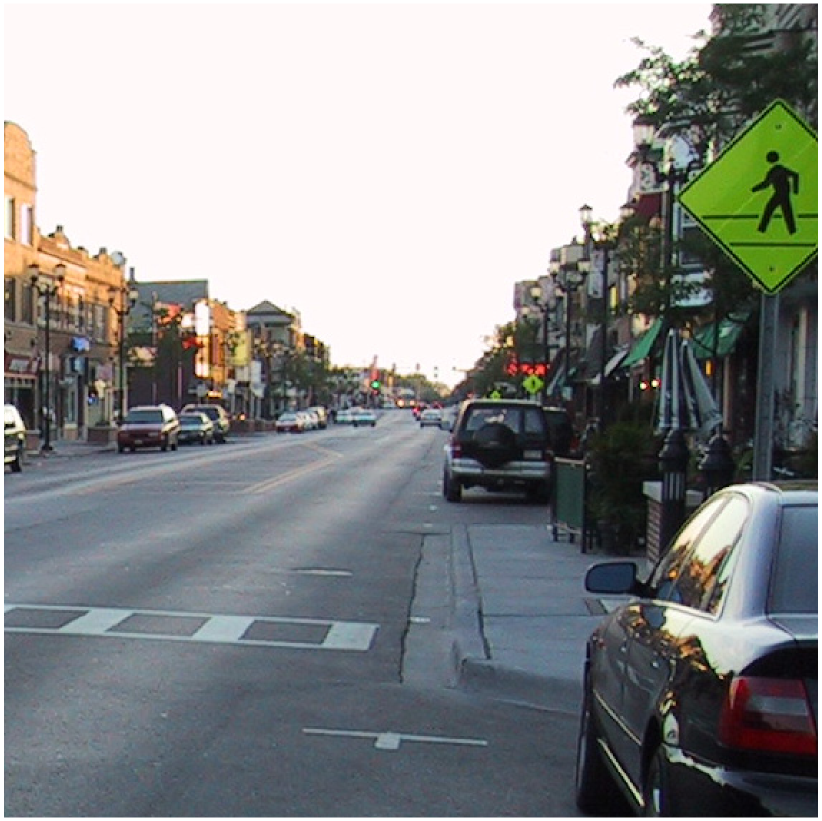
On-Street Parking

What: On-street parking is the placement of parked vehicles on the roadway closest to the curb. On-street parking may be parallel or angle parking.

Where: On-street parking can be placed on most roadways in developed areas and should be considerend whenever it is desirable to provide parking for adjacent land uses and where a buffer between pedestrians and moving vehicles is desired.

Why: The placement of on-street parking reduces travel speeds on the roadway and can reduce the severity of crashes by reducing vehicle speeds. On urban streets with posted speeds of less than 35 mph, streets with on-street parking experience less than half as many severe and fatal crashes than streets without on-street parking [15].

How: Parking lanes are usually 8 feet wide, but 7-foot parking lanes, per state law, can be allowed, particularly where adjacent to a bike lane. If the travel lane adjacent to on-street parking is less than 12 feet wide and is used by bicyclists, shared lane markings may be used to encourage bicyclists to ride outside of the "door zone." Diagonal parking is not permitted on Michigan trunk line highways.



Potential Crashes			Potential Mobility Improvements			Cost
Motor Vehicles	Pedestrians	Bicyclists	Motor Vehicles	Pedestrians	Bicyclists	
No Difference	Reduce	Reduce*	No Difference	Better	Better	Low

*When bicyclists ride outside the "door zone."

Rear-In Diagonal Parking

What: Rear-in diagonal parking is the placement of angle parking where the front of the automobile is parked facing the travel lane with the back of the vehicle at the curb.

Where: Rear-in diagonal parking should be considered wherever angle parking exists or is planned.

Why: Rear-in diagonal parking eliminates the blind spots associated with angle parking which particularly helps bicyclists traveling adjacent to the parking lane. Additionally, rear-in diagonal parking directs children exiting vehicles to the curb, and loading items in the trunk also occurs at the curb.

How: Guidance for the placement of angle parking is provided by FHWA as part of *Designing Roads and Parking Areas* for the Recreational Trails Program under the Office of Planning, Environment, and Realty. Per state law, diagonal parking is not permitted on Michigan trunkline highways.

Image: www.pedbikeimages.org/Carl Sundstrom

Potential Crashes			Potential Mobility Improvements			Cost
Motor Vehicles	Pedestrians	Bicyclists	Motor Vehicles	Pedestrians	Bicyclists	
Reduce	Reduce	Reduce	No Difference	No Difference	Better	Low/Med

Bike Lane

What: Bike lanes are portions of the roadway that are delineated with pavement markings for the exclusive use by bicyclists. Normally, one bike lane is provided on each side of the roadway and travels in the same direction as the automobile lane. Bike lane signs can be used to supplement the pavement markings.

Where: Bike lanes should be installed on roadways as part of a bicycle route to improve the visibility of bicyclists to motorists, provide space for bicyclists as part of a bicycle route, reduce the occurrence of wrong-way bicycling in traffic, and reduce the number of bicyclists riding on the sidewalk.

Why: The addition of bike lanes has been shown to reduce bicycle crashes by 50%[10]. Bike lanes are a much more cost-effective method of providing bicycle facilities than a sidepath, which typically requires additional right-of-way and is subject drainage and alignment issues independent of the roadway.

How: Bike lanes currently are considered a design option in the Michigan Design Manual Section 12.12. Additional guidance can be found in the AASHTO *Guide for the Development of Bicycle Facilities*.

Potential Crashes			Potential Mobility Improvements			Cost
Motor Vehicles	Pedestrians	Bicyclists	Motor Vehicles	Pedestrians	Bicyclists	
No Difference	No Difference	Reduce	No Difference	No Difference	Better	Medium

Shared Lane Markings

What: A shared lane marking is a pavement marking placed on roadways that are recommended for bicycle travel but do not have adequate space for a separate bike lane.

Where: Shared lane markings can be used on any street recommended for bicycle travel, on shared roadways where it is helpful to remind motorists of the presence of bicyclists, or in transition areas where it is important to show the recommended bicycling location for bicyclists.

Why: When applied to roadways, shared lane markings are shown to reduce the occurrence of wrong-way riding and bicycling on the sidewalk, and moving bicyclists out of the way of opening doors in the parking lane, all of which help to reduce crashes[12].

How: Guidance for the application of shared lane markings can be found in MMUTCD Section 9C.07.

Potential Crashes			Potential Mobility Improvements			Cost
Motor Vehicles	Pedestrians	Bicyclists	Motor Vehicles	Pedestrians	Bicyclists	
No Difference	No Difference	Reduce	No Difference	No Difference	Better	Low

Buffered Bike Lane

What: A buffered bike lane is a bike lane that is separated from traffic by a painted median with or without collapsible posts. It provides a greater horizontal separation between the bike lane and the automobile travel lane.

Where: Buffered bike lanes should be considered wherever greater separation of bicycle and automobile traffic is desired. They may be placed on either side of the bike lane (next to the through travel lane or the parking lane.)

Why: Buffered bike lanes increase the separation between bicycles and automobiles, which may be helpful on roadways with posted speeds above 35 miles per hour.

How: Refer to the NACTO *Urban Bikeway Design Guide* for guidance on the design of buffered bike lanes.

Image: www.pedbikeimages.org/Steven Faust

Potential Crashes			Potential Mobility Improvements			Cost
Motor Vehicles	Pedestrians	Bicyclists	Motor Vehicles	Pedestrians	Bicyclists	
No Difference	No Difference	Reduce	No Difference	Better	Better	Med/High

Colored Bike Lane

What: A colored bike lane is a portion of a bike lane marked with high-visibility green pavement markings to identify a potential conflict area or transition area of a bicycle facility. Bike lanes are usually colored just in the vicinity of an intersection.

Where: Colored bike lanes should be considered where motor vehicles and bicyclist share a transitioning area of the roadway, such as near turn lanes or when a lane drop occurs for bicycles or motor vehicles.

Why: Colored bike lanes increase the visibility of the bicycle facility and have been shown to increase motorist yielding compliance rates by 11%, and increase bicyclist scanning the roadway for nearby vehicles[13].

How: Green colored bike lanes were given interim approval by FHWA in April 2011 and have been approved for experimental design. This means that they should be included in the next update to the MUTCD. For current information on colored bike lanes, consult the NACTO *Urban Bikeway Design Guide*.

Image: www.nactor.org

Potential Crashes			Potential Mobility Improvements			Cost
Motor Vehicles	Pedestrians	Bicyclists	Motor Vehicles	Pedestrians	Bicyclists	
No Difference	No Difference	Reduce	No Difference	No Difference	Better	Medium

Contra-flow Bike Lane

What: Contra-flow bike lanes are bike lanes that run in the opposite direction as automobile traffic on a street. The most common applications are on one-way streets where a contra-flow bike lane is placed to provide a link to bicycle facility to avoid placing bicyclists on high-speed or high volume arterial roadways.

Where: Contra-flow bike lanes should be considered wherever bicycle facility connectivity is needed.

Why: Contra-flow bike lanes provide a bicycle facility where demand exists, as demonstrated by wrong-way riding. Additionally, by placing bicyclists in a contra-flow lane, it reduces the likelihood of bicycling on streets not recommended for bicyclists.

How: Guidance for the placement of contra-flow bike lanes is provided in the NACTO *Urban Bikeway Design Guide*.

Image: www.nacto.org

Potential Crashes			Potential Mobility Improvements			Cost
Motor Vehicles	Pedestrians	Bicyclists	Motor Vehicles	Pedestrians	Bicyclists	
No Difference	No Difference	Reduce	No Difference	No Difference	Better	Medium

Left Side Bike Lane

What: Left side bike lanes are bike lanes painted on the left side of a roadway. Typically, left side bike lanes are placed on one-way streets, or on two way streets adjacent to a barrier median.

Where: Left side bike lanes are appropriate on roadways with frequent driveways, transit service, or on roadway networks with one-way pairs.

Why: Left side bike lanes reduce the need for a bicyclist to cross one or several lanes to make a left turn in areas where a bicycle facility continues to the left, or to avoid conflicting with pedestrians and transit vehicles at transit stops located on the right side of the road. However, right turns are more difficult with this design.

How: Guidance for the placement of left side bike lanes is provided in the NACTO *Urban Bikeway Design Guide*.

Image: www.pedbikeimages.org/Dan Burden

Potential Crashes			Potential Mobility Improvements			Cost
Motor Vehicles	Pedestrians	Bicyclists	Motor Vehicles	Pedestrians	Bicyclists	
No Difference	No Difference	Reduce	No Difference	No Difference	Better	Medium

Cycle Track

What: A cycle track is a dedicated bicycle facility for bicycles that is physically separated from traffic. It consists of a one or two-way facility for bicycles and is separated from automobile traffic with either a pavement marking buffer, collapsible posts, a curb, a change in elevation, or a combination of these items.

Where: Cycle tracks can be considered for an urban street where a significant amount of protection and separation is desired between automobiles and bicycles. However, cycle tracks can pose a crash risk at intersections where turning automobiles cannot see bicyclists emerging from behind parked cars or standing pedestrians. In these cases, the use of bike signals is recommended.

Why: Cycle tracks physically separate bicycle and automobile traffic, which has been shown to reduce injury crashes by 28%[14].

How: Guidance for the placement of cycle tracks is provided in the NACTO *Urban Bikeway Design Guide*.

Image: www.nacto.org

Potential Crashes			Potential Mobility Improvements			Cost
Motor Vehicles	Pedestrians	Bicyclists	Motor Vehicles	Pedestrians	Bicyclists	
No Difference	No Difference	Reduce	No Difference	No Difference	Better	High

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