Best Design Practices for

Walking and Bicycling

in Michigan

MDOT
Michigan Department of Transportation

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Table of Contents

Acknowledgements

These materials were originally developed for the Michigan Department of Transportation (MDOT) by **T.Y. Lin International** in 2012 as a part of a sponsored research project entitled "*Sharing the Road: Optimizing Pedestrian and Bicycle Safety and Vehicle Mobility*" (RC-1572) including participation from Western Michigan University and the Corradino Group.

Michigan State University updated these materials in 2020 for MDOT as a part of a subsequent sponsored research project entitled "*Synthesis of National Best Practices on Pedestrian and Bicycle Design, Guidance and Technology Innovations*" (OR19-072).

Overview

Toward Zero Deaths™
National Strategy on Highway Safety

As a part of **MDOT's *Towards Zero Death*** vision, the department has sponsored several recent research initiatives in order to accelerate progress towards the department's ultimate vision of zero fatalities and serious injuries on Michigan's roadways. Additionally, supporting mobility for all users of the transportation system is key MDOT's mission of "providing the highest quality integrated transportation services for economic benefit and improved quality of life". This document summarizes best design practices with respect to engineering improvements which can improve both safety and mobility for pedestrians and bicyclists. The guidance is intended to serve as a toolbox of potential treatments which can be considered by practitioners based upon MDOT's research, resources developed at the federal-level, as well as best practices identified from other state and local agencies. It is important to note that the guidance included in this resource is consistent with both the **Michigan Manual on Uniform Traffic Control Devices (MMUTCD)** and relevant interim approvals published by the Federal Highway Administration (FHWA). Specific design practices may not be included in the MMUTCD and require a request to experiment from the FHWA. More information on the experimentation process can be found on **FHWA's website**.

The best practices included in this guidance are categorized by treatments intended to improve (1) signalized intersections, (2) unsignalized crossings and (3) corridors. A summary matrix is provided for each category which details the potential impacts of each best practice with respect to safety performance and mobility. Potential safety performance impacts are characterized as "better" or "no difference" based upon prior research. Potential mobility impacts are characterized as "better", "no difference", or "worse" based upon the expected change in delay after a treatment is implemented. Distinct characterizations for safety performance and mobility impacts are provided for motor vehicles, pedestrians and bicyclists. A generalized cost estimate is also provided for implementing each best practice, characterized as "low" (less than $20,000), "medium" ($20,000 to $100,000), or "high" (greater than $100,000).

Each best practice is then detailed in a single-page format, including the "what", "where", "why", and "how" of implementing each treatment. Supporting photographs, figures or other visual aids are included for each best practice. Key references for each practice are included for more detailed information.

Funding Sources

There are a several potential funding sources which can be leveraged to implement treatments intended to improve safety and mobility for non-motorized road users in Michigan. While details on core funding programs are detailed below, there may be additional opportunities available to fund **pedestrian** and **bicycle** projects by contacting MDOT.

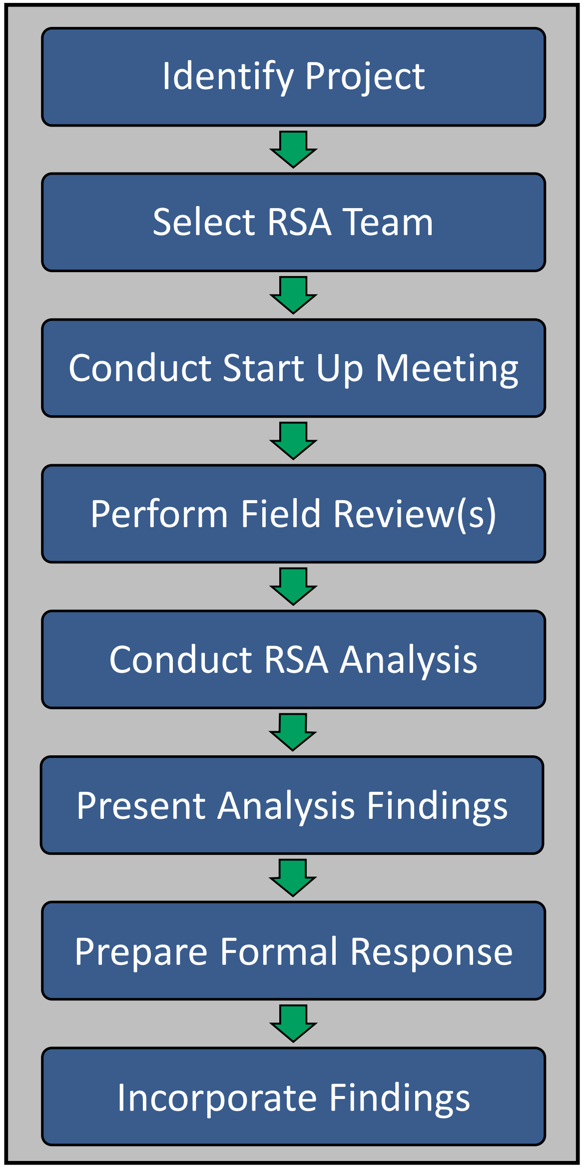
Safe Routes to School (SRTS) is “an international movement—and now a federal program—to make it safe, convenient, and fun for children, including those with disabilities, to bicycle and walk to school.” Michigan’s SRTS program is managed by MDOT and supported by the Michigan Fitness Foundation. The competitive program provides “Major Grants” which include up to $220,000 per school for potential infrastructure improvements. A variety of potential infrastructure improvements can be funded by the major grants, including sidewalks, bicycle lanes, trails, bicycle parking, traffic calming treatments, lighting, remote drop-off locations and a range of traffic control devices. It should be noted several items can not be funded by SRTS grants, including (but not limited to) preliminary engineering, professional services, bus stop improvements, landscaping, or required traffic signal warrant studies.

The Transportation Alternatives Program (TAP) is a competitive grant program via federal transportation funds designated by the United States Congress for projects which enhance the intermodal transportation system and safe alternative transportation options. Michigan’s program includes approximately $24.5M in annual funding, including $17.6M administered by MDOT and the remaining $6.9M administered by metropolitan planning organizations. The program prioritizes projects which demonstrate a competitive concept and a high likelihood of constructability. Refer to ***MDOT’s TAP Applicant Guide*** for more information.

The Highway Safety Improvement program (HSIP) is a core federal aid program intended to “achieve a significant reduction in traffic fatalities and serious injuries on all public roads through the implementation of infrastructure-related highway safety improvements”. While there are distinct calls for projects along the state trunkline and locally-owned roadways, the treatments outlined within this document are commonly funded as a part of Michigan’s HSIP.

Road Safety Audits

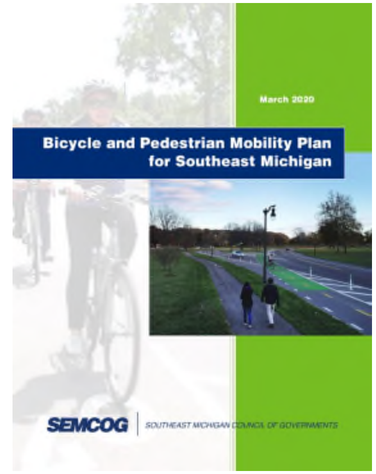
Road safety audits (RSAs) are a formal safety performance examination of an existing or future road or bridge project by an independent, multi-disciplinary RSA team. RSAs contribute to the MDOT's *Towards Zero Death* vision by providing an unbiased assessment of a highway location in an effort to identify potential safety issues and solutions. RSAs can be conducted at any stage of the project development process and includes eight steps (shown right). It is important to note that RSAs consider the needs of all road users, including pedestrians and bicyclists. RSA teams are generally comprised of trained MDOT employees as independent reviewers and facilitated by a contracted consultant. The audit team focuses in four specific areas, including geometry, operations, road users and the environment.

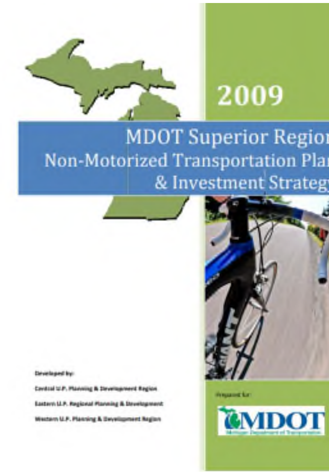


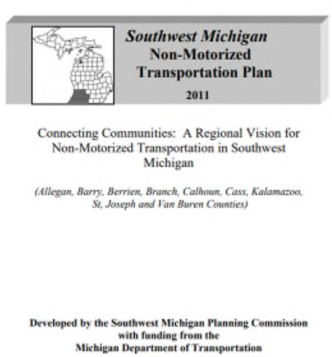
For More Information: ***[MDOT's Road Safety Audit Guidance]***

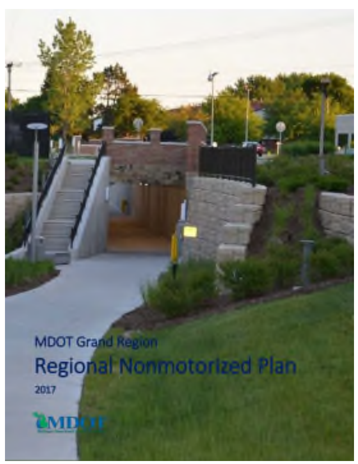
Non-Motorized Safety Plans

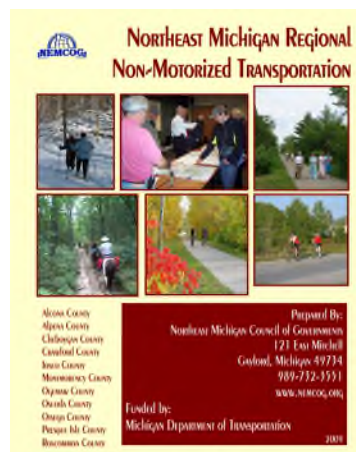
Regional non-motorized safety plans have been developed across the state of Michigan intended to help ensure a coordinated approach towards improving the state's transportation system to meet the needs of pedestrians and bicyclists. The plans employ a data-driven approach to evaluate the current state of the system at a regional level, identify potential opportunities for improvement, prioritize investments, and encourage a cooperative approach among stakeholders. Each regional plan was developed by a team which included staff from MDOT, metropolitan planning organizations, local highway agencies, private consultants, and stakeholder groups.

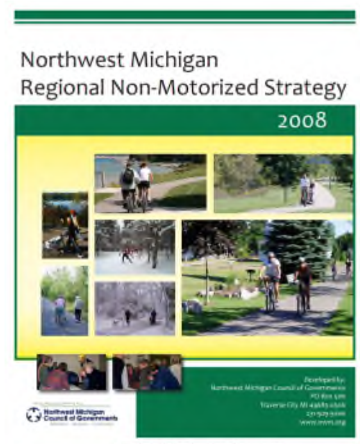












For More Information: ***[Michigan's Regional Non-Motorized Plans]***

Signalized Intersection Improvements

Best Practice	Potential Safety Impacts			Potential Mobility Impacts			Cost Estimate
	Motor Vehicles	Pedestrians	Bicyclists	Motor Vehicles	Pedestrians	Bicyclists	
Pedestrian Clearance Time	No Difference	Better	No Difference	Worse	Better	No Difference	Low
Fixed Time Signals and Actuation	No Difference	No Difference	No Difference	No Difference	Better	No Difference	Low
Countdown Pedestrian Signals	Better	Better	No Difference	No Difference	Better	No Difference	Low
Accessible Pedestrian Signals	No Difference	Better	No Difference	No Difference	Better	No Difference	Low
Leading Pedestrian Intervals	No Difference	Better	No Difference	Worse	Better	No Difference	Low
Exclusive Pedestrian Phases	No Difference	Better	No Difference	Worse	Worse	Worse	Low
Exclusive Left-Turn Phases	Better	Better	Better	Worse	Better	Better	Low
Flashing Yellow Arrows	Better	No Difference	No Difference	Better	No Difference	No Difference	Low
Median U-Turn Intersections	Better	No Difference	No Difference	Better	Better	Better	High
Right-Turn-on-Red Prohibitions	Better	Better	Better	Worse	Better	Better	Low
Advance Stop Markings	Better	Better	No Difference	No Difference	Better	No Difference	Low
Right-Turn Slip-Lane Design	Better	Better	No Difference	Better	Better	No Difference	Med/High
Curb Extensions	Better	Better	No Difference	No Difference	Better	No Difference	Medium
Roundabouts	Better	Better	Better	Better	Better	Better	High
Signal Timing for Bicyclists	No Difference	No Difference	Better	Worse	No Difference	Better	Low
Bicycle Signals	No Difference	No Difference	Better	Worse	No Difference	Better	Medium
Bicycle Signal Detection	No Difference	No Difference	Better	No Difference	No Difference	Better	Low/Med.
Intersection Bicycle Pavement Markings	No Difference	No Difference	Better	No Difference	No Difference	Better	Low
Bicycle Boxes	No Difference	Better	Better	No Difference	No Difference	Better	Low
Two-Stage Bicycle Turn Boxes	No Difference	No Difference	Better	No Difference	No Difference	Better	Low
Centerline Hardening	No Difference	Better	Better	No Difference	Better	Better	Low
Protected/Dedicated Intersections	No Difference	Better	Better	No Difference	Better	Better	High
Alternative Intersections/Interchanges	Better	Better	Better	Better	Better	Better	High

Pedestrian Clearance Time

What	For the purposes of determining pedestrian intervals, pedestrian clearance times are calculated using a walking speed of 3.5 feet per second. In situations where pedestrians who use wheelchairs routinely use the crosswalk, speeds less than 3.5 feet per second should be considered.
Where	All new or rehabilitated pedestrian signals should be timed with this signal timing according to the MMUTCD [1] and MDOT's Electronic Traffic Control Device Guidelines [2].
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 [3].
How	Details can be found in *Section 4E.06* of the MMUTCD [1] and *Section 4.2* of the MDOT Electronic Traffic Control Device Guidelines [2].
Key Reference s	1) Michigan MUTCD (MDOT - 2011) 2) MDOT Electronic Traffic Control Device Guidelines (MDOT) 3) Field Studies of Pedestrian Walking Speed and Start-Up Time (Knoblaugh, Peitrucha, and Nitzburg - 1996)

Potential Safety Impacts			Potential Mobility Impacts			Cost Estimate
Motor Vehicles	Pedestrians	Bicyclists	Motor Vehicles	Pedestrians	Bicyclists	
No Difference	Better	No Difference	Worse	Better	No Difference	Low

Fixed Time Signals and Actuation

What	Fixed time signals have an automatic pedestrian phase built into the signal cycle. For signals which are fully or semi-actuated, or when the time required for pedestrians to cross the intersection is the controlling factor in determining signal timing, pushbuttons or other passive detection devices should be considered [1].
Where	In general, fixed time signals should be used where pedestrian traffic is routine. Pedestrian actuation should be used where pedestrian crossings are infrequent.
Why	Requiring pedestrians to call for the walk interval can increase their delay and should only be used where pedestrian traffic is limited. Fixed-time signals increase mobility for pedestrians.
How	Details on implementing pedestrian detection can be found in MDOT *Traffic and Safety Note 207B* [1], *Section 4E.08* of the MMUTCD [2], *Section 3.0* of MDOT's Electronic Traffic Control Device Guidelines [3], and FHWA's PEDSAFE website [4].
Key References	**1) Traffic and Safety Note 207B: Guidelines for Pedestrian Push Button Use & Location (MDOT -2005)** **2) Michigan MUTCD (MDOT - 2011)** **3) MDOT Electronic Traffic Control Device Guidelines (MDOT)** **4) Push Buttons & Signal Timing (FHWA PEDSAFE)**

www.pedbikeimages.org/DanBurden

Potential Safety Impacts			Potential Mobility Impacts			Cost Estimate
Motor Vehicles	Pedestrians	Bicyclists	Motor Vehicles	Pedestrians	Bicyclists	
No Difference	No Difference	No Difference	No Difference*	Better	No Difference	Low**

*If signal needs to be re-timed for pedestrian walking speeds may be a slight increase in motor vehicle delay; **If signal timing is maintained

Countdown Pedestrian Signals

What	Countdown pedestrian signals provide pedestrians with an indication of the number of seconds left in the flashing DON'T WALK interval [1]. The remaining number of seconds is displayed concurrent with the flashing UPRAISED HAND indication and counts down to the end of the flashing UPRAISED hand indication [2]. After the countdown display reaches zero, the number indication goes dark and a steady UPRAISED HAND indication is provided [2].
Where	Countdown displays are mandatory for all new installations per *Section 3.3* of the Michigan Electronic Traffic Control Device Guidelines [2].
Why	Countdown pedestrian signals have been shown not only to reduce pedestrian-involved crashes by approximately 9 percent, but total crashes by approximately 8 percent [1]. Research has also demonstrated that the device is generally well-understood by pedestrians and improved crossing behavior [1, 3].
How	Details on the use of countdown pedestrian signals can be found in *Section 4E.07* of the MMUTCD [4], *Section 3.3* of the MDOT's Electronic Traffic Control Device Guidelines [2], and Developing Guidelines for Use of Pedestrian Count Down Traffic Signals [3].
Key References	1) Safety Evaluation of Pedestrian Count Down Signals (FHWA – 2019) 2) MDOT Electronic Traffic Control Device Guidelines (MDOT) 3) Developing Guidelines for Use of Pedestrian Countdown Traffic Signals (MDOT – 2007) 4) Michigan MUTCD (MDOT - 2011) 5) A justification for pedestrian countdown signals at signalized intersections: The safety impact on senior motorists (Boateng, R., Kwigizile, V., Miller, J., and Oh, J.S. – 2019)

[3]


[5]

Potential Safety Impacts			Potential Mobility Impacts			Cost Estimate
Motor Vehicles	Pedestrians	Bicyclists	Motor Vehicles	Pedestrians	Bicyclists	
Better	Better	No Difference	No Difference	Better	No Difference	Low

Accessible Pedestrian Signals

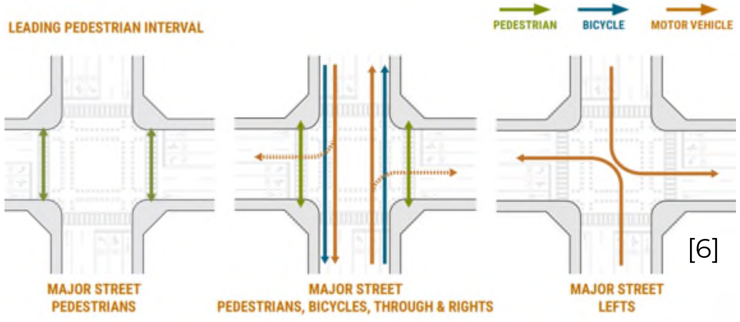
What	Accessible pedestrian signals are devices which can provide information in non-visual formats such as audible tones, speech messages or vibrating surfaces for pedestrians with visual disabilities [1]. Given that pedestrians with vision disabilities rely on the sound of vehicles beginning to move which often corresponds with the beginning of a green interval, the existing environment can be insufficient to provide these road users with the information needed to safely cross the roadway at a signalized location [1].
Where	These devices should be considered at specific locations based upon an engineering study which considers general pedestrian needs as well as the needs of pedestrians with visual disabilities [1].
Why	Research has demonstrated that accessible pedestrian signals can help to improve the crossing performance of pedestrians with vision disabilities, including better judgement of the beginning of the WALK interval, a reduction in crossings which begin during the DON'T WALK interval, reductions in delay, and more crossings completed before the end of the pedestrian interval [2].
How	Details can be found in *Section 4E.09* of the MMUTCD [1], *Section 3.4* of the Michigan Electronic Traffic Control Device Guidelines [3], MDOT Traffic and Safety Note *207C* [4], and NCHRP's Accessible Pedestrian Signals: A Guide to Best Practices [2].
Key References	**1) Michigan MUTCD (MDOT - 2011)** **2) Accessible Pedestrian Signals: A Guide to Best Practices (Harkey, D., Carter, D., Bentzen, B., and Barlow, J. – 2010)** **3) MDOT Electronic Traffic Control Device Guidelines (MDOT)** **4) Traffic and Safety Note 207C – (MDOT – 2005)**

[2]

Potential Safety Impacts			Potential Mobility Impacts			Cost Estimate
Motor Vehicles	Pedestrians	Bicyclists	Motor Vehicles	Pedestrians	Bicyclists	
No Difference	Better	No Difference	No Difference	Better	No Difference	Low

Leading Pedestrian Intervals

What	Conventionally, pedestrian crossing signal phases are run concurrent with adjacent circular green vehicle phases – resulting in potential conflicts between turning vehicles and pedestrians completing crossing movements [1]. Leading pedestrian intervals provide pedestrians with a head start entering the intersection, typically ranging between 3 to 7 seconds, before motor vehicles are given a green signal [1].
Where	Leading pedestrian intervals should be considered at intersections with a history of conflicts between turning vehicles and pedestrians, particularly at locations where volumes are high enough to consider a dedicated interval for pedestrian-only traffic [2].
Why	Research has demonstrated that the implementation of leading pedestrian intervals has reduced conflicts between pedestrians and turning motor vehicles as well as reducing the number of pedestrians ceding the right-of-way to turning vehicles [3]. Research sponsored by the FHWA suggested an approximate 13 percent reduction in pedestrian-related crashes [1].
How	The MMUTCD allows for the use of leading pedestrian intervals as noted in *Section 4E.06* [4]. Appropriate accessible pedestrian signals should be used in conjunction with leading pedestrian intervals [5]. Right turn on red prohibitions [5] and curb extensions [2] should also be considered in conjunction with leading pedestrian intervals.
Key References	1) Safety Evaluation of Protected Left-Turn Phasing and Leading Pedestrian Intervals on Pedestrian Safety (Goughnour, E., Carter, D., Lyon, C., Persaud, B., Lan, B., Chun, P., Hamilton, I., and Signor, K. – 2018) 2) Urban Street Design Guide (NACTO -2018) 3) Field Evaluation of a Leading Pedestrian Interval Signal Phase at Three Urban Intersections (Van Houten, R., Retting, R., Farmer, C., and Van Houten, J. – 2000) 4) Michigan MUTCD (MDOT - 2011) 5) Leading Pedestrian Interval – (FHWA PEDSAFE) 6) Achieving Multimodal Networks (FHWA – 2016)



[6]

Example of Leading Pedestrian Interval [1]

Potential Safety Impacts			Potential Mobility Impacts			Cost Estimate
Motor Vehicles	Pedestrians	Bicyclists	Motor Vehicles	Pedestrians	Bicyclists	
No Difference	Better	No Difference	Worse	Better	No Difference	Low

Exclusive Pedestrian Phases (Scramble or Barnes Dance)

What	Exclusive pedestrian phases, which have also been referred to as "pedestrian scrambles" or a "Barnes Dance", allow for pedestrians to cross the street at signalized intersections while all motor vehicle traffic remains stopped [1]. This often involves allowing pedestrians to cross the intersection in a diagonal directions.
Where	Exclusive pedestrian phases can be considered at intersections with high pedestrian volumes with equivalent desire lines in all directions, relatively high levels of motor vehicle turning movements, or other situations which involve atypical geometry or limited sight distance [1].
Why	Research conducted in New York demonstrated reductions in pedestrian-related crashes with the implementation of an exclusive pedestrian phase [2]. While motor vehicle crashes slightly increased after the implementation of the exclusive pedestrian phase, this effect was not statistically significant.
How	A comprehensive engineering study should be conducted prior to the implementation of an exclusive pedestrian phase. It is important to note that while exclusive pedestrian phases can improve safety performance, delays for both motor vehicles and non-motorized road users will always be worse compared to conventional signal timing strategies [3]. Therefore, designers should consider other signal timing strategies, such as leading pedestrian intervals, when investigating an exclusive pedestrian phase.
Key References	1) Achieving Multimodal Networks (FHWA – 2016) 2) The Relative Effectiveness of Pedestrian Safety Countermeasures at Urban Intersections - Lessons from a New York City Experience (Chen, L., Chen, C., and Ewing, R. – 2012) 3) Guide for the Planning, Design, and Operation of Pedestrian Facilities, 1st Edition (AASHTO – 2004) 4) Meet Los Angeles: Pedestrian Scramble (NACTO – 2017) 5) Walk This Way: Exclusive Pedestrian Signal Phase Treatments Study (NYDOT – 2017)

Example of a Pedestrian Scramble in Los Angels [4]

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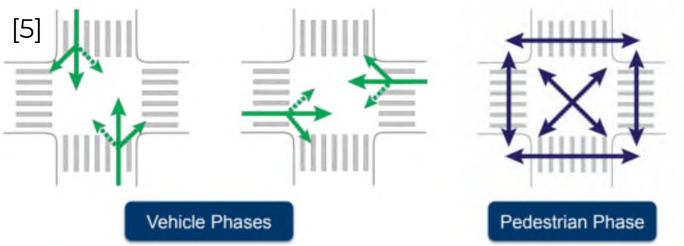
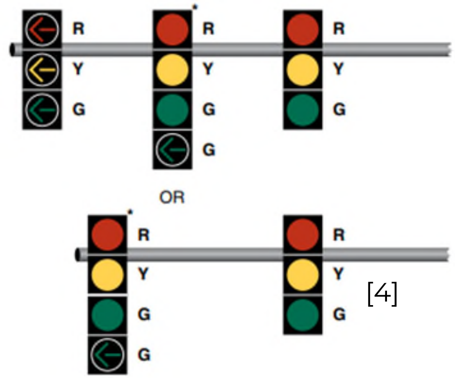


Potential Safety Impacts			Potential Mobility Impacts			Cost Estimate
Motor Vehicles	Pedestrians	Bicyclists	Motor Vehicles	Pedestrians	Bicyclists	
No Difference	Better	No Difference	Worse	Worse	Worse	Low

Exclusive Left-Turn Phases

What	Currently, three types of left-turn phases are used in Michigan [1]: • **Permissive-protected (lagging)** where the left-turn movement begins with a permissive phase (left-turns must yield to opposing traffic) and ends with a protected phase • **Protected-permissive (leading)** where the left-turn movement begins with a protected phase and ends with a permissive phase (left-turns must yield to opposite traffic) • **Protected-only** where left-turn movements can only be made during exclusive phase and conflicts with opposing vehicles and pedestrians are eliminated.
Where	Despite the fact that left-turn phases can improve the level of service for left-turn movements, they often reduce the overall intersection level of service [1]. Therefore, left-turn phasing should only be implemented after a comprehensive engineering study demonstrates that such phasing is necessary for the safe and efficient operation of an intersection [1].
Why	Permissive phasing has previously been associated with conflicts between pedestrians and left-turning vehicles [2]. Research conducted in New York demonstrated a 43 percent reduction in pedestrian-involved crashes after conversion to protected-only left-turn phasing [3]. Recent research sponsored by the FHWA suggested that reductions may be higher at locations with high levels of pedestrian traffic [2].
How	More detailed information can be found in *Section 2.0* of the Michigan Electronic Traffic Control Device Guidelines [1] and *Section 4D.17* of the MMUTCD [4].
Key References	1) MDOT Electronic Traffic Control Device Guidelines (MDOT) 2) Safety Evaluation of Protected Left-Turn Phasing and Leading Pedestrian Intervals on Pedestrian Safety (Goughnour, E., Carter, D., Lyon, C., Persaud, B., Lan, B., Chun, P., Hamilton, I., and Signor, K. – 2018) 3) Safety Countermeasures and Crash Reduction in New York City – Experience and Lessons Learned (Chen, L., Chen, C., Ewing, R., McKnight, C., Srinivasan, R., and Roe, M. – 2012)



[4]

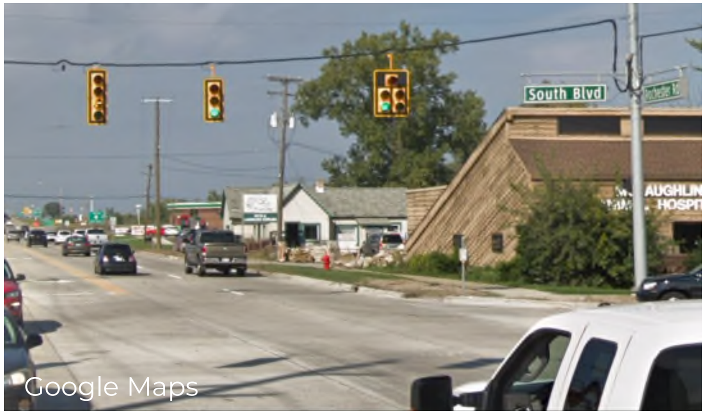
Google Maps

Potential Safety Impacts			Potential Mobility Impacts			Cost Estimate
Motor Vehicles	Pedestrians	Bicyclists	Motor Vehicles	Pedestrians	Bicyclists	
Better	Better	Better	Worse	Better	Better	Low

Flashing Yellow Arrows

What	Flashing yellow arrows are an innovative traffic signal head for left-turn lanes which consists of a four-arrow display, including a steady red arrow, a steady yellow arrow, a flashing yellow arrow and a study green arrow [1]. Flashing yellow arrows replace the existing flashing red indications which were commonly used in Michigan [1].
Where	Flashing yellow arrows have been included as a part of new signal installations or modernizations involving left-turn phasing since 2008 with the long-term intent to replace all flashing red indications [1].
Why	While research conducted in Michigan did not demonstrate safety benefits specific to non-motorized road users [2], studies have consistently demonstrated reductions in vehicular crashes when implemented at an intersection which currently does not include fully protected left-turn phasing [3].
How	More detailed information can be found in MDOT's Flashing Yellow Arrow Left-Turn Signal Guidelines [1], *Section 2.0* of the Michigan Electronic Traffic Control Device Guidelines [4], and *Section 4D.20* of the MMUTCD [5].
Key References	1) Flashing Yellow Arrow Left-Turn Signal Guidelines (MDOT – 2007) 2) Evaluating Pedestrian Safety Improvements: Final Report (Van Houten, R., LaPlante, J., and Gustafson, T. – 2012) 3) Crash Modification Factors for the Flashing Yellow Arrow Treatment at Signalized Intersections (Srinivasan, R., Lan, B., Carter, D., Smith, S., and Signor, K. – 2018) 4) MDOT Electronic Traffic Control Device Guidelines (MDOT) 5) Michigan MUTCD (MDOT - 2011)

[1]

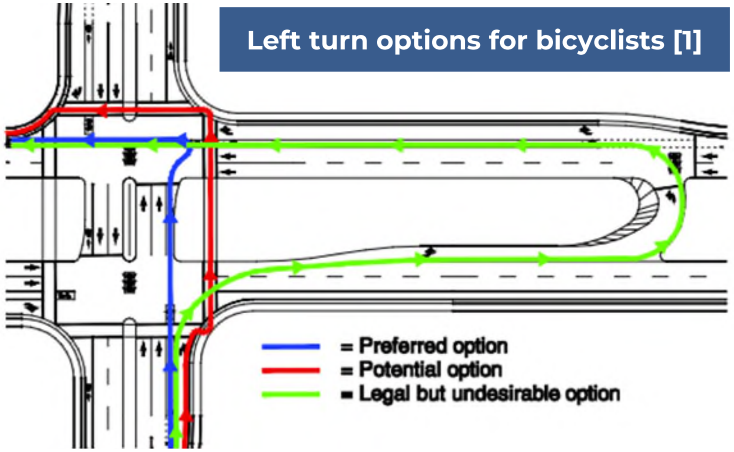


Potential Safety Impacts			Potential Mobility Impacts			Cost Estimate
Motor Vehicles	Pedestrians	Bicyclists	Motor Vehicles	Pedestrians	Bicyclists	
Better*	No Difference	No Difference	Better**	No Difference	No Difference	Low

*When implemented at locations which currently do not include fully protected left-turn phasing; **When installed to replace fully protected left-turn phasing

Median U-Turn Intersections (Michigan Lefts)

What	Median U-turn intersections, also known as a "Michigan Lefts", are an alternative intersection design which accommodate left-turn movements via directional crossovers within the median. Pedestrians cross the intersection via conventional crosswalks (often involving a two-stage crossing along approaches with the median), and bicyclists have three potential options to navigate the intersection (shown right) [1].
Where	Median U-turn intersections should be considered at locations where traffic growth on arterial roadways results in a situation where congestion or safety concerns are observed, particularly involving left-turn conflicts [2].
Why	While median U-turn intersections have previously been shown to improve operational and safety performance for motor vehicles, the unique characteristics of this design can result in both benefits and challenges to non-motorized road users [1].
How	More information can be found in FHWA's Median U-Turn Intersection Informational Guide [1], MDOT's Michigan Intersection Guide [2], MDOT's Road Design Manual [3] and MDOT's geometric guidance and design information [4].
Key References	1) Median U-Turn Intersection Informational Guide (FHWA – 2014) 2) Michigan Intersection Guide (MDOT – 2008) 3) Road Design Manual (MDOT) 4) Geometric Traffic and Safety/Standards and Special Details (MDOT)

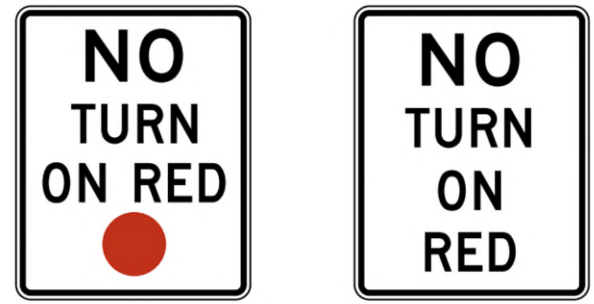


Potential Safety Impacts			Potential Mobility Impacts			Cost Estimate
Motor Vehicles	Pedestrians	Bicyclists	Motor Vehicles	Pedestrians	Bicyclists	
Better	No Difference	No Difference	Better	Better	Better*	High

*Assuming that bicyclists progress through the intersection using a two-stage left turn

Right-Turn-on-Red Prohibitions

What	Permissible right-turn-on-red movements were incorporated in the 1970s due to the operational benefits; however, these movements are also associated with detrimental impacts on non-motorized users [1]. Right-turn-on-red prohibitions involve signing an intersection approach with either a static or dynamic illuminated sign [2].
Where	The prohibition of right-turn-on-red movements should be considered after an engineering study demonstrates that one of the following situations exist [2]: • Approaches which have sight distance restrictions to the left which inhibit right-turn movements • Approaches which have experienced more than three right-turn-on-red crashes during a 12-month period • Intersections with a railroad crossing within 100 feet and additional criteria are met
Why	Despite the fact that the law requires vehicles to come to a full stop when completing a right-turn-on-red movement, drivers often do not comply and may be distracted by looking for vehicles approaching from their left [1]. Research has demonstrated that allowing right-turn-on-red movements increases all crash types, including crashes involving pedestrians and bicyclists [3].
How	More information can be found on FHWA's PEDSAFE website [1], MDOT's Traffic Sign Design, Placement and Application Guidelines [2], and *Section 2B.54* of the MMUTCD [4].
Key References	1) Right-Turn-on-Red Restrictions – (FHWA PEDSAFE) 2) Traffic Sign Design, Placement, and Application Guidelines (MDOT – 2019) 3) Highway Safety Manual (AASHTO – 2010) 4) Michigan MUTCD (MDOT - 2011)

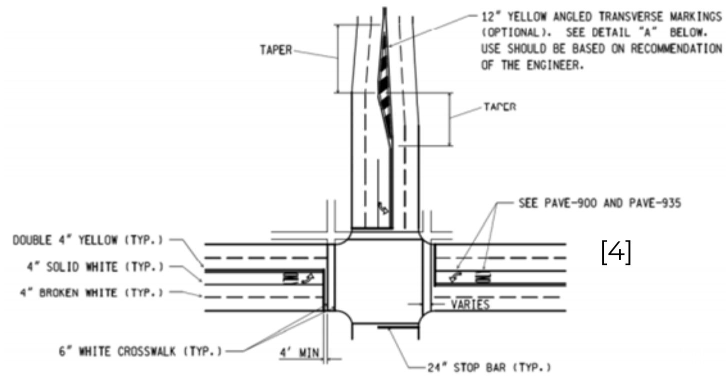


R10-11 R10-11a [4]

Potential Safety Impacts			Potential Mobility Impacts			Cost Estimate
Motor Vehicles	Pedestrians	Bicyclists	Motor Vehicles	Pedestrians	Bicyclists	
Better	Better	Better	Worse	Better	Better	Low

Advanced Stop Markings

What	Advanced stop markings involve implementing the stop bar further back than the standard 4 feet minimum in order to improve visibility of bicyclists and pedestrians, ranging from 15 to 30 feet [1].
Where	Advanced stop markings should be considered at locations with frequent conflicts between pedestrians and right-turning vehicles, as well as locations with a history of right-turn-on-red conflicts [1].
Why	Research has demonstrated that advanced stop bars reduce conflicts between vehicles turning right on red and cross traffic, increase the number of full stops by vehicles turning right on red, and provide more time for drivers to react to pedestrians in adjacent crosswalks [1]
How	More information can be found in FHWA's Signalized Intersection Informational Guide [1], FHWA's PEDSAFE website [2], *Section 3B.16* of the MMUTCD [3], and MDOT's Pavement Marking Standards [4]
Key References	1) Signalized Intersections Informational Guide (FHWA – 2013) 2) Advanced Stop Lines at Traffic Signals (FHWA PEDAFE) 3) Michigan MUTCD (MDOT - 2011) 4) Pavement Markings (MDOT) 5) Infrastructure Reference Guide (MnDOT – 2016)



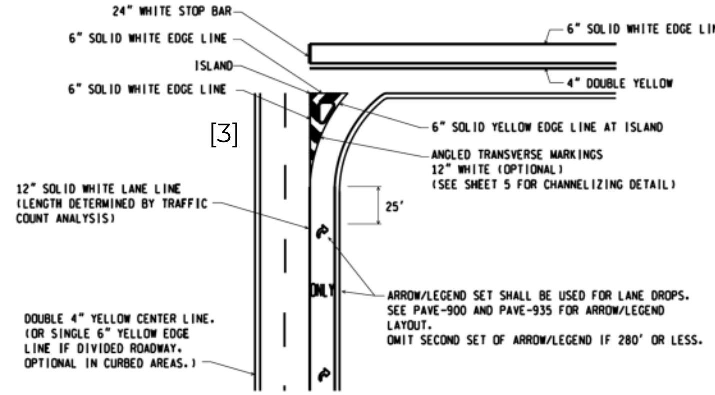
[4]

[5]

Potential Safety Impacts			Potential Mobility Impacts			Cost Estimate
Motor Vehicles	Pedestrians	Bicyclists	Motor Vehicles	Pedestrians	Bicyclists	
Better	Better	No Difference	No Difference	Better	No Difference	Low

Right-Turn Slip-Lane Design

What	Right-turn slip-lanes should include several key design features, including crossing islands (also referred to as “pork chop” islands) which create a channelized right turn [1]. These raised islands should be large enough to accommodate pedestrians waiting to complete a crossing movement and incorporate accessibility features such as curb ramps [1].
Where	These designs should be considered at signalized intersections with relatively high right-turn volumes as well as locations with considerable skew or other geometric features which result in longer pedestrian crossing distances [1].
Why	Right-turn slip-lanes with appropriate design features can help to reduce turning speeds, increase visibility, and reduce pedestrian crossing distances [1]. Research has demonstrated that designs with improved approach angles can reduce the frequency of traffic crashes [2].
How	More information can be obtained from FHWA’s PEDSAFE website, and MDOT’s Pavement Markings Standards [3].
Key References	1) Improved Right-Turn Slip-Lane Design (FHWA PEDSAFE) 2) Safety Impacts of a Modified Right Turn Lane Design at Intersections (Shattler and Hanson – 2016) 3) Pavement Markings (MDOT)



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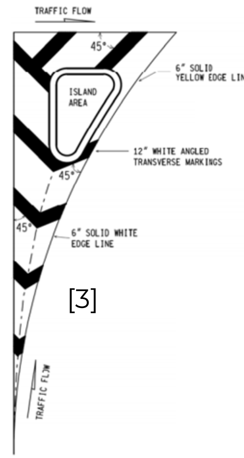


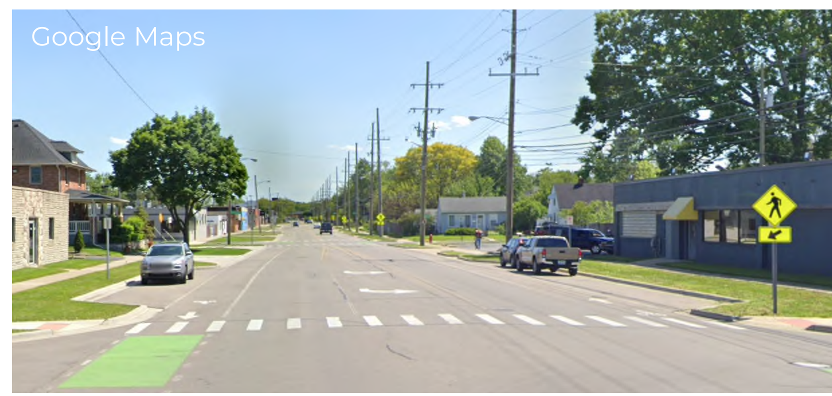
[3]


[1 – Michele Weisbart]

Potential Safety Impacts			Potential Mobility Impacts			Cost Estimate
Motor Vehicles	Pedestrians	Bicyclists	Motor Vehicles	Pedestrians	Bicyclists	
Better	Better	No Difference	Better	Better	No Difference	Med/High

Curb Extensions

What	Curb extensions (also referred to as "bulb-outs") involve extending the sidewalk or curb line into a parking lane in order to reduce the effective width of the street [1-3].
Where	Curb extensions should be considered where a parking lane, bus stop or loading zone is adjacent to either an intersection or midblock location [1-3]. Curb extensions can also be used as a part of gateway treatments [2].
Why	Curb extensions reduce pedestrian crossing distances, improve visibility, reduce curb radii, incorporate space for curb ramps, keep vehicles from parking near the intersection, as well as both visually and physically narrowing the roadway [1-3].
How	More information can be found on FHWA's PEDSAFE website [1], NACTO's Urban Street Design Guide [2], and ITE's Designing Walkable Urban Thoroughfares [3].
Key References	1) Curb Extensions (FHWA PEDSAFE) 2) Urban Street Design Guide (NACTO – 2018) 3) Designing Walkable Urban Thoroughfares: A Context Sensitive Approach (ITE – 2010)



Potential Safety Impacts			Potential Mobility Impacts			Cost Estimate
Motor Vehicles	Pedestrians	Bicyclists	Motor Vehicles	Pedestrians	Bicyclists	
Better	Better	No Difference	No Difference	Better	No Difference	Med

Roundabouts

What	Modern roundabouts are an alternative intersection design which is becoming widely adopted by highway agencies across the United States [1], where traffic travels counterclockwise around a central island and must yield to circulating traffic [2]. A key design feature of modern roundabouts is the speed control provided by geometric features [2].
Where	Mini-roundabouts (up to 15,000 vehicles per day), single-lane roundabouts (up to 25,000 vehicles per day) , and multilane roundabouts (up to 45,000 vehicles per day) may be appropriate under a range of traffic scenarios [2]. Roundabouts may present challenges to pedestrians with visual disabilities and appropriate accommodations should be considered [3]. Multilane roundabouts are generally not recommended for locations with a high level of pedestrian activity due to the potential for "multiple-threat" crashes [3].
Why	Research has demonstrated that roundabouts can reduce the frequency of fatal and injury crashes [2]. The lower speeds associated with roundabouts can help to improve the safety of non-motorized road users by increasing yielding compliance [2].
How	More information can be found in ITE's Designing Walkable Urban Thoroughfares: A Context Sensitive Approach, NCHRP Report 672 – Roundabouts: An Informational Guide [2], FHWA's, PEDSAFE website [3], MDOT's Roundabout Design Aid [4], MDOT Pavement Marking Standards [5], and *Chapter 3C* of the MMUTCD [6].

Key References	1) Designing Walkable Urban Thoroughfares: A Context Sensitive Approach (ITE – 2010) 2) NCHRP Report 672: Roundabouts: An Informational Guide (NCHRP – 2010) 3) Roundabouts (FHWA PEDSAFE) 4) Roundabout Design Aid (MDOT – 2019) 5) Pavement Markings (MDOT) 6) Michigan MUTCD (MDOT - 2011)

Potential Safety Impacts			Potential Mobility Impacts			Cost Estimate
Motor Vehicles	Pedestrians	Bicyclists	Motor Vehicles	Pedestrians	Bicyclists	
Better	Better	Better	Better	Better	Better	High

Signal Timing for Bicyclists

What	Given that the overall goal of signal timing procedures is to provide safe crossings and reduce delay for all road users, potential adjustments to minimum green intervals (shown right), clearance intervals, and extension time should be considered specific to bicyclists [1].
Where	While bicyclist accommodation should be considered as a part of all signal timing procedures, specific attention should be paid at intersections with high vehicular speeds or relatively long crossing distances where the need for bicycle-specific modifications are most likely [1].
Why	The differences in operating characteristics between motor vehicles and bicyclists, including travel speed, acceleration rates and deceleration rates, may require such modifications in order to safely accommodate these road users [2, 3].
How	More information can be found in AASHTO's Guide for the Development of Bicycle Facilities [3], FHWA's Separated Bike Lane Planning and Design Guide [4], and *Part 9* of the MMUTCD [5].

Standing Bicycle Crossing Time [3]

U.S. Customary

$$BCT_{standing} = PRT + \frac{V}{2a} + \frac{(W+L)}{V}$$

where:

$BCT_{standing}$	=	bicycle crossing time (s)
W	=	intersection width (ft)
L	=	typical bicycle length = 6 ft (see Chapter 3 for other design users)
V	=	attained bicycle crossing speed (ft/s)
PRT	=	perception reaction time = 1s
a	=	bicycle acceleration (1.5 ft/s^2)

Minimum Green Time [3]

U.S. Customary

$$BMG = BCT_{standing} - Y - R_{clear}$$

$$BMG = PRT + \frac{V}{2a} + \frac{W+L}{V} - Y - R_{clear}$$

where:

BMG	=	bicycle minimum green time (s)
$BCT_{standing}$	=	bicycle crossing time (s)
Y	=	yellow change interval (s)
R_{clear}	=	all-red (s)
W	=	intersection width (ft)
L	=	typical bicycle length = 6 ft (see Chapter 3 for other design users)
V	=	bicycle speed crossing an intersection (ft/s)
PRT	=	perception reaction time = 1s
a	=	bicycle acceleration (1.5 ft/s^2)

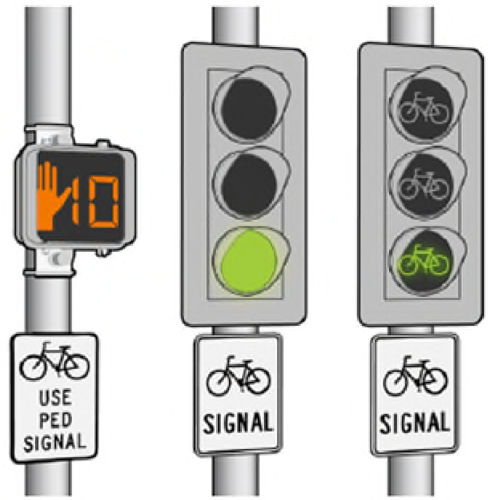
Key References

1) Optimizing Signal Timing for Bicyclists (FHWA BIKESAFE)
2) Achieving Multimodal Networks: Applying Design Flexibility & Reducing Conflicts (FHWA – 2016)
3) Guide for the Development of Bicycle Facilities (AASHTO – 2012)
4) Separated Bike Lane Planning and Design Guide (FHWA – 2015)
5) Michigan MUTCD (MDOT - 2011)

Potential Safety Impacts			Potential Mobility Impacts			Cost Estimate
Motor Vehicles	Pedestrians	Bicyclists	Motor Vehicles	Pedestrians	Bicyclists	
No Difference	No Difference	Better	Worse	No Difference	Better	Low

Bicycle Signals

What	Bicycle signal heads are an additional traffic control device which can be included in conjunction with an existing traffic signal [1]. While signage can be included to identify where crossing for bicyclists is controlled by pedestrian signal indications, independent signal heads can also be used which accommodate bicycle-specific phases or signal timing strategies [1, 2]. The FHWA has also published an interim approval (IA-16) which allows for the optional use of bicycle signal faces (shown right) [3].
Where	Bicycle signal heads should be considered at locations where bicycle-specific movements (such as a separated bicycle lane) need to be accommodated, where bicycle-specific phases (such as an "all-bike" phase or leading bicycle phasing) are being considered, or other complex locations where there are frequent conflicts between bicycles and turning motor vehicles [1, 4].
Why	Bicycle signal heads can help to improve both safety and operational performance at signalized intersections where bicycle-specific guidance is required [4].
How	More information can be found in NACTO's Urban Bikeway Design Guide [1], FHWA's Interim Approval for Optional Use of a Bicycle Signal Face [3], FHWA's BIKESAFE website [4], NACTO's Don't Give Up at the Intersection [5], and *Part 9* of the MMUTCD [5].
Key References	1) Urban Bikeway Design Guide (NACTO – 2018) 2) Achieving Multimodal Networks: Applying Design Flexibility & Reducing Conflicts (FHWA – 2016) 3) Interim Approval for Optional Use of a Bicycle Signal Face (FHWA – 2013) 4) Bicycle Signal Heads (FHWA BIKESAFE)



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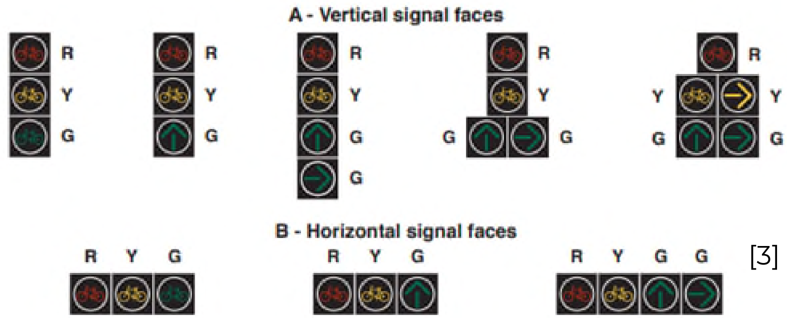


[3]

Potential Safety Impacts			Potential Mobility Impacts			Cost Estimate
Motor Vehicles	Pedestrians	Bicyclists	Motor Vehicles	Pedestrians	Bicyclists	
No Difference	No Difference	Better	Worse	No Difference	Better	Medium

Bicycle Signal Detection

What	Bicycle detection includes technology implemented at actuated signals in order to alert the signal controller of bicycle crossing demand [1]. Without appropriate detection, bicyclists must either wait for a vehicle actuate a green phase for their approach, dismount to push a pedestrian pushbutton, or otherwise cross illegally [1]. Detection devices can include traditional loop detection, video or microwave detection systems, as well as bicycle-specific pushbuttons [1].
Where	Bicycle detection should be considered along approaches where actuation is required, bicycle-specific signal heads or timing is present, or clearly marked locations where bicyclists should wait [1].
Why	Appropriate bicycle detection can help to reduce unsafe crossing behaviors by reducing delay [2] and provide extended green time for bicyclists to clear signalized intersections [1].
How	More information can be found in NACTO's Urban Bikeway Design Guide [1], FHWA's BIKESAFE website [2], FHWA's Separated Bike Lane Planning and Design Guide [3], and AASHTO's Guide for the Development of Bicycle Facilities [4]
Key References	1) Urban Bikeway Design Guide (NACTO – 2018) 2) Bike-Activated Signal Detection (FHWA BIKESAFE) 3) Separated Bike Lane Planning and Design Guide (FHWA – 2015) 4) Guide for the Development of Bicycle Facilities (AASHTO – 2012)

Potential Safety Impacts			Potential Mobility Impacts			Cost Estimate
Motor Vehicles	Pedestrians	Bicyclists	Motor Vehicles	Pedestrians	Bicyclists	
No Difference	No Difference	Better	No Difference	No Difference	Better	Low/Med

Intersection Bicycle Crossing Pavement Markings

What	Bicycle-specific pavement markings can be implemented which help to guide bicyclists on the intended path through intersections, driveways and ramps [1]. While there are variety of designs currently in use, the FHWA published an interim approval (IA-14) which allows for the optional use of green colored pavements (shown right) [2].
Where	Intersection bicycle crossing pavement markings should be considered at wide or complex locations, along roadways with bicycle-specific facilities, and other situations where common vehicle movements may frequently encroach into the bicycle space [1].
Why	Intersection crossing pavement makings can help to raise awareness for both drivers and bicyclists to potential conflict areas, reinforce bicyclist priority over turning vehicles, reduce bicyclist stress, and increase the visibility of bicyclists [1].
How	More information can be found in NACTO's Urban Bikeway Design Guide [1], Interim Approval for Optional Use of Green Colored Pavement for Bike Lanes [2], *Part 9* of the MMUTCD [3], MDOT's Pavement Markings Standards [4], and FHWA's Separated Bike Lane Planning and Design Guide [5].
Key References	1) Urban Bikeway Design Guide (NACTO – 2018) 2) Interim Approval for Optional Use of Green Colored Pavement for Bike Lanes (FHWA – 2011) 3) Michigan MUTCD (MDOT - 2011) 4) Pavement Markings (MDOT) 5) Separated Bike Lane Planning and Design Guide (FHWA – 2015)

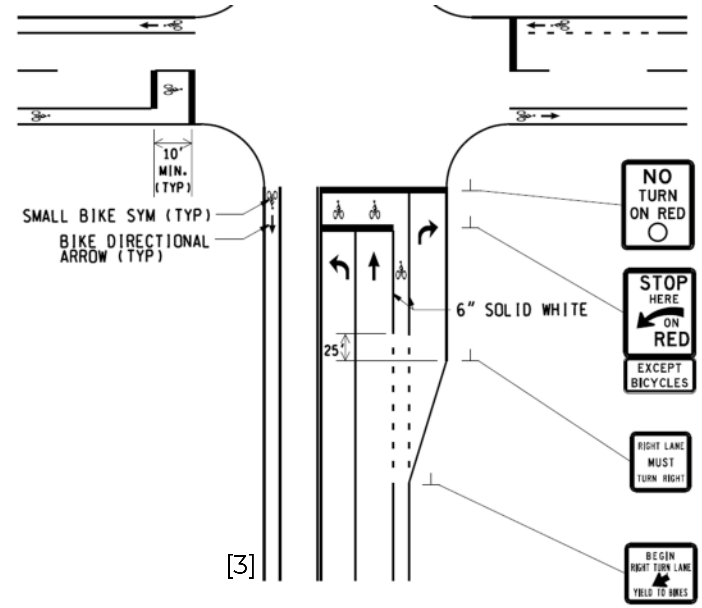

[1]


Google Maps

Potential Safety Impacts			Potential Mobility Impacts			Cost Estimate
Motor Vehicles	Pedestrians	Bicyclists	Motor Vehicles	Pedestrians	Bicyclists	
No Difference	No Difference	Better	No Difference	No Difference	Better	Low

Bicycle Boxes

What	Bicycle boxes are a designated area at the head of an approach to a signalized intersection which provides bicyclists with a space to wait in front of stopped vehicles during the red signal phase [1, 2]. The FHWA published an interim approval in 2016 which provides for the optional use of an intersection bicycle box [2].
Where	Bicycle boxes should be considered at locations with relatively high turn volumes or conflicts (particularly involving left-turning bicyclists or right-turning vehicles) [1]. The implementation of a bicycle box along an intersection approach also requires the prohibition of right-turn-on-red movements [1, 2].
Why	Bicycle boxes can help to improve the visibility of bicyclists, reduce delay for bicyclists, facilitate bicycle left-turning movements, reduce "right-hook" conflicts, and group bicyclists together to minimize their impact on traffic flow [1]. Bicycle boxes can also provide benefits for pedestrians as potential vehicle encroachments into the crosswalk are reduced [1].
How	More information can be found in NACTO's Urban Bikeway Design Guide [1], FHWA's Interim Approval for the Optional Use of an Intersection Bicycle Box [2], MDOT's Pavement Marking Standards [3], and FHWA's Separated Bike Lane Planning and Design Guide [4].
Key References	1) Urban Bikeway Design Guide (NACTO – 2018) 2) Interim Approval for Optional Use of an Intersection Bicycle Box (FHWA – 2016) 3) Pavement Markings (MDOT) 4) Separated Bike Lane Planning and Design Guide (FHWA – 2015)



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Potential Safety Impacts			Potential Mobility Impacts			Cost Estimate
Motor Vehicles	Pedestrians	Bicyclists	Motor Vehicles	Pedestrians	Bicyclists	
No Difference	Better	Better	No Difference	No Difference	Better	Low

Two-Stage Bicycle Turn Boxes

What	Two-stage bicycle turn boxes represent a designated area for bicyclists to queue to turn outside of the travel path of other bicycles and motor vehicles [1]. When used at signalized intersections, bicyclists would proceed to the turn box on a green indication and reorient within the turn box while waiting for the appropriate signal indication on the cross street [1]. The FHWA published an interim approval (IA-20) for the optional use of two-stage bicycle turn boxes in 2017 [1].
Where	Two-stage turn boxes should be considered at signalized intersections, multilane or highway speed roadways where bicyclists commonly turn left from a right-side bicycle facility [2]. While IA-20 only provides for the use at signalized intersections, two-stage bicycle turn boxes have also been implemented at midblock or unsignalized locations [2, 3].
Why	Two-stage turn boxes can help bicyclists safely and comfortably complete turning movements by reducing conflicts between the bicyclist completing the turn and motor vehicles or other bicyclists [2].
How	More information can be found in NACTO's Urban Bikeway Design Guide [2], FHWA's Interim Approval for Optional Use of Two-Stage Bicycle Turn Boxes [1], and FHWA's Separated Bike Lane Planning and Design Guide [3].
Key Reference s	1) Interim Approval for Optional Use of Two-Stage Bicycle Turn Boxes (FHWA – 2017) 2) Urban Bikeway Design Guide (NACTO – 2018) 3) Separated Bike Lane Planning and Design Guide (FHWA – 2015)


[3]

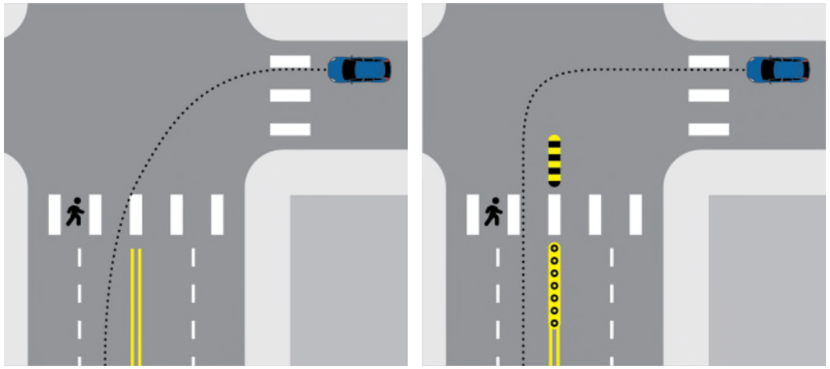

[2]

Potential Safety Impacts			Potential Mobility Impacts			Cost Estimate
Motor Vehicles	Pedestrians	Bicyclists	Motor Vehicles	Pedestrians	Bicyclists	
No Difference	No Difference	Better	No Difference	No Difference	Better	Low

Centerline Hardening

What	Centerline hardening, wedges, or other turn-related traffic calming treatments typically involving speed humps and bollards have been used which are intended to reduce conflicts between turning vehicles and non-motorized road users [1]. Several different configurations have been evaluated which alter vehicle paths to limit crossing over into crosswalks or bicycle facilities (shown right) [1, 2].
Where	Centerline hardening treatments should be considered at locations with historical conflicts between vehicles and non-motorized road users as well as where geometric characteristics exist which may lead to potential crossover concerns – particularly involving larger vehicles [2].
Why	Research has demonstrated that centerline hardening and similar turn-related traffic calming treatments have improved driver behavior [1, 2] and safety performance [2].
How	More information can be found on MDOT's Pavement Marking Standards [3], New York DOT's Left Turn Traffic Calming webpage [2], NACTO's Don't Give Up at the Intersection [4], and a study conducted by IIHS in 2020 [1].
Key References	1) The Effects of Left-Turn Traffic-Calming Treatments on Conflicts and Speeds in Washington, D.C. (Wen, H. and Cicchino, J. – 2020) 2) Left Turn Traffic Calming (NYDOT) 3) Pavement Markings (MDOT) 4) Don't Give Up at the Intersection (NACTO – 2019) 5) Simple Infrastructure Changes Make Left Turns Safer for Pedestrians (IIHS – 2020)

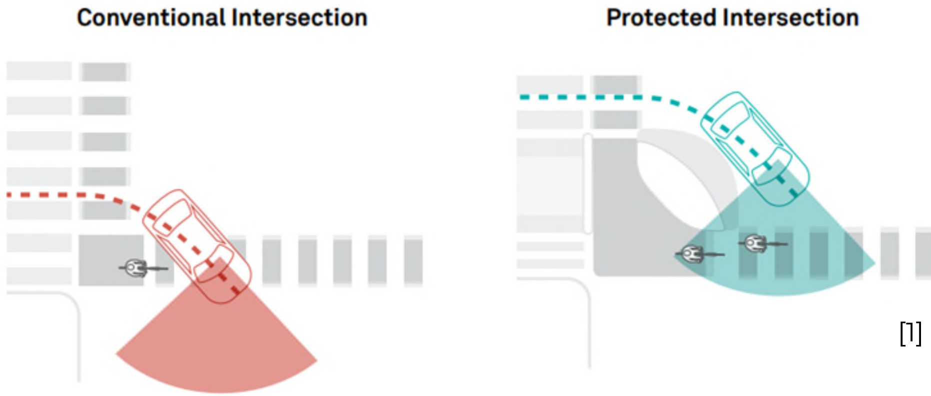
Centerline Hardening – Before and After [5]



Potential Safety Impacts			Potential Mobility Impacts			Cost Estimate
Motor Vehicles	Pedestrians	Bicyclists	Motor Vehicles	Pedestrians	Bicyclists	
No Difference	Better	Better	No Difference	Better	Better	Low

Protected and Dedicated Intersections

What	Protected intersection designs keep bicycles and vehicles physically separated up until the intersection, where bicyclists have a dedicated path through the intersection (upper right) [1]. Dedicated intersections include corner wedges, centerline hardening, speed bumps or crosswalk separators to discourage vehicles from encroaching on the bikeway (lower right) [1].
Where	Protected intersections should be considered at along urban streets where parking-protected or buffered bicycle lanes are provided [1]. Dedicated intersections should be considered where there is not enough room for a full bicycle setback [1].
Why	Protected and dedicated intersections include design features which can help to reduce motor vehicle turning speeds, improve visibility and reduce crossing distances [1].
How	More information can be found in NACTO's Don't Give Up at the Intersection [1].
Key References	1) Don't Give Up at the Intersection (NACTO – 2019)



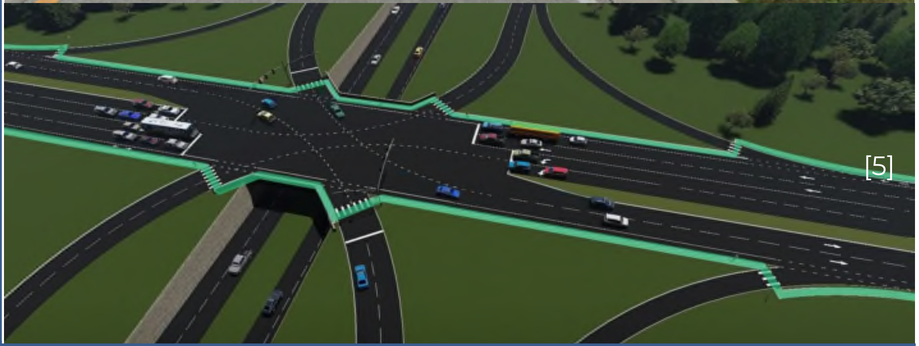
[1]

Example of a Dedicated Intersection [1]

Potential Safety Impacts			Potential Mobility Impacts			Cost Estimate
Motor Vehicles	Pedestrians	Bicyclists	Motor Vehicles	Pedestrians	Bicyclists	
No Difference	Better	Better	No Difference	Better	Better	High

Alternative Intersections and Interchanges

What	Alternative intersections and interchanges, such as diverging diamond interchanges or restricted crossing u-turn intersections, are becoming more popular among highway agencies [1]. These alternative designs often involve reversing traffic lanes from their conventional direction as well as other complex geometric conditions which may result in confusion or other safety concerns for non-motorized road users [1].
Where	Additional information and accommodation for non-motorized road users should be considered at locations where such alternative designs are being implemented [1].
Why	The unfamiliar traffic flows and patterns involved with these alternative designs requires additional information for all road users about the direction of vehicular traffic, crossing locations and bicycle-specific facilities [1].
How	More information can be found in AASHTO's Guide for the Development of Bicycle Facilities [2], FHWA's PEDSAFE website [3], FHWA's Alternative Intersections/Interchanges Informational Report [4], VDOT's Innovative Intersections and Interchanges website [5], ITE's Recommended Design Guidelines to Accommodate Pedestrians and Bicycles at Interchanges [6], and FHWA's Diverging Diamond Interchange Informational Guide [7].



[5]

Key References	1) Guide for Pedestrian and Bicycle Safety at Alternative Intersections and Interchanges (NCHRP – In Process) 2) Guide for the Development of Bicycle Facilities (AASHTO – 2012) 3) Pedestrian Accommodations at Complex Intersections (FHWA PEDAFE) 4) Alternative Intersections/Interchanges: Information Report (FHWA – 2010) 5) Innovative Intersections and Interchanges (VDOT - 2019) 6) Recommended Design Guidelines to Accommodate Pedestrians and Bicycles at Interchanges: An ITE Proposed Recommended Practice (ITE – 2014) 7) Diverging Diamond Interchange Informational Guide (FHWA – 2014)

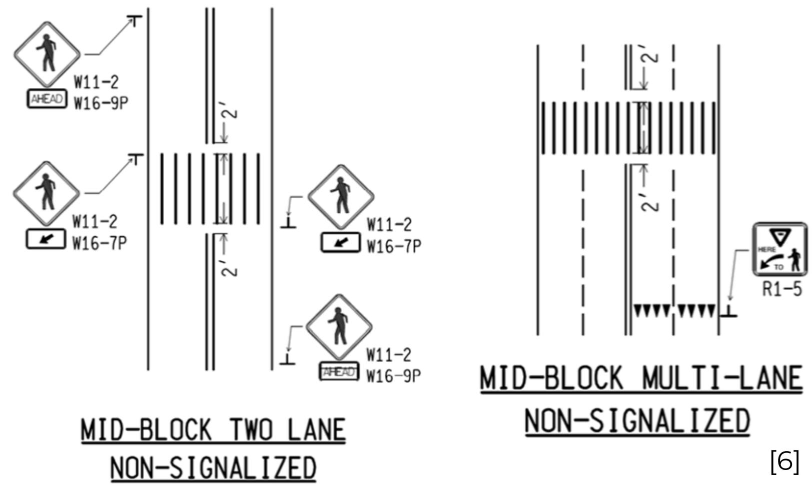
Potential Safety Impacts			Potential Mobility Impacts			Cost Estimate
Motor Vehicles	Pedestrians	Bicyclists	Motor Vehicles	Pedestrians	Bicyclists	
Better	Better	Better	Better	Better	Better	High

Unsignalized Pedestrian Crossing Improvements

Best Practice	Potential Safety Impacts			Potential Mobility Impacts			Cost Estimate
	Motor Vehicles	Pedestrians	Bicyclists	Motor Vehicles	Pedestrians	Bicyclists	
Marked Crosswalks	No Difference	Better	Better	No Difference	Better	Better	Low/Med
Advanced Yield Markings	Better	Better	No Difference	No Difference	Better	Better	Low
Raised Crosswalks	No Difference	Better	No Difference	No Difference	Better	No Difference	Medium
R1-6 Signs and Gateway Treatments	No Difference	Better	No Difference	No Difference	Better	No Difference	Low
Refuge Islands	Better	Better	Better	No Difference	Better	Better	Low/Med
Rectangular Rapid-Flashing Beacons (RRFBs)	No Difference	Better	Better	No Difference	Better	Better	Medium
Pedestrian Hybrid Beacons (PHBs)	Better	Better	Better	Worse	Better	Better	Med/High
Midblock Signals	No Difference	Better	Better	Worse	Better	Better	Med/High
Roadway Lighting	Better	Better	Better	No Difference	Better	Better	Medium
Grade Separated Crossings	Better	Better	Better	Better	Better	Better	High

Marked Crosswalks

What	Marked crosswalks are intended to indicate the optimal or preferred location for pedestrians to cross roadways as well as designate the right-of-way for drivers to yield to pedestrians [1]. While the MMUTCD provides for a variety of marking patterns, high-visibility crosswalk markings are recommended [1, 2].
Where	The MMUTCD states that "crosswalk lines should not be used indiscriminately" and that an engineering study should be conducted before installing crosswalks at uncontrolled locations which considers the number of lanes, median presence, the distance from adjacent intersections, pedestrian and vehicular volumes, speed limit, lighting as well as other appropriate factors [2].
Why	Midblock crossings can provide a convenient location for pedestrians to cross the street where intersection crossings are either infrequent or requires traveling out-of-direction [3]. Appropriately designed midblock crossings can help warn drivers of the potential presence of pedestrians and encourage pedestrians to cross at the safest midblock location [3].
How	More information can be found in FHWA's Safety Effects of Marked Versus Unmarked Crosswalks at Uncontrolled Locations [4], *Section 3B.18* of the MMUTCD [2], MDOT's Guidance for Installation of Pedestrian Crosswalks on Michigan State Trunkline Highways [5], and MDOT Pavement Marking Standards [6].
Key References	1) Marked Crosswalks (FHWA PEDSAFE) 2) Michigan MUTCD (MDOT - 2011) 3) Designing Walkable Urban Thoroughfares: A Context Sensitive Approach (ITE – 2010) 4) Safety Effects of Marked Versus Unmarked Crosswalks at Uncontrolled Locations (FHWA – 2005) 5) Guidance for Installation of Pedestrian Crosswalks on Michigan State Trunkline Highways (MDOT – 2020) 6) Pavement Markings (MDOT)



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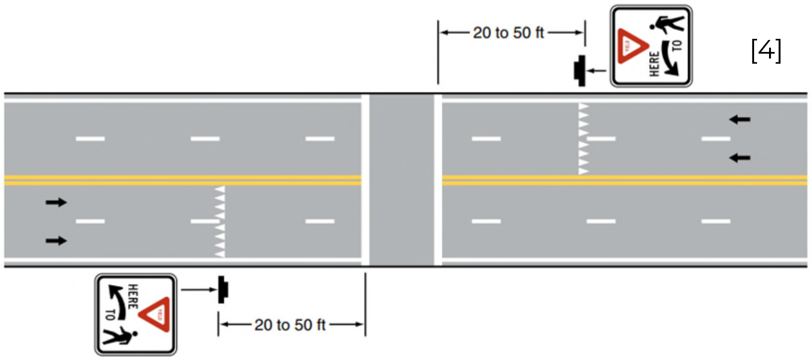
Potential Safety Impacts			Potential Mobility Impacts			Cost Estimate
Motor Vehicles	Pedestrians	Bicyclists	Motor Vehicles	Pedestrians	Bicyclists	
No Difference	Better	Better	No Difference	Better	Better	Low/Med

Advanced Yield Markings

What	Advanced YIELD markings involve implementing the yield markings upstream of an uncontrolled marked crosswalk [1]. The treatment increases the distance at which drivers either yield to pedestrians, which can increase visibility and help reduce the likelihood of "multiple-threat" crashes [1, 2]
Where	Advanced YIELD markings should be considered at uncontrolled marked crossings where there are frequent pedestrian conflicts or visibility may be limited, particularly crossings on roads with four or more lanes and speed limits of 35 MPH or greater [3].
Why	Research has consistently demonstrated that advanced YIELD markings reduce conflicts between vehicles and pedestrians as well as increase driver yielding compliance [2]. Research has shown reductions in both total (11.4%) and pedestrian-involved crashes (25.0%) after implementation [2].
How	More information can be found in FHWA's PEDSAFE website [1], NCHRP's Development of Crash Modification Factors for Uncontrolled Pedestrian Crossing Treatments [2], FHWA's Guide for Improving Pedestrian Safety at Uncontrolled Crossing Locations, and *Section 3B.16* of the MMUTCD [4].
Key References	1) Advance Yield/Stop Lines (FHWA PEDAFE) 2) Development of Crash Modification Factors for Uncontrolled Pedestrian Crossing Treatments (NCHRP – 2017) 3) Guide for Improving Pedestrian Safety at Uncontrolled Crossing Locations (FHWA – 2018) 4) Michigan MUTCD (MDOT - 2011)



Potential Safety Impacts			Potential Mobility Impacts			Cost Estimate
Motor Vehicles	Pedestrians	Bicyclists	Motor Vehicles	Pedestrians	Bicyclists	
Better	Better	No Difference	No Difference	Better	Better	Low

Raised Crosswalks

What	Raised crosswalks are ramped speed tables which span the entire width of the roadway [1, 2]. Raised crosswalks are demarcated with appropriate pavement markings and serve as a traffic calming measure where the crosswalk is at grade with the adjacent sidewalk [1, 2].
Where	Raised crosswalks can be considered along two or three lane roadways with speed limits of 30 MPH or less and daily traffic volumes below 9,000 vehicles per day [1, 2]. Midblock crossings along truck routes, emergency routes and arterial streets may not be appropriate for raised crosswalks [2].
Why	Research has demonstrated that the implementation of raised crosswalks has resulted in improved driver yielding compliance and reductions in pedestrian-involved collisions [1, 2].
How	More information can be found on FHWA's PEDSAFE website [1], FHWA's Raised Crosswalk Countermeasure Tech Sheet [2], and *Section 3B.25* of the MMUTCD [3].
Key References	1) Raised Pedestrian Crossings (FHWA PEDSAFE) 2) Raised Crosswalk Tech Sheet (FHWA – 2018) 3) Michigan MUTCD (MDOT - 2011)

Potential Safety Impacts			Potential Mobility Impacts			Cost Estimate
Motor Vehicles	**Pedestrians**	**Bicyclists**	**Motor Vehicles**	**Pedestrians**	**Bicyclists**	
No Difference	Better	No Difference	No Difference	Better	No Difference	Medium

R1-6 Signs and Gateway Treatments

What	In-street pedestrian crossing signs (MUTCD R1-6) are intended to remind road users of right-of-way laws at unsignalized pedestrian crossings [1]. The sign can be used in combination with other visibility enhancements to improve driver yielding compliance [1]. The R1-6 has been used as a part of a "gateway" treatment where signs are placed on the edge of the road as well as all lane lines which requires drivers to drive between two signs [2].
Where	The gateway treatment can be implemented at roadway crossings with speed limits of 35 MPH or less which posses a range of geometric characteristics [2]. **It is important to note that a FHWA Request to Experiment is required for configurations which involve placing the R1-6 on an edge line or the curb [2].**
Why	Research has demonstrated that the gateway treatment was associated with an increase in driver yielding compliance and a decrease in vehicular speeds [2].
How	More information can be found in MDOT's User Guide for R1-6 Gateway Treatment for Pedestrian Crossings [1], *Section 2B.12* of the MMUTCD [2], and MDOT's Guidance for Installation of Pedestrian Crosswalks on Michigan State Trunkline Highways [3].
Key References	1) In-Street Pedestrian Crossing Sign (FHWA PEDSAFE) 2) User Guide for R1-6 Gateway Treatment for Pedestrian Crossings (MDOT – 2018) 3) Michigan MUTCD (MDOT - 2011) 4) Guidance for Installation of Pedestrian Crosswalks on Michigan State Trunkline Highways (MDOT – 2020)

Potential Safety Impacts			Potential Mobility Impacts			Cost Estimate
Motor Vehicles	Pedestrians	Bicyclists	Motor Vehicles	Pedestrians	Bicyclists	
No Difference	Better	No Difference	No Difference	Better	No Difference	Low

Refuge Islands

What	Refuge islands, also referred to as crossing islands, are areas located within a highway crossing where a pedestrian can take refuge and separate crossings into two stages [1]. Refuge islands must include a raised median at least six feet in width, with larger widths preferred to accommodate bicycles adjacent to shared-use paths [1]. Additional treatments, such as curb extensions, high-visibility crosswalk markings, and R1-6 signs should also be considered in conjunction with the installation of a refuge island [2].
Where	While refuge islands should be considered across a broad range of midblock crossing environments, they are highly desirable for crossings of roadways with four or more lanes - particularly where posted speed limits exceed 30 MPH or daily traffic volumes exceed 9,000 vehicles per day [2].
Why	Appropriately designed refuge islands can enhance the visibility of crossings, reduce approach speeds, and reduce crossing distances [2]. Research has demonstrated a 26% reduction in total crashes and a 32% reduction in pedestrian-involved collisions [3].
How	More information can be found in MDOT's User Guide for R1-6 Gateway Treatment for Pedestrian Crossings [1], FHWA's Pedestrian Refuge Island Tech Sheet [2], and *Section 31.06* of the MMUTCD [4].
Key References	1) Guidance for Installation of Pedestrian Crosswalks on Michigan State Trunkline Highways (MDOT – 2020) 2) Pedestrian Refuge Island Tech Sheet (FHWA – 2018) 3) Development of Crash Modification Factors for Uncontrolled Pedestrian Crossing Treatments (NCHRP – 2017) 4) Michigan MUTCD (MDOT - 2011) 5) Field Guide for Selecting Countermeasures at Uncontrolled Pedestrian Crossing Locations (FHWA – 2018)

[5]

Potential Safety Impacts			Potential Mobility Impacts			Cost Estimate
Motor Vehicles	Pedestrians	Bicyclists	Motor Vehicles	Pedestrians	Bicyclists	
Better	Better	Better	No Difference	Better	Better	Low/Med

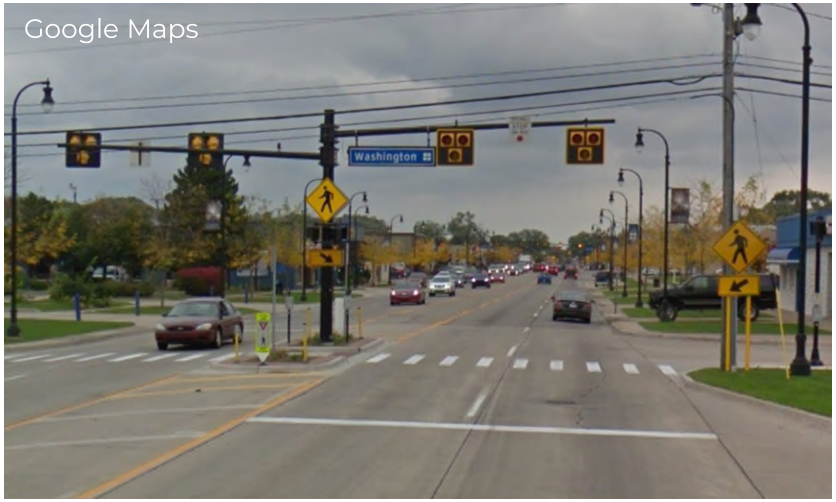
Rectangular Rapid-Flashing Beacons (RRFBs)

What	Rectangular rapid-flashing beacons (RRFBs) are "pedestrian-actuated conspicuity enhancements for pedestrian and school crossing warning signs under certain limited conditions" [1]. RRFBs "use rectangular-shaped high-intensity light-emitting-diode (LED)-based indications, flashes rapidly in a combination wig-wag and simultaneous flash pattern and may be mounted immediately adjacent to the crossing sign" [1]. It is important to note that FHWA published an interim approval (IA-21) in 2018 which allows for the optional use of RRFBs after an agency requests permission [1].
Where	RRFBs require an engineering analysis of the site conditions and should be considered where drivers are not expecting pedestrians or where special emphasis is required [2]. RRFBs can be used in a variety of scenarios, including midblock crossings, uncontrolled intersection crossings, and the approach to or egress from roundabouts [2].
Why	RRFBs can improve the conspicuity of crossings and have been shown to improve driver yielding compliance as well as reduce pedestrian-involved crashes by 47% when used in the appropriate setting [2].
How	More information can be found in FHWA's Interim Approval 21 – Rectangular Rapid-Flashing Beacons at Crosswalks [1], MDOT's Guidance for Installation of Pedestrian Crosswalks on Michigan State Trunkline Highways [2], FHWA's Rectangular Rapid-Flashing Beacon Tech Sheet [3], *Section 1.4.1* of MDOT's Electronic Traffic Control Device Guidelines [4], and MDOT's Rectangular Rapid-Flashing Beacon Special Detail [5].
Key References	1) Interim Approval 21 – Rectangular Rapid-Flashing Beacons at Crosswalks (FHWA - 2018) 2) Guidance for Installation of Pedestrian Crosswalks on Michigan State Trunkline Highways (MDOT – 2020) 3) Rectangular Rapid-Flashing Beacon Tech Sheet (FHWA – 2018) 4) MDOT Electronic Traffic Control Device Guidelines (MDOT) 5) Rectangular Rapid Flashing Beacon Special Detail (MDOT – 2013)

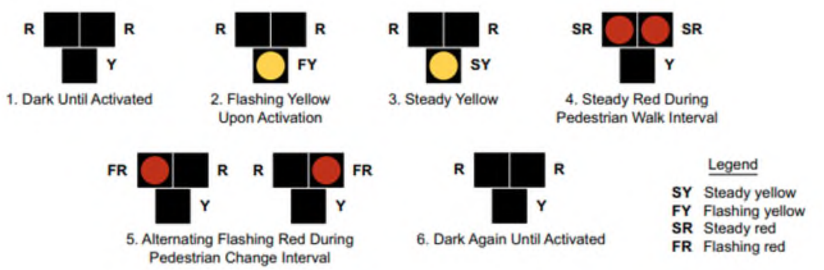
Potential Safety Impacts			Potential Mobility Impacts			Cost Estimate
Motor Vehicles	Pedestrians	Bicyclists	Motor Vehicles	Pedestrians	Bicyclists	
No Difference	Better	Better	Worse	Better	Better	Medium

Pedestrian Hybrid Beacons (PHBs)

What	Pedestrian hybrid beacons (PHBs), which have previously referred to as "high-intensity activated crosswalk beacons" or HAWK signals, are "a special type of hybrid beacon used to warn and control traffic at an unsignalized location to assist pedestrians in crossing a street or highway at a marked crosswalk" [1, 2]. PHBs include two red lenses above a single yellow lens and rest in dark until actuated by a pedestrian (shown lower right) [3].
Where	PHBs are intended to serve as an alternative when signal warrants are not met but crossing demand exists and vehicle speeds or volumes are high [2, 3]. PHBs should only be considered for crosswalks which are at least 100 away from an adjacent intersection or driveway [2].
Why	Research has demonstrated reductions in both total and pedestrian-involved crashes associated with PHBs [4].
How	More information can be found in *Chapter 4F* of the MMUTCD [1], MDOT's Guidance for Installation of Pedestrian Crosswalks on Michigan State Trunkline Highways [2], FHWA's Pedestrian Hybrid Beacon Tech Sheet [3], and *Section 1.4.2* of MDOT's Electronic Traffic Control Device Guidelines [5].
Key References	1) Michigan MUTCD (MDOT - 2011) 2) Guidance for Installation of Pedestrian Crosswalks on Michigan State Trunkline Highways (MDOT – 2020) 3) Pedestrian Hybrid Beacon Tech Sheet (FHWA – 2018) 4) Development of Crash Modification Factors for Uncontrolled Pedestrian Crossing Treatments (NCHRP – 2017) 5) MDOT Electronic Traffic Control Device Guidelines (MDOT)



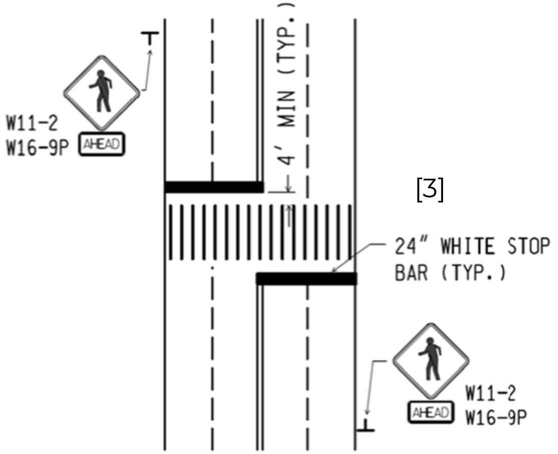
Sequence for a Pedestrian Hybrid Beacon [1]



Potential Safety Impacts			Potential Mobility Impacts			Cost Estimate
Motor Vehicles	Pedestrians	Bicyclists	Motor Vehicles	Pedestrians	Bicyclists	
Better	Better	Better	Worse	Better	Better	Med/High

Midblock Signals

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 MMUTCD 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	More information can be found in *Section 4C.05* of the MMUTCD [1], MDOT's Electronic Traffic Control Device Guidelines [2], MDOT's Pavement Design Standards [3], and MDOT's Guidance for Installation of Pedestrian Crosswalks on Michigan State Trunkline Highways [4].
Key References	1) Michigan MUTCD (MDOT - 2011) 2) MDOT Electronic Traffic Control Device Guidelines (MDOT) 3) Pavement Markings (MDOT) 4) Guidance for Installation of Pedestrian Crosswalks on Michigan State Trunkline Highways (MDOT – 2020)



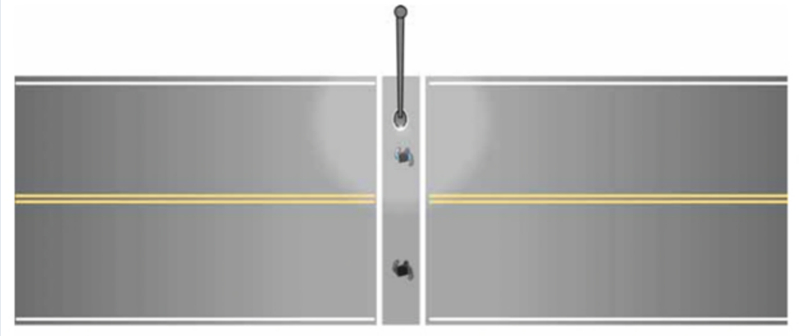
[3]

Potential Safety Impacts			Potential Mobility Impacts			Cost Estimate
Motor Vehicles	Pedestrians	Bicyclists	Motor Vehicles	Pedestrians	Bicyclists	
No Difference	Better	Better	Worse	Better	Better	Med/High

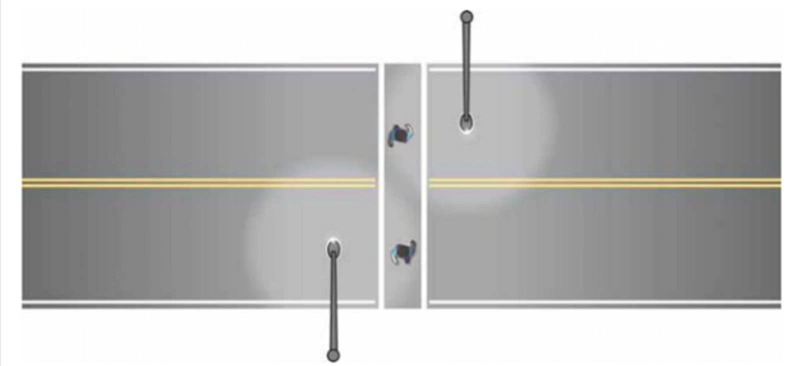
Roadway Lighting

What	Roadway lighting which illuminates crosswalks and reduces glare for drivers is an important consideration in designing for non-motorized road users [1]. While traditionally one luminaire has been installed directly over the crosswalk, new designs now include two luminaires placed upstream of the crosswalk [2].
Where	Sufficient roadway illumination should be considered at all marked crossings where pedestrian and bicyclist crossing activity is observed or expected.
Why	The appropriate quality and placement of lighting can increase comfort and safety for all road users [1]. Overhead lighting can generally provide greater visibility than headlights alone to illuminate crosswalks [2].
How	More information can be found in FHWA's Informational Report on Lighting Design for Midblock Crosswalks [2], *Section 9.03.01* of MDOT's Road Design Manual [3], and MDOT's Guidance for Installation of Pedestrian Crosswalks on Michigan State Trunkline Highways [4].
Key References	1) Lighting and Illumination (FHWA PEDSAFE) 2) Informational Report on Lighting Design for Midblock Crosswalks (FHWA – 2008) 3) Road Design Manual (MDOT) 4) Guidance for Installation of Pedestrian Crosswalks on Michigan State Trunkline Highways (MDOT – 2020)

Traditional Midblock Crosswalk Lighting Layout [2]



New Design Midblock Crosswalk Lighting Layout [2]



Potential Safety Impacts			Potential Mobility Impacts			Cost Estimate
Motor Vehicles	Pedestrians	Bicyclists	Motor Vehicles	Pedestrians	Bicyclists	
Better	Better	Better	No Difference	Better	Better	Medium

Grade Separated Crossings

What	Grade separated crossings, such as pedestrian bridges or underpasses, allow for the uninterrupted flow of non-motorized road user movements [1].
Where	Grade separated crossings should only be considered as a last resort given that they are costly and poorly utilized when a direct grossing at-grade can be completed [1]. Grade separated crossings may be appropriate at freeways, high-speed arterials, railroads and natural barriers where implementing at-grade crossings is not feasible [1].
Why	Research has demonstrated reductions in both total and pedestrian-involved crashes associated with overpasses and underpasses [2].
How	More information can be obtained on FHWA's PEDSAFE website [1], MDOT's Michigan Bridge Design Manual [3], as well as AASHTO's Pedestrian [4] and Bicycle [5] Guides.
Key References	1) Pedestrian Overpasses/Underpasses (FHWA PEDSAFE) 2) Toolbox of Countermeasures and Their Potential Effectiveness for Pedestrian Crashes (FHWA – 2008) 3) Michigan Bridge Design Manual (MDOT) 4) Guide for the Planning, Design, and Operation of Pedestrian Facilities (AASHTO – 2004) 5) Guide for the Development of Bicycle Facilities (AASHTO – 2012)


Google Maps

Michigan DNR

Potential Safety Impacts			Potential Mobility Impacts			Cost Estimate
Motor Vehicles	Pedestrians	Bicyclists	Motor Vehicles	Pedestrians	Bicyclists	
Better	Better	Better	Better	Better	Better	High

Corridor Improvements

Best Practice	Potential Safety Impacts			Potential Mobility Impacts			Cost Estimate
	Motor Vehicles	Pedestrians	Bicyclists	Motor Vehicles	Pedestrians	Bicyclists	
Sidewalks and Paved Shoulders	Better	Better	Better	Better	Better	Better	Med/High
Shared Use Paths and Sidepaths	No Difference	Better	Better	Better	Better	Better	High
Road Diets	Better	Better	Better	No Difference	Better	Better	Low/Med
Raised Medians	Better	Better	Better	Better	Better	Better	High
On-Street Parking	Worse	Better	Better	Worse	Better	Better	Varies
Back-In Angle Parking	Better	Better	Better	Worse	No Difference	Better	Varies
Shared Lane Markings	No Difference	No Difference	Better	No Difference	No Difference	Better	Low
Bicycle Lanes	No Difference	No Difference	Better	Better	No Difference	Better	Medium
Buffered Bicycle Lanes	No Difference	No Difference	Better	Better	Better	Better	Med/High
Contra-Flow Bicycle Lanes	No Difference	No Difference	Better	Better	No Difference	Better	Medium
Left-Side Bicycle Lanes	No Difference	No Difference	Better	Better	No Difference	Better	Medium
Separated Bicycle Lanes	Better	Better	Better	Better	Better	Better	High
Transit Accommodation	Better	Better	Better	Better	Better	Better	High
Bicycle Wayfinding	No Difference	No Difference	Better	No Difference	No Difference	Better	Low

Sidewalks and Paved Shoulders

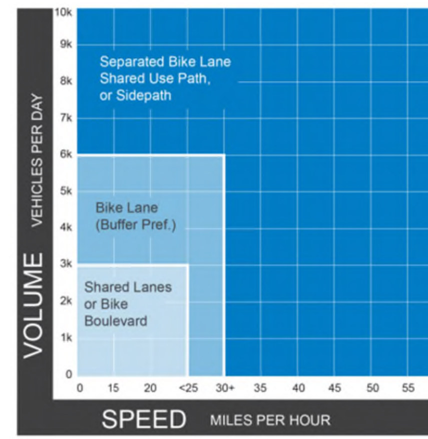
What	Sidewalks are intended to provide a dedicated space for pedestrians that is safe, comfortable, and accessible [1]. The inclusion of paved shoulders along a highway can also offer a variety of benefits for non-motorized road users, including providing space for travel, facilitating safer passing behaviors and increasing comfort [2].
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	Sidewalks serve a variety of key functions in cities, including providing access and mobility for pedestrians, enhancing connectivity and promoting walking [3]. Wide paved shoulders "can greatly improve bicyclist safety and comfort, particularly on higher-speed, higher-volume roadways" [2]. Research has shown that the inclusion sidewalks have reduced pedestrian-involved crashes by 88% and paved shoulders of at least four feet in width have reduced pedestrian-involved crashes by 71% [4].
How	More information can be found in FHWA's Small Town and Rural Multimodal Networks [1], FHWA's Achieving Multimodal Networks [2], NACTO's Urban Street Design Guide [3], and MDOT's Road Design Manual [5].
Key References	1) Small Town and Rural Multimodal Networks (FHWA – 2016) 2) Achieving Multimodal Networks: Applying Design Flexibility & Reducing Conflicts (FHWA – 2016) 3) Urban Street Design Guide (NACTO – 2018) 4) Toolbox of Countermeasures and Their Potential Effectiveness for Pedestrian Crashes (FHWA – 2013) 5) Road Design Manual (MDOT)

Potential Safety Impacts			Potential Mobility Impacts			Cost Estimate
Motor Vehicles	Pedestrians	Bicyclists	Motor Vehicles	Pedestrians	Bicyclists	
Better	Better	Better	Better	Better	Better	Med/High

Shared Use Paths and Sidepaths

What	Shared use paths provide non-motorized road users with a travel area separated from vehicular traffic [1]. Sidepaths, or a shared use path which is located parallel to an adjacent roadway, have been used extensively in Michigan (shown upper right) [2].
Where	Shared use paths have a variety of applications, but are often included adjacent to parks, rivers, beaches, greenbelts or utility corridors [1]. While the installation of a shared use path or sidepath should consider bicycle user comfort thresholds, best practices, available right-of-way, highway network characteristics and adjacent land uses, the included chart (lower right) can help to identify scenarios where such facilities may be appropriate for an “interested but concerned” design user [2].
Why	Shared use paths and sidepaths can help to provide a more comfortable experience for non-motorized road users [1].
How	More information can be found in MDOT’s Sidepath Intersection and Crossing Treatment Guide [2], AASHTO’s Guide for the Development of Bicycle Facilities [3], MDOT’s Pavement Marking Standards [4], *Chapter 12* of MDOT’s Road Design Manual [5], and *Section 9C.03* of the MMUTCD [6].
Key References	1) Small Town and Rural Multimodal Networks (FHWA – 2016) 2) Sidepath Intersection and Crossing Treatment Guide (MDOT – 2018) 3) Guide for the Development of Bicycle Facilities (AASHTO – 2012) 4) Pavement Markings (MDOT) 5) Road Design Manual (MDOT) 6) Michigan MUTCD (MDOT - 2011)

Bicycle Facility Selection for Interested but Concerned Design Users
[2]

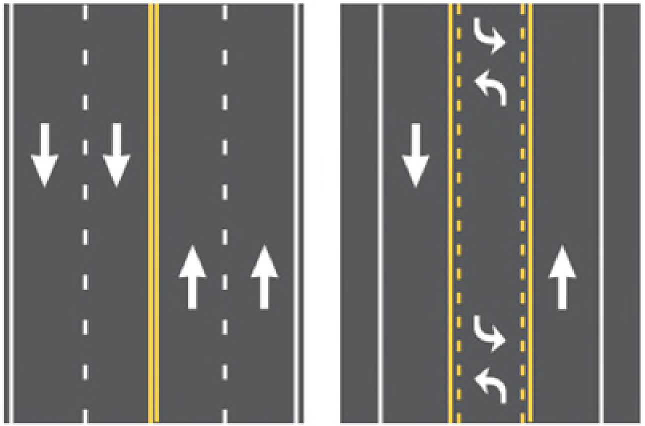


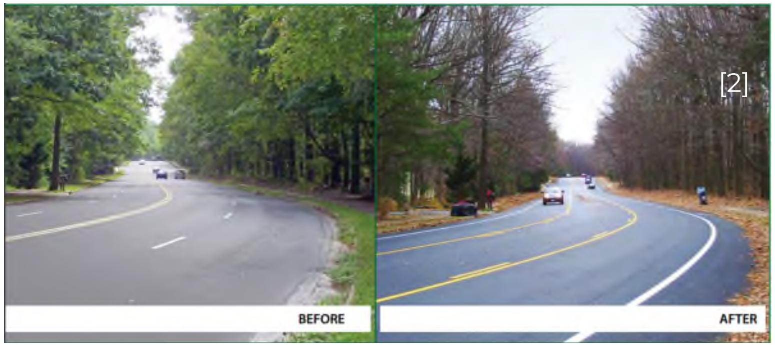
Potential Safety Impacts			Potential Mobility Impacts			Cost Estimate
Motor Vehicles	Pedestrians	Bicyclists	Motor Vehicles	Pedestrians	Bicyclists	
No Difference	Better	Better	Better	Better	Better	High

Road Diets

What	Road diets represent "the reallocation of road space through the reduction of the number of motorized traffic lanes" [1]. While there are a variety of potential roadway reconfigurations, the most common road diet involves the conversion of a four-lane undivided roadway to a two-lane roadway which includes a center two-way left-turn lane [2]. This reallocation of space allows for the inclusion of bicycle facilities, refuge islands, transit applications or parking [2].
Where	There are a variety of factors which need to be considered in order to determine if a road diet is appropriate and feasible for a given corridor, including the surrounding land use, access point density, right-of-way considerations, traffic volumes, and speed [2].
Why	Road diets can offer a variety of traffic safety benefits as four-lane undivided highways often suffer from relatively poor safety performance at higher traffic volumes due to conflicts between through traffic and left-turning vehicles [2]. The implementation of a road diet can also offer safety benefits specific to pedestrians and bicyclists given the ability to reduce crossing distances and incorporate dedicated bicycle facilities [2].
How	More information can be found in FHWA's Road Diet Conversions: A Synthesis of Safety Research [1], FHWA's Road Diet Informational Guide [2], and MDOT's Safety and Operational Analysis of 4-Lane to 3-Lane Conversions (Road Diets) in Michigan [3].
Key References	1) Road Diet Conversions: A Synthesis of Safety Research (FHWA – 2013) 2) Road Diet Informational Guide (FHWA – 2014) 3) Safety and Operational Analysis of 4-Lane to 3-Lane Conversions (Road Diets) in Michigan (MDOT – 2012)

Before and After Road Diet Conversion [2]



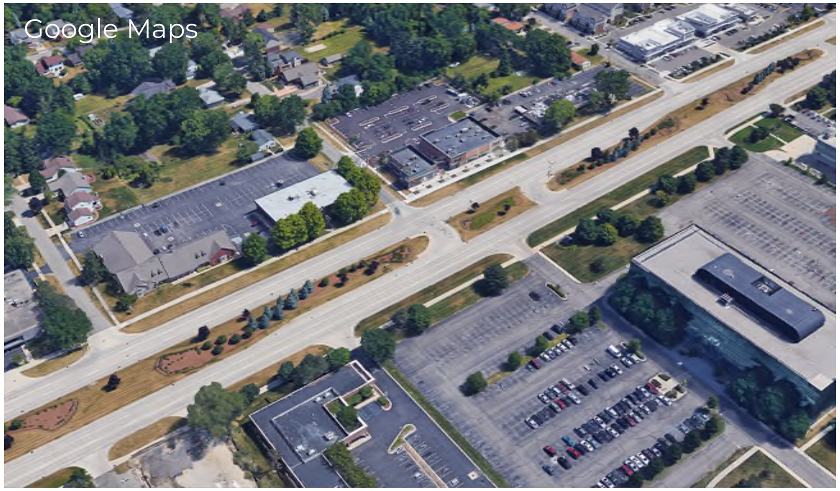


Potential Safety Impacts			Potential Mobility Impacts			Cost Estimate
Motor Vehicles	Pedestrians	Bicyclists	Motor Vehicles	Pedestrians	Bicyclists	
Better	Better	Better	No Difference*	Better	Better	Low/Med

*Depending on the daily traffic volumes served by the roadway, 4-lane to 3-lane conversions may not be feasible when volumes exceed 15,000 to 25,000 vehicles per day

Raised Medians

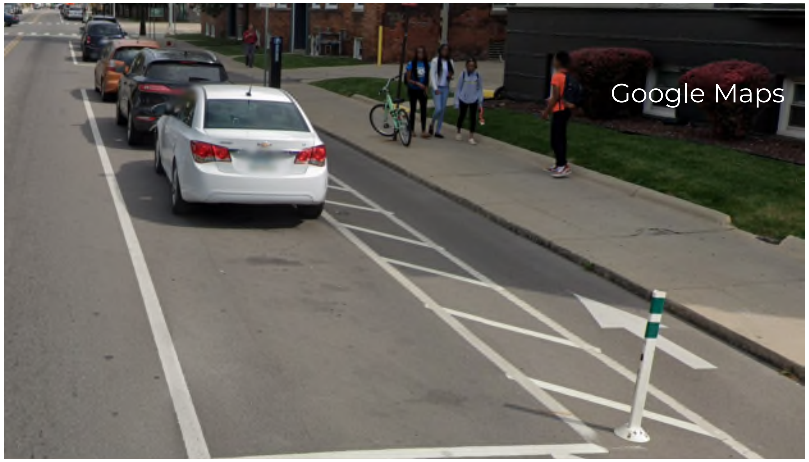
What	Raised medians are curbed sections in the center of a roadway which can help to facilitate crossing movements by allowing non-motorized road users to complete two-stage crossings, reducing the effective crossing distance [1].
Where	Raised medians can provide the largest benefits along roadways with relatively high traffic volumes or speeds [1]. Consideration should also be given to whether the space allocated to a raised median could be better used by providing other design features specific to non-motorized road users, such as wider sidewalks or bicycle lanes [1].
Why	Raised medians separate opposing traffic streams, restrict turning movements, reduce effective crossing distances, improve non-motorized road user visibility, as well as provide an area for lighting and landscaping [1]. Research has shown that the implementation of a raised median has reduced both total and pedestrian-involved crashes [2].
How	More information can be found on FHWA's PEDSAFE website [1], FHWA's Safety Benefits of Raised Medians and Pedestrian Refuge Areas [2], MDOT's Road Design Manual [3], and *Section 31.06* of the MMUTCD [4].
Key Reference s	1) Raised Medians (FHWA PEDSAFE) 2) Safety Benefits of Raised Medians and Pedestrian Refuge Areas (FHWA) 3) Road Design Manual (MDOT) 4) Michigan MUTCD (MDOT - 2011)



Potential Safety Impacts			Potential Mobility Impacts			Cost Estimate
Motor Vehicles	Pedestrians	Bicyclists	Motor Vehicles	Pedestrians	Bicyclists	
Better	Better	Better	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 either parallel (upper right) or angle parking. While on on-street parking is key to serving the needs of certain land uses adjacent to urban streets, the presence of on-street parking can have both positive and negative impacts related to non-motorized road users [1-3].
Where	Parallel parking is generally included along higher-volume urban arterials, while angled parking is generally included along low-speed and low-volume collector avenues and streets [3]. On-street parking should not be included along roadways with speeds greater than 35 MPH [3]. It should be noted that while pull-in angle parking is not permitted on state trunkline highways, back-in may be considered [4].
Why	On-street parking can result in lower travel speeds, reduce the crossing width, and serve as a buffer between vehicles and pedestrians walking along a sidewalk [1-3]. On-street parking can also reduce walking distances to destinations for disabled persons [3]. Appropriate design treatments can also reduce the potential for conflicts between bicyclists, vehicles pulling into or out of parking spacings, as well as opening vehicle doors [2].
How	More information can be found on FHWA's PEDSAFE [1] and BIKESAFE [2] websites, FHWA's Designing Walkable Urban Thoroughfares [3], *Section 2.2.3* of MDOT's Geometric Design Guidance [4], MDOT's Pavement Marking Standards [5], and *Section 3B.19* of the MMUTCD [6].



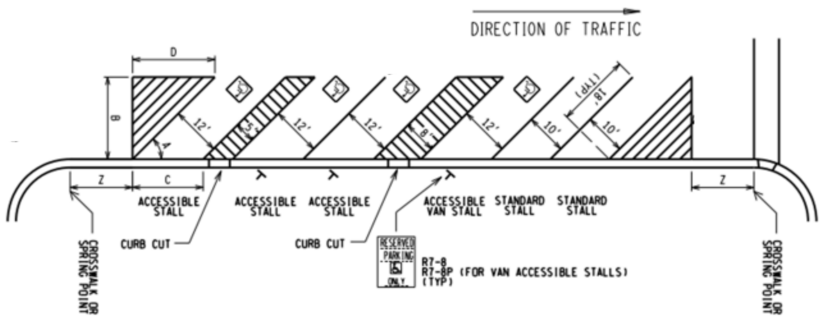
Key References	1) On-Street Parking Enhancements (FHWA PEDSAFE) 2) Parking Treatments (FHWA BIKESAFE) 3) Designing Walkable Urban Thoroughfares: A Context Sensitive Approach (ITE – 2010) 4) Geometric Design Guidance (MDOT – 2017) 5) Pavement Markings (MDOT) 6) Michigan MUTCD (MDOT - 2011)

Potential Safety Impacts			Potential Mobility Impacts			Cost Estimate
Motor Vehicles	Pedestrians	Bicyclists	Motor Vehicles	Pedestrians	Bicyclists	
Worse	Better	Better	Worse	Better	Better	Varies

Back-In Angle Parking

What	Back-in angle parking is the placement of angle parking where the front of the vehicle is parked facing the travel lane with the back of the vehicle at the curb.
Where	Given that conventional angle parking is not permitted on state trunkline highways, back-in angle parking can be used to increase on-street parking capacity in specific downtown areas [1]. MDOT provides specific criteria for the consideration of back-in angle parking in these scenarios [1].
Why	Back-in angle parking has several advantages over conventional angle parking, including providing drivers access to their trunk at the curb instead of the street, directing children to the curb due to the direction of open doors, and improving visibility for drivers when pulling out of a parking space [2].
How	More information can be found in *Section 2.2.3* of MDOT's Geometric Design Guidance [1], FHWA's PEDSAFE website [2], and MDOT's Pavement Marking Standards [3].
Key Reference s	1) Geometric Design Guidance (MDOT – 2017) 2) On-Street Parking Enhancements (FHWA PEDSAFE) 3) Pavement Markings (MDOT)

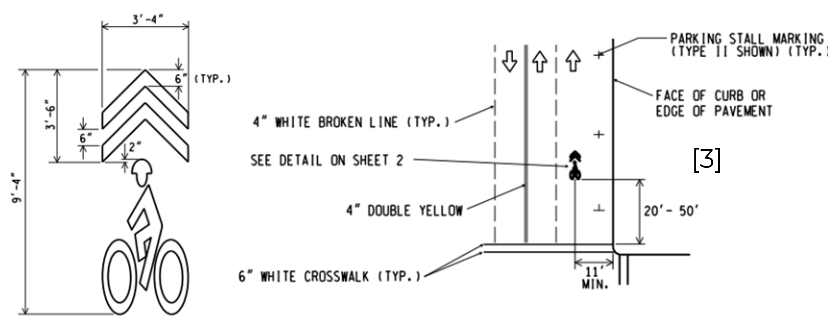
MDOT's Back-In Angle Parking Detail [3]



Potential Safety Impacts			Potential Mobility Impacts			Cost Estimate
Motor Vehicles	Pedestrians	Bicyclists	Motor Vehicles	Pedestrians	Bicyclists	
Better	Better	Better	Worse	No Difference	Better	Varies

Shared Lane Markings

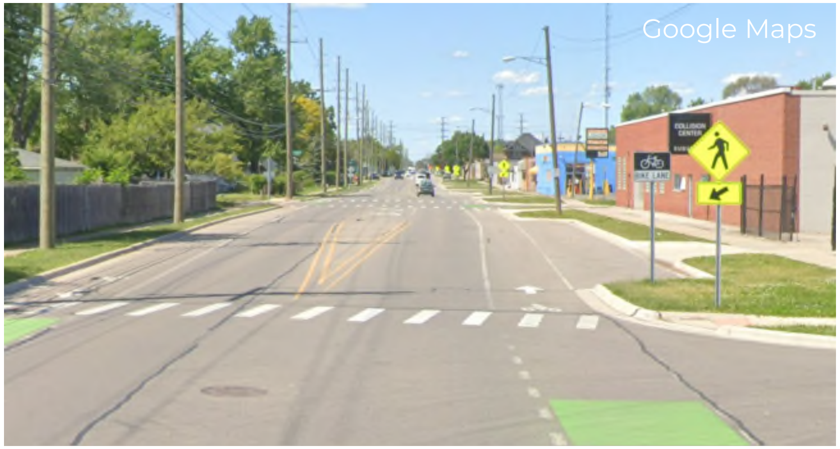
What	Shared lane markings, also referred to as “sharrows”, are pavement markings intended to indicate a shared lane environment for bicycles and vehicles [1]. Shared lane markings are comprised of a bicycle symbol with chevrons [2].
Where	Shared lane markings are used along non-freeways within urban areas in order to designate a bicycle route [2]. The design is only used along roadways with speeds of 35 MPH or less and are not used along shoulders or bicycle lanes [2].
Why	Shared lane markings can help to route bicyclists to avoid on-street parking, assist bicyclists with lateral positioning, warn drivers of the position within a lane a bicyclist will likely occupy, promote safe overtaking behaviors, and reduce the likelihood of wrong-way bicycling [2]. The markings can also help to reduce sidewalk riding, indicate the proper path for bicyclists, as well as inform other road users of the bicycle route [1].
How	More information can be found in NACTO’s Urban Bikeway Design Guide [1], MDOT’s Pavement Marking Standards [3], and *Section 9C.07* of the MMUTCD [2].
Key Reference s	1) Shared Lane Markings (NACTO – 2018) 2) Michigan MUTCD (MDOT - 2011) 3) Pavement Markings (MDOT)



Potential Safety Impacts			Potential Mobility Impacts			Cost Estimate
Motor Vehicles	Pedestrians	Bicyclists	Motor Vehicles	Pedestrians	Bicyclists	
No Difference	No Difference	Better	No Difference	No Difference	Better	Low

Bicycle Lanes

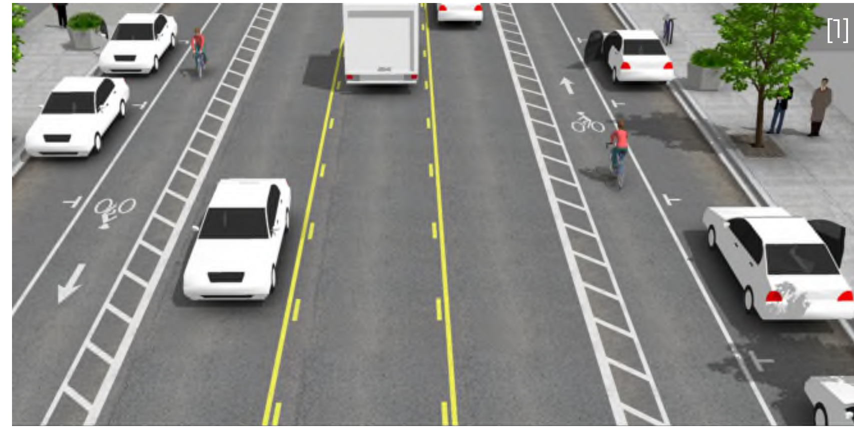
What	Bicycle lanes are "a portion of the roadway that has been designated by striping, signage, and pavement markings for the preferential or exclusive use of bicyclists." [1]. While the MMUTCD does include provisions for conventional bicycle lanes [2], it is important to note that FHWA published an interim approval in 2011 (IA-14) which allows for the optional use of green colored pavement in both marked bicycle lanes as well as extensions through intersections and other conflict areas [3].
Where	Bicycle lanes provide the largest benefit on roadways which serve greater than 3,000 vehicles per day with speeds between 25 MPH and 35 MPH [1].
Why	Bicycle lanes allow bicyclists to ride at their preferred speed, facilitate predictable behavior between vehicles and bicyclists, increase bicyclist comfort, creates a separation between vehicles and bicyclists, as well as increase the capacity for streets which serve mixed bicycle and vehicle traffic [1].
How	More information can be found in NACTO's Urban Bikeway Design Guide [1], *Section 9C.04* of the MMUTCD [2], FHWA's Interim Approval for Optional Use of Green Colored Pavement Markings [3], *Section 12.12.10* of MDOT's Road Design Manual [4], MDOT's Pavement Marking Standards [5], and AASHTO's Guide for the Development of Bicycle Facilities [6].
Key References	1) Bike Lanes (NACTO – 2018) 2) Michigan MUTCD (MDOT - 2011) 3) Interim Approval for Optional Use of Green Colored Pavement for Bike Lanes (FHWA – 2011) 4) Road Design Manual (MDOT) 5) Pavement Markings (MDOT) 6) Guide for the Development of Bicycle Facilities (AASHTO – 2012)



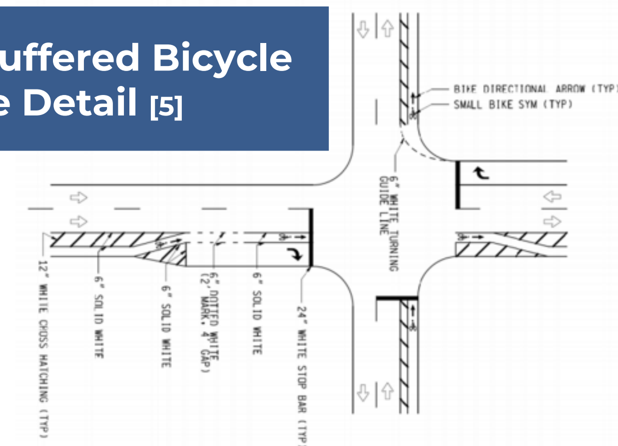
Potential Safety Impacts			Potential Mobility Impacts			Cost Estimate
Motor Vehicles	Pedestrians	Bicyclists	Motor Vehicles	Pedestrians	Bicyclists	
No Difference	No Difference	Better	Better	No Difference	Better	Medium

Buffered Bicycle Lanes

What	Buffered bicycle lanes are similar to conventional bicycle lanes except that a designated buffer space is included to separate the bicycle lane from travel or parking lanes [1]. FHWA has recognized that buffered bicycle lanes are allowable per the 2009 MUTCD [2].
Where	Buffered bicycle lanes can be considered along any route where a conventional bicycle lane would be appropriate, in addition to streets with higher speeds or traffic volumes (particularly truck volumes) [1].
Why	Buffered bicycle lanes can help to create a greater shy distance between vehicles and bicyclists, provide space for bicyclists to overtake other bicyclists, encourage bicyclists to ride outside the "door" zone adjacent to on-street parking, and improve the perceived safety of the bicycle network [1].
How	More information can be found in NACTO's Urban Bikeway Design Guide [1], *Section 9C.04* of the MMUTCD [3], *Section 12.12.10* of MDOT's Road Design Manual [4], and MDOT's Pavement Marking Standards [5].
Key Reference s	1) Buffered Bike Lanes (NACTO – 2018) 2) Bicycle Facilities and the Manual on Uniform Traffic Control Devices (FHWA) 3) Michigan MUTCD (MDOT - 2011) 4) Road Design Manual (MDOT) 5) Pavement Markings (MDOT)


[1]

MDOT's Buffered Bicycle Lane Detail [5]



Potential Safety Impacts			Potential Mobility Impacts			Cost Estimate
Motor Vehicles	Pedestrians	Bicyclists	Motor Vehicles	Pedestrians	Bicyclists	
No Difference	No Difference	Better	Better	Better	Better	Med/High

Contra-Flow Bicycle Lanes

What	Contra-flow bicycle lanes are designed to allow bicyclists to ride in the direction opposite of the vehicular traffic stream [1]. Contra-flow bicycle lanes allow for the conversion of a one-way street into a two-way street for bicyclists [1]. The FHWA has recognized that contra-flow bicycle lanes are allowable per the 2009 MUTCD [2].
Where	Contra-flow bicycle lanes can be considered along routes where frequent wrong-way bicycle movements are occurring, where alternatives require out-of-direction travel or would include uncomfortable streets for bicyclists, where two-way a connection is needed for bicyclist facilities [1]. Contra-flow bicycle lanes are appropriate along low speed and low volume streets unless a buffer or physical separation is included [1].
Why	Contra-flow bicycle lanes can help to provide connectivity for bicyclists, reduce the likelihood of wrong-way or sidewalk riding, reduce out-of-direction travel and utilize streets which are more appropriate for on-street bicycle facilities [1].
How	More information can be found in NACTO's Urban Bikeway Design Guide [1], *Section 9C.04* of the MMUTCD [3], *Section 12.12.10* of MDOT's Road Design Manual [4], and MDOT's Pavement Marking Standards [5].
Key Reference s	1) Contra-Flow Bike Lanes (NACTO – 2018) 2) Bicycle Facilities and the Manual on Uniform Traffic Control Devices (FHWA) 3) Michigan MUTCD (MDOT - 2011) 4) Road Design Manual (MDOT) 5) Pavement Markings (MDOT)

Potential Safety Impacts			Potential Mobility Impacts			Cost Estimate
Motor Vehicles	Pedestrians	Bicyclists	Motor Vehicles	Pedestrians	Bicyclists	
No Difference	No Difference	Better	Better	No Difference	Better	Medium

Left-Side Bicycle Lanes

What	Left-side bicycle lanes represent the placement of a conventional bicycle lane on the left-side of either one-way or two-way divided streets [1]. The FHWA has recognized that left-side bicycle lanes are allowable per the 2009 MUTCD [2].
Where	Left-side bicycle lanes can be considered along one-way streets or two-lane streets divided by a median, streets with frequent bus stops or loading zones, streets with a high turnover of on-street parking, streets with relatively high volumes of right-turning vehicles or left-turning bicyclists, streets where a lane is added on the right-hand side (such as a freeway off-ramp), or other scenarios where it would allow for favorable alignment to connect to other bicycle facilities [1].
Why	Left-sided bicycle lanes improve visibility of bicyclists by placing them on the driver's side, minimize potential conflicts with vehicles in on-street parking opening doors, and reduce potential conflicts with bus stops or loading zones located along the right-side of the street [1].
How	More information can be found in NACTO's Urban Bikeway Design Guide [1], *Section 9C.04* of the MMUTCD [3], *Section 12.12.10* of MDOT's Road Design Manual [4], and MDOT's Pavement Marking Standards [5].
Key References	1) Contra-Flow Bike Lanes (NACTO – 2018) 2) Bicycle Facilities and the Manual on Uniform Traffic Control Devices (FHWA) 3) Michigan MUTCD (MDOT - 2011) 4) Road Design Manual (MDOT) 5) Pavement Markings (MDOT)

Potential Safety Impacts			Potential Mobility Impacts			Cost Estimate
Motor Vehicles	Pedestrians	Bicyclists	Motor Vehicles	Pedestrians	Bicyclists	
No Difference	No Difference	Better	Better	No Difference	Better	Medium

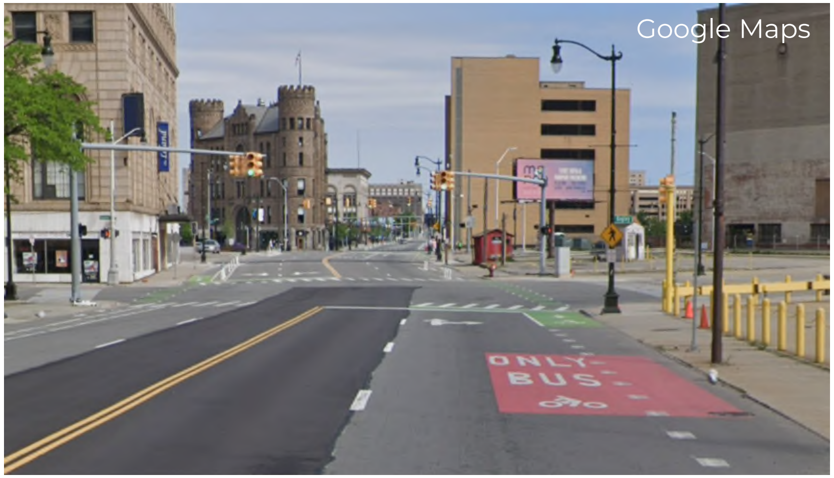
Separated Bicycle Lanes

What	Separated bicycle lanes, also known as "cycle tracks" or "protected bicycle lanes", are exclusive bicycle facilities located either within or adjacent to a roadway and are physically separated from vehicles via a vertical element [1]. Separated bicycle lanes can operate either as one-way or two-way facilities [1]. The vertical element separation can be provided by delineator posts, bollards, concrete barriers, raised medians, raised lanes, planters, parking stops, or parked cars [1].
Where	Separated bicycle lanes can be implemented along urban corridors with a variety of characteristics in order to serve a broad range of potential road users [1]. The FHWA supports a flexible design process through a context sensitive approach which considers the available options for separation as well as accommodating driveways, transit stops, intersections, parking and loading zones [1].
Why	Separated bicycle lanes can help to organize all traffic modes into designated space, reduce pedestrian crossing distances, and decrease "leapfrogging" behavior between buses and bicyclists [1]. Research has demonstrated reductions in total traffic crashes [1]. While crashes involving bicyclists have increased at locations where separated bicycle lanes were implemented, these increases were offset by increases in bicycle volumes associated with the new facilities [1].
How	More information can be found in FHWA's Separated Bike Lane Planning and Design Guide [1], *Section 9C.04* of the MMUTCD [2], *Section 12.12.10* of MDOT's Road Design Manual [3], and MDOT's Pavement Marking Standards [4].
Key References	1) Separated Bike Lane Planning and Design Guide (FHWA – 2015) 2) Michigan MUTCD (MDOT - 2011) 3) Road Design Manual (MDOT) 4) Pavement Markings (MDOT)

Potential Safety Impacts			Potential Mobility Impacts			Cost Estimate
Motor Vehicles	Pedestrians	Bicyclists	Motor Vehicles	Pedestrians	Bicyclists	
Better	Better	Better	Better	Better	Better	High

Transit Accommodation

What	Highway agencies must maintain streets which share space with transit routes through Michigan [1]. There are specific design concepts or elements which can be applied to all roadways which carry transit vehicles [1]. It should be noted that FHWA published an interim approval (IA-22) which allows for the optional use of red-colored pavement for transit lanes [2].
Where	Transit routes are incorporated within a broad range of roadway environments, and include a variety of transit amenities, surrounding land uses, ridership, and vehicle types [1].
Why	Appropriate accommodation of these transit routes into the right-of-way can help to ensure that transit riders can use the system safety and comfortably [1].
How	More information can be found in MDOT's M2D2 Guidebook [1], FHWA's Interim Approval for Optional Use of Red-Colored Pavement for Transit Lanes [2], NACTO's Transit Street Design Guide [3], FTA's Manual on Pedestrian and Bicycle Connections to Transit [4], FHWA's Pedestrian Safety Guide for Transit Agencies [5], and TCRP's Guidelines for Providing Access to Public Transportation Stations [6].
Key Reference s	1) M2D2 Guidebook (MDOT - 2019) 2) Interim Approval (IA-22) for Optional Use of Red-Colored Pavement for Transit Lanes (FHWA 2019) 3) Transit Street Design Guide (NACTO – 2018) 4) Manual on Pedestrian and Bicycle Connections to Transit (FTA – 2017) 5) Pedestrian Safety Guide for Transit Agencies (FHWA – 2008) 6) Guidelines for Providing Access to Public Transportation Stations (TCRP – 2015)



Potential Safety Impacts			Potential Mobility Impacts			Cost Estimate
Motor Vehicles	Pedestrians	Bicyclists	Motor Vehicles	Pedestrians	Bicyclists	
Better	Better	Better	Better	Better	Better	High

Bicycle Wayfinding

What	Bicycle wayfinding is provided by a system of comprehensive signing and pavement markings intended to guide bicyclists along preferred bicycle routes [1]. Signs are generally placed at intersections, key locations or other decision points along the route [1]. It should be noted that FHWA published an interim approval (IA-15) for the optional use of an alternative design for the U.S. Bicycle Route (M1-9) Sign in 2012 [2].
Where	Wayfinding should be considered along streets or bicycle facilities which are incorporated into the bicycle network [1]. Signs can be used to help direct users to destinations such as on-street bikeways, commercial areas, public transit, schools, parks or trails, hospitals, as well as other community destinations [1].
Why	Wayfinding can help to familiarize bicyclists with the network, identify the optimal route, reduce the barrier to entry for some bicyclists, estimate the time to destinations, and indicate to drivers they are traveling along a route where bicycles are likely present [1].
How	More information can be found in NACTO's Urban Bikeway Design Guide [1], FHWA's Interim Approval for the Optional use of an Alternative Design for the U.S. Bicycle Route (M1-9) Sign [2], FHWA's Bicycle Facilities and the MUTCD [4], and *Sections 9B.20 and 9B.21* of the MMUTCD [5], and AASHTO's Guide for the Development of Bicycle Facilities [6].
Key References	1) Bike Route Wayfinding Signage and Markings System (NACTO – 2018) 2) Interim Approval for the Optional Use of an Alternative Design for the U.S. Bicycle Route (M1-9) Sign (FHWA – 2012) 3) U.S. Bicycle Routes in Michigan (MDOT) 4) Bicycle Facilities and the Manual on Uniform Traffic Control Devices (FHWA – 2017) 5) Michigan MUTCD (MDOT - 2011) 6) Guide for the Development of Bicycle Facilities (AASHTO – 2012)

Potential Safety Impacts			Potential Mobility Impacts			Cost Estimate
Motor Vehicles	Pedestrians	Bicyclists	Motor Vehicles	Pedestrians	Bicyclists	
No Difference	No Difference	Better	No Difference	No Difference	Better	Low