DEVELOPING A CONSISTENT DATA DRIVEN METHODOLOGY TO MULTIMODAL, PERFORMANCE BASED AND CONTEXT SENSITIVE DESIGN

Final Report

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September 30, 2022

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. MDOT Project Manager
SPR-1719	N/A	John Martin

4. Title and Subtitle
Developing a Consistent Data Driven Methodology to Multimodal, Performance Based and Context Sensitive Design

5. Report Date
September 30, 2022

6. Performing Organization Code
N/A

7. Author(s)
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8. Performing Organization Report No.
N/A

9. Performing Organization Name and Address
Michigan State University
428 S. Shaw Lane
East Lansing, Michigan 48824

10. Work Unit No. (TRAIS)
N/A

11. Contract or Grant No.
Contract 2019-0996

11 (a). Authorization No.
N/A

12. Sponsoring Organization Name and Address
Michigan Department of Transportation
Research Administration
8885 Ricks Rd.
P.O. Box 30049
Lansing, Michigan 48909

13. Type of Report and Period Covered
Final Report, 10/01/2019 – 9/30/2022

14. Sponsoring Agency Code
N/A

15. Supplementary Notes
Conducted in cooperation with the U.S. Department of Transportation, Federal Highway Administration. MDOT research reports are available at www.michigan.gov/mdotresearch.

16. Abstract
Transportation agencies have begun to adopt design practices that introduce greater flexibility and promote a more holistic approach to design as opposed to a strict adherence in designing to standards. This allows for explicit consideration of economic, social, and environmental resources as opposed to more traditional design strategies that are largely focused on physical aspects, standards, and specifications. This approach results in the development of transportation facilities that are well suited to contextual factors that are unique to communities, as well as the range of transportation users and modes that are expected to use these facilities.

The purpose of this project was to develop methods and tools that can be used at the early planning stage in order to aid the Michigan Department of Transportation (MDOT) in key design decisions, such as the consideration of specific travel modes and the selection of relevant cross-sectional characteristics. The study involved a review of state and national guidance focused on the selection of appropriate treatments to accommodate pedestrians and bicyclists, including associated decision criteria. A review was also conducted as to the availability of pertinent data sources at the statewide level. A review of best practices led to the identification of various pedestrian and bicyclist treatments for various site types. This information was supplemented by a review of current MDOT practices, culminating in the development of treatment matrices for four site types: (1) pedestrian segments; (2) bicycle segments; (3) midblock crossings; and (4) intersection crossings. For each site type, the corresponding matrices identify potential treatments that are appropriate based upon annual average daily traffic, speed limit, context, number of lanes, and median type. For each combination of these input variables, up to three prospective treatments were identified. To aid transportation agency staff in utilizing these matrices, a decision-support tool was developed using Visual Basic for Applications. The tool allows the user to enter site-specific information, which is then used to identify prospective treatments that can be applied across a range of scenarios. The content developed as a part of this project will assist MDOT in apply a consistent data-driven approach to highway design that is multimodal, performance-based, and context-sensitive.

17. Key Words
Context sensitive design; pedestrian; bicyclist; decision-support tool

18. Distribution Statement
No restrictions. This document is available to the public through the Michigan Department of Transportation

19. Security Classification (of this report)	20. Security Classification (of this page)	21. No. of Pages	22. Price
Unclassified.	Unclassified.	178	N/A

Form DOT F 1700.7 (8-72) **Reproduction of completed page authorized**

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EXECUTIVE SUMMARY

Historically, highway design has focused on the primary functions of mobility and accessibility as part of a hierarchical functional classification system. Context has largely been considered at a very aggregate level (e.g., rural versus urban), introducing challenges given the wide range of contexts that are encountered in practice. This tended to result in designs that did not adequately serve the needs of pedestrians, bicyclists, and transit riders. Subsequently, transportation agencies have begun to adopt design practices that introduce greater flexibility and promote a more holistic approach to design as opposed to a strict adherence in designing to standards.

For example, the Michigan Department of Transportation (MDOT) has largely adopted context-sensitive solutions and design (CSS/D), Complete Streets policies, and a Multimodal Development and Delivery (M2D2) process. This allows for explicit consideration of economic, social, and environmental resources as opposed to more traditional design strategies that are largely focused on physical aspects, standards, and specifications. This approach results in the development of transportation facilities that are well suited to contextual factors that are unique to communities, as well as the range of transportation users and modes that are expected to use these facilities. Research has shown that transportation agencies often focus on CSS/D during later project planning and design phases. Ideally, these issues should be considered earlier, which would result in cost efficiencies and a more proactive approach to addressing community concerns. To that end, the purpose of this project was to develop methods and tools that can be used at the early planning stage in order to aid MDOT in key design decisions, such as the consideration of specific travel modes and the selection of relevant cross-sectional characteristics.

This study involved a review of state and national guidance focused on the selection of appropriate treatments to accommodate pedestrians and bicyclists, including associated decision criteria. This review showed that facilities for non-motorized users were generally selected on the basis of factors such as annual average daily traffic (AADT), speed limit, number of travel lanes, and context (e.g., urban, suburban, rural). A review was also conducted as to the availability of pertinent data sources at the statewide level that could be used for early stage planning activities.

A review of best practices led to the identification of various pedestrian and bicyclist treatments for various site types. This information was supplemented by a review of current MDOT practices, culminating in the development of treatment matrices for four scenarios: (1) pedestrian segments; (2) bicycle segments; (3) midblock crossings; and (4) intersection crossings. For each facility type, the corresponding matrices identify potential treatments that are appropriate based upon AADT, speed limit, context, number of lanes, and median type. In general, scenarios that present higher risks for non-motorized users (e.g., higher AADT, higher speed limits) led to treatments that provided greater protection to such users.

For each combination of these input variables, up to three prospective treatments were identified. This included a default treatment, as well as alternative treatments that were one order higher (i.e., providing greater separation or protection for non-motorized users) and one order lower (i.e., lesser separation for non-motorizes users). This provides designers with flexibility in consideration of the various factors that influence project-level design decisions.

To aid engineers, planners, and other transportation agency staff in utilizing these matrices, a decision-support tool was developed using Visual Basic for Applications (VBA). The tool allows the user to enter site-specific information, which is then used to identify a series of prospective treatments that can be applied for a broad range of scenarios. This VBA tool is expected to be most useful during the early stages of a project, especially during scoping and project development. During these stages, it is generally easier and more economical to accommodate pedestrian- and bicyclist-friendly treatments. The tool is also designed such that it is complementary to other resources, such as the multimodal tool developed for use by MDOT and the Southeast Michigan Council of Governments (SEMCOG).

Ultimately, the tools developed as a part of this project will assist MDOT in apply a consistent data-driven approach to highway design that is multimodal, performance-based, and context-sensitive. This includes project prioritization, detailed modal analyses, and design at various stages of the project development process. These tools are applicable across various contexts and travel modes and consider a diverse range of qualitative and quantitative data related to important contextual factors.

1 INTRODUCTION AND OVERVIEW

As noted in the Michigan Department of Transportation (MDOT) *Road Design Manual*, “the American Association of State Highway and Transportation Officials (AASHTO) national guides remain the standard for planning and designing Michigan roadways and multi-modal facilities”. With the recent publication of the 7th edition of *A Policy on Geometric Design of Highways and Streets* (American Association of State Highway and Transportation Officials 2018) (i.e., the “Green Book”), a new framework for geometric design has been presented. Previous editions of the Green Book focused on design based upon a functional classification system, which designated all highways and streets according to a hierarchy (e.g., arterials, collectors, and local roads) in consideration of the primary functions of mobility and accessibility. The context of these facilities was considered across these general functional classes, as well as between rural and urban environments. However, this system was criticized on several fronts as the urban vs. rural designation was unable to adequately account for the range of contexts that is encountered in the design of highways and streets (Stamatiadis et al. 2018). Furthermore, the old system was focused on motor vehicles and did not adequately serve the needs of pedestrians, bicyclists, and transit riders. The classification system also tended to promote “designing to standards” rather than careful consideration of safety, operational, and other impacts of design decisions (Stamatiadis et al. 2018).

The “new” Green Book has expanded from the two general (urban and rural) contexts to five (rural, rural town, suburban, urban, and urban core), providing a greater emphasis on design flexibility (American Association of State Highway and Transportation Officials 2018). From an agency standpoint, this framework allows for more explicit consideration of Context-Sensitive Design (CSD), which is a design process that considers economic, social, and environmental resources as opposed to more traditional design strategies that are largely focused on physical aspects, standards, and specifications. The term Context-Sensitive Solutions (CSS) is often used interchangeably, though CSS more accurately represents the larger multi-dimensional nature of the project development and implementation process. Ultimately, Context-Sensitive Solutions and Design (CSS/D) refer to this broader transportation decision-making process that aims to develop transportation facilities that are well suited to the contextual factors that are unique to the community in which the road facility is located, as well as the range of transportation users and modes that are expected to utilize the facility.

Nationally, the concepts of CSS/D were first introduced in 1997 (Federal Highway Administration 1997). The Federal Highway Administration defines CSS/D as- "a collaborative, interdisciplinary approach that involves all stakeholders in providing a transportation facility that fits its setting. It is an approach that leads to preserving and enhancing scenic, aesthetic, historic, community, and environmental resources, while improving or maintaining safety, mobility, and infrastructure conditions (Federal Highway Administration 2018). Figure 1 shows the linkage between CSS/D and various focus areas of transportation.

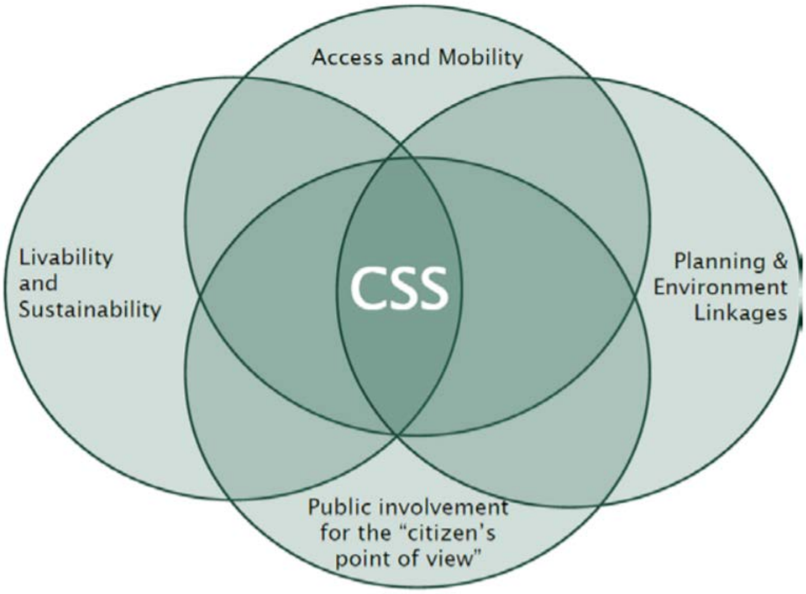

Figure 1. The linkage between CSS and key transportation focus areas (Bender et al. 2013)

The context of every project is different, and it can be divided based on the project's natural environment, social environment, functional class of roads, and travel behavior of people. The context may include community values, transportation conditions, political and policy environment, etc. (Federal Highway Administration n.d.-a).

In Michigan, early progress included the establishment of State Transportation Commission Policy 10099 on Aesthetics in 2000. The Governor's Executive Directive 2003-25 required MDOT to incorporate CSS into transportation projects whenever possible and the agency developed a CSS Draft Implementation Plan in 2004. One year later, State Transportation Commission Policy 10138 outlined the tenets of MDOT's CSS program (Michigan Department of Transportation 2005) and the agency eventually developed a CSS Manual and associated training program (Michigan Department of Transportation 2006a). Subsequently, CSS/D policies have been adopted at large-scale, both in Michigan and nationwide, culminating in a recent state-of-the-practice assessment (Fordham, Lane, Snyder, et al. 2018) and a targeted technical assistance effort by the FHWA (Fordham, Lane, Toth, et al. 2018).

In terms of its CSS/D efforts, MDOT has prioritized efforts such as Complete Streets, as well as its Multimodal Development and Delivery (M2D2) process. Collectively, these programs are oriented towards balancing the potentially competing needs of motorists, bicyclists, pedestrians, transit riders, and other users of the transportation system. These contextual factors may introduce physical, social, or environmental constraints where designing to "full standards" is not possible (Ray et al. 2014). This generally requires the design process to consider tradeoffs among competing objectives. For example, in urban areas with high volumes of non-motorized users, the use of narrower lanes or the introduction of a raised median may negatively impact motor vehicles, but significantly improve the mobility and accessibility for pedestrians and bicyclists.

Examining these types of tradeoffs is becoming an increasingly important part of the design process as costs play increasingly important roles when scoping projects. To this end, the aforementioned state-of-the-practice assessment notes that DOTs generally focus on CSS/D during the project planning and design phases, with a limited number of states incorporating such considerations in the early transportation planning stages (Fordham, Lane, Snyder, et al. 2018). This addresses a longstanding concern as, for many years, the planning, design, and construction of highways proceeded with minimal input from the public and other external agencies (Nueman et al. 2002).

Unfortunately, in these later phases, project-related decisions are generally reactive to community concerns and changes are more costly to implement. Furthermore, a critical limitation of existing design efforts is the lack of explicit guidance as to when and where specific CSS/D solutions are most appropriate. One challenge that applies broadly to project scoping and design, particularly with respect to CSS/D, is trying to assess the impacts of various design decisions. To this end, performance-based design has emerged as a means to use both quantitative and qualitative data to inform the design process in consideration of broader objectives related to CSS/D (Ray et al. 2014). This includes identifying and evaluating the impacts of pertinent design decisions on various performance measures related to objectives such as mobility, speed, and safety, among others.

The preceding discussion demonstrates a clear need to develop methods and tools that can be used at the early planning stage in order to aid MDOT in key design decisions, such as the consideration of specific travel modes and the selection of relevant cross-sectional characteristics. For these methods and tools to be broadly useful, it is important for them to be applicable across various contexts and travel modes. Furthermore, these resources should consider a diverse range of qualitative and quantitative data related to important contextual factors, including community characteristics and project stakeholders.

To that end, the purpose of this project is to assist MDOT in the development of decision support tools for use in performance-based CSS/D, allowing for project prioritization and detailed modal analyses. This report summarizes work conducted as a part of this project, which included the following objectives:

- Develop an understanding of the national best practices.
- Define the data needed for multimodal, performance based, and context sensitive design decisions.
- Develop a data driven quantitative way to define the context of all transportation modes and demands and the long-term needs in a community.
- Determine a consistent repeatable design decision methodology based on appropriate standards, contextual circumstances, and performance history.
- Develop a series of educational materials to assist MDOT in implementing this methodology.

The related to context-sensitive solutions and design (CSS/D). Chapter 3 details existing CSS/ remainder of this report is organized as follows. Chapter 2 provides a review of national best practices D guidance for various state DOTs. Chapter 4 summarizes data that are available at various temporal and spatial scales for use by MDOT. Chapter 5 summarizes those data that were collected for use in this project and the associated tool development. Chapter 6 outlines the methodology that was used in developing the treatment matrices and decision-support tool. Finally, Chapter 7 presents conclusions and recommendations for next steps.

2 REVIEW OF NATIONAL STATE-OF-PRACTICE FOR CONTEXT SENSITIVE SOLUTIONS/DESIGN

The research team conducted a comprehensive review of prior research, publications, and other resources, which detail national, state, and local practices of CSS/D. This allowed for the identification of different types of contexts and their characteristics, principles of CSS/D, the role of CSS/D in transportation/network planning, and project development. Additionally, this review will help in understanding how to achieve CSS/D, treatments and design controls, and CSS/D performance measurement programs. The understanding of CSS/D could assist MDOT to identify potential gaps and develop transportation facilities according to the context of the area.

2.1 History and Development of CSS/D

Recently, many states and local agencies have adopted CSS/D policies or are making strategies to apply CSS/D in their transportation projects. Though the foundation of CSS/D was laid in 1969, through NEPA, the concept of CSS/D was explicitly pitched for the first time during the 1990s. The following points explain the chronological development of CSS/D as a transportation policy in the US (Moler 2002):

- The concept of CSS/D was first pitched during the development of 1991’s Intermodal Surface Transportation Efficiency Act (ISTEA). In its final version, it underscored "environmentally sensitive highway design" and expanded public involvement and coordinated effort with local communities.
- Passing of the 1995 National Highway System Act put many of the Surface Transportation Policy Project’s environmental and aesthetic considerations into law, as an aspect of transportation design of Federal projects.
- In July 1997, FHWA, in collaboration with the American Association of State Highway Transportation Officials (AASHTO) and other interest groups, published “Flexibility in Highway Design,” which explains ways to use flexible design standards to minimize the negative effects of transportation on nature.
- In May 1998, the Maryland Department of Transportation held a workshop named “Thinking Beyond Pavement,” which explained 15 principles of CSS/D. This was aimed to bring together State and Federal officials, academia, and the public so that context sensitive designs should be introduced into mainstream transportation projects.

- In mid-1998, the National Training Steering Committee was formed from the representatives of- Connecticut, Kentucky, Maryland, Minnesota, and Utah DOTs, which aimed to develop training programs and guidelines to apply CSS/D in transportation projects.
- In June 1999, the American Society of Civil Engineers (ASCE), AASHTO, the Institute of Transportation Engineers (ITE), and FHWA hosted a Context Sensitive Highway Design Workshop in Reston, VA, to enhance the understanding of those who are working in CSS/D.
- In September 2001, a national CSS/D workshop was held in Missoula MT, which illustrated CSD using the US 93 project.

After 1998, the CSS/D gained much attention from planners, engineers, and designers. It is worth noting that most of the CSS/D documents and reports were published after this year. Many states have developed, updated, or been developing their CSS/D guidelines. The following section gives a brief on the purposes, needs, and benefits of CSS/D.

2.2 Principles of CSS/D

CSS/D is a collaborative and interdisciplinary approach, which helps in greater stakeholder participation and development of transportation solution that suits the context of the area. The general guideline for the principles should be concise, focused, self-explanatory, and capable of conveying the intended meaning (Stamatiadis et al. 2009). FHWA suggests four CSS/D core principles for each of the decision making process and design approach, which are mentioned in CSS/D FHWA website (Federal Highway Administration 2020a).

The CSS/D core principles for decision-making process are (Federal Highway Administration 2020a):

- Move towards a shared stakeholder vision to give a premise for decisions.
- Demonstrate an exhaustive comprehension of contexts.
- Promote continuous interaction and collaboration to reach an agreement.
- Exercise flexibility and creativity to obtain transportation solutions while preserving and upgrading community and natural environments

The CSS/D core principles for design approach are (Federal Highway Administration 2020a):

- Safe for all users

- The design process includes a shared stakeholder vision as a foundation for decisions and for taking care of issues that may emerge.
- The designs add values to the community, environment, and transportation system as it surpasses the desires of designers and stakeholders.
- Demonstrate effective and efficient use of resources.

A workshop named "Thinking Beyond the Pavement" took place in 1998, hosted by Maryland DOT in conjunction with FHWA and AASHTO, catalyzed the CSS/D related work that was being done in the United States. This workshop found 7 qualities of excellence in transportation design and 8 characteristics of the process that would yield excellence in the process of CSS/D (Pigman et al. 2004). Later these qualities and characteristics became the principles of CSS/D, that were discussed in the above paragraph. This workshop also concluded, "Context sensitive design asks questions first about the need and purpose of the transportation project, and then equally addresses safety, mobility, and the preservation of scenic, aesthetic, historic, environmental, and other community values. Context sensitive design involves a collaborative, interdisciplinary approach in which citizens are part of the design team" (Federal Highway Administration n.d.-b).

NCHRP 642 *Quantifying the Benefits of Context Sensitive Solutions* enlists 15 principles of CSS/D, in a hierarchical order of application, that are in harmony with the above mentioned 8 principles of CSS/D FHWA website (Federal Highway Administration 2020a). Some of these principles might be overlapping; Table 1 shows the 15 principles of CSS/D (Stamatiadis et al. 2009).

Table 1. Principles of CSS/D (Stamatiadis et al. 2009)

No.	Principles
1	Use interdisciplinary teams
2	Involve stakeholders
3	Seek broad-based public involvement
4	Use full range of communication strategies
5	Achieve consensus on purpose and need
6	Address alternatives and all modes
7	Consider a safe facility for users and community
8	Maintain environmental harmony
9	Address community and social issues
10	Address aesthetic treatments and enhancements
11	Utilize full range of design choices
12	Document project decisions
13	Track and meet all commitments
14	Use agency resources effectively
15	Create a lasting value for the community

2.3 Purposes Need and Benefits of CSS/D

This section identifies the benefits that can be achieved by applying CSS/D principles. Application of CSS/D framework to any project provides better value, tailored solutions, customer satisfaction, and on-time delivery of the project (Federal Highway Administration 2017b).

Better value: The projects that apply CSS/D framework deliver better project value in terms of reduced cost or more cost-effective projects. It also helps in reducing the project's cost by-right-sizing of facilities, avoidance of actions that lead to environmental clearance, which finally leads to costly litigations. CSS/D also provides a wider range of funding opportunities, which also includes non-traditional funding sources (Federal Highway Administration 2017b).

Tailored solutions: The manuals developed by DOTs suggest the design standards that may address a problem. However, the challenge for designers may arise when the solution from the manual does not fit well due to space limitations, environmental concerns, or any other issue. In this condition, a designer with appropriate knowledge of CSS/D might be helpful as they know when to apply a tailored approach. The designer may look for solutions that may avoid, minimize, or reduce the impact on the environment and well aligns with the community. A "context sensitive" designer knows how to carefully exercise the following design control and roadway elements- Design speed, design traffic and level of service, design vehicle, design elements, and facility operations (Federal Highway Administration 2017b).

The designer with a background in CSS/D knows that the design choices are influenced by contexts: topography, location, functional class of facility, land use, natural/environmental features, built environment etc. It is expected that the context sensitive designer will look for a creative solution that enhances operational safety while satisfying the stakeholders' needs (Federal Highway Administration 2017b).

Customer satisfaction: The CSS/D projects not only satisfy the customers but also induces pride into stakeholders. It also develops a stronger relationship between the transportation agency and its customers. A CSS/D process requires customers/stakeholders to get involved in finding the solution to a problem, though it requires time to listen to public but developing solutions, and this way is less expensive than redesigning the project (Federal Highway Administration 2017b).

On-time Delivery: The CSS/D projects are likely to be completed on time because the project development process can be reduced, and time wasted in redesign and litigations can be saved by understanding the issues of stakeholders in the very beginning. Some benefits may include- Simpler, Faster Permit Approvals, Reduced Environmental Analysis Requirements and Community Support (Federal Highway Administration 2017b).

Besides, these 4 main benefits transportation agencies acknowledge that the CSS/D provides many benefits to them and the road users. NCHRP: 642 *Quantifying the Benefits of Context* Sensitive Solutions, published in 2009, outlines 22 benefits of applying CSS/D framework. Table 2 summarizes these benefits, the first 11 benefits belong to a transportation agency, and the remaining 11 belong to road users/community (Stamatiadis et al. 2009).

Table 2. Benefits of implementing CSS/D

No.	Benefits
1	Improved predictability of project delivery
2	Improved project scoping and budgeting
3	Improved long-term decisions and investments
4	Improved environmental stewardship
5	Optimized maintenance and operations
6	Increased risk management and liability protection
7	Improved stakeholder/public feedback
8	Increased stakeholder/public participation, ownership, and trust
9	Decreased costs for overall project delivery
10	Decreased time for overall project delivery
11	Increased partnering opportunities
12	Minimized overall impact to human and natural environment
13	Improved mobility for users
14	Improved walkability and bikeability
15	Improved safety (vehicles, pedestrians, and bikes)
16	Improved multi-modal options (including transit)
17	Improved community satisfaction
18	Improved quality of life for community
19	Improved speed management
20	Design features appropriate to context
21	Minimized construction-related disruption
22	Improved opportunities for economic development

2.4 Types of Contexts and Characteristics

Context can be broadly described as a project's physical/natural, social, and economic setting. It may also include transportation conditions, community, ecological, aesthetic, political, and policies on the area (Federal Highway Administration 2018). The context of every project is different, and hence each context requires different types of solutions. An inventory of different contexts includes the following (Federal Highway Administration 2018), but is not limited to-

- Natural environment of area (e.g., river, mountain, open space etc.)
- Social environment of area (e.g., demographics, socioeconomic status of stakeholders, gathering places etc.)
- Function and design of transportation facility (e.g., users and trips the facility accommodate)
- Travel behavior in the area (e.g., travel mode choice, travel time etc.)
- Economic environment of area (e.g., land use, relationship of transportation facility with businesses and inhabitants of the area)
- Cultural characteristics of area (e.g., how much importance do the stakeholders give to community values)

The above mentioned six contexts categories are identified by FHWA, but they are not exhaustive, and a context can be divided further into many other categories. The AASHTO's "Green Book" version prior to 2018 (*A Policy on the Geometric Design of Highways and Streets*) used only urban and rural contexts. This was one of the most significant gaps in the Green Book as a binary of rural and urban cannot capture all contexts. Furthermore, they used a roadway functional classification system, which was composed of arterials, collectors, and local roads. This classification system coupled with the binary of urban and rural, was incompatible with context sensitive design and practical design, and had the following concerns (Stamatiadis et al. 2018):

- Binary of urban and rural are insufficient to capture for a range of contexts.
- The focus of this classification system was on automobiles, and not much focus was given to other users like bicycle, transit, pedestrian etc. this created disbenefits to these user groups.
- This classification leads to limited design choices that increased the practice of following the design standards, rather than considering for safety, operations, and other important factors.
- The public often questioned about the design decisions that were based on the classification system.

To overcome these concerns, the AASHTO Green Book's version of 2018 suggested a total of 5 contexts- Rural Context, Rural Town Context, Suburban Context, Urban Context, and Urban Core Context (American Association of State Highway and Transportation Officials 2018). These contexts cover nearly all types of areas and are based on the development density (structure and structure types per sq. unit of land), land use (residential, commercial, agricultural and/or open land) and building setbacks (distance of the building/structure from the road) (American Association of State Highway and Transportation Officials 2018). Figure 2 shows a pictorial representation of these contexts and the characteristics of these contexts as per AASHTO 2018 and NCHRP 855, are as follows (American Association of State Highway and Transportation Officials 2018; Stamatiadis et al. 2018):

Rural: These are the areas with the lowest housing density, widely dispersed or no residential/commercial area, no industries, and have large setbacks. It includes undeveloped land, farms, outdoor recreation areas, and other low density developments.

Rural Town: These are the rural areas with developed communities but low density. These have diverse land use, on-street parking, presence of sidewalks at some locations, and small building setbacks. These include residential neighborhoods, schools, industrial facilities, and commercial main street business districts.

Suburban: These are typically the outlying portions of urban areas have low to medium density, mixed land uses, and varied setbacks. The drivers have higher speed expectation than the urban areas and urban core. Here, the pedestrian and bicyclist flow are higher than the rural context but lower than urban and urban core.

Urban: Urban areas have high density, mixed land uses, and prominent destinations, with mixed setbacks. On-street parking and sidewalks in urban areas are more common than suburban areas.

Urban Core: These areas have the highest density, mixed land uses, and small building setbacks. This is the central business district of a major metropolitan area, and on-street parking is often limited and time restricted as compared to urban areas.

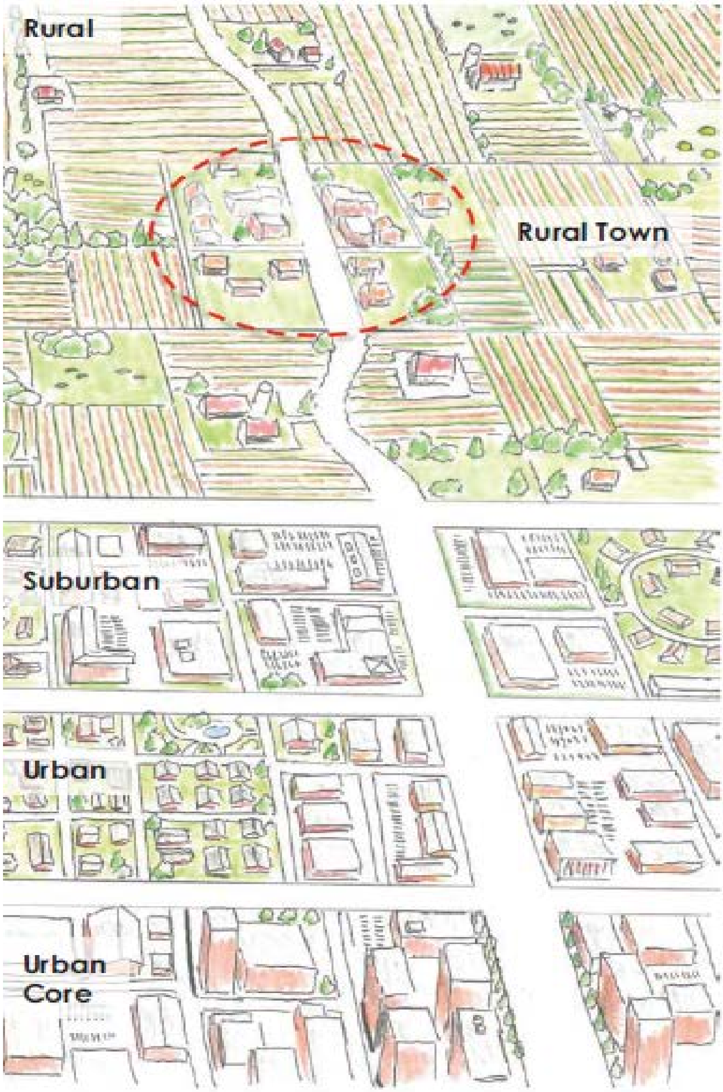

Figure 2. Five Context Categories (Stamatiadis et al. 2018)

2.5 CSS/D in Transportation Planning and Project Development

Traditionally, transportation planning relies on technical problem solving, but this is a narrower approach while accomplishing a project. Conversely, in CSS/D approach, many issues that were formerly considered outside the domain of transportation planning and designing are discussed, and their solutions and implementation plan are prepared. In this process, not only physical environment but the social, natural, and cultural environment plays an important role. Besides this, physical activity of residents and their health are also gaining attention nowadays (Federal Highway Administration 2007). CSS/D can be integrated into a transportation plan by the following ways (Federal Highway Administration 2007):

- Commitment to using CSS/D regularly.

- Understanding that CSS/D consumes times initially and be ready to invest time in visioning, identifying objectives, and priorities.
- Development of public involvement and outreach plan, with a particular focus on those communities, who were not involved in prior transportation plans.
- Develop new partnerships, look for new individuals and organizations that can serve as a resource and can assist with CSS/D process by becoming members of advisory committee, assisting with public outreach, and providing information/data for context.
- Considering the planning process as a platform to educate public, government officials, and policymakers about various transportation-related issues and the implications of transportation solutions deployed to solve that issue.
- Improved public-involvement techniques and taking assistance from facilitators.
- Improved documentation for internal/external processes and interactions.
- Use CSS/D principles as evaluation criteria to assess progress in implementing CSS/D.
- Be bold and innovative.

Some of the characteristics of transportation planning process with a focus on CSS/D includes-stakeholder communication, involvement of multidisciplinary team, upfront pre-planning of the project. It also includes the evaluation of transportation plans based on safety and access/mobility and air quality standards. Moreover, identification of quality and quantity of available data and identification of adopted municipal/State/FHWA plans and understanding of landscape and community values are also the part of CSS/D plans (Federal Highway Administration 2007).

It is a known fact that the transportation planning process can be applied at 3 tiers- National, Regional and Local agency. The CSS/D can be applied to each tier that can address various responsibilities. The CSS/D applications at the National level include the development of CSS/D and flexible design guidance, project demonstration, and research programs that address design issues. Similarly, the major CSS/D applications at Regional/ Statewide level include development of connectivity plans, multimodal and CSS/D policies, revision of state design manuals, context sensitive design of highways, and training of staff and local agency. Lastly, the major CSS/D applications at Local agency level include development of corridor plans and thoroughfare plans, integration of CSS/D into project development process, development of multimodal, and CSS/D policies (Daisa 2006).

After applying the CSS/D principles in the transportation planning process, the next stage is the project development phase. CSS/D in project development simply means the consideration of context in a comprehensive and consistent manner during the project development process (Federal Highway Administration 2007). CSS/D in project development includes the following, but not limited to (Fordham, Lane, Snyder, et al. 2018; Stamatiadis et al. 2009):

1. Flexibility in design standards with increased focus on context sensitivity
2. Encouragement of multimodal transportation
3. Fulfillment of environmental commitments
    a. Promoting an agency environmental stewardship ethics
    b. Commitment assurance
    c. Commitment tracking tools
    d. Interagency cooperation etc.
4. Involvement of multidisciplinary teams and stakeholders in early stages
5. Communication with stakeholders and communities
6. Training of CSS/D staff
7. Following a CSS/D approach on day to day basis
8. Inclusion of Performance Based Practical Design etc.

2.6 Performance-Based Practical Design (PBPD)

In the past decades due to an increased understanding of the performance of transportation facility that gives the best return on investment, PBPD has come into the light. "PBPD is a decision -making approach that helps agencies better manage transportation investments and serve system-level needs and performance priorities with limited resources" (Federal Highway Administration 2017c). PBPD is one of the basic principles of both Moving Ahead for Progress in 21st Century (MAP-21) Act and Fixing America's Surface Transportation (FAST) Act legislation. Practical design, CSS/D, and Value Engineering (V. E.) are all considered a key component of PBPD.

PBPD is a quantitative approach that increases the performance of the whole system by influencing the decisions of the project development process. PBPD examines each component of project relative to value, need, and urgency to maximize greater returns. Furthermore, it does not eliminate, modify, or degrade the existing design standards. Agencies are becoming familiar with this approach, and they are paying attention to the overall performance of transportation system (Federal Highway Administration 2017c). The key elements to initiate a PBPD program are shown in Table 3.

Table 3. Key Elements to Initiate PBPD program (Federal Highway Administration 2017c)

Step	Key Element	Brief
Learn	Become PBPD champions	It means to become a state who truly believes in PBPD, vocally support it at both leadership and staff level.
	Learn more about PBPD	Talk to the peer states about PBPD approach and its success.
Market	Obtain executive buy-in	Educate the leadership of the organization about this approach and its importance.
	Gather stakeholders	Gather stakeholders from the organizations, which involves people from policy, procurement, planning and environment, safety, and other groups.
Rollout	Determine baseline	Identification of existing processes, tools, analytical methods, project development activities etc.
	Set a goal	Establish a goal to implement PBPD program and identify the milestones in the process.
	Establish a schedule	Develop a time frame to achieve PBPD it generally takes 18 to 24 months to deploy PBPD.
Execute	Become familiar with data and analytical tools	Educate and train the staff in safety and operational tools, like Safety Analyst, Highway Safety Manual, traffic simulation etc. so that alternatives can be prepared.
	Provide technical support to staff	Provide training to the staff in understanding the tools and techniques.
	Create a sense of team	Work together and create a feeling of a team to achieve the goals.

After the initial steps have been taken, and the state is ready to implement the PBPD, few lessons that are learned from other states are highlighted (Federal Highway Administration 2017c):

- Set measurable performance targets (e.g., in a given time frame, say 5 years the total saving on a project would be 10% without compromising the commitment to public).
- Engage with the stakeholders (consultants, contractors, public, media, FHWA etc.).
- Establish a set of rules to guide the process; it may include safety, communication, and quality.

- Dedicated staff for PBPD process.
- Communication among the team is of prime importance for PBPD.
- Keeping an open mind for the new ideas and solutions.
- Keeping a document of every meeting, narrative and decisions made.
- Measure and recognize the success of PBPD process.

2.7 Procedures/Steps to Achieve CSS/D

The movement to apply CSS/D in actual practice took a new shape when the Maryland DOT in cooperation with AASHTO and FHWA hosted a workshop named "Thinking Beyond Pavement: A National Workshop on Integrating Highway Development with Communities and the Environment While Maintaining Safety and Performance" (Federal Highway Administration 2001). The conclusions of this workshop suggest that application of CSS/D is urgently needed in the highway development projects. This laid the foundation to develop a document that can provide crucial steps to achieve CSS/D, and hence *NCHRP Report 480: A Guide to Best Practices for Achieving Context Sensitive Solutions* was developed (Nueman et al. 2002). This guide suggested the following measures broadly to achieve and apply CSS/D in a project (Nueman et al. 2002)-

1. **Effective Decision Making:** This is the first and foremost step that outlines the success of a project. The critical success factor for any project is making right decisions from the beginning itself and clearly have the idea of- how the project will proceed, what are the responsibilities of each person, what analyses, methods, and discussions are needed for important decision making.
2. **Reflecting Community Values:** This generally means employing the principles of public involvement in transportation decision making so that it can represent the whole community. The general characteristics of public involvement are- proactiveness, tailoring the solutions to local needs, regularly occurring, utilizing a blend of techniques, strong leadership, and education on technical matters.
3. **Achieving Environmental Sensitivity:** This measure assures that the transportation project has minimal impact on the environment. The persons engaged in context sensitive designs (CSS/D professionals) see themselves as environmental curators rather than transportation providers. This attitude is different from the old way of solving transportation-related issues, which creates a significant difference on ground.

4. **Ensuring Safe and Feasible Solutions:** This measure emphasizes to develop transportation solutions that are safe and feasible (meeting the constructability and financial limits). This step requires the application of management techniques and technical skills. The feasibility can be assured by establishing suitable design criteria, policies, procedures for design decision making, employing risk management practices to ensure the company may not lose any lawsuit filed against them, securing the project funding.
5. **Organizational Needs:** To successfully implement and achieve the CSS/D, the organization has to face many challenges, and there will be a need to change the organizational structure, work processes, staff make-up, and work culture. This means to change the collective skills and abilities of the involved people, to change the formal policies, processes in which the work is done, and to change the organizational structure of the team/units has been employed to accomplish a task.

Besides this, there are many other ways to introduce flexibility in the design procedure. One way is to introduce resurfacing, restoration and rehabilitation (3R) improvements suggested in *Designing Safer Roads, Practices for Resurfacing, Restoration, and Rehabilitation* (National Academies of Sciences, Engineering, and Medicine 1987). This method suggests maintaining the existing vertical, horizontal, and cross-sectional profile of the road by 3R improvements. These 3R projects have minimal effect on the surrounding environment/context and character of the roadway.

Other such ways that can be used by designers to introduce flexibility and achieve a balanced road design are- use design flexibility within the standards of state, apply design exceptions may be in projects where environmental consequences are important, reevaluate decisions that are made in planning stage, understand the safety and operational impact of design features, and many more (Federal Highway Administration 1997).

2.8 Public involvement to Achieve CSS/D

The backbone of CSS/D is public involvement; hence a public involvement plan is needed for effective implementation of CSS/D. This plan must be integrated with the design process, and public must be involved from the beginning so that their issues must be known to the planners/designers/engineers from the start. The aim of this plan is to inform the affected public at each decision point so that meaningful inputs can be taken from them. The public involvement plan generally consists of four steps (Nueman et al. 2002):

1. Identifying stakeholders
2. Interviewing stakeholders
3. Selecting public involvement techniques
4. Planning for implementation

The first step is identifying stakeholders, meaning getting input from the public who have a "stake" in the project outcome. These are those individuals or communities that are affected by the project, which includes (but not limited to these) (Nueman et al. 2002):

- Adjacent property owners (residential, commercial, industrial etc.)
- Adjacent property renters
- Facility users (commuters, employers etc.)
- Local jurisdiction elected and appointed officials (city, council, township etc.)
- Regional transportation professionals (MPO transportation planners)
- State DOT and FHWA professionals
- Transportation and Environmental interest groups
- Historic prevention and scenic conservation group

To identify potential stakeholders, the sponsoring agency can play an important role as they can suggest who can be affected by the project; this can make this step a lot convenient.

The second step is interviewing stakeholders, which involves conducting one on one interviews with selected stakeholders. The stakeholders must be from a diverse background so that all types of views can be gathered. At the start of the interview, an overview of the transportation need is given to the stakeholder, and a variety of questions are asked (e.g., issues, techniques for information exchange etc.) to get an understanding of the stakeholder's issues and characteristics (Nueman et al. 2002).

The third step is selecting the appropriate public involvement technique at various stages of the transportation decision-making process. As the projects' types and sizes vary, the tools and techniques of public involvement also vary. This alters with geographic locations, cultural differences, and stakeholder characteristics. For e.g., agencies in Alaska found that the local tribes react better to formal presentations. The key here is to select a tool/technique that is highly acceptable by public. This can range from presentations in person to emails, telephonic calls, group meetings, and many others (Nueman et al. 2002).

The last step is planning for implementation, which involves integrating the public involvement in the project scope, schedule, and budget. It must be kept in mind that a public involvement plan is a useful tool for the project implementation, but at the end, it is just a roadmap to achieve CSS/D, it may require modifications as per the project needs (Nueman et al. 2002).

2.9 Network and Corridor Planning with CSS/D

This section provides the details of consideration of the CSS/D principles in the stage of transportation network and corridor planning. This stage provides an early opportunity to establish and integrate CSS/D framework (Daisa 2006). Understanding the relationship between CSS/D and network planning helps in addressing critical issues of community, achieving the objectives of community, and developing broader set of alternative solutions (Daisa and Bochner 2010).

The aim of transportation network plan is to: link the transportation system to other metropolitan functions (land use, environment, ecology etc.), define transportation systems for large as well as fine-grained networks, and integrate multimodal transportation systems (bicycle, transit, freight etc.) (Daisa and Bochner 2010). The principles of CSS/D in network planning can be divided into 3 parts: network planning, connectivity and spacing, and performance measures (Daisa 2006).

The network planning related principles suggest: the multimodal network planning must integrate with long-range comprehensive plans, must address mobility, land use, freight needs, and emergency services. It also suggests the reservation of right of way based on long term community needs, and the network planning must be refined and updated so that more detailed planning and development can be done (Daisa 2006).

The connectivity and spacing related principles suggest the networks must provide high level of connectivity to all users, support the development pattern, and provide intermodal connectivity. It also pays emphasis on building the network capacity through a densely connected network. The principles also emphasized minimizing the direct property access onto arterials through connected networks and conclude network capacity is the foundation for access management and corridor capacity (Daisa 2006).

The performance measures related principles suggest that such transportation performance measures must be selected that reflect the stakeholder objectives and system priorities. It also suggests that performance measures can vary from different parts of the network, must recognize all the modes, and measure mobility for all the users. It also talks about the accessibility index, connectivity index, and other such measures (Daisa 2006).

To measure and ensure network connectivity and accessibility, Table 4 suggests some of the indices/connectivity standards (Criterion Planners/Engineers INC 2002; Idaho Smart Growth 2014).

Table 4. Indices/Connectivity Standards for Network Planning

Indices	**Defined by**	**Desirable for walking**
Connectivity Index	It is the ratio of roadway links and number of nodes; it excludes the link on perimeter arterial. It ranges from 1.00 (poorest) to 2.5 (full grid).	1.4 to 1.6
Intersection ratio	It is calculated by dividing the number of intersections by intersections and dead ends. It ranges from 0 to 1.0.	0.75
Average intersection spacing	It is clear from its name that it is the average spacing between any two intersections.	Max 660 ft. and desirable less than 400 ft.
Intersection density	Number of intersections per unit area.	More intersections per unit area are desired
Blocks per square mile	Number of blocks per unit area	The desired minimum value is 100
Directness	This is the ratio of actual distance traveled and crow fly distance (direct distance. It is also called as the accessibility ratio, and its ideal value is 1.0	Less than 1.5

For any project, the alternatives are identified with the participation of public, and stakeholder input is necessary to identify values, issues, priorities etc. for the alternative assessment. An alternative is evaluated based on mobility for all users, social and economic effects, environmental effects, cost-effectiveness and affordability, compatibility with regional plans etc. After the evaluation, the best alternative is selected (Daisa and Bochner 2010).

2.10 Design Guidance for Achieving CSS/D

FHWA published a report: *Achieving Multimodal Networks: Applying Design Flexibility and Reducing Conflicts* that can help planners and designers to select the better alternative to improve: flexibility, roadway design, multimodal issues, walking/biking network, comfort etc. (Porter et al. 2016). A few of the widely adopted treatments and design control measures to achieve CSS/D are explained in this section. These treatments include but are not limited to intersection design and control, pedestrian mobility and safety, speed management, street rightsizing, transit design, signal design. These treatments are provided to enhance the mobility of all road users- pedestrians, bicyclists, transit, automobiles, freight, and other unconventional modes. Below are a few widely adopted treatment and design control measures to achieve CSS/D:

- Narrowing lane width: Narrower lanes improve the comfort and safety of ped bike users. Through this measure, designers and planners can create space for various ped bike facilities: segregated bike lane, marked bike lane, sidewalk with buffer etc. (Moore et al. 2017). This is a similar concept to street rightsizing, in this reallocation of street space is done to serve a full range of road users. An example can be a four-lane two-way street with two lanes per direction can be transformed into one turn lane, two motor vehicle, and bike lanes per direction (Federal Highway Administration 2016).
- Medians: Medians can be highly useful at a multilane highway where pedestrian crossing is present. It can act as a pedestrian refuge and can assist in staged crossing (Porter et al. 2016).
- Enhanced transit stops: Extending sidewalk to create bus bulbs helps in speeded bus operations as buses can stop in traffic. Further adding amenities like shelter and seating enhances the experience of transit users (Moore et al. 2017).
- Gateway treatments: These types of treatments add a physical feature to the existing environment and affect the driver's behavior and reduce speed. As the name suggests, it creates a gate like environment on the road, example of such treatments are chicanes, raised medians, provision of curb line etc. (Porter et al. 2016).
- Rectangular Rapid Flashing Beacons (RRFB): RRFBs can be used at uncontrolled crossings when a signal or pedestrian hybrid beacon is not warranted, costly, or unnecessary (Porter et al. 2016).
- Pedestrian crossing phases: Providing a separate pedestrian crossing phase at an intersection prevents pedestrian and vehicle crashes, especially at those intersections where drivers can turn right/left in a pedestrian walk phase. Designers must conduct an engineering study to determine the suitability of this solution before application (Porter et al. 2016).

- Bicycle parking: Bicycle serves as first and last mile connector to public transit. Provision of bicycle parking stations at these transit stations may increase the share of transit. Enclosed bike racks, on-demand lockers, and high-quality access controlled bicycle parking are key considerations for this measure (Porter et al. 2016).
- Mountable truck aprons: At the locations where large vehicles occasionally turn, mountable truck aprons can be considered. These reduce the speed of passenger cars by not letting them cross over it but allows the trucks to pass over it (Porter et al. 2016).

Besides these treatment measures, there are a plethora that are not discussed in this section. The purpose of discussing these was to familiarize the reader about the types of treatments and the rationale behind it.

In addition to the FHWA, the National Association of City Transportation Officials (NACTO) provides guidance as to context-sensitive treatments that are appropriate for urban settings that serve pedestrian, bicycle, and transit modes (National Association of City Transportation Officials 2022). NACTO has developed nine guides to assist engineers and planners in building transportation facilities that are sustainable, accessible, and safe. Each of these guides focuses on a different area, which cover topics such as transit design and bikeway design. The central theme of these guides is to prioritize the movements of pedestrians, bicyclists, and transit users of all age groups and abilities. The document most pertinent to CSS/D is the Urban Street Design Guide, which provides details of key design elements for both streets and intersections.

The street design elements include features ranging from sidewalks to travel lanes to transit stops. The Urban Street Design Guide of NACTO (National Association of City Transportation Officials 2015) suggests understanding of the context of street is crucial to optimize the benefits of street design. It is recommended that the designer must account for city goals, policies and the vision of community while designing for the street. The basic principles of street design are- the streets must be designed for safety, public spaces, and flexible to suit to context. Some examples of the street design elements include (not limited to), as shown in Figure 3.

- Lane width (allocation of space for all users)
- Sidewalks
- Dedicated bus lanes/bulbs
- Curb extensions (gateway, chicane, pinchpoint etc.)
- Vertical speed control elements (speed table, speed hump, speed cushion)

Road diet

Accessible sidewalk

Speed table

Dedicated bus lane

Figure 3. Street Design Elements (National Association of City Transportation Officials 2015)

Intersections are an important part of the road network as these are the shared spaces. A successful intersection design is the one that ensures safety and movement of all the road users. The NATCO Urban Street Design Guide (National Association of City Transportation Officials 2015) suggests intersections should be compact, suit the context, and be aligned with existing and future land uses. Some of the intersection design elements include the following treatments and are shown in Figure 4:

- Crosswalks and crossings
- Pedestrian safety island
- Roundabouts
- Median refuge

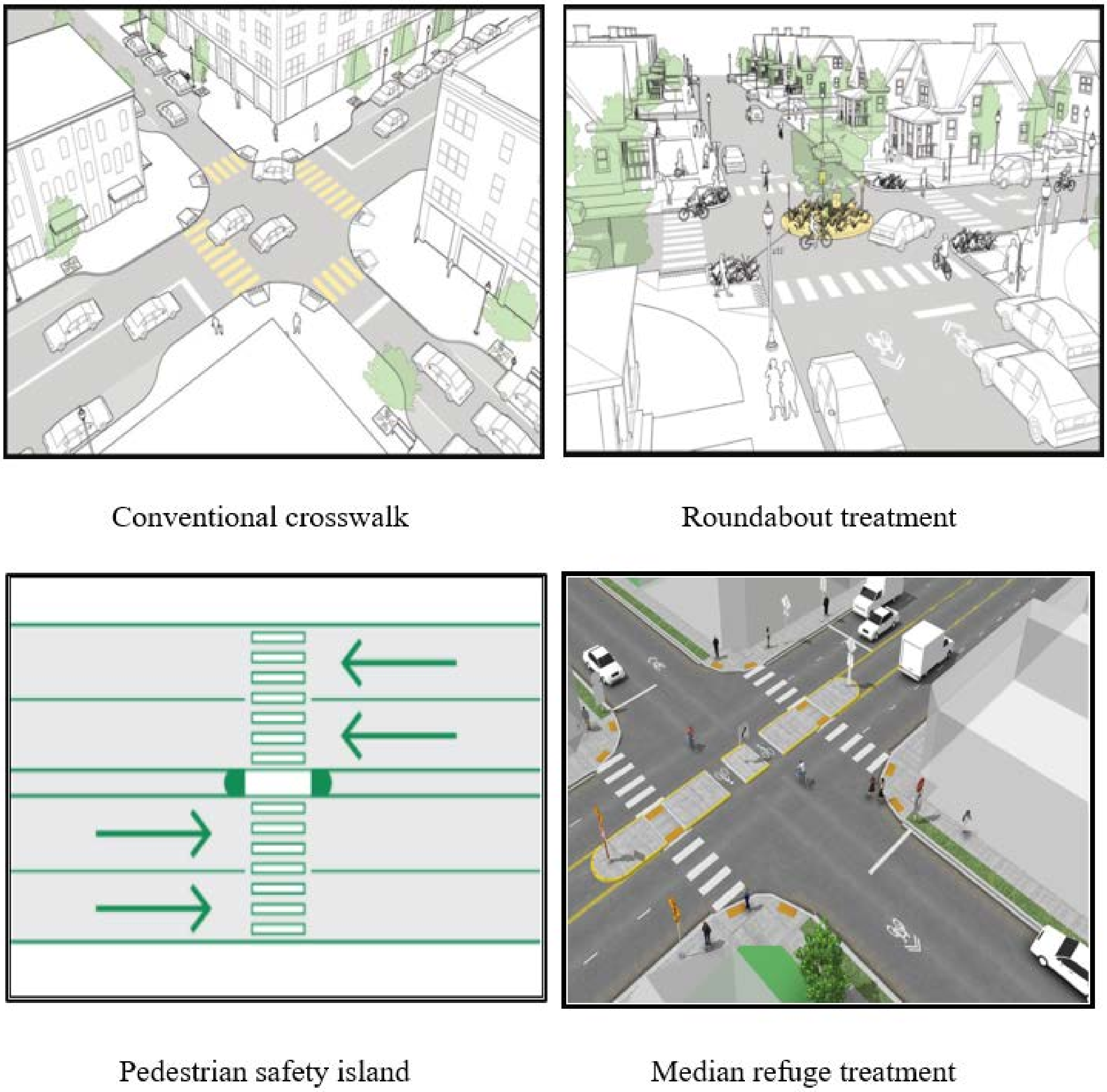

Figure 4. Intersection Design Elements (National Association of City Transportation Officials 2015)

2.11 CSS/D Performance Measurement

It was realized by practitioners that context sensitive solutions generally appear simple yet holistic, multidisciplinary, and driven by the community, which makes the performance measurement of CSS/D projects challenging. This calls for a CSS/D performance measurement program, which led to the development of *Performance Measures for Context-Sensitive Solutions- A Guidebook for State DOTs*. The main aim of this guidebook is to assist DOTs in developing their tailored CSS/D performance measurement program (TransTech Management, Inc, Oldham Historic Properties, Inc., and Parsons Brinckerhoff Quade & Douglas, Inc. 2004).

CSS/D performance measurements program can make CSS/D a state of practice, strengthen agency leadership support for CSS/D principles, maintain focus of CSS goals, and strengthen trust between stakeholder, agency, and elected officials (TransTech Management, Inc et al. 2004). The above CSS performance measure guide suggests six "process" and three "outcome" related focus areas that may help to effectively measure the performance of CSS/D program.

Process related focus areas and their measurement (TransTech Management, Inc et al. 2004):

- Use of multi-disciplinary team: A well-managed multi-disciplinary team is needed to handle wide variety of projects. The success of CSS/D depends on right team members that's why many agencies prepare a team that brings together planners, traffic engineers, environmental experts, public leaders etc. Utilization of multi-disciplinary team can be measured by checking whether the right people are in the team, and it functions effectively, with a common goal to achieve CSS/D principle.
- Public engagement: This is the key component of successful transportation projects, and effective engagement must be tailored to satisfy local needs, frequently occurring, innovative, and intended to affect the project outcomes. This ensures that the needs of the affected communities are met, and appropriate meeting occurred. Public engagement can be measured by public involvement plan, public input in key decisions, quality of public engagement, adequacy, and expertise of DOT in explaining the project to the community and other similar methods.
- Consensus on project problems, opportunities, and needs: After the team is prepared, the research team should develop and reach a consensus of problems, opportunities, and needs the project may address. This includes transportation, community, and environmental needs. This consensus can be measured by checking whether the statement of problems, opportunities, and needs identified by project team and same as that of stakeholders about the transportation needs and issues.
- Consensus on project vision or goals: The public and research agency staff must come to a consensus about the project vision or project goals. This informs how a project will look in next 10-20 years. This consensus can be measured by checking whether the project vision is consistent with local plans, the team project, staff and public are in consensus with the project vision, and after completion, does the project support the community needs.
- Alternative analysis: This requires careful comparison of all the available alternatives. It must be kept in mind that the stakeholder's problems, opportunities, and needs must

be reflected in the alternative analysis. The alternative analysis can be measured by-checking whether the project team and stakeholders were satisfied with the range of alternatives developed, what criteria were used to select the alternative, was public involved in alternative selection, is the design alternative promotes all types of modes, and similar other measures can be implemented.

- Construction and maintenance: The multi-disciplinary team must have members from construction background so that constructability issues can be known beforehand, and all the commitments can be fulfilled at the time of final project delivery. This performance indicator can be measured by checking whether all the commitments made to stakeholders are in the construction document or not, whether the community agrees to maintain the structure after construction of not, and how many requests were made to change the construction.

Outcome related focus areas and their measurement (TransTech Management, Inc et al. 2004):

- Achievement of project vision and goals: A clear project vision and goal that address the needs of all the stakeholders can be used to project outcomes. The achievement of project vision can be measured by comparing the original problem, opportunities, and needs with the final project delivered. It can also be measured by checking whether the project goals are met, environmental resources and community values are preserved, and project fulfilled all the commitments.
- Stakeholder satisfaction: Stakeholders include a diverse group (property owners, facility user, neighborhood organization, transportation, and environmental interest group etc.) that are affected by a project. Stakeholder satisfaction can be measured by taking surveys/opinions of stakeholders.
- Quality assurance review: The principles of CSS/D suggests external stakeholders be the part of project team, which can review the project for two hours and share the opinion with the rest of the team. Maryland State Highway Association (SHA) developed a project review and evaluation format that can be used for Quality assurance and review.

2.12 Barriers/challenges to the CSS/D implementation

Despite the initiatives for CSS/D, there are some barriers to implementing CSS/D solutions. These barriers are generally due to unidirectional thinking, vehicle-oriented thought process, fixed design standards, limited time and cost, and not involving the community in designing solutions. The following points show some barriers/challenges in implementing CSS/D and proposed solutions (Federal Highway Administration 2017a):

- Internal Resistance to Change: This represents that the team members do not want to change their working style and upgrade their skills. It can be overcome if the managers can explain to the team members with proper rationale, how the required skills can be utilized in developing CSS/D solutions.
- Inflexible Design Standards: This challenge arises when the design standards are rigid and cannot be modified in any situation; this is the way in which designs are typically done. To overcome this, opportunities must be provided to the design staff to learn from other practitioners. This also helps designers to learn strategies to overcome the mindset of fixed design standards.
- Added Budget for Process: This issue suggests that the cost incurred particularly due to adding stakeholders, will increase the cost of project. This is a valid concern, but it can be overcome by limiting the stakeholder involvement based on project size and complexity.
- Added Time for Process: Application of CSS/D requires a huge time investment, particularly at the initial stages of the project. But this time invested pays off as the team understands the context of the project, so with little rework, they can design the facility.
- Lack of Stakeholder Trust: CSS/D process develops a relationship between state DOTs, participating agencies, and stakeholders, which was absent in traditional approach. If there is some resistance to shift from traditional approach to collaborative CSS/D approach, the DOTs may train their employees, start pilot programs to develop a shared understanding of roles and responsibilities of one another.

Lastly, other factors that negatively affect CSS/D are not limited to (Ewing 2002):

- The design standards of states in addition to AASHTO requirements
- The minimum LOS standards for drivers' ease and convenience, which are not conducive for pedestrians and bicyclists.
- Reliance on conventional designs mentioned in state DOT manuals, when a tailored design is needed in that land use type to promote multimodal transport.
- Designers and engineers are hesitant to use design exceptions.

3 REVIEW OF STATE DOT GUIDELINES FOR CONTEXT SENSITIVE SOLUTIONS/DESIGN

Many states realized that adopting CSS/D principles will assist in project planning, project development, and alternative development. In order to do that, many states have developed their own CSS/D guidelines. In general, each guideline provides details of the degree to which DOTs are currently integrating CSS/D into their project development processes. Ultimately, these guidelines are aimed at incorporating flexibility into the design process. This includes explicit consideration of environmental concerns, preservation of natural resources, and assessment of economic factors as a part of the roadway design process.

This chapter summarizes the CSS/D guidelines for each state DOT. While these documents cover a similar range of topics, they also consider the needs, resources and goals of each respective DOT. In general, the more recently developed guidelines are more extensive and tend to promote public engagement and the usage of interdisciplinary teams to a higher degree.

Table 5 provides a high-level summary of each guideline, including details such as the year of publication, the overarching goal of each document, and specific treatments and principles that are emphasized as a part of the agency's efforts to achieve CSS/D. The remainder of this chapter synthesizes key elements of the guideline document for each of these 12 state DOTs.

Table 5. Summary of state DOT Guidelines Reviewed

State DOT	CSS/D Document/ Year	Overarching Goal	Treatments/Principles
Delaware Department of Transportation (DelDOT)	Context Sensitive Solutions for Delaware Byways in 2011	To plan, design, construct, operate, and maintain the Delaware Byways.	Byway character; public involvement; creative alternative.
District Department of Transportation (DDOT)	Context Sensitive Design Guidelines in 2005	To achieve success in planning and design of transportation projects.	Transportation need; public involvement; environment; design elements; safety.
Florida Department of Transportation (FDOT)	Complete Streets Handbook in 2017	To incorporate CSS in all roadway projects to the maximum possible extent.	Complete streets for all users; fit local land development; promote safety.
Georgia Department of Transportation (GDOT)	CSS/D manual in 2018	To provide information about the latest research and development.	Effective decision making; community needs; integrate stakeholders.
Idaho Transportation of Department (ITD)	Context Sensitive Solutions Guide in 2006	To promote CSS/D approach in all aspects of transportation.	Interdisciplinary team; public involvement; giving value to natural resources.
Illinois Department of Transportation (IDOT)	Context Sensitive Solutions Detailed Guidelines for Practice in 2003	To facilitate CSS/D process in Illinois.	Project development process; flexibility in design criteria; interdisciplinary team.
Iowa Department of Transportation (Iowa DOT)	Project Development Process Manual in 2013	To increase cooperation between Iowa DOT and resource agencies.	Involve stakeholders and multidisciplinary team; define project purpose and need; flexible design criteria.
Maryland State Highway Association (MSHA)	Context Sensitive Solutions for work on Maryland Byways in 2008	To enhance and protect the scenic, historic, and culturally important Byway-roads.	Define, maintain, and preserve byways features
Michigan Department of Transportation (MDOT)	Draft Implementation Plan for CSS/D in 2003	To follow CSS/D principles in all the transportation projects wherever possible	Engage stakeholders; safety; encouraging multimodal transportation; respect the environment
Montana Department of Transportation (MDT)	Context Sensitive Solutions Designs Guide in 2015	To make CSS/D an organizational culture and provide conceptual guidance to staff.	Enhance safety; cost effective; improve mobility; involve community; preserve the environment
New Mexico Department of Transportation (NMDOT)	Guide to Context Sensitive Solutions in 2006	To integrate community balance, historic and environmental values with transportation safety	Multimodal approach; public involvement; environmental stewardship; safety; performance measure
Washington Department of Transportation (WSDOT)	Flexibility in Transportation Design Manual in 2005	To assist the engineers/planners/designers in project development and design process	Maintaining natural environment; community needs; safety; healthy economy

3.1 Delaware Department of Transportation (DelDOT)

DelDOT developed a CSS/D manual in 2011 named "*Context Sensitive Solutions for Delaware Byways*" (Mahan Rykiel Associates Inc. and Whitman, Requardt & Associates LLP 2011)**,** which integrates CSS/D principles into the project development process and provides assistance for projects within specified byway corridors. DelDOT byways are important from scenic, historical, recreational, cultural, archaeological, and natural standpoint, and these are termed as six intrinsic qualities of byways. Any kind of construction, maintenance, safety improvement at these byways over the course of time may change the travel experience positively or negatively for tourists. This manual can be used by DelDOT's designers, planners, and consultants to plan, design, construct, operate, and maintain the Delaware Byways.

There are three main principles of achieving CSS/D for Byways:

1. Identification of Byway character and defining features:
   Identification of project's is the first priority while working on Delaware's Byways. It is important to recognize character defining features of Byways, and this will assist in identifying suitable treatments.
2. Provision of stakeholder and public involvement:
   Public involvement is the backbone of CSS/D implementation and DelDOT acknowledges this and mentions key features of successful public involvement. Some of the key features are:
   - Open clear and early communication.
   - Clear understanding of surroundings, community, and valued resources.
   - A tailored process to meet the needs and expectations of the project and people.
3. Exploration of flexible and creative alternatives:
   DelDOT designers/planners/engineers must tailor the design alternatives that enhance, preserves, and maintains the byway's features. This can vary based on the transportation goals and community requirements. The alternatives developed in this process generally fall in any of these three categories- preservation, conservation, and enhancement.

This guide suggests that roadside features significantly affect Byway's character, and the designers must be updated with the best practices to identify right solutions and flexible designs for the current transportation issue. The guide also lists outs some CSS/D treatments (e.g., shared-use path, sidewalks, landscaped medians etc.) so that a sustainable transportation system is obtained. Lastly, the guide covers a wide range of case studies that includes the improvement of Brackenville road's condition where the main issues were improper drainage and safety concerns. Another case study was access to Applecross development, where the main aims were to protect and maintain the existing vegetation and aesthetic qualities. A myriad of other case studies can be found in this guidebook.

3.2 District Department of Transportation (DDOT)

The DDOT published a manual in 2005 named "*Context Sensitive Design Guidelines*" (District Department of Transportation n.d.) that explains the DDOT approach to CSS/D and mentions the key steps to achieve success in planning and design of transportation projects. DDOT, since its inception incorporates CSS/D design principles to some degree by extending public involvement, preserving historic character of the District, and avoiding negative impacts of transportation projects on nature. The key elements of CSS/D for any project as per DDOT are:

- Purpose and Transportation Need
- Environment
- Public Participation
- Transportation Design Elements
- Safety and Mobility

The key design guidelines of DDOT are:

- The physical, environmental, social, cultural, aesthetic, and transportation elements must be identified in the very beginning.
- The requirements of the project area must be taken care of, and the transportation solution must blend with the surrounding environment.
- The community must be involved from the beginning, and designs must respect community values.
- There is no fixed design approach to CSS/D, and the designs must vary w.r.t project, surroundings, and needs.
- The developed design must balance the safety, community values, design consistency, and environment.
- The final design of the project should:
    a. Serve its function and setting
    b. In accordance with original plan, in which community was involved

c. Blend well with environment and has minimal impact on it

- The design must include risk assessment.

To apply CSS/D approach, DDOT adopted a CSS/D model that was developed by "*Flexibility in Highway Design*," (Federal Highway Administration 1997), and it can be seen in Figure 5.

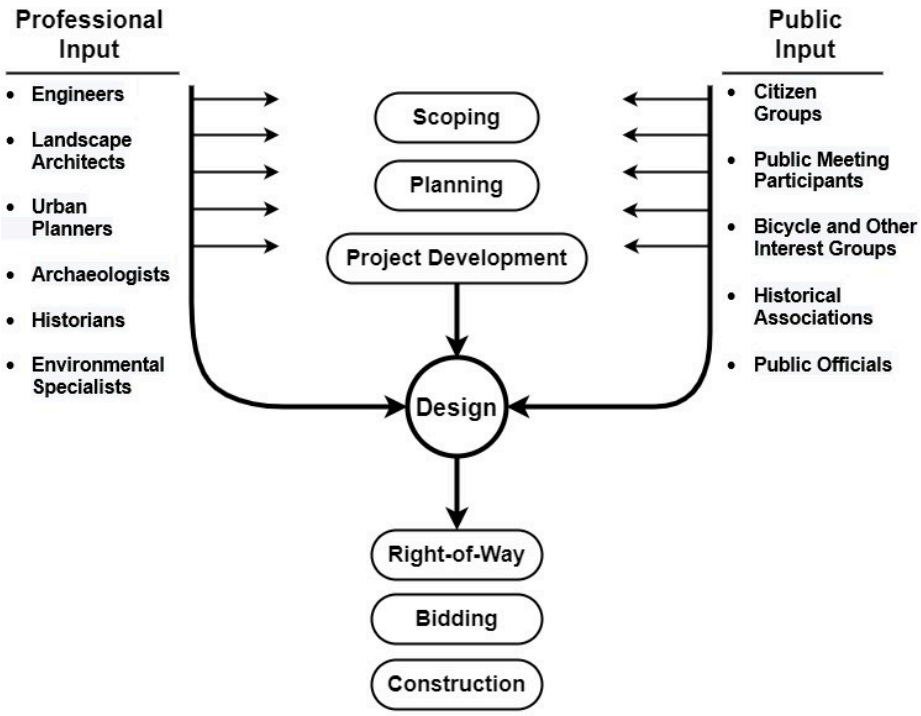

Figure 5. Context Sensitive Approach (Federal Highway Administration 1997)

The DDOT recognizes public involvement as an important factor and suggests that it should be carried out at each phase: planning, design, and construction. Furthermore, it advocates for the public involvement program to gather information and background of the project. This step mainly includes reviewing the project purpose, project goals, environmental impact, management plan etc. Next in this series is the community involvement plan, which includes identification of public concerns, building public support, informing decision-makers, establishing group meetings, achieving stakeholder consensus etc. Lastly, DDOT recommends the usage of print media, radio, and television to reach out to the stakeholders.

3.3 Florida Department of Transportation (FDOT)

FDOT's "*Complete Streets Handbook*" (Florida Department of Transportation 2015), which was published in 2017, tries to incorporate context sensitive design in all the state roadway projects to the maximum possible extent. The stepping stone to achieve CSS/D was laid in 2014 when FDOT adopted statewide Complete Streets Policy, which promotes flexibility and innovation in planning and design on state roads. There are three core concepts of complete streets policy of FDOT:

- Complete streets serve the transportation needs of all the users (pedestrians, bicyclists, transit riders, automobile users, freight handler etc.) with varying abilities and age.
- The transportation solutions provided by Complete street design must be context sensitive i.e. they must fit the local land development pattern.
- The transportation solution developed by Complete street principles must- promote safety, improve quality of life, and contribute to economic development.

The above-mentioned core concepts served as base for the seven Complete streets principles of FDOT:

1. Safety for all road users is paramount
2. Invest in existing and emerging communities
3. Enhance of transportation system performance
4. Promotes all the modes of transportation
5. Connect the community centers
6. Create quality places to live, learn, work and play
7. Transportation solution must support the context of the area

The FDOT Complete streets manual acknowledges that during the project development and design process, the planners and designers must develop a flexible design that can support the context of the area. The flexible design solution must balance mobility and community needs. While developing this solution, coordination with environmental resource agencies, local government, and public is necessary.

FDOT also supports local and regional vision and collaborate with locals to identify the context and development pattern. The context classification of a roadway along with its transportation characteristics helps in identifying the type of road users, the demand on roadway, and the issues a road user may face. The context can be divided into eight types, which can be seen in Table 6.

There are other measures also to define the context classification like the residential density, population density, employment density, intersection density etc. The data sources that may be required for these measures are Census information, regional travel demand model, land development regulations etc.

Table 6. Context Classification Table (Florida Department of Transportation 2015):

Type of context	Land use characteristics	Building height (Number of floors)	Building placement
Natural	Conservation Land, Open Space, or Park	N/A	N/A
Rural	Agricultural or Single-Family Residential	1 to 2	Detached buildings with no consistent pattern of setbacks
Rural town	Retail, Office, Single-Family or Multi-Family Residential, Institutional, or Industrial	1 to 2	Both detached and attached buildings with no, shallow (<10'), or medium (10' to 24') front setbacks
Suburban Residential	Single-Family or Multi-Family Residential	1 to 2, with some 3	Detached buildings with medium to large (>10') front setbacks
Suburban Commercial	Retail, Office, Multi-Family Residential, Institutional, or Industrial	1 (retail uses) and 1 to 4 (office uses)	Detached buildings with medium to large (>10') setbacks on all sides
Urban General	Single-Family or Multi-Family Residential, Institutional, Neighbourhood Scale Retail, or Office	1 to 3, with some taller buildings	Both detached and attached buildings with no, shallow (<10'), or medium (10' to 24') front setbacks
Urban Center	Retail, Office, Single-Family or Multi-Family Residential, Institutional, or Light Industrial	1 to 5, with some taller buildings	Both detached and attached buildings with no, shallow (<10'), or medium (10' to 24') front setbacks
Urban Core	Retail, Office, Institutional, or Multi-Family Residential	>4, with some shorter buildings	Mostly attached buildings with no or shallow (<10') front setbacks

The guide also lists out examples of potential data to determine user needs by various modes (pedestrians, bicyclists, cars, transit, and freight). The example of such data is location of signalized pedestrian crossings, pedestrian counts, crash data, Lighting levels, design and projected traffic, Average Annual Daily Traffic (AADT), designated truck routes etc.

After understanding the context, the next is the process of implementing complete streets policies through project planning, which involves the following three steps-

1. Understanding the needs of the stakeholders and their issues

2. Defining the purpose, needs, and evaluation measures and determining how well the solutions cater to the needs of all users.
3. Defining and evaluating the alternatives, a range of alternatives is defined in this step.

Lastly, the design considerations for complete streets is to be discussed, and FDOT complete streets manual suggests selecting the appropriate context-based design controls to reflect the roadway context and intended outcomes. These context-based controls can be divided into four types:

- Design users
  - E.g. pedestrian, bicyclist, motorist, and freight.
  - These must be used when determining the design details such as sidewalk width, type of bicycle facility, a pedestrian crossing.
- Design vehicle
  - FDOT generally uses the largest vehicle that might be using that road.
  - The design vehicle must be accommodated on all roadways of Florida, and a smaller turning radius can be expected on roads with lesser truck volume.
- Design speed
  - Lower vehicular speeds are safer (reduces crash frequency and severity)
  - The roadway geometric and cross-sectional elements, in conjunction with context, develop a driving environment that allows the driver to choose a reasonable speed.
- Traffic characteristics
  - E.g. traffic volume, traffic composition, level of service etc.
  - Design traffic has been used historically to determine the number of travel lanes, which directly affects the comfort, safety, and convenience of road users.

The FDOT's context classification, traffic characteristics, functional class etc. are used during design consideration. After considering the community's surroundings and its vision, the FDOT assigns a context classification and finally chooses transportation elements that suit the assigned context.

3.4 Georgia Department of Transportation (GDOT)

Since 2005, the GDOT started taking proactive steps to incorporate CSS/D principles into design and project development. GDOT developed a CSS/D manual in 2018 (Georgia Department of Transportation 2018), and the purpose of this manual was three-fold:

- To provide the information about the latest research and development regarding CSS/D in Georgia and the U. S. to GDOT management, staff, and practitioners.
- To set the policy guidelines/procedures to achieve design flexibility, environmental sensitivity, and higher stakeholder involvement so that CSS/D can be achieved.
- To project the CSS/D examples in Georgia and other states, so that GDOT can benefit from it.

This manual also describes the five steps to achieve CSS/D. The first step is initiation of effective decision making, which involves developing a management framework and interdisciplinary teams. Second step is to understand the community values, which involve identification of community needs/values and stakeholders. The third step is to achieve sensitivity towards environmental and social concerns. This can be done by understanding and scoping the problem and finding the way through which adverse effects on environment can be minimized. This requires continuous monitoring of the project. The fourth step is to integrate stakeholders' interest through CSS/D this involves incorporation of flexible design standards, and considering and evaluating the impact of each alternative design on environment. The last step is ensuring the solutions that work. It must be noted that the traditional methods of measuring success of a project like cost, mobility, and safety cannot be used to assess the CSS/D projects. There is no measure to implement this step, but it can be achieved by observing how a completed project satisfies the needs of full range of stakeholders. These five steps were adopted by GDOT from the NCHRP Report 480 (Nueman et al. 2002), and are explained in section 2.6 "Procedures/steps to achieve CSS/D" of this report. Figure 6 shows these five steps and sub-steps taken in each category to achieve a successful CSS/D.

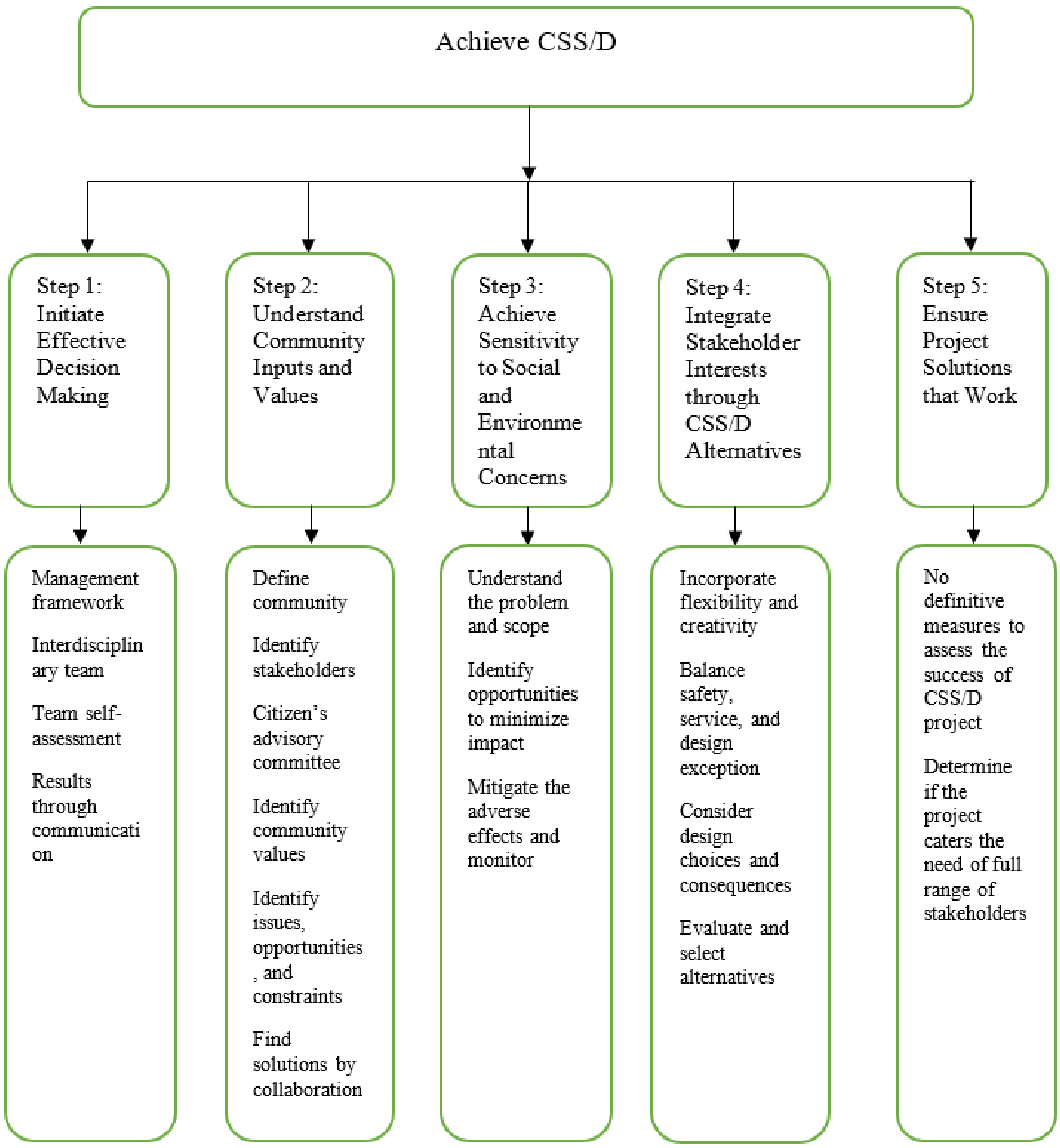

Figure 6. Five Steps to achieve CSS/D (Georgia Department of Transportation 2018)

Besides mentioning the methods to achieve CSS/D, the GDOT CSS/D manual also informs about the projects in Georgia and the US that are completed using CSS/D principles. The lessons learned for each of these CSS/D projects are also highlighted in this manual. Few projects that used CSS/D principles were the widening and reconstruction of certain sections of I-16/I-75, connecting savannah project whose aim was to mitigate congestion issues and promote other modes (epitome of public involvement). The GDOT CSS/D manual summarized a wide range of such projects.

3.5 Idaho Transportation of Department (ITD)

The ITD Context Sensitive Solutions Guide (Idaho Transportation Department 2006) was published in 2006 and highlighted the vision principles of IDT: Mobility for all users, Compatibility with environment, Preservation of community assets, and Flexibility and responsiveness. This covers nearly all the components of a modern CSS/D guidance documents and at favors stakeholders' involvement. Furthermore, the purpose of this CSD guide was to promote CSS/D approach in all aspects of transportation.

This guidance document mentions that since 1970, environmental issues played an important role in transportation planning, development, construction, operations, and maintenance process. IDT acknowledges these issues and adopted an environmental ethics statement, that emphasizes methods that use CSS/D principles. The statement is as follows: "The IDT respects and values the many facets of Idaho's natural and human environment and will protect and enhance those assets while providing high quality, fiscally responsible transportation systems for the citizens of Idaho." This guidance document suggests that adoption of CSS/D approach is not limited to obtaining environmental clearance. It is going beyond the conventional ways and being responsive to the community and environment.

This guide mentions that transforming to CSS/D approach requires adoption of new design philosophy, culture, and organizational structure. The proposed solutions must be technologically feasible but also environmentally sensitive and must enhance the surroundings of inhabitants. This guidebook also suggests the common approaches to apply CSS/D: commitment to CSS/D, use of interdisciplinary team, public involvement, understanding community/environment, giving value to natural resources, and using full range of tools for communication (internet, visualization, plans etc.). The IDT acknowledges that public involvement is the key to CSS/D approach, and the public involvement coordinator is the key person for stakeholder outreach. This coordinator is made available to district engineers, program, and headquarters managers with the aim to get sufficient public involvement in the project development phase.

Furthermore, the IDT has an Environmental wing that has the responsibility to identify the environmental issues associated with a transportation project. This wing is highly important from CSS/D perspective, but it also provides training and technical expertise with environmental mitigation and clearance responsibilities, reviews environmental evaluations and perform Environmental Impact Assessment (EIA), assist IDT in establishing environmental policies and procedures, and maintains an archive of project environmental submittals.

The IDT is committed to CSS/D, which is reflected in their adoption of CSS/D principles for long term projects and even in construction and maintenance activities. This manual also lists some examples of CSS/D projects completed by IDT: construction of a 27-mile corridor in Blaine county to mitigate congestion, replacement of highway culverts in Warm Springs area to facilitate movement of migratory and endangered fishes etc.

3.6 Illinois Department of Transportation (IDOT)

IDOT published a CSS/D manual named "*Context Sensitive Solutions Detailed Guidelines For Practice*" (Illinois Department of Transportation n.d.), to facilitate CSS/D process in Illinois. However, in 2003, a legislation (PA 93-0540) was passed that made CSS principles mandatory for IDOT's major projects. The state's mission and vision are largely driven by the state's traffic congestion problem, suburban sprawl, preserving landscapes, and ability to use walk, bike, and public transport. The IDOT's CSS manual addresses these concerns by encouraging stakeholders' participation in developing transportation solutions.

The IDOT identifies Design Flexibility as an important part of CSS/D design. It can be achieved by adhering to the following principles:

- Project Development Process: Developing an instructive and comprehensive project development process is the key to achieve CSS/D. It is also necessary to educate stakeholders about the overall project development process and time frame involved.
- Interdisciplinary Team: Each project has its context, features, characteristics, resources, and public attitudes. A collaborative interdisciplinary team is necessary for any project that unique aspects of each project can be discussed, and potential solutions can be found. Developing a dynamic interdisciplinary team, whose members changes as new issues and perspective arise, would be the best approach.
- Flexibility in Design Criteria: The IDOT CSS/D guidebook advocates for the use of flexible design that suits the need of the area, and encourage tailored solutions to certain situations.
- Use of Design Criteria and Design Exception: The IDOT CSS/D guidebook allows flexibility in design standards and permits for the exceptions in design criteria, with proper documentation and justification. It also suggests that designers must also use their own experience, judgment, and creativity to develop these criteria and exceptions.

The IDOT recognizes stakeholders as an asset to CSS/D process, and that is why they prepared a Stakeholder Involvement Plan (SIP) to seek inputs from stakeholders and involve them in problem-solving. The SIP consists of four activities:

- Stakeholder identification and meet with local official and interest group
- Developing and discussing the purpose of project with public
- Defining alternatives that can work for the project
- Approval of final alternatives in consensus with stakeholders

Furthermore, this manual also suggests the following stakeholder involvement techniques: group briefing, workshops, advisory committees, technical advisory groups, elected officials meetings, interest group meetings, focus group meetings, charrettes, speakers' (or listeners') bureaus, newsletter and information hotlines and websites. Any or multiple techniques can be used to involve public depending on situation and project.

This manual suggests that the IDOT staff should receive training to be updated with the approach and techniques to apply CSS/D. The further development of IDOT in CSS/D field includes improvement of cost sharing policies for bicycles and pedestrians, consideration of ways to integrate public involvement at higher level in project planning, developing regular courses and training for CSS/D in engineering schools, and give excellence design award for outstanding project achievements.

3.7 Iowa Department of Transportation (Iowa DOT)

Iowa DOT revised the "*Project Development Process Manual*" (Iowa Department of Transportation 2013) in 2013 to re-develop the project development process, increase cooperation between Iowa DOT and resource agencies, and integrate the NEPA and clean water act in highway development process. This manual encourages the multidisciplinary project management, application of CSS/D principles and stakeholder involvement in transportation projects.

Application of CSS/D principles allows for flexibility while designing the facility. CSS/D principles are not a new concept to Iowa DOT, the basics of these are applied to various projects and concepts like- updating the rest area of Iowa, addition to bike lane for roadways and bridges, accounting for light and noise pollution, conducting pre and post construction condition survey etc. The key elements of CSS/D as per Iowa DOT are not limited to:

- Involvement of multidisciplinary team from early stages

- Stakeholder involvement from early stages, with proper project understanding
- Clear definition of project purpose and need
- Extensive field reviews
- Development of multiple alternatives
- Application of flexible design criteria

Iowa DOT suggests the stakeholder’s involvement in early stages is beneficial as at that time need for the project is defined. Furthermore, stakeholders can assist in assessing the area characteristics, identifying the community values and alternative designs, and solving any design conflicts. Iowa DOT recommends working with those stakeholders/communities who are most affected by the project, and they suggest stakeholder involvement program that:

- Get meaningful feedback from the public
- Provide a platform to public for discussion with decision makers
- Help in reaching a consensus on recommended course of action
- Includes public views preferences etc.

The commonly used techniques to involve stakeholders are open forum public meetings and hearings, on-site information centers, briefings, media strategies (radio, television, emails etc.), surveys, telephones, brainstorming sessions, transportation fair etc. It must be kept in mind that all the types of stakeholders (varies by different education level, income level, profession etc.), minorities, persons of limited English proficiency are covered by the chosen stakeholder involvement techniques.

Along with stakeholder involvement, development of CSS/D also requires consensus building in many design considerations related to safety, capacity, multimodal transportation, historic and scenic, environmental quality, cost, physical character etc. these characteristics assist the designer in developing the alternatives.

The main factors that need to be considered while developing alternatives is that it should match with the character of the context and avoid environmental conflicts. The CSS/D may not be the most cost-effective design, but it fits the environment better and minimizes the impact on environment. Out of a list of alternatives, the best alternative is selected based on the abovementioned criterion, and then the project moves in the final design stage and right of way acquisition phase. In this phase, the designers must follow the design related commitments they made to the public and must prepare the mitigation measures. They are free to make minor changes in the design, which can result in better products.

3.8 Maryland State Highway Association (MSHA)

The MSHA developed a manual in 2008 named "*Context Sensitive Solutions for work on Maryland Byways*" (Maryland State Highway Administration 2008) to enhance and protect the scenic, historic, and culturally important Byway-roads. These roads are important from the tourism point of view and generate unique experiences for all. MSHA acknowledges that any kind of maintenance or modification work like repair of drainage culvert, adding signage, changing approach of an intersection etc. may upgrade or degrade the travel experience on that byway route. The Maryland CSS Byway guide aims to develop guidelines that must be followed during the project development, planning, design, construction, and maintenance and operations of its Byways.

MSHA prepared four CSS principle for Byways:

- Identify the character defining features of Byways
    - Identification of the intrinsic qualities of byways (e.g. scenic, historic, natural, cultural, recreational, archaeological).
- Preserve the character defining features of Byways
    - This process involves simply preserving the existing form of byway so that its character remains unaltered.
- Maintain the overall character of the roadway
    - This is the key point behind the CSS principles of Byways, and it aims at maintaining the distinct qualities, features, intrinsic qualities, and characteristics of Byways.
- Enhance the Byway so that its special character is maintained
    - Developing project solutions that complement the roadway characteristics of the Byway.
    - Include the roadside enhancement projects that can improve the traveler's experience.

Besides this, this guide also lists some treatments that can enhance the scenic Byways like roadside barriers, grading and drainage (using suitable slopes, blending road design with natural landscape etc.), traffic control devices (integrating regulatory signs, appropriate traffic control devices etc.), landscaping, lighting (use of street lights, minimize light pollution etc.), access management (adjusting acceleration/deceleration lanes), roadside enhancements (native plants, decorative treatments etc.) and many more.

3.9 Michigan Department of Transportation (MDOT)

Michigan's governor issued a directive in 2003 that requires MDOT to follow CSS/D principles in all the transportation projects wherever possible. As per MDOT- "CSS is an interdisciplinary process that engages all stakeholders in planning, designing, constructing, operating and maintaining a safe, effective, and integrated multimodal transportation system that supports a community's vision" (Michigan Department of Transportation 2006a).

Stakeholder engagement is an important principle of CSS/D; to ensure this, MDOT consults with local governments, road commission, industry group, land use advocates, and other stakeholders regarding the project. CSS/D also makes sure that all the transportation projects (which range from interchanges to bike paths) must "fit" the context of the area (Michigan Department of Transportation n.d.). While designing for a facility, MDOT examines a wide range of environmental concerns-social and cultural issues, air and water quality, traffic noise etc. so that the negative impacts can be minimized (Michigan Department of Transportation 2006b). The essential CSS principles and practices are as follows (Michigan Department of Transportation 2006a):

- Stakeholder engagement
- Utilization of interdisciplinary team
- Encouraging the multimodal transportation
- Transportation solution must respect the environment and social context
- Developing a safe and efficient transportation system
- Application of CSS/D principles to all activities of transportation agency

CSS/D process is known to streamline the program delivery and improve the community's quality of life (Michigan Department of Transportation 2006a). A pictorial representation of streamlining can be seen in Figure 7, where the implementation of CSS/D principles changes the situation from Figure 7a to 7b.

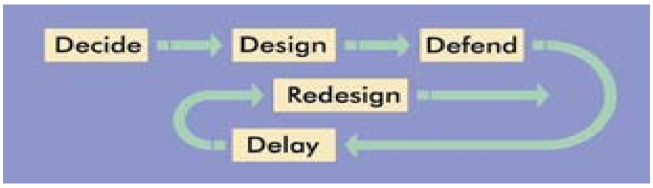

Figure 7a. Without CSS/D

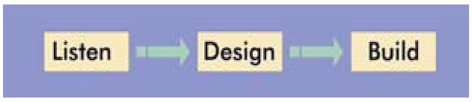

Figure 7b. With CSS/D

Figure 7. Design process without and with CSS/D implementation (Michigan Department of Transportation 2006a)

The MDOT CSS/D scoping and preliminary design is similar to the other states it involves (Michigan Department of Transportation 2006d)-

1. Application CSS/D principles
2. Identification of alternatives
3. Evaluation of alternatives
4. Selection of the preferred alternative

At each stage of the project, stakeholder involvement and their consent are necessary (Michigan Department of Transportation 2006d). The MDOT CSS policy suggests for shared responsibilities between transportation agencies and stakeholders. This will help in developing plans, constructing, operating, and maintaining structures according to CSS principles, without delaying the project and increasing its cost (Michigan Department of Transportation 2006a).

Lastly, the Draft Implementation Plan for CSS/D suggests eight recommendations that must be applied to expand the CSS for transportation projects. The recommendations are (Michigan Department of Transportation 2006c):

- Partnering to improve interagency cooperation
- Improve stakeholder participation through public engagement
- Introduce flexibility in design standards
- Educate the MDOT staff and stakeholders about the CSS/D principles
- Ensure mobility
- Use corridor approach instead of single project approach

- Implement a transition plan to introduce CSS principles
- Measure the success of CSS

3.10 Montana Department of Transportation (MDT)

MDT published a CSS/D guide (Montana Department of Transportation 2015) in 2015 they realized the importance of CSS/D in the early 2000s, and since then, they started taking small steps to achieve it. It can be noted in a CSS management memo published in 2003 (Montana Department of Transportation 2003), which aims to- reinforce the MDT's commitment to work with stakeholders, listen to the needs of communities, make CSS/D an organizational culture, and provide conceptual guidance to staff about the CSS/D so that it can be applied at various stages of project.

The MDT's CSS guide (Montana Department of Transportation 2015) is designed to educate both internal and external users about the CSS/D approach and environmental ethics in all stages of a project. The CSS/D policies of MDT are:

1. Start and apply CSS/D approaches in early stages of a project
2. Involve local government and citizens
3. Balance wants, needs, money and the law
4. Think "outside the box"– be innovative (i.e., no exact approach to achieve CSS/D)
5. Listen and keep an open mind for solutions
6. Support, teamwork, and communication

MDT's vision for CSS/D is to adopt a community incorporated approach, that can assist in future planning, and decision making of local and statewide transportation system, while emphasizing on the quality, safety, cost effectiveness, economic feasibility, and environmental sensitivity. To achieve the MDT's vision six connecting goals were developed so that CSS/D can be achieved:

- Enhance safety
- Be cost effective
- Improve mobility
- Be sensitive to environment
- Preserve community assets
- Be flexible and responsive

It must be kept in mind that the balancing of the above-mentioned goals is important for successful implementation of CSS/D. If any goal dominates, then it may hamper the quality of the project.

The MDT guide to implementing CSS/D suggests identification of transportation concerns, commitment to CSS/D, use of interdisciplinary team, continuous public involvement, valuing community/natural resources, and using full range of tools for communication (internet, visualization, plans etc.). The MDT guide also suggests inclusion of Environmental Bureau staff into the project team and inclusion of CSS/D approach into the preconstruction and design activities. Besides this, the CSS/D approach is also involved in the long-range transportation plan of Montana, which shows the seriousness of Montana towards CSS/D. MDT also accomplished certain projects using CSS/D approach. One example is Lewistown Southeast project that leads to the reconstruction of Secondary Highway 238, with the goal to improve the mobility and safety of both motorized and non-motorized traffic. Another example is-Shiloh road corridor also used CSS/D approach whose aim was to alleviate congestion by reconstructing 4.5 miles of this road. Lastly, the MDT CSS/D guide is full of such examples where CSS/D is implemented.

3.11 New Mexico Department of Transportation (NMDOT)

The NMDOT published manual in 2006 named "*Guide to Context Sensitive Solutions*" (New Mexico Department of Transportation 2006), which defines CSS/D as an innovative approach that "integrate community balance, aesthetics, historic and environmental values with transportation safety, maintenance and performance goals". To achieve these goals and values, NMDOT integrates CSS/D principles in planning, designing, construction, and operation stages of its transportation system.

The NMDOT's CSS/D Directive principles of 2006 are applicable to all projects from planning to operational stage, which includes the following guidelines:

- The proposed transportation project must be planned for its context, transportation objectives, mobility, aesthetic, social economic and environmental values, needs, and opportunities.
- Engage with stakeholders and affected communities from the start of the project.
- Ensure that the transportation objectives of the project are clearly defined and are discussed with the community.
- Pay attention to the community's and citizen's concerns.

- Promote multimodal transportation wherever possible.

The main benefits of applying these directives are that: it builds community support, develop positive relationship with stakeholders, making timely decisions, improve project delivery, protects and enhance environment, decreases time and cost of redoing task.

As per NMDOT, there are five primary components of CSS/D:

- Multimodal Approach: The NMDOT adopted a multimodal transportation approach to provide access to employment, health, education, recreation, and other community services. The CSS/D multimodal approach includes:
    - Review full range of transportation modes (including pedestrian, bicyclist, emergency vehicles, trucks, aged and handicapped vehicles etc.) so that better alternatives for project's need can be developed.
    - Improve the operational movements as per project's need.
    - Coordinate with public transportation agencies to determine the kinds of transportation agencies.
    - Develop multimodal performance measures.
- Public Involvement: NMDOT acknowledges that public involvement is a key to achieve CSS/D, and having a wide range of stakeholders is crucial for successful decision making. Some of the qualities of stakeholders are:
    - Experience/interest in transportation systems and issues
    - Information about the community
    - Diverse background
    - Affected by the project

  Some of the potential stakeholders include elected or appointed officials, business community, residents, public agency representatives etc. To engage the public NMDOT also suggest having a Public Involvement Plan (PIP) whose main function is to think strategically about public involvement, identify stakeholders, develop performance measure for public involvement etc.

- Environmental Stewardship: The CSS/D Directives of NMDOT suggests that transportation solutions that fit the context will be developed. This shows the commitment of NMDOT towards environmental stewardship. The CSS/D directive principles of NMDOT strive to preserve the scenic, environmental, historical, and cultural resources.

- Performance Measures: NMDOT suggests checking the performance of the transportation systems/solutions developed by applying CSS/D principles and approaches. For performance measurement, it highly recommends the usage of *Performance Measures for Context Sensitive Solutions – A guidebook for State DOTs* (TransTech Management, Inc et al. 2004).
- CSS and Safety Conscious Planning (SCP): SCP is a system-wide process that integrates safety at all stages of transportation decision making. It is an approach to prevent crashes and unsafe conditions. Some of the performance measures recommended for SCP are number and rate of crashes/fatalities, crashes that involve heavy vehicles and pedestrians etc.

Besides this, the NMDOT is responsible for CSS planning (either multimodal or long-range plan), project development using CSS approach, and construction and maintenance and operations using CSS approach. NMDOT accomplishes each by a CSS plan, public involvement, and performance measures.

3.12 Washington Department of Transportation (WSDOT)

The WSDOT published a manual in 2005 named "*Flexibility in Transportation Design Manual*" (Washington State Department of Transportation 2005)**,** which was developed to assist the engineers/planners/designers in project development and design process so that both CSS/D principles and balanced design are achieved. It also helps in optimizing the surrounding conditions and resources.

This guide divides the context into two distinct categories- urban and rural environments, like the older versions of AASHTO 2018 (American Association of State Highway and Transportation Officials 2018). However, this guide divided these two environments into eight contexts and mentioned the relative volume of transportation modes in each of these contexts. Table 7 shows the various contexts and the relative volume of various transportation modes. In all the above-mentioned eight contexts, it is necessary to understand the "sense of place" (how people see this place) to achieve CSS/D. After understanding this, the CSS/D solution can be ensured by- providing safety and comfort to all users, maintaining natural environment, supporting healthy economy, and incorporating a community's desires and needs.

Table 7. Contexts with Volume of Transportation Modes (Washington State Department of Transportation 2005)

Context	High Volume	Medium Volume	Low Volume
Urban Centers	Automobiles Bicycles Pedestrians Transit	Trucks	NA
Urban Corridors and Nodes	Automobiles Transit Trucks	Bicycles Pedestrians	NA
Suburban Corridors and Nodes	Automobiles Trucks	Bicycles Pedestrians Transit	NA
Industrial Corridors	Automobiles Trucks	Transit	Bicycles Pedestrians
Rural Town Centers	Pedestrians	Automobiles Bicycles Trucks	Transit
Transitional Areas (Within the Designated Urban Growth Area)	Automobiles	Bicycles Trucks	Pedestrians Transit
Rural Connecting Corridors	Automobiles	Trucks	Bicycles Pedestrians Transit
Residential Areas	Bicycles Pedestrians	Automobiles	Transit Trucks

Furthermore, this guide supports multimodal transportation and suggest a blend of pedestrian, bicycle, transit, and motorized vehicle is necessary to achieve CSS/D. Certain measures must be taken to accommodate each of these modes. Walking as a mode can be supported by creating interconnectivity between different land uses, provide transfer points between modes, and separating pedestrians from vehicular traffic. In addition to this, many treatments for e.g., warning signs, sidewalks, overpass, pedestrian signals etc. can be implemented to increase the share of pedestrians. This guide identifies some issues with bicycling like the physical barriers and obstructions, personal safety and security, conflict with other road users etc. To overcome these issues, the guide suggests a series of treatment measures like- continuous bicycle route, safer bicycle parking, increased curb lane width, higher connectivity etc. Similarly, to improve the transit share and connectivity the guide suggests providing exclusive bus lanes and bus bays, clear and distinct bus signs and markings, passenger shelters and transit centers etc. Lastly, for motorized vehicles, the guide identifies the main issues to be pedestrian interaction with motorized vehicles, delivery vehicle access to narrow streets, improper match of facility and context etc. This can be addressed by designing the intersections in such a way so that it can accommodate turning movements of design vehicle without leaving paved shoulder. In some cases, it may be judicious to develop alternate truck routes for rural and urban town center, that largely depends on the size and characteristics of the vehicle using the facility.

Besides this, the guide also talks about certain environmental considerations that must be accounted for to achieve CSS/D. It is highly important to preserve urban forestry, urban streams, fish wildlife and plant resources, cultural and historic resources, and air quality. Lastly, prevention of noise pollution and vibration is important with increased use of recycled materials so that environmental sustainability is maintained.

4 SUMMARY OF INTERNAL AND EXTERNAL DATA

This project is focused on the development of a data-driven methodological framework that can be used for project scoping and planning activities. As such, a critical aspect is the identification, collection, and integration of a diverse range of datasets, which are available both internally from MDOT, as well as through various other public agencies.

Data for this project were collected primarily from online resources maintained by the MDOT, Michigan open GIS data, and the Southeast Michigan Council of Governments (SEMCOG) portal. The data was collected at various levels of coverage, ranging from statewide, to regional (e.g., MPO), to county levels. For the purposes of this study, the data available at the statewide or regional level are most pertinent. In addition to these resources, the MSU team also maintains copies of MDOT's legacy Sufficiency File database, which contains much of the pertinent information of interest to this project, such as traffic volumes, cross-sectional characteristics, lane characteristics, posted speed limit, capacity/level-of-service, etc. Table 8 shows the available categories in each of the following data sources:

- Michigan open GIS portal (State of Michigan 2022) (https://gis-michigan.opendata.arcgis.com/)
- MDOT open GIS portal (Michigan Department of Transportation 2022a) (https://gis-mdot.opendata.arcgis.com/)
- SEMCOG open GIS portal (Southeast Michigan Council of Governments 2022) (https://maps-semcog.opendata.arcgis.com/)

Table 8. Available GIS Data by Category and Data Source

Data source	Michigan Open GIS Data	MDOT GIS	SEMCOG
Data category (as per website)	Boundaries Demographics Elevation Environment Fish & Wildlife Geology Hydro MI Geographic Public Health Transportation	Boundaries Facilities Planning Road Assets Traffic	Aerial Photography Boundary Economy Elevation Contours Land Data Transportation

Available datasets from each of the categories detailed in Table 8 was thoroughly reviewed. Datasets that were determined to potentially be pertinent to this project were downloaded from each website. These datasets were aggregated into four general categories based upon the type of information that was provided. All datasets included information that was available in both spreadsheet and GIS shapefile format. Table 9 classifies each dataset into the following four broad categories:

1. Road/Traffic: The datasets in this category provide information about the roadway and traffic features, railroads, sidewalks, crosswalks, mileage, and others similar to these. The typical information in these datasets are traffic volume, crashes, Physical Road (PR) number, road name, Beginning and Ending mile point (BMP, EMP), etc. This is important from the CSS/D standpoint as this can assist in developing a context-sensitive roadway facility based on traffic volume, road geometry, ped bike volume, and other factors.

2. Adjacent Land Use: The datasets in this category provide information about the land use, urban/rural boundaries, city and county names within the area, information regarding the unincorporated places, wetlands etc. This will help in understanding the context of the area, which can assist the planner/engineer in designing a facility that suits the context, which is the core of CSS/D.

3. Census: The datasets in this category provide information regarding the census tracts, community boundaries, demographic information, and other such details. Such kind of information is important, as the planner/designer gets to know the general demographic profile of the area, which can help in designing a facility that suits most of the population. For example, if an area has a high population of older population residents, then it would be logical to:

    - Provide more time for pedestrians at the signal,
    - Use smaller rise in stairs as compared to the standard practice, and
    - Use bigger fonts for informative signs and similar other measures.

4. Michigan Department of Natural Resources (MDNR) and Miscellaneous: The datasets in this category provide information about the forest cover area, conservation and recreational lands, trails, etc. These datasets will help in identifying and locating such areas, and the planner/designer would be in a better position to design the facility for such areas based on the forecasted land expansion, afforestation/deforestation, and other natural resources of that area.

Table 9. Potential Dataset names with Category, Source, and Coverage

Data Category	Dataset name	Source	Coverage
Road/traffic/rail roads	All Roads (v17a)	MI Open GIS	MI
	Railroads (v17a)	MI Open GIS	MI
	Michigan MIRIS Railroads	MI Open GIS	MI
	Traffic Volume	MDOT/MS2; MSU	MI
	MDOT Lane Mile Inventory (LMI)	MDOT	MI
	Mile Markers	MDOT	MI
	2014-2018 Crash Data	MSP	MI
	Culverts	MDOT	MI
	MDOT Carpool Lots	MDOT	MI
	MDOT Non-Freeway Network	In house dataset	MI
	MDOT Cargo Ports	SEMCOG	MI
	Traffic Volume	SEMCOG	Regional
	Sidewalks and Crosswalks	SEMCOG	Regional
	Bicycle Network	SEMCOG	Regional
	Detroit People Mover Route and Stations	SEMCOG	Regional
	Truck Routes	SEMCOG	Regional
	Rail	SEMCOG	Regional
Adjacent land use/nearby features/boundaries	Michigan State House Districts (v17a)	MI Open GIS	MI
	Adjusted Census Urban Boundaries (v 17a)	MI Open GIS	MI
	Cities (v17a)	MI Open GIS	MI
	Counties (v17a)	MI Open GIS	MI
	Villages (v17a)	MI Open GIS	MI
	Unincorporated Places (v17a)	MI Open GIS	MI
	Minor Civil Divisions (Cities & Townships) (v17a)	MI Open GIS	MI
	Potential Wetland Restoration	MI Open GIS	MI
	National Wetlands Inventory	MI Open GIS	MI
	Public Land Survey Quarter-Quarter Sections	MDOT	MI
	Buildings St. Clair, Detroit, Wayne, Oakland, Macomb, Livingston, Monroe, Washtenaw	SEMCOG	Regional
	Land Use	SEMCOG	Regional
	Parks and Park Attribute	SEMCOG	Regional
Census	Census Designated Places (v17a)	MI Open GIS	MI
	2010 Census Tracts (v17a)	MDOT	MI
	2010 Block Groups (v17a)	MDOT	MI
	Metropolitan Planning Organizations	MDOT	MI
	Community Boundaries	SEMCOG	Regional
	2010 Census Block Groups	SEMCOG	Regional
	2010 Census Tracts	SEMCOG	Regional
	2010 Census Urban Area	SEMCOG	Regional
Michigan DNR and Other Miscellaneous	Michigan State Forest Cover type	MI Open GIS	MI
	Michigan DNR Designated Bicycle Trails	MI Open GIS	MI
	Non-Motorized Trails	MI Open GIS	MI
	Michigan DNR Designated Hiking Pathways	MI Open GIS	MI
	Michigan DNR Designated Motorcycle Trails	MI Open GIS	MI
	Conservation and Recreation Lands (Fee and Other)	MI Open GIS	MI
	Aerial Survey 2018	MI Open GIS	MI

The remainder of this chapter provides further details for each of the datasets from Table 9. Descriptions of each of these datasets are included in Table 10 through Table 14. Table 10 and Table 11 provide details of roadway and traffic related datasets for MDOT roads and SEMCOG roads. This includes general roadway information, such as an All Roads dataset that is part of the Michigan Geographic Framework (MGF). Several of the other datasets can be directly integrated with the All Roads file, providing information regarding traffic volumes, crash data, and roadway inventory data. Separate files are maintained for select features, such as culverts.

Table 10. Road/Traffic datasets MDOT (shapefiles available)

Dataset name (Coverage, Source)	Description
All Roads v17a (State, MI open GIS)	This dataset is part of the Michigan Geographic Framework (MGF). It has all the information on the roads like- PR number, length, zip code, road name, county number, Beginning Mile Point (BMP), End Mile Point (EMP) etc.
Railroads v17a (State, MI open GIS)	This is also the part of MGF and shows the active railroad tracks. This also gives the information about length of railroad, name of service provider etc.
Michigan MIRIS Railroads (State, MI open GIS)	This dataset has information about the Railroads of entire Michigan. The data is edited through the forest compartment review process. Original linework came from the Michigan Resource Inventory System (MiRIS) base maps, which were digitized from the 1978 USGS Topographic Quadrangles.
Traffic Volume (MI) (State, MDOT/ MS2/MSU)	This dataset provides information on commercial and vehicular traffic volumes. Also, it also provides information for PR number, county number, road number etc.
MDOT Lane Mile Inventory (State, MDOT)	This dataset is a GPS assisted windshield survey data collection of the number of lanes on any given segment of Michigan state highway (trunkline). It is also referred to as "striped lane mile inventory." A lane mile can be defined as "one mile of roadway that is intended for driving." This dataset has attributes like- number of lanes, lane function, maintenance responsibility, road type, speed limit, bike lanes, on-street parking, and sidewalks.
Mile Markers (State, MDOT)	This dataset has the information about mile marker location information about Michigan's highways. This also has the information for latitude and longitude, route name, region, county, control section number, physical reference (PR) number, PR mile point, and mile number.
2014-2018 Crash Data (State, MSP)	This dataset provides information about the crash location, crash type, crash severity, facility type on which crash occurred. This will help in identifying the safety-critical areas, and it can be used to prioritize the location at which treatment has to be provided.
Culverts (State, MDOT)	This dataset contains the locations of culverts collected as part of the MDOT Transportation Asset Management System (TAMS). This inventory establishes a monitoring protocol for smaller culverts between 1 foot and 10 feet (larger culverts are inventoried in the Michigan Structure Inventory as part of the National Bridge Inspection Standards).
MDOT Carpool Lots (State, MDOT)	The Michigan Carpool Parking Lot Program (also referred to as Park and Ride sometimes) started as a pilot program in 1974 with 11 carpool parking lots. Currently, there are more than 240 carpool parking lots located across the state, which provides approx.—9,000 parking spaces.

Table 11 includes several datasets maintained by SEMCOG. This includes several that are highly pertinent to CSS/D, such as sidewalks and crosswalks, bicycle networks, and truck routes. Similar data are not currently available at the statewide level, though data from the SEMCOG region can be integrated with MDOT's existing datasets and serve as a model for the development of similarly diverse datasets for the remainder of the state where pertinent.

Table 11. Road/Traffic Datasets SEMCOG (shapefiles available)

Dataset name (Coverage, Source)	Description
MDOT Non-Freeway Network (State, in house dataset)	This is the in-house dataset developed by MSU, which provides the information for Non-freeways like length, surface type, VMT, volume, driveway density etc.
MDOT Cargo Ports (Regional, SEMCOG)	This dataset of MDOT's Cargo Ports has the information of inbound and outbound tonnage for each cargo port. This data is used for: state long-range plans, freight planning, economic analysis studies, and various other projects of local agencies.
Traffic Volume (Regional, SEMCOG)	This dataset has information about the volume, number of lanes, functional class of road etc. for the SEMCOG region. It has more details than that of MDOT datasets.
Sidewalks and Crosswalks (Regional, SEMCOG)	This dataset was created in 2019 by using aerial imagery and was initially created for the 2020 Bicycle and Mobility Plan for Southeast Michigan. It has information about the sidewalks and crosswalks for the SEMCOG region and gives the details like length and width.
Bicycle Network (Regional, SEMCOG)	This dataset was built off of MGF version 12b, uses the road network to identify roadways with existing or planned bicycle and/or pedestrian facilities in Southeast Michigan. It identifies existing and planned bike routes and bicycle-friendly roadways, which may not have appropriate ped bike facilities, but, due to a combination of low traffic volumes and low posted speed, are none-the-less more comfortable to travel on.
Detroit People Mover Route (Regional, SEMCOG)	This dataset has information about the route of Detroit People Mover (DPM). It is a light rail route in Michigan.
Detroit People Mover Stations (Regional, SEMCOG)	This dataset has information about the stations of Detroit People Mover (DPM). There are total of 13 stations.
Truck Routes (Regional, SEMCOG)	This dataset consists of roadway features that are either Class-A all-season roads that have higher pavement design standards and allow higher weights during annual spring thaw weight restrictions or part of designated intermodal connectors that lead from freeways to critical freight intermodal activity centers, such as ports and rail yards.
Rail (Regional, SEMCOG)	This dataset contains information about the railroads of SEMCOG region. This dataset is derived from MGF, but it has additional information like BMP, EMP, Length, county number etc.

Table 12 describes those datasets that fall under the land use/boundaries category. This table covers a range of datasets that defines the boundaries of cities, villages, and counties. It also has information about wetlands and land usage in general.

Table 12. Adjacent land use/Nearly features/Boundaries (shapefile available)

Dataset name (Coverage, Source)	**Description**
Michigan State House Districts (State, MI Open GIS)	It is a part of MGF base map. It has the information about the State House Representative for each District, the area (in sq. miles and sq. kms) of the district, and the peninsula it belongs.
Adjusted Census Urban Boundaries (State, MI Open GIS)	This dataset details Adjusted Census Urban Boundaries (ACUB), which include: urban cluster areas (where the minimum population is 5,000) or urbanized area as designated by the U.S. Census; the corporate limits of any city or village designated as partially urban by the Census; and the adjacent area which meets specified criteria and is agreed upon by MDOT in cooperation with the responsible local officials. This dataset has information about the number code of urban area, size of area, area type etc.
Cities (State, MI Open GIS)	This is a part of MGF base map and gives information about a city of Michigan. The information covered are name of city, size of area, peninsula information etc.
Counties (State, MI Open GIS)	This a part of MGF base map and gives the information of county boundaries, county area, county number code etc.
Villages (State, MI Open GIS)	This is a part of MGF base map and details the information about the villages of Michigan. It has the following information: name of the village, size of area, peninsula information etc.
Unincorporated Places (State, MI Open GIS)	This is a part of MGF base map and typically current or former small towns, communities, or locations. This dataset has the following information: X and Y coordinates of the area, Place ID of the area etc.
Minor Civil Divisions (Cities & Townships) (State, MI Open GIS)	This data set is a part of MGF and consists of polygons that represent the boundaries of cities and townships. The aggregation of all polygons provides 100% coverage of Michigan. It has information about the name of the cities and townships, its area, peninsula etc.
Potential Wetland Restoration (State, MI Open GIS)	This dataset details the information about the Potential wetland Restoration in Michigan. It has information about the size of the area, perimeter, and location of the wetland restoration.
National Wetlands Inventory (State, MI Open GIS)	This dataset details the extent, approximate location, and type of wetlands and deep-water habitats for all states in the US. Data for Michigan can be extracted and include the following information: type of wetland, area, and perimeter.
Public Land Survey Quarter Sections (State, MI Open GIS)	This dataset has the information of county, town, range, section, quarter polygons, government lot polygons, or private claim polygons in Michigan's Upper and Lower Peninsula.
Buildings footprints for SEMCOG region (Regional, SEMCOG)	This is a group of seven datasets of the seven counties of SEMCOG region, which shows the building footprint data of each of this county. This dataset has information on building types, area of buildings, housing units, zip code etc.
Land use (Regional, SEMCOG)	This dataset has information on the land type (Agricultural, cemetery, hospital, institutional etc.), area size, and perimeter.
Parks (Regional, SEMCOG)	This dataset contains information of basic location information on parks in the SEMCOG region. More detailed information about these parks can be found in the following Park Attributes dataset, which is also maintained by SEMCOG. This dataset contains information about area of park, perimeter, area, and name of owner.
Park Attribute (Regional, SEMCOG)	This dataset has the details of the attributes of park like- dog park, entry fees, boating, golf course, picnic shelter etc. It can be joined with the "Parks" dataset using the NAME and PARK_NAME field.

Table 13 provides details of datasets that include census information. This information can be used to provide important contextual factors that characterize socioeconomic characteristics, land area, and land use characteristics, among others.

Table 13. Census Information (shapefile available)

Dataset name (Coverage, Source)	Description
Census Designated Places (State, MI Open GIS)	This dataset was derived from MGF base map. These are the counterparts of incorporated places and provide data for settled population that are recognizable able by name, however, are not lawfully consolidated under the laws of the state in which they are found. The boundaries of these areas may change in every census (every 10 years) because of the change in settlement pattern. This dataset provides information about the name of the area, size of area, perimeter etc.
2010 Census Tracts (State, MI Open GIS)	This census tract dataset was also derived from the MGF base map and was created for statistical purposes that usually average about 4000 people. It provides information about the county, size of census tract (in sq. kms and sq. miles), peninsula etc.
2010 Block Groups (State, MI Open GIS)	This dataset was also derived from MGF base map and it provides information like area of block group (in sq. km or sq. miles), perimeter etc.
Metropolitan Planning Organizations (State, MI Open GIS)	This dataset represents all localities in all the urbanized areas of Michigan with population over 50,000 as per U.S. Census, and 14 MPOs.
Community Boundaries (Regional, SEMCOG)	This dataset was a part of MGF but was modified by SEMCOG and gives information about minor civil divisions, communities, cities, villages, and townships.
2010 Census Block Groups (Regional, SEMCOG)	This is derived from MGF base map and modified by SEMCOG. It has information about county code, land area, water area and other such details for each census block group of SEMCOG region.
2010 Census Tracts (Regional, SEMCOG)	This is derived from MGF base map and modified by SEMCOG. It has information about county code, land area, water area, and other such details for each census tract of SEMCOG region.
2010 Census Urban Area (Regional, SEMCOG)	All the SEMCOG area that was categorized as "urban" by the US census in 2010 is shown in this area. It has both urbanized area and urban clusters, but it is not same as the Adjusted urban area/boundary of MI open GIS portal.

Lastly, Table 14 provides details of geospatial data that are available from the Michigan Department of Natural Resources (DNR), as well as several other miscellaneous datasets. A brief description is provided for each dataset in this category. This includes information regarding land cover, conservation and recreational areas, and motorcycle and bicycle trails.

Table 14. Michigan DNR and Miscellaneous Datasets (shapefile available)

Dataset name (Coverage, Source)	Description
Michigan State Forest Cover type (State, MI Open GIS)	This dataset demarcates the forest stand cover types by Michigan DNR. This also includes the information of Michigan State Park and Michigan Wildlife Division lands where forest inventory is completed. This dataset gives information about the area size of the abovementioned areas, natural plantation, plantation density, natural plants etc.
Michigan DNR Designated Bicycle Trails (State, MI Open GIS)	This dataset gives information about the trails that are designed for bicycles and mountain bikes; but are not limited to motorized vehicles, bicycle trails, equestrian trials etc. The location of these trails may be on State, Federal, County, Local, and Private lands. This dataset gives the information about the name of the path, recommended use for which type of bike, surface type, length etc.
Non-Motorized Trails (State, MI Open GIS)	This dataset provides information about the non-motorized trails in Michigan. This dataset gives the information regarding the trail length, watchable wildlife, availability of picnic shelter, etc.
Michigan DNR Designated Hiking Pathways (State, MI Open GIS)	This dataset gives the information about the designated hiking pathways; these are the trails specifically designed for hiking and are not limited to motorized vehicles, bicycle trails, equestrian trials etc. The location of these trails may be on State, Federal, County, Local, and Private lands. This dataset gives the information about the name of the path, seasonal restriction, surface type, length etc.
Michigan DNR Designated Motorcycle Trails (State, MI Open GIS)	This dataset provides information about the trails designated for motorcycle use, and this includes ATV and ORV routes. The location of these trails may be on State, Federal, County, Local, and Private lands. This dataset has information about the seasonal restriction, length of trail, trail owner, and trail network.
Conservation and Recreation Lands (Fee and Other) (State, MI Open GIS)	This dataset provides information about the conservation and recreation lands of Michigan. This dataset provides the information about the site name, area, owners' name, type of land etc.
Aerial Survey 2018 (State, MI Open GIS)	This dataset has the information from the aerial survey that has been conducted in 2018, which can be used for forestry, planning decisions.

Collectively, the data described in this chapter provide an extensive amount of information that can potentially be used to help inform decisions at various stages of the project scoping and development processes. These datasets will be critically reviewed, in consultation with MDOT, to identify specific data that are currently used as a part of this process or data that may potentially be leveraged to enhance MDOT's ability to proactively consider CSS/D.

5 DATA PREPARATION

Various guidelines and best practice documents were reviewed that focus on providing pedestrian and bicyclist treatment. This includes *STEP studio* (Federal Highway Administration 2020b), *Bikeway Selection Guide* (Schultheiss et al. 2019), *Urban Bikeway Design Guide* (National Association of City Transportation Officials 2012), *Multimodal Development and Delivery Guidebook* (Michigan Department of Transportation 2019), and *Best Design Practices for Walking and Bicycling in Michigan* (Michigan Department of Transportation 2012a).

Collectively, these resources generally consider a combination of speed, AADT, context, and median-lane configuration to identify appropriate pedestrian and bicyclist treatments at the segment, midblock, and intersection levels. Consequently, datasets were identified that included as much pertinent information as possible at the state-wide level. Ultimately, three datasets were used in the development of the final database that was used to create the decision support tool:

- Lane mile inventory file
- State-owned roads file
- MDOT's legacy sufficiency file

The following sections provide details of each dataset, information regarding how the data were prepared and integrated, and a discussion of challenges that were encountered as a part of these activities.

5.1 Data Description

The following paragraphs provide a brief about each dataset used in this study and the data summary of relevant variables.

The lane mile inventory dataset is a GPS-assisted windshield survey data of the Michigan trunkline roadways. The total number of segments in this dataset were 84,000 with following variables- number of lanes, functional class, PR number, PR BMP, PR EMP, maintenance responsibility, road type, speed limit, bike lane presence, on-street parking, sidewalks etc. shows the distribution of lane miles by functional class and speed limit for Michigan state highway system. It is clear from Table 15 that the majority of the Michigan state highways have speed limit greater than or equal to 55 mph. Further, most of these roads are of higher functional class i.e., arterial and above.

Table 15. Lane Miles by Functional Class and Speed for Michigan State Highways

Functional class	Speed limit (mph)								
	<=25	30	35	40	45	50	55	>55	Total
Interstates	0.0	0.1	1.7	0.0	20.5	0.0	227.0	6123.0	6372.1
Other Freeways	0.0	0.0	1.1	4.9	9.1	7.2	237.6	2869.4	3129.2
Other Principal Arterials	65.8	290.4	796.8	863.0	1414.6	807.8	6150.8	114.3	10503.5
Minor Arterials	80.7	197.6	341.3	236.7	578.8	275.5	7166.4	0.9	8877.9
Major Collectors	28.3	12.1	31.7	14.3	78.2	37.7	650.1	1.0	853.5
Minor Collectors	0.0	0.0	0.0	0.0	0.0	0.9	0.0	0.0	0.9
Local	25.1	0.0	1.3	0.0	4.4	0.0	6.1	0.0	37.0
Total	199.8	500.1	1173.9	1118.9	2105.7	1129.0	14438.1	9108.5	29774.0

Another dataset of interest is the state-owned roads. This dataset is a part of Michigan Geographic Framework and serves as a base map for State of Michigan government. This dataset has 63,000 segments and has similar variables to the lane mile inventory, such as number of lanes, NFC, PR number, PR BMP, PR EMP etc. But the key variable here is roadway contexts which is divided into- rural (pop. <5K), small urban area (pop. 5K-50K), small urbanized area (pop. 50K-200K), and large urbanized area (pop. >200K). Table 16 shows the distribution of lane miles by different roadway function classes and contexts. It was observed that the majority of the roads were under rural context, followed by large urbanized areas.

Table 16. Lane Miles by Functional Class and Context for Michigan State Highways

Functional class	Context				
	Rural (pop. <5K)	Small urban areas (5K-50K)	Small urbanized areas (50K-200K)	Large urbanized areas (>200K)	Total
Interstates	2454.9	344.4	773.6	2799.3	6372.1
Other Freeways	1413.4	259.0	366.8	1090.0	3129.2
Other Principal Arterials	5046.4	1061.0	1027.6	3368.4	10503.5
Minor Arterials	7207.3	834.1	377.2	459.2	8877.9
Major Collectors	808.5	17.0	6.2	21.8	853.5
Minor Collectors	0.9	0.0	0.0	0.0	0.9
Local	19.5	4.2	1.5	11.8	37.0
Total	16950.9	2519.7	2552.9	7750.6	29774.0

Figure 8 shows the Michigan state highways with contexts. It can be seen that a major portion of large urbanized areas, demarcated with red lines, lie in the SEMCOG region, particularly concentrated in Detroit.

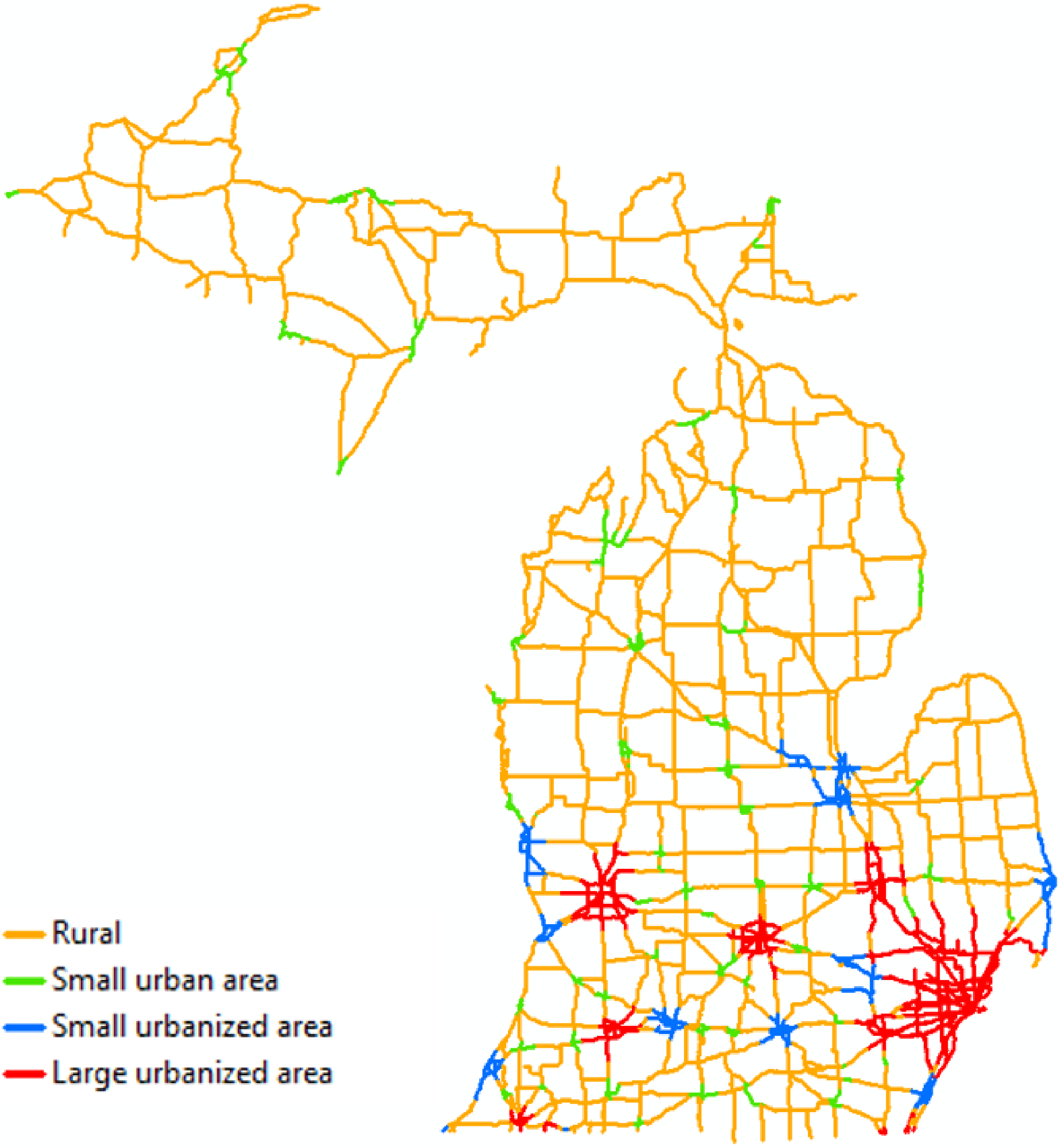

Figure 8. Roadway Contexts Michigan State Highways

Figure 9 shows the aerial and street view of all four contexts. It can be seen that as the contexts shift from rural to large urbanized areas, the housing density tends to increase along the roadsides.

Rural aerial

Rural street view

Small urban area aerial

Small urban area street view

Small urbanized area aerial

Small urbanized area street view

Large urbanized area aerial

Large urbanized area street view

Figure 9. Aerial and Street View of all Four Contexts

Other than lane mile inventory and state-owned roads dataset, MDOT's legacy sufficiency file 2015 was also used to prepare the final database. The sufficiency file has 7,500 segments and has a lot of useful variables such as- speed limit, AADT, number of lanes, functional class of roads, contexts, PR number, PR BMP, PR EMP etc. The key variables obtained from the sufficiency file were AADT and median type information. It should be noted that AADT datasets are available on MDOT open GIS website (Michigan Department of Transportation 2022a), but they have missing information (explained in the next section: challenges), that's why sufficiency files were used. Table 17 shows the distribution of lane miles with AADT ranges and contexts. Nearly one-third of the lane miles are in the AADT range of less than 5,000, which indicates that significant lane miles of the MDOT routes are either of low volume or rural.

Table 17. Lane miles by AADT ranges and Contexts

AADT ranges	Contexts				
	Rural	Small urban areas	Small urbanized areas	Large urbanized areas	Total
<5,000	9573.9	327.4	101.1	159.1	10161.4
5,000-10,000	4616.1	871.3	570.5	463.5	6521.4
10,000-20,000	2055.4	1082.9	995.4	1844.4	5978.1
>20,000	705.5	238.1	885.9	5283.6	7113.1
Total	16950.9	2519.7	2552.9	7750.6	29774.0

Lastly, it should be noted that in all these three datasets, the number of segments was different, but the overall length of roadways is almost the same in each dataset because they represent MDOT-maintained routes.

5.2 Challenges in Data Preparation

As the final database was prepared with different sources, there were some challenges. The first challenge was the missing data in the recent traffic volume files available on the MDOT open GIS website (Michigan Department of Transportation 2022a). It was found that some of the divided highways were missing in the traffic volume files but were present in the lane mile inventory and state-owned files. An example of it can be seen in Figure 10.

Due to these missing segments in the traffic volume file, if it is joined with the lane mile inventory and state-owned files, it would result in an incomplete dataset with missing segments. Another challenge with the traffic volume file is that in some segments, the traffic volume increased drastically by 50-100% as compared to the older sufficiency files. Such an increase in traffic volume in some segments is unexpected and raises data quality concerns in these segments.

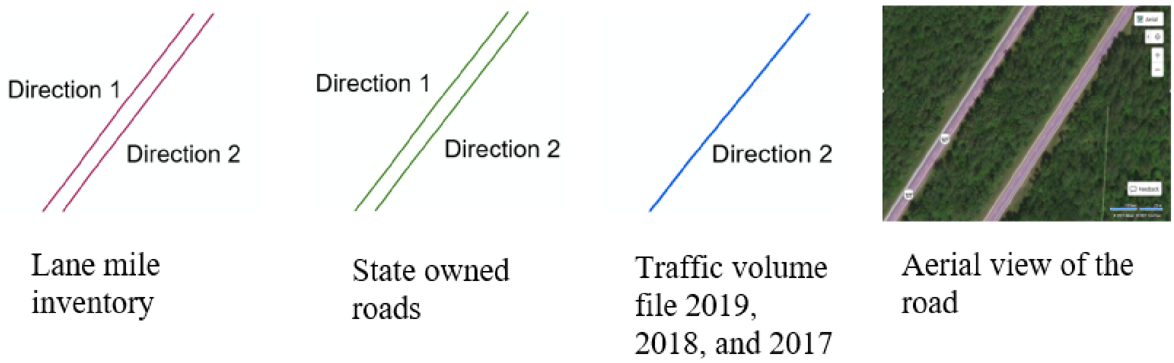

Figure 10. Demonstration of Missing Data in Traffic Volume Files

To overcome these challenges of traffic volume, MDOT’s sufficiency file 2015 was used as it overlaps with the lane mile inventory and state-owned files, i.e., no missing segments. It should be noted that the sufficiency file has the data that was collected in 2015, and traffic volume might have increased over the years. But the overall idea is to use the broad AADT ranges- <5K, 5K-10K, 10K-20K, and >20K in the tool, which remains unaffected by these volume changes between 2015 and 2019 (as 2020 and 2021 were pandemic affected).

The last challenge was related to the routine file updating procedure of MDOT. It was observed that the lane mile inventory dataset was removed from the MDOT open GIS website (Michigan Department of Transportation 2022a), and a new dataset was added, namely road asset inventory. Both these datasets have nearly the same attributes and same coverage; as such, MSU continued to use the lane mile inventory dataset.

5.3 Steps of Data Preparation and Data Summary

A series of tools and techniques were used to prepare the final database to be used in this study, such as ArcGIS and MS-Excel. The following steps briefly describe the data preparation process:

1. A spatial join in ArcGIS was performed between lane mile inventory (number of lanes, bike lane, speed limit etc.) and state-owned roads file (contextual information: rural, small urban, small urbanized, and large urbanized) by considering lane mile inventory as the base file.
2. A quality check was performed on the joined data by:
    a. Comparing the PR number of lane mile inventory and state-owned roads file.

    b. Checking if any segment is repeated twice in the data joining process. If yes, carefully remove the duplicate segments.
3. Save the dataset prepared after step 2.
4. Sufficiency file was used to obtain the AADT information. Remove the segments that have zero AADT as it might be a computational error (there were only a few segments with zero AADT). Save this dataset with only AADT, PR number, PR BMP, and PR EMP columns.
5. In ArcGIS linear referencing tool (tool name: overlay route events) was used to join the dataset prepared in step 4 with the one prepared in step 3. This will add the AADT data to the file prepared in step 3.
6. In this dataset, the segments that have the same PR number, PR BMP, and PR EMP corresponding to a row were removed. These are basically the segments that are extremely small (equivalent to point), i.e., BMP equals EMP.
7. The data prepared in step 6 has AADT information. But this AADT information may be incorrect for a few segments that do not have their BMP and EMP within the same sufficiency file segments as lane mile inventory is the base file. This problem will occur where a lane mile inventory segment overlaps on two sufficiency file segments. In these cases, the average AADT of these two overlapped segments was assigned to that lane mile inventory segment.
8. Now the AADT is assigned, contextual information is added, and the dataset has speed limit, number of lanes, and median type information. The dataset was cleaned by removing any zeros in speed limit.

The final dataset that was prepared has approximately 73,000 road segments with 30,000 lane miles of Michigan state highways (trunkline) or MDOT routes. Figure 11 shows the lane miles in each context by AADT ranges and speed limit.

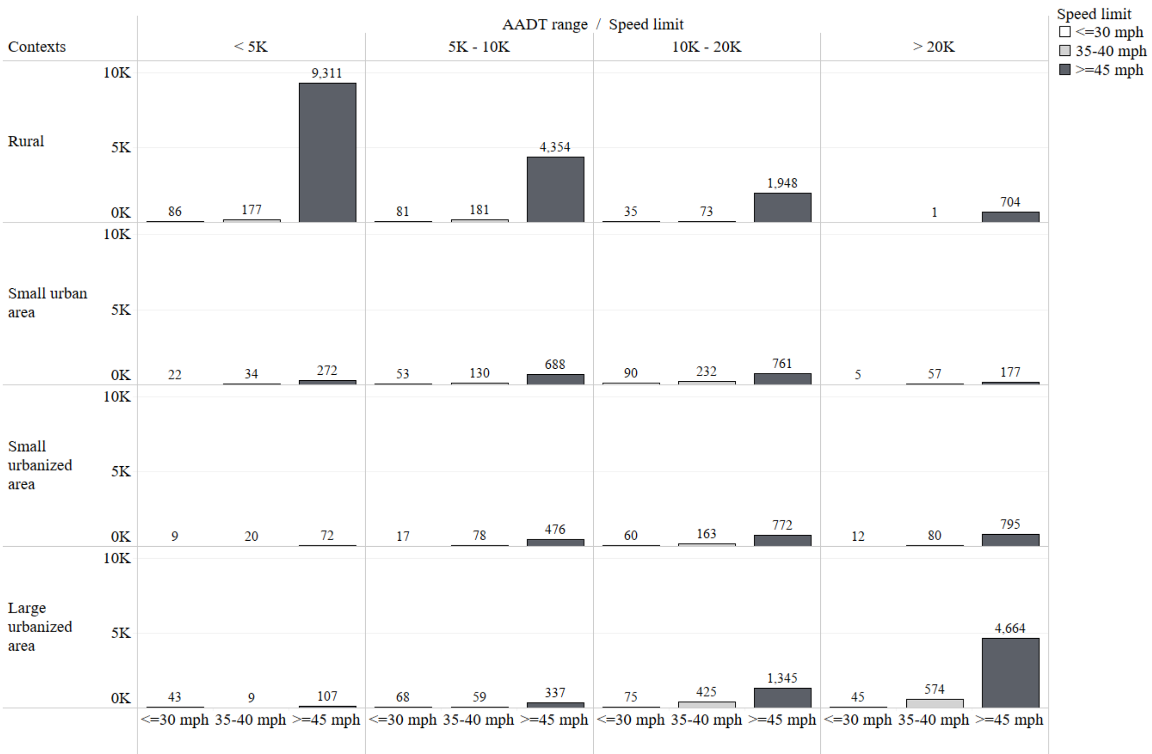

Figure 11. Total Lane Miles by Contexts, AADT, and Speed limit

It can be seen in Figure 11 that as the context moves from rural to large urbanized areas, the lane miles increase in higher AADT ranges (> 20,000), which was expected as urban areas tend to have higher traffic volume. Additionally, in all the contexts and AADT ranges, speed limit >=45 mph has the highest lane miles of Michigan state highways or trunkline. Further, rural context with AADT <5,000 has nearly one-third, and rural context alone has half of the total lane-miles of the Michigan state highways. This indicates that the majority of the roads are rural in nature.

Figure 12 shows the lane mile distribution in rural context with various AADT ranges, speed limits, and median-lane configurations. It can be seen that roads were divided by median types- undivided roads (roads with no median), raised (only raised medians), others (medians other than raised, e.g., guard rail, concrete barrier, graded with ditch etc.). Among the rural context, the majority of the Michigan state highways are undivided 2-lane roads, and that too in the AADT range below 10K. This type of lane mile distribution is expected as most rural roads may not expect higher traffic; that's why undivided roads are preferred as they can serve the purpose.

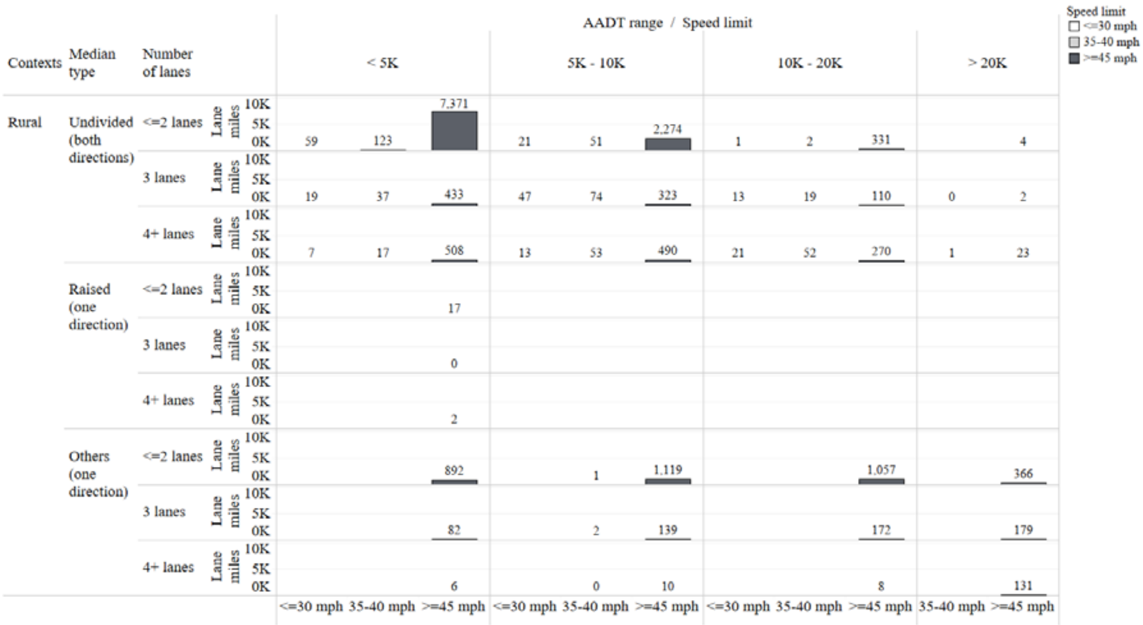

Figure 12. Lane Miles Distribution in Rural Context with AADT, Speed limit, and Median-lane configuration

Figure 13 shows the lane mile distribution in small urban areas with various AADT ranges, speed limits, and median-lane configurations. Similar to rural areas, in small urban areas also the majority of the lane miles are on undivided roads. It can be seen that a significant portion of Michigan state highways has other types of medians, particularly in speed limit >=45 mph.

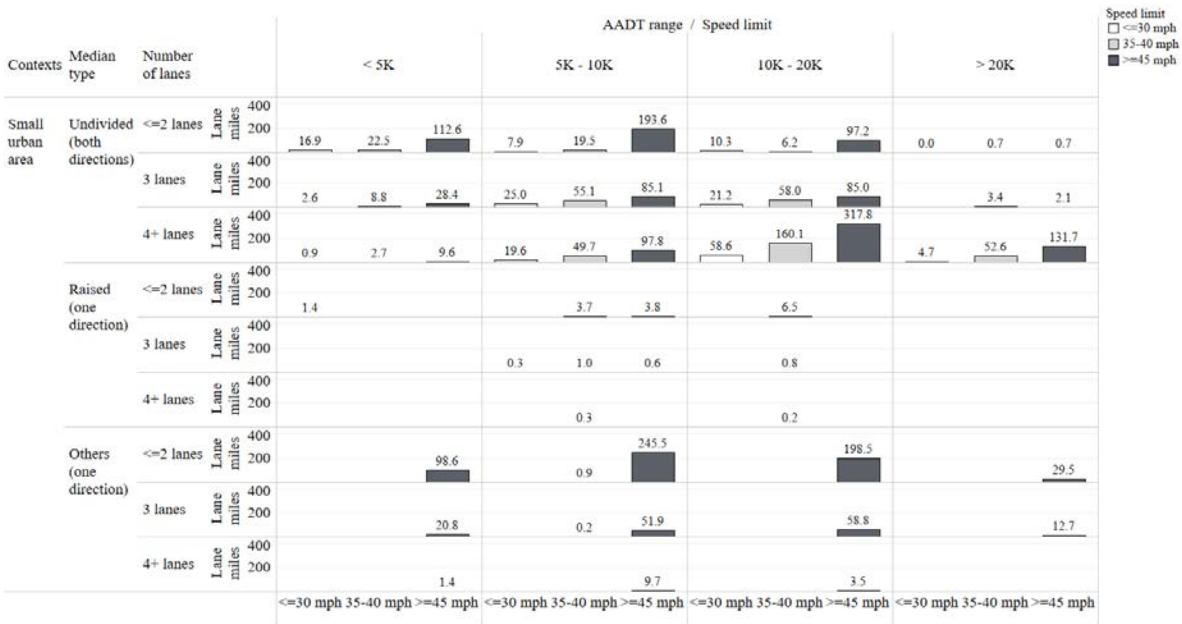

Figure 13. Lane Miles Distribution in Small Urban Areas with AADT, Speed limit, and Median-lane configuration

Figure 14 shows the lane mile distribution in small urbanized areas with various AADT ranges, speed limits, and median-lane configurations. As compared to rural and small urban areas, most of the Michigan state highways have other types of median. This shift in lane miles may be due to the shift in contexts. As contexts become more urbanized, traffic volume also tends to increase, which calls for spatial separation between the vehicles traveling in the opposite direction to avoid conflict.

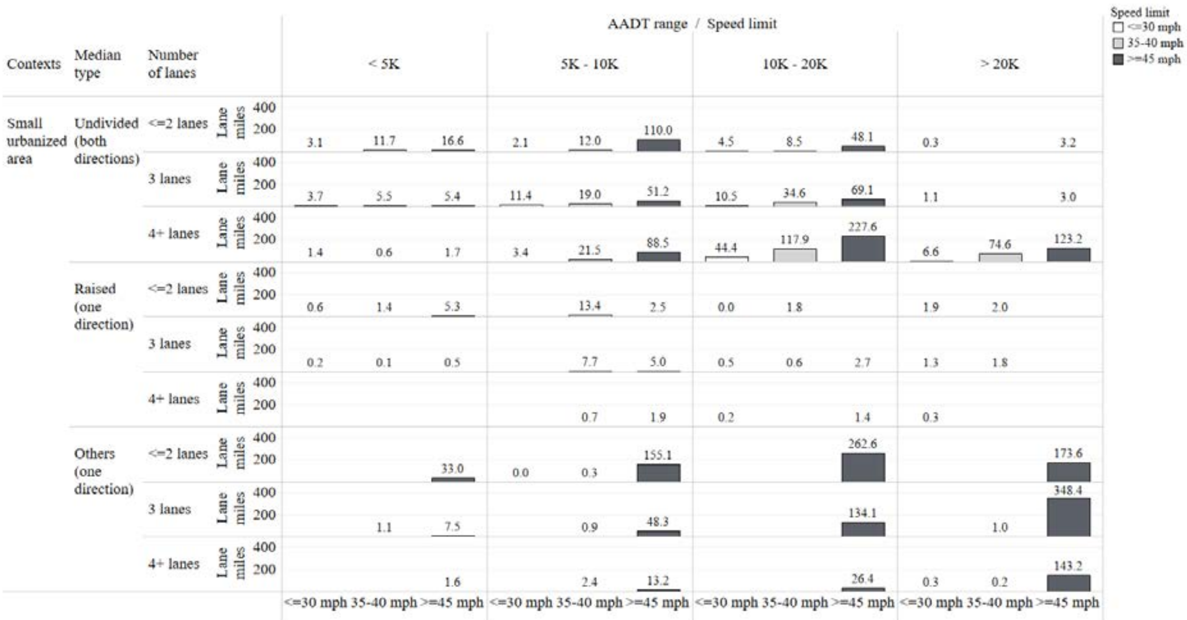

Figure 14. Lane Miles Distribution in Small Urbanized Areas with AADT, Speed limit, and Median-lane configuration

Figure 15 shows the lane mile distribution in large urbanized areas with various AADT ranges, speed limits, and median-lane configurations. It can be clearly seen that the majority of the Michigan state highways have other types of median, in large urbanized areas that increases separation between the opposing traffic flows. Further, as expected, significant road segments in this context have AADT >10K.

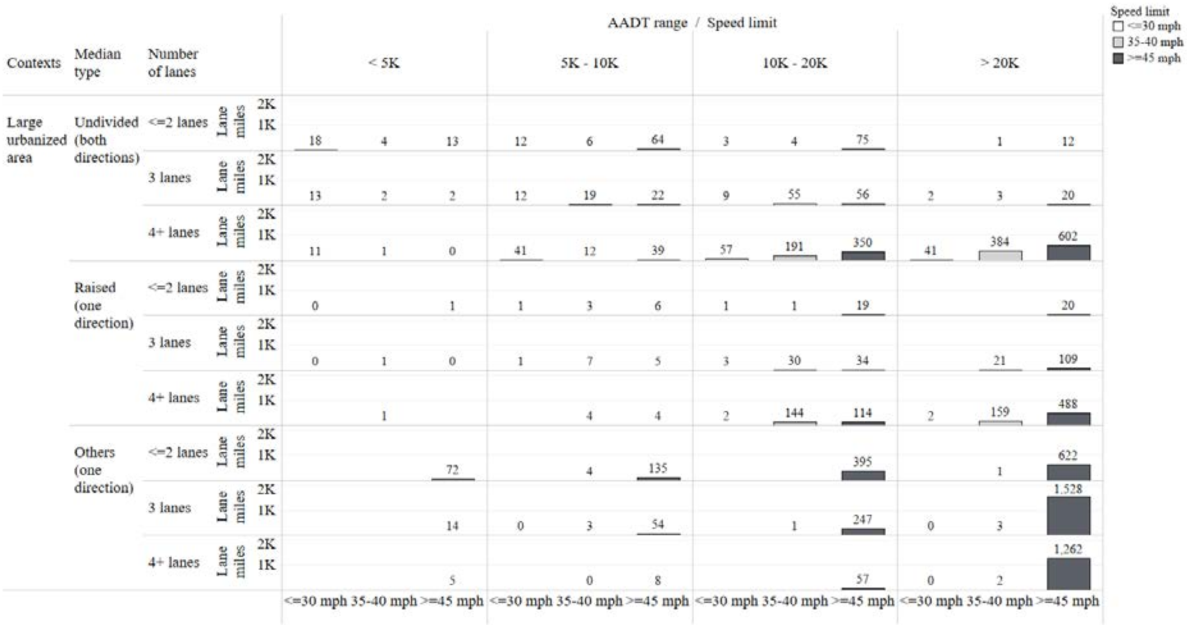

Figure 15. Lane Miles Distribution in Large Urbanized Areas with AADT, Speed limit, and Median-lane configuration

6 METHODOLOGY FOR TREATMENT SELECTION

This chapter details the methodology that was used to select the treatments for each facility type of interest (i.e., segment, midblock, intersection). Multiple guidance documents were reviewed, including *Best Design Practices for Walking and Bicycling in Michigan* (Michigan Department of Transportation 2012a), *Multimodal Development and Delivery Guidebook* (Michigan Department of Transportation 2019), *Bikeway Selection Guide* (Schultheiss et al. 2019), *STEP Studio* (Federal Highway Administration 2020b), and *Unsignalized Intersection Improvement Guide* (Institute of Transportation Engineers 2015).

The following section of the report provides further details of these guidance documents and how the associated decision criteria were incorporated in the development of the decision-support tool as a part of this project. Subsequently, a detailed description is provided for each of the facility types included in the tool, including explanations of how each input variable (i.e., context, median-lane configuration, speed limit, AADT) impacts the treatment selection matrices.

6.1 Treatment Selection in Existing Guidelines

A series of guidelines have been reviewed: *Urban Bikeway Design Guide* (National Association of City Transportation Officials 2012), *Multimodal Development and Delivery Guidebook* (Michigan Department of Transportation 2019), *Bikeway Selection Guide* (Schultheiss et al. 2019), *STEP Studio* (Federal Highway Administration 2020b), *Unsignalized Intersection Improvement Guide* (Institute of Transportation Engineers 2015), *Urban Street Design Guide* (National Association of City Transportation Officials 2015) etc.; to understand the idea behind treatments selection for pedestrian/bicyclist in different contextual and roadway conditions.

Multimodal Development and Delivery Guidebook (Michigan Department of Transportation 2019) or M2D2 of MDOT divides the contexts into four categories: urban, suburban, small town, and rural roadways and corridors. Table 18 shows the key features of each of these contexts. This guidebook also provides a series of design elements that should be considered to improve the multi-modal conditions in each context. However, the main gap is that this document does not explicitly mention which types of treatments shall be used or preferred under what median-lane configuration, speed, and AADT range. Another gap in this guidebook is that the criteria used for the division of contexts are not the same as that of datasets on MDOT open GIS (Michigan Department of Transportation 2019).

Table 18. Keys Features of Contexts as per M2D2 (Michigan Department of Transportation 2019)

Contexts	Criteria
Urban	Generally, population >100,000 Dense urban areas diverse mix of land uses
Suburban	Generally, population 20,000-100,000 Lower density auto-oriented commercial areas
Small Town	Generally, population less than 20,000 Low density areas distinct land use
Rural roadways and corridors	Connects cities suburbs and towns (no population criteria) Accommodate freight traffic

Figure 16, Figure 17, Figure 18, and Figure 19 show the design elements to improve the multimodal conditions on urban, suburban, small town, and connecting corridors as per the M2D2 document (Michigan Department of Transportation 2019). It was observed that protected bike lanes are recommended in urban environments, and bike lanes are recommended in suburban environments. Similarly, pedestrian and bicyclist counters are recommended in urban and suburban areas but not in small-town and rural areas. In general, it was observed that more pedestrian/bicyclist-friendly design elements were recommended in urban contexts compared to rural ones. This is logically defensible as well because a large amount of pedestrian and bicyclist activities can be expected in urbanized areas as compared to others. As such in order to protect these vulnerable road users, higher/better pedestrian and bicyclist facilities must be provided.

Figure 16. Design Elements for Urban Roads (Michigan Department of Transportation 2019)

Figure 17. Design Elements for Suburban Roads (Michigan Department of Transportation 2019)

Figure 18. Design Elements for Small Town and Rural Roads (Michigan Department of Transportation 2019)

Figure 19. Design Elements on Connecting Corridors (Michigan Department of Transportation 2019)

A similar guidebook, *Bikeway Selection Guide* (Schultheiss et al. 2019), has also been reviewed. This document was developed to assist transportation engineers/practitioners in selecting appropriate bikeway types in various contexts. The guidebook considers various types of bicycle treatments such as shoulders, shared lanes, bike boulevards, bike lanes, separated bike lanes etc. Other factors such as comfort, safety, visibility etc., of bicyclists are also considered in the treatment selection process. Figure 20 and Figure 21 show the intersection performance characteristics by bikeway type. It can be seen that separated bike lanes and bike lanes tend to provide more comfort, visibility, and safety to bicyclists. These treatments also enhance the predictability of bicycle movements and increase the separation between motorized vehicles and bicycles. Further, separated bike lanes and sidepaths reduce the opportunity of sideswipes and overtaking-related crashes by segregating the bicycle traffic from motorized vehicles.

	Shared Lanes	Boulevards	Shoulders	Bike Lanes	One-Way Separated Bike Lanes with Mixing Zones	Separated Bike Lanes and Sidepaths with Protected Intersections
Functionality (Comfort) - Roads can be categorized by their function						
Lowest at higher vehicle speeds and volumes	✓	✓	✓	✓		
Highest at lower vehicle speeds and volumes	✓	✓	✓	✓		
Moderate to High due to separation from traffic and constrained entry point					✓	
High due to separation from traffic and constrained conflict point						✓
Homogeneity - Roads with vehicles of balanced speeds, directions, and masses are the safest						
Intersection approach exposure to potential motorist conflict is high	✓	✓	✓			
Turning conflict exposure correlates with vehicle speeds and volumes	✓		✓	✓	✓	✓
Turning conflict exposure generally lower due to lower vehicle speeds and volumes		✓				
Constrained entry point reduces approach exposure if visibility is good					✓	
Constrained conflict point eliminates approach exposure, and constrains conflicts to a single point						✓
Predictability (Right-of-Way) - Roads should be intuitive						
No ability to imply right-of-way priority to bicyclists	✓		✓			
Right-of-way priority can be clarified by providing a bikeway on the approach or restricting through-vehicle access		✓				
Right-of-way priority is clarified to require motorists to yield				✓	✓	✓
Conflicts may occur anywhere within the facility	✓	✓	✓	✓		
Conflict point is constrained to one location increasing predictability					✓	✓

Figure 20. Functionality Homogeneity and Predictability by Bikeway Type (Schultheiss et al. 2019)

	Shared Lanes	Boulevards	Shoulders	Bike Lanes	One-Way Separated Bike Lanes with Mixing Zones	Separated Bike Lanes and Sidepaths with Protected Intersections
Forgiveness (Safety) - Infrastructure can be designed to accommodate human error						
Relies upon perfect user (driver and bicyclist) behavior to avoid crashes	✓	✓	✓	✓		
Minimal: bicyclists operating in shared space with vehicles	✓					
Moderate: application of traffic calming treatments and lower operating speeds can improve safety		✓				
Moderate: bicyclists operate in separated space from vehicles, however vehicles can encroach into the facility at any location			✓	✓		
Moderate: bicyclists operate in separated space from vehicles except for defined entry point, followed by shared operating space					✓	
High: bicyclists operate in separated space from vehicles except for defined conflict point which can be designed to reduce motorist speed, but contraflow movement from two-way operation can increase risk						✓
Awareness (Visibility) - Awareness improves safety for all users						
Visibility may be restricted by parking necessitating parking restrictions					✓	✓
Visibility is typically unrestricted	✓	✓	✓	✓		
Requires high level of motorists scanning to identify bicyclists approaching from behind or operating beside them	✓	✓	✓	✓		
Requires moderate level of motorists scanning to identify bicyclists approaching or within the conflict point					✓	✓
Key Crash Types Associated with Bikeway Type						
Right and left hooks	✓	✓	✓	✓	✓	✓
Sideswipes	✓	✓	✓	✓		
Overtaking	✓	✓	✓	✓		
Hit from behind	✓	✓	✓	✓		
Merging	✓	✓	✓	✓	✓	
Failure to yield at conflict point	✓	✓	✓	✓	✓	✓

Figure 21. Forgiveness Awareness and Crash type by Bikeway Type (Schultheiss et al. 2019)

The *Bikeway Selection Guide* (Schultheiss et al. 2019) also recommended various bikeway facilities at the segment level for all five contexts: urban core, urban, suburban, rural town, and rural. Figure 22 shows the preferred bikeway type for four contexts- urban core, urban, suburban, and rural town by speed and AADT. It can be seen in all four contexts as the speed and AADT increase, the bicycle facility tends to become safer, i.e., increase the separation between bicyclist and motorized vehicle. On the segments with speed above 35 mph and AADT above 7,000, separated bike lanes or shared-use paths are preferred. But on lower AADTs (below 7,000) and speed (below 35 mph), bike lanes and shared lanes are preferred. This guidebook also suggests that advisory bike lanes can be used if traffic volume is less than 3,000.

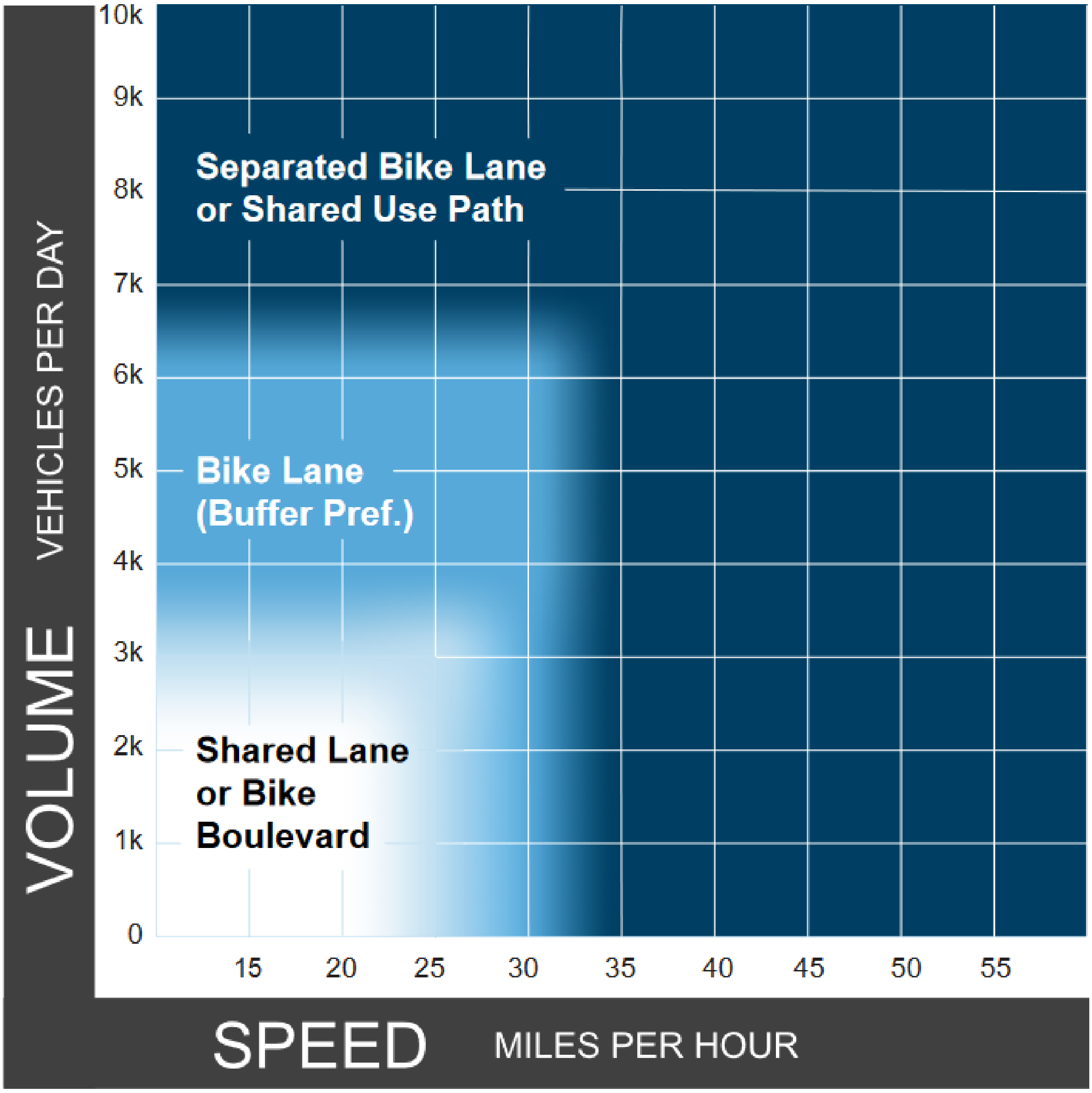

Figure 22. Preferred Bikeway Type for Urban core, Urban, Suburban, and Rural Town Context (Schultheiss et al. 2019)

Lastly, this guidebook suggests that shared lanes (AADT below 1,000) and paved shoulders shall be preferred on rural roads. The width of paved shoulders can be 5, 8, and 10 feet depending on the traffic volume and speed. As the speed and traffic volume increase, the width of shoulder also increases.

This extensive guidebook explains the preferred bikeway based on context, speed, and AADT. The only gap is that it does not consider the median-lane configuration while recommending the bikeway facility.

Another example of the reviewed guidebook is *STEP Studio* (Federal Highway Administration 2020b), developed by FHWA, which suggests different treatments at midblock locations. Figure 23 depicts the matrix developed by the guidebook that shows the variety of crossing treatments with different speed limit, AADT, and roadway configurations. This guidebook suggests that the selection of any treatment should be based on engineering judgment. In general, it can be seen in this matrix that as the speed limit and AADT increase, the treatment becomes safer for pedestrians to cross the road. Further, it can also be noted that as the number of lanes to cross the road increase, the treatments also tend to become safer.

For example, consider AADT range <9,000 and roadway configuration 2 lanes, as the speed limit shifts from <= 30 mph to >=40 mph, the recommended treatment also shifts from high visibility crosswalk to Rectangular Rapid Flashing Beacon (RRFB)/Pedestrian Hybrid Beacon (PHB). Similarly, in AADT range 9,000-15,000 and speed limit <= 30 mph, as the number of lanes increases from 2 lanes to 4+ lanes w/o raised median, the treatment shifts from high visibility crosswalk to advance yield sign/pedestrian refuge island/RRFB/PHB. It should be noted that all the treatments are recommended with high visibility crosswalk; this makes it as the minimum recommended at any site. However, the only gap in this guidebook is that contextual information is missing in the treatment selection process.

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

Given the set of conditions in a cell,

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

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

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

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

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

Figure 23. Recommended Crossing Treatments at Midblock Locations (Federal Highway Administration 2020b)

Similarly, other guidelines such as *Best Design Practices for Walking and Bicycling in Michigan* (Michigan Department of Transportation 2012a), *Unsignalized Intersection Improvement Guide* (Institute of Transportation Engineers 2015), *Urban Bikeway Design Guide* (National Association of City Transportation Officials 2012), *Urban Street Design Guide* (National Association of City Transportation Officials 2015), and *User Guide for R1-6 Gateway Treatment for Pedestrian Crossings* (McQuiston et al. 2016) were also reviewed. In general, the treatment selection process in these guides is consistent, i.e., as the speed limit, AADT, and number of lanes increase, the treatment becomes safer for pedestrians and bicyclists. The main gap in the existing literature is that most of these guidelines do not consider context while recommending treatments.

6.2 MSU's Treatment Selection Procedure

The treatment selection process developed by MSU is consistent with the existing guidelines. As the AADT, speed, and number of lanes increase and the context becomes urbanized, the facilities become much safer by increasing the separation (space and time) between ped/bike and motorized vehicles. MSU developed the treatment matrices for various site types, i.e., segment, midblock, and intersection level, to ensure the safety and mobility of pedestrians and bicyclists at each site. Additionally, alternative treatments matrices were also developed to suggest the treatments in fringe areas and also to provide alternatives due to budget constraints. This also introduces flexibility in the decision-making process. It is recommended that the users should use their engineering judgment before applying any of the treatments discussed in this section. The following subsections explain treatment selection procedure for pedestrian segment, bicycle segment, midblock, and intersection.

6.2.1 Pedestrian segment: treatment selection process

This subsection explains the treatment selection procedure for pedestrian treatments at segment level. Multiple MDOT and federal sources were used to identify these treatments- *Multimodal Development and Delivery Guidebook* (Michigan Department of Transportation 2019), *Best Design Practices for Walking and Bicycling in Michigan* (Michigan Department of Transportation 2012a), *NCHRP-855 An Expanded Functional Classification System for Highways and Streets* (Stamatiadis et al. 2018), and *Michigan Road Design Manual* (Michigan Department of Transportation 2012b) etc. In general, the following decision criteria were used to determine specific treatments in various contexts:

- As the speed limit, AADT, and number of lanes increase, the treatments provide greater levels of safety for pedestrians.
- As the context shifts from rural to large urbanized areas, the treatments provide greater levels of safety for pedestrians.
- For speed limits of 45 mph or more, wide paved shoulders or sidepaths are suggested as potential treatments for all contextual environments.
    - Wide paved shoulders are recommended in rural areas as there are generally fewer non-motorized users as compared to more urbanized areas.
    - Sidepaths are recommended in small urban, small urbanized, and large urbanized areas in this higher speed range, given the expectation of higher non-motorized mode shares.

Table 19 shows the pedestrian segment level treatment matrix. It should be noted that while developing this matrix along with contextual and roadway characteristics, the number of lane miles is also considered. It has a total of 240 cells, and each cell suggests a treatment corresponding to a unique combination of context, median type, number of lanes, speed limit, and AADT. In this matrix, darker color represent a facility that provides higher safety and mobility for pedestrians. This matrix has the following unique treatments (arranged in increasing order of safety):

1. Wide paved shoulder
2. Sidepath
    a. Sidepath with lane reduction
3. Sidewalk
4. Streetscaping
    a. Streetscaping with lane reduction

The following paragraphs give a brief definition of the above-mentioned pedestrian segment treatments and the contextual and roadway characteristics where these treatments are generally used.

Wide paved shoulder: Wide paved shoulder is a part of paved roadway adjacent to the traveled way that can be used to accommodate current/potential non-motorized traffic (North Carolina Department of Transportation n.d.). This is similar to the paved shoulder as defined by MDOT (Michigan Department of Transportation 2014a).

With consultation from MDOT during the research advisory panel (RAP) meeting, the word "wide" was added in front of "paved shoulder" so that it gives an indication to the engineers/planners that the width should be kept more than 4 feet if the site conditions permit. This treatment is only recommended in rural areas, with speed >=45 mph. The logic behind using this treatment in rural areas is that there is less pedestrian and bicyclist activity in these areas.

Sidepath: Sidepath is a facility immediately parallel to the existing roadway that can accommodate pedestrians, bicyclists, skaters, and other non-motorized users (Michigan Department of Transportation 2014a).

Sidepath is a potential treatment in small urban, small urbanized, and large urbanized areas with speed >= 45 mph as it physically separates non-motorized users from main traffic. It is also considered a potential treatment in rural areas with a speed of 35-40 mph. Additionally, wherever a higher number of lanes were present, this treatment was suggested with lane reduction, i.e., sidepath with lane reduction.

Sidewalk: Sidewalk is a portion of roadway's right of way that is designated for pedestrian usage and extends beyond the edge of the roadway pavement (Michigan Department of Transportation 2014a).

Sidewalk is a potential treatment in areas where significant pedestrian activity is expected. It is mainly considered in all rural and small urban areas with AADT <10,000 and speed <=30 mph. It is also identified as a potential treatment for small and large urbanized areas with AADT >=10,000, and speed 35-40 under all median-lane configurations.

Streetscaping: Streetscaping is used to describe the street's architectural and natural elements, and it is defined as the street's aesthetic appeal, particularly in how the paved area is organized and maintained. There are various elements of streetscaping, such as bus shelters, plantations, seating arrangements etc. (Yumpu.com 2004).

In the present matrix, streetscaping refers to a wide sidewalk with seating facility, i.e., an environment friendly for pedestrians. Streetscaping is used in small urbanized and large urbanized areas only where high pedestrian and bicyclist activity is expected. As such, it is considered heavily in these contexts with AADT <10,000 and speed <=40 mph. Further, as the AADT range increases beyond 10,000 this treatment is not considered for speed range 35-40 mph. In general, streetscaping with lane reduction is suggested on roadways with AADT <10,000 and more than 2 lanes (i.e., undivided and divided 3+ lanes).

Table 20 shows the alternative pedestrian treatments w.r.t. various potential treatments. In general, there are two alternative treatments for each potential treatment, i.e., lower order and higher order treatment. These are defined as below:

Alternative treatment 1 (lower-order treatment): This suggests one step lower treatment than the potential treatment. This can be selected if the study location lies in lower fringe areas or if there are budget constraints.

Alternative treatment 2 (higher-order treatment): This suggests one step higher treatment than the potential treatment. This can be selected if the study location lies in higher fringe areas.

Table 19. Pedestrian Segment Level Treatments

Context	Median type	Lane configuration	AADT (below 5,000)			AADT (5,000-10,000)			AADT (10,000-20,000)			AADT (above 20,000)		
			<=30mph	35-40 mph	>=45 mph	<=30mph	35-40 mph	>=45 mph	<=30mph	35-40 mph	>=45 mph	<=30mph	35-40 mph	>=45 mph
Rural (Pop < 5K)	Undivided	2 lanes, both directions total	Sidewalk	Sidepath	Wide paved shoulder	Sidewalk	Sidepath	Wide paved shoulder	Sidepath	Sidepath	Wide paved shoulder	Sidepath	Sidepath	Wide paved shoulder
		3 lanes, both directions total (including TWLTL)	Sidewalk	Sidepath	Wide paved shoulder	Sidewalk	Sidepath	Wide paved shoulder	Sidepath	Sidepath	Wide paved shoulder	Sidepath	Sidepath	Wide paved shoulder
		4+ lanes, both directions total	Sidewalk	Sidepath	Wide paved shoulder	Sidewalk	Sidepath	Wide paved shoulder	Sidepath	Sidepath	Wide paved shoulder	Sidepath	Sidepath	Wide paved shoulder
	Median (Raised, guard rail, concrete barrier etc.)	1-2 lanes in one direction	Sidewalk	Sidepath	Wide paved shoulder	Sidewalk	Sidepath	Wide paved shoulder	Sidepath	Sidepath	Wide paved shoulder	Sidepath	Sidepath	Wide paved shoulder
		3+ lanes in one direction	Sidewalk	Sidepath	Wide paved shoulder	Sidewalk	Sidepath	Wide paved shoulder	Sidepath	Sidepath	Wide paved shoulder	Sidepath	Sidepath	Wide paved shoulder
Small urban areas (Pop 5K to 50K)	Undivided	2 lanes, both directions total	Sidewalk	Sidepath	Sidepath	Sidewalk	Sidepath	Sidepath	Sidewalk	Sidewalk	Sidepath	Sidewalk	Sidewalk	Sidepath
		3 lanes, both directions total (including TWLTL)	Sidewalk	Sidepath	Sidepath	Sidewalk	Sidepath	Sidepath	Sidewalk	Sidewalk	Sidepath	Sidewalk	Sidewalk	Sidepath
		4+ lanes, both directions total	Sidewalk	Sidepath	Sidepath	Sidewalk	Sidewalk	Sidepath	Sidewalk	Sidewalk	Sidepath	Sidewalk	Sidewalk	Sidepath
	Median (Raised, guard rail, concrete barrier etc.)	1-2 lanes in one direction	Sidewalk	Sidepath	Sidepath	Sidewalk	Sidepath	Sidepath	Sidewalk	Sidewalk	Sidepath	Sidewalk	Sidewalk	Sidepath
		3+ lanes in one direction	Sidewalk	Sidepath	Sidepath	Sidewalk	Sidewalk	Sidepath	Sidewalk	Sidewalk	Sidepath	Sidewalk	Sidewalk	Sidepath
Small urbanized areas (Pop 50K to 200K)	Undivided	2 lanes, both directions total	Streetscaping	Sidewalk	Sidepath	Streetscaping	Sidewalk	Sidepath	Sidewalk	Sidewalk	Sidepath	Sidewalk	Sidewalk	Sidepath
		3 lanes, both directions total (including TWLTL)	Streetscaping	Streetscaping	Sidepath	Streetscaping	Streetscaping	Sidepath	Streetscaping	Sidewalk	Sidepath	Streetscaping	Sidewalk	Sidepath
		4+ lanes, both directions total	Streetscaping with lane reduction	Streetscaping with lane reduction	Sidepath with Lane reduction	Streetscaping with lane reduction	Streetscaping with lane reduction	Sidepath with lane reduction	Streetscaping	Sidewalk	Sidepath	Streetscaping	Sidewalk	Sidepath
	Median (Raised, guard rail, concrete barrier etc.)	1-2 lanes in one direction	Streetscaping	Sidewalk	Sidepath	Streetscaping	Sidewalk	Sidepath	Sidewalk	Sidewalk	Sidepath	Sidewalk	Sidewalk	Sidepath
		3+ lanes in one direction	Streetscaping with lane reduction	Streetscaping with lane reduction	Sidepath with Lane reduction	Streetscaping with lane reduction	Streetscaping with lane reduction	Sidepath with lane reduction	Streetscaping	Sidewalk	Sidepath	Streetscaping	Sidewalk	Sidepath
Large urbanized areas (> 200K)	Undivided	2 lanes, both directions total	Streetscaping	Sidewalk	Sidepath	Streetscaping	Sidewalk	Sidepath	Sidewalk	Sidewalk	Sidepath	Sidewalk	Sidewalk	Sidepath
		3 lanes, both directions total (including TWLTL)	Streetscaping with lane reduction	Streetscaping with lane reduction	Sidepath	Streetscaping with lane reduction	Streetscaping with lane reduction	Sidepath	Streetscaping	Sidewalk	Sidepath	Streetscaping	Sidewalk	Sidepath
		4+ lanes, both directions total	Streetscaping with lane reduction	Streetscaping with lane reduction	Sidepath with Lane reduction	Streetscaping with lane reduction	Streetscaping with lane reduction	Sidepath with lane reduction	Streetscaping	Sidewalk	Sidepath	Streetscaping	Sidewalk	Sidepath
	Median (Raised, guard rail, concrete barrier etc.)	1-2 lanes in one direction	Streetscaping	Sidewalk	Sidepath	Streetscaping	Sidewalk	Sidepath	Sidewalk	Sidewalk	Sidepath	Sidewalk	Sidewalk	Sidepath
		3+ lanes in one direction	Streetscaping with lane reduction	Streetscaping with lane reduction	Sidepath with Lane reduction	Streetscaping with lane reduction	Streetscaping with lane reduction	Sidepath with lane reduction	Streetscaping	Sidewalk	Sidepath	Streetscaping	Sidewalk	Sidepath

It can be seen in Table 20 that for wide paved shoulder, the alternative treatment 1 (lower-order treatment) is NA, which indicates that there is no treatment lower than wide paved shoulder, and it is the minimum that shall be provided. Further, the higher-order treatment for wide paved shoulder is sidepath. It provides better safety than wide paved shoulder by physically segregating the pedestrian traffic from motorized vehicles. Similarly, wherever streetscaping was the potential treatment, the lower order treatment was sidewalk as it can serve a similar purpose. However, in the case of streetscaping, there is no higher-order treatment, as no treatment is higher than the current one in the given matrix.

Table 20. Alternative Treatments Selection for Pedestrians

Potential Pedestrian Treatments	**Alternative treatment 1 (i.e. lower order treatment)**	**Alternative treatment 2 (i.e. higher order treatment)**
Wide paved shoulder	NA	Sidepath
Sidepath	Wide paved shoulder	Sidewalk
Sidepath with lane reduction	Wide paved shoulder	Sidewalk
Sidewalk		
Condition 1: Rural and small urban areas, all AADT/speed/lanes	Sidepath	NA
Condition 2: Small urbanized and large urbanized areas, all AADT/speed/lanes)	Sidepath	Streetscaping
Streetscaping with lane reduction	Sidewalk	NA
Streetscaping	Sidewalk	NA

Table 21 shows the alternative pedestrian treatments at segment level. In each cell of this table, the first alternative is the lower-order treatment, and the second alternative, followed by a semicolon (;), is the higher-order treatment. In this table, if for any cell, the lower order or higher order treatment is unavailable, it is denoted as NA.

For the following conditions- Context: large urbanized area, Median type: undivided, Lane configuration: 4+ lanes both directions total, AADT: 10,000-20,000, and Speed: 35-40 mph; the potential treatment is sidewalk as can be seen in Table 19. The lower order and higher order treatment under the same contextual and roadway condition are sidepath and streetscaping, respectively, as per Table 21. Where sidewalk is entitled to be used by pedestrians only, sidepath can be used by both pedestrians and bicyclists, which can lead to more interaction between these two road users. On the other hand, streetscaping is suggested as higher-order treatment that comprises of wide sidewalk, seating facility, and planters, which improves safety and mobility than sidewalk alone.

Table 21. Alternative Pedestrian Treatments at Segment Level

Context	Median type	Lane configuration	AADT (below 5,000)			AADT (5,000-10,000)			AADT (10,000-20,000)			AADT (above 20,000)		
			<=30mph	35-40 mph	>=45 mph	<=30mph	35-40 mph	>=45 mph	<=30mph	35-40 mph	>=45 mph	<=30mph	35-40 mph	>=45 mph
Rural (Pop < 5K)	Undivided	2 lanes, both directions total	Sidepath; NA	Wide paved shoulder; Sidewalk	NA; Sidepath	Sidepath; NA	Wide paved shoulder; Sidewalk	NA; Sidepath	Wide paved shoulder; Sidewalk	Wide paved shoulder; Sidewalk	NA; Sidepath	Wide paved shoulder; Sidewalk	Wide paved shoulder; Sidewalk	NA; Sidepath
		3 lanes, both directions total (including TWLTL)	Sidepath; NA	Wide paved shoulder; Sidewalk	NA; Sidepath	Sidepath; NA	Wide paved shoulder; Sidewalk	NA; Sidepath	Wide paved shoulder; Sidewalk	Wide paved shoulder; Sidewalk	NA; Sidepath	Wide paved shoulder; Sidewalk	Wide paved shoulder; Sidewalk	NA; Sidepath
		4+ lanes, both directions total	Sidepath; NA	Wide paved shoulder; Sidewalk	NA; Sidepath	Sidepath; NA	Wide paved shoulder; Sidewalk	NA; Sidepath	Wide paved shoulder; Sidewalk	Wide paved shoulder; Sidewalk	NA; Sidepath	Wide paved shoulder; Sidewalk	Wide paved shoulder; Sidewalk	NA; Sidepath
	Median (Raised, guard rail, concrete barrier etc.)	1-2 lanes in one direction	Sidepath; NA	Wide paved shoulder; Sidewalk	NA; Sidepath	Sidepath; NA	Wide paved shoulder; Sidewalk	NA; Sidepath	Wide paved shoulder; Sidewalk	Wide paved shoulder; Sidewalk	NA; Sidepath	Wide paved shoulder; Sidewalk	Wide paved shoulder; Sidewalk	NA; Sidepath
		3+ lanes in one direction	Sidepath; NA	Wide paved shoulder; Sidewalk	NA; Sidepath	Sidepath; NA	Wide paved shoulder; Sidewalk	NA; Sidepath	Wide paved shoulder; Sidewalk	Wide paved shoulder; Sidewalk	NA; Sidepath	Wide paved shoulder; Sidewalk	Wide paved shoulder; Sidewalk	NA; Sidepath
Small urban areas (Pop 5K to 50K)	Undivided	2 lanes, both directions total	Sidepath; NA	Wide paved shoulder; Sidewalk	Wide paved shoulder; Sidewalk	Sidepath; NA	Wide paved shoulder; Sidewalk	Wide paved shoulder; Sidewalk	Sidepath; NA	Sidepath; NA	Wide paved shoulder; Sidewalk	Sidepath; NA	Sidepath; NA	Wide paved shoulder; Sidewalk
		3 lanes, both directions total (including TWLTL)	Sidepath; NA	Wide paved shoulder; Sidewalk	Wide paved shoulder; Sidewalk	Sidepath; NA	Wide paved shoulder; Sidewalk	Wide paved shoulder; Sidewalk	Sidepath; NA	Sidepath; NA	Wide paved shoulder; Sidewalk	Sidepath; NA	Sidepath; NA	Wide paved shoulder; Sidewalk
		4+ lanes, both directions total	Sidepath; NA	Wide paved shoulder; Sidewalk	Wide paved shoulder; Sidewalk	Sidepath; NA	Sidepath; NA	Wide paved shoulder; Sidewalk	Sidepath; NA	Sidepath; NA	Wide paved shoulder; Sidewalk	Sidepath; NA	Sidepath; NA	Wide paved shoulder; Sidewalk
	Median (Raised, guard rail, concrete barrier etc.)	1-2 lanes in one direction	Sidepath; NA	Wide paved shoulder; Sidewalk	Wide paved shoulder; Sidewalk	Sidepath; NA	Wide paved shoulder; Sidewalk	Wide paved shoulder; Sidewalk	Sidepath; NA	Sidepath; NA	Wide paved shoulder; Sidewalk	Sidepath; NA	Sidepath; NA	Wide paved shoulder; Sidewalk
		3+ lanes in one direction	Sidepath; NA	Wide paved shoulder; Sidewalk	Wide paved shoulder; Sidewalk	Sidepath; NA	Sidepath; NA	Wide paved shoulder; Sidewalk	Sidepath; NA	Sidepath; NA	Wide paved shoulder; Sidewalk	Sidepath; NA	Sidepath; NA	Wide paved shoulder; Sidewalk
Small urbanized areas (Pop 50K to 200K)	Undivided	2 lanes, both directions total	Sidewalk; NA	Sidepath; Streetscaping	Wide paved shoulder; Sidewalk	Sidewalk; NA	Sidepath; Streetscaping	Wide paved shoulder; Sidewalk	Sidepath; Streetscaping	Sidepath; Streetscaping	Wide paved shoulder; Sidewalk	Sidepath; Streetscaping	Sidepath; Streetscaping	Wide paved shoulder; Sidewalk
		3 lanes, both directions total (including TWLTL)	Sidewalk; NA	Sidewalk; NA	Wide paved shoulder; Sidewalk	Sidewalk; NA	Sidewalk; NA	Wide paved shoulder; Sidewalk	Sidewalk; NA	Sidepath; Streetscaping	Wide paved shoulder; Sidewalk	Sidewalk; NA	Sidepath; Streetscaping	Wide paved shoulder; Sidewalk
		4+ lanes, both directions total	Sidewalk; NA	Sidewalk; NA	Wide paved shoulder; Sidewalk	Sidewalk; NA	Sidewalk; NA	Wide paved shoulder; Sidewalk	Sidewalk; NA	Sidepath; Streetscaping	Wide paved shoulder; Sidewalk	Sidewalk; NA	Sidepath; Streetscaping	Wide paved shoulder; Sidewalk
	Median (Raised, guard rail, concrete barrier etc.)	1-2 lanes in one direction	Sidewalk; NA	Sidepath; Streetscaping	Wide paved shoulder; Sidewalk	Sidewalk; NA	Sidepath; Streetscaping	Wide paved shoulder; Sidewalk	Sidepath; Streetscaping	Sidepath; Streetscaping	Wide paved shoulder; Sidewalk	Sidepath; Streetscaping	Sidepath; Streetscaping	Wide paved shoulder; Sidewalk
		3+ lanes in one direction	Sidewalk; NA	Sidewalk; NA	Wide paved shoulder; Sidewalk	Sidewalk; NA	Sidewalk; NA	Wide paved shoulder; Sidewalk	Sidewalk; NA	Sidepath; Streetscaping	Wide paved shoulder; Sidewalk	Sidewalk; NA	Sidepath; Streetscaping	Wide paved shoulder; Sidewalk
Large urbanized areas (> 200K)	Undivided	2 lanes, both directions total	Sidewalk; NA	Sidepath; Streetscaping	Wide paved shoulder; Sidewalk	Sidewalk; NA	Sidepath; Streetscaping	Wide paved shoulder; Sidewalk	Sidepath; Streetscaping	Sidepath; Streetscaping	Wide paved shoulder; Sidewalk	Sidepath; Streetscaping	Sidepath; Streetscaping	Wide paved shoulder; Sidewalk
		3 lanes, both directions total (including TWLTL)	Sidewalk; NA	Sidewalk; NA	Wide paved shoulder; Sidewalk	Sidewalk; NA	Sidewalk; NA	Wide paved shoulder; Sidewalk	Sidewalk; NA	Sidepath; Streetscaping	Wide paved shoulder; Sidewalk	Sidewalk; NA	Sidepath; Streetscaping	Wide paved shoulder; Sidewalk
		4+ lanes, both directions total	Sidewalk; NA	Sidewalk; NA	Wide paved shoulder; Sidewalk	Sidewalk; NA	Sidewalk; NA	Wide paved shoulder; Sidewalk	Sidewalk; NA	Sidepath; Streetscaping	Wide paved shoulder; Sidewalk	Sidewalk; NA	Sidepath; Streetscaping	Wide paved shoulder; Sidewalk
	Median (Raised, guard rail, concrete barrier etc.)	1-2 lanes in one direction	Sidewalk; NA	Sidepath; Streetscaping	Wide paved shoulder; Sidewalk	Sidewalk; NA	Sidepath; Streetscaping	Wide paved shoulder; Sidewalk	Sidepath; Streetscaping	Sidepath; Streetscaping	Wide paved shoulder; Sidewalk	Sidepath; Streetscaping	Sidepath; Streetscaping	Wide paved shoulder; Sidewalk
		3+ lanes in one direction	Sidewalk; NA	Sidewalk; NA	Wide paved shoulder; Sidewalk	Sidewalk; NA	Sidewalk; NA	Wide paved shoulder; Sidewalk	Sidewalk; NA	Sidepath; Streetscaping	Wide paved shoulder; Sidewalk	Sidewalk; NA	Sidepath; Streetscaping	Wide paved shoulder; Sidewalk

6.2.2 Bicyclist segment: treatment selection process

This subsection explains the selection procedure for bicyclist treatments at the segment level. Multiple MDOT and federal guidelines were reviewed to identify candidate treatments- *Best Design Practices for Walking and Bicycling in Michigan* (Michigan Department of Transportation 2012a), *Multimodal Development and Delivery Guidebook* (Michigan Department of Transportation 2019), *Bikeway Selection Guide* (Schultheiss et al. 2019), *Urban Bikeway Design Guide* (National Association of City Transportation Officials 2012), *NCHRP-855 An Expanded Functional Classification System for Highways and Streets* (Stamatiadis et al. 2018) etc. The decision criteria for bicyclist treatments were similar to pedestrians. The following decision criteria were used to determine specific treatments in various contexts:

- As the speed limit, AADT, and number of lanes increase, the treatments provide greater levels of safety for bicyclists.
- As the context shifts from rural to large urbanized areas, the treatments provide greater levels of safety for bicyclists.
- For speed limits of 45 mph or more, wide paved shoulders or sidepaths are suggested as potential treatments for all contextual environments.
    - Wide paved shoulders are recommended in rural areas as there are generally fewer non-motorized users as compared to more urbanized areas.
    - Sidepaths are recommended in more urbanized areas in this higher speed range given the expectation of higher non-motorized mode shares.

Table 22 shows the bicycle segment level treatment matrix. It also shows treatments for 240 unique context combinations, median type, number of lanes, speed limit, and AADT. In this matrix, darker colors again reflect treatments that provides higher safety or mobility for bicyclists. The following treatments are included (arranged in increasing order of safety):

1. Wide paved shoulder
2. Sidepath
    a. Sidepath with lane reduction
3. Shared lane
4. Bike Boulevard
5. Bike lane
6. Bike lane with buffer
7. Separated bike lane

The following paragraphs give a brief definition of the above-mentioned treatments and the contextual and roadway characteristics where these treatments are generally applied.

Wide paved shoulder: Wide paved shoulder is a part of paved roadway adjacent to the traveled way that can be used to accommodate current/potential non-motorized traffic (North Carolina Department of Transportation n.d.). This is similar to the paved shoulder as defined by MDOT (Michigan Department of Transportation 2014a).

With consultation from MDOT during the research advisory panel (RAP) meeting, the word “wide” was added in front of “paved shoulder" so that it gives an indication to the engineers/planners that width should be kept more than 4 feet if the site conditions permit. This treatment is only recommended in rural areas, with speed >=45 mph. The logic behind using this treatment in rural areas is that there is less pedestrian and bicyclist activity in these areas.

Sidepath: It is the same as that of pedestrian segment level treatment. Defined as- a facility immediately parallel to the existing roadway that can accommodate pedestrians, bicyclists, skaters, and other non-motorized users (Michigan Department of Transportation 2014a).

Sidepath is a potential treatment in small urban, small urbanized, and large urbanized areas with speed >= 45 mph as it physically separates non-motorized users from main traffic. It is also considered a potential treatment in rural areas with a speed of 35-40 mph. Additionally, wherever higher number of lanes were present, this treatment was suggested with lane reduction, i.e., sidepath with lane reduction.

Shared lane: Shared lane is a type of roadway facility that can be used by both motorized vehicles and bicyclists (Michigan Department of Transportation 2014a).

In the bicyclist treatment matrix, it is always recommended to use this treatment with shared lane markings. It is generally considered as a potential treatment on roadways with AADT <10,000, and speed <= 30 mph in all contexts.

Bike Boulevard: Bike boulevard is also called a bicycle boulevard or neighborhood greenway. These are a street segment or a series of segments that are developed to facilitate through bicycle traffic and reduce through motorized vehicle traffic (Michigan Department of Transportation 2014a).

In the bicycle treatment matrix, bike boulevards are mainly recommended in areas with slightly higher bicyclist activity than in rural areas and lower AADT. As such, it is a potential treatment in small urban areas, small urbanized areas, and large urbanized areas with 2 lanes, AADT <5,000, and speed <=30 mph.

Bike lane: Bike lane or bicycle lane is a portion of roadway that is designated for bicyclists only. It has pavement markings and signs that indicate exclusive bicycle usage (Michigan Department of Transportation 2014a).

Bike lane is a potential treatment in areas where high bicycle activity is expected, or bicyclists need more protection than shared lanes and bike boulevards. In general, it is a potential treatment in small urban, small urbanized, and large urbanized areas. As the AADT range increases in each of these contexts, the consideration for bike lanes reduces from a speed of 35-40 mph to <=30 mph. For example, in small urbanized areas it is considered generally with AADT <10,000 and speed 35-40 mph; but in same context for AADT >=10,000 it is considered a potential treatment for speed range <= 30 mph.

Bike lane with buffer: Bike lane with buffer or buffered bike lane is similar to bike lane (i.e., a portion of a roadway designated for bicyclist use only with markings) but with a buffer space between motorized vehicle lane and bike lane (Michigan Department of Transportation 2014a).

Bike lane with buffer is a potential treatment in areas with high AADT, speed, number of lanes, or urbanized context. It provides higher level of mobility and safety than bike lane. It is a potential treatment in small urban, small urbanized, and large urbanized areas. As the context shifts from small urbanized to large urbanized, its usage drops from 35-40 mph range to <=30 mph. It is generally considered in small urbanized areas with AADT >=10,000 and speed of 35-40 mph. But in large urbanized areas, it is mainly considered in areas with AADT >20,000 and speed <=30 mph.

Separated bike lane: Separated bike lane is a bicycle facility physically separated from motorized vehicles through a barrier. This facility is also for the exclusive use of bicyclists only (Michigan Department of Transportation 2014a).

Separated bike lane is the safest treatment provided in the matrix and is suggested in the areas that require higher mobility and safety for bicyclists. It is mainly suggested in large urbanized areas. In large urbanized areas, as the AADT increases within speed limit of 35-40 mph, it is considered more often. It is highly considered in the same context with AADT >=10,000, and speed of 35-40 mph.

Table 22. Bicycle Segment Level Treatments

Context	Median type	Lane configuration	AADT (below 5,000)			AADT (5,000-10,000)			AADT (10,000-20,000)			AADT (above 20,000)		
			<=30mph	35-40 mph	>=45 mph	<=30mph	35-40 mph	>=45 mph	<=30mph	35-40 mph	>=45 mph	<=30mph	35-40 mph	>=45 mph
Rural (Pop < 5K)	Undivided	2 lanes, both directions total	Shared lane	Sidepath	Wide paved shoulder	Shared lane	Sidepath	Wide paved shoulder	Sidepath	Sidepath	Wide paved shoulder	Sidepath	Sidepath	Wide paved shoulder
		3 lanes, both directions total (including TWLTL)	Shared lane	Sidepath	Wide paved shoulder	Shared lane	Sidepath	Wide paved shoulder	Sidepath	Sidepath	Wide paved shoulder	Sidepath	Sidepath	Wide paved shoulder
		4+ lanes, both directions total	Shared lane	Sidepath	Wide paved shoulder	Shared lane	Sidepath	Wide paved shoulder	Sidepath	Sidepath	Wide paved shoulder	Sidepath	Sidepath	Wide paved shoulder
	Median (Raised, guard rail, concrete barrier etc.)	1-2 lanes in one direction	Shared lane	Sidepath	Wide paved shoulder	Shared lane	Sidepath	Wide paved shoulder	Sidepath	Sidepath	Wide paved shoulder	Sidepath	Sidepath	Wide paved shoulder
		3+ lanes in one direction	Shared lane	Sidepath	Wide paved shoulder	Shared lane	Sidepath	Wide paved shoulder	Sidepath	Sidepath	Wide paved shoulder	Sidepath	Sidepath	Wide paved shoulder
Small urban areas (Pop 5K to 50K)	Undivided	2 lanes, both directions total	Bike boulevard	Sidepath	Sidepath	Shared lane	Sidepath	Sidepath	Bike lane	Bike lane	Sidepath	Bike lane	Bike lane	Sidepath
		3 lanes, both directions total (including TWLTL)	Shared lane	Sidepath	Sidepath	Shared lane	Sidepath	Sidepath	Bike lane	Bike lane	Sidepath	Bike lane	Bike lane	Sidepath
		4+ lanes, both directions total	Shared lane	Sidepath	Sidepath	Shared lane	Bike lane	Sidepath	Bike lane	Bike lane with buffer	Sidepath	Bike lane	Bike lane with buffer	Sidepath
	Median (Raised, guard rail, concrete barrier etc.)	1-2 lanes in one direction	Bike boulevard	Sidepath	Sidepath	Shared lane	Sidepath	Sidepath	Bike lane	Bike lane	Sidepath	Bike lane	Bike lane	Sidepath
		3+ lanes in one direction	Shared lane	Sidepath	Sidepath	Shared lane	Bike lane	Sidepath	Bike lane	Bike lane with buffer	Sidepath	Bike lane	Bike lane with buffer	Sidepath
Small urbanized areas (Pop 50K to 200K)	Undivided	2 lanes, both directions total	Bike boulevard	Bike lane	Sidepath	Shared lane	Bike lane	Sidepath	Bike lane	Bike lane with buffer	Sidepath	Bike lane	Bike lane with buffer	Sidepath
		3 lanes, both directions total (including TWLTL)	Shared lane	Bike lane	Sidepath	Shared lane	Bike lane	Sidepath	Bike lane	Bike lane with buffer	Sidepath	Bike lane	Bike lane with buffer	Sidepath
		4+ lanes, both directions total	Shared lane	Bike lane	Sidepath with lane reduction	Shared lane	Bike lane	Sidepath with lane reduction	Bike lane	Bike lane with buffer	Sidepath	Bike lane	Separated bike lane	Sidepath
	Median (Raised, guard rail, concrete barrier etc.)	1-2 lanes in one direction	Bike boulevard	Bike lane	Sidepath	Shared lane	Bike lane	Sidepath	Bike lane	Bike lane with buffer	Sidepath	Bike lane	Bike lane with buffer	Sidepath
		3+ lanes in one direction	Shared lane	Bike lane	Sidepath with lane reduction	Shared lane	Bike lane	Sidepath with lane reduction	Bike lane	Bike lane with buffer	Sidepath	Bike lane	Separated bike lane	Sidepath
Large urbanized areas (> 200K)	Undivided	2 lanes, both directions total	Bike boulevard	Bike lane	Sidepath	Shared lane	Bike lane	Sidepath	Bike lane	Bike lane with buffer	Sidepath	Bike lane	Separated bike lane	Sidepath
		3 lanes, both directions total (including TWLTL)	Shared lane	Bike lane	Sidepath	Shared lane	Bike lane	Sidepath	Bike lane	Separated bike lane	Sidepath	Bike lane with buffer	Separated bike lane	Sidepath
		4+ lanes, both directions total	Shared lane	Bike lane	Sidepath with lane reduction	Shared lane	Separated bike lane	Sidepath with lane reduction	Bike lane	Separated bike lane	Sidepath	Bike lane with buffer	Separated bike lane	Sidepath
	Median (Raised, guard rail, concrete barrier etc.)	1-2 lanes in one direction	Bike boulevard	Bike lane	Sidepath	Shared lane	Bike lane with buffer	Sidepath	Bike lane	Separated bike lane	Sidepath	Bike lane	Separated bike lane	Sidepath
		3+ lanes in one direction	Shared lane	Bike lane	Sidepath with lane reduction	Shared lane	Separated bike lane	Sidepath with lane reduction	Bike lane	Separated bike lane	Sidepath	Bike lane with buffer	Separated bike lane	Sidepath

Table 23 shows the alternative treatments selected for bicyclists at segment level for various combinations of context, AADT, speed limit, and median-lane configuration. These were also categorized into lower order and higher order treatments. Similar to pedestrian, alternative treatments of wide paved shoulder do not have a lower order treatment as it is the lowest treatment in the matrix for rural areas. Additionally, shared lane also does not have any lower-order treatment as it was used in roadways with speed limit <=30 mph and AADT <10,000. The lower-order alternative for sidepath is only wide paved shoulder, and the higher-order alternatives are separated bike lane, bike lane with buffer, and bike lane. These higher-order alternatives tend to become safer as the speed and AADT increase and the context shifts from rural to urban. Similarly, lower and higher-order alternatives for bike boulevard, bike lane, and bike lane with buffer were proposed. Lastly, separated bike lane was the highest order treatment in the matrix, and its lower-order treatment was bike lane with buffer.

Table 23. Alternative Treatments Selection for Bicyclists

Potential Bicycle Treatments	Alternative treatment 1 (i.e. lower order treatment)	Alternative treatment 2 (i.e. lower order treatment)
Wide paved shoulder	NA	Sidepath
Sidepath		
Condition 1: Small urban, small urbanized and large urbanized areas, Speed>=45mph, AADT>5K	Wide paved shoulder	Separated bike lane
Condition 2: Small urban, small urbanized, large urbanized areas, AADT <5K, Speed >=45mph	Wide paved shoulder	Bike lane with buffer
Condition 3: Rural areas, Speed 35-40mph, AADT >10K	Wide paved shoulder	Bike lane with buffer
Condition 4: Rural areas, AADT <10K, Speed 35-40mph	Wide paved shoulder	Bike lane
Condition 5: Rural areas, AADT >10K, Speed <=30mph	Wide paved shoulder	Bike lane
Sidepath with lane reductions		
Condition 1: All contexts, speed >=45mph and AADT >5K	Wide paved shoulder	Separated bike lane
Condition 2: All contexts, speed >=45mph and AADT <5K	Wide paved shoulder	Bike lane with buffer
Shared lane		
Condition 1: Small urban, small urbanized, large urbanized areas, > 2 lanes undivided and divided both, all speed/AADT ranges	NA	Bike lane
Condition 2: Rural context only, > 2 lanes undivided and divided both, all speed/AADT ranges	NA	Sidepath
Condition 3: All contexts, Lanes = 2 in undivided and 1 or 2 in divided roads, all speed/AADT ranges	NA	Bike Boulevard
Bike Boulevard	Shared lane	Bike lane
Bike lane	Wide paved shoulder	Bike lane with buffer
Bike lane with buffer	Bike lane	Separated bike lane
Separated bike lane	Bike lane with buffer	NA

Table 24 shows the bicyclist alternative treatments at segment level. In each cell of this table, the first treatment shows the lower order treatment, and the second treatment after the semicolon (;) shows the higher order treatment. In any of the cells, if either lower order or higher order treatment is not available, it is denoted by NA. For example, the higher-order treatment for separated bike lane is NA.

For the following conditions- Context: small urbanized area, Median type: undivided, Lane configuration: 4+ lanes both directions total, AADT: below 5,000, and Speed: 35-40 mph; the potential treatment is bike lane as can be seen in Table 22. Under the same contextual and roadway conditions, the lower order treatment is shared lane, and the higher-order is bike lane with buffer as per Table 24. It should be noted that shared lane will be used by other motorized vehicles and may create friction between bicyclists and motorists. This might make the condition less safe for bicyclists as compared to bike lane. However, using bike lane with buffer may improve safety and mobility of bicyclists by creating a gap between these two road users. Likewise, all the other treatments can be compared between Table 22 and Table 24.

Table 24. Bicyclist Alternative Treatments at Segment Level

Context	Median type	Lane configuration	AADT (below 5,000)			AADT (5,000-10,000)			AADT (10,000-20,000)			AADT (above 20,000)		
			<=30mph	35-40 mph	>=45 mph	<=30mph	35-40 mph	>=45 mph	<=30mph	35-40 mph	>=45 mph	<=30mph	35-40 mph	>=45 mph
Rural (Pop < 5K)	Undivided	2 lanes, both directions total	NA; Bike Boulevard	Wide paved shoulder; Bike lane	NA; Sidepath	NA; Bike Boulevard	Wide paved shoulder; Bike lane	NA; Sidepath	Wide paved shoulder; Bike lane	Wide paved shoulder; Bike lane with buffer	NA; Sidepath	Wide paved shoulder; Bike lane	Wide paved shoulder; Bike lane with buffer	NA; Sidepath
		3 lanes, both directions total (including TWLTL)	NA; Sidepath	Wide paved shoulder; Bike lane	NA; Sidepath	NA; Sidepath	Wide paved shoulder; Bike lane	NA; Sidepath	Wide paved shoulder; Bike lane	Wide paved shoulder; Bike lane with buffer	NA; Sidepath	Wide paved shoulder; Bike lane	Wide paved shoulder; Bike lane with buffer	NA; Sidepath
		4+ lanes, both directions total	NA; Sidepath	Wide paved shoulder; Bike lane	NA; Sidepath	NA; Sidepath	Wide paved shoulder; Bike lane	NA; Sidepath	Wide paved shoulder; Bike lane	Wide paved shoulder; Bike lane with buffer	NA; Sidepath	Wide paved shoulder; Bike lane	Wide paved shoulder; Bike lane with buffer	NA; Sidepath
	Median (Raised, guard rail, concrete barrier etc.)	1-2 lanes in one direction	NA; Bike Boulevard	Wide paved shoulder; Bike lane	NA; Sidepath	NA; Bike Boulevard	Wide paved shoulder; Bike lane	NA; Sidepath	Wide paved shoulder; Bike lane	Wide paved shoulder; Bike lane with buffer	NA; Sidepath	Wide paved shoulder; Bike lane	Wide paved shoulder; Bike lane with buffer	NA; Sidepath
		3+ lanes in one direction	NA; Sidepath	Wide paved shoulder; Bike lane	NA; Sidepath	NA; Sidepath	Wide paved shoulder; Bike lane	NA; Sidepath	Wide paved shoulder; Bike lane	Wide paved shoulder; Bike lane with buffer	NA; Sidepath	Wide paved shoulder; Bike lane	Wide paved shoulder; Bike lane with buffer	NA; Sidepath
Small urban areas (Pop 5K to 50K)	Undivided	2 lanes, both directions total	Shared lane; Bike lane	Wide paved shoulder; Bike lane	Wide paved shoulder; Bike lane with buffer	NA; Bike Boulevard	Wide paved shoulder; Bike lane	Wide paved shoulder; Separated bike lane	Wide paved shoulder; Bike lane with buffer	Wide paved shoulder; Bike lane with buffer	Wide paved shoulder; Separated bike lane	Wide paved shoulder; Bike lane with buffer	Wide paved shoulder; Bike lane with buffer	Wide paved shoulder; Separated bike lane
		3 lanes, both directions total (including TWLTL)	NA; Bike lane	Wide paved shoulder; Bike lane	Wide paved shoulder; Bike lane with buffer	NA; Bike lane	Wide paved shoulder; Bike lane	Wide paved shoulder; Separated bike lane	Wide paved shoulder; Bike lane with buffer	Wide paved shoulder; Bike lane with buffer	Wide paved shoulder; Separated bike lane	Wide paved shoulder; Bike lane with buffer	Wide paved shoulder; Bike lane with buffer	Wide paved shoulder; Separated bike lane
		4+ lanes, both directions total	NA; Bike lane	Wide paved shoulder; Bike lane	Wide paved shoulder; Bike lane with buffer	NA; Bike lane	Wide paved shoulder; Bike lane with buffer	Wide paved shoulder; Separated bike lane	Wide paved shoulder; Bike lane with buffer	Bike lane; Separated bike lane	Wide paved shoulder; Separated bike lane	Wide paved shoulder; Bike lane with buffer	Bike lane; Separated bike lane	Wide paved shoulder; Separated bike lane
	Median (Raised, guard rail, concrete barrier etc.)	1-2 lanes in one direction	Shared lane; Bike lane	Wide paved shoulder; Bike lane	Wide paved shoulder; Bike lane with buffer	NA; Bike Boulevard	Wide paved shoulder; Bike lane	Wide paved shoulder; Separated bike lane	Wide paved shoulder; Bike lane with buffer	Wide paved shoulder; Bike lane with buffer	Wide paved shoulder; Separated bike lane	Wide paved shoulder; Bike lane with buffer	Wide paved shoulder; Bike lane with buffer	Wide paved shoulder; Separated bike lane
		3+ lanes in one direction	NA; Bike lane	Wide paved shoulder; Bike lane	Wide paved shoulder; Bike lane with buffer	NA; Bike lane	Wide paved shoulder; Bike lane with buffer	Wide paved shoulder; Separated bike lane	Wide paved shoulder; Bike lane with buffer	Bike lane; Separated bike lane	Wide paved shoulder; Separated bike lane	Wide paved shoulder; Bike lane with buffer	Bike lane; Separated bike lane	Wide paved shoulder; Separated bike lane
Small urbanized areas (Pop 50K to 200K)	Undivided	2 lanes, both directions total	Shared lane; Bike lane	Wide paved shoulder; Bike lane with buffer	Wide paved shoulder; Bike lane with buffer	NA; Bike Boulevard	Wide paved shoulder; Bike lane with buffer	Wide paved shoulder; Separated bike lane	Wide paved shoulder; Bike lane with buffer	Bike lane; Separated bike lane	Wide paved shoulder; Separated bike lane	Wide paved shoulder; Bike lane with buffer	Bike lane; Separated bike lane	Wide paved shoulder; Separated bike lane
		3 lanes, both directions total (including TWLTL)	NA; Bike lane	Wide paved shoulder; Bike lane with buffer	Wide paved shoulder; Bike lane with buffer	NA; Bike lane	Wide paved shoulder; Bike lane with buffer	Wide paved shoulder; Separated bike lane	Wide paved shoulder; Bike lane with buffer	Bike lane; Separated bike lane	Wide paved shoulder; Separated bike lane	Wide paved shoulder; Bike lane with buffer	Bike lane; Separated bike lane	Wide paved shoulder; Separated bike lane
		4+ lanes, both directions total	NA; Bike lane	Wide paved shoulder; Bike lane with buffer	Wide paved shoulder; Bike lane with buffer	NA; Bike lane	Wide paved shoulder; Bike lane with buffer	Wide paved shoulder; Separated bike lane	Wide paved shoulder; Bike lane with buffer	Bike lane; Separated bike lane	Wide paved shoulder; Separated bike lane	Wide paved shoulder; Bike lane with buffer	Bike lane with buffer; NA	Wide paved shoulder; Separated bike lane
	Median (Raised, guard rail, concrete barrier etc.)	1-2 lanes in one direction	Shared lane; Bike lane	Wide paved shoulder; Bike lane with buffer	Wide paved shoulder; Bike lane with buffer	NA; Bike Boulevard	Wide paved shoulder; Bike lane with buffer	Wide paved shoulder; Separated bike lane	Wide paved shoulder; Bike lane with buffer	Bike lane; Separated bike lane	Wide paved shoulder; Separated bike lane	Wide paved shoulder; Bike lane with buffer	Bike lane; Separated bike lane	Wide paved shoulder; Separated bike lane
		3+ lanes in one direction	NA; Bike lane	Wide paved shoulder; Bike lane with buffer	Wide paved shoulder; Bike lane with buffer	NA; Bike lane	Wide paved shoulder; Bike lane with buffer	Wide paved shoulder; Separated bike lane	Wide paved shoulder; Bike lane with buffer	Bike lane; Separated bike lane	Wide paved shoulder; Separated bike lane	Wide paved shoulder; Bike lane with buffer	Bike lane with buffer; NA	Wide paved shoulder; Separated bike lane
Large urbanized areas (> 200K)	Undivided	2 lanes, both directions total	Shared lane; Bike lane	Wide paved shoulder; Bike lane with buffer	Wide paved shoulder; Bike lane with buffer	NA; Bike Boulevard	Wide paved shoulder; Bike lane with buffer	Wide paved shoulder; Separated bike lane	Wide paved shoulder; Bike lane with buffer	Bike lane; Separated bike lane	Wide paved shoulder; Separated bike lane	Wide paved shoulder; Bike lane with buffer	Bike lane with buffer; NA	Wide paved shoulder; Separated bike lane
		3 lanes, both directions total (including TWLTL)	NA; Bike lane	Wide paved shoulder; Bike lane with buffer	Wide paved shoulder; Bike lane with buffer	NA; Bike lane	Wide paved shoulder; Bike lane with buffer	Wide paved shoulder; Separated bike lane	Wide paved shoulder; Bike lane with buffer	Bike lane with buffer; NA	Wide paved shoulder; Separated bike lane	Bike lane; Separated bike lane	Bike lane with buffer; NA	Wide paved shoulder; Separated bike lane
		4+ lanes, both directions total	NA; Bike lane	Wide paved shoulder; Bike lane with buffer	Wide paved shoulder; Bike lane with buffer	NA; Bike lane	Bike lane with buffer; NA	Wide paved shoulder; Separated bike lane	Wide paved shoulder; Bike lane with buffer	Bike lane with buffer; NA	Wide paved shoulder; Separated bike lane	Bike lane; Separated bike lane	Bike lane with buffer; NA	Wide paved shoulder; Separated bike lane
	Median (Raised, guard rail, concrete barrier etc.)	1-2 lanes in one direction	Shared lane; Bike lane	Wide paved shoulder; Bike lane with buffer	Wide paved shoulder; Bike lane with buffer	NA; Bike Boulevard	Bike lane; Separated bike lane	Wide paved shoulder; Separated bike lane	Wide paved shoulder; Bike lane with buffer	Bike lane with buffer; NA	Wide paved shoulder; Separated bike lane	Wide paved shoulder; Bike lane with buffer	Bike lane with buffer; NA	Wide paved shoulder; Separated bike lane
		3+ lanes in one direction	NA; Bike lane	Wide paved shoulder; Bike lane with buffer	Wide paved shoulder; Bike lane with buffer	NA; Bike lane	Bike lane with buffer; NA	Wide paved shoulder; Separated bike lane	Wide paved shoulder; Bike lane with buffer	Bike lane with buffer; NA	Wide paved shoulder; Separated bike lane	Bike lane; Separated bike lane	Bike lane with buffer; NA	Wide paved shoulder; Separated bike lane

6.2.3 Midblock: treatment selection process

This subsection explains the treatment selection procedure at midblock crossing locations. Among all the guidelines, *STEP studio* (Federal Highway Administration 2020b) was mostly used to identify the treatments. In addition to this, other MDOT and federal guidelines were also reviewed- *Multimodal Development and Delivery Guidebook* (Michigan Department of Transportation 2019), *Best Design Practices for Walking and Bicycling in Michigan* (Michigan Department of Transportation 2012a), *User Guide for R1-6 Gateway Treatment for Pedestrian Crossings* (McQuiston et al. 2016), *Guidance for Installation of Pedestrian Crosswalks on Michigan State Trunkline Highways* (Michigan Department of Transportation 2014b) etc. After reviewing these guidelines, midblock crossing treatments for ped/bike were identified, and the treatment matrix was developed. This was developed for undivided roads and raised median facilities only (i.e., medians with barriers are generally not accessible by pedestrians/bicyclists). The following decision criteria were used to determine specific treatments in various contexts at midblock locations:

- As the speed limit, AADT, and number of lanes increase, the treatments provide greater levels of safety for pedestrians/bicyclists.
- As the context shifts from rural to large urbanized areas, the treatments provide greater levels of safety for pedestrians/bicyclists.
- It is assumed if treatment is safe for pedestrians, then it is safe for bicyclists as well.
- High-visibility crosswalks are suggested at all locations.
- Pedestrian warning signs are suggested at all locations where the existing treatment is of a higher order than a pedestrian warning sign.
- Pedestrian refuge islands are suggested on all undivided roadway with 4 or more lanes.

Table 25 shows the midblock treatment matrix. It shows treatments for 240 unique combinations of context, median type, number of lanes, speed limit, and AADT. In this matrix, darker color also shows the treatments that provide higher level of safety to pedestrians and bicyclists. The following unique treatments are used in this matrix (arranged in increasing order of safety):

1. High visibility crosswalk
2. Pedestrian warning sign
3. Advance yield here to pedestrian signs and yield line
4. Gateway treatment

5. Pedestrian refuge island
6. Rectangular rapid flashing beacon
7. Pedestrian hybrid beacon

The following paragraphs give a brief definition of the above-mentioned midblock treatments and the contextual and roadway characteristics where these treatments are generally used.

High visibility crosswalk: It is the portion of road at an intersection or elsewhere that is intended for the crossing of pedestrians/bicyclists and is indicated by crossing lines or other markings (Michigan Department of Transportation 2014a).

High visibility crosswalk is the minimum suggested treatment in the matrix. It is recommended to use high visibility crosswalk along with all the treatments. It is generally a potential treatment in rural and small urban contexts with AADT <10,000 and speed <=30 mph. Further, as the AADT shifts to higher ranges, in each of these contexts, safer treatments than high visibility crosswalks are considered as potential treatments. This provides lowest order of safety among all the treatments; that’s why it is used mainly in rural and small urban areas where pedestrian/bicyclist crossing is less often and that too with lower speeds.

Pedestrian warning sign: Pedestrian warning signs are designed to warn motorists about the possibility of pedestrians on road (ELTEC 2022).

These signs provide higher level of safety than simply using high visibility crosswalk as they can alert the drivers from a far distance. That’s why these are generally considered in rural, small urban, and small urbanized areas with AADT <10,000 and speed of 35-40 mph. As the AADT range increases in these three contexts to >=10,000, this treatment is majorly used on roadways with speed limit <=30 mph. This was done to provide higher level of safety to pedestrian/bicyclist crossing and compensate for higher AADT range. Lastly, the use of pedestrian warning sign is encouraged at all treatments that are safer than it.

Advance yield here to pedestrian sign and yield line: These are signs placed 20 to 50 feet ahead of the crosswalk line along with yield line markings on the road to improve the visibility of pedestrians/bicyclists to drivers (Federal Highway Administration 2020b).

Advance yield here to pedestrian signs and yield line provides higher level of safety as compared to pedestrian warning sign, by alerting the driver in advance and reducing the chances of crashes at high speed. As the AADT shifts to higher ranges, the usage of this treatment shifts from higher speeds (>=45 mph) to lower (<=30 mph). For example, this is identified as potential treatment in rural, small urban, small urbanized areas with: AADT <10,000 and speed >= 45mph; and AADT >=10,000 and speed 35-40 mph. Further, in large urbanized areas, these are identified as potential treatments when AADT <10,000 and speed <=30 mph. Lastly, it is recommended to use high visibility crosswalk and pedestrian warning/crossing sign along with advance yield to pedestrian signs and yield line.

Gateway treatment: These are R1-6 signs installed at crosswalks by mounting them on lane lines and the edge of the road. All motorized vehicles must navigate between the two gateway signs. The apparent narrowing of the road affects treatment efficiency (McQuiston et al. 2016).

Gateway treatment gives perceived effect that width of the road is reduced; this may help in decreasing drivers' speed. It is identified as a potential treatment in large urbanized areas only, where ped/bike activity is highest with AADT <10,000 and speed of 35-40 mph. Lastly, it is recommended to use high visibility crosswalk and pedestrian warning sign along with gateway treatment.

Pedestrian refuge island: This is a median island at the center of the road that physically divides the two directions of the traffic and offers refuge to pedestrians that can facilitate crossing (Michigan Department of Transportation 2014a).

As pedestrian refuge island provides refuge to pedestrians and facilitates safe crossing, it is identified as a potential treatment in all contexts on all the undivided roads with 4+ lanes. This refuge is necessary for ped/bike as crossing 4+ lanes in one go can be precarious. To ensure safety, even if a potential treatment in the matrix for 4+ undivided roads is other than pedestrian refuge island on 4+ lanes, it is still provided. For example, in context: large urbanized area, AADT: 5,000-10,000, median type: undivided, lane configuration: 4+ lanes both directions, the potential treatment is pedestrian hybrid beacon. It should be noted that in this case, the pedestrian hybrid beacon is provided with pedestrian refuge island because the median lane configuration was undivided 4+ lanes. Similar to other treatments, it is recommended to use high visibility crosswalk and pedestrian warning sign along with pedestrian refuge island.

Rectangular rapid flashing beacon: Rectangular rapid flashing beacon, or RRFB, is a user-actuated LED beacon that warns the driver that a road user is about to cross the midblock. RRFB can be activated through a push button or a pedestrian detection system. The flash pattern of RRFB is similar to police vehicles (Michigan Department of Transportation 2014a).

RRFB provides a higher level of conspicuity to ped/bike than the above-mentioned treatments. In general, it is identified as a potential treatment in small and large urbanized areas. As the context shifts from small urbanized areas to large urbanized areas, the consideration of this treatment reduces from speed >=45 mph to 35-40 mph. For example, it is considered in small urbanized areas with AADT >=10,000 and speed >=45 mph; but in large urbanized areas (highest ped/bike activity among all contexts), it is considered on roadways with AADT >=10,000 and speed of 35-40 mph. It is recommended to use high visibility crosswalks and pedestrian warning signs in addition to RRFB.

Pedestrian hybrid beacon: Pedestrian hybrid beacon or PHB, also known as high-intensity activated crosswalk or HAWK, is a user-actuated beacon that informs the driver to stop at a marked crosswalk by displaying the red light. The beacon stays dark until pedestrians cross the street (Michigan Department of Transportation 2014a).

PHB provides the highest level of conspicuity to ped/bike as compared to all the treatments used in the matrix; that's why it is only considered in large urbanized areas. As the AADT range, speed, and number of lanes increase within this context, PHB is considered heavily. For example, it is considered as a potential treatment in large urbanized areas with AADT <5,000, speed >=45 mph, with raised median 3+ lanes only. But for large urbanized areas and AADT >=20,000, speed >=45 mph, it is considered for all median-lane configurations. Similar to other treatments, it is recommended to use high visibility crosswalks, and pedestrian warning signs along with pedestrian hybrid beacon.

Table 25. Midblock Crossing Treatments

Context	Median type	Lane configuration	AADT (below 5,000)			AADT (5,000-10,000)			AADT (10,000-20,000)			AADT (above 20,000)		
			<=30mph	35-40 mph	>=45 mph	<=30mph	35-40 mph	>=45 mph	<=30mph	35-40 mph	>=45 mph	<=30mph	35-40 mph	>=45 mph
Rural (Pop < 5K)	Undivided	2 lanes, both directions total	High visibility crosswalk	High visibility crosswalk	Advance yield here to pedestrian sign and yield line	High visibility crosswalk	Pedestrian warning sign	Advance yield here to pedestrian sign and yield line	High visibility crosswalk	Pedestrian warning sign	Pedestrian refuge island	High visibility crosswalk	Pedestrian warning sign	Pedestrian refuge island
		3 lanes, both directions total (including TWLTL)	High visibility crosswalk	High visibility crosswalk	Advance yield here to pedestrian sign and yield line	High visibility crosswalk	Pedestrian warning sign	Advance yield here to pedestrian sign and yield line	Pedestrian warning sign	Pedestrian warning sign	Pedestrian refuge island	Pedestrian warning sign	Pedestrian warning sign	Pedestrian refuge island
		4+ lanes, both directions total	Pedestrian refuge island	Pedestrian refuge island	Pedestrian refuge island	Pedestrian refuge island	Pedestrian refuge island	Pedestrian refuge island	Pedestrian refuge island	Pedestrian refuge island	Pedestrian refuge island	Pedestrian refuge island	Pedestrian refuge island	Pedestrian refuge island
	Median	1-2 lanes in one direction	High visibility crosswalk	High visibility crosswalk	Advance yield here to pedestrian sign and yield line	High visibility crosswalk	Pedestrian warning sign	Advance yield here to pedestrian sign and yield line	High visibility crosswalk	Pedestrian warning sign	Advance yield here to pedestrian sign and yield line	High visibility crosswalk	Pedestrian warning sign	Advance yield here to pedestrian sign and yield line
		3+ lanes in one direction	High visibility crosswalk	Pedestrian warning sign	Advance yield here to pedestrian sign and yield line	High visibility crosswalk	Pedestrian warning sign	Advance yield here to pedestrian sign and yield line	Pedestrian warning sign	Advance yield here to pedestrian sign and yield line	Advance yield here to pedestrian sign and yield line	Pedestrian warning sign	Advance yield here to pedestrian sign and yield line	Advance yield here to pedestrian sign and yield line
Small urban areas (Pop 5K to 50K)	Undivided	2 lanes, both directions total	High visibility crosswalk	High visibility crosswalk	Advance yield here to pedestrian sign and yield line	High visibility crosswalk	Pedestrian warning sign	Advance yield here to pedestrian sign and yield line	Pedestrian warning sign	Pedestrian warning sign	Pedestrian refuge island	Pedestrian warning sign	Pedestrian warning sign	Pedestrian refuge island
		3 lanes, both directions total (including TWLTL)	High visibility crosswalk	Pedestrian warning sign	Advance yield here to pedestrian sign and yield line	High visibility crosswalk	Pedestrian warning sign	Advance yield here to pedestrian sign and yield line	Pedestrian warning sign	Advance yield here to pedestrian sign and yield line	Pedestrian refuge island	Pedestrian warning sign	Advance yield here to pedestrian sign and yield line	Pedestrian refuge island
		4+ lanes, both directions total	Pedestrian refuge island	Pedestrian refuge island	Pedestrian refuge island	Pedestrian refuge island	Pedestrian refuge island	Pedestrian refuge island	Pedestrian refuge island	Pedestrian refuge island	Pedestrian refuge island	Pedestrian refuge island	Pedestrian refuge island	Pedestrian refuge island
	Median	1-2 lanes in one direction	High visibility crosswalk	High visibility crosswalk	Advance yield here to pedestrian sign and yield line	High visibility crosswalk	Pedestrian warning sign	Advance yield here to pedestrian sign and yield line	High visibility crosswalk	Pedestrian warning sign	Advance yield here to pedestrian sign and yield line	High visibility crosswalk	Pedestrian warning sign	Advance yield here to pedestrian sign and yield line
		3+ lanes in one direction	High visibility crosswalk	Pedestrian warning sign	Advance yield here to pedestrian sign and yield line	High visibility crosswalk	Pedestrian warning sign	Advance yield here to pedestrian sign and yield line	Pedestrian warning sign	Advance yield here to pedestrian sign and yield line	Advance yield here to pedestrian sign and yield line	Pedestrian warning sign	Advance yield here to pedestrian sign and yield line	Advance yield here to pedestrian sign and yield line
Small urbanized areas (Pop 50K to 200K)	Undivided	2 lanes, both directions total	High visibility crosswalk	Pedestrian warning sign	Advance yield here to pedestrian sign and yield line	High visibility crosswalk	Pedestrian warning sign	Advance yield here to pedestrian sign and yield line	Pedestrian warning sign	Advance yield here to pedestrian sign and yield line	Pedestrian refuge island	Pedestrian warning sign	Advance yield here to pedestrian sign and yield line	Pedestrian refuge island
		3 lanes, both directions total (including TWLTL)	High visibility crosswalk	Pedestrian warning sign	Pedestrian refuge island	High visibility crosswalk	Pedestrian warning sign	Pedestrian refuge island	Advance yield here to pedestrian sign and yield line	Advance yield here to pedestrian sign and yield line	Rectangular rapid flashing beacon	Advance yield here to pedestrian sign and yield line	Advance yield here to pedestrian sign and yield line	Rectangular rapid flashing beacon
		4+ lanes, both directions total	Pedestrian refuge island	Pedestrian refuge island	Pedestrian refuge island	Pedestrian refuge island	Pedestrian refuge island	Pedestrian refuge island	Pedestrian refuge island	Pedestrian refuge island	Rectangular rapid flashing beacon	Pedestrian refuge island	Pedestrian refuge island	Rectangular rapid flashing beacon
	Median	1-2 lanes in one direction	High visibility crosswalk	Pedestrian warning sign	Advance yield here to pedestrian sign and yield line	High visibility crosswalk	Pedestrian warning sign	Advance yield here to pedestrian sign and yield line	Pedestrian warning sign	Advance yield here to pedestrian sign and yield line	Rectangular rapid flashing beacon	Pedestrian warning sign	Advance yield here to pedestrian sign and yield line	Rectangular rapid flashing beacon
		3+ lanes in one direction	High visibility crosswalk	Pedestrian warning sign	Advance yield here to pedestrian sign and yield line	High visibility crosswalk	Pedestrian warning sign	Advance yield here to pedestrian sign and yield line	Advance yield here to pedestrian sign and yield line	Advance yield here to pedestrian sign and yield line	Rectangular rapid flashing beacon	Advance yield here to pedestrian sign and yield line	Advance yield here to pedestrian sign and yield line	Rectangular rapid flashing beacon
Large urbanized areas (> 200K)	Undivided	2 lanes, both directions total	Advance yield here to pedestrian sign and yield line	Gateway treatment	Pedestrian refuge island	Advance yield here to pedestrian sign and yield line	Gateway treatment	Rectangular rapid flashing beacon	Pedestrian refuge island	Rectangular rapid flashing beacon	Pedestrian hybrid beacon	Pedestrian refuge island	Rectangular rapid flashing beacon	Pedestrian hybrid beacon
		3 lanes, both directions total (including TWLTL)	Advance yield here to pedestrian sign and yield line	Gateway treatment	Pedestrian refuge island	Advance yield here to pedestrian sign and yield line	Gateway treatment	Pedestrian hybrid beacon	Pedestrian refuge island	Rectangular rapid flashing beacon	Pedestrian hybrid beacon	Pedestrian refuge island	Rectangular rapid flashing beacon	Pedestrian hybrid beacon
		4+ lanes, both directions total	Pedestrian refuge island	Pedestrian refuge island	Pedestrian refuge island	Pedestrian refuge island	Pedestrian refuge island	Pedestrian hybrid beacon	Pedestrian refuge island	Rectangular rapid flashing beacon	Pedestrian hybrid beacon	Pedestrian refuge island	Rectangular rapid flashing beacon	Pedestrian hybrid beacon
	Median	1-2 lanes in one direction	Advance yield here to pedestrian sign and yield line	Gateway treatment	Rectangular rapid flashing beacon	Advance yield here to pedestrian sign and yield line	Gateway treatment	Pedestrian hybrid beacon	Advance yield here to pedestrian sign and yield line	Rectangular rapid flashing beacon	Pedestrian hybrid beacon	Advance yield here to pedestrian sign and yield line	Rectangular rapid flashing beacon	Pedestrian hybrid beacon
		3+ lanes in one direction	Advance yield here to pedestrian sign and yield line	Gateway treatment	Pedestrian hybrid beacon	Advance yield here to pedestrian sign and yield line	Gateway treatment	Pedestrian hybrid beacon	Rectangular rapid flashing beacon	Pedestrian hybrid beacon	Pedestrian hybrid beacon	Pedestrian hybrid beacon	Pedestrian hybrid beacon	Pedestrian hybrid beacon

Table 26 shows the alternative treatments selected at midblock locations for pedestrians and bicyclists for different combinations of context, AADT, speed limit, and median-lane configuration. Besides lower and higher-order treatments, the alternative treatments can be divided by median types as well- undivided roads and raised median. In this table, it can be seen that there is no lower-order treatment for high visibility crosswalk, i.e., it is the minimum that shall be provided at midblock crossing. Similarly, there is no higher-order treatment than pedestrian hybrid beacon as per the matrix. All the other treatments besides these two have both lower and higher-order treatments under divided and undivided roads.

Table 26. Alternative Treatment Selection at Midblock

Potential Midblock Treatments	**Alternative treatments- Undivided Roads**		**Alternative treatments- Raised median divided roads**	
	Alternative treatment 1 (i.e. lower order treatment)	**Alternative treatment 2 (i.e. higher order treatment)**	**Alternative treatment 1 (i.e. lower order treatment)**	**Alternative treatment 2 (i.e. higher order treatment)**
High visibility crosswalk	NA	Pedestrian warning sign	NA	Pedestrian warning sign
Pedestrian warning sign				
Condition 1: AADT <10K, All contexts/speed/AADT	High visibility crosswalk	Advance yield here to pedestrian sign and yield line	High visibility crosswalk	Advance yield here to pedestrian sign and yield line
Condition 2: AADT >10K, Speed <30mph, all contexts/AADT	High visibility crosswalk	Advance yield here to pedestrian sign and yield line	High visibility crosswalk	Advance yield here to pedestrian sign and yield line
Condition 3: AADT >10K; Speed 35-40mph, all contexts/AADT	High visibility crosswalk	Pedestrian refuge island	High visibility crosswalk	Advance yield here to pedestrian sign and yield line
Advance yield here to pedestrian sign and yield line	Pedestrian warning sign	Pedestrian refuge island	Pedestrian warning sign	Rectangular Rapid Flashing Beacon
Gateway treatment	Advance yield here to pedestrian sign and yield line	Pedestrian refuge island	Advance yield here to pedestrian sign and yield line	Rectangular Rapid Flashing Beacon
Pedestrian refuge island	Advance yield here to pedestrian sign and yield line	Rectangular Rapid Flashing Beacon	NA (no such treatment in median divided as it already has one.)	NA (no such treatment in median divided as it already has one.)
Rectangular Rapid Flashing Beacon	Pedestrian refuge island	Pedestrian Hybrid Beacon	Advance yield here to pedestrian sign and yield line	Pedestrian Hybrid Beacon
Pedestrian Hybrid Beacon	Rectangular Rapid Flashing Beacon	NA	Rectangular Rapid Flashing Beacon	NA

Table 27 shows the midblock alternative treatments for pedestrians and bicyclists. In each cell of this matrix, the first treatment indicates the lower order treatment, and the second treatment after the semicolon (;) indicates higher-order treatment. Similar to other matrices, if either lower order or higher order treatment is not available, it is represented as NA.

For the following conditions- Context: small urbanized area, Median type: undivided, Lane-configuration: two lanes both directions total, AADT: 5,000-10,000, and Speed: 35-40 mph, the potential treatment is pedestrian warning sign as identified in Table 25. For the same contextual and roadway configurations, the lower order and higher order treatments are high visibility crosswalk and advance yield here to pedestrian sign and yield line as per Table 27. As mentioned previously, all the treatments in the midblock tools shall have high visibility crosswalk as default. As such, the potential treatment becomes pedestrian warning sign with high visibility crosswalk, which definitely provides higher levels of safety/conspicuity as compared to high visibility crosswalk (lower-order treatment) alone. Similarly, advance yield here to pedestrian sign and yield line with high visibility crosswalk (higher-order treatment) provides higher levels of safety/conspicuity as compared to pedestrian warning sign with high visibility crosswalk. Likewise, all the other treatments can be compared between Table 25 and Table 27.

Table 27. Midblock Alternative Treatments

Context	Median type	Lane configuration	AADT (below5,000)			AADT (5,000-10,000)			AADT (10,000-20,000)			AADT (above 20,000)		
			<=30mph	35-40 mph	>=45 mph	<=30mph	35-40 mph	>=45 mph	<=30mph	35-40 mph	>=45 mph	<=30mph	35-40 mph	>=45 mph
Rural (Pop < 5K)	Undivided	2 lanes, both directions total	NA; Pedestrian warning sign	NA; Pedestrian warning sign	Pedestrian warning sign; Pedestrian refuge island	NA; Pedestrian warning sign	High visibility crosswalk; Advance yield here to pedestrian sign and yield line	Pedestrian warning sign; Pedestrian refuge island	NA; Pedestrian warning sign	High visibility crosswalk; Pedestrian refuge island	Advance yield here to pedestrian sign and yield line; Rectangular rapid flashing beacon	NA; Pedestrian warning sign	High visibility crosswalk; Pedestrian refuge island	Advance yield here to pedestrian sign and yield line; Rectangular rapid flashing beacon
		3 lanes, both directions total (including TWLTL)	NA; Pedestrian warning sign	NA; Pedestrian warning sign	Pedestrian warning sign; Pedestrian refuge island	NA; Pedestrian warning sign	High visibility crosswalk; Advance yield here to pedestrian sign and yield line	Pedestrian warning sign; Pedestrian refuge island	High visibility crosswalk; Advance yield here to pedestrian sign and yield line	High visibility crosswalk; Pedestrian refuge island	Advance yield here to pedestrian sign and yield line; Rectangular rapid flashing beacon	High visibility crosswalk; Advance yield here to pedestrian sign and yield line	High visibility crosswalk; Pedestrian refuge island	Advance yield here to pedestrian sign and yield line; Rectangular rapid flashing beacon
		4+ lanes, both directions total	Advance yield here to pedestrian sign and yield line; Rectangular rapid flashing beacon	Advance yield here to pedestrian sign and yield line; Rectangular rapid flashing beacon	Advance yield here to pedestrian sign and yield line; Rectangular rapid flashing beacon	Advance yield here to pedestrian sign and yield line; Rectangular rapid flashing beacon	Advance yield here to pedestrian sign and yield line; Rectangular rapid flashing beacon	Advance yield here to pedestrian sign and yield line; Rectangular rapid flashing beacon	Advance yield here to pedestrian sign and yield line; Rectangular rapid flashing beacon	Advance yield here to pedestrian sign and yield line; Rectangular rapid flashing beacon	Advance yield here to pedestrian sign and yield line; Rectangular rapid flashing beacon	Advance yield here to pedestrian sign and yield line; Rectangular rapid flashing beacon	Advance yield here to pedestrian sign and yield line; Rectangular rapid flashing beacon	Advance yield here to pedestrian sign and yield line; Rectangular rapid flashing beacon
	Raised Median	1-2 lanes in one direction	NA; Pedestrian warning sign	NA; Pedestrian warning sign	Pedestrian warning sign; Rectangular rapid flashing beacon	NA; Pedestrian warning sign	High visibility crosswalk; Advance yield here to pedestrian sign and yield line	Pedestrian warning sign; Rectangular rapid flashing beacon	NA; Pedestrian warning sign	High visibility crosswalk; Advance yield here to pedestrian sign and yield line	Pedestrian warning sign; Rectangular rapid flashing beacon	NA; Pedestrian warning sign	High visibility crosswalk; Advance yield here to pedestrian sign and yield line	Pedestrian warning sign; Rectangular rapid flashing beacon
		3+ lanes in one direction	NA; Pedestrian warning sign	High visibility crosswalk; Advance yield here to pedestrian sign and yield line	Pedestrian warning sign; Rectangular rapid flashing beacon	NA; Pedestrian warning sign	High visibility crosswalk; Advance yield here to pedestrian sign and yield line	Pedestrian warning sign; Rectangular rapid flashing beacon	High visibility crosswalk; Advance yield here to pedestrian sign and yield line	Pedestrian warning sign; Rectangular rapid flashing beacon	Pedestrian warning sign; Rectangular rapid flashing beacon	High visibility crosswalk; Advance yield here to pedestrian sign and yield line	Pedestrian warning sign; Rectangular rapid flashing beacon	Pedestrian warning sign; Rectangular rapid flashing beacon
Small urban areas (Pop 5K to 50K)	Undivided	2 lanes, both directions total	NA; Pedestrian warning sign	NA; Pedestrian warning sign	Pedestrian warning sign; Pedestrian refuge island	NA; Pedestrian warning sign	High visibility crosswalk; Advance yield here to pedestrian sign and yield line	Pedestrian warning sign; Pedestrian refuge island	High visibility crosswalk; Advance yield here to pedestrian sign and yield line	High visibility crosswalk; Pedestrian refuge island	Advance yield here to pedestrian sign and yield line; Rectangular rapid flashing beacon	High visibility crosswalk; Advance yield here to pedestrian sign and yield line	High visibility crosswalk; Pedestrian refuge island	Advance yield here to pedestrian sign and yield line; Rectangular rapid flashing beacon
		3 lanes, both directions total (including TWLTL)	NA; Pedestrian warning sign	High visibility crosswalk; Advance yield here to pedestrian sign and yield line	Pedestrian warning sign; Pedestrian refuge island	NA; Pedestrian warning sign	High visibility crosswalk; Advance yield here to pedestrian sign and yield line	Pedestrian warning sign; Pedestrian refuge island	High visibility crosswalk; Advance yield here to pedestrian sign and yield line	Pedestrian warning sign; Pedestrian refuge island	Advance yield here to pedestrian sign and yield line; Rectangular rapid flashing beacon	High visibility crosswalk; Advance yield here to pedestrian sign and yield line	Pedestrian warning sign; Pedestrian refuge island	Advance yield here to pedestrian sign and yield line; Rectangular rapid flashing beacon
		4+ lanes, both directions total	Advance yield here to pedestrian sign and yield line; Rectangular rapid flashing beacon	Advance yield here to pedestrian sign and yield line; Rectangular rapid flashing beacon	Advance yield here to pedestrian sign and yield line; Rectangular rapid flashing beacon	Advance yield here to pedestrian sign and yield line; Rectangular rapid flashing beacon	Advance yield here to pedestrian sign and yield line; Rectangular rapid flashing beacon	Advance yield here to pedestrian sign and yield line; Rectangular rapid flashing beacon	Advance yield here to pedestrian sign and yield line; Rectangular rapid flashing beacon	Advance yield here to pedestrian sign and yield line; Rectangular rapid flashing beacon	Advance yield here to pedestrian sign and yield line; Rectangular rapid flashing beacon	Advance yield here to pedestrian sign and yield line; Rectangular rapid flashing beacon	Advance yield here to pedestrian sign and yield line; Rectangular rapid flashing beacon	Advance yield here to pedestrian sign and yield line; Rectangular rapid flashing beacon
	Raised Median	1-2 lanes in one direction	NA; Pedestrian warning sign	NA; Pedestrian warning sign	Pedestrian warning sign; Rectangular rapid flashing beacon	NA; Pedestrian warning sign	High visibility crosswalk; Advance yield here to pedestrian sign and yield line	Pedestrian warning sign; Rectangular rapid flashing beacon	NA; Pedestrian warning sign	High visibility crosswalk; Advance yield here to pedestrian sign and yield line	Pedestrian warning sign; Rectangular rapid flashing beacon	NA; Pedestrian warning sign	High visibility crosswalk; Advance yield here to pedestrian sign and yield line	Pedestrian warning sign; Rectangular rapid flashing beacon
		3+ lanes in one direction	NA; Pedestrian warning sign	High visibility crosswalk; Advance yield here to pedestrian sign and yield line	Pedestrian warning sign; Rectangular rapid flashing beacon	NA; Pedestrian warning sign	High visibility crosswalk; Advance yield here to pedestrian sign and yield line	Pedestrian warning sign; Rectangular rapid flashing beacon	High visibility crosswalk; Advance yield here to pedestrian sign and yield line	Pedestrian warning sign; Rectangular rapid flashing beacon	Pedestrian warning sign; Rectangular rapid flashing beacon	High visibility crosswalk; Advance yield here to pedestrian sign and yield line	Pedestrian warning sign; Rectangular rapid flashing beacon	Pedestrian warning sign; Rectangular rapid flashing beacon
Small urbanized areas (Pop 50K to 200K)	Undivided	2 lanes, both directions total	NA; Pedestrian warning sign	High visibility crosswalk; Advance yield here to pedestrian sign and yield line	Pedestrian warning sign; Pedestrian refuge island	NA; Pedestrian warning sign	High visibility crosswalk; Advance yield here to pedestrian sign and yield line	Pedestrian warning sign; Pedestrian refuge island	High visibility crosswalk; Advance yield here to pedestrian sign and yield line	Pedestrian warning sign; Pedestrian refuge island	Advance yield here to pedestrian sign and yield line; Rectangular rapid flashing beacon	High visibility crosswalk; Advance yield here to pedestrian sign and yield line	Pedestrian warning sign; Pedestrian refuge island	Advance yield here to pedestrian sign and yield line; Rectangular rapid flashing beacon
		3 lanes, both directions total (including TWLTL)	NA; Pedestrian warning sign	High visibility crosswalk; Advance yield here to pedestrian sign and yield line	Advance yield here to pedestrian sign and yield line; Rectangular rapid flashing beacon	NA; Pedestrian warning sign	High visibility crosswalk; Advance yield here to pedestrian sign and yield line	Advance yield here to pedestrian sign and yield line; Rectangular rapid flashing beacon	Pedestrian warning sign; Pedestrian refuge island	Pedestrian warning sign; Pedestrian refuge island	Pedestrian refuge island; Pedestrian hybrid beacon	Pedestrian warning sign; Pedestrian refuge island	Pedestrian warning sign; Pedestrian refuge island	Pedestrian refuge island; Pedestrian hybrid beacon
		4+ lanes, both directions total	Advance yield here to pedestrian sign and yield line; Rectangular rapid flashing beacon	Advance yield here to pedestrian sign and yield line; Rectangular rapid flashing beacon	Advance yield here to pedestrian sign and yield line; Rectangular rapid flashing beacon	Advance yield here to pedestrian sign and yield line; Rectangular rapid flashing beacon	Advance yield here to pedestrian sign and yield line; Rectangular rapid flashing beacon	Advance yield here to pedestrian sign and yield line; Rectangular rapid flashing beacon	Advance yield here to pedestrian sign and yield line; Rectangular rapid flashing beacon	Advance yield here to pedestrian sign and yield line; Rectangular rapid flashing beacon	Pedestrian refuge island; Pedestrian hybrid beacon	Advance yield here to pedestrian sign and yield line; Rectangular rapid flashing beacon	Advance yield here to pedestrian sign and yield line; Rectangular rapid flashing beacon	Pedestrian refuge island; Pedestrian hybrid beacon
	Raised Median	1-2 lanes in one direction	NA; Pedestrian warning sign	High visibility crosswalk; Advance yield here to pedestrian sign and yield line	Pedestrian warning sign; Rectangular rapid flashing beacon	NA; Pedestrian warning sign	High visibility crosswalk; Advance yield here to pedestrian sign and yield line	Pedestrian warning sign; Rectangular rapid flashing beacon	High visibility crosswalk; Advance yield here to pedestrian sign and yield line	Pedestrian warning sign; Rectangular rapid flashing beacon	Advance yield here to pedestrian sign and yield line; Pedestrian hybrid beacon	High visibility crosswalk; Advance yield here to pedestrian sign and yield line	Pedestrian warning sign; Rectangular rapid flashing beacon	Advance yield here to pedestrian sign and yield line; Pedestrian hybrid beacon
		3+ lanes in one direction	NA; Pedestrian warning sign	High visibility crosswalk; Advance yield here to pedestrian sign and yield line	Pedestrian warning sign; Rectangular rapid flashing beacon	NA; Pedestrian warning sign	High visibility crosswalk; Advance yield here to pedestrian sign and yield line	Pedestrian warning sign; Rectangular rapid flashing beacon	Pedestrian warning sign; Rectangular rapid flashing beacon	Pedestrian warning sign; Rectangular rapid flashing beacon	Advance yield here to pedestrian sign and yield line; Pedestrian hybrid beacon	Pedestrian warning sign; Rectangular rapid flashing beacon	Pedestrian warning sign; Rectangular rapid flashing beacon	Advance yield here to pedestrian sign and yield line; Pedestrian hybrid beacon
Large urbanized areas (> 200K)	Undivided	2 lanes, both directions total	Pedestrian warning sign; Pedestrian refuge island	Advance yield here to pedestrian sign and yield line; Pedestrian refuge island	Advance yield here to pedestrian sign and yield line; Rectangular rapid flashing beacon	Pedestrian warning sign; Pedestrian refuge island	Advance yield here to pedestrian sign and yield line; Pedestrian refuge island	Pedestrian refuge island; Pedestrian hybrid beacon	Advance yield here to pedestrian sign and yield line; Rectangular rapid flashing beacon	Pedestrian refuge island; Pedestrian hybrid beacon	Rectangular rapid flashing beacon; NA	Advance yield here to pedestrian sign and yield line; Rectangular rapid flashing beacon	Pedestrian refuge island; Pedestrian hybrid beacon	Rectangular rapid flashing beacon; NA
		3 lanes, both directions total (including TWLTL)	Pedestrian warning sign; Pedestrian refuge island	Advance yield here to pedestrian sign and yield line; Pedestrian refuge island	Advance yield here to pedestrian sign and yield line; Rectangular rapid flashing beacon	Pedestrian warning sign; Pedestrian refuge island	Advance yield here to pedestrian sign and yield line; Pedestrian refuge island	Rectangular rapid flashing beacon; NA	Advance yield here to pedestrian sign and yield line; Rectangular rapid flashing beacon	Pedestrian refuge island; Pedestrian hybrid beacon	Rectangular rapid flashing beacon; NA	Advance yield here to pedestrian sign and yield line; Rectangular rapid flashing beacon	Pedestrian refuge island; Pedestrian hybrid beacon	Rectangular rapid flashing beacon; NA
		4+ lanes, both directions total	Advance yield here to pedestrian sign and yield line; Rectangular rapid flashing beacon	Advance yield here to pedestrian sign and yield line; Rectangular rapid flashing beacon	Advance yield here to pedestrian sign and yield line; Rectangular rapid flashing beacon	Advance yield here to pedestrian sign and yield line; Rectangular rapid flashing beacon	Advance yield here to pedestrian sign and yield line; Rectangular rapid flashing beacon	Rectangular rapid flashing beacon; NA	Advance yield here to pedestrian sign and yield line; Rectangular rapid flashing beacon	Pedestrian refuge island; Pedestrian hybrid beacon	Rectangular rapid flashing beacon; NA	Advance yield here to pedestrian sign and yield line; Rectangular rapid flashing beacon	Pedestrian refuge island; Pedestrian hybrid beacon	Rectangular rapid flashing beacon; NA
	Raised Median	1-2 lanes in one direction	Pedestrian warning sign; Rectangular rapid flashing beacon	Advance yield here to pedestrian sign and yield line; Rectangular rapid flashing beacon	Advance yield here to pedestrian sign and yield line; Pedestrian hybrid beacon	Pedestrian warning sign; Rectangular rapid flashing beacon	Advance yield here to pedestrian sign and yield line; Rectangular rapid flashing beacon	Rectangular rapid flashing beacon; NA	Pedestrian warning sign; Rectangular rapid flashing beacon	Advance yield here to pedestrian sign and yield line; Pedestrian hybrid beacon	Rectangular rapid flashing beacon; NA	Pedestrian warning sign; Rectangular rapid flashing beacon	Advance yield here to pedestrian sign and yield line; Pedestrian hybrid beacon	Rectangular rapid flashing beacon; NA
		3+ lanes in one direction	Pedestrian warning sign; Rectangular rapid flashing beacon	Advance yield here to pedestrian sign and yield line; Rectangular rapid flashing beacon	Rectangular rapid flashing beacon; NA	Pedestrian warning sign; Rectangular rapid flashing beacon	Advance yield here to pedestrian sign and yield line; Rectangular rapid flashing beacon	Rectangular rapid flashing beacon; NA	Advance yield here to pedestrian sign and yield line; Pedestrian hybrid beacon	Rectangular rapid flashing beacon; NA	Rectangular rapid flashing beacon; NA	Rectangular rapid flashing beacon; NA	Rectangular rapid flashing beacon; NA	Rectangular rapid flashing beacon; NA

6.2.4 Intersection: treatment selection process

This subsection explains the treatment selection procedure at intersections. Multiple MDOT and federal guidelines were reviewed to identify the treatments- *Urban Bikeway Design Guide* (National Association of City Transportation Officials 2012), *Urban Street Design Guide* (National Association of City Transportation Officials 2015), *PEDBIKESAFE* (Federal Highway Administration 2013f), *Unsignalized Intersection Improvement Guide* (Institute of Transportation Engineers 2015), *Developing and Using Tables Showing the Pedestrian Optimum and Bicyclist Optimum Feasible Intersection Designs* (Hummer 2021), *Guide for Pedestrian and Bicyclist Safety at Alternative and Other Intersections and Interchanges* (National Academies of Sciences, Engineering, and Medicine 2021), *Multimodal Development and Delivery Guidebook* (Michigan Department of Transportation 2019) etc. Intersection crossing treatments were identified for both pedestrians and bicyclists to develop the intersection crossing matrices. The following criteria/assumptions were used to determine specific treatments in various contexts at intersection locations:

- As the speed limit, AADT, and number of lanes increase, the treatments provide greater levels of safety for pedestrians/bicyclists.
- As the context shifts from rural to large urbanized areas, the treatments provide greater levels of safety for pedestrians/bicyclists.
- It is assumed if treatment is safe for pedestrians then it is safe for bicyclist as well.
- High-visibility crosswalks are suggested at all locations.
- In cases where a median is present, it generally precedes the intersection and includes all types (e.g., raised, guardrail, concrete barrier).
- For flashing yellow beacons, the yellow beacons are generally installed on the major road approaches while red flashing beacons are installed on the minor road approaches.
- When bicycle signals are provided, right-turn-on-red should generally be prohibited.

Table 28 shows the intersection crossing treatment matrix. Similar to other matrices, it also shows the treatments for 240 unique combinations of context, median type, number of lanes, speed limit, and AADT. The darker color in the matrix represents safer treatment for pedestrians and bicyclists. It should be noted that significant nuances are involved in the treatment selection process for intersections because of diversity at site locations. As such, treatments may include additional facilities, e.g., at one site traffic signal with a leading pedestrian interval is suggested, and on another site traffic signal with a leading pedestrian interval and bike box is suggested. The following treatments are used in this matrix (arranged in increasing order of safety):

1. Yield sign
    a. Yield sign with advance pedestrian warning sign
2. Stop control
    a. Stop control with pedestrian warning sign
    b. Stop control with splitter island and pedestrian warning sign
    c. Stop control with reduction in curb radius and hardened centerline
    d. Stop control with pedestrian warning sign and median U-turn
3. Flashing yellow/red
    a. Flashing yellow with pedestrian warning sign
    b. Flashing yellow with advance pedestrian warning sign
    c. Flashing yellow with advance pedestrian warning sign and median U-turn
    d. Flashing red with pedestrian warning sign
4. Roundabout
5. Traffic signal with pedestrian push button
6. Traffic signal with pedestrian countdown signal
    a. Traffic signal with pedestrian countdown signal and bike box
    b. Traffic signal with pedestrian countdown signal and two-stage turn queue boxes
7. Traffic signal with leading pedestrian interval
    a. Traffic signal with leading pedestrian interval and bike box
    b. Traffic signal with leading pedestrian interval and two-stage turn queue boxes
    c. Traffic signal with leading pedestrian interval and bike signal
    d. Traffic signal with leading pedestrian interval and bike signal with two-stage turn queue boxes
8. Traffic signal with exclusive pedestrian phasing
    a. Traffic signal with exclusive pedestrian phasing and bike box
    b. Traffic signal with exclusive pedestrian phasing and two-stage turn queue boxes
    c. Traffic signal with exclusive pedestrian phasing and bike signal with two-stage turn queue boxes

It can be noted above that there are eight main treatments in this matrix. Along with these main treatments, as per site conditions, several additional treatments are also provided, and the definitions of these additional treatments are listed below:

<u>Additional Treatments:</u>

Bike box: Bike box is a green-colored designated area at the front portion of a traffic lane at a signalized intersection. The bicyclists can move to this area during the red phase of the traffic signal and can get ahead of all motorized vehicles providing safety and visibility to bicyclists (National Association of City Transportation Officials 2012).

Bike signal: Bike or bicycle signal can be used to guide bicyclists at traffic signal. This can be used in combination with traffic signals (National Association of City Transportation Officials 2012).

Two stage turn queue boxes: Two-stage turn queue boxes allow bicyclists to make a secure left turn from a right-sided cycle track at multi-lane intersections or make a right turn from the left sided cycle track. The main function of these boxes is to facilitate the left-turn bicyclist movement (National Association of City Transportation Officials 2012).

Pedestrian warning sign: Pedestrian warning signs are designed to warn motorists about the possibility of pedestrians on road (ELTEC 2022).

Splitter island: These are channelizing islands employed at intersections to separate the opposing traffic. It is used for multiple purposes: to improve awareness at intersections, enhance the visibility of stop sign, and create a barrier between entering and exiting vehicles (Unsignalized Intersection Improvment Guide n.d.).

Advance pedestrian warning sign: These are similar to pedestrian warning sign. The only difference is that these are used in places where motorists do not expect pedestrians to cross the road (Federal Highway Administration 2013g). This makes advance pedestrian warning sign a suitable treatment in rural areas.

Median U-turn: Median U-turns or MUTs prohibit the left-turn movement of a vehicle on a major street, forcing drivers to take a right turn, followed by a U-turn downstream, generally through a directional crossover (Reid et al. 2014).

Reduction in curb radius and hardened centerline: In this treatment, a wide curb radius is converted to a tighter radius through reconstruction. This makes it challenging for motorists to maneuver at high speed and reduce the crossing distance for pedestrians and bicyclists (Federal Highway Administration 2013a).

The following paragraphs give a brief definition of the eight main treatments of the intersection matrix and also provides the contextual and roadway characteristics where these treatments are generally used.

Description of Treatments:

Yield sign: Yield signs are regulatory signs and look like a downward pointing triangle. These are intended to slow down the motorists at intersections and yield to pedestrians and oncoming traffic (Driving-Tests.org 2022b).

Yield signs are the lowest order treatment in the intersection matrix. These are used only in rural context with AADT <5,000 and speed limit <=30 mph.

Yield sign with advance pedestrian warning sign: Yield signs are used with advance pedestrian warning signs to warn drivers ahead of the crossing. Under rural context with AADT <5,000 and speed limit <=30 mph, if the number of lanes is high (i.e., undivided 4+ lanes in total or median with 3+ lanes in one direction), it is considered as a potential treatment.

Stop control: Stop control sign is also a regulatory sign and looks like an octagon. These signs alert drivers to slow down and stop before entering the intersection. The motorists must yield the right-of-way to pedestrians and oncoming traffic (Driving-Tests.org 2022a).

Stop control signs are generally identified as a potential treatment in all contexts with lower AADT and speed. Further, additional treatments such as pedestrian warning sign, median U-turn, reduction in curb radius with hardened centerline, and splitter island are used in combination with stop control in the intersection treatment matrix with various site-specific conditions. Lastly, it can be observed that as the context shifts to more urbanized areas, stop control also shifts to lower AADT and speed ranges.

Stop control with pedestrian warning sign: In this treatment, pedestrian warning sign is used along with stop control to alert drivers regarding the possibility of pedestrians. In general, these are identified as potential treatments in small urban, small urbanized, and large urbanized areas with AADT <5000 and speed <=30 mph areas and a lesser number of lanes (<4 lanes total on undivided and <=2 lanes on median divided).

Stop control with splitter island and pedestrian warning sign: In this treatment, splitter island and pedestrian warning sign are used along with stop control. It requires construction of splitter island on roads. Similar to the above treatment, it is generally identified as potential treatment in small urban, small urbanized, and large urbanized areas on roadways with AADT <5000 and speed <=30 mph, and high number of lanes (4+ lanes total on undivided and 3+ lanes on median divided).

Stop control with reduction in curb radius and hardened centerline: In this treatment, reduction in curb radius is used along with stop control sign. This treatment requires reconstruction and redesign of the curb radius. Reduction in curb radius reduces the distance between the crossing points and reduces drivers' speed; and hardened centerline tightens the turning radius for left turns; that's why this combination is identified as a potential treatment in large urbanized area with AADT <5,000 and speed <=30 mph.

Stop control with pedestrian warning sign and median U-turn: In this treatment, pedestrian warning sign and median U-turn are used along with stop control sign. This treatment requires construction of median U-turn and is mostly used on roadways with high number of lanes (4+ lanes total on undivided and 3+ lanes on median divided). This combination of treatments is identified as potential treatment in small urban areas with AADT 5,000-10,000 and speed <=30 mph.

Flashing yellow: A flashing yellow signal means that motorists are required to slow down and navigate through the intersection with caution (Wisconsin Department of Transportation 2011).

In the intersection treatment matrix, flashing yellow along with additional treatments are generally used in rural and small urban areas for AADT <10,000 and speed >=35 mph; and AADT >=10,000 and speed <45 mph. Flashing yellow signal is used with pedestrian warning sign, advance pedestrian warning sign, and median U-turn in the intersection treatment matrix. Lastly, it can be noted in the intersection treatment matrix, as the contexts become more urbanized, the flashing yellow is likely to be used in lower AADT and speed ranges.

Flashing yellow with pedestrian warning sign: In this treatment, pedestrian warning signs are used along with flashing yellow signal. In general, this combination of treatments is identified as a potential treatment in- small urban areas with AADT <10,000, speed >= 35 mph, and various median-lane configurations; and small urbanized areas with AADT <10,000, speed <35 mph, and lesser number of lanes (<4 lanes total on undivided and <=2 lanes on median divided).

Flashing yellow with advance pedestrian warning sign: In this treatment, advance pedestrian warning signs are used along with flashing yellow signal. These are mainly considered in areas where motorists do not expect pedestrians. In general, this is considered a potential treatment in rural and small urban areas. In rural areas, with AADT <10,000 it is considered on roadways with speed >=35 mph; and in the same context with AADT >=10,000 it is considered on roadways with speed <=40 mph. In small urban areas, this treatment is mainly considered for AADT >= 10,000, speed <=30 mph, and a lesser number of lanes (<4 lanes total on undivided and <=2 lanes on median divided).

Flashing yellow with pedestrian warning sign and median U-turn: In this treatment, both pedestrian warning sign and median U-turn are used along with flashing yellow signal. As median U-turn is also a part of this treatment, it can significantly reduce the conflict points of pedestrians and enhance safety. In general, these are identified as potential treatments in rural and small urban areas with AADT >= 10,000, speed <= 30 mph, and higher number of lanes (4+ lanes total on undivided and 3+ lanes on median divided).

Flashing red: A flashing red signal means that the motorists must come to a complete stop before navigating through the intersection (Wisconsin Department of Transportation 2011). Flashing red is considered in only large urbanized areas where pedestrian and bicyclist traffic is high, and it is used only with pedestrian warning sign in the treatment matrix.

Flashing red with pedestrian warning sign: In this treatment, pedestrian warning sign is used along with flashing red signal. Flashing red requires the drivers to come to a complete stop; that's why this is identified as a potential treatment in large urbanized areas only. In the intersection treatment matrix, it is considered for large urbanized areas with AADT <5,000 and speed of 35-40 mph; and large urbanized areas with AADT of 5,000-10,000, speed <=30 mph and lesser number of lanes (<4 lanes total on undivided and <=2 lanes on median divided).

Roundabout: Roundabouts are circular intersection that forces the vehicles to move anti-clockwise around the central island. It is required for the entering vehicles to yield to circulating traffic, pedestrians, and bicyclists (Federal Highway Administration 2013e).

In the intersection treatment matrix, roundabouts are mainly used in small urban and small urbanized areas and sparingly used in rural areas. This treatment is used on roadways with AADT <20,000. Further, it can be observed that as the context becomes more urbanized, the roundabouts are used in lower AADT ranges and speed.

For example, in rural areas, with AADT 5,000-10,000, speed >=45 mph, this treatment is considered as potential treatment on roadways with higher number of lanes (4+ lanes total on undivided and 3+ lanes on median divided). For the rural and small urban areas with AADT 10,000-20,000 and speed of 35-40 mph, it is suggested on roadways with a lesser number of lanes (<4 lanes total on undivided and <=2 lanes on median divided). For small urban areas, it is predominantly used on roadways with AADT 5,000-10,000 and speed >=45 mph. But in small urbanized areas, it is mostly used on roadways with AADT 5,000-10,000 and speed of 35-40 mph.

Traffic signal with pedestrian push button: This treatment consists of a pedestrian push button that activates the pedestrian signal when pressed. It ensures safer crossing by giving a proper crossing indication to pedestrians (Federal Highway Administration 2013d).

Pedestrian push button is mainly considered in rural and small urban areas with higher AADT and speed ranges. In general, as the context becomes more urbanized, this treatment is used in relatively lower speed ranges.

In rural and small urban areas, it is mainly considered on roadways with AADT >=10,000 and speed >=45 mph. In small urban areas, it is also considered on roadways with AADT >=20,000 and speed of 35-40 mph. It provides a higher degree of safety to pedestrians and bicyclists by sending stop signal to motorists so that pedestrians and bicyclists can cross the road safely.

Traffic signal with pedestrian countdown signal: This treatment consists of a pedestrian countdown signal that consists of a separate pedestrian signal head that shows the amount of time left to cross the street. The main benefit of using this treatment is that pedestrians can see the time left to cross the street and can take the decision to cross or not (Chicago Metropolitan Agency for Planning n.d.).

This treatment is mostly considered as a potential treatment in small urbanized and large urbanized areas. In general, within the same context, as the AADT range increases, this treatment shifts to a smaller speed range for the same median-lane configuration. For example, pedestrian countdown signal is considered a potential treatment in small urbanized area with AADT 5,000-10,000 and speed >=45 mph for all median-lane configurations. As the AADT range moved to 10,000-2000, in the same context and median-lane configuration, this treatment is provided in speed range of 35-40 mph. Similarly, when AADT range moved to >=20,000, in same context and median-lane configuration, this treatment shifted to speed range <=30 mph. Likewise, this same trend can be seen in large urbanized areas with AADT range <5,000 and 10,000-20,000 for speed ranges >=45 mph and 35-40 mph.

Pedestrian countdown signals are also combined with bike box and two-stage turn queue box. These combination of treatments are used in small urbanized areas for AADT >=20,000 and speed 35-40 (Note: any type of bike facility is not suggested on roads with speed >=45 mph, as bicyclist volume are extremely low on these high-speed roads).

Traffic signal with pedestrian countdown signal and bike box: It is identified as potential treatment in: small urbanized areas, AADT >=20,000, speed 35-40, on undivided 2 lane and median divided 1-2 lane roadways.

Traffic signal with pedestrian countdown signal and two-stage turn queue boxes: It is identified as potential treatment in: small urbanized areas, AADT >20,000, speed 35-40, on undivided 3 lane roadways. This combination of treatments is considered for only 1 out of 240 cells.

Traffic signal with leading pedestrian interval: Leading pedestrian interval (LPI) gives the pedestrians a walk signal 3 to 7 seconds before it gives green to motorists. This helps establish pedestrians in the middle of crosswalk, thus improving the visibility and reducing the chances of crashes (Federal Highway Administration 2013b).

These are mainly considered in areas where high pedestrian activity is expected, or they need higher safety while crossing. LPIs are identified as potential treatments in small urbanized and large urbanized areas. In general, as the context shifts from small urbanized to large urbanized areas, either the AADT range or speed range decreases for this treatment. For example, in small urbanized areas these are considered on roadways with AADT >=10,000 and speed >=45 mph. As the context shifts to large urbanized areas it is considered on roadways with AADT range 5,000-10,000, and speed >=45 mph.

Traffic signals with LPIs are also considered in combination with various other treatments such as bike box, two-stage turn queue boxes, and bike signal. These are described below:

Traffic signal with leading pedestrian interval and two-stage turn queue boxes: This combination of treatments is considered in small urbanized areas with AADT>20,000, speed 35-40 mph, and roadways with higher number of lanes (4+ lanes total on undivided and 3+ lanes on median divided roadways).

Traffic signal with leading pedestrian interval and bike box: It is a potential treatment in large urbanized area with AADT 10,000-20,000, speed 35-40 mph, and undivided 2 lanes total.

Traffic signal with leading pedestrian interval and bike signal: It is a potential treatment in large urbanized area with AADT 10,000-20,000, speed 35-40 mph, for undivided 3 lane and median divided <=2 lane roads.

Traffic signal with leading pedestrian interval and bike signal with two-stage turn queue boxes: It is a potential treatment in large urbanized area with AADT 10,000-20,000, speed 35-40 mph, and higher number of lanes (4+ lanes total on undivided and 3+ lanes on median divided roadways).

Traffic signal with exclusive pedestrian phasing: This treatment refers to a pedestrian phase where all the conflicting vehicular movements are stopped, and only pedestrians are allowed to move. In this phase, pedestrians can even diagonally cross the intersection (Federal Highway Administration 2013c).

Exclusive pedestrian phasing is considered only in large urbanized where high pedestrian and bicyclist activity is expected. In general, it is a potential treatment in large urbanized area with AADT >=10,000, speed >=45 mph, across all median-lane configurations.

Exclusive pedestrian phasing are considered in combination with bike box, two-stage turn queue box, and bike signal. In general, as the number of lanes or speed increases, two-stage turn queue boxes are considered over bike box. Lastly, bike signals are considered only in speed range 35-40 mph. At lower speeds may not require any bicycle regulation, and at higher speeds, bicycle traffic might be absent.

Traffic signal with exclusive pedestrian phasing and bike box: It is a potential treatment in large urbanized area, with AADT >=20,000, speed <=30 mph, and undivided 2 lane roadway.

Traffic signal with exclusive pedestrian phasing and two-stage turn queue boxes: It is a potential treatment in large urbanized area, with AADT >=20,000, speed <=30 mph, and median-lane configuration higher than undivided 2 lane roadway (i.e. undivided 3+ lanes and divided 1+ lane).

Traffic signal with exclusive pedestrian phasing and bike signal with two-stage turn queue boxes: It is similar to the above-mentioned treatment but with an additional bike signal, because this is used in speed range 35-40 mph. It is a potential treatment in large urbanized area, with AADT >=20,000, speed 35-40 mph, and median-lane configuration higher than undivided 2 lane roadway (i.e., undivided 3+ lanes and divided 1+ lane).

As noted previously, due to nuances in site type, various additional treatments were used along with the main treatments. As such, some combinations of treatments were used less frequently. For example, “Traffic signal with exclusive pedestrian phasing and bike box” was used only once out of 240 cells. However, in the given contextual and roadway configuration it fits well. Likewise, other treatments also occurred less frequently in the treatment matrix (traffic signal with leading pedestrian interval and bike box = 1, traffic signal with pedestrian countdown signal and two-stage turn queue box = 1, yield sign =3, and a few others) but are apt as per site conditions.

Table 28. Intersection Treatments

Context	Median type (preceding to intersection)	Lanes to be crossed	AADT (below 5,000)			AADT (5,000-10,000)			AADT (10,000-20,000)			AADT (above 20,000)		
			<=30mph	35-40 mph	>=45 mph	<=30mph	35-40 mph	>=45 mph	<=30mph	35-40 mph	>=45 mph	<=30mph	35-40 mph	>=45 mph
Rural (Pop < 5K)	Undivided	2 lanes, both directions total	Yield sign	Stop control	Flashing yellow with advance pedestrian warning sign	Stop control	Flashing yellow with advance pedestrian warning sign	Flashing yellow with advance pedestrian warning sign	Flashing yellow with advance pedestrian warning sign	Roundabout	Traffic signal with pedestrian push button	Flashing yellow with advance pedestrian warning sign	Flashing yellow with advance pedestrian warning sign	Traffic signal with pedestrian push button
		3 lanes, both directions total (including TWLTL)	Yield sign	Stop control	Flashing yellow with advance pedestrian warning sign	Stop control	Flashing yellow with advance pedestrian warning sign	Flashing yellow with advance pedestrian warning sign	Flashing yellow with advance pedestrian warning sign	Roundabout	Traffic signal with pedestrian push button	Flashing yellow with advance pedestrian warning sign	Flashing yellow with advance pedestrian warning sign	Traffic signal with pedestrian push button
		4+ lanes, both directions total	Yield sign with advance pedestrian warning sign	Flashing yellow with advance pedestrian warning sign	Flashing yellow with advance pedestrian warning sign	Flashing yellow with advance pedestrian warning sign	Flashing yellow with advance pedestrian warning sign	Roundabout	Flashing yellow with advance pedestrian warning sign and median u-turn	Flashing yellow with advance pedestrian warning sign and median u-turn	Traffic signal with pedestrian push button	Flashing yellow with advance pedestrian warning sign and median u-turn	Traffic signal with pedestrian push button	Traffic signal with pedestrian push button
	Median	1-2 lanes in one direction	Yield sign	Stop control	Flashing yellow with advance pedestrian warning sign	Stop control	Flashing yellow with advance pedestrian warning sign	Flashing yellow with advance pedestrian warning sign	Flashing yellow with advance pedestrian warning sign	Roundabout	Traffic signal with pedestrian push button	Flashing yellow with advance pedestrian warning sign	Flashing yellow with advance pedestrian warning sign	Traffic signal with pedestrian push button
		3+ lanes in one direction	Yield sign with advance pedestrian warning sign	Flashing yellow with advance pedestrian warning sign	Flashing yellow with advance pedestrian warning sign	Flashing yellow with advance pedestrian warning sign	Flashing yellow with advance pedestrian warning sign	Roundabout	Flashing yellow with advance pedestrian warning sign and median u-turn	Flashing yellow with advance pedestrian warning sign and median u-turn	Traffic signal with pedestrian push button	Flashing yellow with advance pedestrian warning sign and median u-turn	Traffic signal with pedestrian push button	Traffic signal with pedestrian push button
Small urban areas (Pop 5K to 50K)	Undivided	2 lanes, both directions total	Stop control	Stop control with pedestrian warning sign	Flashing yellow with pedestrian warning sign	Stop control with pedestrian warning sign	Flashing yellow with pedestrian warning sign	Roundabout	Flashing yellow with advance pedestrian warning sign	Roundabout	Traffic signal with pedestrian push button	Flashing yellow with advance pedestrian warning sign	Traffic signal with pedestrian push button	Traffic signal with pedestrian push button
		3 lanes, both directions total (including TWLTL)	Stop control	Stop control with pedestrian warning sign	Flashing yellow with pedestrian warning sign	Stop control with pedestrian warning sign	Flashing yellow with pedestrian warning sign	Roundabout	Flashing yellow with advance pedestrian warning sign	Roundabout	Traffic signal with pedestrian push button	Flashing yellow with advance pedestrian warning sign	Traffic signal with pedestrian push button	Traffic signal with pedestrian push button
		4+ lanes, both directions total	Stop control with splitter island and pedestrian warning sign	Flashing yellow with pedestrian warning sign	Roundabout	Stop control with pedestrian warning sign and median u-turn	Roundabout	Roundabout	Flashing yellow with advance pedestrian warning sign and median u-turn	Traffic signal with pedestrian push button	Traffic signal with pedestrian push button	Flashing yellow with advance pedestrian warning sign and median u-turn	Traffic signal with pedestrian push button	Traffic signal with pedestrian push button
	Median	1-2 lanes in one direction	Stop control	Stop control with pedestrian warning sign	Flashing yellow with pedestrian warning sign	Stop control with pedestrian warning sign	Flashing yellow with pedestrian warning sign	Roundabout	Flashing yellow with advance pedestrian warning sign	Roundabout	Traffic signal with pedestrian push button	Flashing yellow with advance pedestrian warning sign	Traffic signal with pedestrian push button	Traffic signal with pedestrian push button
		3+ lanes in one direction	Stop control with splitter island and pedestrian warning sign	Flashing yellow with pedestrian warning sign	Roundabout	Stop control with pedestrian warning sign and median u-turn	Roundabout	Roundabout	Flashing yellow with advance pedestrian warning sign and median u-turn	Traffic signal with pedestrian push button	Traffic signal with pedestrian push button	Flashing yellow with advance pedestrian warning sign and median u-turn	Traffic signal with pedestrian push button	Traffic signal with pedestrian push button
Small urbanized areas (Pop 50K to 200K)	Undivided	2 lanes, both directions total	Stop control with pedestrian warning sign	Flashing yellow with pedestrian warning sign	Roundabout	Flashing yellow with pedestrian warning sign	Roundabout	Traffic signal with pedestrian countdown signal	Flashing yellow with pedestrian warning sign	Traffic signal with pedestrian countdown signal	Traffic signal with leading pedestrian interval	Traffic signal with pedestrian countdown signal	Traffic signal with pedestrian countdown signal and bike box	Traffic signal with leading pedestrian interval
		3 lanes, both directions total (including TWLTL)	Stop control with pedestrian warning sign	Flashing yellow with pedestrian warning sign	Roundabout	Flashing yellow with pedestrian warning sign	Roundabout	Traffic signal with pedestrian countdown signal	Flashing yellow with pedestrian warning sign	Traffic signal with pedestrian countdown signal	Traffic signal with leading pedestrian interval	Traffic signal with pedestrian countdown signal	Traffic signal with pedestrian countdown signal and two-stage turn queue boxes	Traffic signal with leading pedestrian interval
		4+ lanes, both directions total	Stop control with splitter island and pedestrian warning sign	Roundabout	Traffic signal with pedestrian countdown signal	Roundabout	Roundabout	Traffic signal with pedestrian countdown signal	Roundabout	Traffic signal with pedestrian countdown signal	Traffic signal with leading pedestrian interval	Traffic signal with pedestrian countdown signal	Traffic signal with leading pedestrian interval and two-stage turn queue boxes	Traffic signal with leading pedestrian interval
	Median	1-2 lanes in one direction	Stop control with pedestrian warning sign	Flashing yellow with pedestrian warning sign	Roundabout	Flashing yellow with pedestrian warning sign	Roundabout	Traffic signal with pedestrian countdown signal	Flashing yellow with pedestrian warning sign	Traffic signal with pedestrian countdown signal	Traffic signal with leading pedestrian interval	Traffic signal with pedestrian countdown signal	Traffic signal with pedestrian countdown signal and bike box	Traffic signal with leading pedestrian interval
		3+ lanes in one direction	Stop control with splitter island and pedestrian warning sign	Roundabout	Traffic signal with pedestrian countdown signal	Roundabout	Roundabout	Traffic signal with pedestrian countdown signal	Roundabout	Traffic signal with pedestrian countdown signal	Traffic signal with leading pedestrian interval	Traffic signal with pedestrian countdown signal	Traffic signal with leading pedestrian interval and two-stage turn queue boxes	Traffic signal with leading pedestrian interval
Large urbanized areas (> 200K)	Undivided	2 lanes, both directions total	Stop control with pedestrian warning sign	Flashing red with pedestrian warning sign	Traffic signal with pedestrian countdown signal	Flashing red with pedestrian warning sign	Traffic signal with pedestrian countdown signal	Traffic signal with leading pedestrian interval	Traffic signal with leading pedestrian interval	Traffic signal with leading pedestrian interval and bike box	Traffic signal with exclusive pedestrian phasing	Traffic signal with exclusive pedestrian phasing and bike box	Traffic signal with exclusive pedestrian phasing and two-stage turn queue boxes	Traffic signal with exclusive pedestrian phasing
		3 lanes, both directions total (including TWLTL)	Stop control with pedestrian warning sign	Flashing red with pedestrian warning sign	Traffic signal with pedestrian countdown signal	Flashing red with pedestrian warning sign	Traffic signal with pedestrian countdown signal	Traffic signal with leading pedestrian interval	Traffic signal with leading pedestrian interval	Traffic signal with leading pedestrian interval and bike signal	Traffic signal with exclusive pedestrian phasing	Traffic signal with exclusive pedestrian phasing and two-stage turn queue boxes	Traffic signal with exclusive pedestrian phasing and bike signal with two-stage turn queue boxes	Traffic signal with exclusive pedestrian phasing
		4+ lanes, both directions total	Stop control with reduction in curb radius and hardened centerline	Flashing red with pedestrian warning sign	Traffic signal with pedestrian countdown signal	Traffic signal with pedestrian countdown signal	Traffic signal with pedestrian countdown signal	Traffic signal with leading pedestrian interval	Traffic signal with exclusive pedestrian phasing	Traffic signal with leading pedestrian interval and bike signal with two-stage turn queue boxes	Traffic signal with exclusive pedestrian phasing	Traffic signal with exclusive pedestrian phasing and two-stage turn queue boxes	Traffic signal with exclusive pedestrian phasing and bike signal with two-stage turn queue boxes	Traffic signal with exclusive pedestrian phasing
	Median	1-2 lanes in one direction	Stop control with pedestrian warning sign	Flashing red with pedestrian warning sign	Traffic signal with pedestrian countdown signal	Flashing red with pedestrian warning sign	Traffic signal with pedestrian countdown signal	Traffic signal with leading pedestrian interval	Traffic signal with leading pedestrian interval	Traffic signal with leading pedestrian interval and bike signal	Traffic signal with exclusive pedestrian phasing	Traffic signal with exclusive pedestrian phasing and two-stage turn queue boxes	Traffic signal with exclusive pedestrian phasing and bike signal with two-stage turn queue boxes	Traffic signal with exclusive pedestrian phasing
		3+ lanes in one direction	Stop control with reduction in curb radius and hardened centerline	Flashing red with pedestrian warning sign	Traffic signal with pedestrian countdown signal	Traffic signal with pedestrian countdown signal	Traffic signal with pedestrian countdown signal	Traffic signal with leading pedestrian interval	Traffic signal with exclusive pedestrian phasing	Traffic signal with leading pedestrian interval and bike signal with two-stage turn queue boxes	Traffic signal with exclusive pedestrian phasing	Traffic signal with exclusive pedestrian phasing and two-stage turn queue boxes	Traffic signal with exclusive pedestrian phasing and bike signal with two-stage turn queue boxes	Traffic signal with exclusive pedestrian phasing

Table 29 shows the alternative treatments selected at intersection locations for pedestrians and bicyclists for different combinations of context, AADT, speed limit, and median-lane configuration.

Table 29. Alternative Treatment Selection at Intersection

Potential Intersection Treatment	Alternative treatment 1 (lower order)	Alternative treatment 2 (higher order)
Yield sign	NA	Yield sign with advance pedestrian warning sign
Yield sign with advance pedestrian warning sign	Yield sign	Stop control
Stop control	Yield sign with advance pedestrian warning sign	Stop control with pedestrian warning sign
Stop control with pedestrian warning sign	Stop control	Flashing yellow with pedestrian warning sign
Stop control with pedestrian warning sign and median U-turn	Stop control with pedestrian warning sign	Roundabout
Stop control with reduction in curb radius and hardened centerline	Stop control with pedestrian warning sign	Flashing red with pedestrian warning sign
Stop control with splitter island and pedestrian Warning Sign		
Condition 1: small urban areas, all speed/AADT/lane	Stop control with pedestrian warning sign	Stop control with pedestrian warning sign AND median U-turn
Condition 2: small urbanized areas, all speed/AADT/lane	Stop control with pedestrian warning sign	Roundabout
Flashing yellow with pedestrian warning sign	Stop control with pedestrian warning sign	Roundabout
Flashing yellow with advance pedestrian warning sign	Stop control with pedestrian warning sign	Traffic signal with pedestrian push button
Flashing yellow with advance pedestrian warning sign AND median U-turn	Flashing yellow with advance pedestrian warning sign	Traffic signal with pedestrian push button
Flashing red with pedestrian warning sign	Stop control with pedestrian warning sign	Traffic signal with pedestrian push button
Roundabout	Flashing yellow with advance pedestrian warning sign AND median U-turn	Traffic signal with pedestrian push button
Traffic signal with pedestrian push button		
Condition 1: AADT <20K, all contexts/speed/AADT/lane	Roundabout	Traffic signal with leading pedestrian interval
Condition 2: AADT >=20K, all contexts/speed/AADT/lane	Flashing yellow with advance pedestrian warning sign	Traffic signal with leading pedestrian interval
Traffic signal with pedestrian countdown signal		
Condition 1: small urbanized area; AADT <20K, all speeds/lanes	Roundabout	Traffic signal with leading pedestrian interval
Condition 2: small urbanized; AADT >=20K, all speeds/lanes	Traffic signal with pedestrian push button	Traffic signal with leading pedestrian interval
Condition 3: large urbanized areas, all contexts/speed/AADT	Flashing red with pedestrian warning sign	Traffic signal with leading pedestrian interval
Traffic signal with pedestrian countdown signal and bike box	Traffic signal with pedestrian countdown signal	Traffic signal with leading pedestrian interval AND bike box
Traffic signal with pedestrian countdown signal and two-stage turn queue boxes	Traffic signal with pedestrian countdown signal	Traffic signal with leading pedestrian interval AND two-stage turn queue boxes
Traffic signal with leading pedestrian interval	Traffic signal with pedestrian countdown signal	Traffic signal with exclusive pedestrian phasing
Traffic signal with leading pedestrian interval and bike box	Traffic signal with leading pedestrian interval	Traffic signal with exclusive pedestrian phasing AND bike box
Traffic signal with leading pedestrian interval and two-stage turn queue boxes	Traffic signal with leading pedestrian interval	Traffic signal with exclusive pedestrian phasing AND two-stage turn queue boxes
Traffic signal with leading pedestrian interval and bike signal	Traffic signal with leading pedestrian interval	Traffic signal with exclusive pedestrian phasing AND bike signal
Traffic signal with leading pedestrian interval and bike signal with two-stage turn queue boxes	Traffic signal with leading pedestrian interval	Traffic signal with exclusive pedestrian phasing AND bike signal with two-stage turn queue boxes
Traffic signal with exclusive pedestrian phasing	Traffic signal with leading pedestrian interval	NA
Traffic signal with exclusive pedestrian phasing and bike box	Traffic signal with leading pedestrian interval AND bike box	NA
Traffic signal with exclusive pedestrian phasing and two-stage turn queue boxes	Traffic signal with leading pedestrian interval AND two-stage turn queue boxes	NA
Traffic signal with exclusive pedestrian phasing and bike signal with two-stage turn queue boxes	Traffic signal with leading pedestrian interval AND bike signal with two-stage turn queue boxes	NA

It can be seen in Table 29 that there are some nuances in the intersection matrix because of additional treatments. Similar to other matrices, these were also divided into lower and higher-order treatments. The minimum suggested treatment in the matrix is yield sign; it is mainly suggested in rural areas, and there is no lower-order treatment for yield sign. The maximum suggested treatment in the matrix is traffic signal with exclusive pedestrian phasing. These provide the highest order of safety to ped/bike at intersections; as such, there is no higher-order treatment for exclusive pedestrian phasing. All the other treatments in the matrix have both lower and higher order treatments. For example, roundabouts have flashing yellow as lower-order treatment, but traffic signal with pedestrian push button are considered a higher-order treatment. Similarly, traffic signal with pedestrian countdown signal has the following as lower order treatments under different contextual and roadway conditions: roundabout, pedestrian push button, and flashing red. But as higher-order, it only has traffic signal with leading pedestrian interval as it provides higher degree of safety. Traffic signal with leading pedestrian interval has been used with various other additional treatments such as bike box, bike signal, and two-stage turn queue box. The lower order treatment for any such combination was kept as leading pedestrian interval only. The higher-order treatment for any combination of leading pedestrian interval with bike box, bike signal, and two-stage turn queue box is- exclusive pedestrian phasing along with that additional treatment (bike box, bike signal, and two-stage turn queue box).

Table 30 shows the intersection alternative treatments for pedestrians and bicyclists. Similar to other alternative treatment matrices, the first treatment indicates the lower-order treatment, and the second treatment after the semicolon (;) indicates the higher-order treatment. If lower or higher-order treatment is not available it is shown as NA.

For the following conditions- small urban area, Median type: Undivided, Lane-configuration: two-lanes both directions total, AADT 10,000-20,000, and speed: >=45 mph, the potential treatment is traffic signal with pedestrian push button as identified in Table 28. For the same contextual and roadway conditions the lower order and higher order treatments are roundabout and traffic signal with leading pedestrian interval Table 30. It is clearly evident that as compared to pedestrian push button roundabout provide a lower level of safety as drivers do not get a visual cue from any traffic control device. On the other hand, as compared to pedestrian push button, leading pedestrian interval provides higher level of safety by providing a head start to ped/bike while crossing, which increases their visibility as well. Similarly, all the other treatments can be compared between Table 28 and Table 30.

Table 30. Intersection Alternative Treatments

Context	Median type (preceding to intersection)	Lanes to be crossed	AADT (below 5,000)			AADT (5,000-10,000)			AADT (10,000-20,000)			AADT (above 20,000)		
			<=30mph	35-40 mph	>=45 mph	<=30mph	35-40 mph	>=45 mph	<=30mph	35-40 mph	>=45 mph	<=30mph	35-40 mph	>=45 mph
Rural (Pop < 5K)	Undivided	2 lanes, both directions total	NA; Yield sign with advance pedestrian warning sign	Yield sign with advance pedestrian warning sign; Stop control with pedestrian warning sign	Stop control with pedestrian warning sign; Traffic signal with pedestrian push button	Yield sign with advance pedestrian warning sign; Stop control with pedestrian warning sign	Stop control with pedestrian warning sign; Traffic signal with pedestrian push button	Stop control with pedestrian warning sign; Traffic signal with pedestrian push button	Stop control with pedestrian warning sign; Traffic signal with pedestrian push button	Flashing yellow with advance pedestrian warning sign and median u-turn; Traffic signal with pedestrian push button	Roundabout; Traffic signal with leading pedestrian interval	Stop control with pedestrian warning sign; Traffic signal with pedestrian push button	Stop control with pedestrian warning sign; Traffic signal with pedestrian push button	Flashing yellow with advance pedestrian warning sign; Traffic signal with leading pedestrian interval
		3 lanes, both directions total (including TWLTL)	NA; Yield sign with advance pedestrian warning sign	Yield sign with advance pedestrian warning sign; Stop control with pedestrian warning sign	Stop control with pedestrian warning sign; Traffic signal with pedestrian push button	Yield sign with advance pedestrian warning sign; Stop control with pedestrian warning sign	Stop control with pedestrian warning sign; Traffic signal with pedestrian push button	Stop control with pedestrian warning sign; Traffic signal with pedestrian push button	Stop control with pedestrian warning sign; Traffic signal with pedestrian push button	Flashing yellow with advance pedestrian warning sign and median u-turn; Traffic signal with pedestrian push button	Roundabout; Traffic signal with leading pedestrian interval	Stop control with pedestrian warning sign; Traffic signal with pedestrian push button	Stop control with pedestrian warning sign; Traffic signal with pedestrian push button	Flashing yellow with advance pedestrian warning sign; Traffic signal with leading pedestrian interval
		4+ lanes, both directions total	Yield sign; Stop control	Stop control with pedestrian warning sign; Traffic signal with pedestrian push button	Stop control with pedestrian warning sign; Traffic signal with pedestrian push button	Stop control with pedestrian warning sign; Traffic signal with pedestrian push button	Stop control with pedestrian warning sign; Traffic signal with pedestrian push button	Flashing yellow with advance pedestrian warning sign and median u-turn; Traffic signal with pedestrian push button	Flashing yellow with advance pedestrian warning sign; Traffic signal with pedestrian push button	Flashing yellow with advance pedestrian warning sign; Traffic signal with pedestrian push button	Roundabout; Traffic signal with leading pedestrian interval	Flashing yellow with advance pedestrian warning sign; Traffic signal with pedestrian push button	Flashing yellow with advance pedestrian warning sign; Traffic signal with leading pedestrian interval	Flashing yellow with advance pedestrian warning sign; Traffic signal with leading pedestrian interval
	Median	1-2 lanes in one direction	NA; Yield sign with advance pedestrian warning sign	Yield sign with advance pedestrian warning sign; Stop control with pedestrian warning sign	Stop control with pedestrian warning sign; Traffic signal with pedestrian push button	Yield sign with advance pedestrian warning sign; Stop control with pedestrian warning sign	Stop control with pedestrian warning sign; Traffic signal with pedestrian push button	Stop control with pedestrian warning sign; Traffic signal with pedestrian push button	Stop control with pedestrian warning sign; Traffic signal with pedestrian push button	Flashing yellow with advance pedestrian warning sign and median u-turn; Traffic signal with pedestrian push button	Roundabout; Traffic signal with leading pedestrian interval	Stop control with pedestrian warning sign; Traffic signal with pedestrian push button	Stop control with pedestrian warning sign; Traffic signal with pedestrian push button	Flashing yellow with advance pedestrian warning sign; Traffic signal with leading pedestrian interval
		3+ lanes in one direction	Yield sign; Stop control	Stop control with pedestrian warning sign; Traffic signal with pedestrian push button	Stop control with pedestrian warning sign; Traffic signal with pedestrian push button	Stop control with pedestrian warning sign; Traffic signal with pedestrian push button	Stop control with pedestrian warning sign; Traffic signal with pedestrian push button	Flashing yellow with advance pedestrian warning sign and median u-turn; Traffic signal with pedestrian push button	Flashing yellow with advance pedestrian warning sign; Traffic signal with pedestrian push button	Flashing yellow with advance pedestrian warning sign; Traffic signal with pedestrian push button	Roundabout; Traffic signal with leading pedestrian interval	Flashing yellow with advance pedestrian warning sign; Traffic signal with pedestrian push button	Flashing yellow with advance pedestrian warning sign; Traffic signal with leading pedestrian interval	Flashing yellow with advance pedestrian warning sign; Traffic signal with leading pedestrian interval
Small urban areas (Pop 5K to 50K)	Undivided	2 lanes, both directions total	Yield sign with advance pedestrian warning sign; Stop control with pedestrian warning sign	Stop control; Flashing yellow with pedestrian warning sign	Stop control with pedestrian warning sign; Roundabout	Stop control; Flashing yellow with pedestrian warning sign	Stop control with pedestrian warning sign; Roundabout	Flashing yellow with advance pedestrian warning sign and median u-turn; Traffic signal with pedestrian push button	Stop control with pedestrian warning sign; Traffic signal with pedestrian push button	Flashing yellow with advance pedestrian warning sign and median u-turn; Traffic signal with pedestrian push button	Roundabout; Traffic signal with leading pedestrian interval	Stop control with pedestrian warning sign; Traffic signal with pedestrian push button	Flashing yellow with advance pedestrian warning sign; Traffic signal with leading pedestrian interval	Flashing yellow with advance pedestrian warning sign; Traffic signal with leading pedestrian interval
		3 lanes, both directions total (including TWLTL)	Yield sign with advance pedestrian warning sign; Stop control with pedestrian warning sign	Stop control; Flashing yellow with pedestrian warning sign	Stop control with pedestrian warning sign; Roundabout	Stop control; Flashing yellow with pedestrian warning sign	Stop control with pedestrian warning sign; Roundabout	Flashing yellow with advance pedestrian warning sign and median u-turn; Traffic signal with pedestrian push button	Stop control with pedestrian warning sign; Traffic signal with pedestrian push button	Flashing yellow with advance pedestrian warning sign and median u-turn; Traffic signal with pedestrian push button	Roundabout; Traffic signal with leading pedestrian interval	Stop control with pedestrian warning sign; Traffic signal with pedestrian push button	Flashing yellow with advance pedestrian warning sign; Traffic signal with leading pedestrian interval	Flashing yellow with advance pedestrian warning sign; Traffic signal with leading pedestrian interval
		4+ lanes, both directions total	Stop control with pedestrian warning sign; Stop control with pedestrian warning sign and median u-turn	Stop control with pedestrian warning sign; Roundabout	Flashing yellow with advance pedestrian warning sign and median u-turn; Traffic signal with pedestrian push button	Stop control with pedestrian warning sign; Roundabout	Flashing yellow with advance pedestrian warning sign and median u-turn; Traffic signal with pedestrian push button	Flashing yellow with advance pedestrian warning sign and median u-turn; Traffic signal with pedestrian push button	Flashing yellow with advance pedestrian warning sign; Traffic signal with pedestrian push button	Roundabout; Traffic signal with leading pedestrian interval	Roundabout; Traffic signal with leading pedestrian interval	Flashing yellow with advance pedestrian warning sign; Traffic signal with pedestrian push button	Flashing yellow with advance pedestrian warning sign; Traffic signal with leading pedestrian interval	Flashing yellow with advance pedestrian warning sign; Traffic signal with leading pedestrian interval
	Median	1-2 lanes in one direction	Yield sign with advance pedestrian warning sign; Stop control with pedestrian warning sign	Stop control; Flashing yellow with pedestrian warning sign	Stop control with pedestrian warning sign; Roundabout	Stop control; Flashing yellow with pedestrian warning sign	Stop control with pedestrian warning sign; Roundabout	Flashing yellow with advance pedestrian warning sign and median u-turn; Traffic signal with pedestrian push button	Stop control with pedestrian warning sign; Traffic signal with pedestrian push button	Flashing yellow with advance pedestrian warning sign and median u-turn; Traffic signal with pedestrian push button	Roundabout; Traffic signal with leading pedestrian interval	Stop control with pedestrian warning sign; Traffic signal with pedestrian push button	Flashing yellow with advance pedestrian warning sign; Traffic signal with leading pedestrian interval	Flashing yellow with advance pedestrian warning sign; Traffic signal with leading pedestrian interval
		3+ lanes in one direction	Stop control with pedestrian warning sign; Stop control with pedestrian warning sign and median u-turn	Stop control with pedestrian warning sign; Roundabout	Flashing yellow with advance pedestrian warning sign and median u-turn; Traffic signal with pedestrian push button	Stop control with pedestrian warning sign; Roundabout	Flashing yellow with advance pedestrian warning sign and median u-turn; Traffic signal with pedestrian push button	Flashing yellow with advance pedestrian warning sign and median u-turn; Traffic signal with pedestrian push button	Flashing yellow with advance pedestrian warning sign; Traffic signal with pedestrian push button	Roundabout; Traffic signal with leading pedestrian interval	Roundabout; Traffic signal with leading pedestrian interval	Flashing yellow with advance pedestrian warning sign; Traffic signal with pedestrian push button	Flashing yellow with advance pedestrian warning sign; Traffic signal with leading pedestrian interval	Flashing yellow with advance pedestrian warning sign; Traffic signal with leading pedestrian interval
Small urbanized areas (Pop 50K to 200K)	Undivided	2 lanes, both directions total	Stop control; Flashing yellow with pedestrian warning sign	Stop control with pedestrian warning sign; Roundabout	Flashing yellow with advance pedestrian warning sign and median u-turn; Traffic signal with pedestrian push button	Stop control with pedestrian warning sign; Roundabout	Flashing yellow with advance pedestrian warning sign and median u-turn; Traffic signal with pedestrian push button	Roundabout; Traffic signal with leading pedestrian interval	Stop control with pedestrian warning sign; Roundabout	Roundabout; Traffic signal with leading pedestrian interval	Traffic signal with pedestrian countdown signal; Traffic signal with exclusive pedestrian phasing	Traffic signal with pedestrian push button; Traffic signal with leading pedestrian interval	Traffic signal with pedestrian countdown signal; Traffic signal with leading pedestrian interval and bike box	Traffic signal with pedestrian countdown signal; Traffic signal with exclusive pedestrian phasing
		3 lanes, both directions total (including TWLTL)	Stop control; Flashing yellow with pedestrian warning sign	Stop control with pedestrian warning sign; Roundabout	Flashing yellow with advance pedestrian warning sign and median u-turn; Traffic signal with pedestrian push button	Stop control with pedestrian warning sign; Roundabout	Flashing yellow with advance pedestrian warning sign and median u-turn; Traffic signal with pedestrian push button	Roundabout; Traffic signal with leading pedestrian interval	Stop control with pedestrian warning sign; Roundabout	Roundabout; Traffic signal with leading pedestrian interval	Traffic signal with pedestrian countdown signal; Traffic signal with exclusive pedestrian phasing	Traffic signal with pedestrian push button; Traffic signal with leading pedestrian interval	Traffic signal with pedestrian countdown signal; Traffic signal with leading pedestrian interval and two-stage turn queue boxes	Traffic signal with pedestrian countdown signal; Traffic signal with exclusive pedestrian phasing
		4+ lanes, both directions total	Stop control with pedestrian warning sign; Roundabout	Flashing yellow with advance pedestrian warning sign and median u-turn; Traffic signal with pedestrian push button	Roundabout; Traffic signal with leading pedestrian interval	Flashing yellow with advance pedestrian warning sign and median u-turn; Traffic signal with pedestrian push button	Flashing yellow with advance pedestrian warning sign and median u-turn; Traffic signal with pedestrian push button	Roundabout; Traffic signal with leading pedestrian interval	Flashing yellow with advance pedestrian warning sign and median u-turn; Traffic signal with pedestrian push button	Roundabout; Traffic signal with leading pedestrian interval	Traffic signal with pedestrian countdown signal; Traffic signal with exclusive pedestrian phasing	Traffic signal with pedestrian push button; Traffic signal with leading pedestrian interval	Traffic signal with leading pedestrian interval; Traffic signal with exclusive pedestrian phasing and two-stage turn queue boxes	Traffic signal with pedestrian countdown signal; Traffic signal with exclusive pedestrian phasing
	Median	1-2 lanes in one direction	Stop control; Flashing yellow with pedestrian warning sign	Stop control with pedestrian warning sign; Roundabout	Flashing yellow with advance pedestrian warning sign and median u-turn; Traffic signal with pedestrian push button	Stop control with pedestrian warning sign; Roundabout	Flashing yellow with advance pedestrian warning sign and median u-turn; Traffic signal with pedestrian push button	Roundabout; Traffic signal with leading pedestrian interval	Stop control with pedestrian warning sign; Roundabout	Roundabout; Traffic signal with leading pedestrian interval	Traffic signal with pedestrian countdown signal; Traffic signal with exclusive pedestrian phasing	Traffic signal with pedestrian push button; Traffic signal with leading pedestrian interval	Traffic signal with pedestrian countdown signal; Traffic signal with leading pedestrian interval and bike box	Traffic signal with pedestrian countdown signal; Traffic signal with exclusive pedestrian phasing
		3+ lanes in one direction	Stop control with pedestrian warning sign; Roundabout	Flashing yellow with advance pedestrian warning sign and median u-turn; Traffic signal with pedestrian push button	Roundabout; Traffic signal with leading pedestrian interval	Flashing yellow with advance pedestrian warning sign and median u-turn; Traffic signal with pedestrian push button	Flashing yellow with advance pedestrian warning sign and median u-turn; Traffic signal with pedestrian push button	Roundabout; Traffic signal with leading pedestrian interval	Flashing yellow with advance pedestrian warning sign and median u-turn; Traffic signal with pedestrian push button	Roundabout; Traffic signal with leading pedestrian interval	Traffic signal with pedestrian countdown signal; Traffic signal with exclusive pedestrian phasing	Traffic signal with pedestrian push button; Traffic signal with leading pedestrian interval	Traffic signal with leading pedestrian interval; Traffic signal with exclusive pedestrian phasing and two-stage turn queue boxes	Traffic signal with pedestrian countdown signal; Traffic signal with exclusive pedestrian phasing
Large urbanized areas (> 200K)	Undivided	2 lanes, both directions total	Stop control; Flashing yellow with pedestrian warning sign	Stop control with pedestrian warning sign; Traffic signal with pedestrian push button	Flashing red with pedestrian warning sign; Traffic signal with leading pedestrian interval	Stop control with pedestrian warning sign; Traffic signal with pedestrian push button	Flashing red with pedestrian warning sign; Traffic signal with leading pedestrian interval	Traffic signal with pedestrian countdown signal; Traffic signal with exclusive pedestrian phasing	Traffic signal with pedestrian countdown signal; Traffic signal with exclusive pedestrian phasing	Traffic signal with leading pedestrian interval; Traffic signal with exclusive pedestrian phasing and bike box	Traffic signal with leading pedestrian interval; NA	Traffic signal with leading pedestrian interval and bike box; NA	Traffic signal with leading pedestrian interval and two-stage turn queue boxes; NA	Traffic signal with leading pedestrian interval; NA
		3 lanes, both directions total (including TWLTL)	Stop control; Flashing yellow with pedestrian warning sign	Stop control with pedestrian warning sign; Traffic signal with pedestrian push button	Flashing red with pedestrian warning sign; Traffic signal with leading pedestrian interval	Stop control with pedestrian warning sign; Traffic signal with pedestrian push button	Flashing red with pedestrian warning sign; Traffic signal with leading pedestrian interval	Traffic signal with pedestrian countdown signal; Traffic signal with exclusive pedestrian phasing	Traffic signal with pedestrian countdown signal; Traffic signal with exclusive pedestrian phasing	Traffic signal with leading pedestrian interval; Traffic signal with exclusive pedestrian phasing and bike signal	Traffic signal with leading pedestrian interval; NA	Traffic signal with leading pedestrian interval and two-stage turn queue boxes; NA	Traffic signal with leading pedestrian interval and bike signal with two-stage turn queue boxes; NA	Traffic signal with leading pedestrian interval; NA
		4+ lanes, both directions total	Stop control with pedestrian warning sign; Flashing red with pedestrian warning sign	Stop control with pedestrian warning sign; Traffic signal with pedestrian push button	Flashing red with pedestrian warning sign; Traffic signal with leading pedestrian interval	Flashing red with pedestrian warning sign; Traffic signal with leading pedestrian interval	Flashing red with pedestrian warning sign; Traffic signal with leading pedestrian interval	Traffic signal with pedestrian countdown signal; Traffic signal with exclusive pedestrian phasing	Traffic signal with leading pedestrian interval; NA	Traffic signal with leading pedestrian interval; Traffic signal with exclusive pedestrian phasing and bike signal with two-stage turn queue boxes	Traffic signal with leading pedestrian interval; NA	Traffic signal with leading pedestrian interval and two-stage turn queue boxes; NA	Traffic signal with leading pedestrian interval and bike signal with two-stage turn queue boxes; NA	Traffic signal with leading pedestrian interval; NA
	Median	1-2 lanes in one direction	Stop control; Flashing yellow with pedestrian warning sign	Stop control with pedestrian warning sign; Traffic signal with pedestrian push button	Flashing red with pedestrian warning sign; Traffic signal with leading pedestrian interval	Stop control with pedestrian warning sign; Traffic signal with pedestrian push button	Flashing red with pedestrian warning sign; Traffic signal with leading pedestrian interval	Traffic signal with pedestrian countdown signal; Traffic signal with exclusive pedestrian phasing	Traffic signal with pedestrian countdown signal; Traffic signal with exclusive pedestrian phasing	Traffic signal with leading pedestrian interval; Traffic signal with exclusive pedestrian phasing and bike signal	Traffic signal with leading pedestrian interval; NA	Traffic signal with leading pedestrian interval and two-stage turn queue boxes; NA	Traffic signal with leading pedestrian interval and bike signal with two-stage turn queue boxes; NA	Traffic signal with leading pedestrian interval; NA
		3+ lanes in one direction	Stop control with pedestrian warning sign; Flashing red with pedestrian warning sign	Stop control with pedestrian warning sign; Traffic signal with pedestrian push button	Flashing red with pedestrian warning sign; Traffic signal with leading pedestrian interval	Flashing red with pedestrian warning sign; Traffic signal with leading pedestrian interval	Flashing red with pedestrian warning sign; Traffic signal with leading pedestrian interval	Traffic signal with pedestrian countdown signal; Traffic signal with exclusive pedestrian phasing	Traffic signal with leading pedestrian interval; NA	Traffic signal with leading pedestrian interval; Traffic signal with exclusive pedestrian phasing and bike signal with two-stage turn queue boxes	Traffic signal with leading pedestrian interval; NA	Traffic signal with leading pedestrian interval and two-stage turn queue boxes; NA	Traffic signal with leading pedestrian interval and bike signal with two-stage turn queue boxes; NA	Traffic signal with leading pedestrian interval; NA

6.2.5 Crash modification factors (CMFs) of treatments

The crash modification factors clearing house website (Federal Highway Administration 2022) maintains a list of treatments with CMFs from historical research. The treatments used in this tool were searched on this website to obtain the CMFs as it can give an idea to users about the reduction in crashes when a particular treatment was used. As such, the following steps were implemented to obtain the CMF for treatments:

1. All the pedestrian and bicyclist-related treatments were selected and downloaded (142 pedestrian and 25 bicyclists CMFs, in total).
2. The following filters were applied:
    a. Start rating >=3
        i. Star rating is a criteria that suggest the quality of the CMF developed. The star rating varies from 1 to 5, where 5 is the highest or best and 1 is the lowest. This rating is based on methodology of research, data collection procedure etc.
    b. Select applicable countermeasures
        i. In this step, only those countermeasures selected were used in the tool.
    c. Remove crash types pertinent to motor vehicles
        i. In this step, those crash types that were removed were pertinent to motor vehicles, e.g., angle crash, head-on crash, rear-end etc.
3. Lastly, after applying these filters, only 8 distinct pedestrian treatments and 2 distinct bicycle treatments were left (21 CMFs for pedestrians and 5 CMFs for bicyclists).

As the actual number of ped/bike treatments in the tool was 40+, but only 10 treatments have CMFs available. Due to this reason, these CMFs were not included in the tool as it would create a significant number of NAs in the tool and may not give sufficient information to the user. Table 31 and Table 32 shows the CMFs for pedestrian and bicycle treatments that were used in the tools. The purpose of these tables is to provide an idea to the tool user of where to use which treatment. Further, it can also be noted that some treatments have CMFs greater than one, which does not imply that the presence of these treatments increases crash risk. Instead, it indicates site selection bias where treatment is installed at a problematic location. For e.g., bicycle lanes are installed at a location that has more bicycle traffic, which may cause more bicycle crashes.

Table 31. Crash Modification Factors for Pedestrian Treatments

Countermeasure	CMF	Crash Type	KABCO Crash Severity	Roadway Type	Area Type	Star Quality Rating
Install raised median with marked crosswalk (uncontrolled)	0.54	Vehicle/pedestrian	All	Principal Arterial Other	Urban and Suburban	3
Widen sidewalks at intersections	1.12	All	A, B, C	Not specified	Not specified	3
Modify signal phasing (implement a leading pedestrian interval)	0.413	Vehicle/pedestrian	All	Principal Arterial Other	Urban	4
Modify signal phasing (implement a leading pedestrian interval)	0.87	All	All	All	Urban and suburban	5
Modify signal phasing (implement a leading pedestrian interval)	0.86	All	K, A, B, C	All	Urban and suburban	5
Modify signal phasing (implement a leading pedestrian interval)	0.87	Vehicle/pedestrian	All	All	Urban and suburban	5
Install a pedestrian hybrid beacon (PHB or HAWK)	0.849	All	K, A, B, C	Not Specified	Urban and suburban	3
Install a pedestrian hybrid beacon (PHB or HAWK)	0.309	Vehicle/pedestrian	All	Not Specified	Urban and suburban	3
Install a pedestrian hybrid beacon (PHB or HAWK)	0.453	Vehicle/pedestrian	All	Minor Arterial	Urban and suburban	3
Install a pedestrian hybrid beacon (PHB or HAWK)	0.818	All	All	All	Urban and suburban	5
Install a pedestrian hybrid beacon (PHB or HAWK)	0.748	All	K, A, B, C	All	Urban and suburban	5
Install a pedestrian hybrid beacon (PHB or HAWK)	0.543	Vehicle/pedestrian	All	All	Urban and suburban	5
Install a pedestrian hybrid beacon (PHB or HAWK)	0.55	Vehicle/pedestrian	K, A, B, C	All	Urban and suburban	5
Install pedestrian countdown timer	0.3	Vehicle/pedestrian	All	Not specified	Not specified	3
Install pedestrian countdown timer	0.912	All	All	Not specified	Not specified	5
Install pedestrian countdown timer	0.952	All	K ,A ,B,C	Not specified	Not specified	4
Install pedestrian countdown timer	0.929	All	O only	Not specified	Not specified	5
Install pedestrian hybrid beacon (PHB or HAWK) with advanced yield or stop markings and signs	0.432	Vehicle/pedestrian	All	Minor Arterial	Urban and suburban	4
Install pedestrian hybrid beacon (PHB or HAWK) with advanced yield or stop markings and signs	0.82	All	All	Minor Arterial	Urban and suburban	4
Install rectangular rapid flashing beacon (RRFB)	0.526	Vehicle/pedestrian	All	Minor Arterial	Urban and suburban	3
Median treatment for ped/bike safety	0.14	Vehicle/bicycle Vehicle/pedestrian	K	Not specified	Urban	3

Table 32. Crash Modification Factors for Bicyclist Treatments

Countermeasure	CMF	Crash Type	KABCO Crash Severity	Roadway Type	Area Type	Star Quality Rating
Presence of median	0.97	Vehicle/bicycle	All	Not Specified	Urban and suburban	3
Install bicycle lanes	1.057	All	All	Not specified	Urban	3
Install bicycle lanes	1.065	Vehicle/pedestrian	All	Not specified	Urban	3
Install bicycle lanes	1.281	Vehicle/bicycle	All	Not specified	Urban	3
Install bicycle lanes	1.07	All	K, A, B, C	Not specified	Urban	3

7 CONCLUSIONS AND RECOMMENDATIONS

The primary objective of this study was to assist MDOT in the development of decision support tools for use in performance-based context-sensitive solutions and design (CSS/D), allowing for project prioritization and detailed modal analyses. In support of this objective, a series of national and state best practices documents were summarized that were related to CSS/D and the selection of multimodal treatments. This was followed by the identification of data that are consistently available for MDOT-maintained roads at the state-wide level. Using these resources, a series of multimodal treatment matrices were developed for various site types, including: pedestrian segment; bicycle segment; midblock crossing; and intersection crossing. Finally, to allow for ease of use, a Visual Basics for Applications (VBA) tool was developed that considers input parameters that include context, AADT, speed limit, and median-lane configuration, resulting in output in the form of three potential treatments, including a default treatment, as well as associated higher and lower order alternative treatments.

7.1 National and State Best Practices for CSS/D

Various national guidance documents have been developed in support of CSS/D. Overall, the literature suggests that applying CSS/D principles to a project increases flexibility and allows for greater creativity in developing solutions that are appropriate for important site-specific conditions. Further, CSS/D more effectively engages stakeholders and adds value to the community, environment, and broader transportation system. It can also lead to more cost-effective investment decisions as tailored solutions are developed to specific problems. From a multimodal point of view, CSS/D can be highly useful as it considers roadway and contextual characteristics while developing any solution.

Several states have also developed their own guidelines for the application of CSS/D principles. As all states have different needs, priorities, contexts, and budget constraints, the guidelines developed by these states also highlight these points to some degree. In general, despite all the variability in states, it was found that most of them preferred interdisciplinary teams, design flexibility, community involvement, and improved safety and mobility for pedestrians and bicyclists. Some states explicitly mentioned environmental protection and preserving historical routes. Others talked about effective decision-making, project development process, and cost-effectiveness. However, most of these states did not refer to the performance measurement of CSS/D elements.

7.2 Treatments Selection in Existing Guidelines

Multiple MDOT and national guidelines were reviewed to understand the treatment selection process in various contexts. Most of these guidelines use AADT and speed limit as the decision criteria to recommend treatments. In general, increased emphases were placed on designing for pedestrians and bicyclists in scenarios where traffic volumes, speed limits, and the roadway width or number of lanes increased. Similarly, greater accommodation was provided for non-motorized users in more urbanized areas. Many of the existing guidelines do not explicitly consider contexts (e.g., rural, urban, suburban) when identifying specific treatments of interest. Among those guidelines that do consider context in decision-making, the definitions and contextual categories tend to vary across agencies. For example, most states have not yet adopted the five nearly defined contexts from the 2018 Green Book. Further, some of this guidance considers context, but not other factors such as AADT and speed limit. Finally, a few of the guidelines consider the median-lane configuration as a part of the decision-making. Collectively, the existing guidelines provide a strong foundation for the decision criteria that were used to develop the treatment matrices and VBA tool.

7.3 Treatments Selection in Developed Matrices and VBA Tool

Different treatment matrices were developed for four general site types: (1) pedestrian segment; (2) bicyclist segment; (3) midblock crossing; and (4) intersection crossing. These matrices provide engineers and planners with data-driven support in determining scenarios where various pedestrian and bicyclist treatments are most appropriate.

The treatment selection process and decision criteria for all site types follows the same general approach. As traffic volumes, speed limits, and the number of travel lanes increase, the needs of non-motorized users are given higher priority. Similarly, pedestrian and bicyclist treatments receive precedence in more urbanized areas. In general, this greater accommodation is in the form of increased separation (space and time) between non-motorized users and motor vehicles.

For each combination of variables and site type, a default treatment matrix was identified. In addition, alternative treatment matrices were developed to provide a higher order and lower order treatment, providing engineers and planners with flexibility in cases where a site is near a threshold value(s) for specific decision criteria or where budgetary or other constraints may inhibit the use of specific treatments.

Finally, a VBA tool was developed to assist engineers/planners in utilizing the matrices. The VBA tool includes a series of drop-down menus, allowing the user to input AADT, speed limit, median lane configuration, and site type.

7.4 Use of the Decision-Support Tool

Ultimately, this report and the associated decision-support tool provide MDOT and local agency staff with a consistent, data-driven approach that can be used to identify candidate treatments for pedestrians and bicyclists across a diverse range of contextual environments and roadway conditions.

As the tool generally provides three treatments, including a default, as well as a higher- and lower-order treatment, the tool is expected to be very useful at the project scoping and development phases where many detailed design decisions have not yet been made. Based on site conditions, context, and roadway characteristics, alternatives can be compared while providing agency staff with the flexibility to accommodate constraints introduced by these factors or by project budgets. The tool also provides a means to proactively consider the needs of non-motorized users across a wide range of project and facility types. It is expected that the tool will also assist agencies in effective engagement and obtaining support for the development of solutions that are tailored to the needs of specific communities.

Lastly, it should be noted that this tool and the associated guidance is intended to aid engineers and planners in decision-making. The matrices do not represent a standard or specification, they are primarily intended to serve as one of a number of important tools to support the broad project development, planning, and design processes. As such, tool users should use engineering judgement and can deviate from the suggested treatments listed in the matrices.

7.5 Limitations and Directions for Future Research

The current tool considers site type, context, AADT, speed limit, and median-lane configuration when identifying candidate treatments. This provides a solid foundation for informed decision-making. However, besides considering the aforementioned characteristics, other data can be collected and utilized to make the tool more robust. One particularly important element is the availability of pedestrian and bicycle volume data. The current tool uses context information that is based on population data from the census, which serves as a proxy for pedestrian and bicyclist volumes. Ultimately, actual measured or estimated volumes would provide a useful supplement that could be incorporated as an additional decision criteria in future iterations of the tool.

Similarly, the current version of the tool considers four contextual environments based upon MDOT-defined categories of rural, small urban, small urbanized, and large urbanized areas. It is feasible to potentially expand the tool to additional contexts or to consider related factors such as land use characteristics (e.g., residential area, setback distance, presence of high-rise structures) or the AASHTO five-category context system (i.e., rural, rural town, suburban, urban and urban core).

The tool is well suited for integration with other resources, including the MDOT/SEMCOG Multimodal Tool. Moving forward, project development activities will be enhanced by the explicit integration of these and other tools as part of holistic planning and design efforts. Future versions of the tool can also consider other important characteristics, such as the presence of transit routes/stations and bus stops.

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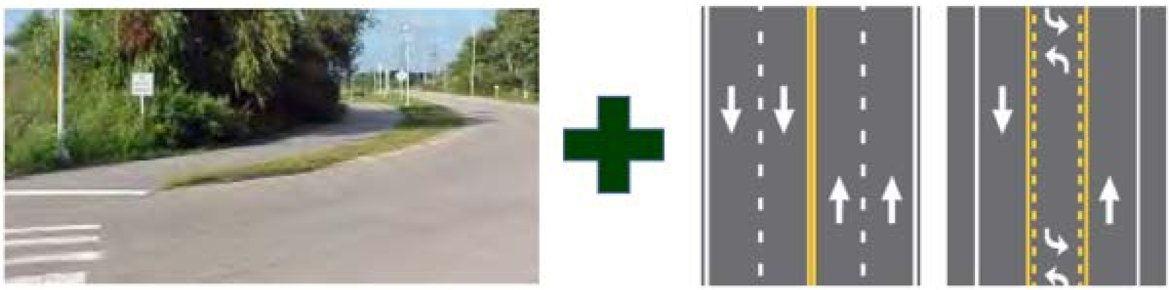
APPENDIX A: IMAGES OF TREATMENTS

Pedestrian Segment

Wide paved shoulder (North Carolina Department of Transportation n.d.)

Sidepath (Michigan Department of Transportation 2014a)

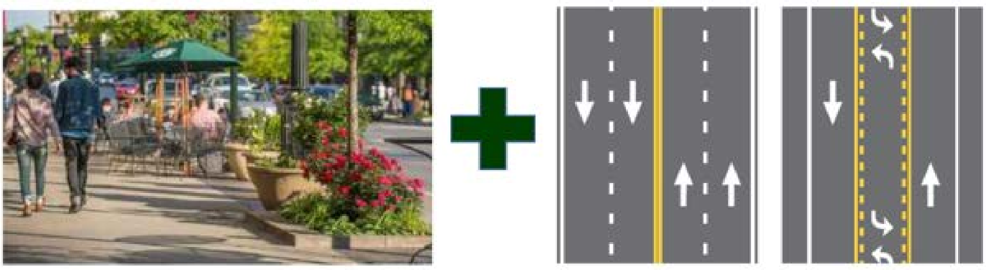


Sidepath (Michigan Department of Transportation 2014a) + Lane reduction (Michigan Department of Transportation 2019)

Sidepath with lane reduction

Sidewalk (Michigan Department of Transportation 2014a)

Streetscaping (Michigan Department of Transportation 2019)



Streetscaping (Michigan Department of Transportation 2019) + Lane reduction (Michigan Department of Transportation 2019)

Streetscaping with lane reduction

Bicycle Segment

Wide paved shoulder (North Carolina Department of Transportation n.d.)

Shared lane (Michigan Department of Transportation 2014a)

Bike boulevard (Michigan Department of Transportation 2014a)

Bike lane (Michigan Department of Transportation 2014a)

Bike lane with buffer (Michigan Department of Transportation 2014a)

Separated bike lane (or cycle track) (Michigan Department of Transportation 2014a)

Midblock Crossing

High visibility crosswalk (Michigan Department of Transportation 2014a)

Pedestrian warning sign (ELTEC 2022)

Advance yield here to pedestrian sign and yield line (Federal Highway Administration 2020b)

Gateway treatment (McQuiston et al. 2016)

Pedestrian refuge island (Michigan Department of Transportation 2014a)

Rectangular rapid flashing beacon (Michigan Department of Transportation 2014a)

Pedestrian hybrid beacon (Michigan Department of Transportation 2014a)

Intersection Crossing

Yield sign (Driving-Tests.org 2022b)

Yield sign (Driving-Tests.org 2022b)

Advance pedestrian warning sign (Burden 2006a)

Yield sign with advance pedestrian warning sign

Stop sign (Driving-Tests.org 2022a)

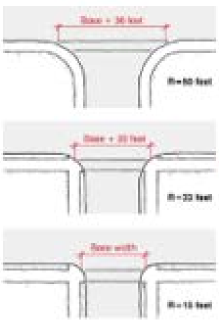
Stop sign (Driving-Tests.org 2022a)

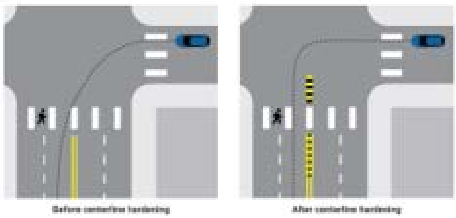
Pedestrian warning sign (ELTEC 2022)

Stop control with pedestrian warning sign

Stop sign (Driving-Tests.org 2022a) + Splitter island (Local Government and Municipal n.d.) + Pedestrian warning sign (ELTEC 2022)

Stop sign with splitter island and pedestrian warning sign





Stop sign (Driving-Tests.org 2022a) + Reduction in curb radius (SF Better Streets 2012) + Centerline hardening (Green Car Congress 2020)

Stop sign with reduction in curb radius and hardened centerline

Stop sign (Driving-Tests.org 2022a) + Pedestrian warning sign (ELTEC 2022) + Median U-turn (Reid et al. 2014)

Stop sign with pedestrian warning sign and median U-turn

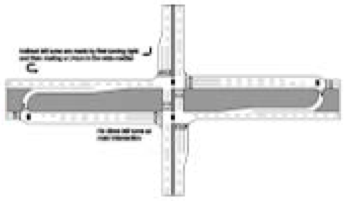
Flashing yellow (FreeDMVTest.org 2022b)

Pedestrian warning sign (ELTEC 2022)

Flashing yellow with pedestrian warning sign

Flashing yellow (FreeDMVTest.org 2022b) Advance pedestrian warning sign (Burden 2006a)

Flashing yellow with advance pedestrian warning sign



Flashing yellow (FreeDMVTest.org 2022b) + Advance pedestrian warning sign (Burden 2006a) + Median U-turn (Reid et al. 2014)

Flashing yellow with advance pedestrian warning sign and median U-turn

Flashing red (FreeDMVTest.org 2022a) Pedestrian warning sign (ELTEC 2022)

Flashing red with pedestrian warning sign

Roundabout (Michigan Department of Transportation 2022b)

Traffic signal with pedestrian push button (Burden 2006b)

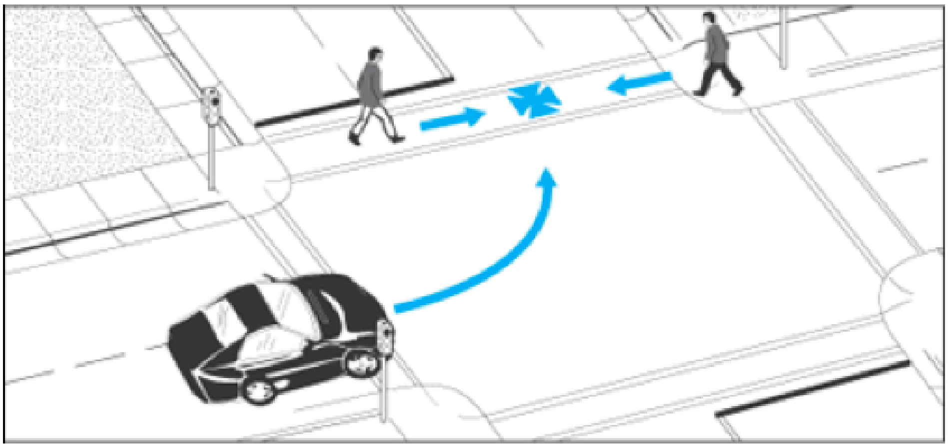
Traffic signal with pedestrian countdown signal (Chicago Metropolitan Agency for Planning n.d.)

Traffic signal with pedestrian countdown signal (Chicago Metropolitan Agency for Planning n.d.) + Bike box (Michigan Department of Transportation 2014a)

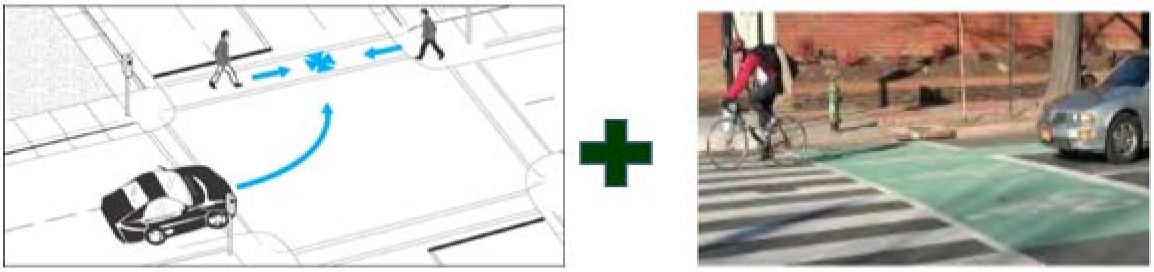
Traffic signal with pedestrian countdown signal and bike box

Traffic signal with pedestrian countdown signal (Chicago Metropolitan Agency for Planning n.d.) + Two stage turn ques boxes (National Association of City Transportation Officials 2012)

Traffic signal with pedestrian countdown signal and two-stage turn queue boxes

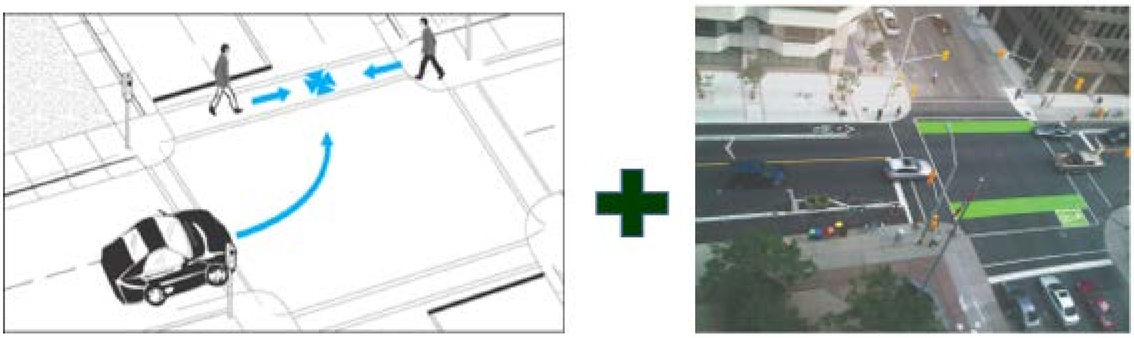


Traffic signal with leading pedestrian interval (Federal Highway Administration 2013b)



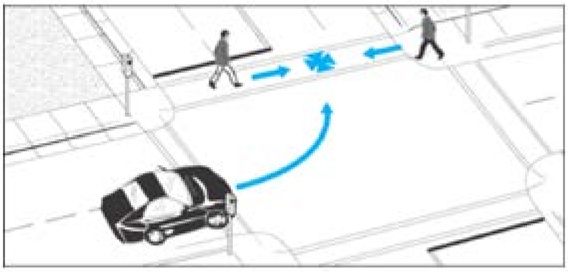
Traffic signal with leading pedestrian interval (Federal Highway Administration 2013b) + Bike box (Michigan Department of Transportation 2014a)

Traffic signal with leading pedestrian interval and bike box



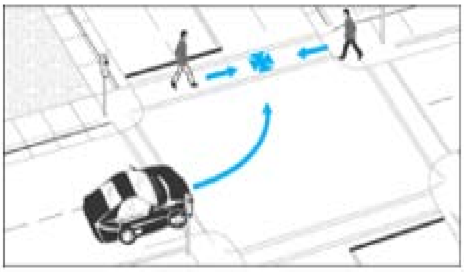
Traffic signal with leading pedestrian interval (Federal Highway Administration 2013b) + Two-stage turn queue boxes (National Association of City Transportation Officials 2012)

Traffic signal with leading pedestrian interval and two-stage turn queue boxes

Traffic signal with leading pedestrian interval (Federal Highway Administration 2013b) + Bike signal (National Association of City Transportation Officials 2012)

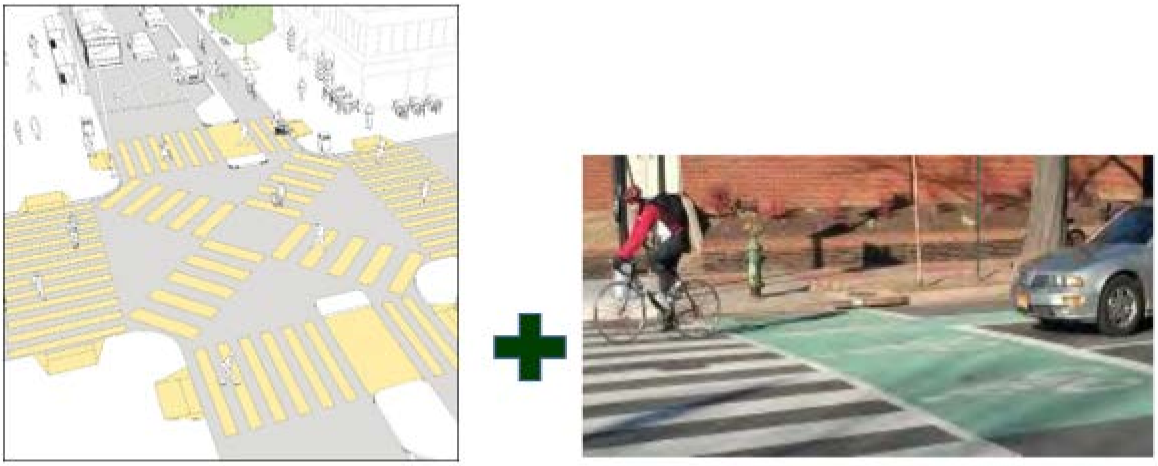
Traffic signal with leading pedestrian interval and bike signal

Traffic signal with leading pedestrian interval (Federal Highway Administration 2013b) + Bike signal (National Association of City Transportation Officials 2012) + Two-stage turn ques boxes (National Association of City Transportation Officials 2012)

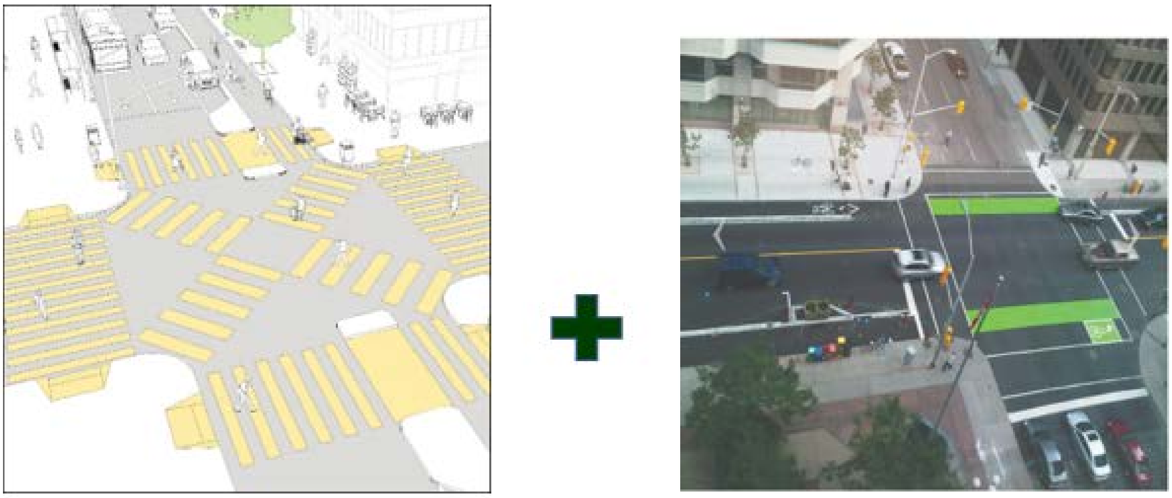
Traffic signal with leading pedestrian interval and bike signal with two-stage turn queue boxes

Traffic signal with exclusive pedestrian phasing or pedestrian scramble (Global Designing Cities Initiative n.d.)



Traffic signal with exclusive pedestrian phasing or pedestrian scramble (Global Designing Cities Initiative n.d.) + Bike box (Michigan Department of Transportation 2014a)

Traffic signal with exclusive pedestrian phasing and bike box



Traffic signal with exclusive pedestrian phasing or pedestrian scramble (Global Designing Cities Initiative n.d.) + Two-stage turn ques boxes (National Association of City Transportation Officials 2012)

Traffic signal with exclusive pedestrian phasing and two-stage turn queue boxes

Traffic signal with exclusive pedestrian phasing or pedestrian scramble (Global Designing Cities Initiative n.d.) + Two-stage turn ques boxes (National Association of City Transportation Officials 2012) + Bike signal (National Association of City Transportation Officials 2012)

Traffic signal with exclusive pedestrian phasing and two-stage turn queue boxes with bike signal

APPENDIX B: USER MANUAL

Overview

This user manual details the decision-support tool that was developed by Michigan State University (MSU) as a part of the Michigan Department of Transportation (MDOT) project, titled "Developing a Consistent Data-Driven Methodology to Multimodal, Performance Based, and Context Sensitive Design." The purpose of this project was to provide resources to assist MDOT staff in making planning- and design-level decisions that are multi-modal, performance-based, and context-sensitive. There is significant benefit in considering these perspectives during the early planning stage in order to make more informed design decisions, such as the consideration of specific travel modes and the selection of relevant cross-sectional characteristics.

To that end, the tool can be used as a proactive means to explicitly consider these issues as a part of project prioritization, multi-modal analyses, and at various stages of planning, design, and project development. This addresses a related concern in that these types of project-related decisions are often made during the latter stages of the development process and, as such, are reactive to community concerns and more costly to implement. The tool also helps to provide explicit guidance as to when and where specific solutions may be appropriate.

The decision-support tool is based upon a Visual Basic Application (VBA) that integrates high-level qualitative (e.g., context) and quantitative (e.g., speed limit, traffic volume) as input and yields potential solutions that provide accommodation for pedestrians and bicyclists in consideration of constraints introduced by these inputs.

The tool leverages various guidelines and best practices, including the Federal Highway Administration *STEP Studio* (Federal Highway Administration 2020b), the United States Department of Transportation *Bikeway Selection Guide* (Schultheiss et al. 2019), and the National Association of City Transportation Officials *Urban Bikeway Design Guide* (National Association of City Transportation Officials 2012). The majority of these guidelines are based on quantitative metrics, including annual average daily traffic, speed limit, and the number of travel lanes. Additional nuance is provided by considering differences across contextual environments, including the integration of guidance documents, such as the MDOT *Multi Modal Development and Delivery Guidebook* (Michigan Department of Transportation 2019).

Data were identified that are available to MDOT at the statewide level, allowing for consistent application of the tool across the trunkline network. The resulting tool is useful for engineers, planners, designers, project managers, and other practitioners as it provides insights as to pedestrian and bicyclist facilities that represent promising solutions for a wide range of settings. While this tool is intended to assist MDOT and other Michigan transportation agencies in the decision-making process, it is important to note that the associated guidance is one of several inputs to this process and does not represent a standard or specification.

Overview of Decision-Support Tool

The decision-support tool is based upon a series of five questions, with the response to each question serving as an input to a series of decision matrices. These questions were developed in consultation with MDOT and consider various site-specific factors that reflect the relative priority that is given to pedestrian and bicyclist needs in consideration of the degree of risk posed to non-motorized users, as well as the expected mode shares. These specific questions were selected as the underlying data are available to MDOT at a statewide level, and they are strongly correlated with pedestrian and bicyclist activity, mobility, and/or safety. These questions are answered using the pull-down menus that are built into the VBA tool, as illustrated in Figure B1.

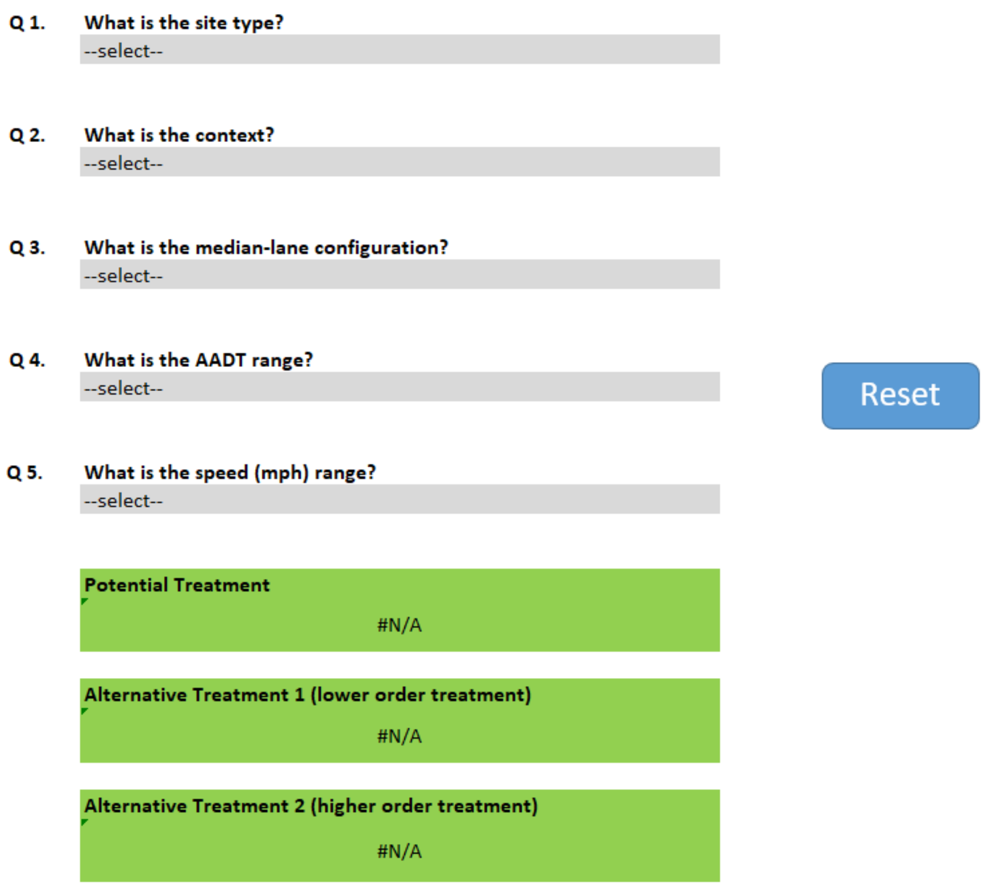


Figure B1. Pedestrian Bicyclist Facility Selection Tool- Interface

After selecting a response for each of these five questions, a series of prospective treatments that could be implemented at the site under investigation are displayed to the user. This includes a default “potential treatment” that was identified using various guidance documents, as well as one “lower-order treatment” (i.e., a treatment that is generally lower cost or less extensive) and one “higher-order treatment” (i.e., a treatment that is higher cost or more extensive).

Prior to selecting responses to each of the five input questions, the treatment cells display #N/A for not applicable. After entering responses to all questions, the user must click on the “RESET” button in order to vary the question responses.

The following sections of this manual provide further explanation of the questions and input variables, including brief discussions of how these inputs are used in selecting potential and alternative treatments.

Site type

The site type variable characterizes the type of roadway facility that is being considered. The decision-support tool is applicable for four general types of facilities:

- Midblock – This site type is applicable for midblock crossings on road segments that are located outside of the influence area of an intersection. This option covers treatments that are applicable to both pedestrians and bicyclists.
- Segment level-pedestrian treatment – This site type is applicable for treatments that are implemented longitudinally along a road segment (e.g., wide shoulders, sidewalks, side paths). This option is applicable specifically for pedestrian treatments.
- Segment level-bike treatment – This site type is applicable for treatments that are implemented longitudinally along a road segment (e.g., wide paved shoulders, bike lanes, bike lanes with buffers). This option is applicable specifically for bicycle treatments.
- Intersection – This site type is applicable for crosswalks that are located at intersection. This option covers treatments that are applicable to both pedestrians and bicyclists.

Figure B2 illustrates these four site types as they appear in the tool. In general, treatments at midblock or intersection crossings are selected such that they would provide increased protection for both pedestrians and bicyclists. For the segment-focused scenarios, separate treatments are provided for each group of non-motorized users.

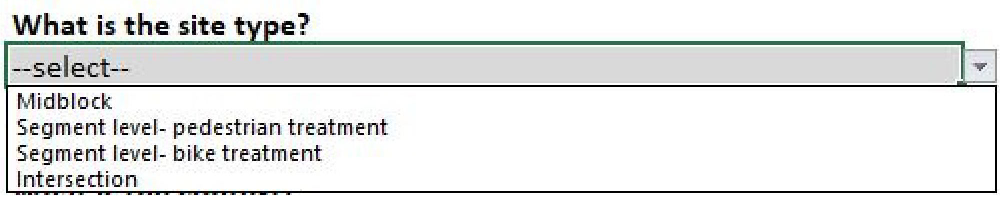


Figure B2. Site Types Included in the Decision-Support Tool

Context

The context variable represents the four contextual environments as defined in the MDOT open GIS data portal. These include:

- Rural – Sites that are located in areas with populations of less than 5,000.
- Small urban areas – Sites that are located in areas with populations from 5,000 to 50,000
- Small urbanized areas – Sites that are located in areas with populations from 50,000 to 200,000.
- Large urbanized areas – Sites that are located in areas with populations of more than 200,000.

These contextual categories are shown in Figure B3 as they appear in the tool. In general, the type of treatment that is selected is influenced by the contextual environment. Generally speaking, the level of protection provided for non-motorized users tends to increase as the contextual environment becomes denser and more urban. This largely reflects the large mode share of pedestrians and bicyclists in these settings. Speeds are important and generally higher in rural settings, but this is accounted for subsequently through a separate question/input.

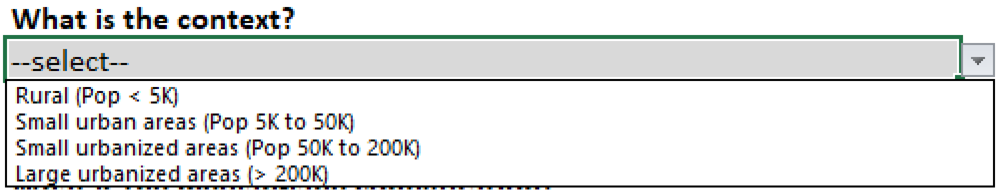


Figure B3. Context Types Included in the Decision-Support Tool

Median-lane configuration

The median-lane configuration variable describes the cross-sectional environment where a project is being implemented. The tool is designed for five distinct types of roadway configurations, as illustrated in Figure B4 and described here:

- Undivided – 2 lanes, both directions
- Undivided – 3 lanes both directions
- Undivided – 4+ lanes both directions
- Median 1 – 2 lanes in one direction
- Median – 3+ lanes in one direction

Please note that for undivided roads, the lanes are counted in both directions. In contrast, on roads with a median, the number of lanes is counted in one direction. In general, as the number of lanes (and associated crossing distance) increases, greater emphasis is placed on the safety of non-motorized users.

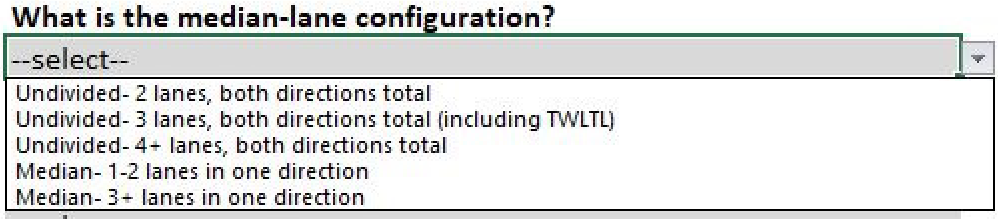


Figure B4. Median-Lane Configuration Included in the Decision-Support Tool

AADT range

The AADT variable indicates the two-way annual average daily traffic (AADT) on the roadway where the project is being implemented. These traffic volumes are aggregated into four categories, as listed here and illustrated in Figure B5, which provides an excerpt from the tool:

- Annual average daily traffic (AADT) of less than 5,000 vehicles per day
- Annual average daily traffic (AADT) of 5,000 to 10,000 vehicles per day
- Annual average daily traffic (AADT) of 10,000 to 20,000 vehicles per day
- Annual average daily traffic (AADT) of more than 20,000 vehicles per day

As traffic volumes increase, so does the frequency of interaction between motor vehicle traffic and non-motorized users. As such, greater levels of protection are generally provided in higher AADT ranges.

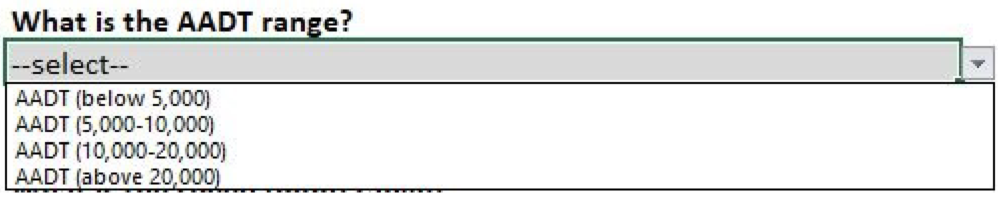


Figure B5. AADT Ranges Included in the Decision-Support Tool

Speed range

The speed range variable indicates the prevailing speed limit on the roadway where the project is being implemented. These speed limits have been aggregated into three categories as listed here and shown in Figure B6 from the tool:

- Speed limits of 30 miles per hour or less
- Speed limits of 35 to 40 miles per hour
- Speed limits of 45 miles per hour or more

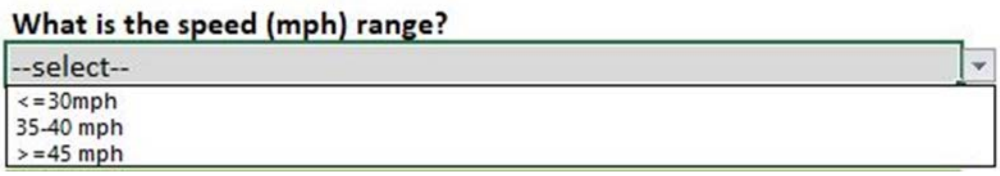


Figure B6. Speed Limit Ranges Included in the Decision-Support Tool

Treatments

As indicated previously, the decision-support tool provides up to three potential treatments that can be implemented based upon the site type and the associated site-specific factors described above. The specific treatments are determined based upon guidance from MDOT-specific guidance documents where applicable. In lieu of such guidance, decision criteria are generally based on national (e.g., NACTO) or state-level guidelines, or the results of the existing research literature. Up to three treatments are provided for each scenario as detailed here:

1. Potential Treatment: This is the preliminary treatment that is suggested for the project location based on the site type, context, roadway configuration, AADT, and speed limit range.
2. Alternative Treatment 1 (lower order treatment): The first alternative that is provided is one level lower than the preliminary treatment. This accounts for the fact that at a given location, one of the parameters may be slightly above the corresponding threshold values for the input parameters. For example, an AADT of 5,100 vehicles per day would fall under the second of the four categories (range from 5K to 10K). However, there may be little substantive difference in the risks between these categories and the tool is meant to provide flexibility to the designer.
3. Alternative Treatment 2 (higher order treatment): Similarly, the second alternative provides a treatment that is one level higher than the preliminary treatment. This may be useful in similar fringe areas where one or more of the input values occurs near the upper threshold for a category. For example, a location may have an AADT of 9,900 vehicles per day. While this falls in the second category (5K to 10K), there may be other site-specific factors (e.g., the presence of bus stops, schools, or senior centers) that warrant use of a treatment that provides greater protection to non-motorized users.

Ultimately, the tool is not meant to be prescriptive, but it is intended to give the designer flexibility and a menu of alternatives that warrant further consideration based upon the characteristics of the specific project and location.

Tool Functionality

VBA tool and decision matrices

The VBA that supports the decision-support tool is based on a series of treatment matrices that were developed separately for the four site types. The following sections of the manual provide details as to the decision criteria for each of site type.

Pedestrian segment tool

A variety of MDOT and federal sources were used to identify treatments at the segment level that were appropriate for pedestrians. These resources include the Multimodal Development and Delivery Guidebook (Michigan Department of Transportation 2019), Best Design Practices for Walking and Bicycling in Michigan (Michigan Department of Transportation 2012a), and NCHRP-855 An Expanded Functional Classification System for Highways and Streets (Stamatiadis et al. 2018). The full list of treatments that are included in the pedestrian segment level matrix is shown in Table B1, where darker colors are reflective of those treatments providing greater levels of safety for pedestrians.

Table B1. Pedestrian Segment Level Treatments

Wide paved shoulder
Sidepath
Sidepath with lane reductions
Sidewalk
Streetscaping with lane reduction
Streetscaping

The selection of a specific treatment is determined from the corresponding matrix based on the following decision criteria:

- As the speed limit, AADT, and number of lanes increase, the treatments provide greater levels of safety for pedestrians.
- As the context shifts from rural to large urbanized areas, the treatments provide greater levels of safety for pedestrians.
- For speed limits of 45 mph or more, wide paved shoulders or sidepaths are suggested as potential treatments for all contextual environments.
    - Wide paved shoulders are recommended in rural areas as there are generally fewer non-motorized users as compared to more urbanized areas.
    - Sidepaths are recommended in small urban, small urbanized, and large urbanized areas in this higher speed range, given the expectation of higher non-motorized mode shares.

The pedestrian segment level treatment matrix includes 240 combinations of contexts, AADTs, speed limits, and median-lane configurations. The user is referred to the worksheet titled "Tool-Ped_Seg" for more details.

Table B2 provides an example of the preliminary treatments that are provided for AADT below 5,000 in a rural context. A similar matrix was prepared for alternative treatments. As noted previously, this provides flexibility in fringe areas to implement alternative treatments that may be dictated by budget constraints or site-specific risk factors.

Table B2. Example of Pedestrian Segment Level Treatment- Potential

Context	Median type	Lane configuration	AADT (below 5,000)		
			<=30mph	35-40 mph	>=45 mph
Rural (Pop < 5K)	Undivided	2 lanes, both directions total	Sidewalk	Sidepath	Wide paved shoulder
		3 lanes, both directions total (including TWLTL)	Sidewalk	Sidepath	Wide paved shoulder
		4+ lanes, both directions total	Sidewalk	Sidepath	Wide paved shoulder
	Median (Raised, guard rail, concrete barrier etc.)	1-2 lanes in one direction	Sidewalk	Sidepath	Wide paved shoulder
		3+ lanes in one direction	Sidewalk	Sidepath	Wide paved shoulder

The user is referred to the worksheet titled, "Ped_seg_Alternatives" for further details. In each cell, there are two alternatives provided as illustrated in Table B3. The first alternative is the lower order treatment and the second (following the semicolon) is the higher order treatment. In cases where the treatment is the lowest or highest alternative, these treatments are indicated to be not applicable (i.e., NA).

Table B3. Example of Pedestrian Segment level Treatment- Alternatives

Context	Median type	Lane configuration	AADT (below5,000)		
			<=30mph	35-40 mph	>=45 mph
Rural (Pop < 5K)	Undivided	2 lanes, both directions total	Sidepath; NA	Wide paved shoulder; Sidewalk	NA; Sidepath
		3 lanes, both directions total (including TWLTL)	Sidepath; NA	Wide paved shoulder; Sidewalk	NA; Sidepath
		4+ lanes, both directions total	Sidepath; NA	Wide paved shoulder; Sidewalk	NA; Sidepath
	Median (Raised, guard rail, concrete barrier etc.)	1-2 lanes in one direction	Sidepath; NA	Wide paved shoulder; Sidewalk	NA; Sidepath
		3+ lanes in one direction	Sidepath; NA	Wide paved shoulder; Sidewalk	NA; Sidepath

For example, refer to the top left treatments shown in Table B2 and Table B3 and highlighted by a red border. In Table B2, a sidewalk is recommended for the following input parameters:

- Rural context
- Undivided two-lane highway
- AADT below 5K

- Speed limit < 30mph

For the same combination of inputs, Table B3 shows a lower order treatment of sidepath while a higher order treatment is not applicable in this setting. Functionally, sidewalks and sidepaths fill similar roles, but the sidepath serves both pedestrians and bicyclists. As such, it is perceived to provide slightly less protection as compared to sidewalks given potential risks of pedestrian/bicyclist crashes. While the decision matrices can be used directly, it can be challenging to compare the large number of potential combinations of treatments. As such, the VBA tool was developed to automate this process. Figure B7 shows the same example through the use of the VBA tool.

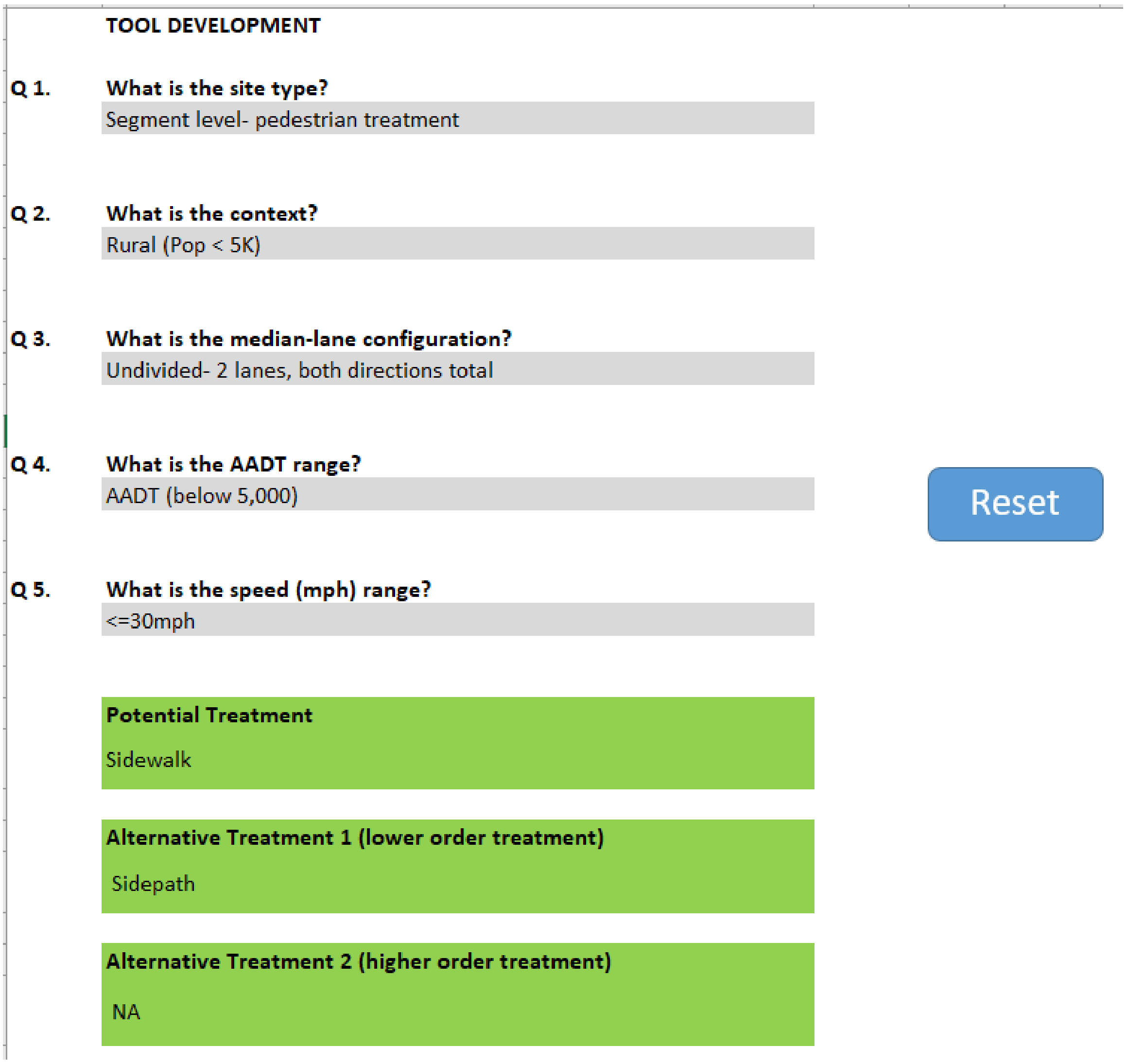


Figure B7. VBA tool example- Pedestrian Treatment

Bicycle segment tool

The treatment matrix for the bicycle segment-level tool was based upon similar guidance documents as for the pedestrian tool, including the Multimodal Development and Delivery Guidebook (Michigan Department of Transportation 2019), Best Design Practices for Walking and Bicycling in Michigan (Michigan Department of Transportation 2012a), NCHRP-855 An Expanded Functional Classification System for Highways and Streets (Stamatiadis et al. 2018), Bikeway Selection Guide (Schultheiss et al. 2019), and Urban Bikeway Design Guide (National Association of City Transportation Officials 2012). The full list of treatments included in the bicycle segment level matrix is shown in Table B4, where darker colors reflect treatments that provide higher levels of safety for bicyclists.

Table B4. Bicycle Segment Level treatment

Wide paved shoulder
Sidepath
Sidepath with Lane reductions
Shared lane
Bike Boulevard
Bike lane
Bike lane with buffer
Separated bike lane

Specific treatments are identified from the corresponding matrix using the following decision criteria:

- As the speed limit, AADT, and number of lanes increase, the treatments provide greater levels of safety for bicyclists.
- As the context shifts from rural to large urbanized areas, the treatments provide greater levels of safety for bicyclists.
- For speed limits of 45 mph or more, wide paved shoulders or sidepaths are suggested as potential treatments for all contextual environments.
    - Wide paved shoulders are recommended in rural areas as there are generally fewer non-motorized users as compared to more urbanized areas.
    - Sidepaths are recommended in small urban, small urbanized, and large urbanized areas in this higher speed range given the expectation of higher non-motorized mode shares.

As in the pedestrian case, the bicycle segment-level matrix also includes 240 combinations of context, AADT, speed limits, and median-lane configuration. Bicycle treatments were suggested for each combination (see excel sheet- Tool-Bike_Seg for more details). An example of it can be seen in Table B5 for AADT between 10,000 and 20,000 in small urban areas.

Table B5. Example of Bicyclist Segment Level Treatment- Potential

Context	Median type	Lane configuration	AADT (10,000-20,000)		
			<=30mph	35-40 mph	>=45 mph
Small urban areas (Pop 5K to 50K)	Undivided	2 lanes, both directions total	Bike lane	Bike lane	Sidepath
		3 lanes, both directions total (including TWLTL)	Bike lane	Bike lane	Sidepath
		4+ lanes, both directions total	Bike lane	Bike lane with buffer	Sidepath
	Median (Raised, guard rail, concrete barrier etc.)	1-2 lanes in one direction	Bike lane	Bike lane	Sidepath
		3+ lanes in one direction	Bike lane	Bike lane with buffer	Sidepath

Table B6 provides alternative bicycle treatments for the same scenario from Table B5 (i.e., AADT 10K-20K and small urban area context). It can be seen that alternative treatments to sidepath are wide paved shoulders and separated bike lanes, which represents lower order and higher order treatments, respectively.

Table B6. Example of Bicyclist Segment Level Treatment- Alternatives

Context	Median type	Lane configuration	AADT (10,000-20,000)		
			<=30mph	35-40 mph	>=45 mph
Small urban areas (Pop 5K to 50K)	Undivided	2 lanes, both directions total	Wide paved shoulder; Bike lane with buffer	Wide paved shoulder; Bike lane with buffer	Wide paved shoulder; Separated bike lane
		3 lanes, both directions total (including TWLTL)	Wide paved shoulder; Bike lane with buffer	Wide paved shoulder; Bike lane with buffer	Wide paved shoulder; Separated bike lane
		4+ lanes, both directions total	Wide paved shoulder; Bike lane with buffer	Bike lane; Separated bike lane	Wide paved shoulder; Separated bike lane
	Median (Raised, guard rail, concrete barrier etc.)	1-2 lanes in one direction	Wide paved shoulder; Bike lane with buffer	Wide paved shoulder; Bike lane with buffer	Wide paved shoulder; Separated bike lane
		3+ lanes in one direction	Wide paved shoulder; Bike lane with buffer	Bike lane; Separated bike lane	Wide paved shoulder; Separated bike lane

Figure B8 shows the same example through use of the VBA tool.

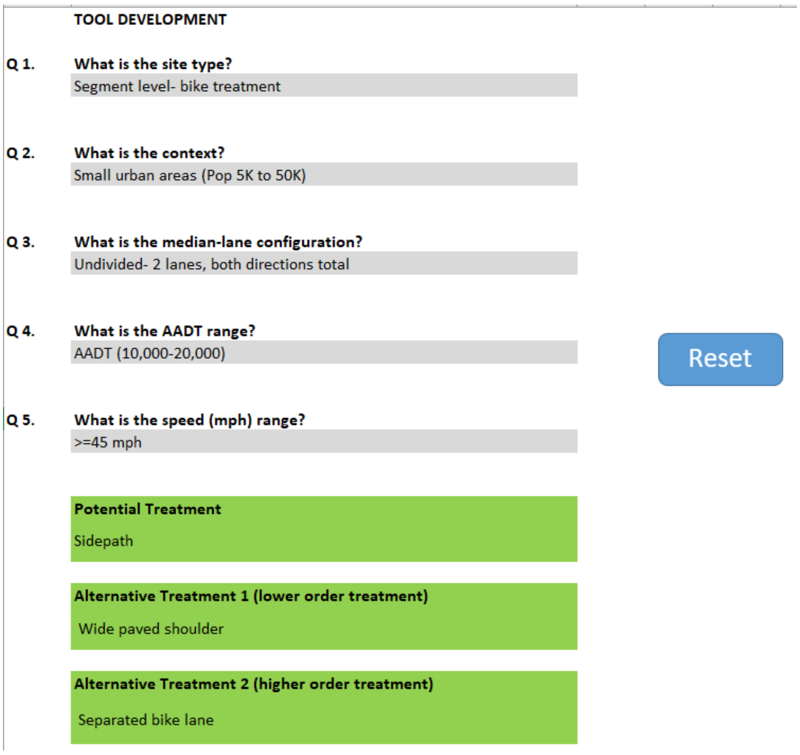


Figure B8. VBA Tool Example- Bicycle Treatment

Midblock crossing

The midblock crossing matrix is mainly based upon the STEP studio (Federal Highway Administration 2020b) guide developed by the FHWA. The other MDOT guidelines used were User Guide for R1-6 Gateway Treatment for Pedestrian Crossings (McQuiston et al. 2016), Guidance for Installation of Pedestrian Crosswalks on Michigan State Trunkline Highways (Michigan Department of Transportation 2014b) etc. This tool is applicable for crossings that are traversed by both pedestrians and bicyclists. The matrix is for undivided roads and raised median facilities only (i.e., medians with barriers are generally not accessible by non-motorized users). In addition, the following general assumptions are made when applying this tool:

- High-visibility crosswalks are suggested at all locations.
- Pedestrian warning signs are suggested at all locations where the existing treatment is of a higher order than a pedestrian warning sign.
- Pedestrian refuge islands are suggested on undivided roadway with 4 or more lanes.

The full list of treatments that are used in the midblock crossing tool matrix is shown in Table B7, where darker colors indicate treatments that provide higher levels of safety for pedestrians and bicyclists.

Table B7. Midblock Crossing Treatments

High visibility crosswalk
Pedestrian warning sign
Advance yield sign
Gateway treatment
Pedestrian refuge island
Rectangular rapid flashing beacon
Pedestrian hybrid beacon

Beyond the general rules noted above, the selection of a specific treatment is determined from the corresponding matrix, which uses similar criteria to the pedestrian and bicycle segment tools:

- As the speed limit, AADT, and number of lanes increase, the treatments provide greater levels of safety for pedestrians.
- As the context shifts from rural to large urbanized areas, the treatments provide greater levels of safety for pedestrians.
- For speed limits of 45 mph or more, wide paved shoulders or sidepaths are suggested as potential treatments for all contextual environments.
    - o Wide paved shoulders are recommended in rural areas as there are generally fewer non-motorized users as compared to more urbanized areas.
    - o Sidepaths are recommended in small urban, small urbanized, and large urbanized areas in this higher speed range given the expectation of higher non-motorized mode shares.

An excerpt of the midblock crossing tool matrix is provided in Table B8 for large urbanized areas. Specific treatments are selected based upon context, AADT, speed limits, and median-lane configuration.

Table B8. Example of Midblock Treatments – Potential

Context	**Median type**	**Lane configuration**	**AADT (5,000-10,000)**		
			<=30mph	35-40 mph	>=45 mph
Large urbanized areas (> 200K)	Undivided	2 lanes, both directions total	Advance yield here to pedestrian sign and yield line	Gateway treatment	Rectangular rapid flashing beacon
		3 lanes, both directions total (including TWLTL)	Advance yield here to pedestrian sign and yield line	Gateway treatment	Pedestrian hybrid beacon

Context	Median type	Lane configuration	AADT (5,000-10,000)		
			<=30mph	35-40 mph	>=45 mph
		4+ lanes, both directions total	Pedestrian refuge island	Pedestrian refuge island	Pedestrian hybrid beacon
	Raised Median only	1-2 lanes in one direction	Advance yield here to pedestrian sign and yield line	Gateway treatment	Pedestrian hybrid beacon
		3+ lanes in one direction	Advance yield here to pedestrian sign and yield line	Gateway treatment	Pedestrian hybrid beacon

Table B9 provides alternative treatments at midblock crossings for this same scenario from Table B8 (i.e., AADT 5,000-10,000 and large urbanized area context). The first alternative is a lower order treatment, while the second alternative is a higher-order treatment. If the preliminary potential treatment is the highest or lowest among all alternatives, "NA" is provided.

The midblock treatment tool is somewhat unique in that there are several suggested minimum treatments for specific site types as noted above. These are in addition to the preliminary potential (and alternative) treatments. For example, Table B10 illustrates the same scenario as Table B8, but also includes the other suggested treatments (i.e., high visibility crosswalks and pedestrian warning signs). Ultimately, the VBA tool only presents the potential and alternative treatments as shown in Figure B9.

Table B9. Example of Midblock Treatments – Alternatives

Context	Median type	Lane configuration	AADT (5,000-10,000)		
			<=30mph	35-40 mph	>=45 mph
Large urbanized areas (> 200K)	Undivided	2 lanes, both directions total	Pedestrian warning sign; Pedestrian refuge island	Advance yield here to for pedestrians sign and yield line; Pedestrian refuge island	Pedestrian refuge island; Pedestrian hybrid Beacon
		3 lanes, both directions total (including TWLTL)	Pedestrian warning sign; Pedestrian refuge island	Advance yield here to for pedestrians sign and yield line; Pedestrian refuge island	Rectangular rapid flashing beacon; NA
		4+ lanes, both directions total	Advance yield here to for pedestrians sign and yield line; Rectangular Rapid Flashing Beacon	Advance yield here to for pedestrians sign and yield line; Rectangular Rapid Flashing Beacon	Rectangular rapid flashing beacon; NA
	Median (Raised, guard rail, concrete barrier etc.)	1-2 lanes in one direction	Pedestrian warning sign; Rectangular Rapid Flashing Beacon	Advance yield here to for pedestrians sign and yield line; Rectangular rapid flashing beacon	Rectangular rapid flashing beacon; NA

Context	Median type	Lane configuration	AADT (5,000-10,000)		
			<=30mph	35-40 mph	>=45 mph
		3+ lanes in one direction	Pedestrian warning sign; Rectangular Rapid Flashing Beacon	Advance yield here to for pedestrians sign and yield line; Rectangular rapid flashing beacon	Rectangular rapid flashing beacon; NA

Table B10. Example of Midblock Treatments in combination (as applied on field)

Context	Median type	Lane configuration	AADT (5,000-10,000)		
			<=30mph	35-40 mph	>=45 mph
Large urbanized areas (> 200K)	Undivided	2 lanes, both directions total	Advance yield here to for pedestrians sign and yield line; High visibility crosswalk; Pedestrian warning sign	Gateway treatment; High visibility crosswalk; Pedestrian warning sign	Rectangular rapid flashing beacon; High visibility crosswalk; Pedestrian warning sign
		3 lanes, both directions total (including TWLTL)	Advance yield here to for pedestrians sign and yield line; High visibility crosswalk; Pedestrian warning sign	Gateway treatment; High visibility crosswalk; Pedestrian warning sign	Pedestrian hybrid beacon; High visibility crosswalk; Pedestrian warning sign
		4+ lanes, both directions total	Pedestrian refuge island; High visibility crosswalk; Pedestrian warning sign	Pedestrian refuge island; High visibility crosswalk; Pedestrian warning sign	Pedestrian hybrid beacon; High visibility crosswalk; Pedestrian warning sign; Pedestrian refuge island
	Raised Median only	1-2 lanes in one direction	Advance yield here to for pedestrians sign and yield line; High visibility crosswalk; Pedestrian warning sign	Gateway treatment; High visibility crosswalk; Pedestrian warning sign	Pedestrian hybrid beacon; High visibility crosswalk; Pedestrian warning sign
		3+ lanes in one direction	Advance yield here to for pedestrians sign and yield line; High visibility crosswalk; Pedestrian warning sign	Gateway treatment; High visibility crosswalk; Pedestrian warning sign	Pedestrian hybrid beacon; High visibility crosswalk; Pedestrian warning sign

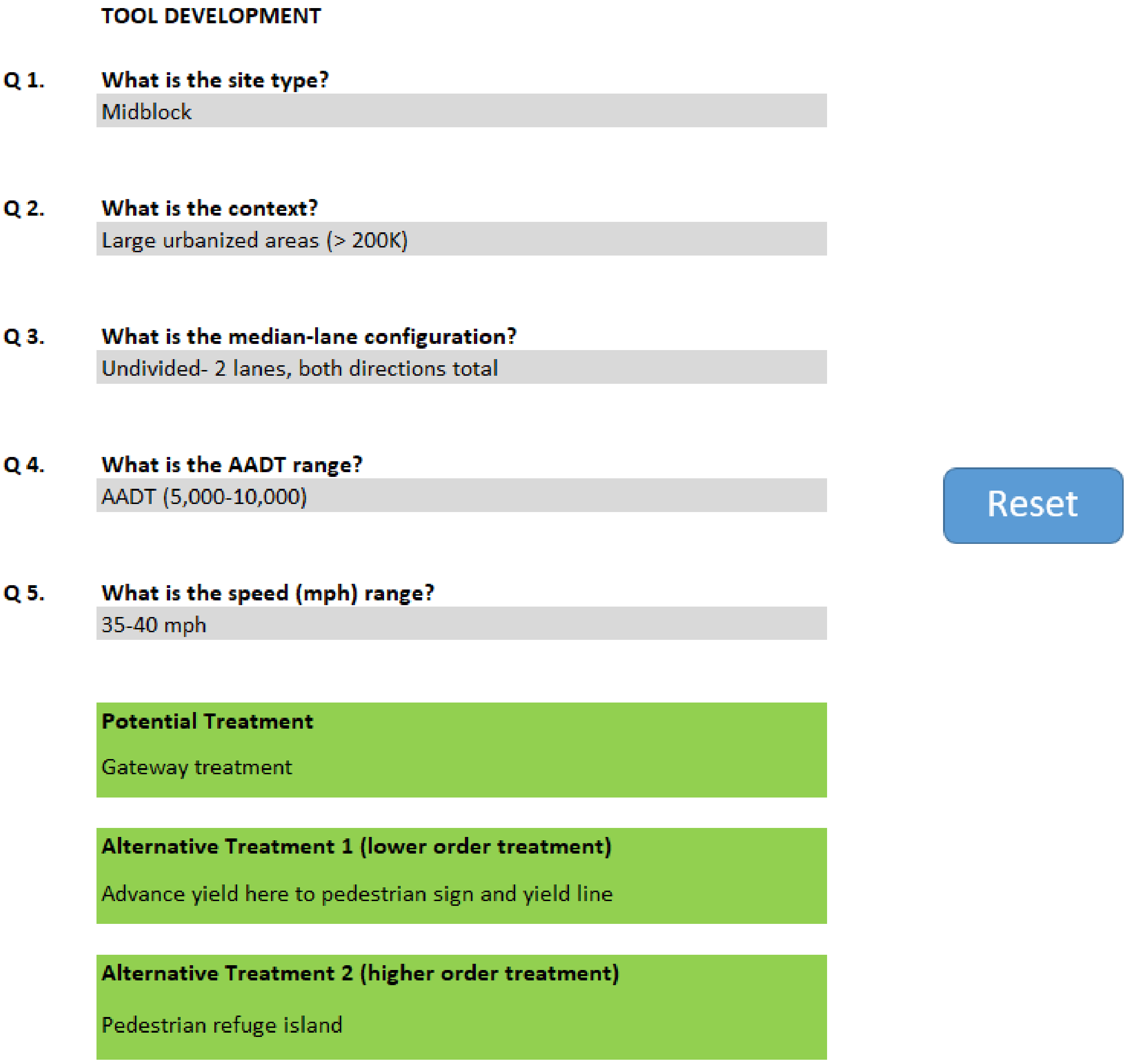


Figure B9. VBA Tool Example- Midblock Treatment

Intersection crossing

MSU used multiple sources to develop the matrix for intersection, including the Urban Bikeway Design Guide (National Association of City Transportation Officials 2012), Urban Street Design Guide (National Association of City Transportation Officials 2015), PEDBIKESAFE (Federal Highway Administration 2013f), Unsignalized Intersection Improvement Guide (Institute of Transportation Engineers 2015), Developing and Using Tables Showing the Pedestrian Optimum and Bicyclist Optimum Feasible Intersection Designs (Hummer 2021), Guide for Pedestrian and Bicyclist Safety at Alternative and Other Intersections and Interchanges (National Academies of Sciences, Engineering, and Medicine 2021), Multimodal Development and Delivery Guidebook (Michigan Department of Transportation 2019). There is significant nuance involved with the identification of treatments at intersection crossings given the diversity in site-specific characteristics. Suggested treatments may include various types of traffic control (e.g., yield-control, stop-control, traffic signal), signal timing/phasing strategies, or supplemental traffic control devices. The treatments are broadly applicable for both pedestrians and bicyclists. The full list of treatments included in the intersection crossing matrix is shown in Table B11, where dark color indicates treatments that provide greater levels of safety. In addition, the following general assumptions are made when applying this tool:

- High-visibility crosswalks are suggested at all locations.
- In cases where a median is present, it generally precedes the intersection and includes all types (e.g., raised, guardrail, concrete barrier).
- For flashing yellow beacons, the yellow beacons are generally installed on the major road approaches while red flashing beacons are installed on the minor road approaches.
- When bicycle signals are provided, right-turn-on-red should generally be prohibited.

Table B11. List of Treatments for Intersection Tool

Yield sign	Stop Control with Reduction in Curb Radius and hardened centerline	Flashing red with Pedestrian warning sign	Traffic signal with pedestrian countdown signal AND Two-stage turn queue boxes	Traffic signal with Leading Pedestrian Interval AND Bike signal with Two-stage turn queue boxes
Yield sign with Advance Pedestrian Warning Sign	Stop control with splitter island and Pedestrian Warning Sign	Roundabout	Traffic signal with Leading Pedestrian Interval	Traffic signal with Exclusive pedestrian phasing
Stop Control	Flashing yellow with Pedestrian warning sign	Traffic signal with pedestrian push button	Traffic signal with Leading Pedestrian Interval AND Bike box	Traffic signal with Exclusive pedestrian phasing AND Bike box
Stop Control with Pedestrian Warning Sign	Flashing yellow with Advance Pedestrian warning sign	Traffic signal with pedestrian countdown signal	Traffic signal with Leading Pedestrian Interval AND Two-stage turn queue boxes	Traffic signal with Exclusive pedestrian phasing AND Two-stage turn queue boxes
Stop Control with Pedestrian Warning Sign and Median U-turn	Flashing yellow with Advance Pedestrian warning sign and Median U-turn	Traffic signal with pedestrian countdown signal AND Bike Box	Traffic signal with Leading Pedestrian Interval AND Bike signal	Traffic signal with Exclusive pedestrian phasing AND Bike signal with Two-stage turn queue boxes

An excerpt from the preliminary treatment matrix is shown in Table B12 for small urbanized areas with AADT of greater than 20,000 vehicles per day. In this traffic volume range, it is presumed that traffic signals are present. As such, the preliminary potential treatments include variants such as pedestrian countdown signals, two-stage turn queue boxes, bike boxes, and leading pedestrian intervals. For example, on an undivided roadway with two lanes total in both directions and a speed limit of 45 mph or more, a traffic signal with a leading pedestrian interval is suggested as the potential treatment (as shown in red outline).

Table B12. Example of Intersection Treatment Matrix- Potential

Context	**Median type**	**Lane configuration**	**AADT (above 20,000)**		
			<=30mph	35-40 mph	>=45 mph
Small urbanized areas (Pop 50K to 200K)	Undivided	2 lanes, both directions total	Traffic signal with pedestrian countdown signal	Traffic signal with pedestrian countdown signal AND Bike Box	Traffic signal with Leading Pedestrian Interval
		3 lanes, both directions total (including TWLTL)	Traffic signal with pedestrian countdown signal	Traffic signal with pedestrian countdown signal AND Two-stage turn queue boxes	Traffic signal with Leading Pedestrian Interval
		4+ lanes, both directions total	Traffic signal with pedestrian countdown signal	Traffic signal with Leading Pedestrian Interval AND Two-stage turn queue boxes	Traffic signal with Leading Pedestrian Interval
	Median (Raised, guard rail, concrete barrier etc.)	1-2 lanes in one direction	Traffic signal with pedestrian countdown signal	Traffic signal with pedestrian countdown signal AND Bike Box	Traffic signal with Leading Pedestrian Interval
		3+ lanes in one direction	Traffic signal with pedestrian countdown signal	Traffic signal with Leading Pedestrian Interval AND Two-stage turn queue boxes	Traffic signal with Leading Pedestrian Interval

Alternative treatments, both lower and higher order, are shown in Table B13 for this same general scenario (AADT of more than 20,000 and small urbanized area). For the specific case referenced above (undivided two-lane, two-way roadway with speed limit of 45 mph or more), the alternative treatments are a traffic signal with pedestrian countdown signal (lower order treatment) or a traffic signal with an exclusive pedestrian phase (higher order treatment). Lastly, Figure B10 shows output for this same case from the VBA tool.

Table B13. Example of Intersection Treatment Matrix- Alternatives

Context	Median type	Lane configuration	AADT (above 20,000)		
			<=30mph	35-40 mph	>=45 mph
Small urbanized areas (Pop 50K to 200K)	Undivided	2 lanes, both directions total	Traffic signal with pedestrian push button; Traffic signal with Leading Pedestrian Interval	Traffic signal with pedestrian countdown signal; Traffic signal with Leading Pedestrian Interval AND Bike box	Traffic signal with pedestrian countdown signal; Traffic signal with Exclusive pedestrian phasing
		3 lanes, both directions total (including TWLTL)	Traffic signal with pedestrian push button; Traffic signal with Leading Pedestrian Interval	Traffic signal with pedestrian countdown signal; Traffic signal with Leading Pedestrian Interval AND Two-stage turn queue boxes	Traffic signal with pedestrian countdown signal; Traffic signal with Exclusive pedestrian phasing
		4+ lanes, both directions total	Traffic signal with pedestrian push button; Traffic signal with Leading Pedestrian Interval	Traffic signal with Leading Pedestrian Interval; Traffic signal with Exclusive pedestrian phasing AND Two-stage turn queue boxes	Traffic signal with pedestrian countdown signal; Traffic signal with Exclusive pedestrian phasing
	Median (Raised, guard rail, concrete barrier etc.)	1-2 lanes in one direction	Traffic signal with pedestrian push button; Traffic signal with Leading Pedestrian Interval	Traffic signal with pedestrian countdown signal; Traffic signal with Leading Pedestrian Interval AND Bike box	Traffic signal with pedestrian countdown signal; Traffic signal with Exclusive pedestrian phasing
		3+ lanes in one direction	Traffic signal with pedestrian push button; Traffic signal with Leading Pedestrian Interval	Traffic signal with Leading Pedestrian Interval; Traffic signal with Exclusive pedestrian phasing AND Two-stage turn queue boxes	Traffic signal with pedestrian countdown signal; Traffic signal with Exclusive pedestrian phasing

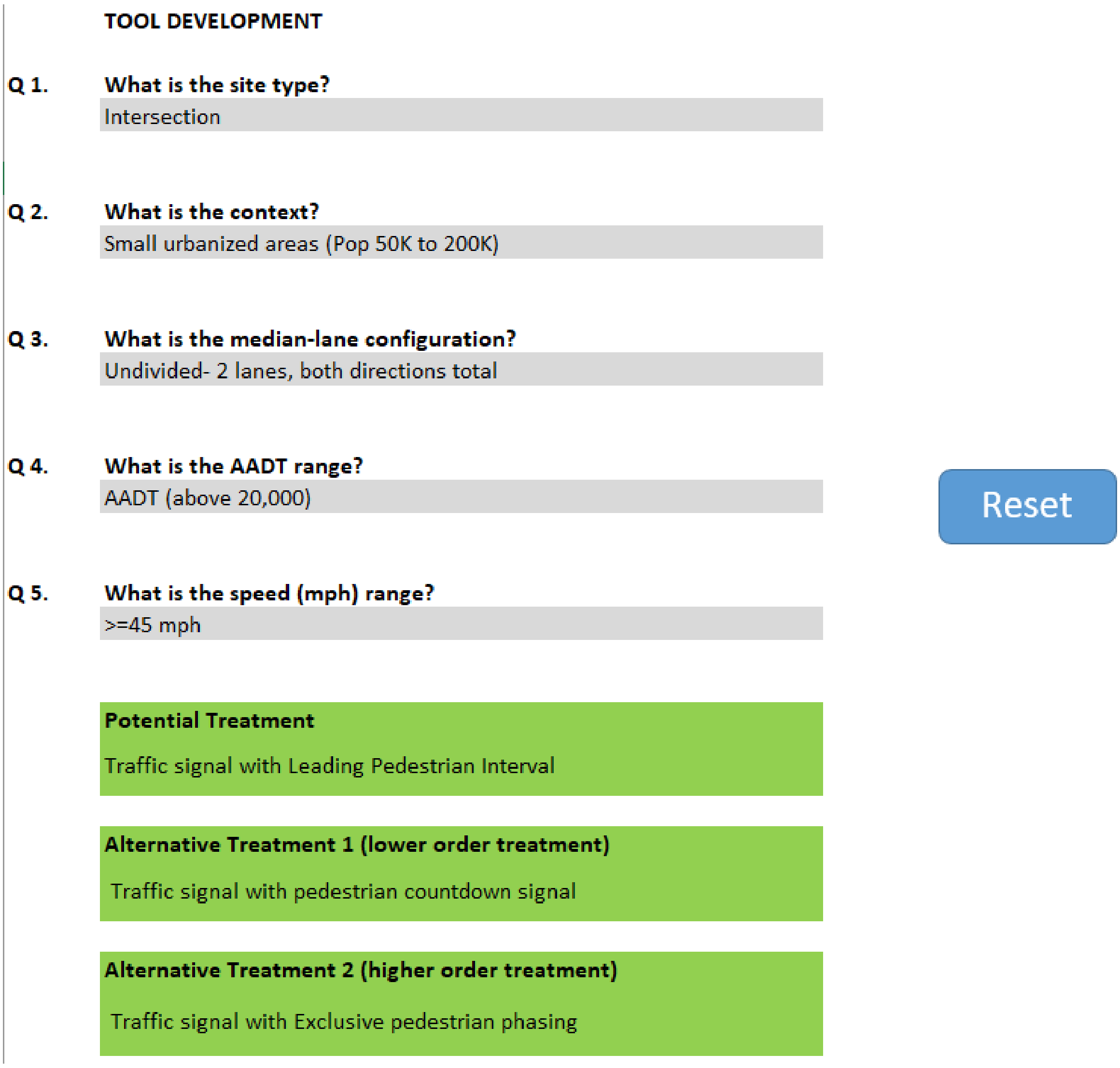


Figure B10. VBA Tool Example- Intersection Treatment