BIKEWAY SELECTION GUIDE

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This document is a resource to help transportation practitioners consider and make informed decisions about trade-offs relating to the selection of bikeway types. This report highlights linkages between the bikeway selection process and the transportation planning process. This guide presents these factors and considerations in a practical process-oriented way. It draws on research where available and emphasizes engineering judgment, design flexibility, documentation, and experimentation.

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1. Introduction

This document is a resource to help transportation practitioners consider and make informed trade-off decisions relating to the selection of bikeway types. It is intended to supplement planning and engineering judgment. It incorporates and builds upon the Federal Highway Administration's (FHWA) support for design flexibility to assist transportation agencies in the development of connected, safe, and comfortable bicycle networks that meet the needs of people of all ages and abilities.

This guide references existing national resources from FHWA, the American Association of State Highway and Transportation Officials (AASHTO), the National Association of City Transportation Officials (NACTO), the Institute of Transportation Engineers (ITE), and others. It is not intended to supplant existing design guides, but rather serve as a decision support tool. It points to relevant sources of design information and focuses on the following question:

What type of bikeway[1] should be chosen on this particular street or in this plan given real-world context, constraints, and opportunities?

1 Bikeway – A facility intended for bicycle travel which designates space for bicyclists distinct from motor vehicle traffic. A bikeway does not include shared lanes, sidewalks, signed routes, or shared lanes with shared lane markings, but does include bicycle boulevards.

This guide focuses on safety, but it also emphasizes the importance of comfort to appeal to a broad spectrum of bicyclists. This will encourage more people to choose to bike and in doing so will help FHWA meet its goal to increase the number of short trips made by bicycling and walking to 30 percent by the year 2025 (a 50 percent increase over the 2009 value of 20 percent), as established in its *Strategic Agenda for Pedestrian and Bicycle Transportation*.

This guide highlights linkages between the bikeway selection process and the larger transportation planning process. The bikeway type selection decision should be informed by active public involvement and participation that occurs as part of the planning process.

Bikeway type selection primarily depends on the traffic volume and operating speed characteristics of the roadway, which are often implied by their functional classification (arterial, collector, local) within various land use contexts. The land use context will likely have a big impact on the available right-of-way, the mix of roadway users, property access, traffic operating speeds, road operations and safety performance, and community goals—all of which will inform trade-off decisions.

This guide presents these factors and considerations in a practical, process-oriented way, as outlined in Figure 1 on page 4. It draws on research where available, and it emphasizes the use of engineering judgment, best practices, design flexibility, documentation, and experimentation. A comprehensive assessment of pertinent research and a literature review is available in a separate document entitled *Literature Review Resource Guide for Separating Bicyclists from Traffic* that can be found here: https://safety.fhwa.dot.gov/ped_bike/tools_solve. It also acknowledges that there are often multiple potential solutions, sometimes none of which are ideal.

Within this context, this guide reinforces the need to be clear about the design choices a practitioner is making, and to thoroughly understand safety and other trade-offs that those choices entail. This guide documents and highlights common trade-offs and advises transportation agencies on practices to describe the trade-offs associated with bikeway selection. It presents the information in a way that is targeted to practitioners, recognizing real-world constraints and focusing on helping to make day-to-day decisions about whether, and to what extent, to separate bicyclists from motor vehicle traffic.

Guide Outline

Section 2: The bikeway selection process begins with policy. This section describes ways that policy provides the framework for bikeway selection decision making in the transportation planning, project development, design, and project delivery processes.

Section 3: This section focuses on key aspects of the planning process that influence bikeway type selection. This section culminates in a discussion about a project's purpose, or why it is being undertaken and what it is intended to accomplish.

Section 4: This section focuses on bikeway selection. It identifies strategies for selecting the desired bikeway type based on the design user and roadway context. It then outlines an approach for assessing and refining options, evaluating their feasibility, and selecting the preferred bikeway type.

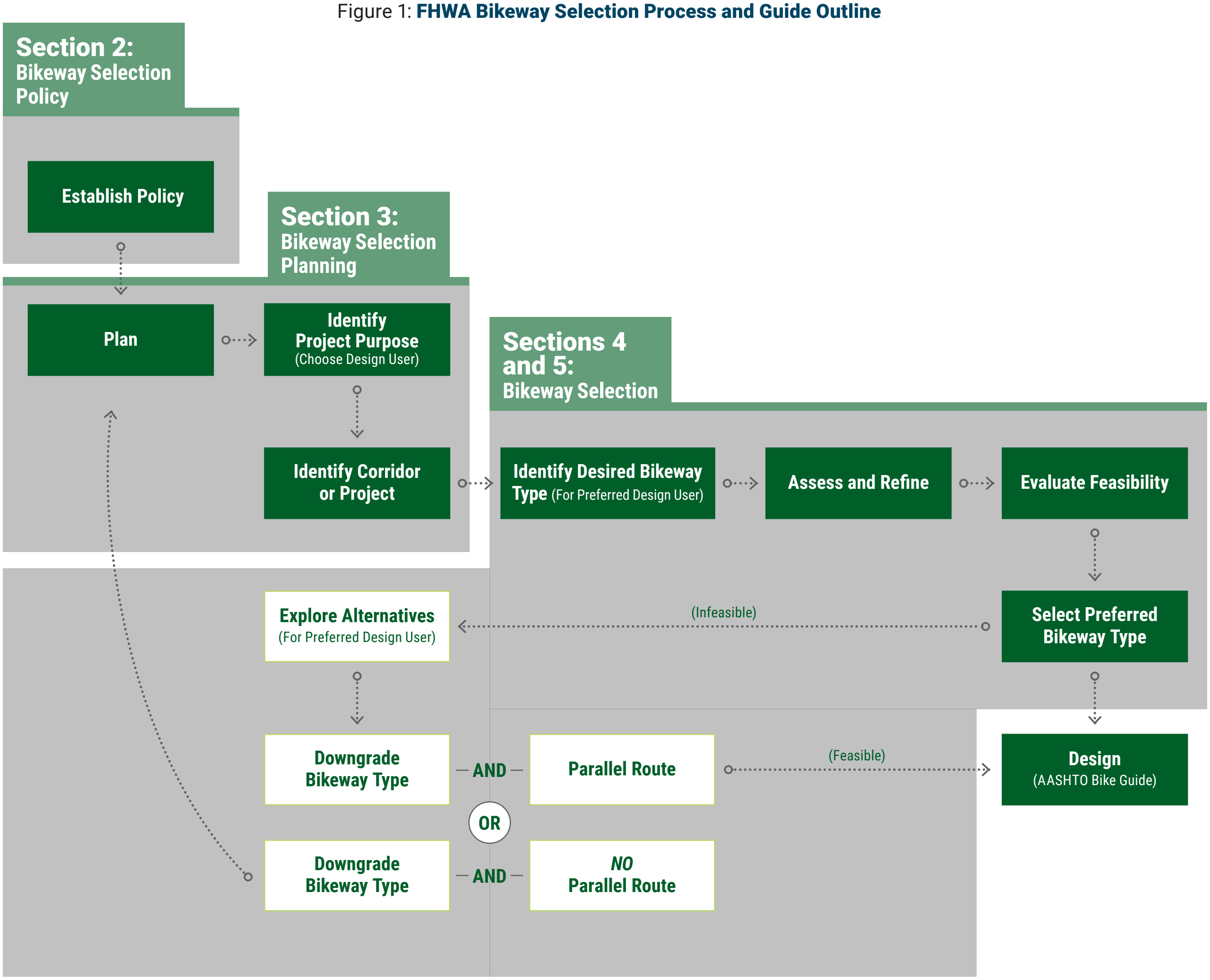
Section 5: This section highlights real-world decisions on a range of common roadway types. It identifies options and describes how the bikeway choice impacts bicyclists and people traveling by other modes.

Bikeway type selection has important safety implications. It also influences other aspects of planning and design of specific projects, whether along a corridor or within a broader bikeway network. The information in this guide is intended to streamline the bikeway selection process, accelerate project delivery, foster the development of connected networks, and improve safety for all users.

Traffic Volumes and Safety of Vulnerable Users

Over the last few decades, research suggests that bicyclist risk decreases as the number of bicyclists increases. This phenomenon is known as "safety in numbers." Greater safety attracts more bicyclists, resulting in safer cycling conditions overall. Multiple studies show that the presence of bikeways, particularly low-stress, connected bikeways, positively correlates with increased bicycling. This in turn results in improvements in bicyclists' overall safety.

Figure 1: **FHWA Bikeway Selection Process and Guide Outline**



2. Bikeway Selection Policy

A transportation agency's policies can help to define a vision for the transportation network. They can also support consistent implementation of projects that meet the needs of all users. Policies can address a broad range of topics, such as bikeway selection, funding, project development, planning, design, accessibility, and maintenance. Policies are also useful to guide and prioritize acceptable trade-offs. The following section highlights examples of how policies can provide context and serve as a framework for the bikeway planning and selection process.

Policies relating to bikeway selection can:

1. **Define specific goals and expectations for the bicycle network.** For example, an agency may establish a policy stating that the primary bicycle network should serve the "interested but concerned" user type and/or be designed to support a target bicycle mode share (see page 13).

2. **Make the linkage between bikeway selection and broader goals for multimodal access and safety.** Vision Zero policies and related "Road to Zero" or "Toward Zero Deaths" initiatives can specifically reference bikeway selection as a strategy for reducing fatalities and serious injuries. Policies can explain how bikeway selection occurs as part of all transportation activities and funding programs. They can also explain the relationship between broader goals for level of service (LOS) and the project's defined purpose. For example, as part of the long-range planning process, an agency can establish a desired LOS for bicyclists and identify the bikeway types that will achieve the desired LOS.

3. **Define the metrics for success.** Complete Streets implementation can be measured by how closely transportation projects match expectations for bikeway selection and achieve desired goals. These metrics can be included and updated in agency policy, and many agencies routinely report on progress toward these goals. Policies can direct the agency to track implementation of the bikeway network and preferred bikeway types. An agency can also evaluate outcomes according to safety and mobility metrics and describe the issues that may have led to a final decision. Tracking and reporting can identify improvements to the agency's bikeway selection policy or implementation strategies. Metrics of success should be tied to performance—instead of using miles of bikeways which may be disconnected, a more effective metric could be low-stress bikeway network connectivity.

4. **Provide a transparent framework for prioritizing and programming transportation projects, including specific bikeway types.** Policies can promote a transparent decision making process for prioritizing and funding transportation projects and bikeways.

5. **Define different planning contexts and design considerations used to select desired bikeways.** Roadways pass through a broad range of land use and development contexts, such as rural areas and urban centers. An agency's policies for bikeway selection can clearly describe planning context and highlight relevant factors such as topography, curbside uses, geographic distribution of destinations, local plans, and traffic characteristics. Policies can also address accessibility requirements and guidelines. For example, agency policy can demonstrate how people with disabilities will be able to cross a separated bike lane.

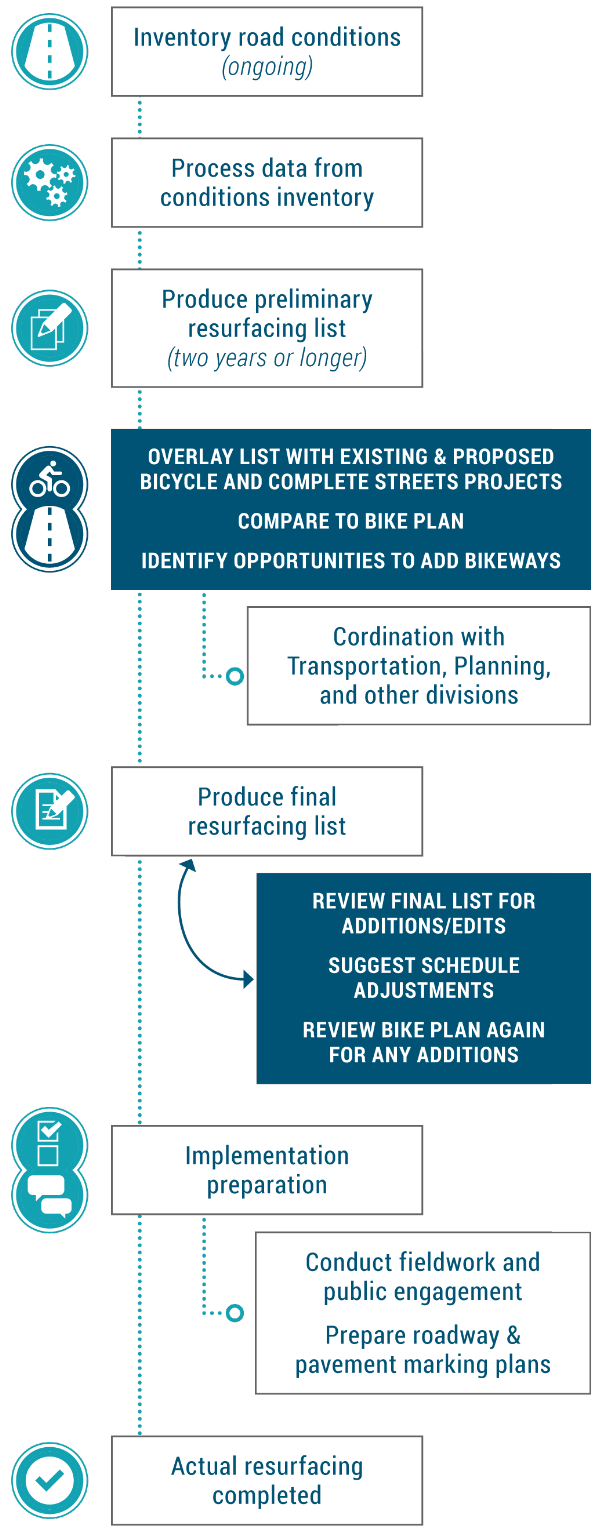
6. **Explain a preferred approach to design flexibility and experimentation when selecting bikeway types.** Projects often encounter constrained rights-of-way and other factors that influence the selection of a preferred bikeway type or an alternative. Policies can describe how strongly the agency will adhere to its bicycle network plan and to what extent the decision making process will grant exceptions to the preferred bikeway type.

7. **Direct the agency to prepare project-level feasibility assessments and engage the public on complex bikeway selection decisions.** As local officials and the public ask questions about potential impacts and trade-offs associated with bikeway options, agency policy can describe an approach to producing a detailed feasibility study or scoping assessment prior to making a final bikeway selection. A feasibility study can also provide for more public input and opportunities to educate the public about the purpose and benefits of various bikeway types. Policies can also describe an approach to engaging the public. An agency may establish an online portal or process by which the public can submit requests for bikeway improvements or comments about existing facility maintenance and operations.

8. **Highlight the linkage between bikeway selection and state or local traffic ordinances and control standards.** For example, some states have laws that require cyclists to ride in designated bikeways, but most provide flexibility to the cyclist depending on the bicyclist's experience and roadway conditions.

9. **Proactively address bikeway selection as part of maintenance activities.** Bikeways can be integrated into routine maintenance activities, such as roadway resurfacing projects. Agency policies can outline a specific process for identifying and capturing opportunities. Figure 2 is an excerpt from FHWA's workbook on *Incorporating On-Road Bicycle Networks into Resurfacing Projects*, and it highlights numerous points in the planning and design process in which bikeway selection decisions will occur.

Figure 2: Roadway Resurfacing



This chart, from FHWA's resource on *Incorporating On-Road Bicycle Networks into Resurfacing Projects*, highlights points in the roadway resurfacing planning and design process where bikeway selection occurs.

Source: FHWA

The Dutch Approach to Safety and Bikeway Selection

Between the 1950s and 1970s, the Netherlands and the United States began an intense period of auto-centric planning. The resulting increases in motor vehicle travel led to a steady increase in transportation related fatalities. In 1972 transportation-related fatalities peaked in both countries. Improvements in roadway design, vehicle design, and medical care since the early 1970s have led to decreases in fatalities between 1972 and 2011, and between 1972 and 2017, as shown in Table 1 below.

While there may be many explanations for these changes in raw numbers, it is notable that even during the period of increased distracted driving (since 2011), fatalities continue to drop in the Netherlands while they have dramatically increased in the United States.

How has the Netherlands built one of the safest transportation systems in the world?

In the early 1970s the Dutch shifted from the auto-centric approach to a Safe Systems (defined as Sustainable Safety in 1997) approach in response to public protests of the high numbers people killed, particularly children (~400 in 1971). The public also opposed the degradation of the public realm, environment, and quality of life resulting that comes with widening roadways through cities. The Dutch Sustainable Safety program has proven to be among the most effective in the world. It is a proactive approach to prevent fatalities and serious injuries through roadway design practices. Because of the program's success, many practitioners look to the Netherlands for inspiration and guidance.

The Most Effective Features of Sustainable Safety

The Dutch Sustainable Safety program includes traditional reactive strategies to address crashes that have occurred as well as efforts to improve vehicle design. The improved safety outcomes, however, are largely obtained by the preventative approach to roadway design which strives to prevent serious crashes, and where crashes do occur, to minimize the risk of severe injury. This approach assumes human error. This results in roadway design practices which strive to minimize situations where there are likely to be large differences in speed and mass operating together or at conflict points.

The Sustainable Safety approach shifts the primary responsibility for safety from the system users (an approach that focues on education and enforcement strategies) to require system designers to accept the primary responsibility to achieve safety goals.

The following page explains the five core elements of the Netherlands Sustainable Safety Program.

Table 1: Comparison of Transportation-Related Fatalities in the United States and the Netherlands, 1972 to 2017

	Fatalities (1972)	Fatalities (2011)	Fatalities (2017)
United States	54,589	32,367 (- 40.7%)	40,100 (- 26.6%)
Netherlands	3,506	661 (- 81.1%)	613 (- 82.5%)

Netherlands Sustainable Safety Design Principles

FUNCTIONALITY: Roads can be categorized by three distinct functions within a hierarchical network—through roads, distributor roads, and access roads. Through roads (arterials) are best suited for through traffic and are designed to move vehicles efficiently from A to B. Access roads (local) feature low speeds, allowing vehicle traffic to mix with pedestrians and cyclists. Residential streets are the majority of access roads and focus on safe, slow streets that prioritize pedestrians. Distributor roads (collector) connect access and through roads, encouraging traffic flow and providing safe interchanges, particularly when intersecting a road with a different function.

HOMOGENEITY: Roads with vehicles of balanced speeds, directions, and masses are the safest. Reductions in speed can mitigate the risk of serious injury or fatality and can be managed through roadway design. Where speeds are high, and road users of varying masses are moving in different directions, separation can prevent conflicts and serious injury.

PREDICTABILITY: Roads should be intuitive so that users can recognize and know what to expect. Roadway design can encourage road users to behave in a way that is expected and in line with the posted speed limit.

FORGIVENESS: Infrastructure can be designed to accommodate human error, minimizing the risk for serious injury or fatality. The layout of a road can significantly influence traffic behavior. Forgiving streets ensure that even when something does go wrong, the risk of severe consequence is mitigated.

STATE AWARENESS: Awareness of individual road users is encouraged to improve safety for all users. Factors that contribute to awareness include the condition of the road, weather, driving skills, impairment, stress, and fatigue.

The Design Manual for Bicycle Traffic (CROW Manual) is a resource that informs decisions about creating and maintaining effective cycling infrastructure in the Netherlands.

For additional related information, see FHWA's report on Bicycle Network Planning and Facility Design Approaches in the Netherlands and the United States at [https://www.fhwa.dot.gov/environment/bicycle_pedestrian/publications/network_planning_design.](https://www.fhwa.dot.gov/environment/bicycle_pedestrian/publications/network_planning_design)

3. Bikeway Selection Planning

Bikeway type selection should not be done in isolation. The decision is part of a broader planning process that accounts for roadway and traffic characteristics of all modes, including freight, transit, personal vehicles, emergency access, bicyclists, and pedestrians. It includes community goals and priorities as well as public involvement and feedback from all parts of the community.

Vision

At the core of the planning process is a vision for a future bicycle network. The vision is developed through a planning process and is typically documented in a local, regional, or state plan. The vision describes desired future characteristics of and outcomes for bicycle transportation and typically defines, explicitly or implicitly, the target bicyclist design user type (as described on page 13).

The vision for the bike network can inform planning-related activities, such as decisions regarding where an agency chooses to pave shoulders and transportation recommendations in a small area plan. It should also be integrated into planning discussions about large scale transportation initiatives and plans for other types of networks, such as transit and freight.

To strengthen the vision, an agency may set it into policy. Agencies may consider adoption of the Safe Systems or Sustainable Safety policy, as described in the previous pages, which applies to all transportation decisions. In this case, the agency might prioritize the most vulnerable road users above other transportation objectives. These priorities inform the planned network and specific objectives for each transportation improvement project.

The Bicycle Network

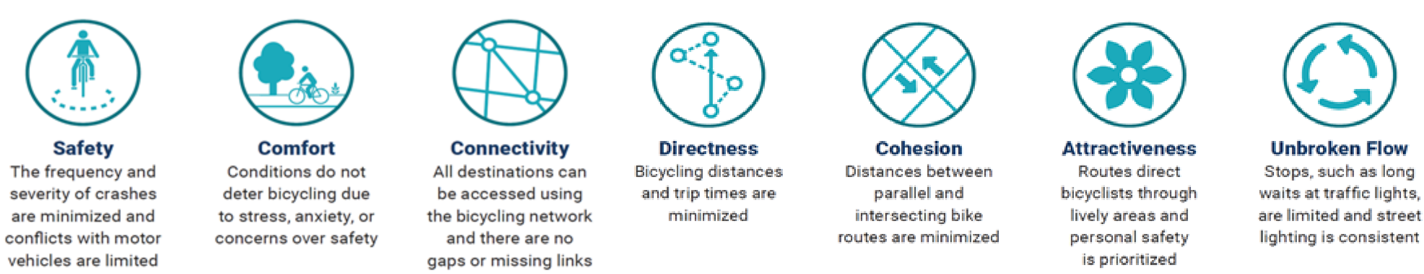
A bicycle network is a seamless interconnected system of bikeways. The purpose and quality of the network depends on the assumptions, goals, and decisions made during the planning process. Networks should be thoughtfully planned to provide necessary and desired connections and access. The most successful bicycle networks enable people of all ages and abilities to safely and conveniently get where they want to go.

The bicycle network informs bikeway type selection by showing where higher quality facilities are needed the most. If a project is planned on a roadway that is a critical link in the bike network, including the appropriate bike infrastructure should be prioritized as a part of that project. A lower quality bikeway such as a regular bike lane on a busy suburban arterial road with high-speed traffic is a missed opportunity to build out a low-stress/high comfort bike network that serves a greater portion of the population. The opportunity to make a high-quality connection may not occur again for decades. While this bike lane may be an improvement over no bikeway facility, it will not be appealing for most people given the context.

Similarly, if a project is planned on a road that is not part of the bike network, a trade-off on the quality of the bike facility might be more acceptable (keeping in mind that bicyclists have a right to travel on all public roads, unless prohibited, whether or not a bicycle facility is present).

By influencing bikeway selection in this way, the planned bicycle network helps communities be strategic about investments and implementation, while also helping to balance competing network needs, such as for transit and freight. It helps agency staff and advocates set priorities by recognizing that every individual street or road does not serve the same role in the network and that some are more important than others. The network also helps to determine the extent to which a parallel route (described on page 34) is a feasible alternative.

Figure 3: Seven Principles of Bicycle Network Design



Bicycle Network Vision Statements

Massachusetts Department of Transportation Statewide Bike Plan Vision

Massachusetts' integrated and multimodal transportation system will provide a safe and well-connected bicycle network that will increase access for both transportation and recreational purposes. The Plan will advance bicycling statewide as a viable travel option - particularly for short trips of three miles or less - to the broadest base of users and free of geographic inequities.

Louisiana Complete Streets Policy Update

The intent of this policy is to create a comprehensive, integrated, connected transportation network for Louisiana that balances access, mobility and safety needs of motorists, transit users, bicyclists, and pedestrians of all ages and abilities, which includes users of wheelchairs and mobility aids.

Network Principles

Effective bicycle networks lead to more people bicycling by creating bicycling routes that are efficient, seamless, and easy to use. Seven key principles for bicycle network design are highlighted in Figure 3.

Of these seven principles, three have particular importance in guiding bikeway selection:

Safety: Roadway and bikeway designs should be selected to reduce the frequency and severity of crashes and minimize conflicts between users.

Comfort: Bikeway facilities should be selected to minimize stress, anxiety, and safety concerns for the target design user. Comfort and safety are closely related.

Connectivity: Trips within a bicycle network should be direct and convenient and offer access to all destinations served by the roadway network. Transitions between roadways and bikeways should be seamless and clear.

Bicycle Network Planning Resources

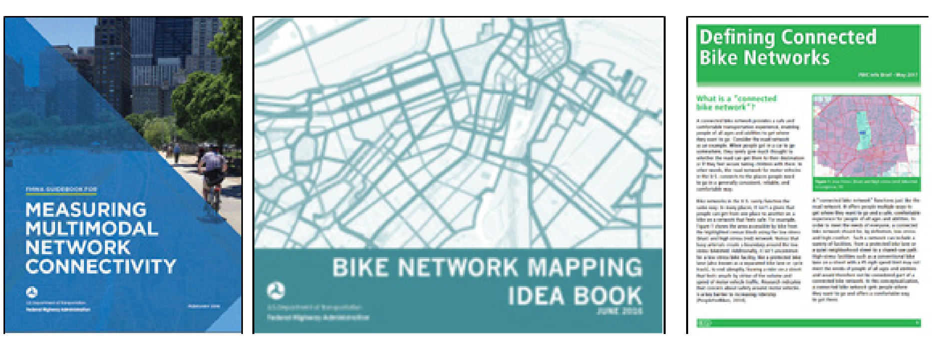
Numerous resources are available to communities that are planning bicycle networks. As shown in Figure 4, two key FHWA resources include *Measuring Multimodal Network Connectivity* and the *Bike Network Mapping Idea Book*. The Pedestrian and Bicycle Information Center also recently published a white paper on Defining Connected Bike Networks. Other resources include the planning chapter of the AASHTO *Guide for the Development of Bicycle Facilities* and the ITE *Transportation Planning Handbook*.

Network Form

Bike networks take on many forms based on community vision, planning horizon, preferred bikeway type, and—most importantly—geographical and physical context. Some bike networks follow an established street grid, while others are primarily comprised of shared use paths following waterways, railroads, and utility easements.

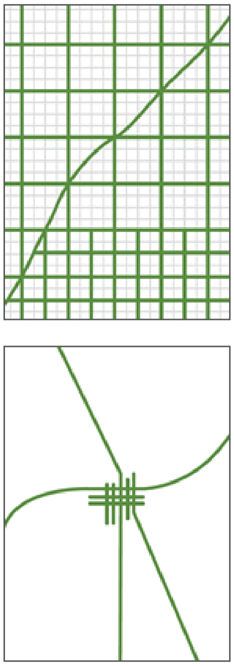
Some bike networks emphasize local circulation within neighborhoods and a challenge in the planning process is to connect these districts to each other. Figure 5 on page 12 shows examples of how bike network form can impact bikeway selection.

Figure 4: National Bike Network Resources



Source: Federal Highway Administration and Pedestrian and Bicycle Information Center

Figure 5: Examples of Bicycle Network Forms



The level to which the preferred bikeway type should be compromised, if compromise is necessary, should be informed by the relative importance of the segment within the larger network and the availability of alternative routes. For example, if the form of the bike network is a grid, a compromise on one segment may be acceptable given that a high-quality parallel route may be available.

In contrast, if there is only one roadway that provides access for bicyclists, for example to a downtown center, compromising on the bikeway type is less desirable.

Common Network Considerations Relating to Bikeway Selection

The following are common questions to ask when selecting a bikeway that will be compatible with the bicycle network.

- Where does this route fit within the bicycle network hierarchy?
- Does the route have a viable parallel alternative? The land use context and transit access along the parallel route should appeal to and attract bicyclists from the primary route while offering a more comfortable bikeway type.
- Does this route connect regional trails or other networks that are frequented by younger, older, or disabled cyclists? The bikeway type should match the needs of users of all ages and abilities.
- Is the route along a road that already supports low-stress bicycling and does not improve connectivity to the network? The roadway may not need to be further improved for bicycling.
- What are the safety implications and potential safety-related trade-offs for different bikeway types along this route?

User Types

Understanding the characteristics of different types of bicyclists helps to inform bikeway selection. Characteristics commonly used to classify user profiles are comfort level, bicycling skill and experience, age, and trip purpose. However, people may not fit into a single user profile, and a bicyclist's profile may change in a single day. For example, a commuter bicyclist who is comfortable bicycling within a bicycle lane when traveling alone may prefer to bicycle on a quiet residential street or shared use path when traveling with children.

In addition to other factors, people who bicycle are influenced by their relative comfort operating in close proximity to motor vehicle traffic. Many people are interested in bicycling for transportation but are dissuaded by the potential for stressful interactions with motor vehicles. The following sections examine how comfort, skill, and age may affect bicyclist behavior and preference for different types of bikeways.

When used to inform bikeway design, the bicyclist user profile becomes the "design user profile." Selecting a design user profile is often the first step in assessing a street's compatibility for bicycling. The design user profile should be used to select a preferred type of bikeway treatment for different contexts. Of adults who have stated an interest in bicycling, research has identified three types of potential and existing bicyclists.[2] Children were not included in the research and require special consideration in the design of bikeways. There is some overlap between these groups and the goal, as it pertains to the planning process, is to better understand and account for the general needs of different types of bicyclists. The three types are highlighted below.

Highly Confident Bicyclist

Highly Confident Bicyclists are the smallest group identified by research. While some of these individuals bicycle less frequently, when they do, they prefer direct routes and do not avoid operating in mixed traffic, even on roadways with higher motor vehicle operating speeds and volumes. Many also enjoy bikeways separated from traffic; however, they may avoid bikeways which they perceive to be less safe or too crowded with pedestrians or other slower moving bicyclists, or which require deviation from their preferred route.

2 Dill, D. and N. McNeil. Revisiting the Four Types of Cyclists. In Transportation Research Record 2587. TRB, National Research Council, Washington, DC, 2016.

Somewhat Confident Bicyclist

Somewhat Confident Bicyclists, also known as Enthused and Confident Bicyclists, are the next-smallest group. They are comfortable on most types of bicycle facilities. They have a lower tolerance for traffic stress than the Highly Confident Bicyclist and generally prefer low-volume residential streets and striped or separated bike lanes on major streets, but they are willing to tolerate higher levels of traffic stress for short distances to complete trips to destinations or to avoid out-of-direction travel.

Interested but Concerned Bicyclist

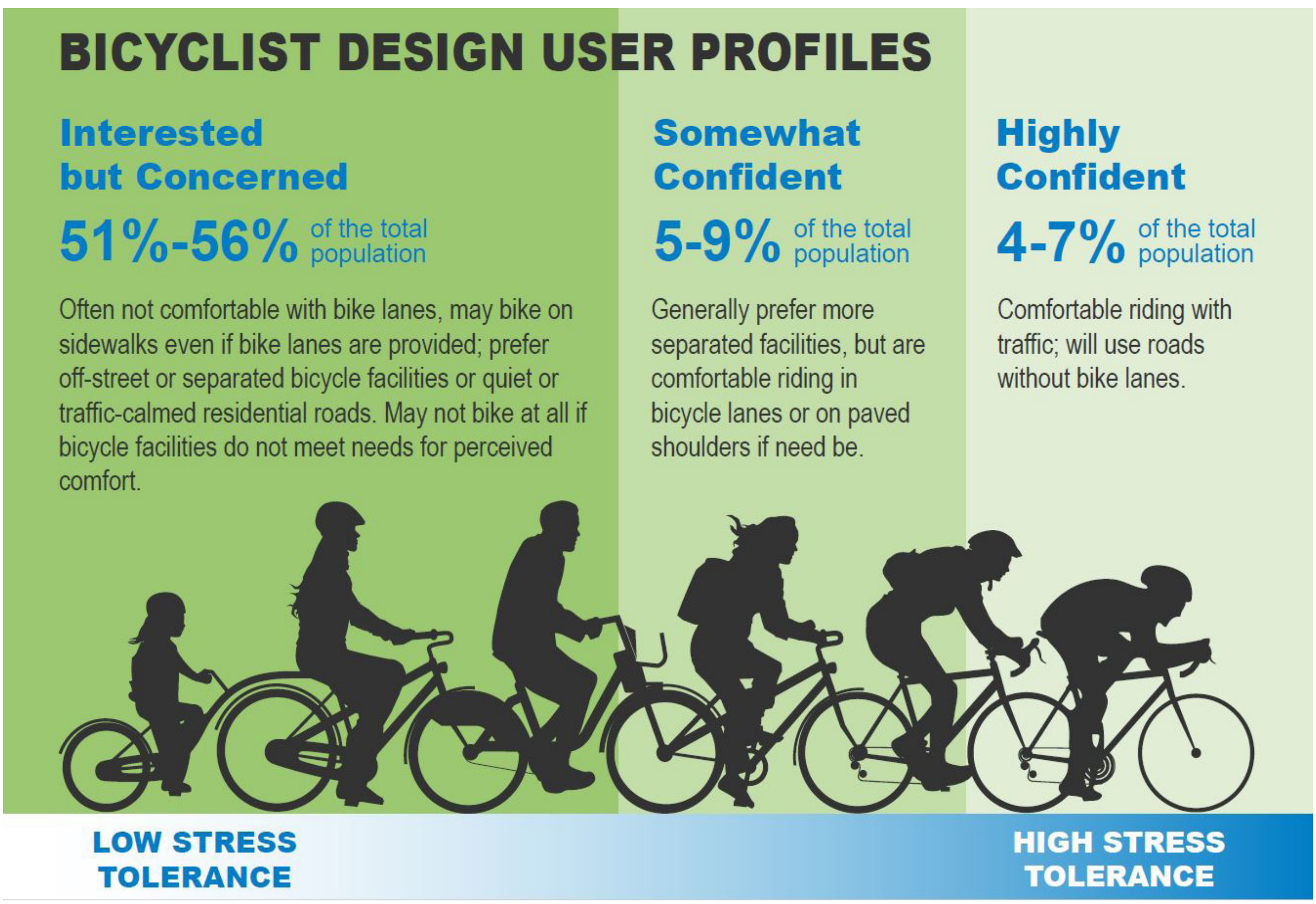
Interested but Concerned Bicyclists are the largest group identified by the research and have the lowest tolerance for traffic stress. Those who fit into this group tend to avoid bicycling except where they have access to networks of separated bikeways or very low-volume streets with safe roadway crossings. To maximize the potential for bicycling as a viable transportation option, it is important to design bicycle facilities to meet the needs of the Interested but Concerned Bicyclist category. This is generally the recommended design user profile as the resulting bikeway network will serve bicyclists of all ages and abilities, which includes Highly Confident and Somewhat Confident Bicyclists.

Target Design User

The target design user influences the safety, comfort, connectivity, and cohesion of the bicycle network. Communities establish a target design user by selecting a target comfort level for the bicycle network. Comfort and stress are inversely correlated. Exposure to high motor vehicle traffic speeds and volumes is the primary contributor of stress. High-comfort/low-stress networks serve the most people while low-comfort/high-stress networks serve the least.

While the target design user and target comfort level should be selected based on the vision, this critical decision is often overlooked. In such cases, the network typically defaults to serving Highly Confident and Somewhat Confident users in a Basic Bikeway Network (as described on page 14). Communities seeking to serve all ages and abilities will need to establish low-stress bicycle networks.

Figure 6: Bicyclist Design User Profiles



Note: the percentages above reflect only adults who have stated an interest in bicycling.

Low-Stress Bicycle Network

A Low-Stress Bicycle Network (also referred to as an "all ages and abilities network" or a "high comfort network") is one that is designed to be safe and comfortable for all users. The emphasis is on the quality of the bikeway, not just the presence of a bikeway. Depending on roadway conditions, a given street or bikeway may not be sufficient to provide a safe and comfortable experience for all bicyclists. For example, an adult new to bicycling or a parent pulling their child in a bike trailer may not be willing to use a traditional bike lane on a multi-lane road with high speeds and volumes of traffic.

Low-Stress Networks rely on separating bicyclists from traffic using separated bike lanes and shared use paths.[3] Low-speed and low-volume streets with the operating characteristics of bicycle boulevards also support these networks if safe crossings of busy roads are provided. Low-Stress Networks can also adequately serve confident bicyclists.

By serving a broad audience of existing and potential bicyclists, Low-Stress Networks maximize system use by serving high percentages of shorter distance transportation and utilitarian trips for all types of bicyclists. Low-Stress Networks have resulted in bicycling rates of 5-15 percent in the United States, and of 15-50 percent in countries that have robust low-stress networks complemented by supportive transit, land use, and other policies. Mode shares will likely vary based on the wide range of contexts found in the U.S.

Interim bikeway network types include:

- **Basic Bikeway Network**: Completing a bikeway network will take time and investment. Many existing bicycle networks rely on bikeways that do not provide separation. These can be improved for bicycling by slowing motor vehicle speeds and implementing other speed management measures. For additional information on current traffic calming practice, visit https://safety.fhwa.dot.gov/speedmgt/traffic_calm.cfm. Bicycle networks that consist primarily of bicycle lanes and shoulders may be called Basic Bikeway Networks. These networks support Highly Confident Bicyclists and some Somewhat Confident Bicyclists. There are several examples of cities in the United States with Basic Bikeway Networks and these networks generally have bicycle mode shares of 2 to 3 percent.
- **Traffic-Tolerant Bicycle Network:** A network that relies primarily on roadways without specific bicycle improvements may be referred to as a Traffic-Tolerant Network to indicate that it serves only those Highly Confident Bicyclists who are likely already riding. This type of network will likely not meet the needs of Somewhat Confident Bicyclists or Interested but Concerned Bicyclists—including children and young adults—because they may find it to be uncomfortable. As a result, the amount of people bicycling will likely remain below 2% over time.

Proximity to motor vehicle traffic is a significant source of stress and discomfort for bicyclists: crash and fatality risks sharply rise for vulnerable users when motor vehicle speeds exceed 25 mph. Further, as motorized traffic volumes increase above 6,000 vehicles/day, it becomes increasingly difficult for motorists and bicyclists to share roadway space.

For example, on a roadway with 10,000 vehicles/day, a bicyclist traveling at 10 mph will be passed approximately every four seconds by a motor vehicle during the peak hour. Research indicates motorists also feel more comfortable operating on streets where bicyclists are separated from motor vehicle traffic.

Blended Networks

Many communities take a hybrid approach to network planning. A common practice is to plan a focused low-stress network (sometimes referred to as a "spine network") that creates the most important connections, and then augment it with a basic bikeway that creates additional connections to less popular destinations.

In these cases, the importance of selecting appropriate bikeway facilities is greatly increased. If a high-stress bicycle facility type is selected for a project on the low-stress subset network, the integrity of the network is compromised.

3 City of Austin. 2014 Austin Bicycle Plan. Austin Transportation Department, Austin, TX. November 2014.

Bikeway Types

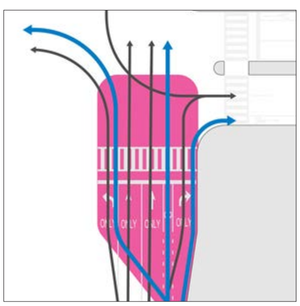
With evidence of the "safety in numbers" effect growing stronger, the development of connected networks of comfortable bikeways that are attractive to the widest range of bicyclists (e.g. the "Interested but Concerned" bicyclist profile) would have the greatest potential to increase bicycle use, and thereby increase individual bicyclist safety. The efficacy of each treatment below requires consideration of many contextual factors such as traffic volume, traffic speed, intersection design, and land use, among other factors. Generally, bikeways have a more positive impact on safety outcomes for bicyclists than shared lanes.

The following discussion provides an overview of shared lanes and bikeways. In general, the bikeway design should be consistent and continuous from mid-block locations through intersections. For example, it is not best practice to design mid-block bike lanes and transition to shared lanes at each intersection. A key consideration for Sustainable Safety is to minimize bicyclists exposure to motor vehicle traffic, which is best accomplished by providing continuous bikeways. Figure 7 provides an overview of bicyclist comfort and safety under the four common intersection configurations: shared lanes, bike lanes/shoulders, mixing zones, and protected intersections.

The table on the following pages highlights intersection considerations and performance characteristics for the bikeway types highlighted in this section. These intersection considerations are organized by the elements of the Netherlands Sustainable Safety Program presented on page 9. This information is intended to build on the information in Figure 7, which compares bicyclist safety and exposure to potential motor vehicle conflict at intersections by bikeway type.

Figure 7: Comparison of Bicyclist Comfort and Safety at Intersections

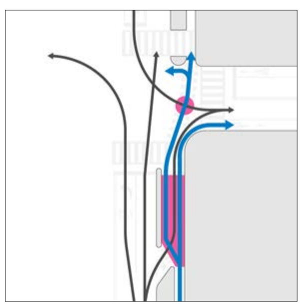
Exposure Level:
High



CONVENTIONAL BIKE LANES AND SHARED LANES

Bike lanes and shared lanes require bicyclists to share and negotiate space with motor vehicles as they move through intersections. Motorists have a large advantage in this negotiation as they are driving a vehicle with significantly more mass and are usually operating at a higher speed than bicyclists. This creates a stressful environment for bicyclists, particularly as the speed differential between bicyclists and motorists increases. For these reasons, it is preferable to provide separation through the intersection.

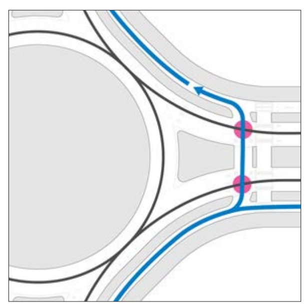
Exposure Level:
High to Medium



SEPARATED BIKE LANES WITH MIXING ZONES

One strategy that has been used in the U.S. at constrained intersections on streets with separated bike lanes is to reintroduce the bicyclist into motor vehicle travel lanes (and turn lanes) at intersections, removing the separation between the two modes of travel. This design is less preferable to providing a protected intersection for the same reasons as discussed under conventional bike lanes and shared lanes. Where provided, mixing zones should be designed to reduce motor vehicle speeds and minimize the area of exposure for bicyclists.

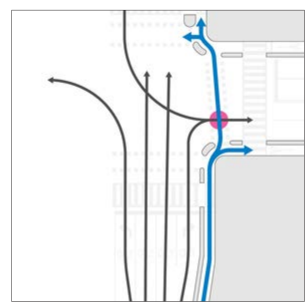
Exposure Level:
Medium to Low



SEPARATED BIKE LANES THROUGH ROUNDABOUTS

Separated bike lanes can be continued through roundabouts, with crossings that are similar to, and typically adjacent to, pedestrian crosswalks. Motorists approach the bicycle crossings at a perpendicular angle, maximizing visibility of approaching bicyclists. Bicyclists must travel a more circuitous route if turning left and must cross four separate motor vehicle path approaches. Yielding rates are higher at single-lane roundabouts.

Exposure Level:
Low



PROTECTED INTERSECTIONS

A protected intersection maintains the physical separation through the intersection, thereby eliminating the merging and weaving movements inherent in conventional bike lane and shared lane designs. This reduces the conflicts to a single location where turning traffic crosses the bike lane. This single conflict point can be eliminated by providing a separate signal phase for turning traffic

bicycle
motor vehicle
conflict area

Source: MassDOT Separated Bike Lane Planning & Design Guide

Table 2: Intersection Performance Characteristics by Bikeway Type

	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					✓	✓

Table 2 (continued): Intersection Performance Characteristics by Bikeway Type

	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	✔	✔	✔	✔	✔	✔

Shared Lanes

In shared lanes, bicyclists ride in mixed traffic, therefore their comfort and safety varies widely based on traffic operating speeds and volumes. Shared lanes can be a positive and affordable solution when designed correctly and used in the correct context; however, the vast majority of bike/car crashes in the U.S. occur in shared lanes that are applied to inappropriate contexts and environments. While operating conditions vary widely, research has shown that the presence of on-street parking can have a significant impact on bicyclist safety operating in shared lanes. While parked vehicles may calm traffic in some scenarios, bicyclists riding alongside parked vehicles in shared lane scenarios are more exposed to being injured or killed when a vehicle operator opens their car door into their operating path. To improve operations in shared lanes, shared lane markings (SLM) and signs can be added to inform people driving that bicyclists may operate in the lane and to show where to expect cyclists. Research consistently indicates SLMs decrease the prevalence of sidewalk riding, but the majority of bicyclists (current or potential) and drivers do not feel comfortable on multi-lane or higher-speed roadways with SLMs. The Manual on Uniform Traffic Control Devices therefore suggests SLMs be restricted to roadways with operating speeds of 35 miles per hour or less.

Another type of shared lane is the wide outside lane, or wide curb lane. Research on wide outside lanes has generally found safety performance to be diminished as bicyclists tend to ride closer to the edge of the pavement, curb, or parking. Wide outside lanes are also associated with higher rates of wrong-way bicycling than streets with bikeways or SLMs.

Bicyclists are exposed to all crash types within shared lanes at intersections. The lack of a bikeway can reduce the predictability of a bicyclist's operating location. This can be exacerbated in locations where bicyclists operate in the wrong direction or on adjacent sidewalks to avoid uncomfortable traffic conditions.

Bicycle Boulevards

Bicycle boulevards are low-stress bikeways primarily located on low-volume, low-speed local streets. Treatments such as shared lane markings, wayfinding signs, and traffic calming features are implemented to prioritize bicycle travel, including at crossings with higher volume arterials. Bicycle boulevards have a lower incidence of bicycle-involved crashes than parallel arterial routes. This may be because the parallel arterial routes often don't have context-appropriate bicycle infrastructure.

On most bicycle boulevards, bicyclists are likely to approach intersections in shared lanes. Due to the lower volume and operating speeds associated with bicycle boulevards, shared lane approaches are likely to have better performance characteristics than shared lanes. A key aspect of bicycle boulevard design is to ensure comfortable and safe crossings of intersecting arterials so that travel along the bicycle boulevard can be maintained. At approaches to higher speed and volume streets, many bicycle boulevards transition to bike lanes, separated bike lanes, or shared use paths.

Advisory Bike Lanes

Advisory bike lanes demarcate a preferred space for bicyclists and motorists to operate on narrow streets that would otherwise be shared lanes. Unlike dedicated bicycle lanes, motor vehicle use is not prohibited in the advisory bike lane and is expected on occasion. Advisory bike lanes are a relatively new treatment in North America. Dutch research has found this treatment has been effective at reducing motor vehicle operating speeds; however, consideration should be given to the bikeway type's general intuitiveness and to the potential need for education around its proper use. In order to install advisory bike lanes, an approved Request to Experiment is required as detailed in Section 1A.10 of the MUTCD.

Intersection approaches with advisory bike lanes should transition to shared lanes or bike lanes to avoid right-of-way confusion and potential for conflicts between motorists operating in opposite directions within the intersection.

Shoulders

Research shows that continuous paved shoulders and bicycle lanes act essentially the same in terms of operations as bike lanes. A major factor in the safety of shoulders for bicyclists is the presence and design of rumble strips, which can present a crash hazard or render a shoulder un-rideable for bicyclists. It should be noted that shoulders may not have any intersection treatments and the comfort of both bikeway types is influenced by maintenance considerations. For more information on rumble strip best practices, visit https://safety.fhwa.dot.gov/roadway_dept/pavement/rumble_strips.

On intersection approaches with shoulders, the shoulder will typically taper to the intersection, implying motorist priority, or transition to a bike lane design to signify that turning and crossing motorists should yield. Shoulders may also transition to one-way separated bike lanes.

Bike Lanes and Buffered Bike Lanes

Conventional and buffered bike lanes designate an exclusive space for bicyclists to operate one-way on the roadway through the use of pavement markings and signs. A research review of the safety impacts of bicycle infrastructure generally finds that they improve bicyclist safety; however, mixed results regarding collision reduction are documented because many studies do not account for factors such as exposure, maintenance, or differences in implementation (i.e., bike lanes that actually terminate to shared lanes at intersections, bike lanes that are narrower than recommended, or blocked bike lanes which require bicyclists to exit).

Intersection approaches with bike lanes require motorists to yield to bicyclists within the bike lane before entering or crossing the bike lane. This clarity can be further enhanced with bicycle lane extensions through the intersections, green colored pavement, and regulatory signs. Bike lanes may also transition to shared lanes or one-way separated bike lanes.

One-Way Separated Bike Lanes

One-way separated bike lanes are physically separated from adjacent travel lanes with a vertical element, such as a curb, flex posts, or on-street parking. One-way separated bike lanes, especially those with a physical curb, have been shown to reduce injury risk and increase bicycle ridership due to their greater actual and perceived safety and comfort.

Intersection designs should promote visibility of bicyclists and raise awareness of potential conflicts. The provision of sufficient sight distance is particularly important at locations where the on-street parking is located between the bike lane and travel lane. One-way separated bike lanes may transition to shared lanes, bike lanes, mixing zones, or protected intersections.

Intersection approaches with mixing zones require motorists to yield to bicyclists before entering or crossing the bike lane. This clarity can be further enhanced with bicycle lane extensions through the intersections, green colored pavement, and regulatory signs. Research shows protected intersections have fewer conflicts and are therefore preferable.

Two-Way Separated Bikes Lanes and Sidepaths

Two-way separated bike lanes and sidepaths are physically separated from adjacent travel lanes using elements such as a curb, flex posts, or on-street parking. They may be located on one side of a street or both sides. Unlike two-way separated bike lanes, which provide for the exclusive travel of bicyclists, sidepaths are designed to support and encourage pedestrian use. Conflicts between path users are a primary source of injuries and can result in a degraded experience for all users where paths are not wide enough to handle the mixture and volume of diverse users.

Care should be taken at intersections and driveways which intersect two-way separated bike lanes and sidepaths due to the two-way operation of bicycles in these locations. Crash patterns consistently show contra-flow movement of bicyclists are a main factor in crashes due to motorists failing to yield or look for approaching bicyclists. Where two-way separated bike lanes are implemented on one-way streets, siting these facilities to the right of automobile lanes has resulted in safer intersections for bicyclists by reducing conflicts. All intersections should be designed with protected intersections due to the two-way operation; transitions to other bikeway types should occur after the intersection.

To mitigate these conflicts, research suggests the following potential solutions:

- The application of separate phases at signals with high volumes of turning motorists
- Slow turning drivers with reduced corner radii or raised crossings
- Improve sight lines
- Raise awareness with marked crossings and regulatory signs

For more information, see the FHWA *Separated Bike Lane Planning and Design Guide*.

Road Context

The selection of a preferred bikeway type requires a balance of community priorities with data analysis and engineering judgment working within relevant constraints for the project.

The land use context is an important consideration when determining the need for and type of separation between users (bicyclists, pedestrians, and motorists). This will influence decisions such as whether to provide a sidepath or a separated bike lane or whether and to what extent to separate bicyclists from pedestrians. Another consideration is the volume, speed, and mass of motor vehicle traffic.

Table 3 shows Context Classifications for Geometric Design from the latest version of AASHTO's Green Book. These context classifications take into account land use, density, setbacks, and other factors. Combined with the existing functional classifications, they are intended to help practitioners balance user needs and safety. Documenting and accounting for context is an important part of the planning process. Context also informs bikeway selection, as described in the following section.

Project Type

The bikeway selection process will be influenced by the type of project pursued and the construction methods inherent in that project type. The AASHTO Green Book categorizes the following three general project types based on the extent of construction:

- **New construction** – Roadway projects constructed on a new alignment
- **Reconstruction** – Projects on existing alignments that change the basic road type
- **Construction on existing roads** – Projects that retain the existing roadway alignment (except for minor changes) and do not change the basic roadway type

For new construction and reconstruction projects, there are usually fewer constraints and the preferred bikeway type can be implemented. However, projects on existing roads and reconstruction projects involve right-of-way and other constraints that should be taken into consideration and may result in a modification to the preferred bikeway. The decision to modify the design should consider allowable design flexibility and trade-offs as

Table 3: Context Classification for Geometric Design

Category	Description
Rural	The rural context applies to roads in rural areas that are not within a developed community. These include areas with the lowest development density; few houses or structures; widely dispersed or no residential, commercial, and industrial land uses; and usually large building setbacks. The rural context may include undeveloped land, farms, outdoor recreation areas, or low densities of other types of development.
Rural Town	The rural town context applies to roads in rural areas located within developed communities. Rural towns generally have low development densities with diverse land uses, on-street parking, and sidewalks in some locations, and small building setbacks. Rural towns may include residential neighborhoods, schools, industrial facilities, and commercial main street business districts, each of which present differing design challenges and differing levels of pedestrian and bicycle activity. The rural town context recognizes that rural highways change character where they enter a small town, or other rural community, and that design should meet the needs of not only through travelers, but also the residents of the community.
Suburban	The suburban context applies to roads and streets, typically within the outlying portions of urban areas, with low to medium development density and mixed land uses (with single-family residences, some multi-family residential structures, and nonresidential development including mixed town centers, commercial corridors, big box commercial stores, light industrial development). Building setbacks are varied with mostly off-street parking. The suburban context generally has lower development densities and drivers have higher speed expectations than the urban and urban core contexts. Pedestrians and bicyclist flows are higher than in the rural context, but may not be as high as found in urban and urban core areas.
Urban	The urban context has high-density development, mixed land uses, and prominent destinations. On-street parking and sidewalks are generally more common than in the suburban context, and building setbacks are mixed. Urban locations often include multi-story and low- to medium-rise structures for residential, commercial, and educational uses. Many structures accommodate mixed uses: commercial, residential, and parking. The urban context includes light industrial, and sometimes heavy industrial, land use. The urban context also includes prominent destinations with specialized structures for entertainment, including athletic and social events, as well as conference centers. In small- and medium-sized communities, the central business district may be more an urban context than an urban core context. Driver speed expectations are generally lower and pedestrian and bicyclist flows higher than in suburban areas. The density of transit routes is generally greater in the urban context than the suburban context, including in-street rail transit in larger communities and transit terminals in small- and medium-sized communities.
Urban Core	The urban core context includes areas of the highest density, with mixed land uses within and among predominantly high-rise structures, and with small building setbacks. The urban core context is found predominantly in the central business districts and adjoining portions of major metropolitan areas. On-street parking is often more limited and time restricted than in the urban context. Substantial parking is in multi-level structures attached to or integrated with other structures. The area is accessible to automobiles, commercial delivery vehicles, and public transit. Sidewalks are present nearly continuously, with pedestrian plazas and multi-level pedestrian bridges connecting commercial and parking structures in some locations. Transit corridors, including bus and rail transit, are typically common and major transit terminals may be present. Driver speed expectations are low and pedestrian and bicycle flows are high.

Source: AASHTO Green Book: A Policy on Geometric Design of Highways and Streets, 7th Edition, 2018.

described in detail in the following section. If the preferred facility type is not feasible, the next-best facility should be considered, as described on page 33.

Regardless of the project type, the resulting design solution should include measures intended to result in motor vehicle operating speeds that are in line with desired operating speeds necessary to improve the safety of all users.

Intersection Considerations

In 2016, 58 percent of cyclist fatalities occurred outside of intersection locations, in both urban and rural areas, and 30 percent occurred at intersections.[4] Research has determined that the following behaviors are most commonly associated with bicyclist crashes, including fatal and non-fatal crashes, on U.S. roadways:[5]

- Cyclists operating in shared lanes
- Cyclists riding against traffic on roadways
- Motorists or cyclists failing to yield or stop at intersections
- Right-hook crashes: motorists pass a cyclist (traveling the same direction) and crash into the cyclist while making a right turn
- Left-hook crashes: motorists crash into the cyclist when making a left turn

Intersection treatments that connect separated bikeways, or roadway designs that minimize vehicle operating speed and volume, may improve safety outcomes for bicyclists compared to operating in shared lanes.[6] However, the practitioner should also consider research that found that bicyclists traveling contra-flow to motor vehicle traffic are at an elevated risk of a crash due to reduced awareness of motorists across all types of facilities.[7] Additional research is needed to understand how poor design or user error may have led to these contra-flow crashes. More research to develop or improve crash modification factors for specific bicycle facility types will improve bikeway selection in the future.

Identify Project Purpose

The design of roadways—and therefore the selection of bikeways—often happens within a continuing, cooperative, and comprehensive planning process that uses a performance-driven approach for decision making. Public agencies that are responsible for the operation, maintenance, and development of transportation systems and facilities work cooperatively to determine long and short-range investments. Public agencies at all scales, from small towns, transit authorities, and Metropolitan Planning Organizations (MPOs) to State Departments of Transportation, carry out planning, with active involvement from the traveling public, the business community, community groups, environmental organizations, and freight operators.

Factors that can inform the identification of a specific project include:

- **Project Limits:** Project limits should enhance network continuity and user safety. Where transitions are necessary, their design should be logical and intuitive for bicyclists, pedestrians, and motorists. Logical project limits should be established to meet the desired connectivity and safety objectives of the project for bicyclists.
- **Land Use Context:** Differences in land use can impact the distances between destinations and the expected number and types of bicyclists. Land use is therefore an important consideration in determining the preferred bikeway type.
- **Types of Bicyclists the Bikeway is Expected to Serve:** Most of the population falls into the Interested but Concerned category, who, along with children, are typically the default design users in urban and suburban contexts. Rural roadways are more likely to serve more confident adult bicyclists, and the default design user profile is typically the Highly Confident or Somewhat Confident categories. However, some rural roadways, for example those near resort and vacation areas or in areas with Amish or Mennonite populations, also attract young bicyclists. Potential latent demand should also be considered.
- **Key Safety and Performance Criteria:** The planning process should address how the proposed bikeway fits within the larger framework of the bicycle network. For example, is this facility a key connection in a regional network of bikeways? Does it connect two off-road shared use paths? It can also highlight important safety issues for bicyclists as well as other modes of travel. The bikeway selection process is initiated once a corridor or project has been identified. This process is outlined in the following section.

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4 National Highway Traffic Safety Administration (NHTSA) National Center for Statistics and Analysis. "2016 Traffic Safety Facts: Bicyclists and Other Cyclists" https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/812507

5 Portland Office of Transportation. (2007). Improving Bicycle Safety in Portland. Thomas, L., Levitt, D., and Farley, E. (2014). North Carolina Bicycle Crash Types: 2008-2012. North Carolina Department of Transportation Division of Bicycle Transportation.

6 Mead, J., McGrane, A., Zegeer, C., Thomas, L. (2014) Evaluation of Bicycle-Related Roadway Measures: A Summary of Available Research. Federal Highway Administration.

7 Wachtel, A., and Lewiston, D. (1994). Risk Factors for Bicycle-Motor Vehicle Collisions at Intersections. ITE Journal, pp. 30-35. Petrisch, T., Landis, B., Huang, H., and Challa, S. (2014). Sidepath Safety Model: Bicycle Sidepath Design Factors Affecting Crash Rates. Transportation Research Record 1982, pp. 194-201.

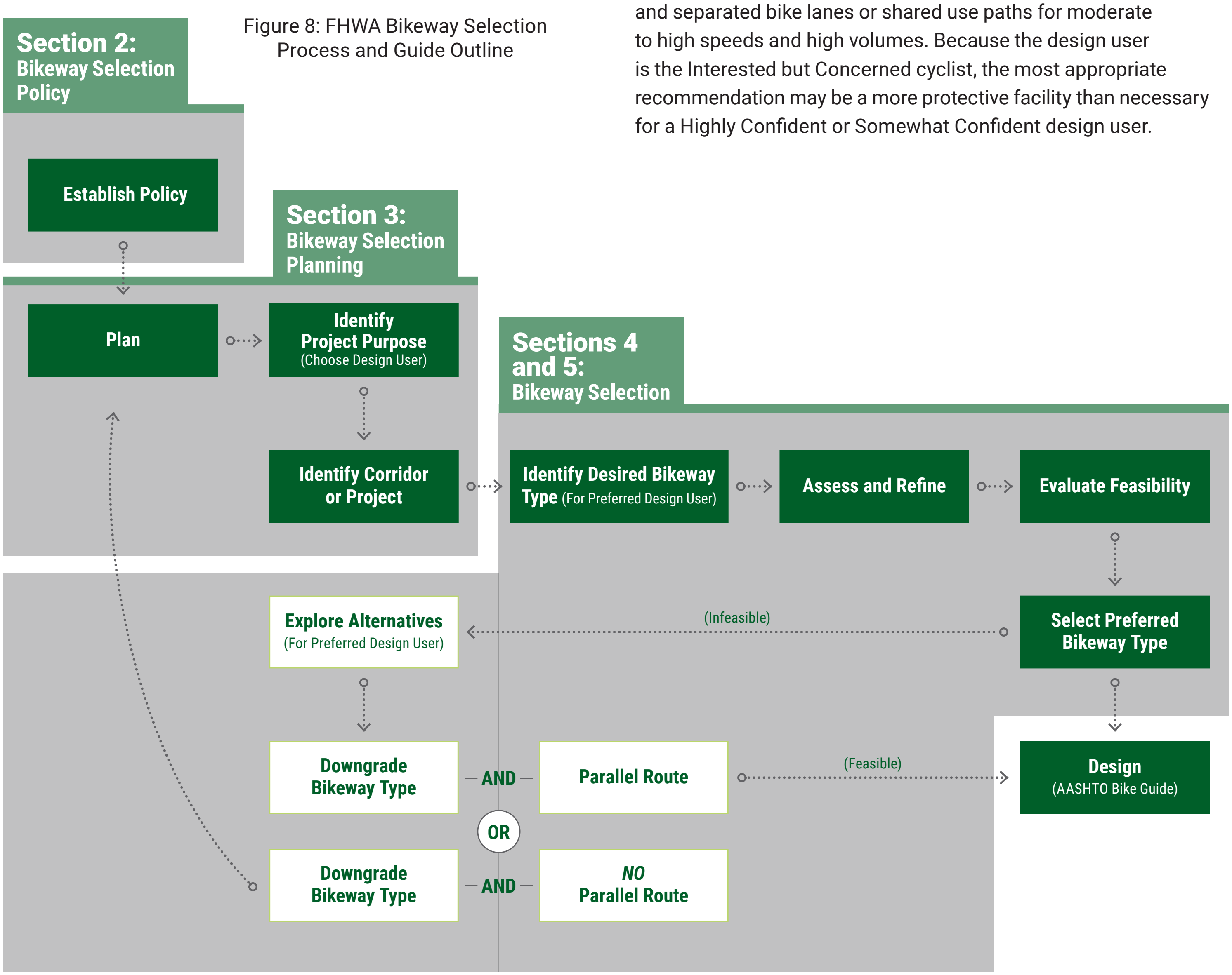
4. Bikeway Selection

Bikeway selection is a context-sensitive decision that involves a planning and engineering based analytical process. This process accounts for the broader network and roadway context and then drills down on a specific corridor. It starts with the identification of a desired facility and then gets refined based on real-world conditions such as available right-of-way and budget.

The quality of the bikeway selected will impact the level of comfort and by extension the amount of people in the community that will benefit from it.

A generalized version of this process is mapped out in the chart below, and the following pages provide detailed information on how each step of the process plays out on different roadway types.

Figure 8: FHWA Bikeway Selection Process and Guide Outline



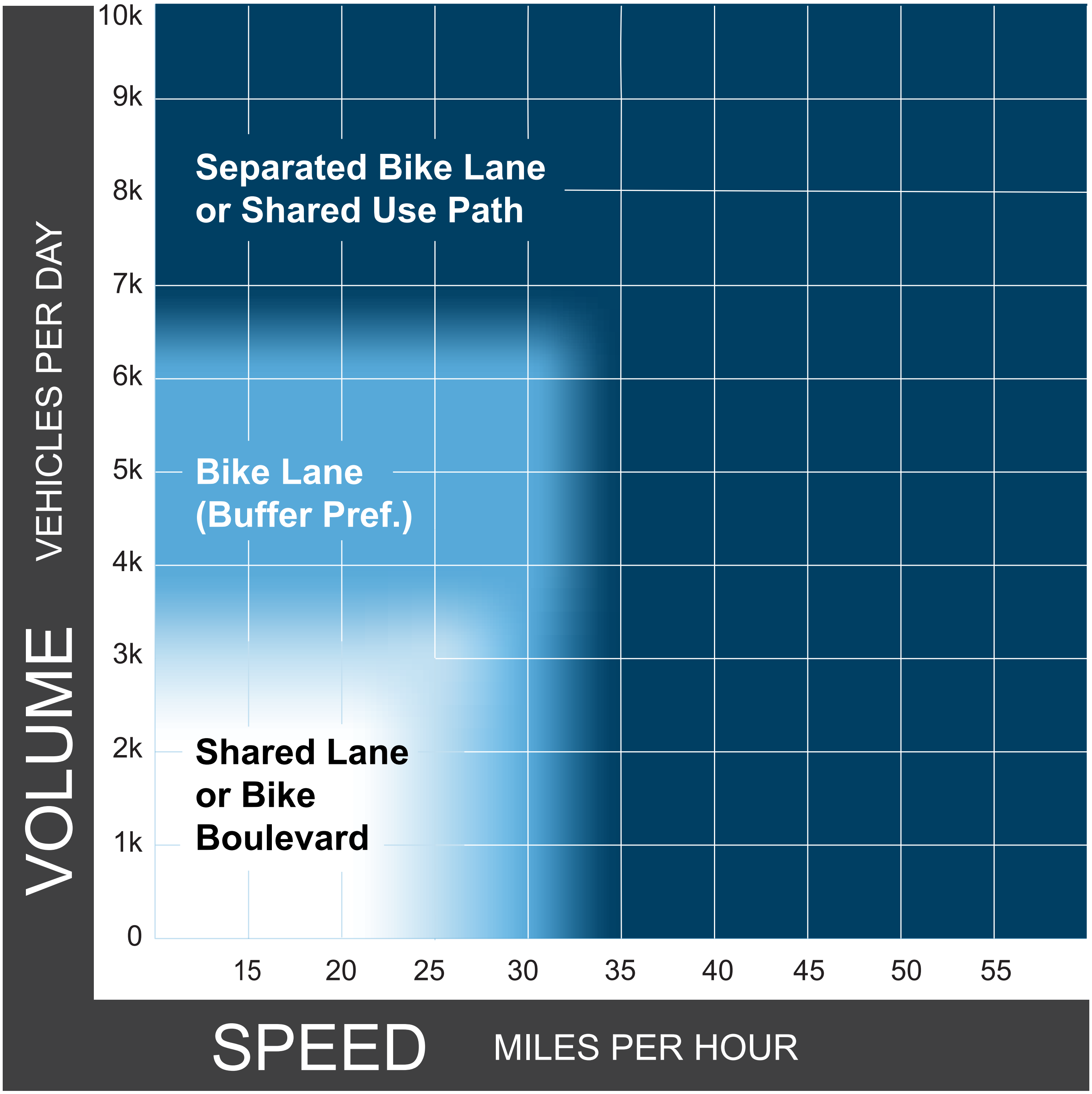
Desired Bikeway Type

Streets in Urban, Urban Core, Suburban, and Rural Town Contexts

The typical bicyclist user type for the urban, urban core, suburban, and rural town land use contexts is the Interested but Concerned category because of the development and density of destinations in these areas. Figure 9 provides guidance for how motor vehicle volume and speed can be taken into consideration to determine a preferred bikeway type.

Generally, the higher the speed and volume of a road, the more protective the recommended bikeway. Shared lanes or bicycle boulevards are recommended for the lowest speeds and volumes; bike lanes for low speeds and low to moderate volumes; and separated bike lanes or shared use paths for moderate to high speeds and high volumes. Because the design user is the Interested but Concerned cyclist, the most appropriate recommendation may be a more protective facility than necessary for a Highly Confident or Somewhat Confident design user.

Figure 9: Preferred Bikeway Type for Urban, Urban Core, Suburban and Rural Town Contexts



Notes

1 Chart assumes operating speeds are similar to posted speeds. If they differ, use operating speed rather than posted speed.

2 Advisory bike lanes may be an option where traffic volume is <3K ADT.

3 See page 32 for a discussion of alternatives if the preferred bikeway type is not feasible.

Rural Context

The typical bicyclist type on roadways in rural areas is the recreational bicyclist, who often fits the Highly Confident or Somewhat Confident category. Shared lanes, paved shoulders, and shared use paths are appropriate bikeway types on rural roadways. Shoulder width is an important consideration to accommodate these bicyclists based on traffic volumes and posted speeds in the rural context. Figure 10 provides guidance for selecting a preferred shoulder width to accommodate bicyclists based on volumes and posted speeds in the rural context.

It is often desirable to provide shared use paths along rural roads with higher speeds (45 mph or greater). This is especially true for locations that attract larger volumes of bicyclists due to scenic views or for routes that serve as key bicycle connections between destinations. Paths are also an important consideration for families and children making connections in rural areas. Shared use paths are also generally preferred on rural roads with Average Daily Traffic above a certain threshold (e.g. above 6,000 or 7,000 ADT depending on context).

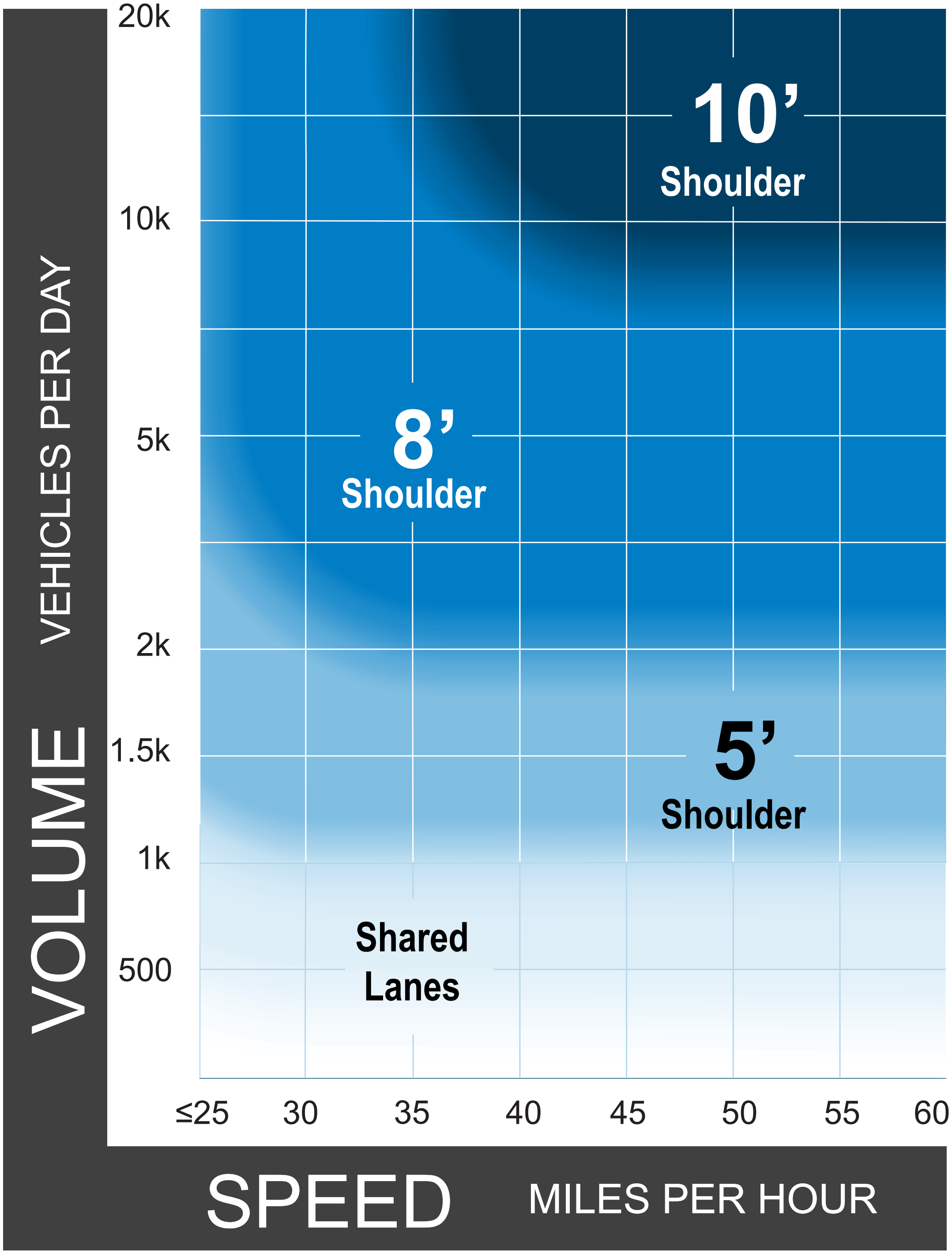
In highly constrained conditions where sufficient shoulder width cannot be achieved, it is preferable to provide a narrow shoulder rather than no shoulder.

Assessing and Refining the Desired Bikeway Type

On many projects, especially new construction and reconstruction, the bikeway selection process only needs to reference Figures 9 and 10; however, on retrofit projects and on projects with other constraints, the bikeway selection process will become more complex. The remainder of this section highlights a variety of other considerations that will arise in the bikeway selection process, for example by indicating the need for greater separation (such as additional buffer width, additional vertical buffer elements, or other measures) between bicyclists and motor vehicles. These factors include:

- **Unusual motor vehicle peak hour volumes** – On roadways that regularly experience unusually high peak hour volumes, more separation can be beneficial, particularly when the peak hour also coincides with peak volumes of bicyclists.
- **Traffic vehicle mix** – Higher percentages of trucks and buses increase risks and discomfort for bicyclists due to vehicle size and weight, and the potential for motorists to not see bicyclists due to blind spots. This is a particular concern for right turns, where large vehicles may appear to be proceeding straight or even turning left as they position to make a wide right turn movement. In addition, designated emergency vehicle routes may influence bikeway selection and design. Additional buffer width between a separated bike lane and the travel lane at an intersection can improve visibility and safety in these locations. Additional separation between bicyclists and motorists is particularly important on moderate to high-volume streets where heavy vehicles are more than 5 percent of traffic.
- **Parking turnover and curbside activity** – Conflicts with parked or temporarily stopped motor vehicles present a risk to bicyclists—high parking turnover and curbside loading (commercial and passenger) may expose bicyclists to being struck by opening vehicle doors or people walking in their travel path. Vehicles stopped within bicycle lanes or travel lanes may require bicyclists to merge into an adjacent travel lane. In locations with high parking turnover, or curbside loading needs, wider bike lanes or separated bike lanes in lieu of bike lanes can help to alleviate conflicts. This issue also encompasses locations where transit vehicles load and unload passengers within a bicycle lane or shared curb lane.
- **Driveway/intersection frequency** – The frequency of driveways and intersections also impacts decisions regarding the amount of separation needed between the street and the separated bike lane. Motorists need adequate sight distance and space to yield to bicyclists. This is particularly important for two-way separated bike lanes located on one side of two-way streets and for sidepaths. Wider buffers and clear sight lines can improve bicyclist safety. Frequently spaced driveways may require elimination of on-street parking adjacent to separated bike lanes and raising of the bike lane to provide separation from traffic.
- **Direction of operation** – With regards to separated bikeways, a determination must be made as to whether the bikeway will be provided as a one-way facility on each side of the road, a two-way facility on one side of the road, or as two-way facilities on both sides of the road. This decision requires engineering judgment based on the bikeway's role in the broader bike network, the locations of destinations within the corridor, physical constraints within the right-of-way, and an assessment of intersection operations.
- **Vulnerable populations** – The presence of high concentrations of children and older adults should be considered during project planning. These groups may only feel comfortable bicycling on physically separated facilities, even where motor vehicle speeds and volumes are relatively low. Typically, these populations are less confident in their bicycling abilities and, in the case of children, may be less visible to motorists and lack both roadway experience as well as sufficient cognitive or physical maturity to recognize and anticipate potential conflicts. They can also create more conflicts with pedestrians when they are expected to share the same space.

Figure 10: Preferred Shoulder Widths for Rural Roadways



Notes

1 This chart assumes the project involves reconstruction or retrofit in constrained conditions. For new construction, follow recommended shoulder widths in the AASHTO Green Book.

2 A separated shared use pathway is a suitable alternative to providing paved shoulders.

3 Chart assumes operating speeds are similar to posted speeds. If they differ, use operating speed rather than posted speed.

4 If the percentage of heavy vehicles is greater than 5%, consider providing a wider shoulder or a separated pathway.

- **Network connectivity gaps** – Separated facilities can help close gaps in a low-stress network. Examples include on-street connections between two major shared use paths, or where routes connect to parks or other recreational opportunities.
- **Transit Considerations for Selecting Bikeways** – Biking offers a valuable "first-mile" and "last-mile" connection to transit systems, effectively expanding the transit shed around a station or stop. It is important to ensure accessibility of transit boarding areas, pedestrian crossings, and parking spaces, while also integrating the bicycle network with transit systems. Traffic laws and agency policy often address transit vehicles and bicycles in the right most lane or right side of the roadway. Some agencies have designated shared "transit lanes" for bicycle riding, but frequent bus stops or roadway design may create delay or less safe conditions for bicyclists sharing a lane with heavy transit traffic. If the preferred bikeway type for a roadway is a bike lane or separated bike lane, the placement of the bike lane with respect to where pedestrians may wait or travel when boarding or alighting transit vehicles should be considered, as should the extent to which transit operations impact bicyclists' level of comfort and safety. As noted in FHWA's *Separated Bike Lane Planning and Design Guide*, options for minimizing conflicts with transit include installing signs, pavement markings, and/or bus bulbs to provide for shared space, placing a separated bike lane on the left side of a one-way street (out of the way of transit stops along the right side), or choosing to install a separated bike lane on a nearby parallel corridor away from transit.

Evaluating Feasibility

Meeting safety and mobility goals are typical objectives for roadway designers. Designers have an ethical obligation to provide for the health, safety, and welfare of the public, which may require a careful evaluation of mobility goals where they have the potential to degrade safety. One user's convenience or mobility should not be prioritized over another user's safety. Most roadway and bikeway design projects can be designed to improve safety for all modes. When evaluating safety trade-offs, options that reduce serious injuries and fatalities should be prioritized over options that may reduce property damage or minor injuries.

Options for Reallocating Roadway Space

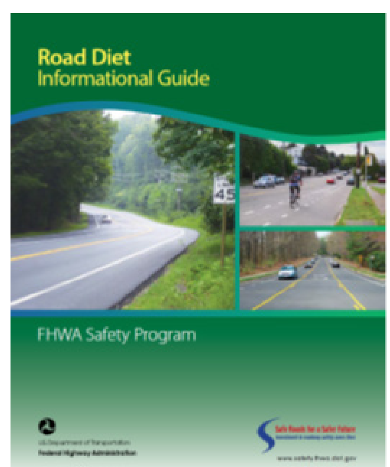
When building new roadways, preferred bikeways should be built to preferred dimensions. When retrofitting existing roadways, it will often be necessary to evaluate options that reallocate space and options that require the use of constrained dimensions for motor vehicle lanes and bikeways. The following options are common strategies for reallocating roadway space to provide a preferred bikeway.

Narrowing Travel Lanes: In some cases, the width needed for bikeways can be obtained by narrowing travel lanes. Lane widths on many roads are greater than the minimum values described by the AASHTO Green Book, and lanes as narrow as 10 feet do not result in an increase in crashes or reduce vehicle capacity on roads with speeds of 45 mph or less.[8] Narrower lane widths can contribute to lower vehicle operating speeds, which can increase safety for all roadway users.

The AASHTO Green Book provides flexibility to use travel lanes as narrow as 10 feet in a variety of situations depending on operating speeds, volumes, traffic mix, horizontal curvature, use of on-street parking, and street context. Travel lanes are not required to be of equal width. For example, some agencies use an 11- foot-wide outer lane to accommodate buses, with the remainder of the travel lanes being 10 feet wide.

Removing Travel Lanes: Removing travel lanes and reconfiguring the resulting roadway space (commonly known as a "road diet") are frequently the result of efforts to improve the safety performance of a roadway segment. Streets that were designed based on forecasts that were unrealized or where conditions may have changed often have excess capacity, encouraging fast speeds that can increase crash risk for all roadway users. Road diets can improve safety for all roadway users by reducing travel speeds, providing space for bikeways, shortening street crossings, adding turn lanes, or by providing wider sidewalks. Road diet conversions have potential operational benefits as well, particularly on streets with high numbers of left-turning vehicles, which impede traffic in the leftmost through lane of an undivided street.

Figure 11: FHWA Road Diet Informational Guide



8 Potts, I. B., D.W., Harwood, and K.R., Richard. Relationship of Lane Width to Safety on Urban and Suburban Arterials. Presented at the 86th Annual Meeting of the Transportation Research Board, Washington, DC, 2007.

Four- to three-lane conversions are the most common road diets, but there are numerous other types. Four-lane undivided streets with traffic volumes of less than 15,000 vehicles/day are candidates for conversions, though there are many examples of conversions on roads with up to 20,000 vehicles/day. Four-lane streets with higher volumes usually need a more detailed engineering study that includes recommendations for signal timing changes and other enhancements at intersections. The FHWA *Road Diet Informational Guide* provides detailed information about this strategy.[9]

One-way streets: Many one-way couplets were originally two-way streets, and in the conversion, all available space was converted to one-way travel lanes, resulting in excess capacity. These streets may offer opportunities to install bike lanes, separated bike lanes, or shared use paths through lane removal or narrowing. Where bikeways replace a vehicle travel lane, there is frequently additional space that can be allocated to other purposes such as on-street parking, wider street buffers, or wider sidewalks.

Reorganizing Street Space: There may be opportunities to create bikeways or upgrade existing facilities by reorganizing street space without removing travel lanes. For instance, in some cases curbside on-street parking can be shifted away from the curb face to create parking-protected separated bike lanes. This type of project requires changes to pavement markings and attention to intersection design treatments. Pre-cast concrete curb sections can be used to augment pavement markings to physically separate parking stalls from the bike lanes.

Making Changes to On-Street Parking: On-street parking may serve residents or street-oriented businesses. On-street parking provides a buffer for pedestrians, improving their comfort and safety; it may also reduce automobile traffic speeds on the street. On-street parking can also provide a physical separation between a separated bike lane and moving traffic. However, on-street parking introduces potential conflicts for bicyclists and motorists and uses road width that might otherwise be used as a travel lane or to create a higher-quality bikeway.

Removing or reducing on-street parking involves working with the affected businesses and residents. It may be possible to accommodate more parking on side streets, or to consolidate it in newly created parking bays or in shared (off-street) parking surface lots or parking structures. Parking consolidation or reconfiguration can take many different forms. Some examples are provided below. When parking is modified, it is important to consider requirements to provide accessible parking spaces for individuals with disabilities. A parking utilization study is often useful in determining if these (and other) solutions are feasible.

Figure 12: Roadway Reconfiguration Opportunities

Source: Florence, SC Neighborhood Revitilization Plan

- ***Removing Parking on One Side*****:** On streets with parking on both sides, adding bikeways may not require the removal of all on-street parking if the parking is not being used efficiently. Deciding where to remove parking may depend on which side of the street has fewer or no businesses. For streets with steep grades, removal of parking on the downhill side may be preferable to minimize conflicts between faster moving bicyclists and parked vehicles. Parking does not need to be retained on the same side of the street through an entire corridor; alternating parking from one side to the other can provide a traffic calming benefit.

9 FHWA. Road Diet Informational Guide. FHWA-SA-14-028. Federal Highway Administration, U.S. Department of Transportation, Washington, DC, November 2014.

Figure 13: Roadway Reconfiguration Opportunities

Source: Active Tyler: Active Transportation Plan for the Tyler, TX Area MPO

- ***Converting Diagonal Parking to Parallel Parking:*** Converting diagonal parking to parallel parking can generate road width for the creation of bikeways and improve bicyclist safety. Front-in, diagonal parking creates conflicts with bicycle travel. Motorists backing out of spaces have poor visibility of approaching traffic, which includes bicyclists, and it can be difficult for bicyclists to see vehicles backing out due to other parked vehicles.[10] Diagonal parking also takes up more roadway width compared to parallel parking spaces.

  Where diagonal parking is to be provided or retained, it is preferable to require backing into the space (also called "reverse-angle parking"). This design improves a parked motorist's visual field to their left and right as they depart the space, and therefore can enhance safety for bicyclists and motorists approaching the vehicle. Reverse-angle parking also has other benefits to motorists, such as better access for loading and unloading.

- ***Converting Parallel Parking to Reverse-Angle Parking on One Side:*** Another possibility is to convert a street with parallel parking on both sides to reverse-angled parking on just one side. This can result in a lower net parking loss and provide additional width for the placement of bicycle facilities.

- ***Pilot Projects:*** Some of the strategies identified above can be implemented as temporary, or pilot projects to test measures to determine if they meet the needs of all users. This can be an effective strategy to engage community members and build long-term support for more permanent solutions.

Approach to Traffic

Bikeways can often be implemented with minimal reductions of motor vehicle capacity or travel times. However, if such impacts are anticipated, they should be evaluated alongside community goals and the safety, comfort, and connectivity benefits to bicyclists. They should also be considered within the context of an agency's policies and evaluated through a project's performance measures. Increasingly, projects have a wider range of performance measures that may include safety, health, equity, quality-of-life, economic vitality, multimodal level of service, and the reduction of vehicle miles traveled.

To determine the design of a roadway, it is common practice to project traffic volumes 10–30 years into the future. When evaluating trade-offs, care should be taken to ensure that the traffic projection adequately considers community goals, agency mode split targets, changes in land uses, improvements to other modal networks (e.g., transit and bicycle), shifts in modal preferences (such as increases in bicycling), and transportation investments. It is also a common practice to analyze the peak 15 minutes of the peak hour to conduct traffic analysis. Alternatives analyses should take a broader view of traffic impacts, as some delay for this very short period of time may be worth the safety benefits gained from an alternative street design or proposed bikeway design.

Intersections are a focus area for evaluating impacts on vehicle operation. The 2010 Highway Capacity Manual includes planning levels of service (PLOS) tools that consider relative impacts to cars, bicyclists, pedestrians, and other traffic while not requiring detailed or extensive traffic counts.

10 FHWA. Lesson 19: Bicycle Lanes, Course on Bicycle and Pedestrian Transportation. FHWA-RD-99-198. Federal Highway Administration, U.S. Department of Transportation, Washington DC, 1999.

Preferred Bikeway Type is Feasible with Preferred Design Values

If an existing space reallocation strategy results in sufficient space for the preferred bikeway to be installed with preferred design values, the bikeway can be installed. There is no need to consider other bikeway types or parallel routes.

Preferred Bikeway Type is Not Feasible with Preferred Design Values

If sufficient space is not available to provide the preferred bikeway type at the preferred design values, it will be necessary to consider other options, several of which are highlighted below.

Reducing Bicycle Facility Widths

Where preferred design values cannot be achieved, reduced or minimum widths can be used to preserve the preferred bikeway type in the design. However, the use of minimum width bikeways should be limited to constrained roadways where desirable or preferred bikeway widths cannot be achieved after all other travel lanes have been narrowed to minimum widths appropriate for the context of the roadway. Where it is necessary to go below minimum widths, the preferred bikeway is infeasible and it will be necessary to select another bikeway type.

Wide Outside Lane or Bike Lane?

In some instances, it may be necessary to choose between the provision of a 10-11-foot-wide travel lane with a bike lane or a 15-16-foot-wide outside travel lane. In the past, it was common practice to provide wide outside lanes under the assumption that motorists in such a lane could pass a person riding a bicycle without encroaching into the adjacent lane and that this practice would improve operating conditions and safety for both bicyclists and motorists.

Figure 14: Roadway Reconfiguration Opportunities

Source: Longview, TX Bicycle and Pedestrian Plan

However, experience and research find that this configuration does not adequately provide safe passing distance and that motorists generally do not recognize that this additional space is intended for bicyclists.[11, 12, 13] Also, wider travel lanes are associated with increases in motor vehicle speeds, which reduce comfort and safety for bicyclists.[14, 15] Wide curb lanes are therefore not recommended as a strategy to accommodate

11 Hunter, W. W., J. R. Feaganes, and R. Srinivasan. Conversions of Wide Curb Lanes: The Effect on Bicycle and Motor Vehicle Interactions. In Transportation Research Record 1939, Transportation Research Board of the National Academies, Washington, DC, 2005, pp. 37–44.

12 McHenry, S. R., and M. J. Wallace. Evaluation of Wide Curb Lanes as Shared Lane Bicycle Facilities. Maryland State Highway Administration, Baltimore, MD, 1985.

13 Duthie, J., and J. F. Brady, A. F. Mills, and R. B. Machemehl. Effects of On-Street Bicycle Facility Configuration on Bicyclist and Motorist Behavior. In Transportation Research Record 2190, Transportation Research Board of the National Academies, Washington, DC, 2010, pp. 37-44.

14 Ewing, R. Traffic Calming: State of the Practice. Prepared for the Federal Highway Administration, U.S. Department of Transportation, Washington, DC, 1999.

15 Fitzpatrick, K., P. J. Carlson, M. D. Wooldridge, and M. A. Brewer. Design Factors That Affect Driver Speed on Suburban Arterials. In Transportation Research Record 1751. TRB, National Research Council, Washington, DC, 2001.

Figure 15: Example Door Zone Biking Space

bicycling except as an interim treatment for retrofits where an existing road is being re-striped and all other travel lanes have been narrowed to the minimum widths.

Door Zone Bike Lane or No Bike Lane?

In some instances, it may be necessary to choose between the provision of a 10-11-foot-wide travel lane with a bike lane or a 15-16-foot-wide outside travel lane adjacent to a parking lane. In these circumstances, where it is not feasible to eliminate the parking, the designer will have to choose between a narrow bicycle lane or a wide outside lane.

Narrow bicycle lanes may direct cyclists into the path of the "door zone" where drivers may open a door into a bike lane unexpectedly. Door zone crashes typically account for 5% - 10% of urban bike crashes, most commonly in shared lanes. Despite this seeming increased risk, studies have shown that the provision of a bicycle lane is still likely safer for the bicyclist than the provision of a wide outside lane. A study of bicycle crashes in Seattle found that streets with bicycle lanes had the fewest total dooring crashes compared to streets with shared lanes or marked shared lanes.

One-Way Separated Bike Lane on Both Sides or Two-Way Separated Bike Lane?

Where it is determined that a separated bike lane is the preferred bikeway type, it will be necessary to determine the most appropriate configuration for the bikeway.

On two-way streets, one-way separated bike lanes on each side of the street are typically preferred over a two-way

Figure 16: Roadway Reconfiguration Opportunities

Source: Active Tyler: Active Transportation Plan for the Tyler, TX Area MPO

separated bike lane or side path on one side of the street. One-way separated bike lanes in the direction of motorized travel are typically the easiest option to integrate into the existing operation of a roadway. This configuration provides intuitive and direct connections with the surrounding transportation network, including simpler transitions to existing bike lanes and shared travel lanes. It is also the most consistent with driver expectations since bicyclist operation is in the same direction as motor vehicle operation.

In circumstances where destinations are concentrated along one side of a street, the bikeway is connecting to other two-way bikeways, or where the bikeway is located on a one-way street for motor vehicle travel, the provision of a two-way separated bike lane may be desirable as wrong-way bicycling is likely in a one-way bike lane configuration.

Selecting the appropriate configuration requires an assessment of many factors, including safety, overall connectivity, ease of access, public feedback, available right-of-way, curbside uses, intersection operations, ingress and egress at the termini, maintenance, and feasibility. The analysis should also consider benefits and trade-offs to people bicycling, walking, taking transit, and driving. The primary objectives for determining the appropriate configuration are to:

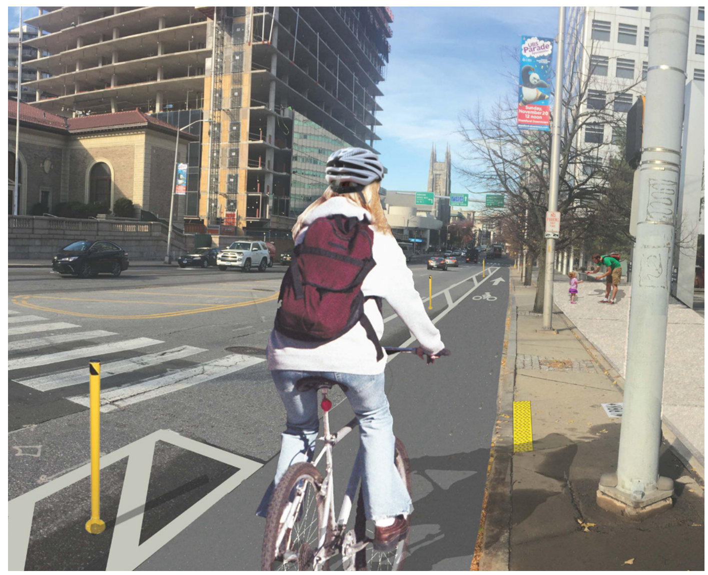
- Provide clear and intuitive transitions to existing or planned links of the bicycle network;
- Minimize conflicts between all users – bicyclists, pedestrians, and motorists;
- Provide convenient access to destinations; and to
- Connect to the roadway network in a direct and intuitive manner with a special consideration for the design of queuing and transition space for bicyclists who are entering and exiting the separated bike lane.

Providing a two-way separated bike lane or side path on one side of a street introduces a counterflow movement by bicyclists, which can be challenging—but not impossible—to accommodate. This also applies to a counterflow separated bike lane on a one-way street. Care should be given to the design of intersections, driveways, and other conflict points, as people walking and driving may not anticipate bicyclists traveling in the counterflow direction. Motorists entering or crossing the roadway often will not notice bicyclists approaching from their right, and motorists turning from the roadway across the bicycle facility may likewise fail to notice bicyclists traveling the opposite direction.

Strategies can be employed to manage or eliminate conflicts between counterflow bicyclists and motorists, who are primarily focused on identifying gaps in oncoming traffic and may be less cognizant of bicyclists approaching the intersection. Where appropriate, signal phasing can be used to eliminate conflicts between turning motorists and bicyclists traveling in the counterflow direction. Geometric treatments to slow turning motorists prior to the conflict point (e.g. raised crossings, parking restrictions, hardened centerlines) can be considered. Traffic control or warning signs, and high visibility bicycle crossing or crosswalk pavement markings, can be installed to alert motorists to the presence of counterflow bicyclists.

At the terminus of the bicycle facility, the counterflow bicyclist must be clearly directed back into the traffic mix in the correct direction of travel. This often requires the design of queuing spaces for bicyclists to wait outside the path of other bicyclists, motorists, and pedestrians while they wait to turn or transition from the bikeway.

Figure 17: Roadway Reconfiguration Opportunities



Source: Stamford, CT Pedestrian and Bicycle Master Plan

Where space is constrained on two-way streets, and one-way separated bike lanes are not feasible, the designer may choose one of the following options:

- Provision of bike lanes or buffered bike lanes
- Provision of a two-way separated bike lane
- Provision of a shared use path

In locations where the counterflow movement can be designed for, the provision of a two-way separated bike lane may be preferable over the provision of bike lanes, buffered bike lanes, or shared use paths.

Shared Use Path or Separated Bike Lane?

Shared use paths may be an acceptable design solution in lieu of separated bike lanes where space is constrained and the project is in land use contexts where both walking and/or bicycling volumes are relatively low and are expected to remain low. The shared use path may be located on one or both sides of the street, depending upon bicycle and pedestrian network connectivity needs. As volumes increase over time, the need for separation between bicyclists and pedestrians should be revisited. Where land use is anticipated to add density over time, right-of-way should be preserved to allow for future separation of bicyclists and pedestrians.

FHWA's Shared Use Path Level of Service Calculator[16] can help designers understand potential volume thresholds where passing movements between bicyclists and pedestrians will limit the effectiveness of a shared use path. To improve comfort and safety for bicyclists and pedestrians, and to improve the efficiency of the shared use path for bicycle travel, separation of bicyclists and pedestrians should be considered when:

- Shared Use Path Level of Service is projected to be at or below level "C" during peak hours.
- Pedestrians can reasonably be anticipated to be 30 percent or more of the volume during peak hours.
- Higher volumes of children, older adults, or individuals with disabilities are likely to be present.
- Where faster bicycle speed is desired to serve regionally significant bicycle travel.

The use of the *Shared Use Path Level of Service Calculator* requires the following inputs to calculate a LOS score:

- Volumes of people walking and running, adult bicyclists, child bicyclists, and in-line skating
- Proposed or existing path width
- Presence of a center line

When volume inputs are not available during the planning process, it may be necessary to estimate activity by using existing volumes on similar streets and shared use paths in the vicinity, allowing for adjustments, as necessary, to account for existing and future land uses adjacent to the facility and regional trends likely to increase shared use path activity.[17]

Narrow Shoulder or No Shoulder?

For any given roadway, the determination of the appropriate shoulder width should be based on the roadway's context and conditions in adjacent lanes. The AASHTO Green Book recommends a preferable shoulder width of 6 to 8 feet on low-volume roads and up to 12 feet on roads with high speeds or large volumes of trucks. This shoulder width may be soft surface or paved in many conditions. For new construction or reconstruction, a paved shoulder at the width recommended in the Green Book will accommodate bicycling activity.

For roadways which are being reconstructed or retrofitted where preferred Green Book shoulder widths cannot be provided, designers should provide the recommended shoulder width shown in Figure 10. Where those recommended widths cannot be provided, the following minimum paved shoulder widths can provide a minimum level of bicycle accommodation:

- A shoulder width of at least 3 feet on open-section roadways with no vertical obstructions immediately adjacent to the roadway and no rumble strips.
- A shoulder width of at least 5 feet is recommended from the face of a guardrail, curb, or other roadside barrier to provide additional operating width, as bicyclists generally shy away from a vertical face.

Increasing the width of shoulders is preferable where higher bicycle usage is expected and if motor vehicle speeds exceed 45 mph; if use by heavy trucks, buses, or recreational vehicles exceeds 5% of ADT; or if obstructions exist along the roadside.

Bicycle Level of Service (BLOS) may be used to determine the minimum shoulder width to provide a comfortable facility. Figure 10 provides recommended shoulder widths to achieve a Bicycle LOS of "C" or better at the speed and volume thresholds shown.

Downgrade Bikeway and Assess Parallel Route Option

At locations where the preferred bikeway is determined to not be feasible it will be necessary to consider downgrading the bikeway to the next best facility and/or to provide a parallel facility.

The impacts on ridership, comfort, safety, and overall network connectivity should be considered when evaluating bikeway alternatives or parallel routes to ensure the project will still meet the purpose identified at the outset as illustrated by these

16 FHWA. Shared Use Path Level of Service Calculator—A User's Guide. FHWA-HRT-05-138. Federal Highway Administration, U.S. Department of Transportation, Washington DC, 2006.

17 Ewing, R., and R. Cervero. Travel and the Built Environment – A Meta-Analysis. Journal of the American Planning Association, Vol. 6, No. 3, 2010, pp. 265-294.

potential trade-offs:

- Reduced or suppressed bicycling activity where:
    - the bikeway comfort does not meet the needs of all ages and abilities bicyclists
    - a parallel route lengthens the route
    - failure to provide a bikeway leaves an important gap in the bicycle network
- Reduced safety where bicyclists must operate with higher speed and/or higher volume traffic in shared lanes
- Reduced safety where bicyclists must operate in narrow bikeways (e.g. narrow bike lanes adjacent to high turnover parking or narrow shared use paths with high volumes of pedestrians or bicyclists)
- Reduced safety where bicyclists improperly use facilities (e.g., ride the wrong way on shared lanes, sidewalks, or separated bike lanes)
- Increased sidewalk bicycling where bicyclists are avoiding low-comfort conditions

All roadways should be safe and accessible by bicycle except where bicycle travel is specifically prohibited by law and clearly signed. Whenever roads are reconstructed or constructed, appropriate bikeways should be included to accommodate bicyclists' needs. However, technical, political, and financial realities may mean that not all roads can be immediately retrofitted or designed with an appropriate bikeway. Further, the project type (reconstruction, resurfacing, restriping, etc.) may limit bikeway options. Thus, choices should be made regarding which improvements receive priority, and what level of accommodation and bikeway each roadway will receive. Making these choices requires an understanding of standards, guidelines, and technical analysis tools as well as local knowledge, engineering judgment, and public input.

The Next Best Facility

When the preferred bikeway is not feasible, other bikeways which maximize user safety and comfort to the greatest extent practicable should be considered. For example, if the preferred bikeway is a shared use path and the current project is a street resurfacing, it may not be feasible for that project to install the shared use path. The only practical option may be the installation of a shoulder.

If a separated bike lane is preferred, but not feasible, and it

is also not feasible or desirable (given pedestrian volumes) to provide a sidepath, then a buffered bike lane should be considered, as it maximizes separation to vehicles over other options.

The reduction of traffic volumes or speeds, using traffic calming or other strategies, should also be considered in situations where the preferred bikeway is not feasible.

The inability to provide the preferred bikeway should not immediately result in dismissal of other options. If the resulting bikeway is not appealing to all ages and abilities, it still may be desirable and beneficial for the comfort and safety of more confident bicyclists. The next best bikeway should be considered, but will often depend on the context and particular constraints of each project. Where project constraints or compromises require a design solution that does not meet the original purpose of the project, it may be necessary to consider alternative parallel routes. It is therefore important to evaluate the project from all angles and consider the impacts on all modes of transportation.

Practitioners should document design decisions. Memoranda, engineering studies, and other methods of documentation can be used to capture the engineering judgment behind a design solution. In some cases, depending on the design criteria involved, applying flexibility may trigger the need for a design exception. Documenting design decisions is usually a critical part of the design exception process.

Parallel Routes

In circumstances where the preferred bikeway is not feasible, and the provision of a lower quality bikeway will not accommodate the target design user on the primary route (e.g. the interested but concerned bicyclist), a parallel route should be evaluated to accommodate the design user to meet the original purpose and need for the project. The land use context and transit access along the parallel route should appeal to and attract bicyclists from the primary route while offering a more comfortable facility type.

In grid networks, these parallel routes are often low-volume, low-speed local streets parallel with high-volume, higher-speed streets. These can be designed to operate and function as bicycle boulevards. For the parallel route to be a viable alternative, street crossings should provide a similar level of service as the primary route. This may require careful assessment of major street crossings associated with the parallel route to ensure they can accommodate safe and comfortable crossings. The viability of the parallel route may require improvements at these crossings. This is especially important at crossing locations of high-speed, or high-volume, traffic that do not have traffic signals.

Another key determinant of bicycling is trip distance. Research indicates that for an alternative low-stress route to be viable, the increase in trip length should be less than 30 percent.[18] Excessive distance is frequently noted as the most powerful deterrent to bicycling.[19] This is supported by research in stated preference and revealed preference studies.[20] Bicycle network and facility design can provide short cuts for bicyclists to make bicycling more time-competitive with motor vehicle travel by providing short segments of path between cul-de-sacs and across parks or stream valleys. Areas with connected networks of separated facilities and high levels of short trips are most likely to result in significant mode shift toward bicycling.

Wrap Up

At locations where the preferred bikeway cannot be provided on the primary route and it is necessary to downgrade the bikeway and the design user, and at locations where a parallel route is not feasible or is not provided, it must be recognized that bicycle activity may be suppressed, and the safety of bicyclists operating on this roadway segment may be reduced. This may negatively impact goals established in adopted bicycle master plans, sector plans, corridor plans, or transportation master plans. Where this occurs, efforts should be made to identify potential remedies that will help a community achieve the bicycling goals established in their adopted plans.

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18 Broach, J., Dill, J., and J., Gliebe. Where Do Cyclists Ride? A Route Choice Model Developed with Revealed Preference GPS Data. Transportation Research Part A: Policy and Practice, Vol. 46, No. 10, 2012, pp. 1730-1740.

19 FHWA. Reasons Why Bicycling and Walking Are Not Being Used More Extensively as Travel Modes. In National Bicycling and Walking Study. FHWA-PD-92-041. Federal Highway Administration, U.S. Department of Transportation, Washington, DC, 1994.

20 Broach, J., and J. Dill. Bridging the Gap: Using Network Connectivity and Quality Measures to Predict Bicycle Commuting. Presented at 96th Annual Meeting of the Transportation Research Board. National Research Council, Washington, DC, 2017.

5. Bikeway Selection in Practice

This section highlights real-world decisions on bikeway type for a broad range of common roadway types. It shows typical bikeway options and describes how the application of different bikeway choices impact bicyclists and people traveling by other modes.

For each context scenario provided in this section, four different bikeway applications are shown, identified as A (baseline), B, C, and D.

This section also provides the opportunity to evaluate how the policy and planning frameworks discussed in Sections 2 and 3 can be applied on different types of roads and in different contexts. These examples can also be used to test and apply the bikeway selection process and factors outlined in Section 4.

When reviewing this section, it will be helpful to reference factors for assessing and refining the desired bikeway type highlighted in the previous section, such as:

- Unusual motor vehicle peak hour volumes
- Traffic vehicle mix
- Parking turnover and curbside activity
- Driveway and intersection frequency
- Direction of operation
- Vulnerable populations
- Network connectivity gaps
- Transit considerations for selecting bikeways

It will also be important to cross reference this information with Figure 9: Preferred Bikeway Type for Urban, Urban Core, Suburban, and Rural Town Contexts and Figure 10: Preferred Shoulder Widths for Rural Roadways on pages 23 and 25.

In addition to these figures, the FHWA Shared Use Path Level of Service Calculator (see page 32) and the following analysis tools can be used to help assess the comfort of the existing roadway conditions and analyze bikeway alternatives.

Bicycle Level of Service (BLOS): BLOS can be used to evaluate the comfort of bike lanes and shared lanes, using an A through F rating with A being the best and F the worst. It is important to consider that this method of evaluation has significant limitations due to the fact that it was developed to analyze a limited set of bicycling conditions within shared lanes, paved shoulders, and bike lanes. It does not allow evaluation of shared use paths, separated bike lanes, or buffered bike lanes.[21]

Level of Traffic Stress (LTS): LTS was created to address deficiencies in the Bicycle LOS method. It is a method of classifying road segments and bikeway networks based on how comfortable bicyclists with different levels of confidence (using the user types discussed on page 12) would feel using them. The LTS ratings[22] are:

- LTS-1: Low Traffic Stress Bikeway comfortable for Interested but Concerned Bicyclists
- LTS-2: Moderate Traffic Stress Bikeway comfortable for Somewhat Confident Bicyclists
- LTS-3: High Traffic Stress Bikeway comfortable for Highly Confident Bicyclists
- LTS-4: Extreme Traffic Stress that is not comfortable for most bicyclists

A bikeway that is LTS-1 is appropriate and comfortable for all user types and is known as an all ages and abilities bikeway.

21 TRB. Highway Capacity Manual. Transportation Research Board, National Research Council, Washington, DC, 2010

22 Mekuria, M.C., P.G. Furth, and H. Nixon. Low-Stress Bicycling and Network Connectivity. MTI Report 11-19. Mineta Transportation Institute, San Jose State University, San Jose, CA, 2012.

2-Lane Roadway (Base Condition)

Bicyclists: The lack of separation from traffic moving at 45-50mph limits is an unforgiving design that decreases comfort and safety during passing events and while operating in darkness. Fewer driveways and intersections reduce conflict points, but locations with limited sight lines increase crash risk. Interested but concerned bicyclists will not feel comfortable operating on the roadway, feeling the highest Level of Traffic Stress (LTS = 4). Confident cyclists are also moderately uncomfortable (BLOS = D) due to the 45mph operating speed and relatively high percentage of trucks (4%).

Motorists: Motorists do not have safe options for overtaking cyclists except to wait for a break in oncoming traffic and move into the opposing travel lane. This may create motorist discomfort and frustration when bicycle and motor vehicle traffic is heavy, especially at locations with limited sight distance.

Pedestrians: No physical separation from traffic moving at 45-50mph limits is an unforgiving design that decreases comfort and safety. Pedestrians must walk in the road.

Transit Operators and Riders: Buses may require in-lane stops and riders may have difficulty accessing the stops.

Background: This is a rural, two-way, 22-foot-wide undivided road. It is a designated state bicycle route connecting two small towns in a bucolic rural valley with a history of attracting bicycle tourists traveling longer distances. The Average Daily Traffic (ADT) is 1,500 (with 4% heavy vehicles) and the operating speed is 45 mph. The public right-of-way extends to 10 feet on either side of the roadway. Low traffic volumes create gaps where motorists can easily change lanes to pass; however, there are locations with limited sight lines. Expected pedestrian volumes are to be 15-20 during peak hours, with 100-150 bicyclists on weekend afternoons.

Considerations: The designer has the option to select a bikeway based on the rural context (Figure 10) or the rural town context. As a popular roadway for touring bicyclists, it would be acceptable to use the rural town context bikeway selection chart (Figure 9) for this roadway. It is recommended that the design user be chosen after consultation with the communities and, if feasible, input from people who bicycle on the route—potentially via a survey of bicycle touring clubs. If it is determined the design user should be the interested but concerned bicyclist to provide an all ages and abilities facility, Figure 9 recommends a shared use path or separated bike lane be considered due to the 45-mph operating speed. FHWA's Shared Use Path Calculator can show volume thresholds where passing movements between pedestrians and bicyclists will limit the effectiveness of the shared use path, warranting a wider path or a separated bike lane with a sidewalk. If confident cyclists are the design users, Figure 10 recommends provision of a shoulder with a minimum width of 5 feet. In both instances, pedestrians are likely to use the bikeway provided, as it creates a place to walk separate from motor vehicles.

2-Lane Roadway (Shared Use Path Option)

Bicyclists: Physical separation and a buffer greatly increase comfort and safety for cyclists, resulting in lowest stress conditions (LTS = 1), especially during periods of darkness. Low pedestrian volumes will result in minimal conflicts on the sidepath. A path width of 8 to 10 feet comfortably services volumes of up to 300 users per hour (SUP LOS = C). A sidepath constructed to a high-quality standard (smooth and level) that is cleared of debris will accommodate touring and recreational bicyclists. A poor-quality sidepath will result in those cyclists continuing to operate in the roadway.

Motorists: The lack of shoulders does not improve motorist safety. Motorist discomfort and frustration is reduced when bicycle and motor vehicle traffic is heavy; especially at locations with limited sight distance. However, if confident and faster cyclists feel they must operate in the roadway due to path conditions, this may result in some conflicts with motorists who expect the bicyclists to be operating on the path. Motorists will need to be aware of counterflow bicyclists.

Pedestrians: The path creates a comfortable and safe place for people to walk. High pedestrian or cyclist volumes may lead to conflicts on the sidepath.

Transit Operators and Riders: Buses may require in-lane stops but riders will have an improved ability to access stops along one side of the roadway. Stops on opposite sides of the path would benefit from the provision of crossings and stop amenities.

2-Lane Roadway (Wide Shoulder Option)

Bicyclists: Wide paved shoulders (>5 feet in width) are operationally similar to bike lanes on rural roads. Paved shoulders 7 feet or more in width result in a highly comfortable route (BLOS = A) for confident cyclists; interested but concerned cyclist traffic stress remains high (LTS = 4). Rumble strips may be located on or near the shoulder line if a minimum of 4 feet of operating space remains for bicyclists.

Motorists: Wider shoulders are more forgiving for driver error, increasing their safety. However, if the shoulder is obstructed or rumble strip placement is not correct, bicyclists operating in the lane may result in unexpected conflicts with motorists who expect the bicyclists to be operating on the shoulder.

Pedestrians: The wide shoulder creates a more comfortable place for people to walk. High pedestrian or cyclist volumes may lead to conflicts, requiring bicyclists to occasionally operate in the traveled lane.

Transit Operators and Riders: Buses may be able to stop fully outside the travel lane within the shoulder. Riders will have an improved ability to access stops on both sides of the roadway.

2-Lane Roadway (Narrow Shoulder Option)

Bicyclists: Narrow paved shoulders (4-5 feet) are operationally similar to bike lanes on rural roads. Paved shoulders 4 feet or more in width result in a very comfortable route (BLOS = B) for confident cyclists; interested but concerned cyclist traffic stress remains high (LTS = 4). Paved shoulders less than 3 feet in width will not accommodate bicyclists. If rumble strips are present, they should be at the edge of the paved surface to maximize the width of the shoulder.

Motorists: Narrow shoulders can be forgiving for driver error, increasing their safety. However, if the shoulder is obstructed or rumble strip placement is not correct, bicyclists operating in the lane may result in unexpected conflicts with motorists who expect the bicyclists to be operating on the shoulder.

Pedestrians: The narrow shoulder creates a more comfortable place for people to walk. High pedestrian or cyclist volumes may lead to conflicts, requiring bicyclists to occasionally operate in the traveled lane.

Transit Operators and Riders: Buses may be able to stop partially outside the travel lane within the shoulder. Riders will have an improved ability to access stops on both sides of the roadway.

Related Resources

1. **AASHTO Guide for the Development of Bicycle Facilities**
2. **FHWA Small Town and Rural Multimodal Networks Guide**
3. **AASHTO Roadside Design Guide**
4. **FHWA Rumble Strips and Rumble Stripes Website**

2-Lane Roadway (Base Condition)

Source: Stamford, CT Pedestrian and Bicycle Master Plan

Bicyclists: The width of the road creates an ambiguous operating space for bicyclists which can lead to motorists driving faster than the speed limit of 30mph decreasing comfort and safety during passing events and while operating in darkness. Interested but concerned bicyclists will feel uncomfortable operating on the roadway feeling a moderately high Level of Traffic Stress (LTS = 3) because of the lack of a defined operating space. Confident cyclists are generally comfortable (BLOS = C) due to the wide operating lane (17 feet) and relatively low percentage of trucks (2%). To bypass stopped or parked vehicles, bicyclists will be required to merge into the traffic lane if they operate within the shoulder area.

Motorists: Motorists can easily overtake cyclists on the roadway but may be unsure where bicyclists are expected to operate. Where bicyclists are moving around stopped or parked vehicles, they will be viewed as unpredictable to motorists. Bicyclists who operate in the lane and not the shoulder area to avoid parked vehicles, may be viewed as "not sharing the roadway."

Pedestrians: The lack of a consistent walking space will require pedestrians to walk in the roadway decreasing their comfort and safety.

Transit Operators and Riders: Buses may be able to stop partially outside the travel lane within the undefined shoulder area which can create conflicts with bicyclists where transit routes operate with higher frequency. Riders will have difficulty accessing stops on both sides of the roadway depending upon sidewalk and crossing conditions.

Background: This is a two-lane, 34-foot-wide street located in a small town. It was originally a farm-to-market road and now is passing from a residential area into the outskirts of the town center. The Average Daily Traffic (ADT) is 6,000 (with 2% heavy vehicles) and the operating speed is 30 mph. The public right-of-way extends to 10 feet on either side of the roadway, but there are trees and utility poles located within the right-of-way. Portions of the route have a sidewalk on one side of the roadway. Expected pedestrian volumes are 25-50 during peak hours, with 100-150 bicyclists on weekend afternoons. There is sporadic parking along roadway, but all properties have driveways and adequate vehicle storage space. There is relatively long distances between driveways.

Considerations: The design user should be the interested but concerned bicyclist to provide an all ages and abilities facility. Based on the traffic context, Figure 9 recommends a bike lane be considered due to the 6,000 vehicles/day. A buffer would improve the comfort for bicyclists. A challenge here is accommodating pedestrians who are likely to use the bikeway if a sidewalk is not provided, as it creates a place to walk separate from motor vehicles. A shared use path could serve both users but may result in conflicts between pedestrians and bicyclists if the path is too narrow to accommodate pedestrians who may desire to walk side-by-side. FHWA's Shared Use Path Calculator can be used to understand volume thresholds where passing movements between pedestrians and bicyclists will limit the effectiveness of the shared use path, warranting a wider path or a bike lane with sidewalk. The presence of occasional parking and the possible need to remove trees presents a need to build community support.

2-Lane Roadway (Bike Lane Option)

Source: Stamford, CT Pedestrian and Bicycle Master Plan

Bicyclists: Narrow bike lanes (5 feet) can create a very comfortable route (BLOS = B) for confident cyclists as well as interested but concerned cyclists due to the relatively low operating speed and volume of the roadway (LTS = 2) and the provision of dedicated operating space for bicycling.

Motorists: Motorists can easily overtake cyclists on the roadway and have decreased stress operating around bicyclists as they have greater awareness for where bicyclists are expected to operate.

Pedestrians: If sidewalks are not provided with the bike lanes, pedestrians are likely to walk in the bike lane to improve their safety. This may lead to conflicts, requiring bicyclists to occasionally operate in the traveled lane. Where sidewalks are provided, the bike lanes create a buffer to traffic lanes improving pedestrian comfort and safety.

Transit Operators and Riders: Buses may be able to stop partially outside the travel lane but within the bike lane, which can create conflicts with bicyclists where transit routes operate with higher frequency. Riders will have difficulty accessing stops on both sides of the roadway depending upon sidewalk and crossing conditions.

2-Lane Roadway (Separated Bike Lane Option)

Bicyclists: Separated bike lanes (5 feet) with a buffer (2 feet minimum) can create a very comfortable route (BLOS = A) for confident cyclists as well as interested but concerned cyclists due to the relatively low operating speed and volume of the roadway (LTS = 1) and the provision of dedicated operating space for bicycling. While this is a narrow buffer, the effective width of the bike lane can be increased by placing vertical separation close to vehicle travel lane. Vertical separation is relatively constant because of the infrequent driveways.

Motorists: Motorists can easily overtake cyclists on the roadway and have decreased stress operating around bicyclists as they have greater awareness for where bicyclists are expected to operate.

Pedestrians: If sidewalks are not provided with the separated bike lanes, pedestrians are likely to walk in the bike lane to improve their safety. This may lead to conflicts, requiring bicyclists to occasionally operate in the traveled lane which can be more challenging due to the barriers. Where sidewalks are provided, the separated bike lanes create a buffer to traffic lanes improving pedestrian comfort and safety.

Transit Operators and Riders: Buses may be able to stop partially outside the travel lane but within the separated bike lane, which can create conflicts with bicyclists where transit routes operate with higher frequency. Riders may have difficulty accessing stops on both sides of the roadway depending upon sidewalk and crossing conditions.

2-Lane Roadway (Shared Use Path Option)

Bicyclists: Physical separation and a buffer greatly increase comfort and safety for cyclists, resulting in lowest stress conditions (LTS = 1), especially during periods of darkness. During periods of heavier pedestrian traffic where pedestrians walk side-by-side, some conflicts are likely on the sidepath. A path width of 10 feet services volumes up to 150 users per hour comfortably (SUP LOS = B). At 200 users or more, a path width of 12 feet is required to maintain a SUP LOS of B. The pedestrian use will likely result in sport and faster cyclists continuing to desire to operate in the roadway.

Motorists: The narrowing of the roadway will have a minimal impact on motorist safety given the slower speed nature of the roadway. Motorist discomfort and frustration is reduced when bicycle and motor vehicle traffic is heavy, especially during periods of darkness. The reduction in space to stop or park motor vehicles may generate controversy if there is not sufficient off-street parking available. Motorists need to be aware of counterflow bicyclists, but the elimination of parking may contribute to adequate sight lines.

Pedestrians: The path creates a comfortable and safe place for people to walk continuously on one side of the roadway. High pedestrian or cyclist volumes may lead to conflicts on the sidepath. Completing a sidewalk on the opposite side of the road would complete the pedestrian network.

Transit Operators and Riders: Buses may require in-lane stops but riders will have an improved ability to access stops along one side of the roadway. Stops on opposite sides of the path would benefit from the provision of crossings and completion of the sidewalk.

Related Resources

1. **AASHTO Guide for the Development of Bicycle Facilities**
2. **FHWA Shared Use Path Calculator**
3. **FHWA Separated Bike Lane Planning and Design Guide**
4. **National Association of City Transportation Officials (NACTO) Bikeway Design Guide**

4-Lane Roadway (Base Condition)

Source: Active Tyler: Active Transportation Plan for the Tyler, TX Area MPO

Bicyclists: Lower volume, multi-lane roads generally allow for free-flowing traffic and operating speeds in excess of the speed limit. Interested but concerned bicyclists will feel very uncomfortable operating on the roadway with a Level of Traffic Stress (LTS = 4) because of the lack of a defined operating space. Confident cyclists are generally uncomfortable (BLOS = D) as well due to the higher operating speeds in a shared lane.

Motorists: Motorists can easily overtake cyclists on the roadway by changing lanes, but they may be tempted to pass bicyclists within the travel lane if they are operating in a platoon and the bicyclists is riding near the edge of the road. Four-lane, undivided roadways without left turn lanes also generally have higher crash rates than other road types. In a suburban area where bicyclists are more frequently merging to turn left, they will not have a safe place to wait, resulting in motorists unexpectedly seeing bicyclists operating or stopped in the left lane, increasing discomfort for motorists.

Pedestrians: Pedestrian comfort and safety is degraded by proximity to the adjacent traffic lanes and potential exposure to multiple-threat crashes at crossings. Crossings at unsignalized intersections may be challenging for many pedestrians.

Transit Operators and Riders: Buses must stop within the outside travel lane, which can create conflicts with bicyclists where transit routes operate with higher frequency.

Background: This is a four-lane, 50-foot-wide street located in a suburban area with various large business and retail parcels. The Average Daily Traffic (ADT) is 9,000 (with 2% heavy vehicles) and the operating speed is 35 mph. The public right-of-way extends to 10 feet on either side of the roadway with continuous sidewalks that have trees and utility poles located within them. Expected pedestrian volumes are to be 25-50 during peak hours, with 200-250 bicyclists on weekend afternoons. There is no parking along the roadway, as all properties have driveways and adequate vehicle storage space. There are relatively long distances between driveways.

Considerations: The design user should be the interested but concerned bicyclist to provide an all ages and abilities facility. Based on the traffic context, Figure 9 recommends a separated bike lane or shared use path be considered due to the 9,000 vehicles/day and 35 mph speed limit. FHWA's Shared Use Path Calculator can be used to understand volume thresholds where passing movements between pedestrians and bicyclists will limit the effectiveness of the shared use path, warranting a wider path or a separated bike lane with sidewalk. If the speed limit can be reduced to 30mph, a buffered bike lane may be sufficient for many users. A challenge here is the built environment will require extensive reconstruction, therefore solutions which do not move curb lines are the most economical option.

4-Lane Roadway (Bike Lane Option)

Bicyclists: Bike lanes (6 feet) can create a very comfortable route (BLOS = B) for confident cyclists. The interested but concerned cyclists is still relatively uncomfortable due to the operating speed and volume of the roadway (LTS = 3) despite the provision of bike lanes. Many may still ride on the sidewalk if operating speeds remain over 35mph. If speeds were lowered to 25-30 mph and a buffer was added to the bike lane, their comfort would increase substantially (LTS = 2).

Motorists: Motorists can easily overtake cyclists on the roadway and have decreased stress operating around bicyclists as they have greater awareness for where bicyclists are expected to operate. The provision of a turn lane increases motorists safety; however, it likely lowers operating speeds, which may cause some to express frustration.

Pedestrians: Pedestrian comfort and safety is greatly improved because the bike lanes create a buffer to traffic lanes. Also, the reduction of through travel lanes eliminates the potential for a multiple-threat crash, and the left turn lane creates opportunities to add pedestrian refuges.

Transit Operators and Riders: Buses may be able to stop partially outside the travel lane but within the bike lane, which can create conflicts with bicyclists where transit routes operate with higher frequency. Rider access is improved with safer street crossings.

4-Lane Roadway (Separated Bike Lane Option)

Bicyclists: Separated bike lanes (6 feet) with a buffer (2 feet minimum) can create a very comfortable route (BLOS = A) for confident cyclists as well as interested but concerned cyclists due to the relatively low operating speed and volume of the roadway (LTS = 1) and the provision of dedicated operating space for bicycling. Vertical separation is relatively constant due to infrequent driveways.

Motorists: Motorists can easily overtake cyclists on the roadway and have decreased stress operating around bicyclists as they have greater awareness for where bicyclists are expected to operate.

Pedestrians: Pedestrian comfort and safety is greatly improved because the bike lanes create a buffer to traffic lanes. Also, the reduction of through travel lanes eliminate the potential for a multiple-threat crash, and the left turn lane creates opportunities to add pedestrian refuges.

Transit Operators and Riders: Buses may be able to stop partially outside the travel lane but within the separated bike lane. This can create conflicts with bicyclists where transit routes operate with higher frequency. Rider access is improved with safer street crossings.

4-Lane Roadway (Shared Use Path Option)

Source: Active Tyler: Active Transportation Plan for the Tyler, TX Area MPO

Related Resources

1. **Institute of Transportation Engineers (ITE) Implementing Context Sensitive Design on Multimodal Corridors: A Practitioner's Handbook**
2. **FHWA Road Diet Information Guide**
3. **Transportation Research Board (TRB) Highway Capacity Manual**
4. **USDOT Memorandum on Level of Service**
5. **ITE Trip Generation Manual**

Bicyclists: Physical separation and a buffer greatly increase comfort and safety for cyclists resulting in lowest stress conditions (LTS = 1), especially during periods of darkness. During periods of heavier pedestrian traffic where pedestrians walk side-by-side, some conflicts are likely on the sidepath. A path width of 12 feet services volumes of up to 200 users per hour comfortably (SUP LOS = B). At 300 users or more, a path width of 14 feet is required to maintain a SUP LOS of B. The pedestrian use will likely result in sport and faster cyclists continuing to desire to operate in the roadway. This width and the volumes are reaching a point where separating pedestrians and bicyclists may be desirable.

Motorists: The narrowing of the roadway will have a minimal impact on motorist safety given the slower speed nature of the roadway. Motorist discomfort and frustration is reduced when bicycle and motor vehicle traffic is heavy, especially during periods of darkness. Motorists will need to be aware of counterflow bicyclists, but the prohibition of parking ensures adequate sight lines.

Pedestrians: The path creates a comfortable and safe place for people to walk continuously on one side of the roadway. High pedestrian or cyclist volumes may lead to conflicts on the sidepath.

Transit Operators and Riders: Buses will be required to stop within the travel lane. Special care will be required at transit stops to ensure waiting pedestrians are not waiting on the shared use path. Rider access is improved with safer street crossings.

5-6 Lane Roadway (Base Condition)

Source: Active Tyler: Active Transportation Plan for the Tyler, TX Area MPO

Bicyclists: Higher volume, multi-lane roads generally allow for free-flowing traffic and operating speeds in excess of the speed limit. Interested but concerned bicyclists will feel very uncomfortable operating on the roadway (LTS = 4) even with the provision of an existing 9-foot shoulder. These bicyclists will avoid this roadway or ride on the sidewalks. Confident cyclists are generally comfortable (BLOS = A) on this roadway operating within the 9-foot shoulder despite the higher operating speeds.

Motorists: Motorists can easily overtake cyclists on the roadway, but they may be tempted to pass bicyclists and not yield to bicyclist operating with the shoulder due to the higher operating speeds. In a suburban area where bicyclists are more frequently merging to turn left, they may wait in the provided left turn lane, but they may have difficulty merging across the multiple lanes of high-speed traffic to enter the lane, resulting in motorists unexpectedly seeing bicyclists operating in left lanes on the roadway, increasing discomfort for motorists.

Pedestrians: Pedestrian comfort and safety is acceptable along the roadway because of the provided separation from traffic but degraded at street crossings due to their potential exposure to multiple-threat crashes and the higher operating speeds. Crossings at unsignalized intersections may be challenging for many pedestrians.

Transit Operators and Riders: Buses can stop within the shoulder, which can create conflicts with bicyclists where transit routes operate with higher frequency. Riders may have challenges crossing the roadway to access stops.

Background: This is a five-lane, 70-foot-wide street with an existing 9-foot shoulder located in a suburban area with various large business and retail parcels. The Average Daily Traffic (ADT) is 26,000 (with 2% heavy vehicles) and the operating speed is 45 mph. The public right-of-way extends to 20 feet on either side of the roadway, with continuous sidewalks that have trees and utility poles located within them. Expected pedestrian volumes are to be 25-50 during peak hours, with 200-250 bicyclists on weekend afternoons. There is no parking along the roadway, as all properties have driveways and adequate vehicle storage space. There are relatively long distances between driveways.

Considerations: The design user should be the interested but concerned bicyclist to provide an all ages and abilities facility. Based on the traffic context, Figure 9 recommends a separated bike lane or shared use path be considered due to the 26,000 vehicles/day and 45 mph speed limit. FHWA's Shared Use Path Calculator can be used to understand volume thresholds where passing movements between pedestrians and bicyclists will limit the effectiveness of the shared use path, warranting a wider path or a separated bike lane with sidewalk. A challenge here is that the shoulder can provide safety benefits for motorists given the higher operating speeds and volumes.

5-6 Lane Roadway (Buffered Bike Lane Option)

Bicyclists: Buffered bike banes can be created by narrowing the shoulders. The 6-foot bike lane with a 3-foot buffer does not improve comfort from the unmarked shoulder (BLOS = A) for confident cyclists, but does improve motorist awareness of bicyclists operating in the lanes. The interested but concerned cyclists is still relatively uncomfortable due to the operating speed and volume of the roadway (LTS = 3) despite the provision of buffered bike lanes. Many may still ride on the sidewalk or avoid the road.

Motorists: Motorists can easily overtake cyclists on the roadway and have decreased stress operating around bicyclists, as they have greater awareness for where bicyclists are expected to operate.

Pedestrians: Pedestrian comfort and safety remains unchanged from the existing conditions.

Transit Operators and Riders: Buses can stop within the shoulder ,which can create conflicts with bicyclists where transit routes operate with higher frequency. Riders may have challenges crossing the roadway to access stops.

5-6 Lane Roadway (Separated Bike Lane Option)

Source: Active Tyler: Active Transportation Plan for the Tyler, TX Area MPO

Bicyclists: The shoulders and travel lanes can be reduced in width to create a bi-directional separated bike lane (8 feet) with a buffer (6-foot minimum) on one side. It can create a very comfortable route (BLOS = A) for confident cyclists as well as interested but concerned cyclists (LTS = 1) due to the physical separation from the traffic.

Motorists: Motorists can easily overtake cyclists on the roadway and have decreased stress operating around bicyclists, as they have greater awareness for where bicyclists are expected to operate. Motorists will need to be aware of counterflow bicyclists, but the elimination of parking ensures adequate sight lines.

Pedestrians: Pedestrian comfort and safety remains unchanged from the existing conditions.

Transit Operators and Riders: Buses will be required to stop within the travel lane. Special care will be required at transit stops to ensure waiting pedestrians are not waiting on the shared use path. Rider access does not change from existing conditions with the exception of access across the separated bike lane.

5-6 Lane Roadway (Shared Use Path Option)

Bicyclists: Instead of narrowing the shoulders, the existing sidewalk can be widened to create a shared use path. Physical separation and a buffer greatly increase comfort and safety for cyclists, resulting in lowest stress conditions (LTS =1), especially during periods of darkness. During periods of heavier pedestrian traffic where pedestrians walk side-by-side, some conflicts are likely on the sidepath. A path width of 12 feet services volumes up to 200 users per hour comfortably (SUP LOS = B). At 300 users or more, a path width of 14 feet is required to maintain a SUP LOS of B. The pedestrian use will likely result in sport and faster cyclists continuing to desire to operate in the roadway. The width and the volumes are reaching a point where separating pedestrians and bicyclists may be preferable.

Motorists: The narrowing of the roadway will have a minimal impact on motorist safety given the slower speed nature of the roadway. Motorist discomfort and frustration is reduced when bicycle and motor vehicle traffic is heavy, especially during periods of darkness. Motorists will need to be aware of counterflow bicyclists, but the prohibition of parking ensures adequate sight lines.

Pedestrians: The path creates a comfortable and safe place for people to walk continuously on one side of the roadway. High pedestrian or cyclist volumes may lead to conflicts on the sidepath.

Transit Operators and Riders: Buses will be required to stop within the travel lane. Special care will be required at transit stops to ensure waiting pedestrians are not waiting on the shared use path. Rider access is improved with safer street crossings.

Related Resources

1. **FHWA Workbook on Incorporating On-Road Bicycle Networks into Resurfacing Projects**
2. **FHWA Proven Safety Countermeasures**
3. **Transportation Research Board (TRB) Highway Capacity Manual**
4. **USDOT Memorandum on Level of Service**
5. **ITE Trip Generation Manual**

6. Conclusion

This document is a resource to help transportation practitioners consider and make informed decisions about trade-offs relating to the selection of bikeway types. It incorporates and builds upon FHWA's active support for design flexibility and connected, safe, and comfortable bicycle networks that meet the needs of people of all ages and abilities.

For new construction and reconstruction projects, the bikeway selection process can be relatively straightforward. Figures 9 and 10 in this guide show the desired bikeway type for roads with different characteristics, and this guidance is based, in large part, on motor vehicle traffic volume and speed.

However, many of the projects that practitioners design and build are retrofits, or construction projects on existing roadways. These roadways often have more constraints and require trade-offs.

This guide outlines a process for balancing these trade-offs by identifying the desired bikeway type, assessing and refining the potential options, and evaluating feasibility. An agency's policies provide the framework for decision making, and the transportation planning process ensures that user types, bicycle networks, road context, and project types are considered.

This process is intended to accelerate the delivery of high-quality multimodal projects that improve safety for everyone and meet the transportation needs of people of all ages and abilities.

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