

ACHIEVING MULTIMODAL NETWORKS

APPLYING DESIGN FLEXIBILITY
& REDUCING CONFLICTS



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16. Abstract Multimodal transportation networks provide access to jobs, education, health care, recreation, transit, and other essential services in urban, suburban, and rural areas throughout the United States. Interconnected pedestrian and bicycle infrastructure makes walking and bicycling a viable transportation choice for everyone and this contributes to the health, equity, and quality of life of our communities. This publication is a resource for practitioners seeking to build multimodal transportation networks. The publication highlights ways that planners and designers can apply the design flexibility found in current national design guidance to address common roadway design challenges and barriers. It focuses on reducing multimodal conflicts and achieving connected networks so that walking and bicycling are safe, comfortable, and attractive options for people of all ages and abilities. This resource includes 24 design topics, organized into two themes. The 12 design topics in Part 1 focus on design flexibility. The 12 topics in Part 2 focus on measures to reduce conflicts between modes. Each design topic is four pages in length and includes relevant case studies and references to appropriate design guidelines. This document covers a wide range of solutions to achieve multimodal transportation networks. It includes solutions for streets and intersections, and has information about shared use paths and other trails that can serve both transportation and recreation purposes. It includes information about crossing main streets, bridges and underpasses, and about interactions with freight and transit. This resource addresses common concerns and perceived barriers among planning and design professionals and provides specific information about flexible design treatments and approaches.			
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Village of Aldie, VA	City of Madison, WI	City of West Palm Beach, FL
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TABLE OF CONTENTS

1 INTRODUCTION

11 PART 1: APPLYING DESIGN FLEXIBILITY

- 13 DESIGN CRITERIA AND LANE WIDTH
- 17 INTERSECTION GEOMETRY
- 21 TRAFFIC CALMING AND DESIGN SPEED
- 25 TRANSITIONS TO MAIN STREETS
- 29 ROAD DIETS AND TRAFFIC ANALYSIS
- 33 ENHANCED CROSSING TREATMENTS
- 37 SIGNALIZED INTERSECTIONS
- 41 PAVED SHOULDERS
- 45 SEPARATED BIKE LANES
- 49 BUS STOPS
- 53 BRIDGE DESIGN
- 57 SLOW STREETS

61 PART 2: REDUCING CONFLICTS

- 63 NETWORK CONNECTIVITY
- 67 SCHOOL ACCESS
- 71 MULTIMODAL ACCESS TO EXISTING TRANSIT STATIONS
- 75 MULTIMODAL ACCESS TO NEW TRANSIT STATIONS
- 79 TRANSIT CONFLICTS
- 83 FREIGHT INTERACTION
- 87 ACCESSIBILITY
- 91 TURNING VEHICLES
- 95 SEPARATED BIKE LANES AT INTERSECTIONS
- 99 SHARED USE PATHS
- 103 MIDBLOCK PATH INTERSECTIONS
- 107 SHARED STREETS

111 CONCLUSION

CASE STUDIES: APPLYING DESIGN FLEXIBILITY

PAGE	CASE STUDY	LOCATION	DESIGN TOPIC
16	Smart Transportation Guidebook	New Jersey/Pennsylvania	Design Criteria and Lane Width
	Gracy Farms Lane Road Diet	Austin, TX	
	Massachusetts Avenue Lane Diet	Boston, MA	
20	Corner Curb Radii—Better Streets Plan	San Francisco, CA	Intersection Geometry
	Mountable Truck Aprons	Portland, OR	
	Outside Truck Aprons	Burlington County, NJ	
24	South Golden Road	Golden, CO	Traffic Calming and Design Speed
	Olive Avenue	West Palm Beach, FL	
	Arterial Slow Zone Program	New York City, NY	
28	Traffic Calming Measures Rte. 50	Aldie, Middleburg, and Upperville, VA	Transitions to Main Streets
	Cascades Avenue Improvement Project	Sisters, OR	
	Danville Transportation Enhancement Project	Danville, VT	
32	W Lawrence Avenue	Chicago, IL	Road Diets and Traffic Analysis
	Lawyers Road	Reston, VA	
	Stone Way North	Seattle, WA	
36	I Street at Makemie Place, SW	Washington, DC	Enhanced Crossing Treatments
	Improvement Plan for Uncontrolled Marked Crosswalks	Seattle, WA	
	SE Bush Street and 122nd Avenue Pedestrian Hybrid Beacon	Portland, OR	
40	2nd Avenue Protected Pedestrian/Bicycle Phase	Seattle, WA	Signalized Intersections
	Leading Pedestrian Intervals	Washington, DC	
	Valencia Street Green Wave	San Francisco, CA	
44	Rumble Strip Policy	Washington State	Paved Shoulders
	Paved Shoulders as Bicycle Accommodations	Arizona	
	11-Foot Lane Width Standard	Vermont	
48	Southwest Moody Avenue Separated Bike Lane	Portland, OR	Separated Bike Lanes
	Polk Street Separated Bike Lane	San Francisco, CA	
	Western Avenue Separated Bike Lane	Cambridge, MA	
52	Stop Request Lights	Seattle, WA	Bus Stops
	Bus Stop Improvement Program	Montgomery County, MD	
56	Building Tunnels for Future Trails	Minneapolis, MN	Bridge Design
	Bridge Accommodation and Widths	Portland, OR	
	Bridge Approach Ramps	West Palm Beach, FL	
56	Heritage Square	Sulphur Springs, TX	Slow Streets
	5th Street NE Bicycle Boulevard	Minneapolis, MN	
	Neighborhood Greenway Program	Portland, OR	

CASE STUDIES: REDUCING CONFLICTS

PAGE	CASE STUDY	LOCATION	DESIGN TOPIC
66	Bicycle Master Plan	Fort Collins, CO	Network Connectivity
	Street Connectivity Policy	Charlotte, NC	
70	Discovery Elementary School	Arlington, VA	School Access
74	Washington Metropolitan Area Transit Authority Access Plan	Washington, DC Metro Area	Multimodal Access to Existing Transit Stations
	Massachusetts Bay Transportation Authority Bicycle Parking	Boston, MA Metro Area	
78	Wiehle-Reston East Metrorail Station	Reston, VA	Multimodal Access to New Transit Stations
	Central Station	Utrecht, The Netherlands	
82	Directing Bikes Across Streetcar Tracks	Boston, MA	Transit Conflicts
	Floating Bus Stop	Seattle, WA	
86	Off-Hour Delivery Program	New York City, NY	Freight Interaction
	Truck Sideguards	Boston, MA	
89	Berkeley 2010 Pedestrian Master Plan	Berkeley, CA	Accessibility
	Oregon State University Accessibility Plan	Corvallis, OR	
94	Massachusetts Avenue at Beacon Street	Boston, MA	Turning Vehicles
	Bicycle and Pedestrian Safety Analysis	Seattle, WA	
98	Separated Bike Lane Planning & Design Guide	Massachusetts	Separated Bike Lanes at Intersections
	Protected Intersection	Davis, CA	
102	Separated Paths	Pinellas Trail, FL	Shared Use Paths
	Marked Separation	Minneapolis, MN	
106	Raised Trail Crossing Burke-Gilman Trail	Seattle, WA	Midblock Path Intersections
	Prioritized Pathway Capital City Trail	Madison, WI	
110	Winthrop Street	Cambridge, MA	Shared Streets
	First Street North	Jacksonville Beach, FL	

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INTRODUCTION

INTRODUCTION

Multimodal transportation networks provide access to jobs, education, health care, and other essential services in urban, suburban, and rural areas throughout the United States. Interconnected pedestrian and bicycle infrastructure makes walking and bicycling a viable transportation choice for everyone and this contributes to the health, equity, and quality of life of our communities.

This publication is intended to be a resource for practitioners seeking to build multimodal transportation networks.

Achieving Multimodal Networks: Applying Design Flexibility and Reducing Conflicts highlights ways that planners and designers can apply the design flexibility found in current national design guidance to address common roadway design challenges and barriers. It focuses on reducing multimodal conflicts and achieving connected networks so that walking and bicycling are safe, comfortable, and attractive options for people of all ages and abilities.

OBJECTIVES

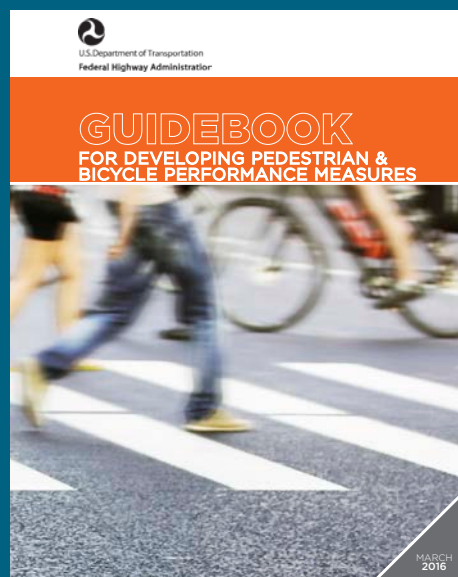
In many communities, accommodating and encouraging walking and bicycling requires retrofitting an existing transportation system with constrained rights-of-way to include new or enhanced pedestrian and bicycle infrastructure. Greater awareness of the flexibility and versatility available in national guidance will help designers overcome many challenges related to both new and retrofit projects. Designers must also manage conflicts between modes. Pedestrians are the most vulnerable roadway user because they are at the greatest risk of injury or death in a collision with someone traveling by any other mode. Bicyclists generally travel at slower speeds than motor vehicles and are inherently more vulnerable in the event of a crash with a car, truck, or transit vehicle. Designers need practical information based on real-world scenarios to address a variety of conflicts that occur between different modes.

This resource is intended to:

1. Equip planners, designers, and policy makers with information on designing safer, more comfortable, and accessible communities so that walking and wheeling are viable transportation choices for everyone, including seniors, children, and people with visual, mobility and other disabilities.
2. Equip planners, designers, and policy makers with information on designing safer, more comfortable, and connected transportation networks to make bicycling a viable transportation choice for people of all ages and abilities.
3. Address common concerns and perceived barriers among design professionals concerned about liability when designing pedestrian and bicycle facilities; and
4. Direct planners and designers to existing national guidelines that provide specific information about flexible design treatments and approaches.

RELATED RESOURCE: PEDESTRIAN AND BICYCLE PERFORMANCE MEASURES

FHWA's Guidebook for Developing Pedestrian and Bicycle Performance Measures is intended to help communities integrate pedestrian and bicycle transportation in their ongoing performance management activities. It highlights a broad range of ways that walking and bicycling investments, activity, and impacts can be measured and documents how these measures relate to goals identified in a community's planning process. It discusses how the measures can be tracked and what data are required, while also identifying examples of communities that are currently using the respective measures in their planning process. The report highlights resources for developing measures to facilitate high-quality performance based planning and is available at www.fhwa.dot.gov/environment/bicycle_pedestrian.



STUDY PROCESS

A comprehensive literature review explored the flexibility that exists within current guidelines and standards, and documented relevant guidelines, plans, and research for addressing multimodal conflict points. A Technical Work Group, consisting of practitioners from throughout the U.S., provided guidance, input, and review throughout the project. Design topics were selected based on needs identified by the Federal Highway Administration (FHWA), State Departments of Transportation, and local practitioners, as well as input from the Technical Work Group. Additional stakeholder outreach included targeted interviews to gather information on case studies, common challenges, and best practices.

DESIGN TOPICS

This resource includes 24 design topics, organized into 2 themes. The 12 design topics in Part 1 focus on design flexibility. The 12 topics in Part 2 focus on measures to reduce conflicts between modes. Each design topic is four pages in length and includes relevant case studies and references to appropriate design guidelines.

PART 1: APPLYING DESIGN FLEXIBILITY

- **Design Criteria and Lane Width** – flexibility in the selection of design criteria, including vehicular lane width.
- **Intersection Geometry** – flexibility in design-vehicle selection and the tolerance for vehicle encroachment; and best practices to create compact intersections.
- **Traffic Calming and Design Speed** – common misconceptions in traffic calming and the selection of design speed.
- **Transitions to Main Streets** – flexibility in creating a context-sensitive street design where a rural highway travels through a small town.
- **Road Diets and Traffic Analysis** – flexibility in volume thresholds, level of service thresholds, assumptions for traffic projections, and traffic analysis
- **Enhanced Crossing Treatments** – flexibility in marking a crosswalk, completing a warrant study for beacons and traffic signals, and applying additional crossing treatments.
- **Signalized Intersections** – flexibility in intersection design to safely accommodate bicyclists and pedestrians.
- **Paved Shoulders** – flexibility in the use and purpose of shoulders, paving shoulders as part of various project types, and the design and placement of rumble strips.
- **Separated Bike Lanes** – flexibility in the design of separated bike lanes.
- **Bus Stops** – flexibility in bus stop design and best practices for placement.
- **Bridge Design** – flexibility in bridge design to accommodate pedestrians and bicyclists across the structure and to provide access to the structure from under-passing trails.
- **Slow Streets** – flexibility in designing streets for speeds lower than 20 mi/h.

PART 2: REDUCING CONFLICTS

- **Network Connectivity** – strategies to develop safe and comfortable pedestrian and bicycle networks.
- **School Access** – strategies to provide safe access to schools by maximizing the safety of walking and bicycling, minimizing motor vehicle trips, and reducing on-site circulation conflicts.
- **Multimodal Access to Existing Transit Stations** – strategies to retrofit transit stations to improve access for pedestrians and bicyclists.
- **Multimodal Access to New Transit Stations** – strategies to reduce conflicts between various modes through transit station site planning and layout.
- **Transit Conflicts** – strategies to reduce conflicts between transit vehicles, motorists, pedestrians, and bicyclists in various scenarios.
- **Freight Interaction** – strategies to reduce conflicts between freight vehicles, loading activities, pedestrians, and bicyclists.
- **Accessibility** – strategies to provide an accessible pedestrian network for people with disabilities.
- **Turning Vehicles** – strategies to reduce conflicts between pedestrians, bicyclists, and right- and left-turning vehicles at intersections.
- **Separated Bike Lanes at Intersections** – strategies to reduce conflicts at intersections with protected intersections and mixing zones.
- **Shared Use Paths** – strategies to determine shared use path width and when separation of modes is necessary.
- **Midblock Path Intersections** – strategies to reduce conflicts at shared use path and roadway intersections.
- **Shared Streets** – strategies to design shared streets for all users and information on when shared streets are appropriate.

CONTEXT FOR DESIGN FLEXIBILITY AND REDUCING CONFLICTS

This section provides a foundation and context for the design topics that follow. It summarizes the flexibility and versatility available in existing national design resources and addresses how to reduce liability concerns through engineering judgment, documentation, and experimentation. It builds on this information by introducing guiding principles for reducing conflicts between modes.

PART 1: APPLYING DESIGN FLEXIBILITY

Applying flexibility requires knowledge of existing standards and guidelines, a recognition of the range of options available, and understanding how deviating from these may impact safety. A flexible approach uses existing tools in creative and varied ways to solve design challenges. It requires a holistic understanding of variables, thresholds, and available alternatives to achieve multiple objectives.

Current national guidelines and standards provide significant design flexibility. In 1997, FHWA published **Flexibility in Highway Design** to highlight the flexibility afforded to designers within existing standards and guidelines, and to encourage them to apply this flexibility when designing roads that fit into the natural and human environment. In 2004, the American Association of State Highway and Transportation Officials (AASHTO) published **A Guide for Achieving Flexibility in Highway Design** to promote the incorporation of sensitive community and environmental issues into the design of highway facilities. On August 20, 2013, FHWA issued a memorandum that clearly stated the agency's support for flexibility in the design of bicycle and pedestrian facilities.

Flexibility in Existing Standards and Guidelines

It is important for designers to recognize what is allowed and encouraged in existing standards and guidelines. The documents listed below are used by designers to inform the selection of traffic controls, geometric design, and traffic analysis.

- The **Manual on Uniform Traffic Control Devices for Streets and Highways (MUTCD)** sets the national standard for signing, pavement markings, and traffic signals. The **MUTCD** is included by reference in the Code of Federal Regulations and is recognized as the national standard for all traffic control devices installed on any street, highway, bikeway, or private road open to public travel.

- **AASHTO's A Policy on Geometric Design of Highways and Streets (Green Book)** and the supplemental guides for pedestrian and bicycle facility design are the national guidelines for the design of roadways and paths. The **Green Book** has been adopted by FHWA as the standard for the design of projects on the National Highway System. These AASHTO guides have been adopted in their entirety by some States. Other States have used them as the basis to create their own design manuals. The **Green Book** provides the most comprehensive guidance on geometric design and is a key resource used by designers.

FLEXIBILITY IN THE GREEN BOOK

The Green Book emphasizes the need for a holistic design approach and the use of engineering judgment, and highlights how the guidelines allow for flexibility:

"The intent of this policy is to provide guidance to the designer by referencing a recommended range of values for critical dimensions. Good highway design involves balancing safety, mobility, and preservation of scenic, aesthetic, historic, cultural, and environmental resources. This policy is therefore not intended to be a detailed design manual that could supersede the need for the application of sound principles by the knowledgeable design professional. Sufficient flexibility is permitted to encourage independent designs tailored to particular situations."

AASHTO Green Book 2011, p. xii

The AASHTO Standing Committee on Highways approved an Administrative Resolution on May 25, 2016 resolving to provide guidance to State DOTs and other users of the Green Book regarding flexibility in design. The resolution noted that this guidance should assist in educating designers on the flexibility inherent in the Green Book, as well as new and additional guidance on specific design issues. It confirmed that this guidance should address designing in and for a multimodal transportation system.

- The **Transportation Research Board (TRB) Highway Capacity Manual (HCM)** is the national guideline for analyzing traffic operations. The HCM does not establish a legal standard but provides guidance on techniques to analyze various modes of traffic.

Each of these documents explicitly states the need for flexibility and encourages the designer to employ engineering judgment and consider context when designing roadways. Regardless of the breadth and depth of a design publication, it cannot cover every real-world situation. For this reason, designers should understand the flexibility within, and engineering principles behind, design guidance.

In addition to the documents mentioned above, there are numerous publications that provide information on best practices and innovations in multimodal design. Such publications include:

- **National Association of City Transportation Officials (NACTO) Urban Bikeway Design Guide,**
- **NACTO Urban Street Design Guide,** and
- **Institute of Transportation Engineers (ITE) Designing Walkable Urban Thoroughfares: A Context Sensitive Approach.**

FHWA supports the use of these resources and has emphasized that they can be used to inform the planning and design process ("**Bicycle and Pedestrian Facility Design Flexibility,**" memorandum, August 20, 2013; "**Questions and Answers about Design Flexibility for Pedestrian and Bicycle facilities,**" July 25, 2014). A number of local government agencies have adopted these publications and are using them to design roadways.

ACCESSIBILITY STANDARDS

The U.S. Access Board published its **Proposed Guidelines for Pedestrian Facilities in the Public Right-of-Way (PROWAG)** in 2011 and a supplemental notice with guidance on shared use paths in 2013. At the time of publication of this document (**Achieving Multimodal Networks: Applying Design Flexibility and Reducing Conflicts**), the Board had not issued a final **PROWAG** rule.

The **PROWAG** will become an enforceable standard only after the Board publishes a final rule and only after the U.S. Department of Justice (USDOD) and/or the U.S. Department of Transportation (USDOT) adopt the final guidelines into their respective ADA and **Section 504 of the Rehabilitation Act** regulations. Until that time, the **USDOD 2010 ADA Standards** and the **USDOT 2006 ADA/Section 504 Standards** (for recipients of Federal financial assistance from USDOT) provide enforceable standards applicable to the public right-of-way. Where the **2010 ADA Standards** or the **2006 ADA/Section 504 Standards** do not address a specific issue in the public right-of-way, FHWA encourages public entities to look to the draft **PROWAG** for best practices. Several jurisdictions have chosen to apply the draft **PROWAG** as an alternative to, or equivalent facilitation for, the **ADA Standards** because they provide more specific coverage of accessibility issues in the public-right-of-way. Jurisdictions that have adopted the draft **PROWAG** as their standard should consistently apply all provisions of the draft **PROWAG**.

This document cites the draft **PROWAG** in anticipation of final **PROWAG** being adopted as the enforceable standard in the near future. Public entities and/or recipients of Federal financial assistance are responsible for complying with the current **ADA** and **Section 504** accessibility standards and/or demonstrating equivalent facilitation.

For more information on designing accessible public rights-of-way, see the design topic on **Accessibility**.

Liability and Risk

Designers sometimes express concern about liability when applying design flexibility. Due to these concerns, some designers adhere strictly to their interpretation of established design criteria, sometimes at the expense of providing adequate bicycle and pedestrian facilities. However, strictly adhering to the most conservative design values without considering other relevant factors may not constitute reasonable care on behalf of the designer. Likewise, a designer who deviates from established design guidance is not necessarily negligent, particularly if the designer follows and documents a clear process, using engineering judgment, when dealing with design exceptions, and experimentation.

A flexible design approach has three key elements:

(1) Engineering Judgment, (2) Documentation and (3) Experimentation.

1. ENGINEERING JUDGMENT

Engineering judgment relies on understanding engineering principles and the assumptions and contingencies incorporated into standards and guidelines. It requires knowledge and understanding of site specific conditions. The **MUTCD** defines engineering judgment as “the evaluation of available pertinent information, and the application of appropriate principles, provisions, and practices” and states “this Manual should not be considered a substitute for engineering judgment.”

To apply design flexibility appropriately, the impacts of different design criteria should be weighed and examined using engineering judgment to determine the most appropriate application of, or deviation from, guidance to achieve the optimal solution. Decision makers should consider safety and comfort alongside competing needs for limited space, resources, and funding – while also accounting for the scenic, historic, aesthetic, and cultural values of the surrounding community.

Public input is another consideration when exercising engineering judgment. It is important to understand the opinions and preferences of the people who use, wish to use, or are affected by the transportation facility. In some cases, the general public may not understand certain aspects of technical design, or may have misconceptions about what design treatments are most effective. The designer’s role, in this case, is to not only consider public opinion, but to also educate people about design solutions that may address underlying concerns.

2. DOCUMENTATION

Practitioners should document design decisions, especially when applying design flexibility. Memoranda, engineering studies, and other methods of documentation can be used to capture the engineering judgment behind a design solution and build a case for applying flexibility or deviating from existing guidance. 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.

The Maine Department of Transportation’s Highway Design Guide, Chapter 15: Flexible Design Practices explains the benefit of careful documentation succinctly: “With reliance on complete and sound documentation, tort liability concerns need not be an impediment to achieving good road design.”

3. EXPERIMENTATION

When deviating from current guidance and design standards, liability concerns should not limit innovations, experimentation, and versatile applications of existing design treatments and proven safety countermeasures. In the case of traffic control devices, experimentation may be possible if the proposed design is not compliant with, or not included in, the **MUTCD**. **Section 1A.10 of the MUTCD** outlines a formal experimentation process that includes evaluation and follow-up adjustments to the design (including removal of the design) as needed. The experimentation process helps drive the advancement of the design practice and the adoption of new traffic control devices in the **MUTCD**. Without conclusive data detailing their impact, new traffic control devices would not be given national approval. Experimentation with newer traffic control devices and facility types such as pedestrian hybrid beacons, bicycle signals, and colored pavement markings have expanded the designer’s toolbox by providing the data necessary to show the success of these measures.

FHWA INTERIM APPROVAL

Some devices shown in this guide are covered under Interim Approvals under the MUTCD, such as green-colored pavement in bicycle lanes and Rectangular Rapid-Flash Beacons. Approval must be obtained from FHWA before installing these devices.

PART 2: REDUCING CONFLICTS

When multiple modes (pedestrians, bicyclists, transit, and motor vehicles) operate in the same vicinity, conflicts can occur. Reducing conflicts is critical for vulnerable road users, such as pedestrians and bicyclists. Vulnerable road users are at a higher risk of injury or death when involved in a crash with a motor vehicle. The design topics in this resource provide practitioners with tools to reduce or eliminate conflicts between modes through various processes, policies, and design strategies.

Planners and designers can use the following guiding principles to minimize and manage conflicts where modes come together. These principles are discussed throughout the design topics in Part 2 and are also relevant to the design topics in Part 1.

Guiding Principles

1. SAFETY

Do the design, operations, and maintenance decrease the severity and likelihood of crashes?

Where modes come together, the design should eliminate conflicts to the greatest extent possible. If it is not feasible to eliminate the conflict entirely, designers should minimize the speed differential between modes to ensure that if a crash occurs, the severity of the injury is likely to be lower. Safety considerations are also incorporated and implied in all other principles.

2. ACCOMMODATION AND COMFORT

Does the design serve all modes and provide a sense of comfort?

Designs should accommodate people of all ages and abilities. Solving conflicts by eliminating access for pedestrians or bicyclists is not an acceptable solution.

3. COHERENCE AND PREDICTABILITY

Are the facilities for each mode recognizable and consistent?

Where different modes come together, the design should provide clear right of way assignments, visibility of all users, and a clear path of travel for all modes, whether they are intended to operate in shared or separated spaces. This encourages predictable and safer behaviors for all users.

4. CONTEXT-SENSITIVITY

Does the design incorporate and support the natural environment and adjacent land use, such as transit stations, employment centers, and other destinations, and does it support community health, economic, and livability goals?

The management of conflict points should consider and incorporate access to current and future adjacent land uses. Designs should minimize barriers to walking, bicycling, and transit use, and promote improved economic and public health.

5. EXPERIMENTATION

Are there innovative and creative solutions that can be tested to reduce conflicts?

Experimenting with new treatments to resolve multimodal conflict points should be considered to expand the tools available to improve multimodal accommodations and reduce the likelihood and severity of conflicts.

ASSESSMENTS

Pedestrian and bicycle assessments and road safety audits are effective tools to evaluate walking and biking conditions in a community. By bringing together Federal, State, regional, and local jurisdictions, elected officials, advocates, public health, and other transportation professionals, assessments and audits allow participants to experience firsthand the challenges and barriers facing people who are walking or biking in their communities.

More information on conducting assessments is provided in the **U.S. Department of Transportation Pedestrian and Bicyclist Road Safety Assessments Summary Report (2015)**.

Guidelines and prompt lists for road safety audits can be found at http://safety.fhwa.dot.gov/ped_bike/tools_solve.

REFERENCE GUIDE

Several design resources are referenced throughout this document. The table below includes both the full document title and the abbreviated title used in this document.

FULL TITLE	ABBREVIATED TITLE
American Association of State Highway and Transportation Officials, A Guide for Achieving Flexibility in Highway Design, 2004	AASHTO Flexibility Guide 2004
American Association of State Highway and Transportation Officials, Guide for the Development of Bicycle Facilities, 2012	AASHTO Bike Guide 2012
American Association of State Highway and Transportation Officials, Guide for Geometric Design of Transit Facilities on Highways and Streets, 2014	AASHTO Transit Guide 2014
American Association of State Highway and Transportation Officials, Guide for Planning, Design, and Operation of Pedestrian Facilities, 2004	AASHTO Pedestrian Guide 2004
American Association of State Highway and Transportation Officials, A Policy on Geometric Design of Highways and Streets, 2011	AASHTO Green Book 2011
American Association of State Highway and Transportation Officials, Roadside Design Guide, 2011	AASHTO Roadside Design Guide 2011
Federal Highway Administration, Separated Bike Lane Planning and Design Guide, 2015	FHWA Separated Bike Lane Guide 2015
Federal Highway Administration, Livability in Transportation Guidebook, 2011	FHWA Livability 2011
Federal Highway Administration, Manual on Uniform Traffic Control Devices for Streets and Highways, 2009	MUTCD 2009
Institute of Transportation Engineers, Designing Walkable Urban Thoroughfares: A Context Sensitive Approach, 2010	ITE Designing Walkable Urban Thoroughfares 2010
National Association of City Transportation Officials, Urban Bikeway Design Guide, 2014	NACTO Urban Bikeway Design Guide 2014
National Association of City Transportation Officials, Urban Street Design Guide, 2013	NACTO Urban Street Design Guide 2013
Transportation Research Board, Highway Capacity Manual, 2010	TRB Highway Capacity Manual 2010
United States Access Board, Proposed Guidelines for Pedestrian Facilities in the Public Right-of-Way, 2011	PROWAG 2011

THEMES

Common themes exist between various design topics and are outlined below.

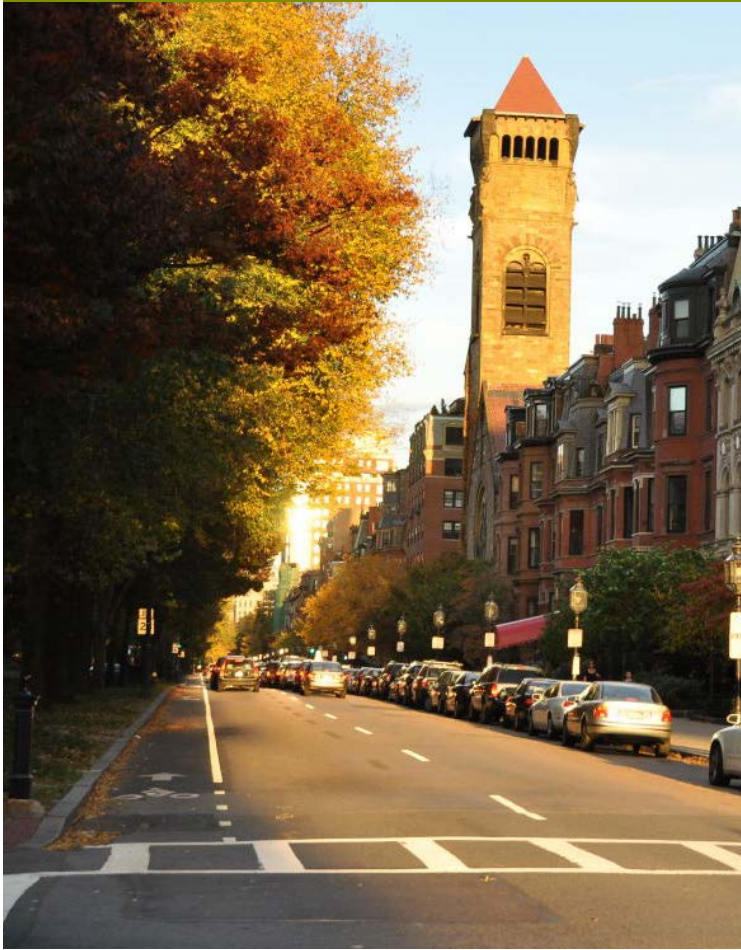
THEME	PAGES
Bus Stops	31, 34, 36, 41, 48, 49-52, 68, 71, 73, 79-82
Crossing Islands (FHWA Proven Safety Countermeasure)	19, 33-36, 64, 68, 72, 88, 92, 96, 104
Design Speed	13, 14, 19, 21-27, 50, 58, 60, 72, 108
Design Vehicle	17-20
Enhancing Access to Opportunity	25-28, 33-36, 41-44, 49-56, 63-78, 87-90, 99-102
Ensuring Accessibility	38, 43, 47, 49-51, 54, 59, 65, 72, 73, 76, 87-90, 92, 107-110
Loading	48, 68, 72, 83, 84, 88, 98, 107, 110
Promoting Equity	4, 33-36, 49-52, 63-78, 87-91
Reconnecting Communities	13-36, 53-56, 57-60, 63-78
Road Diets (FHWA Proven Safety Countermeasure)	16, 29-32, 88
Roundabouts (FHWA Proven Safety Countermeasure)	20, 23, 24, 27, 92
Separated Bike Lanes	14, 15, 30, 39, 40, 42, 45-48, 63-66, 69, 72, 76-78, 80, 82, 84, 85, 92, 94, 95-98
Traffic Analysis	6, 29-32, 38
Transit Stations	63, 66, 71-78, 88, 104

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PART 1:
APPLYING DESIGN FLEXIBILITY

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DESIGN CRITERIA AND LANE WIDTH



Design criteria are values, such as lane widths, shoulder widths and design speeds, which vary depending on the functional classification and context of the roadway. Designers make decisions about these criteria early in project development, and these decisions should reflect the desired purpose and function of a street and prioritize the safety of all users. This design topic provides an introduction on how designers should approach selecting design criteria for multimodal roadways.

Designers sometimes adhere strictly to the most conservative values, leading to wider streets, large curves, and higher operating speeds. This may result in a design that meets all the design criteria, but has a high crash rate compared to expectations.

Designers have flexibility in selecting design criteria and are not always required to choose the most conservative values. Understanding the local context of the roadway, needs of the community, and desired function of the roadway will help the designer identify the appropriate design criteria.

KEY DESIGN FLEXIBILITY

The **2011 AASHTO Green Book** recognizes that functional classification of highways can lead to roadway facilities that do not take into account the local context and that design has impacts beyond traffic service:

"A highway has wide-ranging effects in addition to providing traffic service to users. It is essential that the highway be considered as an element of the total environment. The term 'environment,' as used here refers to the totality of humankind's surroundings: social, physical, natural, and synthetic."

AASHTO Green Book 2011, p. 2-86

OTHER RESOURCES

"After a functional classification has been assigned to a roadway, however, there is still a degree of flexibility in the major controlling factor of design speed. There are no 'cookie-cutter' designs for roadways. Instead, there is a range of geometric design options available."

FHWA Highway Functional Classification: Concepts, Criteria and Procedures 2013, p. 42

"Lane widths of 10 feet are appropriate in urban areas and have a positive impact on a streets safety without impacting traffic operations."

NACTO Urban Streets Design Guide 2013, p. 34

"Conventional roadway design characteristics, including geometry and speed, are associated with each functional classification, but do not capture the nuances of a roadway's context, nor allow for the idea that a large downtown multiway boulevard might have high capacity, lower speeds, and be enjoyable to walk."

FHWA Livability Guide, p. 76

APPLYING DESIGN FLEXIBILITY

SETTING DESIGN CRITERIA

The functional classification of a roadway directs designers to recommended values for each design criterion. Design speed is a fundamental decision because it influences other design criteria such as horizontal and vertical alignment, lane width, shoulder width, grade, and stopping sight distance. For more information, refer to design topics on **Traffic Calming and Design Speed** and **Paved Shoulders**.

The **AASHTO Green Book** allows for flexibility by providing a range of values. For example, design speeds on urban arterials range between 30 and 60 mi/h (2011, p. 7-27) and lane width may vary between 10 and 12 feet (2011, p. 7-29). Additional national resources recommend lower design speeds: **NACTO Urban Street Design Guide** recommends a design speed of less than 35 mi/h for urban arterials (2013, p. 141) and **ITE's Designing Walkable Urban Thoroughfares** recommends a design speed of 25–35 mi/h for a “Boulevard,” which is similar to an arterial (2010, pp. 70–71).

It is essential that designers carefully consider both the context (urban, suburban, rural) and speed of the roadway as these are fundamental elements of design. Some suburban communities and rural towns have characteristics similar to areas typically considered urban. These areas are characterized by denser land use and street networks and increased pedestrian and bicycle activity. As stated in the **AASHTO Roadside Design Guide**, “there also may be whole communities that are separated from the metropolitan center by rural-like conditions but function similarly to an urban area” (2011, p. 10-2). For example, in lower-speed urban environments, the **AASHTO Roadside Design Guide** recognizes that there are limitations to providing large clear zones and offsets should be a minimum of 1.5 feet from the face of curb. ①

CONTEXT SENSITIVE SOLUTIONS, LIVABILITY, AND PERFORMANCE-BASED PRACTICAL DESIGN (PBPD)

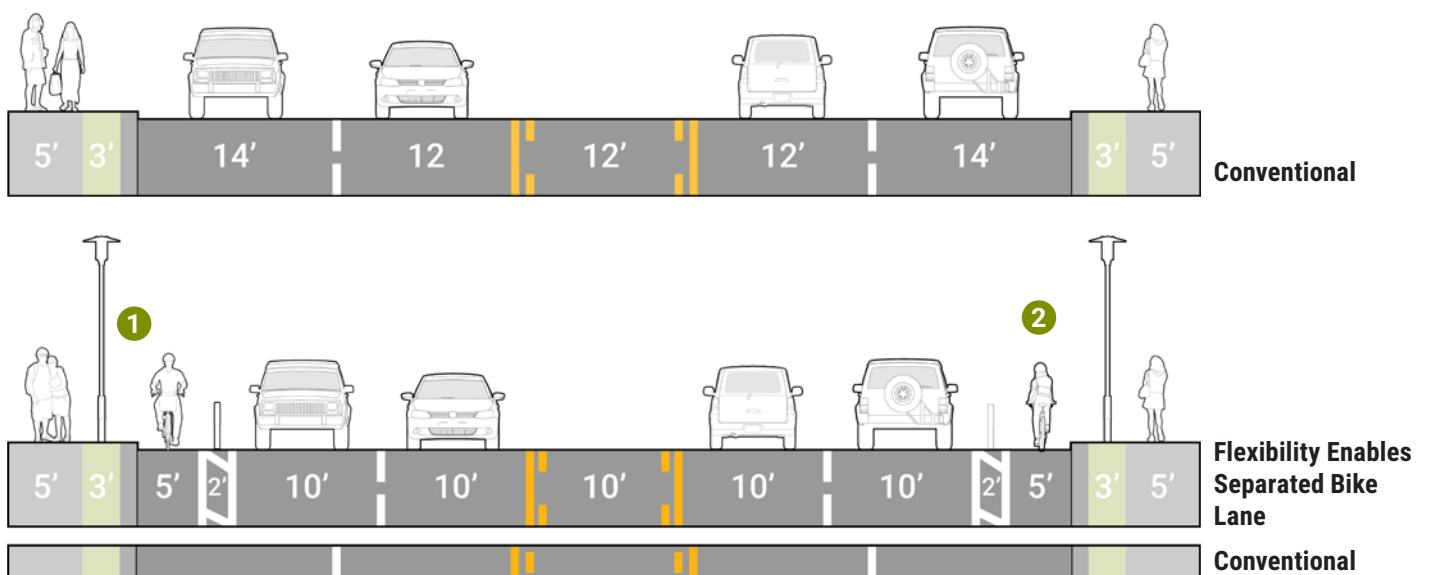
Context-sensitive solutions (CSS), livability, and performance-based practical design (PBPD) rely on flexibility to achieve results that meet a project’s purposes and needs. CSS is a collaborative, interdisciplinary approach that includes the viewpoints of all stakeholders in the development of a shared vision of project goals and uses a defined decision-making process. CSS and livability seek transportation solutions that address the needs of all road users and the functions of the facility within the context of its setting, considering land use, users, the environment, and other factors. PBPD complements CSS and livability by highlighting the value of performance information that supports decision-making. For more information on PBPD, refer to <https://www.fhwa.dot.gov/design/pbpd>.

RECOMMENDED RESOURCES

Several sources provide information on the flexibility available in design criteria selection. In addition to the **AASHTO Guide for the Planning, Design, and Operation of Pedestrian Facilities** and the **AASHTO Guide for the Development of Bicycle Facilities**, the **NACTO Urban Bikeway Design Guide** and **ITE Designing Walkable Urban Thoroughfares** provide useful information on design criteria flexibility. (FHWA, “Bicycle and Pedestrian Facility Design Flexibility,” memorandum, 2013).

CONTROLLING DESIGN CRITERIA AND DESIGN EXCEPTIONS

Historically, 13 controlling design criteria had been identified by FHWA as having substantial importance to the operational



Note: One or both of the outside vehicular lanes in all of the graphics could serve as on-street parking, which would provide a traffic calming effect and a physical buffer for pedestrians and bicyclists. For more information, see design topics on **Road Diets and Traffic Analysis** and **Traffic Calming and Design Speed**.

and safety performance of highways on the National Highway System (NHS). As of May 2016, these criteria have been revised. There are now 10 controlling criteria for high-speed roads. On non-freeways with design speeds under 50 mph on the NHS, only the following two controlling criteria apply: Design Loading Structural Capacity and Design Speed. Refer to FHWA’s website for current information. **(Federal Register, Revision of Thirteen Controlling Criteria for Design and Documentation of Design Exceptions, 2016 and National Cooperative Highway Research Program, Report 783: Evaluation of the 13 Controlling Criteria for Geometric Design, 2015)**

FHWA requires a written design exception if design criteria on the NHS are not met for any of the controlling criteria. For non-NHS roadways, States may have their own design exception processes. Some States require a design waiver to vary from State criteria and a design exception to vary from national criteria.

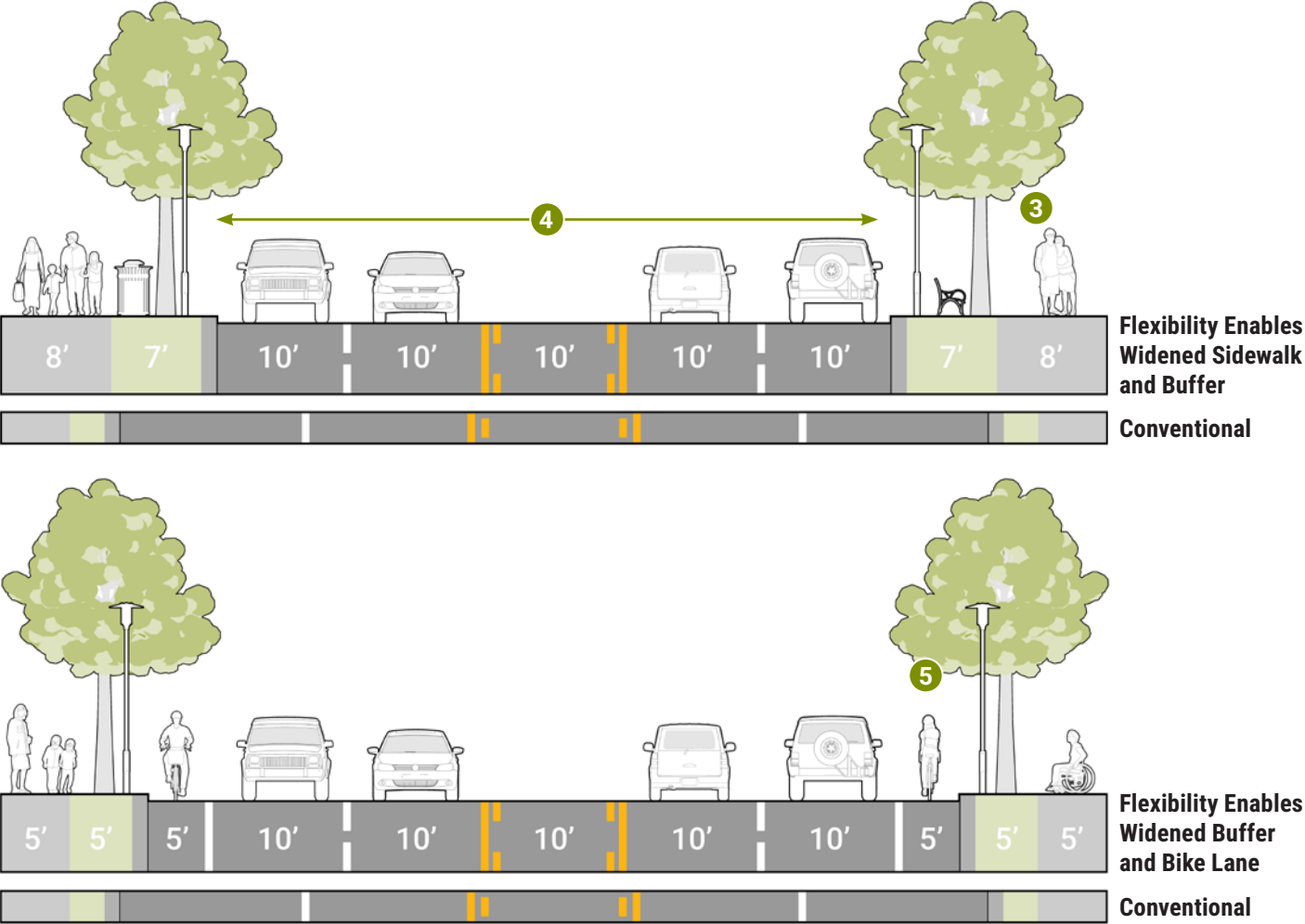
LANE WIDTH

Lane width is an important design criteria. Narrower lanes can improve comfort and safety for vulnerable users. By narrowing lanes, designers can create space for a separated bike lane ②, a widened sidewalk with buffer ③ and reduced crossing distances ④, or a standard bike lane and widened buffer. ⑤

Narrower lanes, as an element of an integrated urban street design, can contribute to lower operating speeds.

The **AASHTO Green Book** offers substantial flexibility regarding lane widths, allowing a range of between 9 and 12 feet depending on desired speed, capacity, and context of a roadway (2011, p. 4-7). While 12-foot lanes have been used historically as motor vehicle travel lanes, the **AASHTO Green Book** allows 10-foot travel lanes in low speed environments (45 mi/h or less) (2011, pp. 4-7-4-8).

Designers have avoided using narrower lane widths in the past due to concerns about safety and congestion especially on arterial roadways. However, research on suburban and urban arterials has shown that in most cases, travel lane widths between 10 feet and 11 feet as a part of a thoughtful, integrated design of arterials and collectors do not negatively impact overall motor vehicle safety or operations and have no measurable effect on vehicular capacity. The study found one exception where 10-foot wide travel lanes should be used with caution—on 4-lane, undivided arterial roadways. **(Potts, Ingrid B., Douglas W. Harwood, and Karen R. Richard. "Relationship of Lane Width to Safety on Urban and Suburban Arterials." *Transportation Research Record*, Issue 2023 (2007): 63–82. doi: 10.3141/2023-08).** For more information, refer to the design topic on **Road Diets and Traffic Analysis** and the **FHWA Crash Modification Factors Clearinghouse** website (<http://www.cmfclearinghouse.org>).



CASE STUDIES

SMART TRANSPORTATION GUIDEBOOK NEW JERSEY/PENNSYLVANIA

The Smart Transportation Guidebook, which received an FHWA Transportation Planning Excellence Award in 2008, defines a context-focused classification system that complements AASHTO's functional classification system. Each category in this system corresponds to a functional classification. However, it recognizes that pedestrian and bicyclist activity may be prioritized in certain land use contexts. The Guidebook tailors ranges for several design values found in the Green Book to apply to the traffic-calming needs of each context. These design values include widths for travel lanes, shoulders, parking lanes, bike lanes, sidewalks, medians, curb radii, and number of travel lanes. In doing so, it acknowledges that in some contexts, guidance should prioritize the pedestrian and bicycle experience, even if it results in decreased vehicular LOS on roadways.

GRACY FARMS LANE ROAD DIET AUSTIN, TX

In 2015, the City of Austin completed a road diet on Gracy Farms Lane to include buffered bicycle lanes. Gracy Farms Lane is classified as a collector street with an average daily traffic of 10,000 vehicles per day and relatively low heavy vehicle volumes. This segment of Gracy Farms Lane provides an important east-west connection for bicyclists in a network where geographical barriers limit other options. The City decided to include a right-turn lane at one intersection due to relatively high turning volumes. To accommodate the right-turn lane while maintaining bicycle facilities through the intersection, designers narrowed travel lane widths, included a 9-foot right turn lane, and provided a continuous bike lane in one direction and sharrows in the other direction.

MASSACHUSETTS AVENUE LANE DIET BOSTON, MA

The City of Boston and the Massachusetts Department of Transportation worked together to develop a multimodal design solution for the reconstruction of Massachusetts Avenue in Boston. The street is a major urban arterial that, in addition to carrying 33,000 vehicles per day, is heavily traveled by pedestrians and bicyclists and has a bus route with the highest ridership in the region. With an \$18 million reconstruction effort, the awarded bid package did not initially include dedicated bicycle facilities. The City of Boston utilized the design exception process to build a case to State and Federal agencies to narrow travel lanes in order to provide additional space for bike lanes. By building consensus, a change order was issued to the contractor with a new cross section consisting of 10.5-foot travel lanes and 5-foot bike lanes.



SMART TRANSPORTATION GUIDEBOOK

*Planning and Designing Highways and Streets
that Support Sustainable and Livable Communities*



Source: Nathan Wilkes, City of Austin



INTERSECTION GEOMETRY



Intersection design must balance the needs of drivers, transit users, pedestrians, and bicyclists. To improve safety for vulnerable road users, such as pedestrians and bicyclists, intersections should have short crossing distances, slow motor vehicle turning speeds, and good visibility. Context-sensitive design derives from key decisions made about intersection geometry. For example, the selection of design vehicle and the tolerance for vehicle encroachment into other lanes will help determine the necessary width of the intersection and impact pedestrian crossing distances.

Designers have flexibility in the selection of the design vehicle and how that vehicle will traverse the intersection. It is not always necessary to design an intersection for the largest vehicle that may ever use it or to oversimplify geometry with large sweeping curves. Designers should consider large vehicle frequency and other contextual factors when selecting a design vehicle. Designers also have flexibility in determining when it is appropriate for large vehicles to encroach into other travel lanes during turns—a key factor for designing tighter, pedestrian-friendly intersections. Design features, such as mountable truck aprons and stop bar placement, can help accommodate large vehicles and result in suitable intersection geometry for vulnerable road users.

KEY DESIGN FLEXIBILITY

The **2011 AASHTO Green Book** recommends that designers select the largest vehicle that will use a facility with considerable frequency, but then goes on to provide more nuanced guidance and flexibility:

"If turning traffic is nearly all passenger vehicles, it may not be cost-effective or pedestrian friendly to design for large trucks. However, the design should allow for an occasional large truck to turn by swinging wide and encroaching on other traffic lanes without disrupting traffic significantly."

AASHTO Green Book 2011, p. 9-80

OTHER RESOURCES

"Design for the most vulnerable street user rather than the largest possible vehicle. While designs must account for the challenges that larger vehicles, especially emergency vehicles, may face, these infrequent challenges must not dominate the safety or comfort of a site for the majority of daily users."

NACTO Urban Street Design Guide 2013, p. 143

"In designing walkable urban thoroughfares, the smallest possible curb-return radii are used to shorten the length of pedestrian crosswalks."

ITE Designing Walkable Urban Thoroughfares 2010, p. 185

"Good intersection design clearly indicates to bicyclists and motorists how they should traverse the intersection."

AASHTO Bike Guide 2012, p. 4-22

"Excessive crossing distances increase the pedestrian exposure time, increase the potential of vehicle-pedestrian conflict, and add to vehicle delay."

AASHTO Pedestrian Guide 2004, p. 74

APPLYING DESIGN FLEXIBILITY

LAYOUT

To the extent feasible, intersections should meet at right angles. This increases sight distance and can help lower vehicle speeds (**AASHTO Green Book 2011, p. 9-25**). Skewed intersections can increase pedestrians' exposure to vehicle traffic, increase speeds for turning vehicles, reduce sight distance for some users, and may not provide clear orientation cues for pedestrians with visual disabilities. (**AASHTO Pedestrian Guide 2004, p. 76**)

TURN RESTRICTIONS

Consider turn restrictions at locations where turning volume is low and pedestrian crossing volumes are high.

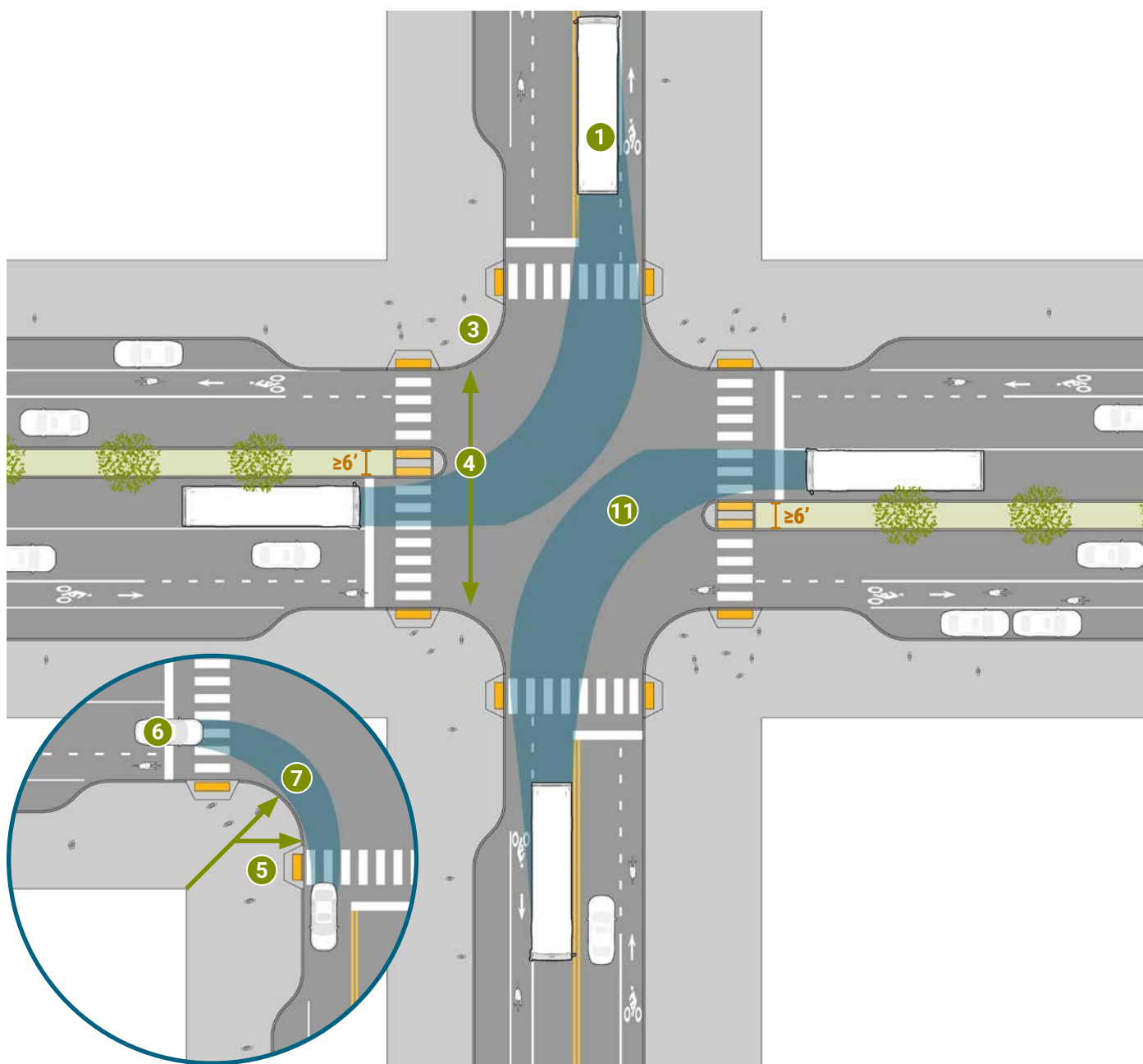
(NACTO Urban Street Design Guide 2013, p. 129)

DESIGN VEHICLE AND ENCROACHMENT

The design vehicle **1** should be the frequent user of the street and should dictate the lane widths and corner radii. Consider a control vehicle, an infrequent user of the intersection, to understand how larger vehicles will negotiate the intersection. Stop bars can be recessed from the intersection **2** to allow control vehicle encroachment (**NACTO Urban Streets Design Guide 2013, p. 144**). Assume emergency vehicles will use the entire right-of-way. See in the **2011 AASHTO Green Book Fig. 9-33** for design considerations when allowing encroachment.

CURB RADII AND CURB EXTENSIONS

Curb radii should be designed for the vehicle that turns at the intersection most frequently. Smaller curb radii and curb



extensions position vulnerable users in a more visible location **3**, reduce crossing lengths **4**, reduce motor vehicle speeds, and provide additional space for curb ramps. **5** Generally, for local urban streets, curb radii should be between 10–15 feet unless special circumstances require a larger radius. (AASHTO Green Book 2011, p. 9-92)

SPEED OF TURNING VEHICLE

The AASHTO Green Book assumes that vehicles are making turns between 0 and 10 mi/h (2011, p. 2-5). If designers anticipate turns at the lower end of that range, vehicle turning envelopes can be further reduced. **6**

EFFECTIVE CURB RADII

Where on-street parking or bike lanes are present, designers should use the “effective” curb radii **7**, rather than the actual, to create a more compact intersection that encourage slower speeds. (AASHTO Green Book 2011, Fig. 5-3)

MOUNTABLE TRUCK APRONS

In locations where large vehicles make occasional turns, designers can consider mountable truck aprons. **8** Mountable truck aprons deter passenger vehicles from making higher speed turns, but accommodate the occasional large vehicle without encroachment or off-tracking into pedestrian waiting areas. Mountable truck aprons should be visually distinct from the adjacent travel lane and sidewalk.

LANE WIDTH

Lane widths are an important element of intersection design for vulnerable users. Narrower lanes reduce pedestrian crossing

distances and encourage motorists to drive slower. For more information, refer to the design topic on Design Criteria and Lane Width.

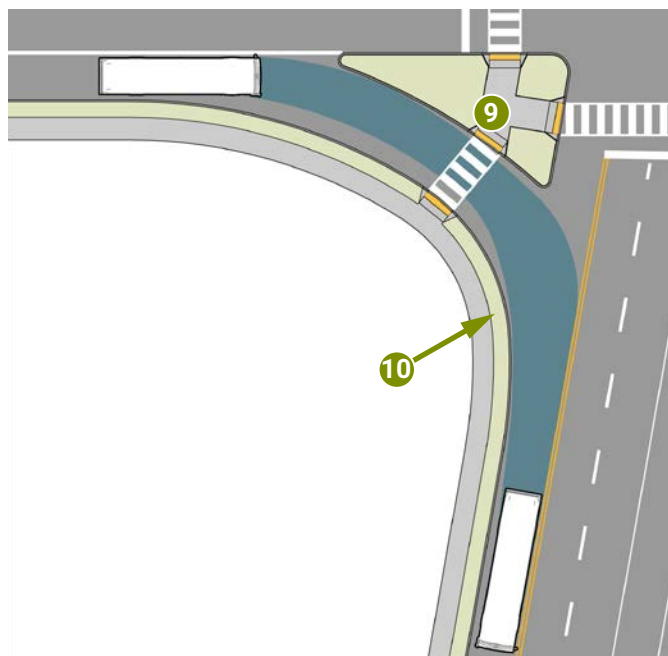
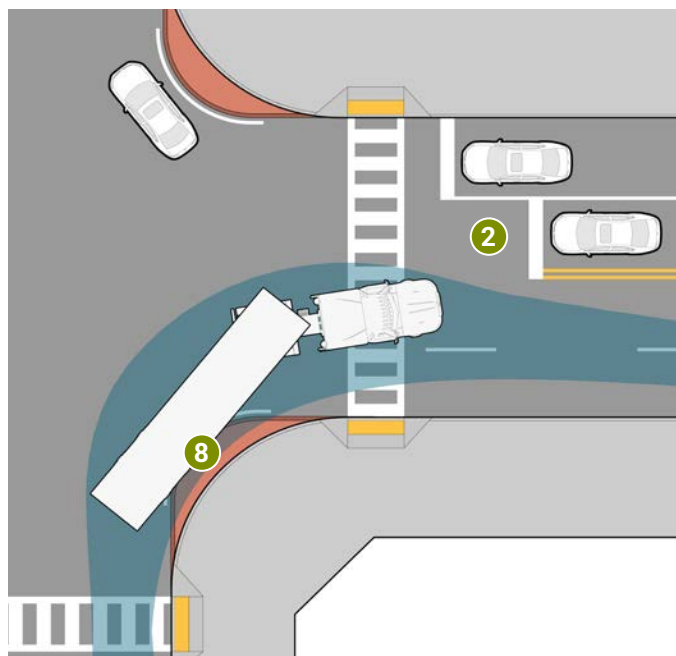
CHANNELIZED RIGHT TURNS

Channelized right turns are typically less pedestrian friendly, but can be appropriate where large curb radii are needed, such as turns with a higher frequency of large vehicles, or at skewed intersections. A right-turn channelizing island can also break up longer crossing distances by providing refuge space and two shorter crossings **9** (AASHTO Pedestrian Guide 2004, p. 78). Designs can be further developed with compound curves that slow vehicular speeds and prioritize pedestrian movements. **10** (See Table 9-18 in the 2011 AASHTO Green Book for guidance on turning roadway lane widths.) Design speeds less than 10 mi/h should be used. (ITE Designing Walkable Urban Thoroughfares 2010, p. 187)

MEDIANS

The presence and shape of medians is dictated by factors such as design vehicle selection, turning speeds, and lane widths. Medians can be particularly useful for pedestrians crossing multilane roads if the median nose extends through the pedestrian crossing area and is sufficiently wide (a minimum of 6 feet wide). Crossings with four or more lanes of traffic should provide a pedestrian refuge **11** as part of a continuous median or dedicated crossing island. (AASHTO Green Book 2011, p. 6-14)

Where they are intended to serve as a pedestrian refuge, medians and crossing islands should be a minimum of 6 feet. (ITE Designing Walkable Urban Thoroughfares 2010, p. 141)



CASE STUDIES

CORNER CURB RADII—BETTER STREETS PLAN SAN FRANCISCO, CA

The San Francisco Better Streets Plan provides guidance on design vehicle selection given the type and frequency of vehicles. Specifically, the plan recommends that designers differentiate between the most frequent vehicle and a vehicle that may only use the intersection occasionally.

For example, a transit route may necessitate a design that allows a bus to turn within the travel lane. On the other hand, locations with higher pedestrian activity may be designed for a Single Unit truck (SU-30), requiring larger vehicles to encroach into adjacent or opposing lanes. Strategies such as allowing encroachment and locating stop bars farther from the intersection allow these intersections to accommodate occasional larger turning vehicles while providing shorter pedestrian crossings.

Corner Curb Radii

5.2

The shape of a corner curb radius (the radius defined by two sidewalks on perpendicular streets that cross together at a corner) has a significant effect on the overall operation and safety of an intersection. Smaller turning radii increase pedestrian safety by shortening crossing distances, increasing pedestrian visibility, and decreasing vehicle turning speed.

The shape and dimensions of curb radii vary based on street type and transportation context.

DEFINITIONS

Design vehicle: selected vehicle type used in determining appropriate curb radius at an intersection.

Design for (a vehicle turn): to allow for a particular vehicle type to complete a turn fully within its designated travel lane or lanes.

Accommodate (a vehicle turn): to allow for a particular vehicle type to complete a turn with limited or no adjacent or opposing lanes on the origin or destination street.

Curb radius: the actual radius prescribed by the curb line at an intersection.

Effective radius: The radius available for the design vehicle to make the vehicle turn, accounting for the presence of parking, bike lanes, medians, or other features.



MOUNTABLE TRUCK APRONS PORTLAND, OR

The City of Portland installed mountable truck aprons at an existing intersection where large turning vehicles were relatively frequent. The character of the neighborhood has changed from an industrial area in recent years and large vehicles are now less frequent.

The mountable truck aprons allow drivers of large vehicles to turn without entering the pedestrian zone or encroaching on vehicle lanes. The height of the mountable section discourages smaller vehicles from making the same turn, which reduces their speed through the intersection.



OUTSIDE TRUCK APRONS BURLINGTON COUNTY, NJ

The Burlington County Engineer's Office reconstructed the skewed intersection of County Route 528 and Old York Road (CR 660). Relatively high speeds were common on the main roadway. The two-way stop controlled intersection was replaced by a modern roundabout with a 15 mi/h circulating speed. The design includes outside truck aprons to achieve the desired entering speeds and roadway widths for cars and school buses, while providing a larger roadway width to accommodate tractor trailers (WB-67) and farm equipment. The outside truck aprons include a mountable curb with a minimal 3 inch reveal and stamped red concrete. Observations have shown that drivers of small vehicles do not ride on the truck apron. As shown in the picture, pedestrians are accommodated in advance of the truck apron.



TRAFFIC CALMING AND DESIGN SPEED



Traffic calming is the combination of measures that reduce some of the negative effects of motor vehicle use, alter driver behavior, and improve conditions for vulnerable road users. Traffic calming uses physical measures to slow motor vehicle speeds and encourages desired behaviors to maximize safety, such as yielding to pedestrians and bicyclists. Typical traffic calming measures include cross-section measures, such as street trees, narrower lanes, and on-street parking. They also include periodic measures, such as curb extensions, speed tables, and chicanes. Traffic calming is an important tool to help improve walking and bicycling conditions.

Design speed is a fundamental factor in roadway design and is used to establish design features. It affects horizontal alignment, vertical alignment, and cross section features. Higher design speeds can result in streets that are less comfortable for vulnerable users. As speeds increase, crash severity and fatality rates increase significantly for all users: pedestrians, bicyclists, and people in motor vehicles. Designers have the flexibility to set design speeds lower than the posted speed limit.

KEY DESIGN FLEXIBILITY

The **2011 AASHTO Green Book** provides flexibility when it comes to selecting appropriate design speeds given the context of a particular roadway:

"Design speed should be a logical one with respect to the anticipated operating speed, topography, the adjacent land use, and the functional classification of the highway. In selection of design speed every effort should be made to attain a desired combination of safety, mobility, and efficiency within the constraints of environmental quality, economics, aesthetics, and social or political impacts"

AASHTO Green Book 2011, p. 2-54

OTHER RESOURCES

"In urban areas, the design of the street should generally be such that it limits the maximum speed at which drivers can operate comfortably, as needed to balance the needs of all users."

FHWA, "Relationship between Design Speed and Posted Speed," memorandum, October 7, 2015

"The severity of pedestrian crashes, a significant concern in urban areas, is greatly increased as speeds increase. Context-sensitive solutions for the urban environment often involve creating a safe roadway environment in which the driver is encouraged by the roadway's features and the surrounding areas to operate at low speeds."

AASHTO Flexibility Guide 2004, p. 19

"There is a direct correlation between higher speeds, crash risk, and the severity of injuries... Design streets using target speed, the speed you intend for drivers to go, rather than operating speed. The 85th percentile of observed target speeds should fall between 10–30 mph on most urban streets."

NACTO Urban Street Design Guide 2014, pp. 140–141

"Traffic calming challenges the traditional design view of a roadway design, namely, that higher speeds are desirable and indicative of a high-quality design."

AASHTO Flexibility Guide 2004, p. 88

TRAFFIC CALMING AND DESIGN SPEED MYTHS

This design topic addresses myths related to traffic calming and setting appropriate design speeds for new roadways and retrofit projects.

MYTH 1: ROUTE MODIFICATIONS ARE A FORM OF TRAFFIC CALMING

Traffic calming is about reducing speeds, not about removing pieces of the street network or changing the route people take from Point A to Point B. These techniques are called “route modifications.” Route modifications remove access through signing and minor geometric changes (i.e., one-way restrictions, street closures, partial closures, turn prohibitions, and diverters). In general, they should be used with caution, because they can have the impact of increasing traffic volumes on other streets that also serve pedestrians and bicyclists. However, route modification can be used to compliment traffic calming efforts on certain project types, such as neighborhood greenways or bike boulevards. In some cases, traffic calming projects may result in reduced traffic volumes and motorists may divert to other routes. This outcome should be factored into a network approach to traffic calming.

MYTH 2: STOP SIGNS ARE TRAFFIC CALMING MEASURES

Sometimes residents request STOP signs to deter drivers from speeding in their neighborhoods. However, STOP signs must meet certain criteria in order to maintain effectiveness. STOP signs installed for the purpose of slowing motorists can be counterproductive: motorists may accelerate rapidly after a stop and maintain higher speeds between signs. This behavior is called “speed spiking.” Additionally, motorists may roll through STOP signs, endangering pedestrians who are expecting vehicles to come to a complete stop.

MYTH 3: DESIGN SPEED SHOULD BE GREATER THAN POSTED SPEED

Some designers use a design speed that is higher than the posted speed with the goal of improving safety. However, higher design speeds can result in more generous vehicular designs that cause motorists to drive faster, which reduces safety. Best practices from ITE and NACTO recommend setting a design speed equal to the target speed. As defined in the **ITE Designing Walkable Urban Thoroughfares**, “Target speed is the highest speed at which vehicles should operate on a roadway consistent with the level of multimodal activity and adjacent land uses to provide both mobility for motor vehicles and a safe environment for pedestrians, bicyclists, and public transit users” (2010, p. 108). Designers should consider several factors in addition to the posted speed to determine an appropriate design speed including, but not limited to, target operating speed, type and density of adjacent land uses, level of pedestrian, bicycle, and transit activity, and frequency of driveways.

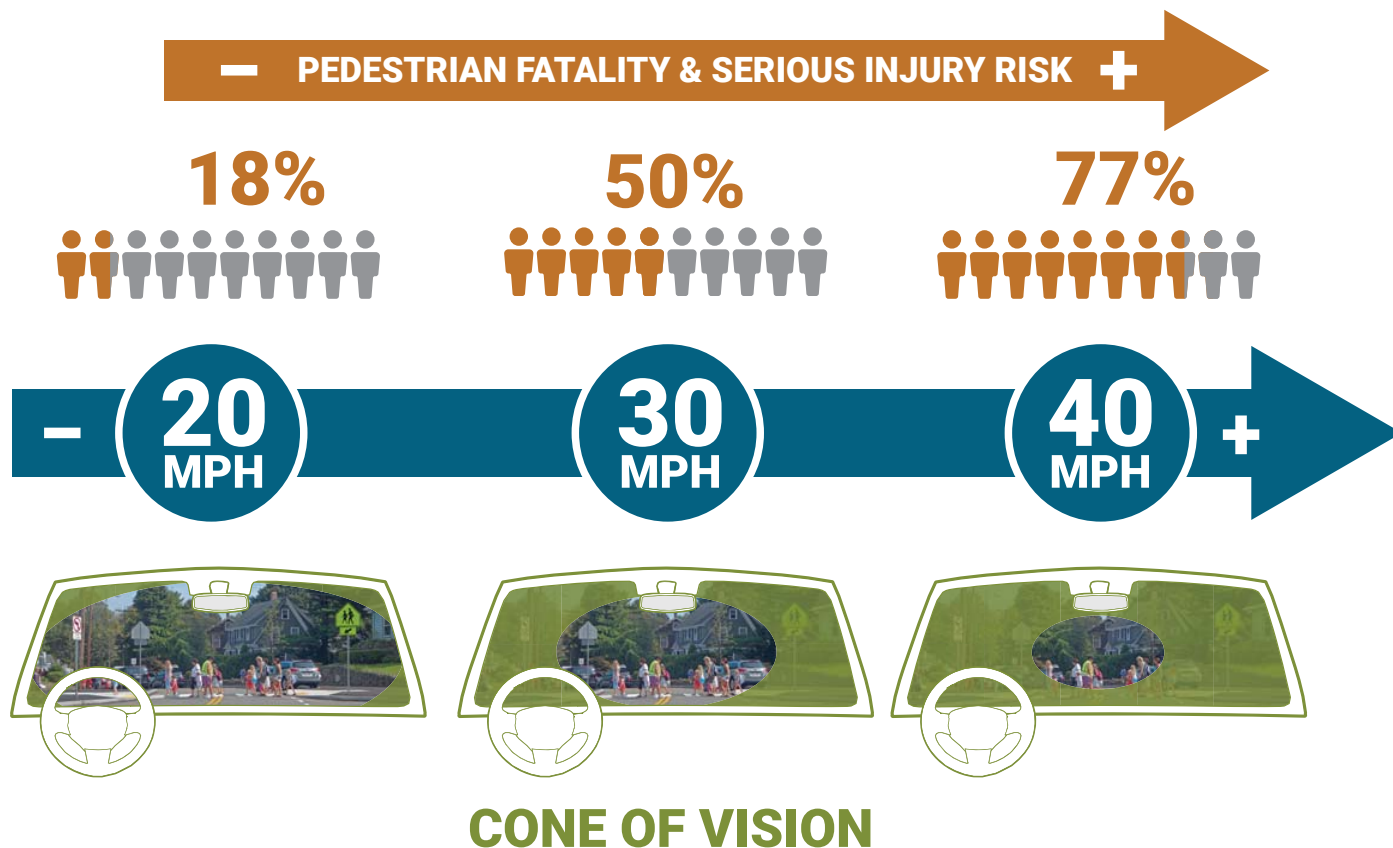
MYTH 4: POSTED SPEED LIMITS MUST USE THE 85TH PERCENTILE METHODOLOGY

The **FHWA Methods and Practices for Setting Speed Limits** summarizes several engineering approaches to setting speed limits. The “Engineering approach” and “Expert system approach” are the most commonly used. The Engineering approach primarily uses the 85th percentile speed (2012, p. 10). However, from a safety perspective this approach can result in excessive speeds. For the Expert system approach, FHWA developed a model called USLIMITS2, which determines an appropriate speed limit for all roadway users. For roadway segments that experience high pedestrian and bicyclist activities, USLIMITS2 recommends speed limits close to 50th percentile instead of 85th percentile speed.

A third approach set forward in **Methods and Practices for Setting Speed Limits** called the “Injury minimization” or “safe system approach.” This approach is often more appropriate in locations with pedestrian and bicycle activity. In this approach, “speed limits are set according to the crash types that are likely to occur, the impact forces that result, and the human body’s tolerance to withstand these forces” (2012, p. 10). This approach is consistent with Vision Zero principles—which state that no loss of life on a road system is acceptable. The “injury minimization” approach is therefore highly appropriate in contexts where people commonly walk or bike. After traffic calming measures have been implemented, a speed study should be conducted to determine if the speed limit can be reduced.

MYTH 5: CLEAR ZONES SHOULD BE APPLIED EQUALLY ON ALL STREETS

Clear zones are a “forgiving” roadside design concept intended to decrease the frequency and severity of fixed-object crashes by providing a space for errant vehicles to recover after leaving the roadway. While clear zones are appropriate for freeways and high speed roadways, the **AASHTO Roadside Design Guide** recognizes that there are practical limitations to clear zones on low-speed curbed streets. In urban, suburban, and small town rural settings where pedestrian and bicycle activity is expected and the traffic speed is lower and depending on the context, roadway design may incorporate street trees, furnishings, and plantings to create a sense of enclosure. This provides a traffic calming effect, which may increase comfort and safety for vulnerable road users.



As motor vehicle speeds increase, the risk of serious injury or fatality for a pedestrian also increases (AARP Impact Speed and a Pedestrian's Risk of Severe Injury or Death 2011, p. 1). Also, motorist visual field and peripheral vision is reduced at higher speeds.

MYTH 6: RAISED INTERSECTIONS AND RAISED CROSSWALKS ARE NOT APPROPRIATE ON ARTERIAL STREETS

Raised measures require motor vehicles to reduce speeds and can be appropriate on arterial roadways, particularly at intersections with slip lanes and on intersecting side streets. As stated in the **AASHTO Flexibility Guide**, “traffic calming techniques may apply on arterials, collectors, or local streets” (2004, p. 87). Raised measures may not be appropriate on higher speed roads. If raised measures are desired to improve pedestrian or bicyclist safety, designers should consider completing a study and reducing the speed limit to 35 mi/h or lower. Raised measures can minimize impacts to emergency vehicle response times through strategic placement and design details such as longer ramps, slots, or tire grooves. Gradual transitions on raised measures benefit passenger comfort and pavement conditions. These slots or grooves can be placed at locations that correspond to emergency vehicle wheelbases.

MYTH 7: LOWER SPEEDS ALWAYS INCREASE TRAVEL TIMES

Roadways designed for lower motor vehicle speeds may not result in longer travel times compared to similar streets with higher motor vehicle speeds. Travel times depend on a wide variety of factors, such as intersection frequency, operational efficiency, and driver characteristics. Delay for motorists in suburban and urban areas is often due to congestion at signalized intersections, and usually not travel speeds between intersections. There are several techniques to lower motor vehicle speeds that improve safety for all roadway users while simultaneously reducing congestion. Replacing signalized intersections with modern roundabouts, a Proven Safety Countermeasure, or coordinating signals for speeds of 15 to 25 mi/h (**AASHTO Green Book 2011, pg. 2-57**) can maintain or reduce vehicular travel times on a corridor.

ADDITIONAL RESOURCES

There are several comprehensive guides to traffic calming that provide additional information such as **Traffic Calming: State of the Practice (1999)** by FHWA and ITE, the **Traffic Calming Website** (<http://www.ite.org/traffic/>) by ITE, and **LA Living Streets Manual: Chapter 10 Traffic Calming (2012)** by the City of Los Angeles.

CASE STUDIES

SOUTH GOLDEN ROAD **GOLDEN, CO**

The City of Golden installed a series of four roundabouts resulting in improvements to traffic operations and economic development. Initially, South Golden Road served 12,000 vehicles per day via four travel lanes and one center turn lane. The wide roadway, inconsistent sidewalks, and numerous driveways contributed to speeding and reduced access to side streets. In 1999, four roundabouts and raised medians were constructed. After installation, the 85th percentile travel speed decreased from 47 mi/h to 35 mi/h, and travel time decreased from an average of 103 to 78 seconds. The crash rate dropped 67 percent and traffic-related injuries dropped over 80 percent. The more pedestrian-oriented environment contributed to economic activity, and sales tax revenue increased 68 percent.



OLIVE AVENUE **WEST PALM BEACH, FL**

In 1999, the City of West Palm Beach completed a traffic calming project on Olive Avenue, a State arterial roadway. The road had been one-way with approximately 12,000 vehicles per day and relatively high speeds. Beach Atlantic College, which occupies both sides of Olive Avenue, was considering building two pedestrian bridges to connect their severed campus. The City of West Palm Beach, the Florida Department of Transportation, and the College collaborated to improve the design. The new design narrowed travel lanes, added landscaping and street trees, and converted the arterial from one-way to two-way. The project incorporated raised crossings, designed with transitions suitable for emergency vehicles. The result provided comfortable at-grade crossings, increased property values, improved quality of life, and reduced traffic volumes.



ARTERIAL SLOW ZONE PROGRAM **NEW YORK CITY, NY**

One strategy to create self-enforcing, slower speeds is through signal progression along signalized corridors, supplemented by other traffic calming measures, education, and enforcement. As a part of New York City's Vision Zero initiative, the Arterial Slow Zone Program focuses on reducing speeds along corridors with high crash rates. On the 25 corridors selected as Arterial Slow Zones, signals were retimed for 25 mi/h speed progression. Slow Zone branding signs similar to the City's Neighborhood Slow Zones program were added to the corridor. In addition, police provide focused enforcement along these zones for speeding, failure to obey traffic signals, and failure to yield to pedestrians.



Source: New York City Department of Transportation

TRANSITIONS TO MAIN STREETS



Highways traveling through “main street” town centers provide both connectivity between communities and local access for pedestrians, bicyclists, and motorists. This dual role can result in traffic speeds and volumes that present safety concerns for all road users, particularly along the main streets. Context-sensitive main streets may be designed to control vehicle speeds and improve safety.

Historically, functional classifications and design speeds for highways have led to higher-speed designs that can negatively impact denser, small town main streets. Community character, adjacent land uses, and safety for all users should dictate the design criteria for a highway that serves as a main street.

Federal and State guidelines encourage the use of traffic calming and context-sensitive design to prioritize safety for all modes rather than designing based solely on functional classification. Designers have the flexibility to take land-use context into account to select lower design speeds, use narrower lane widths, add on-street parking, and provide geometric designs that balance the needs of all users.

KEY DESIGN FLEXIBILITY

2004 AASHTO Flexibility Guide recognizes that functional classification of highways may not always be compatible with the adjacent land use context:

“A roadway’s formal classification as urban or rural may differ from actual site circumstances or prevailing conditions. An example includes a rural arterial route passing through a small town. The route may not necessarily be classified as urban, but there may be a significant length over which the surrounding land use, prevailing speeds, and transportation functions are more urban or suburban than rural.”

AASHTO Flexibility Guide 2004, p. 12

OTHER RESOURCES

“Functional classification does not dictate design; however, the two influence one another. There is a great deal of latitude in the design of a roadway relative to its functional classification.”

FHWA Highway Functional Classification Concepts, Criteria and Procedures 2013, p. 42

“Main streets typically are no wider than two travel lanes, provide on-street parking and may contain bicycle lanes.”

ITE Designing Walkable Urban Thoroughfares 2010, p. 72

“Speeds cannot be reduced simply by changing the posted speed limit. Geometric and cross-sectional elements, in combination with the context, establish a driving environment where drivers choose speeds that feel reasonable and comfortable.”

FHWA Mitigation Strategies for Design Exceptions 2007, p. 26

“There needs to be a distinct relationship between the community speed limit and a change in the roadway character. Emphasizing a change in environment increases awareness.”

NCHRP 737 Design Guidance for High-Speed to Low-Speed Transition Zones for Rural Highways 2012, p. 65

APPLYING DESIGN FLEXIBILITY

FUNCTIONAL CLASSIFICATION AND VARIABLE DESIGN SPEED

The functional classification of a roadway guides a designer to select a design speed based on a range of speeds. The **AASHTO Green Book** allows for flexibility with regard to design speed, providing a range between 40–75 mi/h (2011, p. 7-2) for rural arterial roadways, indicating that speeds between 60–75 mi/h are normally used in level terrain. By comparison, urban arterials are generally designed with a design speed ranging between 30–60 mi/h (2011, p. 7-27) and provide mobility of all users balanced with access to businesses, institutions, and residences (2011, p. 7-26).

Although a main street may exist along a rural arterial roadway, the design principles of a more urban environment apply due to increased population density, increased bicycle and pedestrian activity, and increased need for property access within a community. Therefore, design for a lower speed through a

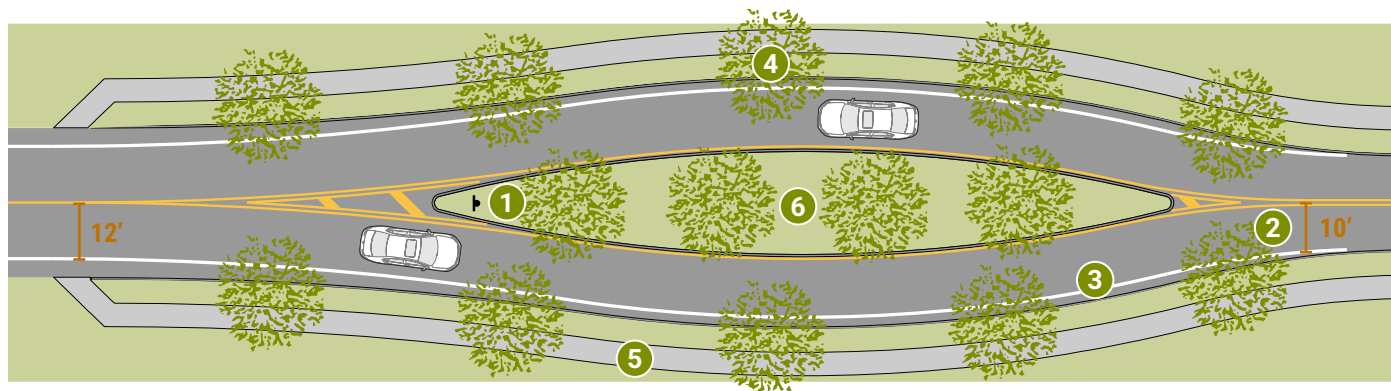
main street environment. The **ITE Designing Walkable Urban Thoroughfares** recognizes that State highways serve as main streets in smaller rural towns and suggests a design speed of 20–25 mi/h on main streets (2010, p. 78).

TRANSITION ZONES

The design speed for a rural arterial roadway should be reduced approaching a main street environment. The **AASHTO Green Book** provides flexibility regarding the design of the transition zone into a lower-speed environment stating that the introduction of a lower design speed should not be done abruptly but should be effected over sufficient distance to permit drivers to gradually change speed before reaching the lower design speed section (2011, p. 2-54). The highway features within this transition zone, such as curvature, superelevation, lane and shoulder widths, and roadside clearances should be designed to encourage slower speeds.

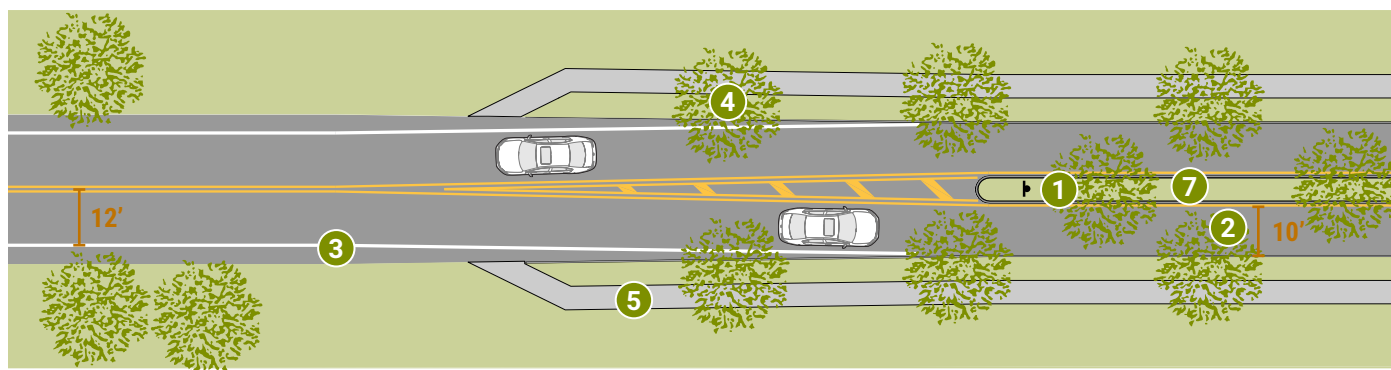
EXAMPLE TRANSITION ZONES AND GATEWAYS

The design treatments shown below can be utilized as transition zone treatments, gateway treatments or both. Both examples include a gateway sign (1), narrowing of lanes (2), the removal of the shoulder (3), and the introduction of curb, street trees (4), sidewalk buffer, and sidewalk. (5)



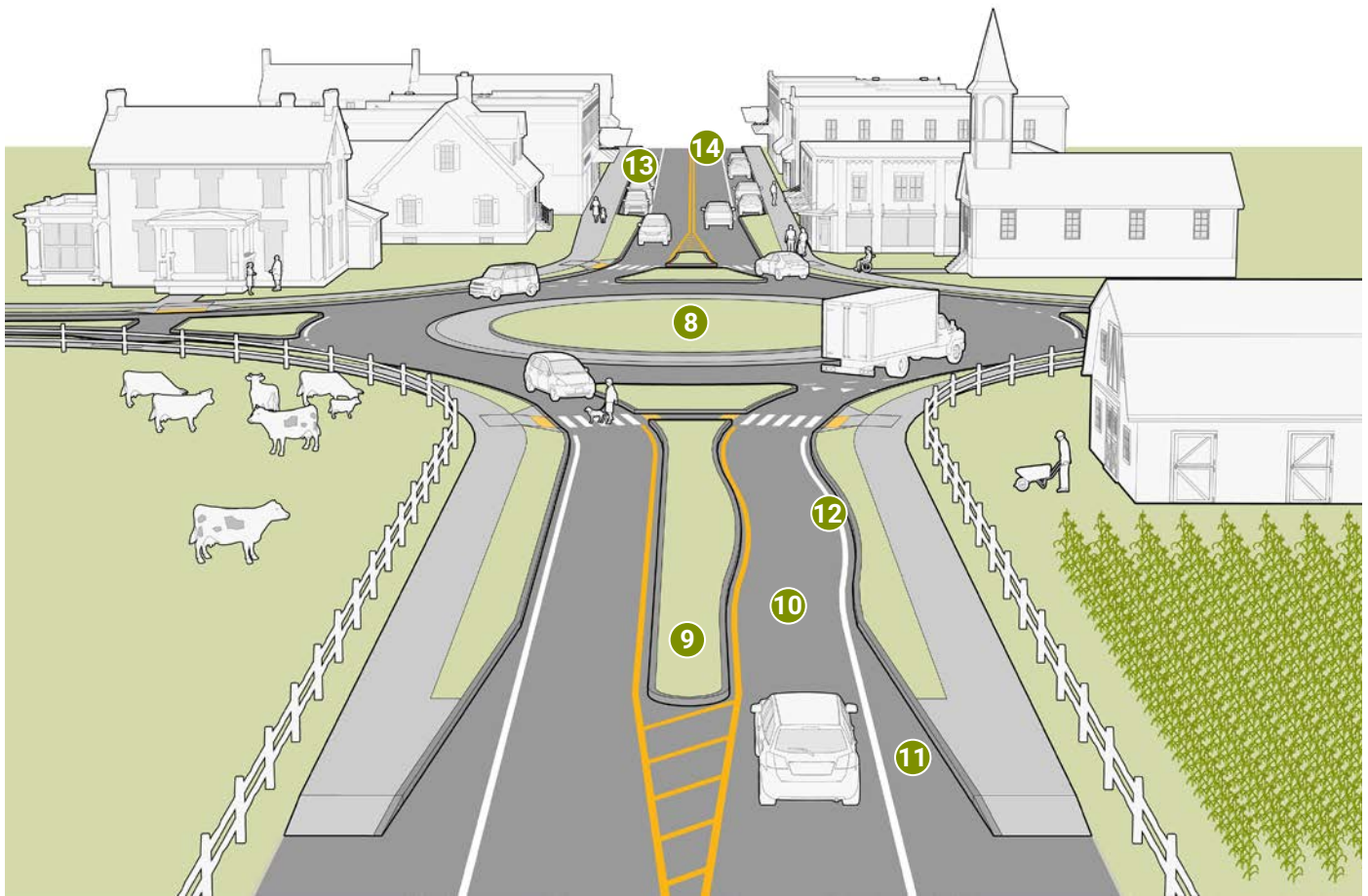
EXAMPLE A:

This example provides horizontal deflection (6) entering and exiting main street.



EXAMPLE B:

This example provides a median (7) and should only be used in constrained environments.



Pavement markings, such as painted center islands, painted narrower lanes, on-pavement speed limit markings, or on-pavement SLOW markings, are not recommended as stand-alone treatments as they have been shown to be either not effective or only marginally effective at influencing motorist speeds. (FHWA. *Traffic Calming on Main Roads Through Rural Communities*. 2009, p. 13).

GATEWAY TREATMENTS

A gateway treatment is a visual and physical feature to communicate to motorists that they are entering a slower speed environment. Physical changes in the roadway alignment or width are the treatments most likely to affect driver behavior and reduce speeds; driver speeds will decrease as roadway deflection increases (NCHRP. *Speed Reduction Techniques for Rural High-to-Low Speed Transitions*. 2011, p. 11), so designers should consider changes in the roadway alignment to physically slow motorists.

Gateway treatments, such as roundabouts (a Proven Safety Countermeasure) 8, chicanes, raised medians 9, reduced lane widths 10, shoulder removal 11, providing a curbline 12 and/or including tall vegetation (e.g., hedges, trees), have been

shown to be effective at reducing travel speeds approaching a main street (NCHRP. *Speed Reduction Techniques for Rural High-to-Low Speed Transitions*. 2011, p. 6). Bicycle facilities, where present, should be carried through gateway treatments.

Roundabouts slow motorists and serve as traffic control at intersections, and also may be installed where signals or stop signs are not warranted. They can provide an ideal solution to incorporate deflection as a gateway treatment and slow motorists at the start of a main street. Where right-of-way is insufficient, chicanes, changes to horizontal alignment, or raised medians should be considered as gateway treatments.

TRAVEL ALONG MAIN STREET

While transition areas and gateway treatments can reduce speeds approaching and exiting main street environments, motorists may resume higher speeds unless additional visual and physical cues are provided along the route through town. Traffic calming measures such as landscaping, street trees, curb extensions, on-street parking 13, and narrower lanes 14 should be considered along the main street. For more information, refer to the design topics on *Traffic Calming and Design Speed* and *Design Criteria and Lane Width*.

CASE STUDIES

TRAFFIC CALMING MEASURES RTE. 50 ALDIE, MIDDLEBURG AND UPPERVILLE, VA

In the foothills of the Blue Ridge Mountains, the U.S. 50 traffic calming corridor begins in the village of Lenah in southeastern Loudoun County and extends westward to the intersection of U.S. 17 near the Clarke County border. It includes the rural communities of Aldie, Middleburg, and Upperville. The roadway's 50 mi/h speed limit reduces to 25 mi/h approaching each main street area. The communities along U.S. 50 participated in a traffic calming plan as an alternate to building a four-lane bypass. Several projects have been implemented and some are underway. Roundabouts were a major element of the traffic calming measures. Other elements include raised medians, curb extensions, high visibility crosswalks, on-street parking, street trees, and raised intersections. Gateway treatments include stamped concrete bands placed at increasing intervals approaching town, curbing, lane and shoulder narrowing, and introduction of a median.



Source: Virginia Department of Transportation

CASCADES AVENUE IMPROVEMENT PROJECT SISTERS, OR

In 2014, the Oregon Department of Transportation and the City of Sisters reconstructed a portion of U.S. 20 which operates as both a freight route and a main street. U.S. 20 has an average annual daily traffic of 12,000 vehicles/day and passes through a business district that attracts tourists. Initially, the project's goal was to repave the quickly deteriorating roadway and replace the sidewalk, but it quickly turned into a revitalization effort. To create a safer pedestrian environment, the project incorporated traffic calming measures such as curb extensions, on-street parking, landscaping, and widening the sidewalk to 8 feet. One intersection was widened to allow freight trucks to more easily navigate turns, while other intersections were improved to reduce turning speeds and crossing distances.



Source: Oregon Department of Transportation

DANVILLE TRANSPORTATION ENHANCEMENT PROJECT DANVILLE, VT

In 2012, U.S. 2 in Danville, VT, was reconstructed to create a pedestrian-focused main street. Outside of Danville, U.S. 2 is a truck route and approximately 11 percent of its daily traffic is heavy vehicles. As the roadway transitions from countryside to town, speed limits change from 50 mi/h to 30 mi/h. Geometric design changes reinforce this reduction in speed: lane widths are narrowed from 12 to 11 feet, and the 5- and 6-foot shoulders are narrowed to 3 feet to make room for a sidewalk. Gateway treatments, such as signs, fence posts, and traffic islands signal the change in environment. Finally, a flashing yellow light—located at the central intersection and surrounded by local businesses and community spaces—was converted to a full traffic signal to facilitate pedestrian crossings.



Source: Nicholas Meltzer, VT Agency of Transportation

ROAD DIETS AND TRAFFIC ANALYSIS



Road Diets are the reconfiguration of one or more travel lanes to calm traffic and provide space for bicycle lanes, turn lanes, streetscapes, wider sidewalks, and other purposes. Four- to three-lane conversions are the most common Road Diet, but there are numerous types (e.g., three to two lanes, or five to three lanes). FHWA has identified Road Diets as a Proven Safety Countermeasure and an Every Day Counts initiative.

Streets are typically designed based on a forecast of future traffic volumes. In many cases, these estimates were either incorrect or circumstances have changed, resulting in fewer vehicles than anticipated. The outcome is excess capacity and streets that encourage fast speeds, and create poor conditions for pedestrians, bicyclists, and transit users.

Road Diets offer a way to rebalance the street to meet the needs of all users. A conventional approach to evaluate the feasibility of a Road Diet is to evaluate the impact on vehicles, not people. Guidance at the national level provides the flexibility to apply engineering judgment to assess the project holistically, incorporating performance measures for all modes and community goals.

KEY DESIGN FLEXIBILITY

The **2010 TRB Highway Capacity Manual** emphasizes the importance of applying engineering judgment to consider a range of performance measures in the analyses:

"Analysts and decision-makers should always be mindful that neither LOS [Level of Service] or any other single performance measure tells the full story of roadway performance."

TRB Highway Capacity Manual 2010, p. 8-11

"As always, engineering judgment should be applied to any recommendations resulting from HCM (or alternative tool) analyses."

TRB Highway Capacity Manual 2010, p. 8-20

OTHER RESOURCES

"Added to the direct safety benefits, a Road Diet can improve the quality of life in the corridor through a combination of bicycle lanes, pedestrian improvements, and reduced speed differential, which can improve the comfort level for all users."

FHWA Road Diet Guide 2014, p. 10

"Road Diets have many benefits, often reducing crashes; improving operations; and improving livability for pedestrians, bicyclists, adjacent residents, businesses, and motorists."

AASHTO Bike Guide 2012, p. 4-30

"Three-lane roadways...create opportunities for pedestrian refuges at midblock and intersection crossings and eliminate the common 'multiple threat' hazards pedestrians experience crossing four-lane roads."

ITE Designing Walkable Urban Thoroughfares 2010, p. 148

"Vibrant cities are active 24 hours a day. Streets designed for peak intervals of traffic flow relieve rush hour congestion, but may fail to provide a safe and attractive environment during other portions of the day."

NACTO Urban Street Design Guide 2013, p. 148

APPLYING DESIGN FLEXIBILITY

VOLUME THRESHOLDS

Volume thresholds, often average daily traffic (ADT), can initially approximate whether a road diet is appropriate given the proposed number of lanes; however, if volumes are at the upper limits of the threshold, designers should consider further analysis. Communities have varying ADT or peak-hour thresholds and some have had success with Road Diets on roads that exceed initial thresholds. “Road Diet projects have been completed on roadways with relatively high traffic volumes in urban areas or near larger cities with satisfactory results” (**FHWA Road Diet Guide 2014, p. 17**).

MOTOR VEHICLE LEVEL OF SERVICE THRESHOLDS

The **2010 TRB Highway Capacity Manual** provides methods for evaluating the multimodal performance of highways in terms of operations and quality of service. It defines Level of Service (LOS) as a quantitative measure, but does not set LOS standards. Local jurisdictions have flexibility in the use of motor vehicle LOS standards. The **AASHTO Green Book** provides guidance for desirable LOS for different contexts and states that the designer has the latitude to choose an appropriate LOS (**2010, pp. 2-66–2-77**). FHWA does not have regulations or policies that require specific minimum LOS values for projects on the NHS. The recommended values in the Green Book are regarded as guidance only. (**USDOT Memorandum, Level of Service on the National Highway System, 2016**). This memo goes on to say that designers should take several factors into account in addition to traffic projections such as land use, context, and agency transportation goals, when planning and designing projects. In jurisdictions where LOS criteria are established, the **FHWA Flexibility in Highway Design** says, “the selection of a level of service that is lower than what is usually recommended may be appropriate” to achieve safety goals or to support adjacent land uses (**1997, p. 61**). In fact, some States and jurisdictions are prioritizing other factors above motor vehicle LOS and relying on it less often as a measure of roadway effectiveness.

TRAFFIC PROJECTIONS

A conventional roadway design approach is to build and operate a facility to accommodate for vehicle traffic forecasts that could occur during the design life of a facility. However, in many cases “the streets were built to accommodate a projected volume that never materialized,” resulting in streets that have underutilized vehicle travel lanes and may not support community goals (e.g., safety, economic activity, livability) (**AASHTO Bike Guide 2012, p. 4-30**).

It is important for designers to recognize that transportation patterns and habits across the country are changing: fewer Americans are driving alone to work, the number of miles driven per capita is stabilizing, and rates of walking, bicycling, and transit use are up. These trends should be factored into decisions about future vehicle volume estimates.

Additionally, designers historically developed trip generation estimates based on data collected from suburban car-oriented developments. The **2012 ITE Trip Generation Manual** has new techniques for estimating trip generation for all modes and for mixed-used developments. Research is ongoing regarding the best practices for trip generation estimates for a larger variety of land uses and modes of travel.

DESIGN HOUR OR PEAK HOUR

On conventional roadway projects, vehicle volumes during the busiest hour of the day are used to evaluate motor vehicle LOS. Street utilization varies throughout the day and some communities are implementing Road Diets because off-peak needs and potential safety benefits outweigh the potential increases in delay or travel time during the peak hour. The **TRB Highway Capacity Manual 2010** provides for flexibility when considering analysis results. Specifically, it states that “the existence of a LOS F condition does not, by itself, indicate that action must be taken to correct the condition” and goes on to say that other issues should be considered, such as safety and pedestrian and bicyclist needs (**TRB Highway Capacity Manual 2010, p. 8-5**).

THE POWER OF SMALLER STREETS AND A STREET NETWORK

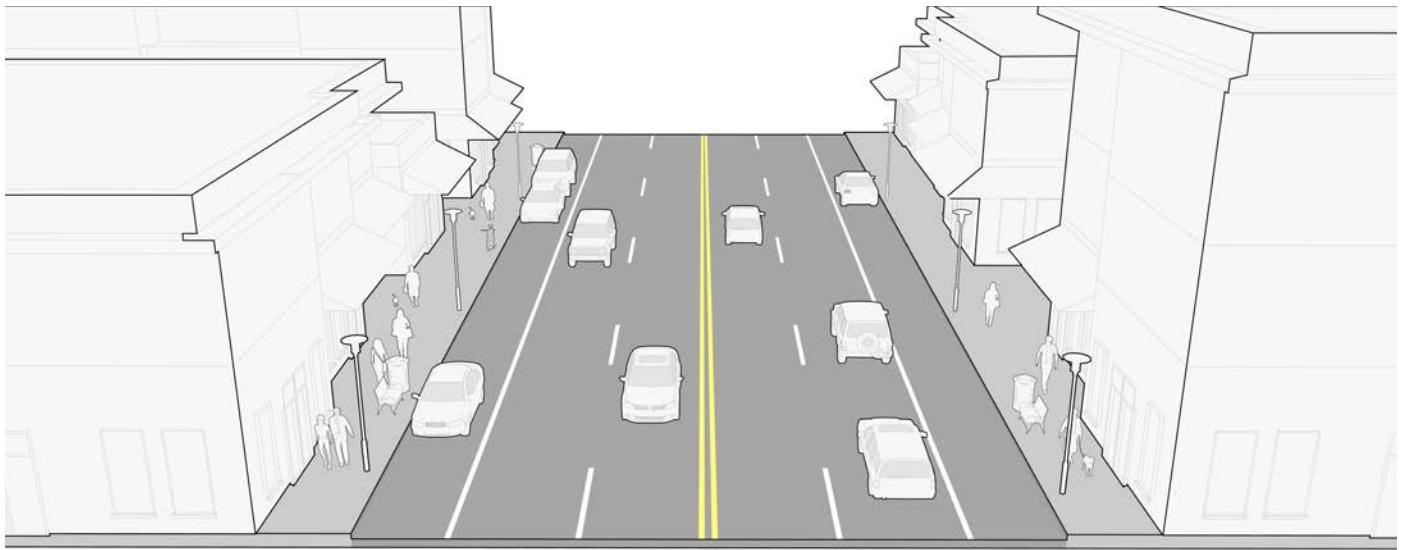
Wide streets with multiple travel lanes and turn lanes at intersections are less efficient in terms of motor vehicle capacity than a denser network of streets with fewer travel lanes. Research has shown that “the marginal capacity increase of additional lanes decreases as the size of the intersection increases” (**ITE Effectiveness of Additional Lanes at Signalized Intersections 2003, p. 26**). This is due to additional signal phases needed to control turning movements, the width of intersection crossings, and other factors.

An interconnected street network with narrower streets (fewer travel lanes) and smaller intersections operates more efficiently because it processes more turning traffic, shortens pedestrian crossings, and provides more route choices for all modes.

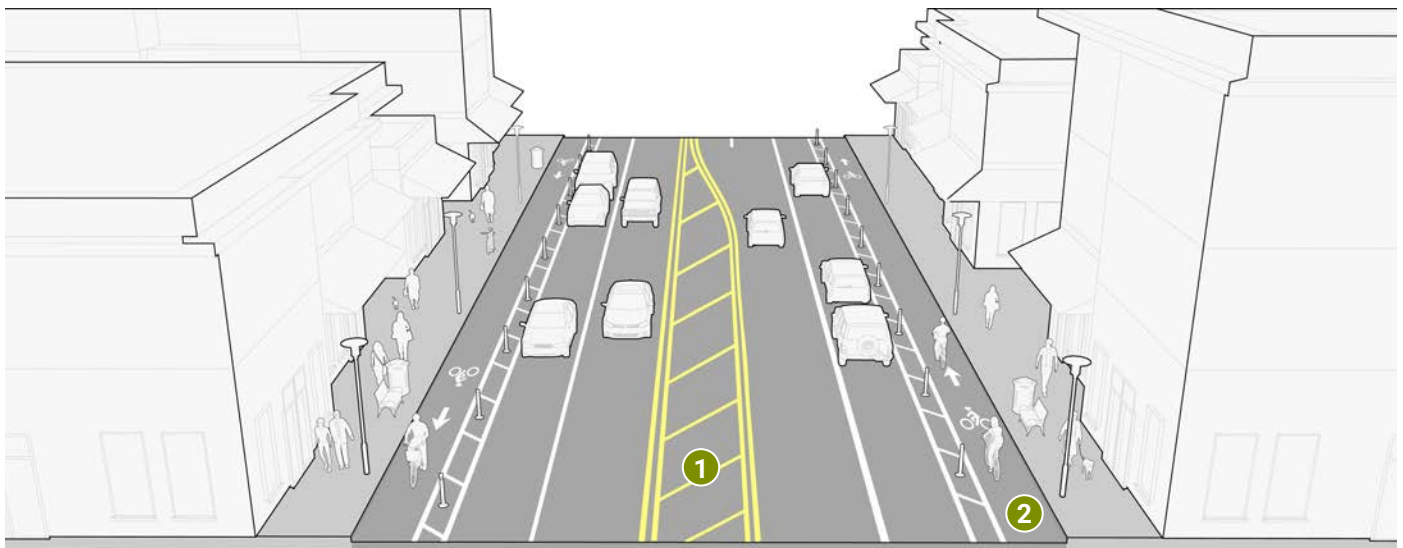
Road Diets can therefore be used as one part of an overall strategy to reduce the width of existing streets and provide a denser street network.

SAFETY BENEFITS OF A ROAD DIET

The common four- to three-lane Road Diet has proven safety benefits with “a 19 to 47 percent reduction in overall crashes” (**FHWA Road Diet Guide 2014, p. 7**). Added two-way left-turn lanes **1** reduce the number of potential conflict points, while slower operating speeds typical of this type of Road Diet reduce the severity of crashes that do occur. In addition to the reduction of speed, pedestrian safety benefits include potentially reduced crossing distances, space for refuge



BEFORE ROAD DIET



AFTER ROAD DIET

islands, and elimination of multiple threat crashes (**FHWA Road Diet Guide 2014, p. 7**). Road Diets often result in a dedicated space for standard or separated bike lanes. **2** For more information, refer to the design topics on **Separated Bike Lanes** and **Separated Bike Lanes at Intersections**. Additionally, refer to the design topic on **Transit Conflicts** for information on managing bus and bike conflicts.

TRANSIT BENEFITS OF A ROAD DIET

Road Diets present an opportunity for transit agencies and local jurisdictions to coordinate improvements for transit passengers and evaluate the effects on all roadway users. As part of the Road Diet, bus stops may be moved, consolidated, or upgraded to reduce delay, enhance the passenger experience, or better align with pedestrian crossings and desire lines. Where on-street parking is retained, consider bus

bulbs for added amenity space and to eliminate inefficient in-and-out operations associated with pull-out spaces. At signalized intersections, consider implementing signal priority for buses and restricting parking on intersection approaches to provide queue-jump lanes. In some instances it may be feasible to implement dedicated bus lanes through a Road Diet. (**FHWA Road Diet Guide 2014, pp. 20–21**)

LANE WIDTH

Local jurisdictions have flexibility in determining appropriate lane width. The **TRB Highway Capacity Manual** recognizes that there is minimal difference in motor vehicle capacity for travel lanes between 10 and 12.9 feet at signalized intersections (**2010, p. 18-36**) and does not provide any capacity factors for lane widths in this range. For more information, refer to the design topic on **Design Criteria and Lane Width**.

CASE STUDIES

W LAWRENCE AVENUE CHICAGO, IL

In 2014, the City of Chicago completed a Road Diet on three-quarters of a mile of W Lawrence Avenue, transforming the four-lane street to two travel lanes and a center turn lane. The remaining right-of-way was reallocated to wider sidewalks for outdoor dining, public art, improved pedestrian access, and standard bike lanes. Additional improvements included pedestrian safety measures (e.g., curb extensions/bulb-outs, refuge islands, and prominent crosswalks made from red asphalt), street trees, and rain gardens. Despite having daily traffic of approximately 30,000 vehicles/day, much higher than the typical threshold for a four-to-three lane road diet, the road diet is largely considered a success by community members.



Source: John Greenfield, Streetsblog Chicago

LAWYERS ROAD RESTON, VA

In 2009, the Virginia Department of Transportation completed a Road Diet for two miles of Lawyers Road as part of a routine repaving project. The project reduced the four-lane roadway to one travel lane and one 5-foot bike lane in each direction separated by a continuous two-way left-turn lane. Since completion, crashes fell by 68 percent after 5 years, average speeds fell by 1 mi/h, and drivers traveling over 50 mi/h fell from 13 percent of daily traffic to 1 percent. The **VDOT Newsroom Website** noted that a 2010 follow-up survey of drivers, bicyclists, and residents found that “69 percent said the road felt safer, 47 percent said they cycled more on Lawyers, 69 percent said their car trips did not take any longer with the new configuration, and 74 percent said the project improved Lawyers Road” (http://www.virginiadot.org/newsroom/northern_virginia/2011/second_road_diet_on54423.asp).



Source: Virginia Department of Transportation

STONE WAY NORTH SEATTLE, WA

In 2007, the City of Seattle implemented a road diet on 1.2 miles of Stone Way North, converting four travel lanes to two travel lanes with a center turn lane and bicycle climbing lane. The Road Diet reduced travel speeds and collision rates while increasing bicycle volumes. The 85th percentile speed decreased and traffic volumes remained consistent with citywide trends without diversion onto adjacent streets. Based on crash data for two years before and two years after Road Diet implementation, total crashes declined by 14 percent and injury collisions declined by 33 percent. Bicycle volumes increased by 35 percent along the corridor.



ENHANCED CROSSING TREATMENTS



Crossings, whether midblock or at an intersection, should provide safe and comfortable locations for people to cross the street. A crossing location should offer adequate gaps between vehicles and encourage motorist yielding or stopping to allow pedestrians to cross.

To justify the installation of a pedestrian hybrid beacon or traffic signal, the **MUTCD 2009** has warrants based primarily on pedestrian volumes and vehicle volumes. These warrants are used to help allocate limited financial resources. In some cases, pedestrians may not be crossing the street in sufficient numbers to satisfy the warrant because there are not adequate gaps in traffic or they do not feel comfortable doing so. This is the common “chicken or the egg” problem: a certain volume of pedestrians is required to meet the warrant to install a beacon or signal, yet pedestrians need enhanced crossing treatments to feel comfortable crossing the street. The unintended consequence of this scenario is that street environments have frequently been built in a manner that discourages walking.

Designers may use a variety of treatments to create convenient and comfortable crossings for pedestrians. These include median crossing islands, signs, Rectangular Rapid Flash Beacons, pedestrian hybrid beacons, and traffic signals. Existing guidance encourages the use of engineering judgment to develop a justification for the installation of a marked crosswalk, pedestrian hybrid beacon, a traffic signal, or other crossing treatments.

KEY DESIGN FLEXIBILITY

The **MUTCD** includes flexibility for the designer to consider factors besides traffic volume during an engineering study to justify the installation of a beacon or traffic signal. It also suggests that even if a traffic signal warrant is met, other treatments (at the designer’s discretion) may be more appropriate to create a safe crossing:

“An engineering study of traffic conditions, pedestrian characteristics, and physical characteristics of the location shall be performed to determine whether installation of a traffic control signal is justified at a particular location.”

MUTCD 2009, Sec. 4C.01

“Consideration should be given to providing alternatives to traffic control signals even if one or more of the signal warrants has been satisfied.”

MUTCD 2009, Sec. 4B.04

OTHER RESOURCES

“Where signalized or stop-controlled pedestrian crossings are not warranted but demand exists or is anticipated, designers should continue to work toward goals of safety and comfort for people walking through other means, such as actuated crossings or enhanced crossing treatments.”

NACTO Urban Street Design Guide 2013, p. 110

“If traffic and roadway characteristics make crossing difficult for the path user, the need for a signal or active warning device (such as a beacon) should be considered based on traffic volumes, speed, number of lanes, and availability of a refuge.”

AASHTO Bike Guide 2012, p. 5-38

“When the spacing of intersection crossings is far apart or when the pedestrian destination is directly across the street, pedestrians will cross where necessary to get to their destination conveniently, exposing themselves to traffic where drivers might not expect them. Midblock crossings, therefore, respond to pedestrian behavior. Properly designed and visible midblock crosswalks, signals and warning signs warn drivers of potential pedestrians, protect crossing pedestrians and encourage walking in high-activity areas.”

ITE Designing Walkable Urban Thoroughfares 2010, p. 136

APPLYING DESIGN FLEXIBILITY

LAND USE CONSIDERATIONS

It is important for designers to consider the existing, anticipated, and desired use of the potential crossing location both midblock and at intersections. Major factors include land uses on either side of the street and walking distances without and with the crosswalks. For example, if a senior center is located on one side of an intersection and a library on the other and the nearest crossing is greater than 300 feet in walking distance, an enhanced marked crossing should be considered.

1 If a community center is located near the center of a long block and a bus stop exists on the opposite side of the street, this location should be considered for a midblock crossing. 2

The **AASHTO Pedestrian Guide** emphasizes the importance of midblock crossings in areas where intersections are spaced relatively far apart and there are pedestrian generators on both sides of the street: “Midblock crossings are preferred because pedestrians should not be expected to make excessive or inconvenient diversions in their travel path to cross at an intersection” (2004, p. 89). In all locations, enhanced pedestrian crossing treatments should be considered based on the number of vehicle travel lanes, and speed and volume of vehicular traffic.

WHEN TO MARK A CROSSWALK

Careful consideration should be given to when to mark a crosswalk and when enhanced crossing treatments are needed. The **MUTCD** states that “crosswalk lines should not be used indiscriminately” (2009, Sec. 3B.18). Before a crosswalk is installed at a midblock location, an engineering study should be completed and include several factors such as the number of lanes, distance to adjacent signalized intersections, pedestrian and vehicle volumes, and vehicle speeds.

At crossing locations with relatively high traffic volumes and speeds and longer crossing distances, designers should consider enhanced crossing treatments (e.g., crossing island, signal, or signing) to supplement a marked crosswalk. **FHWA Safety Effects of Marked Versus Unmarked Crosswalks at Uncontrolled Locations** recommends substantial crossing improvements be installed to supplement a marked crosswalk under any of the following conditions:

- where the speed limit exceeds 40 mi/h.
- on a roadway with four or more lanes without a raised median or crossing island that has (or will soon have) an ADT of 12,000 or greater.

- on a roadway with four or more lanes with a raised median or crossing island that has (or soon will have) an ADT of 15,000 or greater. (2005, p. 52)

It is a misinterpretation of this study to conclude it is undesirable to mark a crosswalk in locations that meet those conditions. The proper conclusion of the study is to supplement the marked crossing with enhanced crossing treatments to provide a convenient and safe crossing.

TRAFFIC SIGNAL OR BEACON WARRANT STUDY

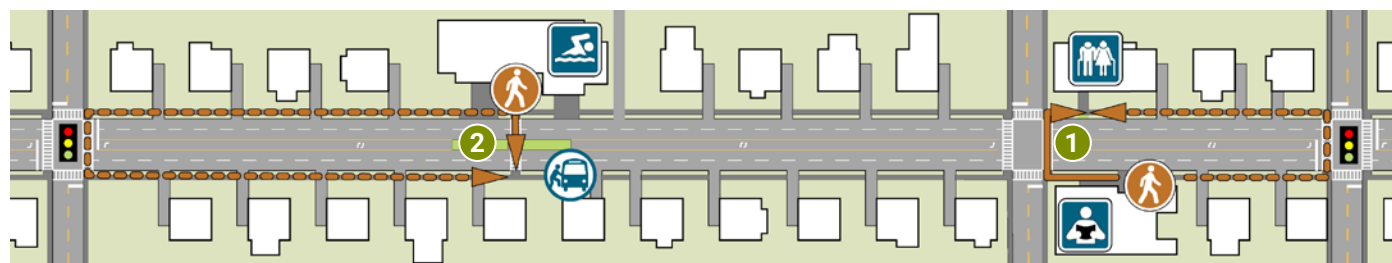
There is a great deal of flexibility in applying warrants to determine if a traffic signal or beacon is needed at a pedestrian crossing. Before a traffic signal or beacon is installed, an engineering study must be completed to determine if the installation of a traffic control signal will improve the overall safety and/or operation of the intersection (**MUTCD 2009, Sec. 4C.01**). **NACTO Urban Street Design Guide** recommends that designers “take into account both existing as well as projected crossing demand” (2013, p. 110). Designers have the flexibility to estimate demand if the absence of a signal limits crossing opportunities of potential users, especially the young, elderly, or persons with disabilities (**MUTCD 2009, Sec. 4C.01**). Additionally, where “it is not possible to obtain a traffic count that would represent future traffic conditions, hourly volumes should be estimated” (**MUTCD 2009, Sec. 4C.01**).

Three of the eight warrants outlined in the **MUTCD** are used as justification for the installation of a signal for pedestrians. These are: Warrant 4 (Pedestrian Crossing), Warrant 5 (School Crossing), and Warrant 7 (Crash Experience). The criterion for Warrant 4 (Pedestrian Crossing) can be reduced by 50 percent if the “15th-percentile crossing speed of pedestrians is less than 3.5 feet per second” (2009, Sec. 4C.05).

An additional warrant for a pedestrian hybrid beacon 3 is provided in **Chapter 4F** of the **MUTCD 2009**. A pedestrian hybrid beacon can be used at locations where warrants for a signal are not satisfied or locations where warrants are satisfied but a decision is made not to install a signal.

ADDITIONAL CROSSING TREATMENTS

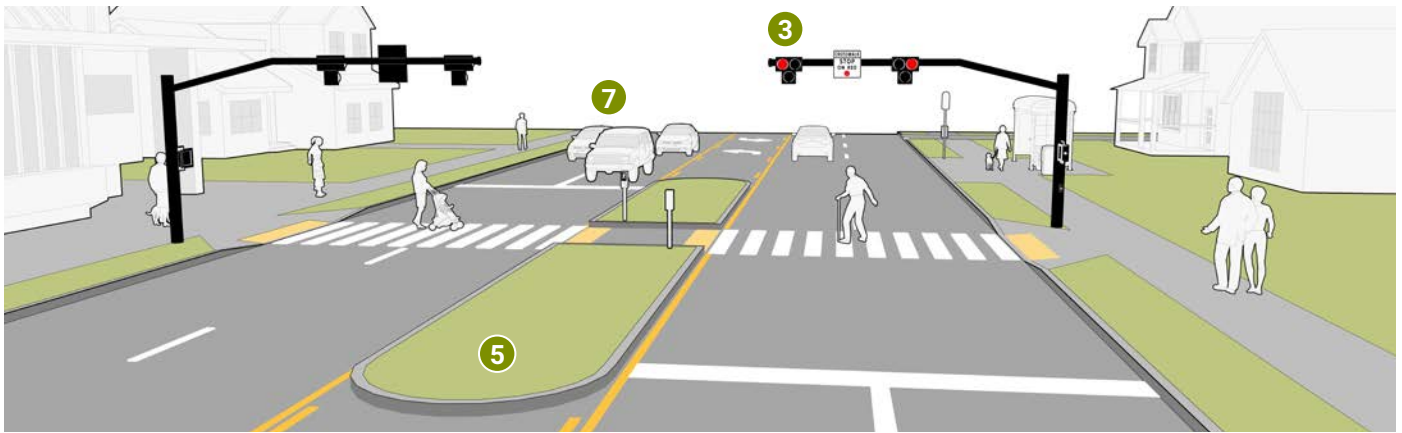
In addition to marking crosswalks and installing traffic signals or beacons, designers have the flexibility to use a variety of treatments such as rectangular Rapid Flash Beacons, pedestrian crossing islands, and advance yield/stop lines and signing.



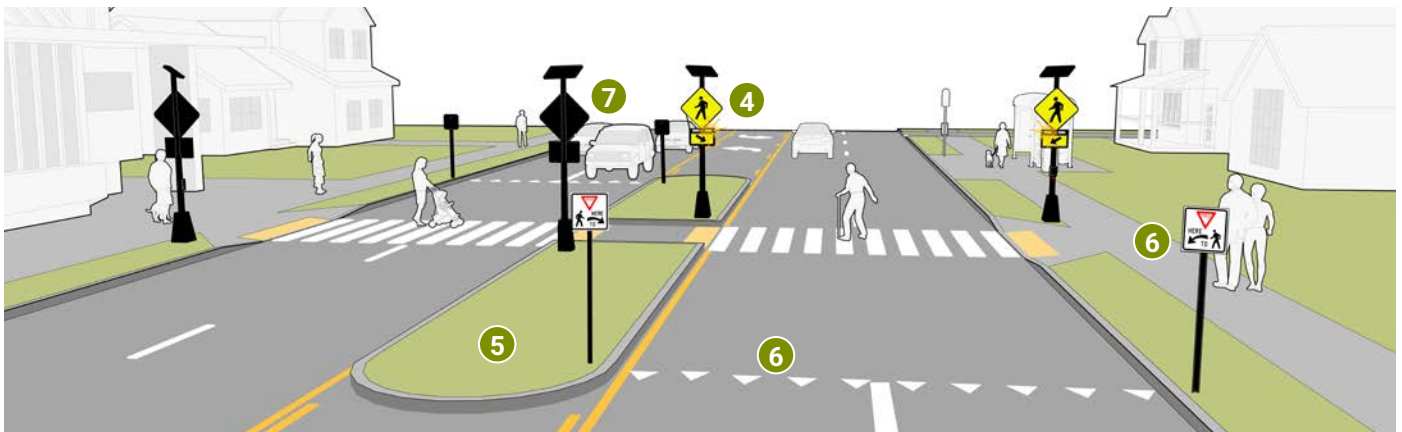
LAND USE CONTEXT EXAMPLE

— Walking distance with crosswalk

- - - Walking distance without crosswalk



PEDESTRIAN HYBRID BEACON AND CROSSING ISLAND



RECTANGULAR RAPID FLASHING BEACON AND CROSSING ISLAND

RECTANGULAR RAPID FLASHING BEACONS

At uncontrolled crossings where a signal or pedestrian hybrid beacon is not warranted, cost prohibitive, or deemed unnecessary designers should consider supplementing pedestrian, bicycle/pedestrian, or school crossing warning signs with Rectangular Rapid Flashing Beacons (RRFBs).

④ Generally, this treatment should be used with caution at crossings with more than two lanes without a refuge. **FWHA Effects of Yellow Rectangular Rapid-Flashing Beacons on Yielding at Multilane Uncontrolled Crosswalks** found an 88-percent average compliance rate for motorists yielding to pedestrians at crossings with RRFBs; this rate was sustained after 2 years (2010, p. 9).

PEDESTRIAN CROSSING ISLANDS

Raised medians or pedestrian crossing islands are a Proven Safety Countermeasure and have demonstrated a 46-percent reduction in pedestrian crashes. Pedestrian refuge areas or islands ⑤ allow pedestrians to cross the street in two stages and significantly reduce the distance a pedestrian must cross at one time. The **AASHTO Pedestrian Guide** states that a crossing island should be considered “where the crossing exceeds 60 ft” (2004, p. 90). **FWHA Safety Effects of Marked**

Versus Unmarked Crosswalks at Uncontrolled Locations

found that providing raised medians on multilane roads “can significantly reduce the pedestrian crash rate and also facilitate street crossing” (2005, p. 55). However, on roadways with a raised median and volumes exceeding 15,000 ADT, a marked crosswalk is appropriate only with additional crossing treatments. Crossing islands should be a minimum of 6 feet wide (ITE **Designing Walkable Urban Thoroughfares 2010**, p. 141). At locations where bicycles may be crossing, such as where a shared use path crosses a roadway, “10 ft is preferred in order to accommodate a bicycle with a trailer” (AASHTO **Bike Guide 2012**, p. 5-48).

ADVANCE YIELD/STOP LINES AND SIGNING

Advance yield/stop lines and signing ⑥ can be installed at locations where there are concerns about multiple threat crashes. ⑦ They indicate to drivers the appropriate location to yield or stop so that they do not “place pedestrians at risk by blocking other drivers’ views of pedestrians and by blocking pedestrians’ views of vehicles approaching in the other lanes” (MUTCD 2009, Sec. 3B.16). Additionally, parking should be prohibited in between the yield or stop line and the crosswalk to increase visibility.

CASE STUDIES

I STREET AT MAKEMIE PLACE, SW WASHINGTON, DC

A Safe Routes to School action plan for Amidon-Bowen Elementary School evaluated the intersection of Makemie Place and I Street SW for a potential crosswalk. Prior to the study, schoolchildren had to cross I Street SW at one of two signalized intersections approximately 600 feet apart to access the main school entrance. The City installed a marked crosswalk halfway between these intersections at the T-intersection of Makemie Place SW along with warning signs, a crossing island, and curb extensions to increase driver awareness of the crossing, reduce vehicle speeds, and increase the pedestrian queuing area. This crossing also connected bus stops on both sides of I Street SW. Crosswalk signs were installed as part of an experiment and are non-compliant.



IMPROVEMENT PLAN FOR UNCONTROLLED MARKED CROSSWALKS SEATTLE, WA

In 2001, the City of Seattle completed a detailed inventory analysis of 622 marked crosswalks at uncontrolled locations. Crosswalks were rated based on traffic volume, number of lanes, and speed. In 2002, the City released a multi-year Improvement Plan for Uncontrolled Marked Crosswalks that addressed identified deficiencies. Rather than just decide “yes” or “no” on whether to mark a crosswalk, the improvement plan asks “what are the most effective measures that can be used to help pedestrians safely cross the street?” The plan was implemented over a period of six years. Deficiencies were addressed with signing, markings, crossing islands, road and lane diets, rectangular rapid flash beacons, pedestrian signals, and other ADA improvements.



SE BUSH STREET AND 122ND AVENUE PEDESTRIAN HYBRID BEACON PORTLAND, OR

As part of the SE Bush neighborhood greenway project, the Portland Bureau of Transportation installed a pedestrian hybrid beacon at the SE Bush Street crossing of 122nd Avenue in July 2012. Counts at this location did not meet the pedestrian hybrid beacon warrant prior to installation. However, engineers designed the intersection to accommodate 50–100 bicycle and pedestrian crossings during the peak hour based on previous experience where bicycle and pedestrian volumes increased following installation of other neighborhood greenways in the City. December 2013 counts indicated that pedestrian hybrid beacon warrants are satisfied at this location.



Source: Scott Batson, City of Portland Bureau of Transportation

SIGNALIZED INTERSECTIONS



Traffic signals manage traffic flow by separating and allocating time to specific movements. They can reduce conflicts between motor vehicles, transit vehicles, bicyclists, and pedestrians. Traffic signal design, which includes detection, phasing, timing, and equipment, should provide a safe and predictable environment for all users, especially the most vulnerable.

Conventional traffic engineering practice focuses on reducing delay to motor vehicles and improving vehicle throughput at signalized intersections. However, traffic signal timing and phasing should consider delay and safety impacts to all users. Traffic signals should be designed to meet the needs of all users through the use of appropriate detection, cycle lengths, phasing, interval timings, and equipment. Additionally, designers should consider the unique operating characteristics of each expected user type throughout the signal design and process of determining the most appropriate signal timing.

It is particularly important to evaluate potential conflicts between turning motorists with pedestrians and bicyclists where left-turns are permissive (i.e., vehicles can turn left on a circular green indication). In a 2015 study, the City of Seattle found that the most significant crash type for pedestrians and bicyclists was a turning motorist crossing their path. At signalized intersections, left-turning motorists accounted for 26 percent of bicyclist crashes and 49 percent of pedestrian crashes. Right turning motorists accounted for 24 percent of bicyclist crashes and 21 percent of pedestrian crashes at signalized intersections. For more information, refer to the design topic on **Turning Vehicles**.

KEY DESIGN FLEXIBILITY

According to **MUTCD**, a traffic signal design should consider pedestrian and bicyclist needs:

"The design and operation of traffic control signals shall take into consideration the needs of pedestrian as well as vehicular traffic."

2009, Sec. 4D.03

"On bikeways, signal timing and actuation shall be reviewed and adjusted to consider the needs of bicyclists."

2009, Sec. 9D.02

OTHER RESOURCES

"Elements, such as crosswalk treatments, signal location, and signal timing, should account for pedestrians and other roadway users."

AASHTO Ped Guide 2004, p. 49

"Actuated traffic signals should detect bicycles; otherwise, a bicyclist may be unable to call a green signal...Various technologies are available for detecting bicycles."

AASHTO Bike Guide 2012, p. 4-47

"Vehicle stops and delay may be less important than transit and pedestrians priority in a CBD, as well as other existing or developing areas with significant pedestrian, bicycle, and transit activity. The practitioner needs to make appropriate adjustments to the traffic signal timing process to account for the operating environment and user priorities."

Transportation Research Board. **NCHRP Report 212: Signal Timing Manual**. 2015, pp. 1-2-1-3

"Urban applications for traffic control devices expand to a multimodal transportation system, not just providing for vehicular traffic."

ITE Traffic Control Devices Handbook, p. 206

APPLYING DESIGN FLEXIBILITY

Pedestrians and bicyclists have a fundamental need to cross roads safely and efficiently at signalized intersections. There is a great deal of inherent flexibility in signal design and there are many new advances that have a positive impact on pedestrian and bicyclist safety at signalized intersections. This resource covers several of these strategies. However, this is a complex area of roadway design and other reference manuals and guidebooks should be consulted for more information, including **MUTCD 2009**, **AASHTO Pedestrian Guide 2004**, **AASHTO Bike Guide 2012**, **NACTO Urban Street Design Guide 2013**, and **NCHRP Report 212: Signal Timing Manual 2015**.

The conventional vehicle-based approach to evaluating signalized intersections may involve relatively high traffic projections, emphasize the peak hour, and focus on minimizing motor vehicle delay. This approach can result in relatively poor conditions for bicyclists and pedestrians. Designers may use qualitative measures to assess non-motor-vehicle-oriented operational objectives to consider in the evaluation process. For more information, refer to the design topic on **Road Diets and Traffic Analysis**.

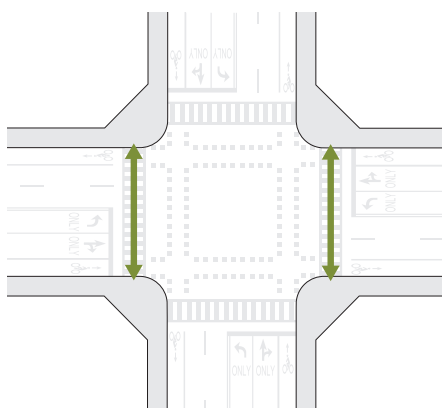
PEDESTRIAN CONSIDERATIONS

The needs of all pedestrians should be taken into account when designing traffic signals at intersections where they can be expected to cross. Pedestrian safety, comfort, and convenience at intersections is fundamentally impacted by several major design decisions:

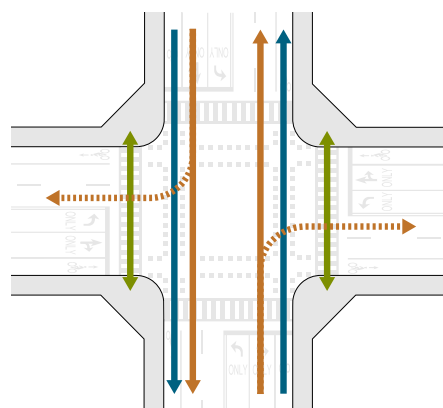
CYCLE LENGTH

When pedestrians are faced with long delays, they are more likely to ignore signals entirely and cross the road when they perceive a gap in traffic. Therefore, strategies to reduce overall cycle length are particularly important for pedestrian safety. In addition to reducing cycle lengths, designers should also consider using half-cycle lengths, particularly during off-peak hours. Cycle lengths also have similar implications for bicyclists. The **NACTO Urban Street Design Guide** recommends cycle lengths between 60–90 seconds for urban areas (2013, p. 131).

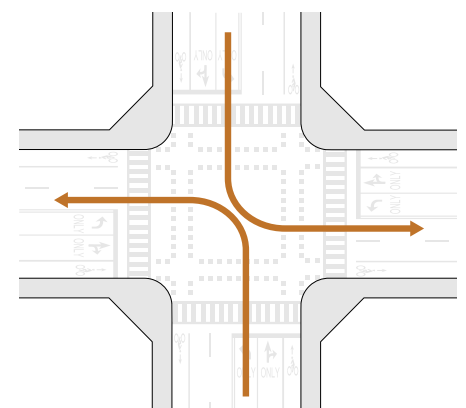
1 LEADING PEDESTRIAN INTERVAL



MAJOR STREET
PEDESTRIANS



MAJOR STREET
PEDESTRIANS, BICYCLES, THROUGH & RIGHTS



MAJOR STREET
LEFTS

PEDESTRIAN SIGNAL HEADS

Pedestrians need to be able to see signal indications (walking person/upraised hand or green/yellow/red) to know when it is safe to cross. An engineering study should be completed to determine if pedestrian signal heads and countdown displays are needed. Factors include signal phasing, intersection geometry complexity, and visibility of vehicular signal indications (**MUTCD 2009, Sec. 4E.03–4E.07**). Pedestrian signals must be accessible to people with disabilities. For more information, refer to the design topic on **Accessibility**.

AUTOMATIC PEDESTRIAN PHASES

At locations with high pedestrian volumes, pedestrians should not be required to push a button to call the pedestrian phase. Studies show that only about 50 percent of pedestrians actually press the push buttons. This is because in locations with longer pedestrian delays and without automatic pedestrian phases, pedestrians may have the impression that the push button is either non-responsive or malfunctioning. All intersections regardless of whether the pedestrian phase is automatic or requires actuation must be accessible for people with disabilities. This commonly means that accessible push-buttons are installed in locations with automatic pedestrian phases. For more information, refer to design topic on **Accessibility**.

PROTECTED CROSSING PHASES

Allowing drivers to turn right or left during a pedestrian WALK signal is a frequent cause of crashes between pedestrians and drivers. Often drivers do not realize they are required to yield to pedestrians in these situations and fail to do so. Dedicated right- and left- turning phases and exclusive pedestrian phases can improve pedestrian safety. Designers should conduct an engineering study to determine if this is an appropriate solution.

LEADING PEDESTRIAN INTERVAL

A leading pedestrian interval ❶ typically gives pedestrians “a 3–7 second head start when entering an intersection” before the vehicle phase (**NACTO Urban Street Design Guide 2013, p. 128**). This can increase the visibility of pedestrians and reduce conflicts. The **MUTCD** says that leading pedestrian intervals “may be used to reduce conflicts between pedestrians and turning vehicles” (**2009, Sec. 4E.06**).

EXCLUSIVE PEDESTRIAN PHASE

Also known as a pedestrian scramble or Barnes Dance, an exclusive pedestrian phase occurs when all pedestrians may cross while all vehicular traffic is stopped. This treatment may be considered where there are relatively high volumes of pedestrians, equal desire lines in all directions, higher turning vehicle movements, or at intersections with restricted sight distance or complex intersection geometry. This treatment “can produce a safer operation over conventional phasing, but delay for both pedestrians and motorists is always higher than conventional signal timing” (**AASHTO Pedestrian Guide 2004, p. 103**). This increase in delay for pedestrians may result in pedestrians crossing with concurrent vehicular movements. Designers should consider whether pedestrians could also be able to cross with concurrent vehicular movements. In some scenarios, a leading pedestrian interval may be a more appropriate solution. If a diagonal crossing is used, designers must consider how a person with a visual disability would know that they could cross diagonally.

RIGHT TURN ON RED

Right Turn on Red (RTOR) introduces pedestrian safety concerns because drivers scanning for gaps in traffic on their left may not look for pedestrians on their right. Drivers are likely to encroach into the crosswalk while watching oncoming vehicles, further eroding pedestrian safety and comfort. These conflicts can be reduced by restricting RTOR movements. The **FHWA Pedestrian Safety Guide and Countermeasure Selection System** suggests that “prohibiting RTOR should be considered where exclusive pedestrian phases or high pedestrian volumes are present” (**2013**).

Right Turn on Red should be prohibited where bicyclists wait in front of motor vehicles, such as at bike boxes and two-stage turn queue boxes (both are subject to experimentation). Designers should also consider prohibiting RTOR where bicycle movements may be unexpected, such as at crossings of contra-flow or two-way separated bike lanes.

SIGNAL TIMING FOR BICYCLISTS

Bicycles have different operating speeds, acceleration rates, and deceleration rates than motor vehicles. Adjustments to minimum green times, clearance intervals, and extension times can allow bicyclists to clear the intersection before opposing traffic is released (**AASHTO Bike Guide 2012, p. 4-22**). At locations with high vehicular speeds and long crossing distances, bicyclists are more likely to have different signal timing needs than motor vehicles.

If used in combination with bicycle detection and permitted by the controller, bicycle-specific timing parameters can be employed for the specific times when a bicycle is present. If bicycle detection is not available, the bicycle-timing needs should be incorporated into the overall signal timing settings in the controller. The **AASHTO Bike Guide 2012** provides additional details on bike detection and signal timing.

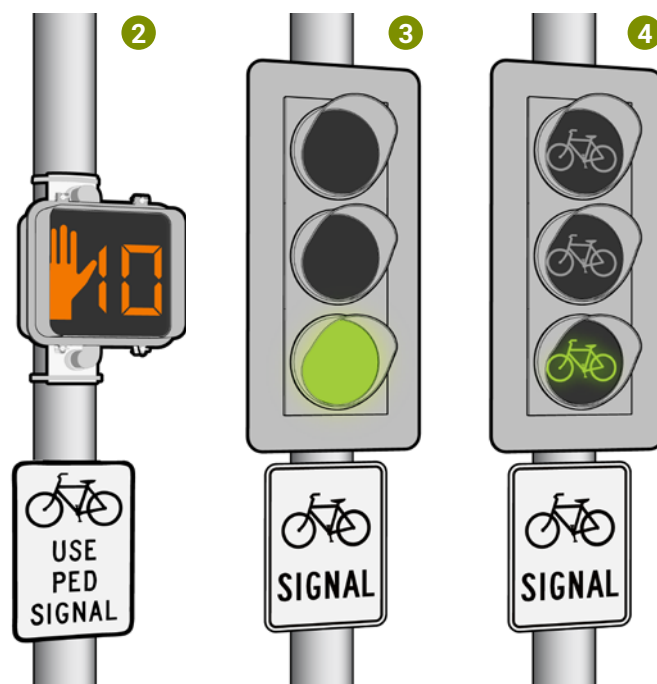
BICYCLE SIGNALS

On-road bicyclists typically use the same traffic signals as vehicles. However, at intersections where bicyclists cannot see vehicle signal faces or where bicyclists have a separate directional movement, phase, or interval, designers should consider alternate signalization options. The **BIKES USE PED SIGNAL** sign ❷ (**MUTCD R9-5**) “may be used where the crossing of a street by bicyclists is controlled by pedestrian signal indications” (**MUTCD 2009, Sec. 9B.11**). However, a bicycle signal ❸ is more suitable as it can be timed for bicyclist speeds increasing the time a bicyclist may legally enter the roadway compared to a pedestrian signal. The **MUTCD** instructs that 8-inch circular signal indications may be used “in a signal face installed for the sole purpose of controlling a bikeway or a bicycle movement” and can be installed without requesting approval (**2009, Sec. 4D.07**). In December 2013, FHWA issued an Interim Approval for the Optional Use of Bicycle Signal Faces. ❹ A bicycle signal face may only be used with a protected phase. Designers should request permission from FHWA before installing a bicycle signal face.

ADDITIONAL SIGNAL CONSIDERATIONS

For additional information on other topics related to traffic signal design, such as signal priority for transit services and emergency vehicles, see **NCHRP Report 212: Signal Timing Manual 2015**.

BIKE SIGNALIZATION ALTERNATIVES



CASE STUDIES

2ND AVENUE PROTECTED PEDESTRIAN/BICYCLE PHASE SEATTLE, WA

In 2014, the Seattle Department of Transportation (SDOT) implemented a two-way separated bike lane on 2nd Avenue. Designers used dedicated left-turn phasing to eliminate conflicts between left-turning vehicles and bicyclists and pedestrians. The project also included RTOR restrictions at conflicting cross streets and created a bicycle facility that is phase-separated at signalized intersections along the corridor. This project is the first phase of a multi-phased effort to create a comprehensive, connected network of separated bike lanes into and through downtown Seattle. Data collected in October 2014 indicated an 85-percent motorist compliance and 92-percent bicyclist compliance rate.



LEADING PEDESTRIAN INTERVALS WASHINGTON, DC

The District Department of Transportation (DDOT) has implemented leading pedestrian intervals at intersections throughout Washington, DC. Beginning with 20 intersections that have a history of crashes involving right-turning vehicles hitting pedestrians in the crosswalk while the WALK or flashing DON'T WALK signal indication was displayed. The program has expanded to over 130 intersections based on count data showing high pedestrian and turning-vehicle volumes and public feedback. DDOT is currently reviewing additional potential locations for leading pedestrian intervals as part of a signal optimization study, which will have evaluated all 1,650 signalized intersections in the District when complete.



VALENCIA STREET GREEN WAVE SAN FRANCISCO, CA

The San Francisco Municipal Transportation Agency (SFMTA) implemented its first "green wave" on Valencia Street as a pilot project in 2011. The "green wave" is a coordinated signal system designed for bicyclists traveling at moderate speeds, rather than the traditional coordination plan designed for vehicle speeds. The Valencia Street coordination plan serves bicyclists traveling in both directions, and signs notify bicyclists that the signals are timed for the 13-mi/h speed. The "green wave" has an added traffic-calming benefit since motor vehicles benefit from traveling at the designated speed. In 2011, SFMTA made the Valencia Street Green Wave a permanent feature and has continued implementing the strategy on other bikeways throughout the city.



Source: Matt Johnson, Montgomery County Department of Transportation

PAVED SHOULDERS



Paved shoulders provide a recovery area for errant motor vehicles, and lengthen the lifespan of the roadway by providing pavement structure support, reducing edge deterioration, and improving drainage. Paved shoulders significantly reduce maintenance costs and are proven to reduce crashes. Paved shoulders provide space for pedestrian and bicycle travel, which facilitates safer passing behaviors and improves comfort for all users.

Paved shoulders serve many purposes. All users should be considered to develop the most appropriate design given the intended use of the shoulder. Designers have flexibility in determining when to pave shoulders, as well as on factors such as shoulder width and rumble strip design and placement.

KEY DESIGN FLEXIBILITY

The **AASHTO Green Book** states the advantages and varied uses of paved shoulders. It also provides ranges for paved shoulder widths:

"Paved shoulders advantages include providing a space for pedestrian and bicycle use, for bus stops, for occasional encroachment of vehicles, for mail delivery vehicles, and for the detouring of traffic during construction."

2011, p. 4-9

"[Shoulders] vary in width from only 2 ft on minor rural roadways...to approximately 12 ft on major roads."

2011, p. 4-8

OTHER RESOURCES

"Wide shoulders and bicycle lanes provide an additional clear area adjacent to the traveled way, so these features potentially could provide a secondary safety benefit for motorists and can be included as part of the clear zone... and also improve the resulting sight distance for motor vehicle drivers at intersecting driveways and streets."

AASHTO Roadside Design Guide 2011, p. 10-11

"Adding or improving paved shoulders can greatly improve bicyclist accommodation on roadways with higher speeds or traffic volumes, as well as benefit motorists...Creating shoulders or bike lanes on roadways can improve pedestrian conditions as well by providing a buffer between the sidewalk and the roadway."

AASHTO Bike Guide 2012, p. 4-7

"Paving part or all of the shoulder also helps reduce crash rates further and helps to facilitate use of the road by bicyclists. Shoulder paving also reduces maintenance requirements"

AASHTO Flexibility Guide 2004, p. 66

APPLYING DESIGN FLEXIBILITY

SHOULDER WIDTH

Sufficiently wide shoulders can greatly improve bicyclist safety and comfort, particularly on higher-speed, higher-volume roadways. Shoulders are most often found on rural roadways and less often on urban roadways. To accommodate bicyclists, a 4-foot or greater paved shoulder width, continuous along the length of the roadway and through intersections, should be provided. (Use at least 5 feet where guardrails, curbs, or other roadside barriers are present.) Designers should consider wider shoulders if vehicle speeds are greater than 50 mi/h (**AASHTO Bike Guide 2012, p. 4-7**). Designers may use the Bicycle Level of Service model, which includes factors for vehicle speeds, traffic volumes, and lane widths to determine the appropriate shoulder width (**AASHTO Bike Guide 2012, p. 4-7**).

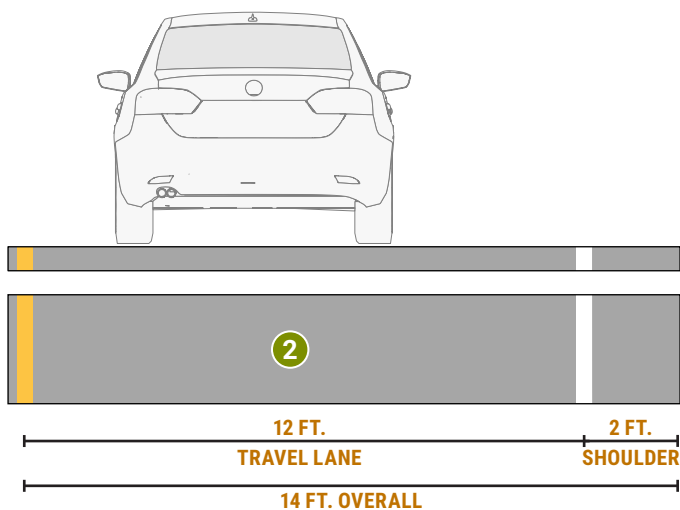
WHEN TO PAVE SHOULDERS

Designers should consider paving shoulders in all project types, particularly in rural settings. The **AASHTO Green Book** presents policies concerning shoulder width for specific highway functional classes (e.g., local, collector, and arterial roads) and it recommends that “usable shoulders on arterials be paved” (**2011, p. 7-5**). Although the **AASHTO Green Book 2011** doesn’t specify that shoulders be paved on local and collector streets, designers should consider paved shoulders to accommodate bicyclists, and possibly pedestrians, in rural areas.

SHOULDERS AND DIFFERENT PROJECT TYPES

It is important to capture opportunities to include or upgrade paved shoulders during all types of roadway projects. Designers should weigh the trade-offs such as proven safety benefits for all users, construction costs, and cost savings over the lifespan of a roadway. Examples of how to capture opportunities to provide bicycle-friendly paved shoulders during different types of roadway projects include:

EXISTING CONFIGURATION



RESURFACING AND RESTORATION

Pavement resurfacing offers an opportunity to reallocate roadway space. In some cases, designers should consider reducing lane widths to provide more paved shoulder width suitable for bicycling. The **AASHTO Flexibility Guide** states that “for lower speed, lower volume rural roads and highways with little or no truck traffic, lane widths as low as 9 ft [2.7 m] may be acceptable” (**2004, p. 65**). For more information, refer to the design topic on **Design Criteria and Lane Width**. For example, in a retrofit situation, the **AASHTO Bike Guide** suggests that a 10- or 11-foot travel lane with a 3- or 4-foot **1** shoulder would be preferable for bicyclists to a 12-foot travel lane and 2-foot shoulder **2** (**2012, 4-28**).

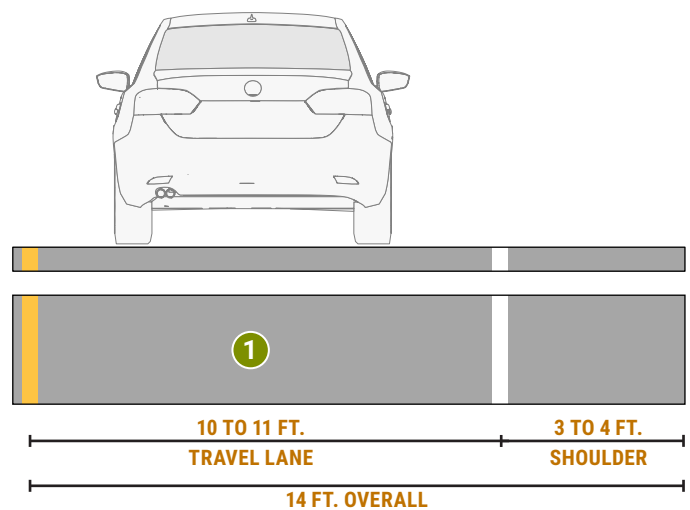
REHABILITATION

Rehabilitating pavements offers an opportunity to add pavement width. This project type includes the complete replacement of pavements which opens opportunities to add paved shoulders as the mainline pavements are replaced. This can be an economical and cost-effective way to implement this type of enhancement. It is also an opportune time to widen narrower paved shoulders, especially if rumble strips are being added to the shoulders and additional width is desired to provide clear space for bicyclists.

RECONSTRUCTION AND NEW CONSTRUCTION

Including paved shoulders when roadways are being newly constructed or reconstructed is cost effective and should be considered on rural and suburban arterial roadway projects. This affords the best opportunity to get a 4-foot or greater paved shoulder in place. This is also the time to consider other treatments such as separated bike lanes, shared use paths, and sidewalks. These treatments may be more desirable in urban and suburban locations with higher bicycle and pedestrian demand. For more information, refer to design topics on **Separated Bike Lanes** and **Shared Use Paths**.

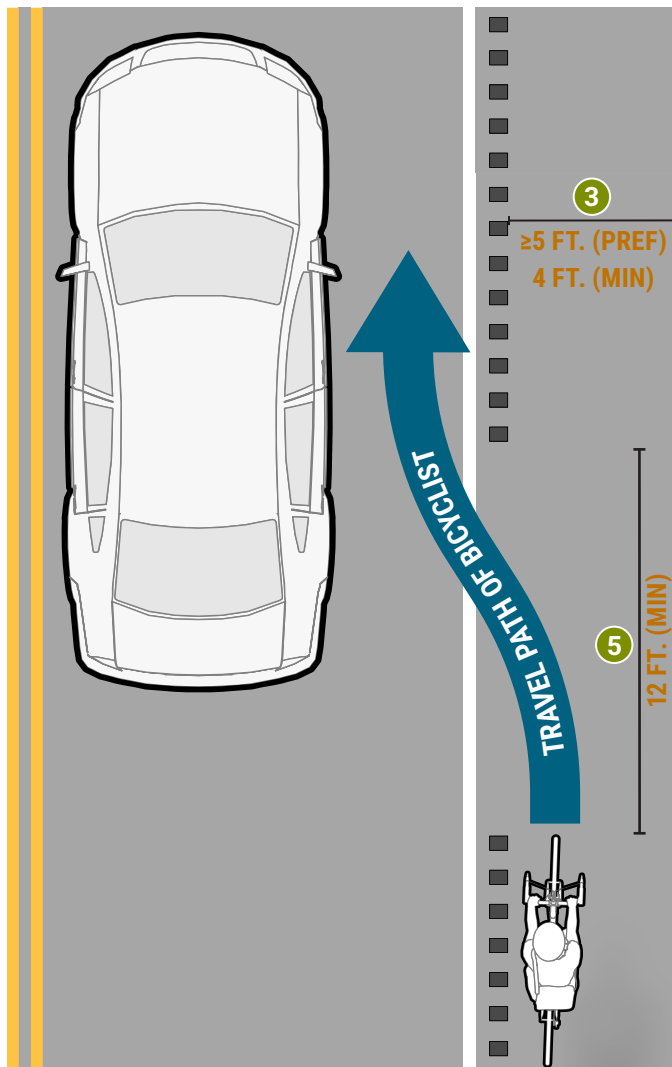
BICYCLE-FRIENDLY CONFIGURATION



RUMBLE STRIPS

Rumble strips are a Proven Safety Countermeasure. Designers have flexibility on the placement and configuration of roadway rumble strips. Therefore, it is important that rumble strips are designed with bicyclist safety in mind. The **AASHTO Bike Guide** recommends providing a 4-foot clear space **(3)** from the rumble strip to the outside edge of a paved shoulder, or 5 feet to an adjacent curb, guardrail, or other obstacle **(2012, p. 4-7)**. A reduced rumble strip length (measured perpendicular to the roadway) or edge line rumble strips, sometimes referred to as a rumble stripes **(4)**, can be considered to provide additional shoulder width for bicyclists. The **AASHTO Bike Guide** recommends providing 12-foot minimum gaps **(5)** in rumble strips spaced every 40–60 feet to allow bicyclists to enter or exit the shoulder as needed **(2012, p. 4-9)**. Designers should consider longer gaps in locations where bicyclists are traveling at relatively high speeds. Designers may also consider bicycle-tolerable rumble strips. Even though the strips can be made more tolerable, they are not considered to be rideable

DESIRABLE (FOR BICYCLISTS) CROSS SECTION



by bicyclists. Additional information on rumble strip design can be found in the **AASHTO Bike Guide 2012** and the **FHWA Rumble Strips and Rumble Stripes Website** (http://safety.fhwa.dot.gov/roadway_dept/pavement/rumble_strips/).

In constrained locations with a paved shoulder width less than 4 feet, designers should consider placing rumble strips at the far right edge of the pavement to give bicyclists additional space near the edge of the lane. **(6)** Results from **NCHRP Report 641: Guidance for the Design and Application of Shoulder and Centerline Rumble Strips 2009** indicate that there may not be a practical difference in the effectiveness of rumble strips placed on the edge line or 2 feet or more beyond the edge line on two-lane rural roads.

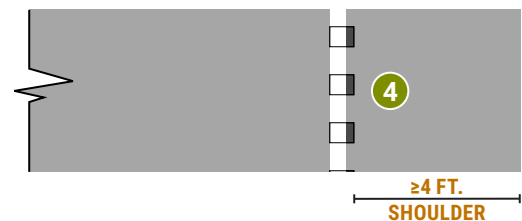
PEDESTRIAN USE OF SHOULDERS

Except where expressly prohibited, pedestrians may legally walk on roadway shoulders. Most highway shoulders are not intended for use by pedestrians but can accommodate occasional pedestrian use. If a shoulder is intended for use as a pedestrian access route "it must meet ADA requirements for pedestrian walkways to the maximum extent possible" (**AASHTO Pedestrian Guide 2004, p. 55**). For more information, refer to the design topic on **Accessibility**.

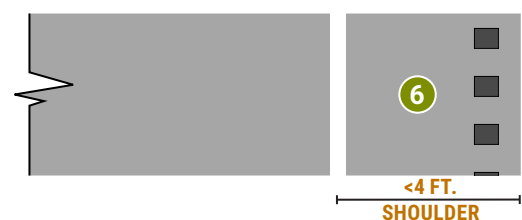
UNDESIRABLE (FOR BICYCLISTS) CROSS SECTION



ADEQUATE CROSS SECTION



CONSTRAINED CROSS SECTION



CASE STUDIES

RUMBLE STRIP POLICY WASHINGTON

The Washington State Department of Transportation (WSDOT) policy for the application of rumble strips on shoulders seeks to strategically reduce run-off-the-road crashes while minimizing impacts to bicyclists. The policy allows rumble strips only if 4 feet of usable shoulder remains after application (5 feet if a guardrail or barrier is present). It also prohibits rumble strips on downhill grades exceeding 4 percent for more than 500 feet along common bike routes. WSDOT's policy allows rumble strips to be placed only along roadways that have above-average levels of run-off-the-road crashes, which can be mitigated by shoulder rumble strips.



Source: John Russell (Creative Commons)

PAVED SHOULDERS AS BICYCLE ACCOMMODATIONS ARIZONA

State departments of transportation pave shoulders based on well-documented benefits they produce for all modes, including the accommodation of bicyclists. For example, the Arizona Department of Transportation (ADOT) typically adds wider paved shoulders (6 feet or greater) to State highways that are part of major reconstruction projects, which is consistent with their bicycle policy. Additionally, on pavement preservation projects, ADOT maintains existing paved shoulders and, in some cases, widens paved shoulders. Sometimes this requires a change in scope for the project and an additional source of funding. ADOT has also revised its **Traffic Engineering Guidelines and Processes on Continuous Longitudinal Rumble Strips** to include a clear shoulder width of 4 feet in order to make shoulders usable for bicyclists.



Source: Kevin Davidson, Hualapai Indian Tribe

11-FOOT LANE WIDTH STANDARD VERMONT

In 2015, the Vermont Agency of Transportation (VTrans) released an "Engineering Instruction" memorandum, specifying the Agency's standard practice of using 11-foot lanes. The memo states that 11 feet is the recommended maximum lane width because roadways with wider travel lanes often result in a "shoulder width that is less than ideal for bicycle traffic." This memorandum represents a major policy shift for a State department of transportation away from wider lanes by default and towards narrower lanes with shoulders that accommodate bicycling.



Highway Safety & Design Engineering Instructions (HSDEI)

Distribution: Highway Division, Director of Policy, Planning and Intermodal Development, Chief of Contract Administration, American Council of Engineering Companies of Vermont

Approved: Michael J. Fowler **Date:** 7/6/2015
Michael J. Fowler, P.E.,
Acting Highway Safety & Design Program Manager

Subject: 11 Foot Lane Width

Administrative Information:

Effective Date: HSDEI 15 – 103 shall be effective from the date of approval.

Superseded HSDEI: Not applicable.

Exceptions: Not applicable.

Disposition of HSDEI Content: The content of HSDEI 15–103 will be incorporated into a future revision of the Vermont State Standards.

Source: Vermont Agency of Transportation

SEPARATED BIKE LANES



Source: New York City Department of Transportation

A separated bike lane—also referred to as a cycle track or protected bike lane—is an exclusive facility for bicyclists that is located within or directly adjacent to the roadway and is physically separated from motor vehicle traffic with a curb, median, or other vertical element. On-street parking may supplement physical separation. Separated bike lanes are integral to the development of low-stress bicycle networks because they enhance safety for all road users, encourage more bicycling, and are preferred by bicyclists and motorists alike.

Key design resources including the **MUTCD 2009**, **AASHTO Green Book 2011**, and **AASHTO Bike Guide 2012** do not define separated bike lanes, which may discourage some designers from incorporating them into roadway designs.

Separated bike lanes are primarily a geometric design solution and are not a traffic control device. Therefore, the **MUTCD 2009** does not restrict their use. However, note that individual elements of separated bike lanes must be used in a manner that is compliant with the **MUTCD 2009**. The **AASHTO Green Book 2011** and **AASHTO Bike Guide 2012** also do not explicitly exclude the design of separated bike lanes. In practice, much of the guidance on sidepaths in the **AASHTO Bike Guide 2012** is applicable to separated bike lanes. Separated bike lane design guidelines have recently been introduced at the Federal and State levels, including the **FHWA Separated Bike Lane Guide 2015**, to communicate best practices, advance design guidance, and encourage flexible solutions to bicycle mobility.

KEY DESIGN FLEXIBILITY

The **AASHTO Green Book 2011** and **MUTCD 2009** do not provide specific design guidance on separated bike lanes. The **FHWA Separated Bike Lane Guide** emphasizes the importance of applying design flexibility when designing separated bike lanes:

“The practice of designing separated bike lanes is still evolving and until various configurations have been implemented and thoroughly evaluated on a consistent basis, design flexibility will remain a priority.”

(2015, p. 27)

OTHER RESOURCES

“By separating cyclists from motor traffic, cycle tracks can offer a higher level of security than bike lanes and are attractive to a wider spectrum of the public.”

NACTO Urban Bikeway Design Guide 2014, p. 27

“In some situations, it may be better to place one-way sidepaths on both sides of the street or highway, directing wheeled users to travel in the same direction as adjacent motor vehicle traffic.”

AASHTO Bike Guide 2012, p. 5-11

“Separated bike lanes can contribute to increased bicycling volumes and mode shares, in part by appealing to less confident riders and this could eventually result in a more diverse ridership across age, gender, and ability.”

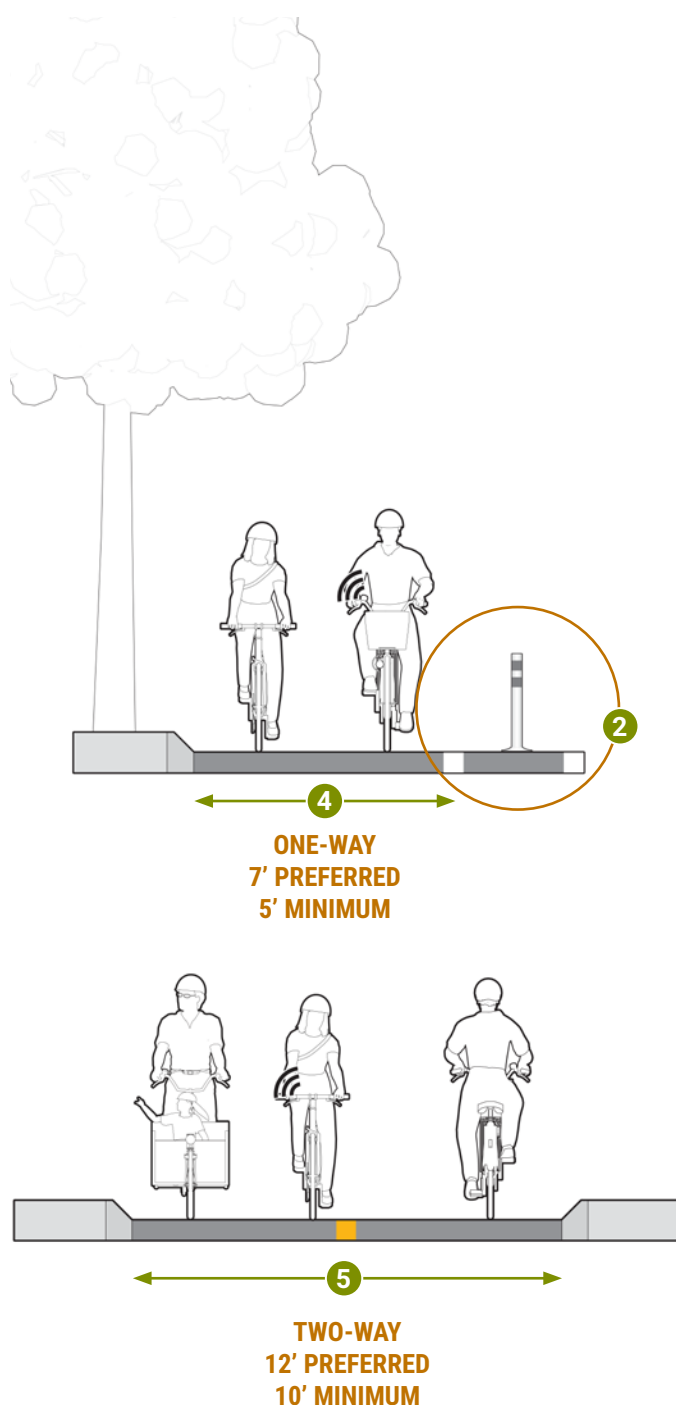
FHWA Separated Bike Lane Guide 2015, p. 16

APPLYING DESIGN FLEXIBILITY

EXISTING SIDEPATH AND STANDARD BIKE LANE GUIDANCE

The **AASHTO Bike Guide 2012** does not cover separated bike lanes, and in some cases discourages their use. However, it is currently under revision with the purpose of providing much needed guidance on the design of separated bike lanes, due in part to the fact that over 250 of these facilities have been installed by communities throughout the U.S.

In the interim, FHWA published the **Separated Bike Lane Guide 2015**, which outlines planning considerations and provides a menu of design options covering typical one- and two-way scenarios.

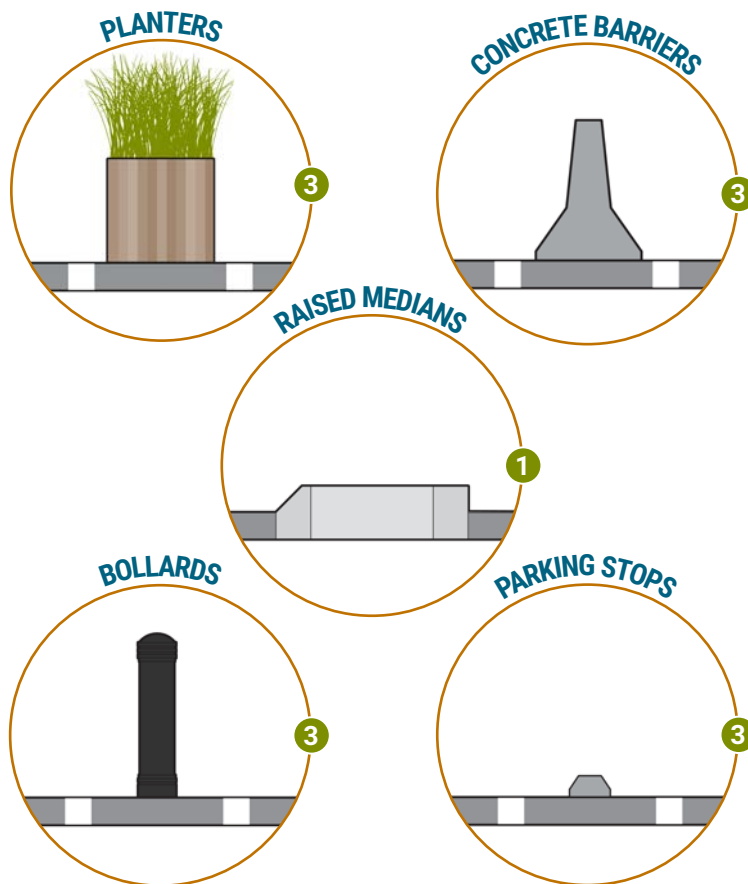


FORMS OF SEPARATION

Separated bike lanes provide a physical separation from motor vehicles by a curb, raised median, or a vertical element. The design of the separation should be based on the presence of on-street parking, overall street and buffer width, cost, durability, aesthetics, traffic speeds, emergency vehicle and service access, and maintenance. (**FHWA Separated Bike Lane Guide 2015, p. 83**)

Raised medians (1) are generally preferred because they provide permanent curb separation. However, they are costly and may impact drainage. Therefore, they are most commonly installed as part of a full roadway reconstruction project. Delineator posts (2) or other lower-cost vertical elements (3) can be ideal for retrofit projects where existing curblines remain. Depending on the project, street buffer widths and vertical element spacing can vary (**FHWA Separated Bike Lane Guide 2015, p. 83**). Designers may increase the street buffer width to create protected bicycle crossings at intersections, which improves motorists' visibility of people bicycling and creates space to yield without blocking traffic. The street buffer also helps manage pedestrian and bicycle conflicts. For more information, refer to the design topic on **Separated Bike Lanes at Intersections**.

Designers should consider the crashworthiness of separation types. Fixed objects in the roadway are generally not recommended and some movable objects, such as planters, may not be appropriate on higher-speed streets. On lower-



speed streets, separation types “need not be of size and strength to redirect errant motorists toward the roadway” (AASHTO Bike Guide 2012, p. 5-11).

BIKE LANE WIDTH

Separated bike lane width depends on a combination of factors, including the existing street characteristics, existing and anticipated demand, and maintenance considerations.

Separated bike lanes may be one-way, either in the direction of vehicle travel or contra-flow, or two-way. Preferred widths range from 7 feet 4 for one-way operation to 12 feet 5 for two-way operation, exclusive of the street buffer. Wider separated bike lanes accommodate greater volumes of bicyclists (FHWA Separated Bike Lane Guide 2015, p. 77 and 80). Narrower widths are sometimes used in constrained locations. However, this may inhibit passing and side-by-side riding, which are important to providing a comfortable bicycling environment that appeals to all ages and bicycling abilities. Narrow separated bike lane widths may also require special maintenance equipment for street sweeping or snowplowing (FHWA Separated Bike Lane Guide 2015, p. 77).

Designers should be mindful of bicyclist operating space and its relation to separated bike lane edge conditions (AASHTO Bike Guide 2012, p. 3-2). Because bicyclists naturally shy away from hazards, proximity to streetscape furniture, vertical elements in the street buffer, or vertical curbs may reduce the usable width of the separated bike lane.

BIKE LANE ELEVATION

Separated bike lanes may be designed at any elevation between the street level and sidewalk level (NACTO Urban

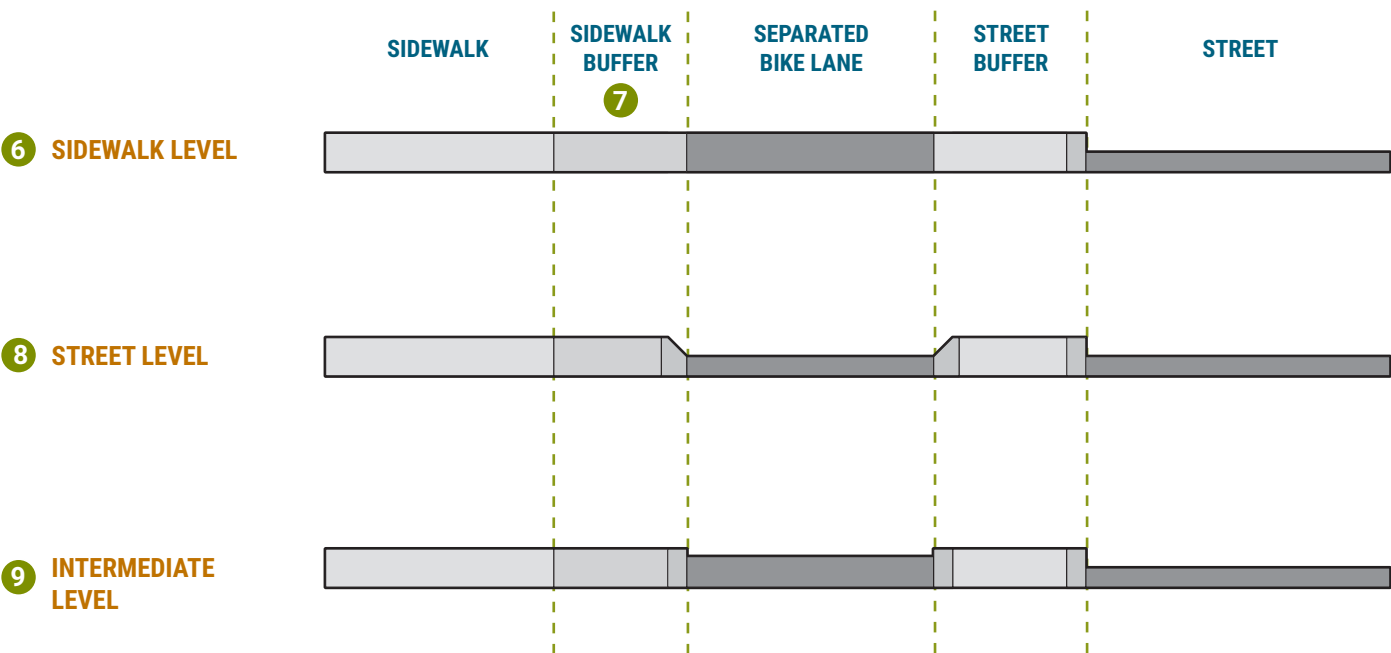
Bikeway Design Guide 2014, p. 35). Many factors contribute to the selection of bike lane elevation, including drainage, accessibility, usable bike lane width, intersection frequency, curbside conflicts, maintenance, and separation from pedestrians and motor vehicles. However, the decision is often dictated by the construction technique (retrofit vs. reconstruction).

Sidewalk-level separated bike lanes 6 typically require reconstruction with drainage modifications. To minimize pedestrian encroachment, sidewalk buffers 7 are preferred. Where buffers are not provided, the separated bike lane should be visually distinct and at a lower grade from the adjacent sidewalk. Sidewalk-level bike lanes simplify raised driveway and street crossings, which improves bicyclist safety.

Street-level separated bike lanes 8 may be implemented as retrofit or reconstruction projects, often allowing the reuse of the existing drainage system. They maximize pedestrian separation, therefore a sidewalk buffer is not required. Raised street and driveway crossings typically require drainage modifications.

Intermediate-level separated bike lanes 9 are located below the sidewalk and above the street and are typically implemented as a reconstruction project. To minimize potential encroachment or conflicts with pedestrians, a minimum 2-inch vertical separation is preferred. Drainage may be captured within the separated bike lane or flow towards a roadway edge collection system.

Separated bike lane elevation may transition throughout a corridor in response to changing conditions (e.g., raising to sidewalk level at driveways, lowering to street level at major intersections). However, designers should avoid frequent transitions to preserve a comfortable bicycling environment.



CASE STUDIES

SOUTHWEST MOODY AVENUE SEPARATED BIKE LANE **PORTLAND, OR**

In 2011, the City of Portland implemented a 0.5 mile two-way separated bike lane as part the SW Moody Avenue reconstruction project. This separated bike lane—the first in downtown Portland—is raised to sidewalk level to further separate bicyclists from motor vehicle traffic. Both the sidewalk and separated bike lane are constructed of concrete, but delineated by trees and unit pavers to provide visual contrast and discourage encroachment. The opening of the Tilikum Crossing Bridge in 2015 brought more changes to SW Moody Avenue: the sidewalk and separated bike lane were flipped to reduce conflicts between these users, and additional green paint further clarified the bicycle path of travel.



Source: PeopleForBikes

POLK STREET SEPARATED BIKE LANE **SAN FRANCISCO, CA**

In 2014, the City of San Francisco installed a contra-flow separated bike lane on a two-block, one-way stretch of Polk Street, permitting bicyclists to safely travel northbound against the flow of southbound vehicular traffic. This separated bike lane creates a low-stress connection between Market Street and Polk Street, two of the busiest and most important bicycling corridors in San Francisco. The City removed a lane of parking to accommodate the bike lane and added a raised vegetated median. A designated vehicle loading area was retained for adjacent buildings. Bicyclists are directed by traffic signals at three intersections. Left-turn queue boxes on Market Street help transition bicyclists into and out of the separated bike lane.



Source: San Francisco Municipal Transportation Agency

WESTERN AVENUE SEPARATED BIKE LANE **CAMBRIDGE, MA**

In 2015, the City of Cambridge completed a full reconstruction of 0.5 miles of Western Avenue, which replaced a standard bike lane with a one-way, sidewalk-level separated bike lane in the same direction of motor vehicle travel. The separated bike lane is visually delineated from the concrete sidewalk through the use of asphalt (which is porous to reduce stormwater runoff) and physically separated with trees and street furniture. The design incorporates raised bicycle and pedestrian crossings at minor street crossings; signalized crossings transition to street level and feature bicycle signals with leading intervals. Conflicts between buses and bicyclists are minimized through the use of floating bus stops. Cambridge performed extensive public outreach for this transformation, including 14 Advisory Committee and public meetings and five neighborhood walks over a 1.5-year period.



BUS STOPS



Bus stops are critical connection points between modes of transportation. Pedestrians, bicyclists, and transferring passengers need to access bus stops. Bus stops are often located in areas with high pedestrian volumes, such as near transportation centers and business districts, but they also serve suburban and rural areas where buses may be the only form of transit. Bus stops should be comfortable, safe, convenient, and designed for the local context. They should complement the larger transportation network.

Accessibility is an essential part in determining bus stop location and layout. In many areas outside urban, low-speed environments, designers need to consider roadway clear-zone requirements and roadside drainage features, which may present challenges to bus stop access. As a method to improve safety, designers sometimes develop “forgiving” roadway designs that include relatively large clear zones. However, this approach may preclude the inclusion of desirable bus stop elements such as bus shelters. The **2011 AASHTO Green Book** identifies flexibility in the clear-zone requirements, where engineering judgment and local context should be used to select an appropriate clear-zone distance for the specific road and bus stop location.

KEY DESIGN FLEXIBILITY

The **2011 AASHTO Roadside Design Guide** provides the basis for design when selecting a clear zone for a roadway. There is flexibility in the clear-zone requirements outlined in the Roadside Design Guide:

“While clear zone dimensions are provided in this guide, they should not be viewed as either absolute or precise. It is expected that the establishment of roadside design criteria and the design of the roadside is a site- or project-specific task for the designer. Also, the Roadside Design Guide suggests that more than one solution may be evident or appropriate for a given set of conditions.”

AASHTO Flexibility Guide 2004, p. 69

OTHER RESOURCES

“Pedestrian access from the catchment areas surrounding bus stops should be convenient, direct, and safe. Connecting streets should be used where available. In other cases, pedestrian connection between bus stops and surrounding neighborhoods should be provided.”

AASHTO Transit Guide 2014, p. 5-11

“For clear zones, the criteria in the AASHTO Roadside Design Guide should be treated as guidance and not as a national standard requiring a design exception if not numerically met.”

FHWA Flexibility in Highway Design 1997, p. 38

“Social safety and traffic safety at transit stops are critical for riders and impact their decisions about where and when to take transit. Prioritizing walking access to transit stops, including direct routes and convenient, low-delay pedestrian crossings, is vital to achieving a safe system.”

NACTO Transit Street Design Guide 2016, p. 58

“The suggested clear-zone distances in Table 3-1 are based on limited empirical data that then were extrapolated to provide data for a wide range of conditions...Appropriate application of the clear-zone concept often will result in more than one possible solution.”

AASHTO Roadside Design Guide 2011, p. 3-10

APPLYING DESIGN FLEXIBILITY

NETWORK

An accessible route, whether a sidewalk **1**, path, or shoulder, must connect to the stop. This may require adding new sidewalks or locating the bus stop where an accessible route already exists. Bus stops should be located where there is existing or future demand, “such as office buildings, schools, medical centers, and apartment complexes. They should also be placed at locations where they connect with other transit lines and major cross-streets” (**AASHTO Transit Guide 2014, p. 5-1**). Both at intersections and midblock, designers should consider if a marked crosswalk and/or additional crossing treatments are necessary. For more information, refer to the design topic on **Enhanced Crossing Treatments**.

CLEAR ZONES

There is a great deal of flexibility afforded to the designer in the selection and application of clear zones. The **AASHTO Roadside Design Guide** provides a range of recommendations for clear zones based on the design speed, average daily traffic of the roadway, and the slope of the area beyond the traveled way (**2011, p. 3-2**).

While the recommendations in the **2011 AASHTO Roadside Design Guide** are the beginning point, engineering judgment and local context should be applied when determining the clear-zone distance. **AASHTO Flexibility in Highway Design** states that determining the clear zone is a project-specific task, and that the width may be limited by right-of-way constraints or the need to provide pedestrian facilities (**2004, p. 68**). The location of, and access to and from, a bus stop may be considered as an appropriate reason to reduce the clear-zone width if needed. **2** Additionally, in low-speed urban environments, the **AASHTO Roadside Design Guide** recognizes that there are practical limitations to clear zones and recommends minimum lateral offsets instead (**2011, p. 10-1**).

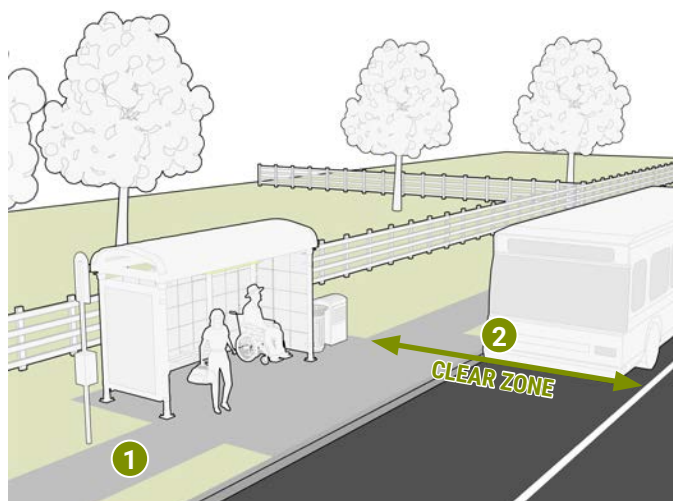
The designer should consider the crash history of a particular road when setting a clear-zone width or locating a bus stop. Other on-roadway treatments including pavement markings, rumble strips, signs, and delineators should be considered when reduced clear-zone width is necessary.

PEDESTRIAN ACCESS TO A BUS STOP ON A SHOULDER

In some cases, such as rural settings, a roadway shoulder may provide the only access to a bus stop. “Where a shoulder serves as part of a pedestrian access route, it must meet ADA requirements for pedestrian walkways to the maximum extent possible” (**AASHTO Pedestrian Guide 2004, p. 55**).

BUS STOP PLACEMENT

Bus stops should be placed as close to the travel way as reasonable, once clear zones are considered. Placing the stop closer to the road increases visibility of the stop users and may



BUS STOP ON ROAD WITH SHOULDER

result in a more direct access route. Additionally, in a retrofit installation, placing the bus stop and shelter close to the travel way reduces impacts to right-of-way.

At intersections, bus stops can be placed far-side (immediately after an intersection) or near-side (immediately before an intersection). Generally, transit agencies prefer far-side stops when traffic flows are heavy, where there are sight distance problems, and where buses turn left. Near-side located bus stops may be appropriate where traffic flow is lower or where transit riders can more easily transfer without crossing the street. Stops can also be placed midblock where there are major passenger generators or where space next to an intersection is insufficient. For more information, refer to the design topic on **Transit Conflicts**.

BUS STOP DESIGN

Bus stop design must be accessible to all transit users, including people with disabilities. Boarding areas must be connected to streets, sidewalks, or pedestrian circulation paths by pedestrian access routes (**PROWAG 2011, R308**; and **ADAAG 810.2.3**). An 8-foot minimum by 5-foot minimum boarding and alighting area **3** free of obstructions is required for accessibility.

Bus stops should be at least 10 feet wide (measured perpendicular from the street) where possible, and long enough to accommodate the bus stop elements (i.e., boarding and alighting area, shelter, etc.) and to coordinate with the front and rear doors of the buses serving the stop to ensure accessibility. **4** Where bus stops are adjacent to sidewalks, the sidewalk width may be included in the bus stop width, as long as the cross slope meets accessibility requirements. The **AASHTO Transit Guide** provides additional guidance on bus stop design (**2014, p. 5-28**).

On lower-speed roadways, vertical curbs should be provided at bus stops, which increases the efficiency and accessibility of boarding and alighting. Curb heights between 6–9 inches accommodate both low floor buses, people with mobility

disabilities, or passengers with strollers (**AASHTO Transit Guide 2014, p. 5-29**).

In a rural setting with higher-speed roadways, vertical curbs should not be used at bus stops. Sloping type curbs with a height not exceeding 4 inches are appropriate (**AASHTO Green Book 2011, p. 4-19**).

The lighting, visibility, and accessibility should be continuous and consistent between the bus stop and any connecting access routes. All bus stops must be accessible with hard-surfaced sidewalks or pathways that are cleared and maintained in all seasons (**AASHTO Transit Guide 2014, p. 5-29**).

Note that there can often be conflicts between bicycles, buses, and boarding passengers. For more information, see the design topic on **Transit Conflicts**.

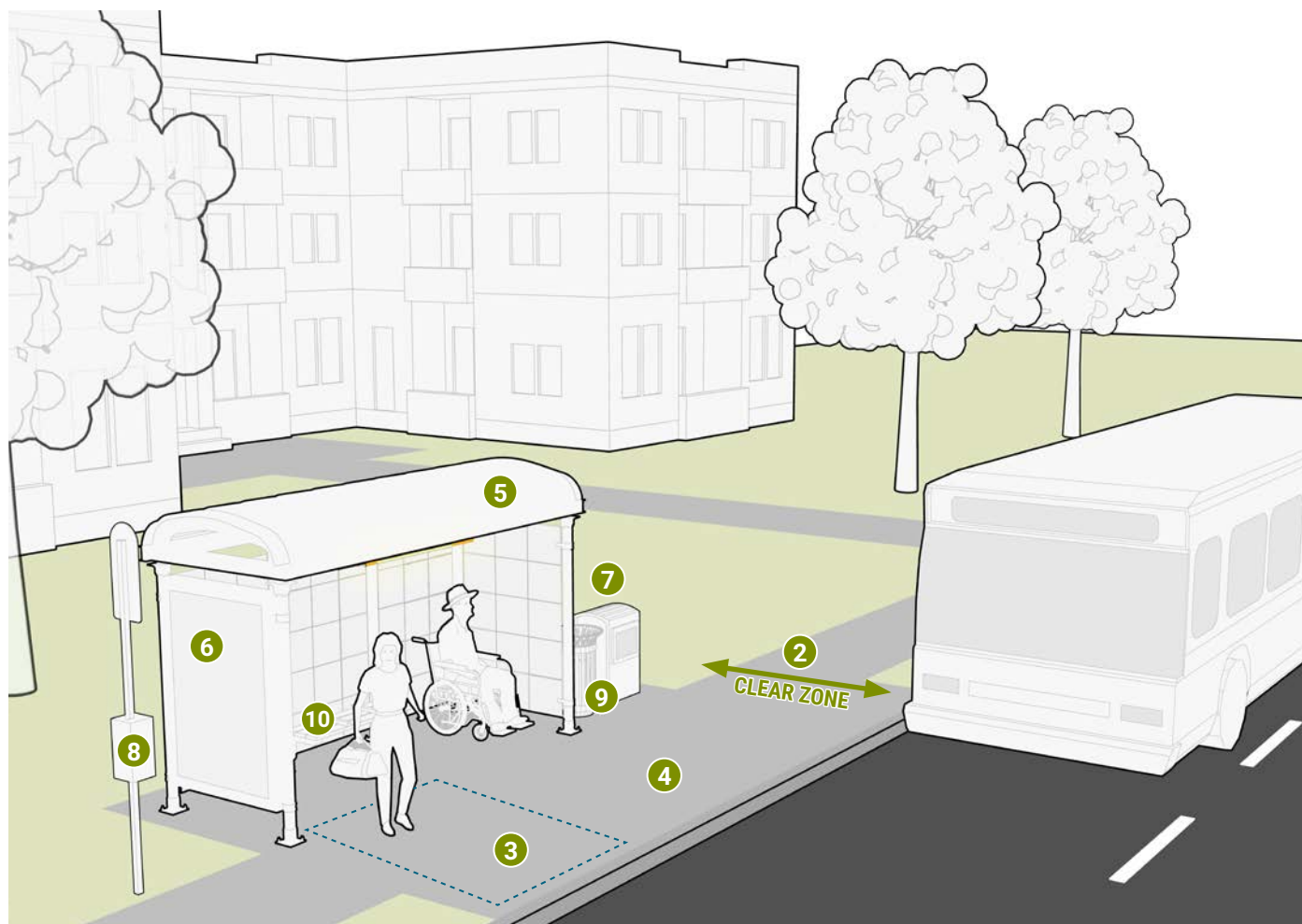
BUS STOP ELEMENTS

Bus stops with elements, such as shelters, benches, and in-shelter lighting increase the comfort, convenience, and visibility of patrons and the stop itself. This investment in infrastructure can raise the overall attractiveness of bus service and help meet a transit agency's targets for ridership growth.

Several factors should be considered when establishing warrants and priorities for shelters **5**, including the "number of passengers using the stop, average passenger waiting time, degree of exposure to weather, availability of alternative shelter nearby, adequacy of sidewalk width to accommodate shelter, proximity of suitable street lighting, and absence of obstructions that limit visibility of shelter (**AASHTO Transit Guide 2014, p. 5-30**). **The Easter Seals Project Action (ESPA) Toolkit for the Assessment of Bus Stop Accessibility and Safety** recommend shelters be provided when 25 or more persons use a bus stop in a suburban setting per day, and 10 or more persons in a rural setting.

Outfitting bus shelters with advertising **6** can help offset the cost of bus shelter installation and maintenance, but may reduce visibility and intersection sight lines.

Additional bus stop amenities include benches, lighting, newspaper vending machines **7**, route/schedule information **8**, trash receptacles **9**, and bicycle parking. Benches **10** and clear spaces for wheelchairs provide comfort, help identify the stop, and are often included within the shelter. In-shelter lighting increases visibility and enhances comfort and sense of security. Bicycle parking should be considered in locations where it is anticipated that transit users would ride to the stop, for example at stops serving longer-distance express buses.



BUS STOP ON ROAD WITHOUT SHOULDER

CASE STUDIES

STOP REQUEST LIGHTS SEATTLE, WA

King County Metro Transit installed solar-powered beacon pole lights at existing and new bus stops to reduce the number of people passed by and not picked up due to low light levels and poor visibility. Metro focused on installing these systems at locations that were especially dark, or where roadway speeds were 35 mi/h or higher. The beacon pole light system allows passengers to activate a light which alerts bus drivers that someone is waiting at the stop. This system includes braille identification plates for people with visual disabilities, and can also include other features such as a locator tone to alert users of the location of the beacon. There has been positive feedback from Metro bus drivers because the lights allow them to make planned, smooth transitions to the stop. This has reduced last-minute braking, which often occurs when visibility is poor.



BUS STOP IMPROVEMENT PROGRAM MONTGOMERY COUNTY, MD

Starting in 2006, the Montgomery County Department of Transportation began an effort to upgrade all of its 5,400 bus stops to improve pedestrian access and to be fully ADA compliant. The effort began with a detailed inventory: each bus stop location was geocoded and 150 attributes were collected. The County identified 3,400 bus stops that needed improvements for a total cost of \$11 million. Improvements included relocating bus stops, installing curb ramps, adding or extending sidewalks, and installing crosswalks and island cut-throughs. At locations with relatively steep slopes, the county installed knee walls (shown to the right) to prevent wheelchairs from rolling and to provide seating space. Field design was key to the success and quick implementation of these improvements. County planners, traffic engineers, and construction contractors met in the field with Maryland State Highway Administration engineers to mark locations of new sidewalk, signs, and pavement markings. To date, most of the bus stops have been improved. Between FY2007 and FY2015, the County spent approximately \$8.2 million to construct over 3,000 concrete boarding and alighting areas, over 85,000 ft² of sidewalk, and over 1,200 curb ramps.



BRIDGE DESIGN



Bridge crossings are significant investments and therefore often occur infrequently. Thus, it is critical that they accommodate pedestrians and bicyclists. A bridge without walking and bicycling access can result in a lengthy detour that makes the entire trip impractical.

Federal law states: "In any case where a highway bridge deck being replaced or rehabilitated with Federal financial participation is located on a highway on which bicycles are permitted to operate at each end of such bridge, and the Secretary determines that the safe accommodation of bicycles can be provided at reasonable cost as part of such replacement or rehabilitation, then such bridge shall be so replaced or rehabilitated as to provide such safe accommodations" (23 USC §217(e)).

Safe pedestrian access can often be included at the same time as bicycle accommodations and should be provided on bridges whenever possible, regardless of funding source. Bridges should also accommodate bicyclists and pedestrians traveling under them so they do not create a barrier. Providing pedestrian and bicycle accommodation during initial construction generally costs less than retrofitting.

While Federal policy, in many cases, requires safe accommodation of pedestrians and bicyclists, design guidance provides adequate flexibility on how to accommodate these users.

KEY POLICY

U.S. DOT recommends transportation agencies and local communities to go beyond minimum design standards and requirements to create safe, attractive, sustainable, accessible, and convenient walking and bicycling networks. Such actions include:

"Integrating bicycle and pedestrian accommodation on new, rehabilitated, and limited-access bridges: DOT encourages bicycle and pedestrian accommodation on bridge projects including facilities on limited-access bridges with connections to streets or paths."

U.S. DOT Policy Statement on Bicycle and Pedestrian Accommodation Regulations and Recommendations 2010

OTHER RESOURCES

"Bridges, viaducts, and tunnels should accommodate bicycles... there are numerous examples of limited access highway bridges that cross major barriers (such as wide waterways) that incorporate a shared use path for bicyclists and pedestrians. The absence of a bicycle accommodation on the approach roadway should not prevent the accommodation of bicyclists on the bridge or tunnel."

AASHTO Bike Guide 2012, p. 4-41

"Provisions should always be made to include some type of walking facility as a part of vehicular bridges, underpasses, and tunnels, if the facility is intended to be part of a pedestrian access route."

AASHTO Ped Guide 2004, p. 63

"It is more effective to plan for increased usage than to retrofit an older facility. Planning projects for the long-term should anticipate likely future demand for bicycling and walking facilities and not preclude the provision of future improvements."

U.S. DOT Policy Statement on Bicycle and Pedestrian Accommodation Regulations and Recommendations 2010

APPLYING DESIGN FLEXIBILITY

PEDESTRIAN AND BICYCLE ACCOMMODATION

Both sides of bridges should accommodate travel for pedestrians and bicyclists. ① Where bidirectional travelways can be provided, they may reduce conflicts if they limit the number of roadway crossings. Similarly, facilities for current and anticipated people who will walk and bicycle to the bridge as well as travel under the bridge should be considered. ② Designers should consider whether to combine pedestrians and bicyclists on a shared use path or to separate them. Refer to the design topic on **Shared Use Paths** for more information.

CONNECTION TO CROSSING FACILITIES

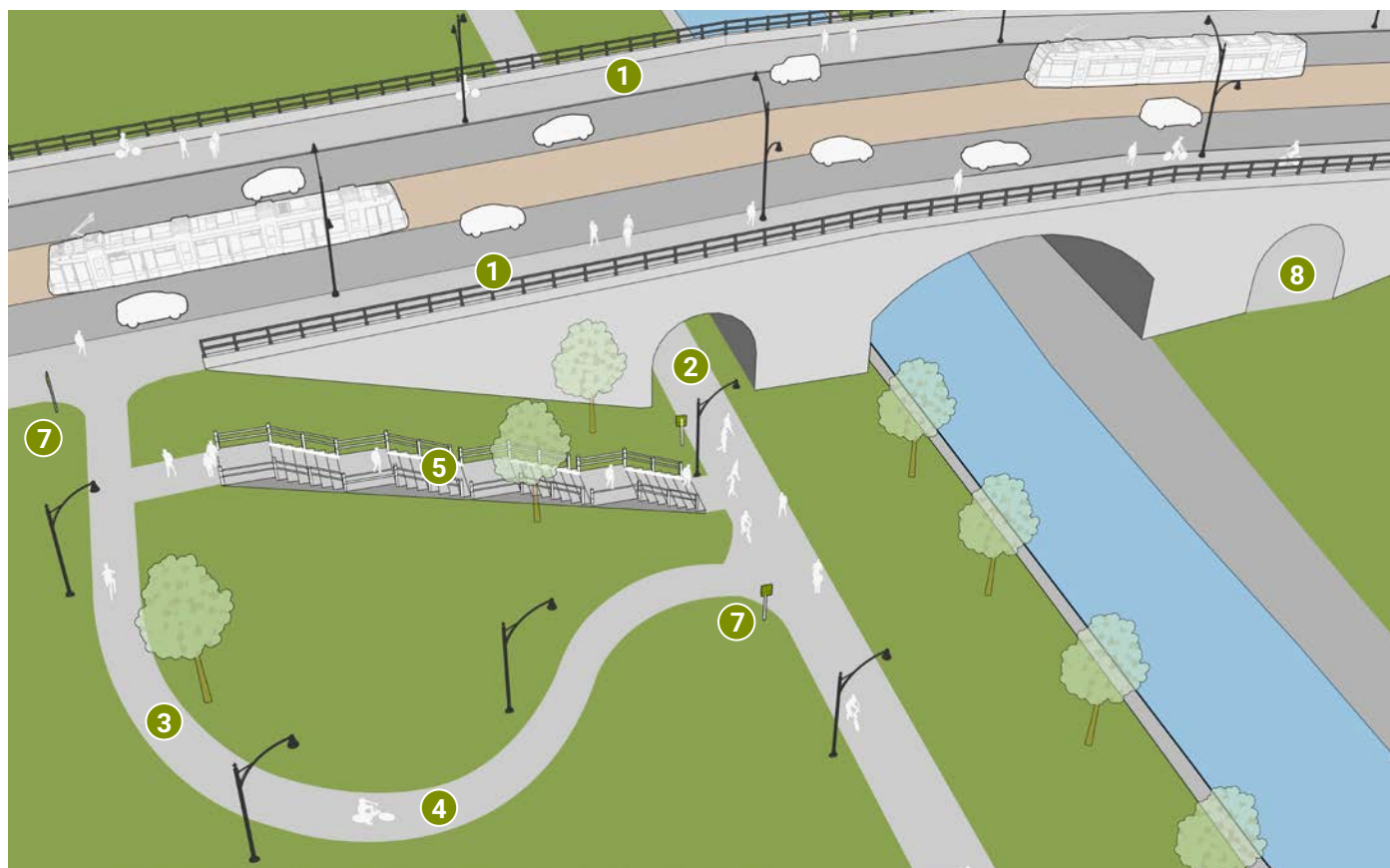
Connections from bicycle and pedestrian facilities on a bridge to related features below, such as shared use paths, sidewalks, or other infrastructure, are a key component of connected networks. Any connection for use by pedestrians must be accessible to people with disabilities. ③ The design should consider the desired route of pedestrians and bicyclists. Common practice is to install switchbacks which may be the only option in a confined space. However, designs without switchbacks often create a more direct route for the majority of users. Grades must meet accessibility standards and ramps may be required. Where bicyclists are permitted to use the connection, the ideal design should not require bicyclists to dismount (**AASHTO Bike Guide 2012, p. 5-14**). Where switchbacks are required, the ramp turns should provide generous width to better accommodate turns by bicyclists. ④

STAIRS WITH BIKE CHANNELS

Stairs may be built to provide a more direct connection for pedestrians and bicyclists, but the accessible route may not be significantly longer. ⑤ Stairs can accommodate bicycles by including a bike channel—a flat ramp parallel to the stairs on which to roll a bicycle. ⑥ Handrail designs must meet current accessibility standards. Specifically, the handrail on stairs with a bike channel needs to project out from the wall with at least the minimum clearance required by the ADA Accessibility Guidelines, and the handrail must be aligned above the stair nosing where people are walking. Pedestrians must be able to easily reach the railing and the bike channel must not present a tripping hazard for people with visual disabilities.

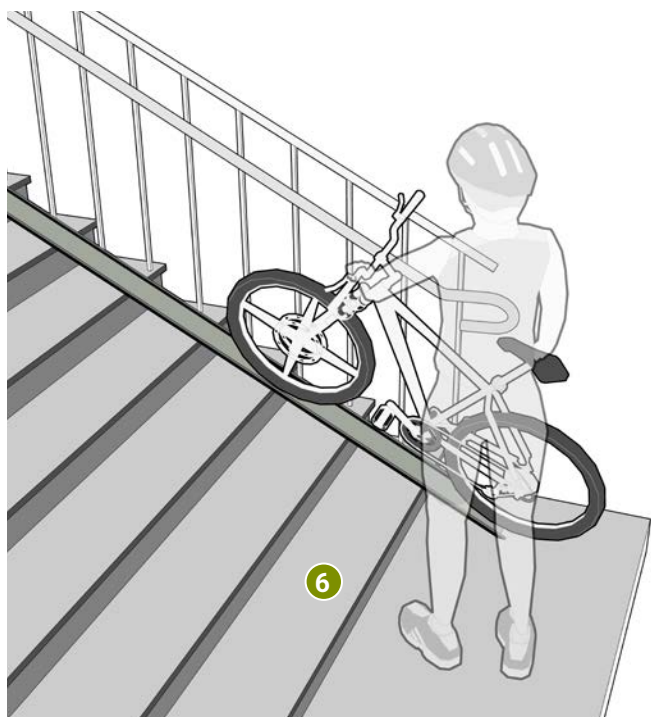
WAYFINDING TO BRIDGE ENTRANCES

Pedestrians and bicyclists may find it difficult to locate bridge access points from the connecting street grid. In some cases, access points for people on foot, in wheelchairs, or on bicycles are different and more difficult to locate than vehicle access points. Wayfinding signs and markings should direct people to bridge access points. ⑦



DESIGNING FOR FUTURE TRAILS

While including facilities for pedestrians and bicyclists on bridges increases access, the bridge design itself may reduce future connectivity. Waterways, railroads, and highways may be desirable corridors for shared use paths. Whether or not there is a current plan to build a path along one of these corridors, bridge design should consider future accommodations for pedestrians and bicyclists under the bridge. **8**



CLEAR WIDTH/USABLE WIDTH

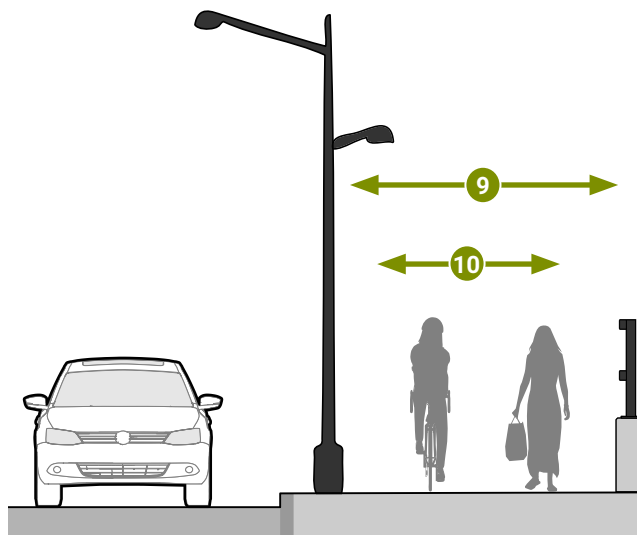
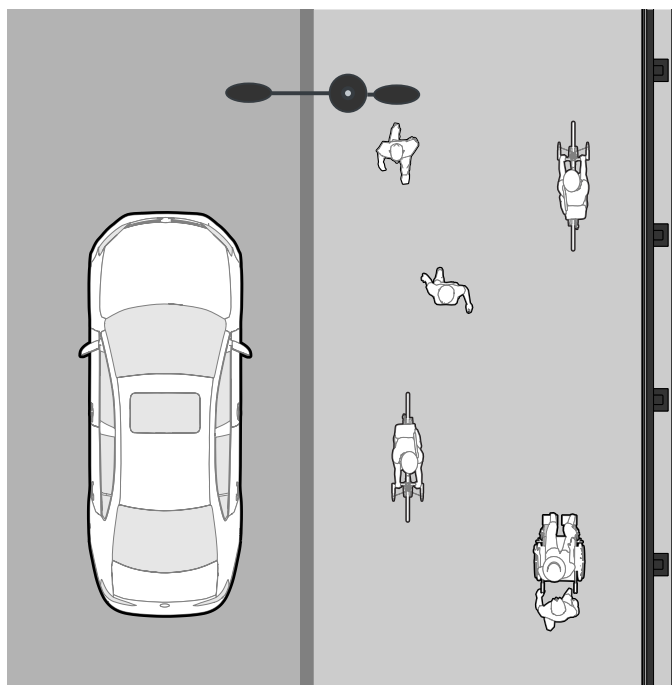
Bridge designs should provide adequate width for current and anticipated pedestrian and bicycle use. Sufficient clear width and usable width should be provided. Clear width **9** is a travelway clear of obstructions such as railings, light poles, signs, etc. (HCM 2010, p. 17.48). The usable width **10** recognizes that pedestrians and bicyclists will not travel at the very edge of a travelway or immediately against a railing, but need at least 1.5 feet of shy distance from vertical objects (HCM 2010, p. 17.48). For more information, refer to the design topic on **Shared Use Paths**.

CONSIDERATIONS

- The desirable clear width for a sidewalk on a bridge is 8 feet (AASHTO Pedestrian Guide 2004, p. 63).
- The minimum width for one-way bicycle travel is 4 feet. (See the AASHTO Bike Guide 2012 for considerations regarding bike lane and shared use path widths.)

BRIDGE RAILINGS

Well-designed bridge railings can contribute to a positive experience on bridges for people who walk or bicycle and can increase safety. Railing designs should consider a 1.5 foot shy distance when determining usable width, and a height that keeps pedestrians and bicyclists safe. As bicyclists have a higher center of gravity, railings should be a minimum of 42 inches high. Where a bicyclist's handlebar or pedal may come into contact with the railing, a smooth wide rub-rail should be installed (AASHTO Bike Guide 2012, p. 5-27). On bridges that accommodate both vehicular and pedestrian/bicycle travel, only a crash-tested railing should be installed.



CASE STUDIES

BUILDING TUNNELS FOR FUTURE TRAILS MINNEAPOLIS, MN

In 2008, the City of Minneapolis, MN completed the reconstruction of the Interstate-35W Bridge crossing the Mississippi River in Minneapolis with careful consideration for future transportation corridors. A large culvert box was constructed under the south end of the bridge to provide a future tunnel connection for pedestrians and bicyclists crossing underneath the interstate. The trail did not exist at the completion of the new bridge and tunnel, as funding for the trail remained unidentified.

The culvert tunnel remained closed for six years, and opened in 2014 as part of the Bluff Street bicycle and pedestrian trail, which provides an important connection between downtown Minneapolis and the University of Minnesota.



BRIDGE ACCOMMODATION AND WIDTHS PORTLAND, OR

In 2015, TriMet completed the Tilikum Crossing Bridge as part of a new light rail alignment in Portland, OR. The Tilikum Crossing is the first major bridge in the U.S. designed for transit vehicles (light rail and buses), pedestrians, and bicyclists but not cars, trucks, or motorcycles. The bridge has two 14-foot pedestrian and bicycle pathways on each side: each with more than 7 feet dedicated to one-way bicycle travel and 6 feet for two-way pedestrian travel. By completing key bicycle and pedestrian connections and expanding the City's bicycle and pedestrian network, the bridge's facilities helped build good will and excitement for the project in the community.



BRIDGE APPROACH RAMP WEST PALM BEACH, FL

In 2003, the City of West Palm Beach, FL reconstructed the Royal Park Bridge connecting West Palm Beach with Palm Beach, FL. The design included a pedestrian and bicycle "interchange" on the West Palm Beach side. The interchange features a new pathway under the bridge that connects to the bridge via a ramp and staircase, which allows bicyclists and pedestrians to comfortably travel from the trail to the bridge without conflicts with motorists. The ramp and stair connection is accessible, well lit, and landscaped. The new trail under the bridge includes a 10-foot wide section for bicyclists and a 10-foot wide section for pedestrians with a 4-foot wide textured separator.



SLOW STREETS



Slow streets are designed to enhance safety and improve pedestrian and bicycle comfort by achieving low motorist speeds. Slow streets are frequently designed to minimize speed differentials between motorists and bicyclists to prioritize bicycle travel. The lower motorist speeds also promote increased yielding to pedestrians crossing the street. These streets are also known as bicycle boulevards, quietways, or neighborhood greenways.

Designers have conventionally designed low-speed, urban streets for speeds between 20–45 mi/h. Slow streets should be designed for a maximum speed of 20 to 25 mi/h with the majority of motorists going slower. Slow streets may require the use of traffic calming measures such as curb extensions, speed tables, gateway treatments, neighborhood traffic circles, textured pavement, and chicanes. For more information, refer to design topic on **Traffic Calming and Design Speed**.

KEY DESIGN FLEXIBILITY

The **2014 NACTO Urban Bikeway Design Guide** addresses the design of bicycle boulevards, a type of slow street:

"Streets developed as bicycle boulevards should have 85th percentile speeds at 25 mph or less (20 mph preferred)."

NACTO Urban Bikeway Design Guide, p. 167

OTHER RESOURCES

"Pedestrians are the lifeblood of our urban areas, especially in the downtown or other retail areas. In general, the most successful shopping sections are those that provide the most comfort and pleasure for pedestrians."

AASHTO Green Book 2011, p. 2-78

"Bicycle boulevards create favorable conditions for bicycling by taking advantage of local streets and their inherently bicycle-friendly characteristics: low traffic volumes and operating speeds."

AASHTO Bike Guide 2012, p. 4-33

"Speed Management measures for bicycle boulevards bring motor vehicle speeds closer to those of bicyclists...[and] is critical to creating a comfortable and effective bicycle boulevard."

NACTO Urban Bikeway Design Guide 2014, p. 167

"Bicycles are an important form of non-motorized travel for social, recreational, and work trips. Local streets often are ideal for bicyclists because of their relatively low traffic levels, relatively low traffic speeds and direct access to a large number of destinations."

ITE Urban Street Geometric Design Handbook 2008, p. 250.

APPLYING DESIGN FLEXIBILITY

Design speeds for slow streets are typically at or below 20 mi/h. This design speed reduces the speed differential between roadway users, thus providing a higher level of comfort and safety. Good candidates for slow streets include neighborhood residential streets, school walking routes, bicycle routes, and shopping streets with a high level of pedestrian activity. Slow streets are also appropriate on streets running adjacent to, or through, parks and public plazas. **1** Lower-speed streets with comfortable pedestrian crossings enhance adjacent public space, while streets designed for higher vehicle speeds and volumes, with difficult crossings, detract from it.

There are various types of slow streets, including (but not limited to):

- Bicycle boulevards
- Bicycle priority streets
- Neighborhood greenways
- Neighborhood slow streets
- Shared streets (also called “flush” streets) are a special type of slow street that are covered separately in the design topic on **Shared Streets**.

STRATEGIES FOR ACHIEVING SLOW SPEEDS

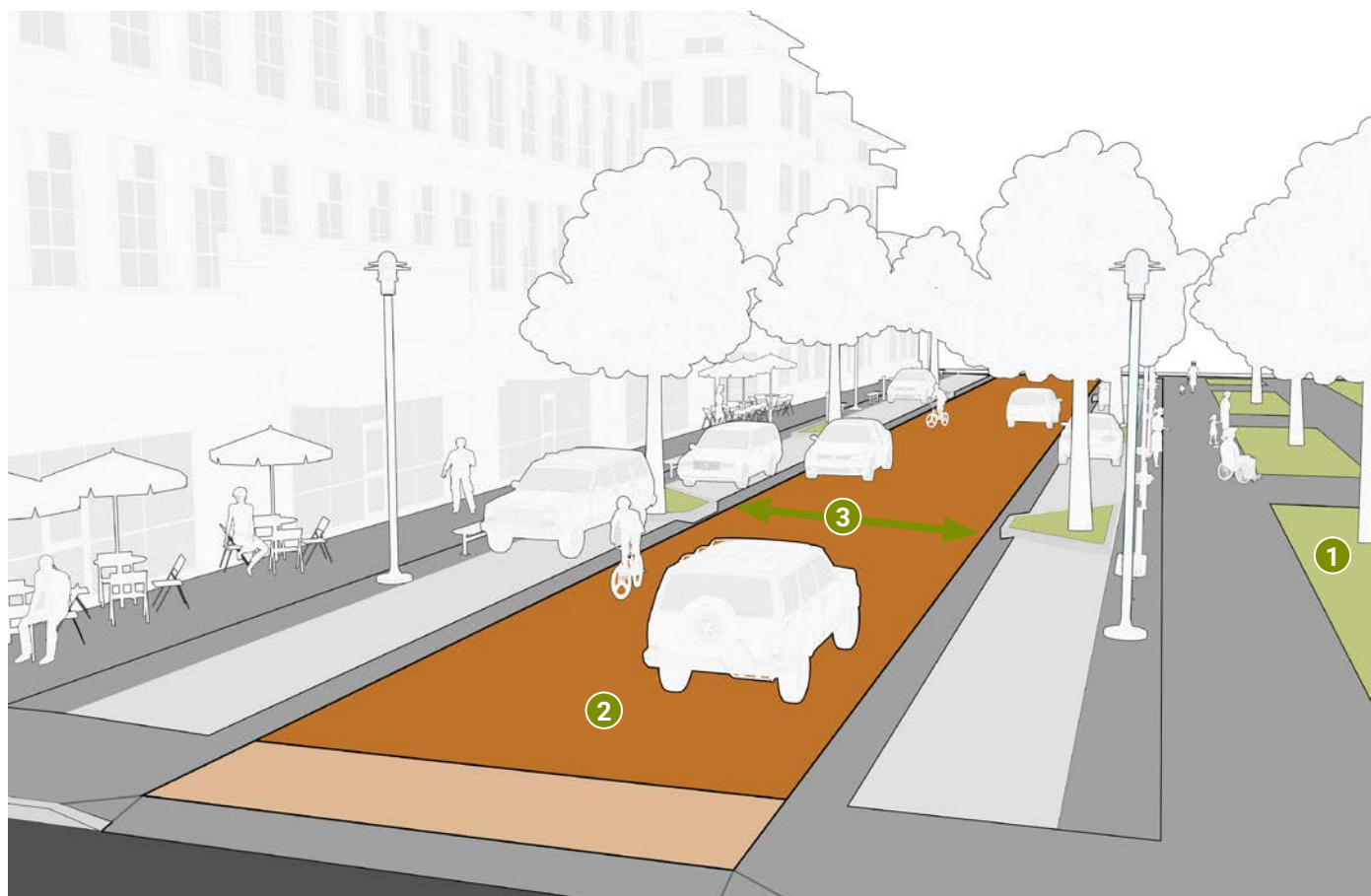
The choice of surface materials can impact traffic safety and speeds, user comfort, and stormwater management. Bricks or pavers provide texture and can produce a traffic calming effect when used in the street, but may be difficult for some people to traverse in the pedestrian areas. **2**

Slow streets often have a narrowed travel way (less than 18 feet in total width), in some cases requiring oncoming motor vehicle traffic to yield prior to passing. **3** Alleys are an example of this strategy for slow street design.

In some cases, slow streets will include bollards, planters, and other vertical elements in close proximity to the travel way, therefore encouraging caution as drivers move along the street.

The removal of traffic controls at intersections, in conjunction with other features that reduce speed, is another strategy to produce cautious behavior for motorists (and therefore slower speeds).

Various other traffic calming measures can be used to slow motor vehicle speeds, provide comfortable places for vulnerable road users, and encourage motorist yielding. For more information, refer to the design topic on **Traffic Calming and Design Speed**.



SLOW STREET ADJACENT TO PARK

Slow street strategies may be implemented in the short or long term. Effective traffic calming measures may be implemented as short-term retrofit project using paint and temporary materials only (e.g., epoxy, flexible delineator posts, planters, etc.). The use of these materials enables practitioners to tweak designs, if necessary, in response to community input and direct observations. It may be appropriate to pursue a retrofit project in the short term while planning and designing for long-term reconstruction. Some measures may require reconstruction of the street to realize full desired outcomes.

GATEWAY TREATMENTS

For a slow street to be successful, drivers must feel that they are entering a new and different environment. This is typically accomplished by locating gateway treatments at the transition point to a slow street (**NACTO Street Urban Design Guide 2013, p. 47**). Gateway treatments are strategically located curb extensions that can feature additional elements, such as raised crossings, landscaping, signs, stormwater management, etc. Cambridge, MA, Boulder, CO, Portland, OR, Seattle, WA, and New York City are examples of municipalities that implement gateway treatments.

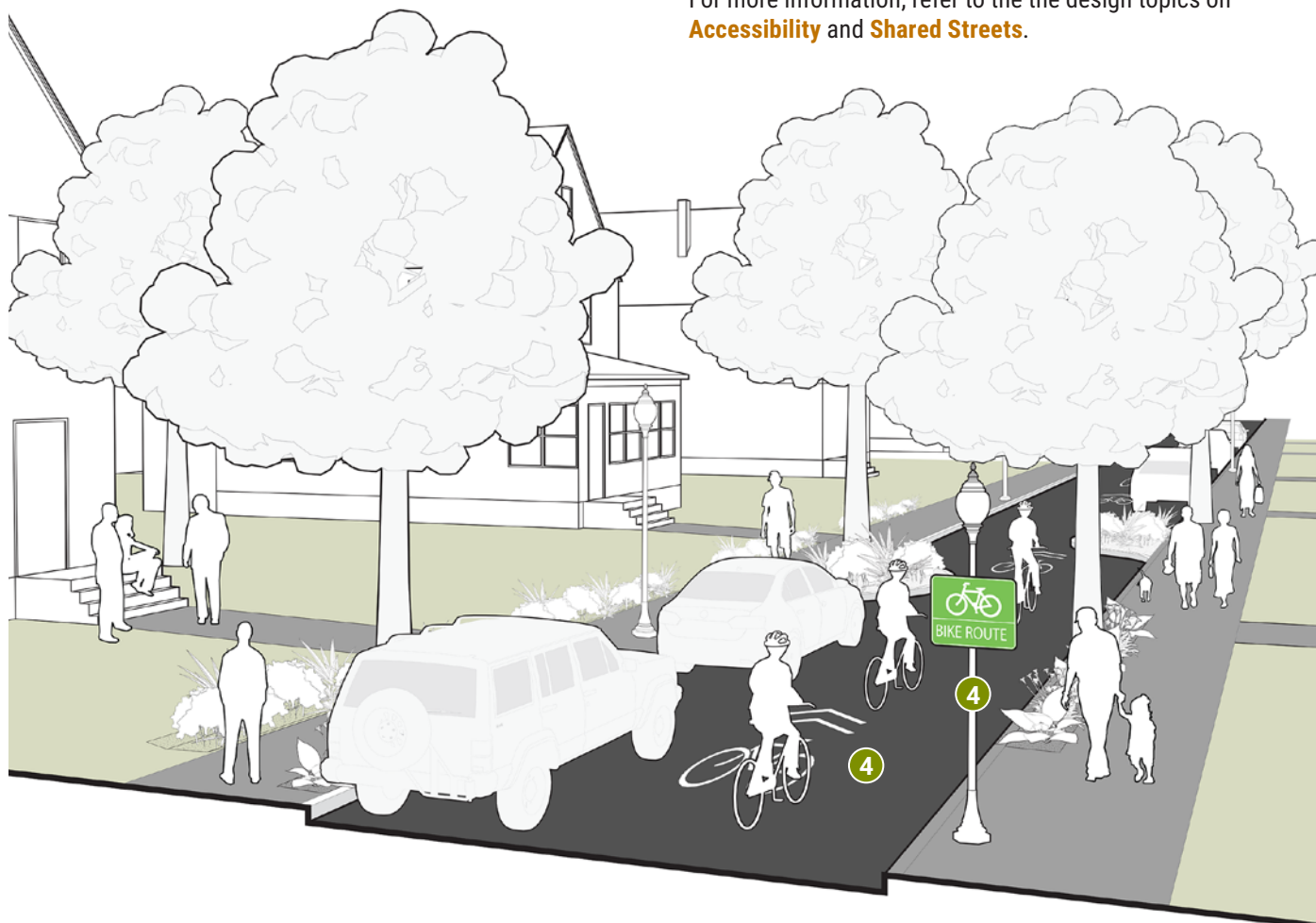
BICYCLE BOULEVARDS (OR BICYCLE PRIORITY STREETS)

Bicycle boulevards are streets with lower motor vehicle speeds that are designed to allow bicyclists to travel comfortably in a low-stress environment. Bicycle boulevards typically give priority to bicycle use and discourage through-traffic by motor vehicles. They are designed to minimize the number of stops that a bicyclist must make along the route.

There is a great deal of flexibility when designing bicycle boulevards. Different types of design treatments can be used. They are easier to implement in areas with a grid street network because drivers have the option to choose an alternate route. Bicycle boulevards are typically designated with special signs or pavement markings. **4** More information on bicycle boulevard design can be found in the **2012 AASHTO Bike Guide** and the **2014 NACTO Urban Bikeway Design Guide**.

ACCESSIBILITY

Slow streets are inherently beneficial to pedestrians of all abilities, because they produce slower and more cautious behavior on the part of motorists. Design elements of slow streets must meet current accessibility standards. For example, all surfaces within pedestrian areas must be designed and maintained to be stable, firm, and slip resistant. For more information, refer to the design topics on **Accessibility** and **Shared Streets**.



BICYCLE BOULEVARD

CASE STUDIES

HERITAGE SQUARE SULPHUR SPRINGS, TX

The City of Sulphur Springs reconstructed Heritage Square to revitalize its downtown and create a welcoming public space next to the historic Hopkins County Courthouse. Four two-lane, one-way streets surrounding the square were narrowed, converted to two-way operation, and reconstructed with a brick surface. The result was a slow-speed street that doubles as festival space during downtown community events, which are now common. The City replaced a parking lot in the center of the square with landscaping, trees, memorials, places to sit, a splash fountain, two public restrooms, and on-street parking.



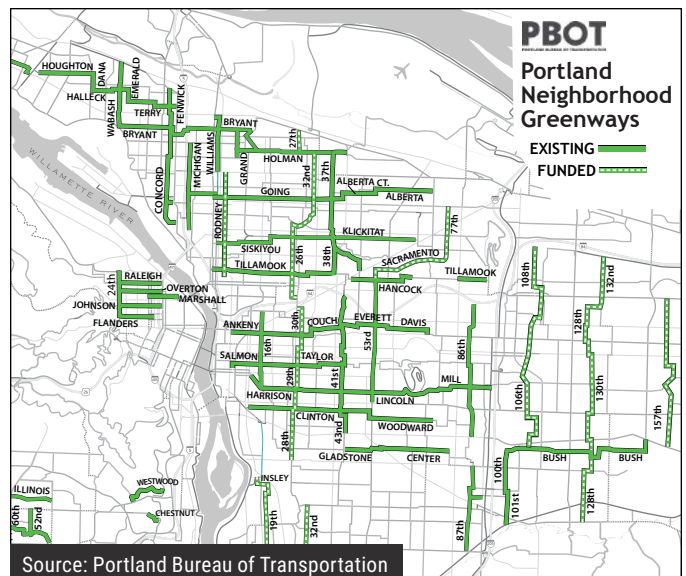
5TH STREET NE BICYCLE BOULEVARD MINNEAPOLIS, MN

In 2011, the City of Minneapolis installed the 5th Street NE Bicycle Boulevard to provide a low-stress bicycling route. 5th Street NE is a quiet, residential street with a 20–25 mi/h design speed. Yield-controlled, landscaped traffic circles replaced stop signs at two locations. The City rebuilt two traffic diverters to allow bicycle-only traffic and installed the city's first bicycle signal to facilitate the crossing of Broadway Street, which carries 20,000 vehicles/day. Today the boulevard connects University of Minnesota students with residential neighborhoods and serves about 700 bicyclists on a typical day.



NEIGHBORHOOD GREENWAY PROGRAM PORTLAND, OR

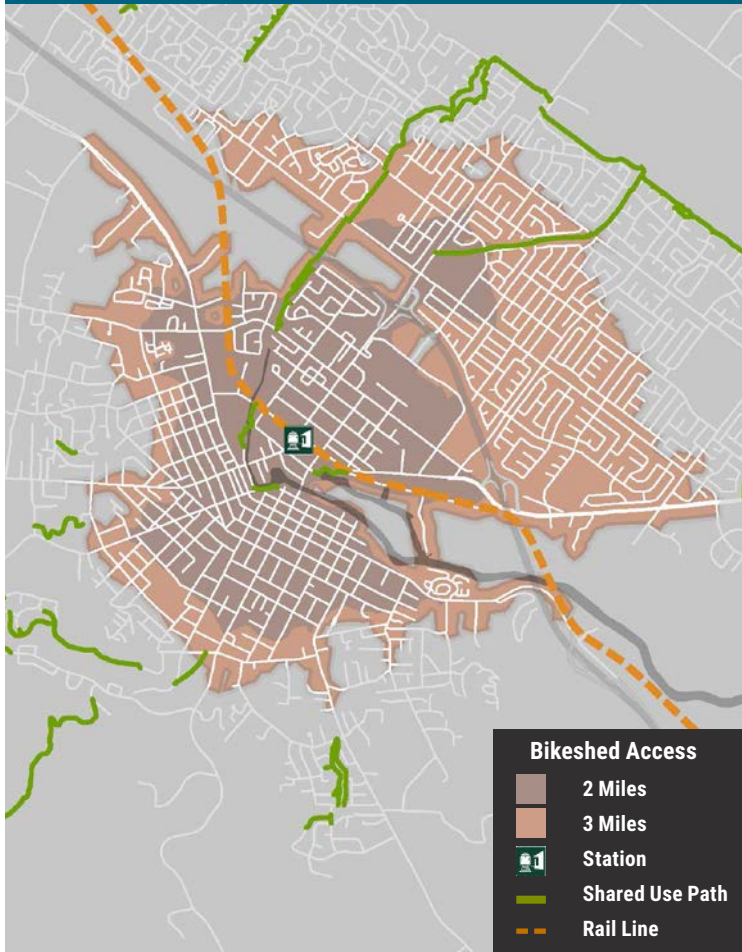
Portland's Neighborhood Greenways program (formerly Bicycle Boulevards) increases the safety, comfort, and convenience of the walking and bicycling environment on residential streets. Neighborhood Greenways provide comfortable bicycle and pedestrian crossing opportunities and are designed to limit motor vehicle operating speeds to no more than 20 mi/h and volumes to approximately 1,500 vehicles per day. These outcomes are achieved through the use of speed humps and traffic diverters to discourage cut-through motor vehicle traffic. As a result, Neighborhood Greenways form the backbone of the City's low-stress bicycling network. The City has installed more than 70 miles of Neighborhood Greenways as of 2016 and continues to expand the program.



PART 2:
REDUCING CONFLICTS

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NETWORK CONNECTIVITY

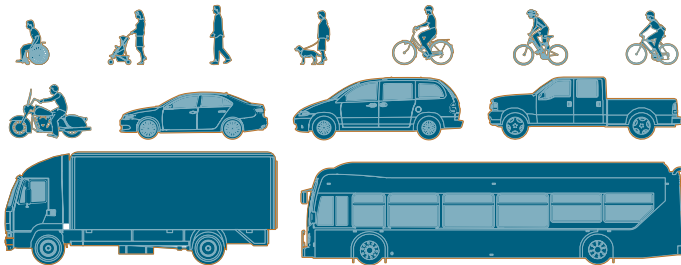


The provision of connected and consistent facilities for pedestrians and bicyclists can reduce conflicts among modes and encourage higher levels of walking and bicycling. Walking and biking routes should form a comfortable network for all ages and abilities.

The network must enable a comfortable trip from beginning to end to maximize use. To accomplish this, disconnected street networks, highway or railroad barriers, high-crash or uncomfortable intersections, and difficult midblock crossings must be addressed. Appropriate treatments along roadways vary widely based on context.

The pedestrian network is a connected transportation system made up of components such as sidewalks, street crossings, shared streets, shared use paths, and in some cases paved shoulders. The bicycle network is a connected system made up of facilities such as separated bike lanes, bike lanes, bicycle boulevards, low-volume streets, shared use paths, and paved shoulders. Pedestrian and bicycle networks should allow people to access any destination including mixed-use developments, transit stations and stops, commercial districts, residential areas, and employment centers. Pedestrian and bicycle facilities are particularly important where destinations are located in close proximity and short trips are likely.

COMMON USERS IN CONFLICT



GUIDING PRINCIPLES TO REDUCE CONFLICTS

SAFETY

The design of pedestrian and bicycle network facilities should decrease the likelihood and severity of all crashes.

ACCOMMODATION AND COMFORT

Pedestrian and bicycle facilities should create a comfortable walking and biking environment for all ages and abilities.

COHERENCE

Pedestrian and bicycle network facilities should be delineated and continuous throughout the user's trip.

PREDICTABILITY

Pedestrians and bicyclists should travel on predictable, defined facilities.

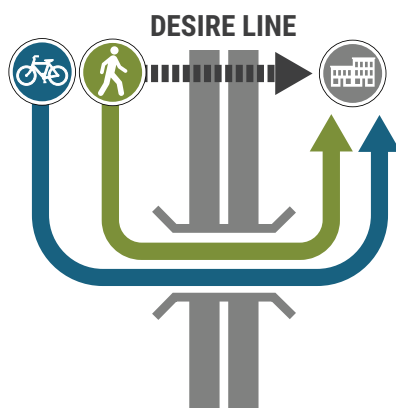
CONTEXT SENSITIVITY

Pedestrian and bicycle facilities should be appropriate to the surrounding environment.

EXPERIMENTATION

Designers should consider innovative solutions to create connected networks, particularly at crossing locations where conflicts are more likely and on higher-speed streets.

A well-connected network of pedestrian and bicycle facilities reduces conflicts by providing access where desired.



DESIGN STRATEGIES

Pedestrian and bicycle networks are planned at many scales from region-wide route systems to small-area plans. The following strategies address the challenges and potential solutions to improve nonmotorized access to a major destination in a suburban region. These network challenges are common in many communities that were constructed with minimal consideration for walking or bicycling needs. For additional destination considerations, refer to the design topics on **School Access**, **Multimodal Access to Existing Transit Stations**, and **Multimodal Access to New Transit Stations**.

DISCONNECTED STREET NETWORKS

Typical suburban street networks are a combination of major arterials and cul-de-sac developments that create challenges for bicyclist and pedestrian circulation. Cul-de-sac street networks force people to use the higher-volume, higher-speed arterials rather than the low-volume, local streets. These street networks lengthen trip routes to the point that people are less willing to bike or walk.

CONSIDERATIONS

- Keep block sizes small to reduce pedestrians walking through parking lots or other undeveloped areas. **1**
- Connect cul-de-sac street networks through a system of shared use paths providing key links. **2**

BARRIERS

Limited-access highways and railroad tracks can create major barriers for people on foot and bike. Infrequent barrier crossings create excessive distances for pedestrians and bicyclists. Adding barrier crossings such as bridges and tunnels will improve network connectivity, provide safer and more comfortable crossings, and reconnect bisected communities. **3** For more information, refer to the design topic on **Bridge Design**.

PEDESTRIAN CONNECTIONS

A well-developed pedestrian network promotes walking trips by providing facilities that are connected, comfortable, and appropriate for their street type.

A lack of appropriate pedestrian facilities can result in people walking in the street, running across the street, or walking on private property. Higher-volume multilane roadways require pedestrians to cross four or more travel lanes at intersections. Long crossing distances expose pedestrians to potential conflicts and create a psychological barrier to walking.

CONSIDERATIONS

- Provide sidewalks on both sides of the street, especially higher-volume, higher-speed roadways. **4** For more information, refer to the design topic on **Accessibility**.

- Narrow travel lanes and construct curb extensions and/or pedestrian crossing islands to reduce crossing distances. **5** For more information, refer to the design topics on **Design Criteria and Lane Width**, **Enhanced Crossing Treatments**, and **Intersection Geometry**.
- Consider enhanced treatments, such as pedestrian hybrid beacons or Rectangular Rapid Flash Beacons, at uncontrolled crossings. For more information, refer to the design topic on **Enhanced Crossing Treatments**.
- Provide pedestrian countdown signals and accessible pedestrian signals at signalized crossings. For more information, refer to the design topic on **Signalized Intersections**.

BICYCLE CONNECTIONS

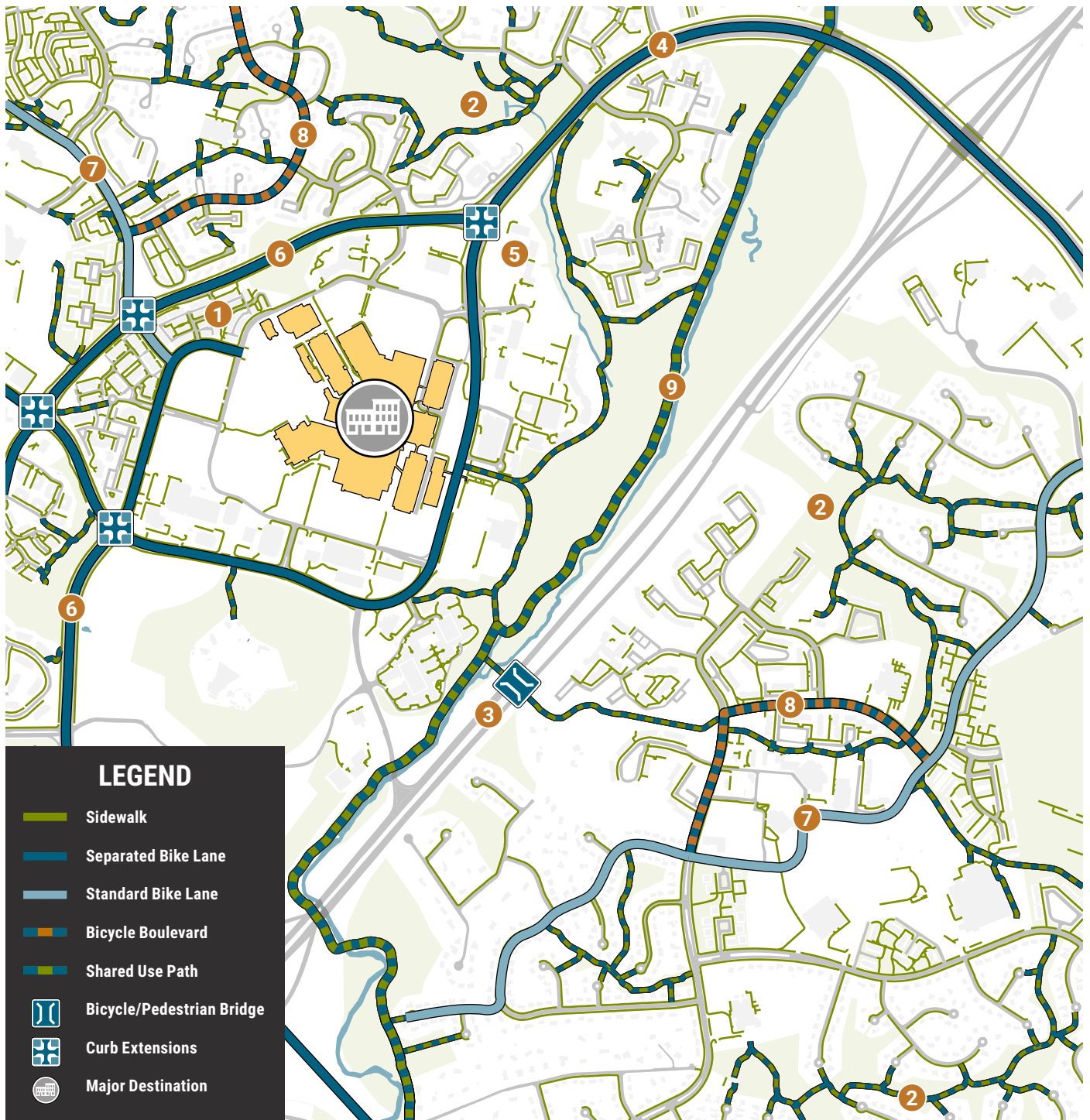
A well-connected bicycle network can encourage people to bike to key area destinations. In addition to appropriate facilities along segments, high-quality networks include safe and comfortable intersection crossings and connections between facilities.

CONSIDERATIONS

- Provide separated bike lanes on higher-volume, higher-speed roadways. **6** For more information, refer to the design topics on **Separated Bike Lanes** and **Separated Bike Lanes at Intersections**, as well as the **FHWA Separated Bike Lane Guide 2015**.
- Provide standard bike lanes to define space for bicyclists. **7** For more information, refer to the **AASHTO Bike Guide 2012**.
- Provide bicycle boulevards on low-volume, low-speed roadways. **8** For more information, refer to the design topic on **Slow Streets**.
- Provide paved shoulders on rural roadways. For more information, refer to the design topic on **Paved Shoulders**.
- Consider enhanced treatments, such as bicycle signals or Rectangular Rapid Flash Beacons, at uncontrolled crossings of higher-volume, higher-speed roadways. For more information, refer to the design topic on **Enhanced Crossing Treatments**.

SHARED USE PATH CONNECTIONS

Regional paths can serve as major components of the transportation network. Paths connecting to important destinations can increase the number of people walking or biking there. Providing a shared use path connection **9** with wayfinding can connect the path users to the destination comfortably. For more information, refer to the design topics on **Shared Use Paths** and **Midblock Path Intersections**.



WAYFINDING AND SIGNS

Wayfinding signs can be used to direct pedestrians and bicyclists to key destinations via low-stress routes. Curvilinear street networks, such as those shown above, can be disorienting to pedestrians and bicyclists. Wayfinding signs can help overcome this challenge. Off-street paths are sometimes difficult to locate, so adding signs can be especially helpful to provide connectivity within and between neighborhoods. Signs should comply with the **MUTCD**.

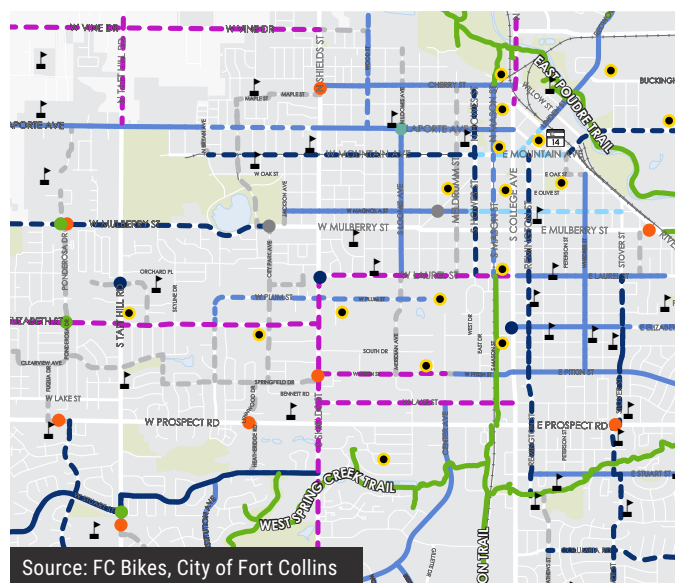
ROUTE-SELECTION APPLICATIONS

Route-selection applications, which allow users to identify routes by entering their origin and destination, are now available on most mobile devices. Developers are currently building options within applications that allow users to optimize their bicycle route for different characteristics. For example, some riders may feel comfortable sharing a higher-volume roadway with automobiles. Other riders may want to avoid those streets and optimize their route accordingly. Applications developed by public agencies must meet accessibility requirements.

CASE STUDIES

BICYCLE MASTER PLAN FORT COLLINS, CO

Creating connections between existing comfortable streets and trails guided the development of the Fort Collins bicycle network. These “low-stress” facilities consist of low-volume and low-speed local streets, local streets with bike lanes, and wide, paved shared use paths. Planning focused on locations where these streets cross major arterials without signalization or where streets are offset across an arterial. Design recommendations for these locations vary but emphasize creating shorter crossing distances and making drivers aware of bicyclists’ presence. Where existing low-stress segments were not present, more robust treatments such as separated bike lanes were recommended on higher-speed arterials.



Source: FC Bikes, City of Fort Collins

STREET CONNECTIVITY POLICY CHARLOTTE, NC

The City of Charlotte undertook a connectivity planning effort starting in 2006 to overcome the mobility and access challenges created by its disconnected street network. An initial project identified 20 high-priority areas within the city where barriers precluded convenient pedestrian and bicyclist access. In 2007, the City launched a capital program with the purpose of connecting local streets.

The City’s connectivity efforts are supported by Charlotte’s subdivision ordinance. These regulations prohibit the use of cul-de-sacs in street network design except where geographic or topographic barriers necessitate their use. In such cases, a pedestrian and bicycle connection may still be required where the street network is fragmented. Cul-de-sacs are also prohibited in transit station areas where pedestrian connections are prioritized.



Source: Charlotte Department of Transportation

FOR MORE INFORMATION

American Association of State Highway and Transportation Officials. *Guide for the Development of Bicycle Facilities*. 2012.

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SCHOOL ACCESS

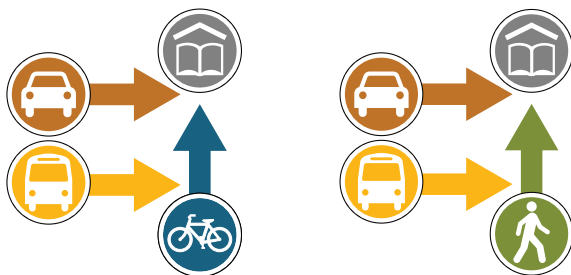
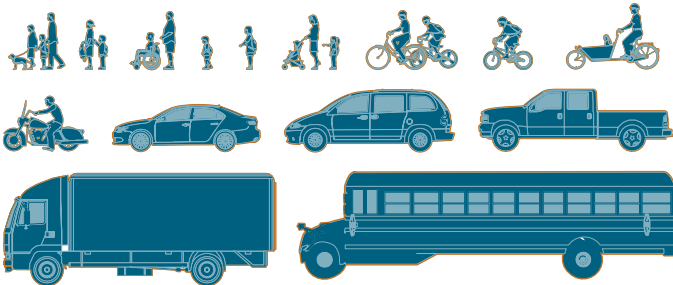


Families and staff traveling to and from school generate significant weekday traffic—whether by foot, bike, school bus, public transit, and private vehicle—for concentrated periods (typically within a 20-minute timeframe). As community gathering spaces, schools may also generate evening and weekend travel.

As multiple travel modes intersect around the school zone, conflicts often occur on the school site and at intersection or driveway crossings nearby. Children walking or biking to school are particularly vulnerable. Designers should give consideration to vehicle speeds, intersection geometry, crossing treatments, and pedestrian and bicycle facilities along key routes to school. Education and enforcement should encourage proper driver, pedestrian, and bicyclist behavior.

Compared to new schools, which are typically located farther from neighborhoods on larger sites, constraints at older schools may limit the ability to provide separate space for all modes. However, careful planning and design of transportation networks around both older and newer schools can encourage pedestrian and bicycle travel, reduce multimodal conflicts, and make travel more efficient. Encouraging walking and bicycling to school can improve academic performance (**Active Living Research 2015**), community health, and reduce vehicle traffic. In practice, schools with infrastructure improvements prioritizing bicyclists and pedestrians had an 18-percent increase in travel by those modes (**McDonald et al. 2014**).

COMMON USERS IN CONFLICT AND TYPICAL CRASH TYPES



Poor roadway and intersection design around schools can contribute to crashes involving children walking or biking to school.

GUIDING PRINCIPLES TO REDUCE CONFLICTS

SAFETY

Facilities around schools should minimize conflicting movements for different modes and slow speeds to mitigate the impacts of conflicts where they may occur.

ACCOMMODATION AND COMFORT

The unique needs of children, as well as their parents, who are traveling by different modes to school should be considered.

COHERENCE

Facilities should clearly delineate a path of travel that is recognizable and highly visible to children.

PREDICTABILITY

Children's walking and bicycling travel patterns may be less predictable than those of adults, so school areas must be designed to encourage predictable behavior.

CONTEXT-SENSITIVITY

Children's smaller size should be considered to ensure clear sight lines in any land use, environment, or traffic context.

EXPERIMENTATION

Design schools to prioritize access by walking and biking and use creative methods to encourage children, as well as staff, to walk or bike.

DESIGN STRATEGIES

Many school sites are designed primarily for ease of access by motor vehicles. As a result, conflicts often occur on school sites between people who walk or bicycle to school and those who drive. This is a particular problem considering that many school systems do not offer bus service to students who live in close proximity to the school, creating a great need to address walking and bicycling issues along routes that lead to schools, as well as in school zones (streets that directly abut school sites).

ON-SITE IMPROVEMENTS

To reduce conflicts among modes, separate space should be provided on the school site for pedestrians and bicyclists ①, bus riders ②, staff parking ③, and those picked up or dropped off by private vehicles ④ to safely access school entrances.

CONSIDERATIONS

- Pedestrian and bicycle routes should be continuous and lead directly to school entrances.
- Conflict points between modes should be minimized by moving bus stops or relocating pickup and dropoff loops to maintain separation.
- Sidewalks on-site should be a minimum of 8 feet wide to accommodate high pedestrian volumes (FHWA 2006).
- Shared use paths on-site should be a minimum of 11 feet wide to reduce conflicts between pedestrians and bicyclists. For more information, refer to the design topic on **Shared Use Paths**.
- Driveways should prioritize pedestrians and bicyclists by maintaining the grade of an intersecting sidewalk or shared use path and altering the grade of the motorist's path of travel.
- Driveway flare radii should be minimized to ensure slow vehicle turning speeds and to reduce the exposure time for pedestrians.
- School bus loading zones should be designated clearly with signs and pavement markings. Children should be dropped off curbside, directly onto the sidewalk.
- Private vehicle pickup and dropoff zones should be designated clearly with signs and pavement markings. The pickup and dropoff area should not require children to walk between vehicles or have vehicles straddle a pedestrian crossing.
- Bicycle parking racks ⑤ should be provided as close as possible to school entrances, without creating conflicts with pedestrians.

SCHOOL ZONES

School zones may be designated and identified with signs and pavement markings as outlined in the **MUTCD**. School zones may specify a reduced speed limit during school hours or when children are present. Periodic school zone enforcement is a common and effective method for reducing speeds in school zones. (**MUTCD 2009, Sec. 7B.08–7B.10**)

STREET CROSSINGS

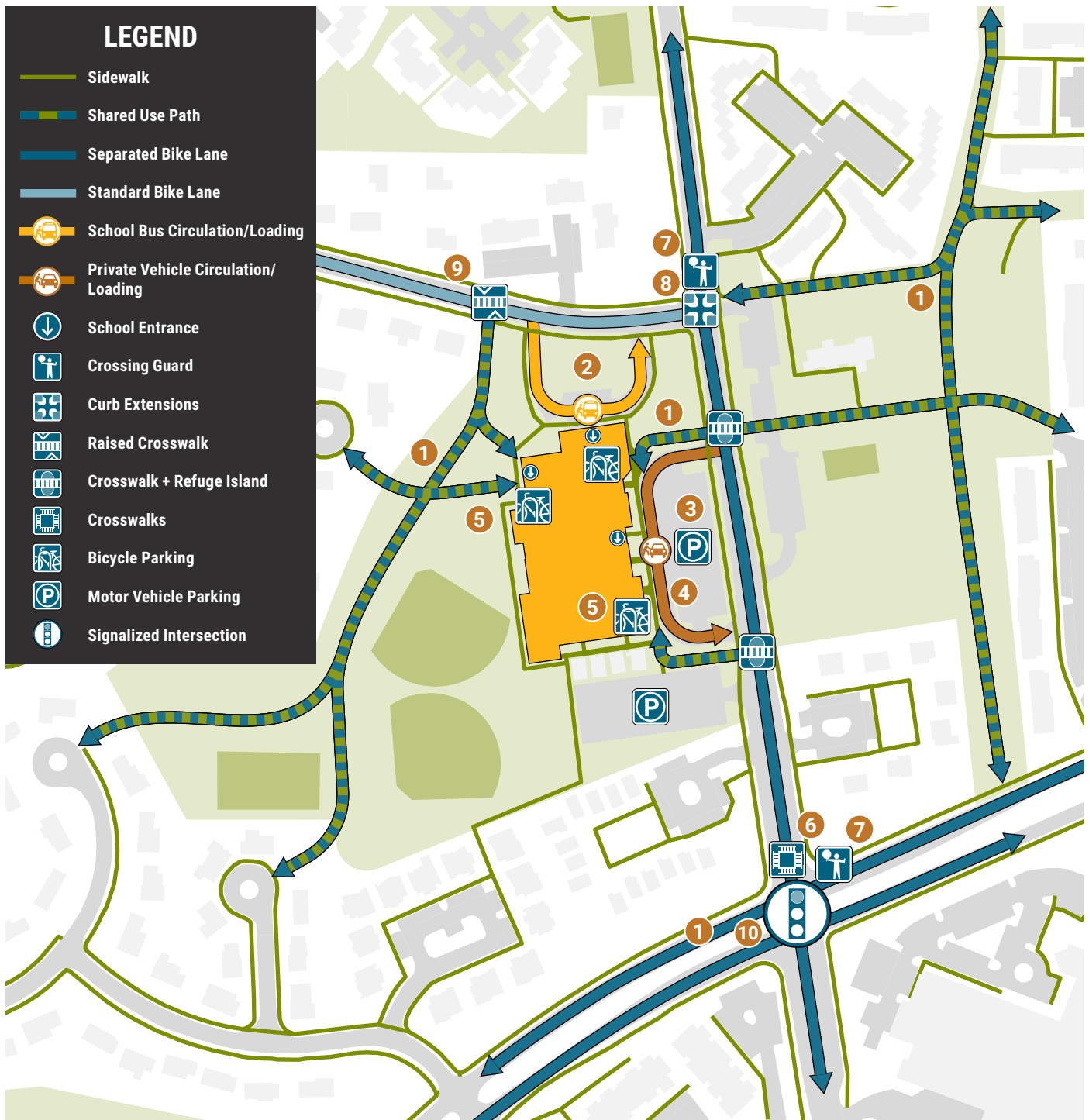
Street crossings, whether controlled or uncontrolled, are the areas of common conflict between modes in school zones.

CONSIDERATIONS

- Crossings should promote predictable movements and be accessible for all pedestrians. For more information, refer to the design topic on **Accessibility**.
- Crosswalks ⑥ should be marked with high-visibility ladder-style crosswalks (**MUTCD 2009, Sec. 3B.18**). Consider crossing guards ⑦ to maximize safety at locations with challenging pedestrian and bicycle conditions.
- Crossing distances should be shortened by narrowing travel lanes, adding a pedestrian crossing island, or adding curb extensions ⑧ to allow for slower moving children and adults to cross safely.
- Uncontrolled crossings should be identified clearly with well-painted pavement markings, warning signs, or other enhanced treatments such as Rectangular Rapid Flash Beacons or raised crosswalks ⑨ that alert drivers to the crossing location. For more information, refer to the design topic on **Enhanced Crossing Treatments** and **Midblock Path Intersections**.
- At signalized crossings, signal timings ⑩ need to accommodate children who tend to walk slower and in large groups. Pedestrian phases should be protected from turning vehicles and set to pedestrian recall, such that the pedestrian phase comes up every cycle. For more information, refer to the design topics on **Turning Vehicles** and **Signalized Intersections**.

EDUCATION AND OUTREACH

Infrastructure improvements should be supplemented with education to encourage proper behavior by drivers, pedestrians, and bicyclists. Everyone who accesses the school site—students, parents, staff, bus drivers—should receive clear direction on how to access the school campus at arrival and dismissal. When new walking and biking infrastructure is constructed near the school, outreach should be conducted to the school community through pamphlets and social media to familiarize all users with its intent and proper use.



CROSSING GUARDS

Adult school crossing guards play an important role for children and families who walk or bicycle to school. Young children may lack the motor and cognitive skills required to safely navigate street crossings. By helping students cross the street safely at key locations, crossing guards can help parents feel comfortable about their children walking or bicycling to school. Crossing guards provide a visual cue to drivers that children are present and, by example, help children to develop the skills necessary to cross streets safely.

INTER-JURISDICTIONAL COORDINATION

While streets and sidewalks adjacent to school sites are typically designed and controlled by city or State transportation agencies, school sites themselves may be controlled by a separate jurisdiction or school district. Cooperation between school districts and other governmental agencies, including both infrastructure and programmatic strategies, is key to decreasing harmful conflicts in school areas.

CASE STUDIES

DISCOVERY ELEMENTARY SCHOOL ARLINGTON, VA

In September 2015, Arlington Public Schools in Arlington, VA, opened the doors to Discovery Elementary School, a new school built on the same site as an existing middle school, Williamsburg Middle. Throughout the planning and design of the new school, Arlington Public Schools worked diligently to provide safe and efficient access for students and staff to walk or bike to school and to mitigate the traffic and parking impacts of the two schools on the surrounding neighborhood.

Key features of the combined campus include multiple sidewalk connections to the school site, an organized on-campus sidewalk network that provides efficient building access without driveway and parking lot crossings; a separate bicycle route for student bicyclists; a shared bus loop centered between the two schools, separate from the parent dropoff and pickup areas; and private vehicle student dropoff and pickup areas that contain pavement markings and directional signs to encourage proper procedures and behaviors.

In addition, Arlington Public Schools created a transportation demand management plan for the two schools, detailing programs to encourage active modes of travel to school by staff and students. The school provided parents with maps of example walking and bicycling routes to school, detailed written procedures for private vehicle dropoff and pickup, and a circulation map showing how all modes access the school site.



Example walking and biking routes to
Discovery Elementary School

FOR MORE INFORMATION

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MULTIMODAL ACCESS TO EXISTING TRANSIT STATIONS

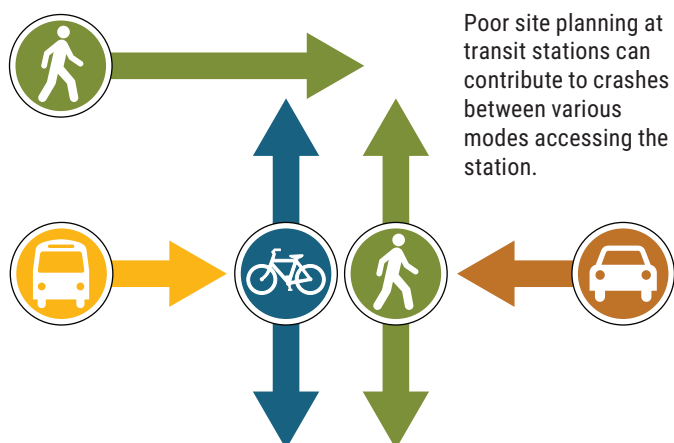
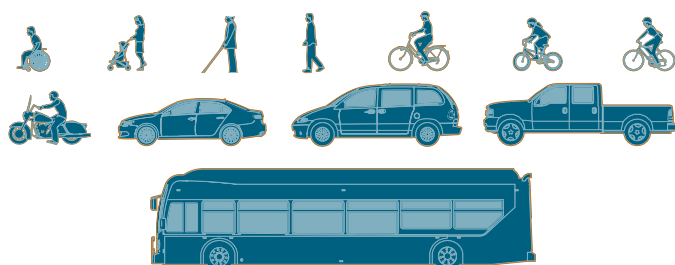


Modal conflicts at transit stations vary depending on the size of the station and nature of transit services provided. Pedestrians and bicyclists may conflict with buses at access points to on-site bus bays or along on-street bus stops. Where passenger car parking garages or lots are provided, car/bike and car/pedestrian conflicts are typical. On station sites and at approaches, conflicts between pedestrians and bicyclists can occur because these users frequently share the same facilities, including sidewalks, pathways, and crosswalks.

To address conflicts through station retrofits, planners and designers should first identify bicycle and pedestrian trip generators and catchment zones in the station's service area. Desire lines and travel routes from each catchment zone can be evaluated for safety, comfort, and convenience. Potential conflict areas can be identified at the station and in surrounding areas.

It is important to minimize and mitigate conflicts in order to increase safety and comfort for bicyclists and pedestrians, and thereby to increase the use of these modes as a means to access transit. For safety improvements to achieve these goals, the following principles should be applied: pedestrians and bicyclists seek the most direct route possible; bicycle parking options should be secure and convenient; and infrastructure improvements should address on-site, off-site, and approaching roadways through agency and interjurisdictional coordination.

COMMON USERS IN CONFLICT AND TYPICAL CRASH TYPES



GUIDING PRINCIPLES TO REDUCE CONFLICTS

SAFETY

At and around transit stations, conflicts between vulnerable road users, private vehicles, and transit buses should be reduced through the separation of modes.

ACCOMMODATION AND COMFORT

Access to and from the station should serve all users and provide a sense of comfort.

COHERENCE

Access to and from the station should be provided along a clear path of travel for each mode.

PREDICTABILITY

Access routes to the station should have clear right-of-way assignments that create predictable behaviors for all users.

CONTEXT SENSITIVITY

The station and its surroundings should support community health, economic, and livability goals.

EXPERIMENTATION

Transit agencies should consider innovative and creative solutions to address conflicts through coordination.

DESIGN STRATEGIES

In general, conflicts at and around transit stations can be mitigated through well-designed retrofits that prioritize direct and convenient pedestrian and bicycle circulation. Installation of barriers and creation of circuitous pedestrian and bicycle routes to the station entrance should be avoided.

Due to typically high volumes of pedestrians and bicyclists at and around transit stations, consideration should be given to separating modes as they approach the station and at the station itself. Where separation is not feasible, sidewalks should be wide enough to accommodate both bicyclists and pedestrians safely. Sidewalk width should accommodate peak period boarding and alighting volumes on a site-specific basis. Preferred dimensions range from 10- to 30-feet wide. For more information, refer to the [Highway Capacity Manual](#).

CONSIDERATIONS

- Provide street crossing improvements on all legs of intersections near the station. **1**
- Provide context-appropriate midblock crossings, if necessary, to accommodate direct pedestrian and bicycle movements to and from the station entrance. These are particularly important where local or regional bus connections stop on-street and not within the station site itself. **2** For more information, refer to the design topics on [Enhanced Crossing Treatments](#) and [Bus Stops](#).
- Reduce pedestrian crossing distances by installing pedestrian crossing islands or curb extensions. **3**
- Tighten curb radii to reduce vehicle turning speeds or provide slip lanes and crossing islands to accommodate bus turning movements. **4**
- Provide bicycle and pedestrian accommodations and wayfinding across station surface parking lots. Ensure walkways from accessible parking and loading to accessible station entrances are as direct as possible.
- Provide designated crossings at bus loading, pick-up and drop-off areas, and motor vehicle access roads.
- Align grade-separated crossing structures with pedestrian and bicycle desire lines where management of at-grade conflicts is infeasible. **5**
- Enhance pedestrian crossings such as raised crosswalks, mitigation of poor sight distances, and other measures that will slow vehicle speeds. **2**
- Install new sidewalks along well-worn tracks on grass (goat paths) that enter or cross portions of the station site. **6**
- Provide direct bicycle connections to the station via separated bike lanes or shared use paths along desire lines that are not served by streets.
- Ensure that nearby paths and trails are linked to the station and that wayfinding signs are provided. **7**

- Provide bike channels—flat ramps parallel to the stairs on which bicycles can be rolled—on stairways to minimize conflicts with users of pedestrian ramps. Handrail designs must meet current accessibility standards. For more information, refer to the design topic on [Bridge Design](#).
- Separate bicyclists from bus-only access roads and driveways on the station site, where possible, by providing adjacent parallel bicycle routes.
- Minimize dismount zones—locations where bicycle riding is prohibited or discouraged. Their use should be limited to station lobbies, concourses, and areas with consistently high pedestrian volumes.

BICYCLE PARKING

Bicycling serves as a first- and last-mile connection to transit stations. As a result, transit stations should provide ample bicycle parking to accommodate both short- and long-term needs.

CONSIDERATIONS

- Provide a variety of parking options, such as high-quality access-controlled parking areas, on-demand lockers, and enclosed bike racks.
- Locate bicycle parking along or easily visible from the bicycle access routes leading to the station entrance.
- Distribute bicycle parking equipment on the station site to conveniently serve all bicycle access routes. **8**
- Locate rack parking as close as possible to the station entrance, without creating conflicts with pedestrians in heavy pedestrian flow areas. **9**
- Lockers and high-quality access-controlled bicycle parking may be located further from the entrance, but should be adjacent to primary bicyclist access routes. **10**

For more information, refer to the design topics on [Transit Conflicts](#), [Traffic Calming and Design Speed](#), [Network Connectivity](#), [Intersection Geometry](#), and [Separated Bike Lanes](#).

MAINTENANCE

Good surface quality is essential for sidewalks and paths. Maintenance should be conducted routinely to eliminate uneven pavement surfaces and trim vegetation. During winter months, sidewalks and paths should be cleared of snow and ice to maintain access for pedestrians and bicyclists.



INTER-JURISDICTIONAL COORDINATION

Transit stations are typically owned and maintained by transit agencies while the adjacent streets may be owned and maintained by local and State highway agencies. To provide a continuous pedestrian and bicycle network to the station entrances and exits, jurisdictional coordination is necessary. Agencies should conduct joint walking and biking assessments for the stations and surrounding networks to determine potential safety improvements and identify the responsible agencies for all the improvements.

ACCESSIBILITY

All transit stations need to meet all Federal accessibility standards as adopted by U.S. Department of Justice and U.S. Department of Transportation. For more information, refer to the design topic on **Accessibility**. When retrofitting an existing transit station to comply with accessibility requirements, consider broader bicycle and pedestrian access and safety needs. Ensure that pedestrian ramps support other users on wheels such as pedestrians with strollers, push scooters, and bicyclists.

CASE STUDIES

WASHINGTON METROPOLITAN AREA TRANSIT AUTHORITY ACCESS PLAN WASHINGTON, DC METRO AREA

The Washington Metropolitan Area Transit Authority (WMATA) conducted a system-wide assessment of pedestrian and bicycle access for all 86 Metrorail stations. WMATA evaluated each station site's access, including the provision of bicycle parking, as well connectivity within 0.5 to 1 miles from station entrances. These efforts resulted in more than 3,000 individual projects across 30 types of deficiencies and recommendations. Example recommendations included barrier removal, nonmotorized access through parking lots, dirt-to-concrete path conversion, pedestrian amenities, accessible ramps, lighting, covered bicycle parking, and more.

WMATA prioritized projects into its Pedestrian and Bicycle Element of the 2012–2017 Capital Improvement Program. Projects with immediate public safety implications were addressed first using WMATA staff and on-call contractors.



MASSACHUSETTS BAY TRANSPORTATION AUTHORITY BICYCLE PARKING BOSTON, MA METRO AREA

The Massachusetts Bay Transportation Authority (MBTA) received funding through the American Recovery and Reinvestment Act to plan and design high-quality bicycle parking facilities at priority transit stations. A detailed station inventory analysis was performed to evaluate existing bicycle parking needs for each bus, rapid transit, and commuter rail station within the system. Site-specific design treatments were developed to maintain access and circulation to and from the bicycle parking facility, siting the bicycle parking facility in a safe and visible location, and maximizing the number of bicycle parking spaces at each transit station. Bicycle parking recommendations included Pedal & Park facilities, which are high-quality access-controlled secure bicycle racks, and Bike Port facilities which are covered bicycle racks.



FOR MORE INFORMATION

Association of Pedestrian and Bicycle Professionals. *Bicycle Parking Guidelines*. 2010.

Federal Highway Administration. *Delivering Safe, Comfortable, and Connected Pedestrian and Bicycle Networks: A Review of International Practices*. 2015.

Federal Highway Administration. *Pedestrian Safety Guide for Transit Agencies*. 2008.

Transportation Research Board. *Highway Capacity Manual*. 2010.

Transportation Research Board. *Report 153: Guidelines for Providing Access to Public Transportation Stations*. 2012.

Transportation Research Board. "TCRP Web-Only Document 44: Literature Review for Providing Access to Public Transportation Stations." Submitted March 2009. http://onlinepubs.trb.org/onlinepubs/tcrp/tcrp_webdoc_44.pdf.

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MULTIMODAL ACCESS TO NEW TRANSIT STATIONS

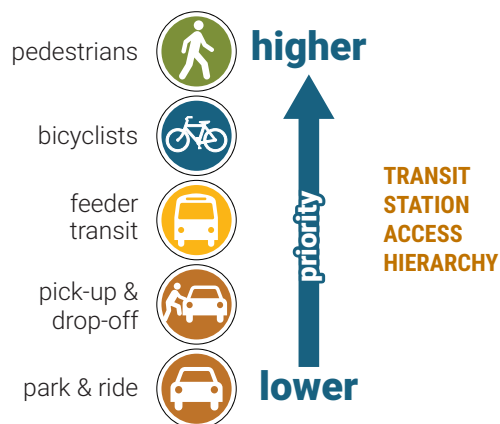
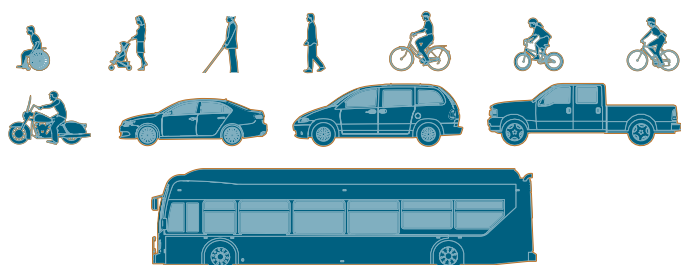


An effective public transit network enables people to access rail and bus stations by bicycling, walking, and feeder transit services. Accommodating a wide variety of access modes at transit stations, including pick-up and drop-off areas and motor vehicle parking at suburban stations, increases ridership and fare revenue. However, it also increases the potential for conflicts between modes.

For newly constructed transit stations, it is important to have station access in place for all travel modes at the opening of the station; retrofitting once opened can be difficult. It is recommended to establish a modal hierarchy and design transit stations for vulnerable road users first. This hierarchy should be applied to minimize conflicts between vulnerable road users and other station users such as buses and other transit vehicles, private vehicles accessing pick-up and drop-off areas, and private vehicles parking at the station. The new station configuration should communicate this hierarchy.

Refer to the design topic on **Multimodal Access to Existing Transit Stations** for strategies to retrofit existing transit stations and reduce conflicts. This design topic focuses on pedestrian and bicycle access to new rail transit stations. Additional considerations may be necessary for bus rapid transit stations.

COMMON USERS IN CONFLICT AND ACCESS HIERARCHY



GUIDING PRINCIPLES TO REDUCE CONFLICTS

SAFETY

Through site design at transit stations, the likelihood of crashes between transit vehicles, private vehicles, pedestrians, and bicyclists should be reduced.

ACCOMMODATION AND COMFORT

Station access should be comfortable and accommodate all travel modes.

COHERENCE

The station should have a clear path of travel to station entrances and exits.

PREDICTABILITY

Circulation facilities on the station site should have clear right-of-way assignments that create predictable behaviors for all users.

CONTEXT SENSITIVITY

The station should be consistent with and support adjacent land uses.

EXPERIMENTATION

Transit agencies should consider station access for all modes during the planning stages of new station.

DESIGN STRATEGIES

Transit stations should be designed using a clear modal hierarchy, making it most convenient to walk or bike to the station. To understand desire lines for a new transit station, planners and designers can conduct a walk and bike shed analysis and/or pedestrian and bicycle assessment. For more information, refer to the design topic on **Network Connectivity** and the **U.S. Department of Transportation Pedestrian and Bicyclist Road Safety Assessments Summary Report**. Based on the shed analysis, the station layout can be developed to prioritize pedestrian and bicycle access routes, ensure accessibility requirements, and reduce conflicts with other modes.

Transit stations are typically owned and maintained by transit agencies while the adjacent streets may be owned and maintained by local or State highway agencies. During the planning of transit stations, inter-jurisdictional coordination is necessary to ensure that access for all modes is functional and safe when the station opens. Jurisdictions should consider pedestrian and bicycle access to station entrances and exits from nearby destinations and future developments.

REDUCE CONFLICTS WITH PRIVATE VEHICLES

In the planning and design process, conflicts among private vehicles, pedestrians, and bicyclists should be avoided where possible and mitigated where it is unavoidable.

CONSIDERATIONS

- Configure private vehicle parking lots and garages so that they do not block direct pedestrian and bicycle desire lines to the station entrance. **1**
- Design surface parking lots to include walkways and bikeways across the lot for safe passage. Where needed, design parking garages for safe pedestrian and bicycle through movements. **2**
- Provide bicycle and pedestrian crossings of access roads and driveways leading to private vehicle parking lots and garages. **3**
- Configure passenger pick-up and drop-off areas near station entrances without impeding direct access for pedestrians and bicyclists. **4**

REDUCE CONFLICTS WITH BUSES

Site planning for new transit stations should minimize conflicts between buses, pedestrians, and bicyclists. Buses are wider, have larger turning radii, and larger blind spots than private vehicles.

CONSIDERATIONS

- If the station includes a bus terminal, provide pedestrian access between bus bays. **5**
- If avoiding a conflict is not feasible, provide traffic calming measures that encourage drivers to maintain safe speeds on station sites. **6**

ADDRESS POTENTIAL BARRIERS

Pedestrians and bicyclists usually choose the most direct path to a station, even if it means crossing roadways away from designated crosswalks or cutting through private property. When developing a transit station site plan, consider how to incorporate these desire lines and encourage compliance.

CONSIDERATIONS

- Use pedestrian and bicycle bridges and tunnels, and well-designed at-grade crossings to ensure that immovable barriers such as major highways, interchange ramps, arterial roads, railroad lines, streams, and secure institutions do not become barriers to direct access. **7**
- Avoid the creation of unsafe pedestrian conditions and the degradation of permeable landscapes by locating and designing stormwater facilities, tree plantings, and landscaped areas to enhance, not block, direct pedestrian and bicycle access to the station.
- Ensure that transit-oriented development on, and immediately adjacent to, the station site is configured for convenient public pedestrian and bicycle access. **8**

ACCESS FOR BICYCLISTS

CONSIDERATIONS

- Provide separated bike lanes or shared use paths to station entrances. **9**
- Ensure that nearby paths and trails are linked to the station and that wayfinding signs are provided. **10**
- Provide appropriate bicycle facilities on station access roads that serve mixed traffic. Separate bicycle and bus access routes to maintain safety and comfort. **11**
- Install covered U-style bicycle racks near station entrances. **12**
- Consider installing high-quality access-controlled bicycle parking facilities within the station. **13**
- In locations where additional development in the station service area is expected, plan sufficient space on-site where bicycle parking can be expanded to accommodate growing demand.
- Consider space for location of bicycle sharing systems. **14**
- On station sites that have multiple level station designs, provide bike channels on stairways to enable bicyclists to use direct routes. Handrail designs must meet current accessibility standards. For more information, refer to the design topic on **Bridge Design**. To minimize conflicts with pedestrians and persons with disabilities, plan elevator car sizes to accommodate standard bicycles.



WAYFINDING

Wayfinding signs for pedestrians and bicyclists increase psychological comfort, guide them to the safest routes, and enable them to focus on safe travel behavior rather than route navigation. In general, signs should be provided on bicycle routes to stations along non-arterial routes of 0.5 miles or longer. Provide pedestrian wayfinding at spot locations within 0.25 miles of the station. Signs should be compliant with the **MUTCD** and **PROWAG**.

SAFETY AND SECURITY

New transit stations should apply Crime Prevention Through Environmental Design concepts to increase pedestrian safety and comfort such as lighting, appropriate landscape design, and use of fencing. Pedestrian and bicycle access routes should be well-lit through parking garages to accommodate direct pedestrian and bicycle movements to the station entrance. Additionally, adjacent land uses should have direct and convenient bicycle and pedestrian access to the station site and station entrance.

CASE STUDIES

WIEHLE-RESTON EAST METRORAIL STATION RESTON, VA

The Washington Metropolitan Area Transit Authority completed a system expansion opening five new stations on the Silver Line in July 2014. The current end-of-line station, Wiehle-Reston East, sits in the middle of the Dulles Access Road. Station access is from either side of the roadway using elevated walkways. The Washington & Old Dominion Trail runs just north of the station, offering both pedestrians and bicyclists easy access to the station. The new station has bicycle racks, lockers, and a state-of-the-art high security, indoor bicycle parking station. The station also contains a bus-only entrance for local and regional buses with separate vehicular access to the pick-up and drop-off area and daily parking garage.

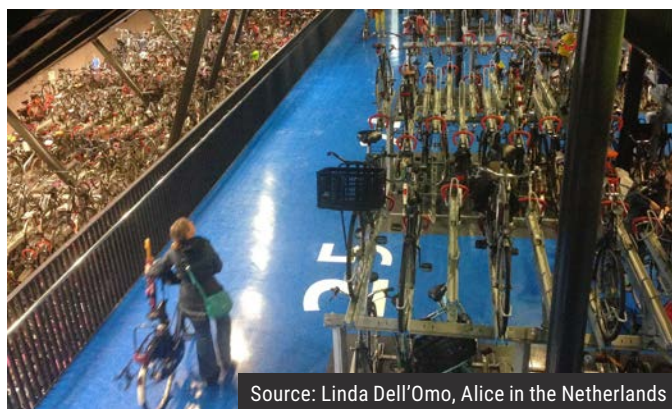
The Federal Transit Administration convened an on-the-ground pedestrian and bicycle network safety assessment in May 2015. The assessment included Federal, State, regional, and local agency officials, along with local stakeholders and advocates. Working in teams, traveling by foot, by wheelchair, and by bike, the assessment identified improvements to the pedestrian network, bicycle network, and intersections.

Through jurisdictional coordination, the wide major arterials that sit between the station and surrounding areas continue to be improved to provide safe, accessible, and comfortable pathways to the station for pedestrians and bicyclists.



CENTRAL STATION UTRECHT, THE NETHERLANDS

Central Station in Utrecht, the Netherlands has constructed an indoor bicycle parking facility with 4,200 bicycle parking spaces. This facility was constructed as part of a rehabilitation of the transit station where a three-story bicycle parking facility is located. With over 900 trains leaving the station daily, approximately 40 percent of train passengers travel to the station by bicycle, creating a demand for high-quality bicycle parking facilities. Bicycle access to the parking facility is conducted with separated bike lanes that lead to the station without conflicting with pedestrian station access.



Source: Linda Dell'Omo, Alice in the Netherlands

FOR MORE INFORMATION

Association of Pedestrian and Bicycle Professionals. *Bicycle Parking Guidelines*. 2010.

Federal Highway Administration. *Delivering Safe, Comfortable, and Connected Pedestrian and Bicycle Networks: A Review of International Practices*. 2015.

Federal Highway Administration. *Manual on Uniform Traffic Control Devices*. 2009.

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Transportation Research Board. *Report 153: Guidelines for Providing Access to Public Transportation Stations*. 2012.

United States Access Board. *Proposed Guidelines for Pedestrian Facilities in the Public Right-of-Way*. 2011.

United States Department of Transportation. *Pedestrian and Bicyclist Road Safety Assessment Summary Report*. 2015.

TRANSIT CONFLICTS



Source: Nathan Wilkes, City of Austin, Texas

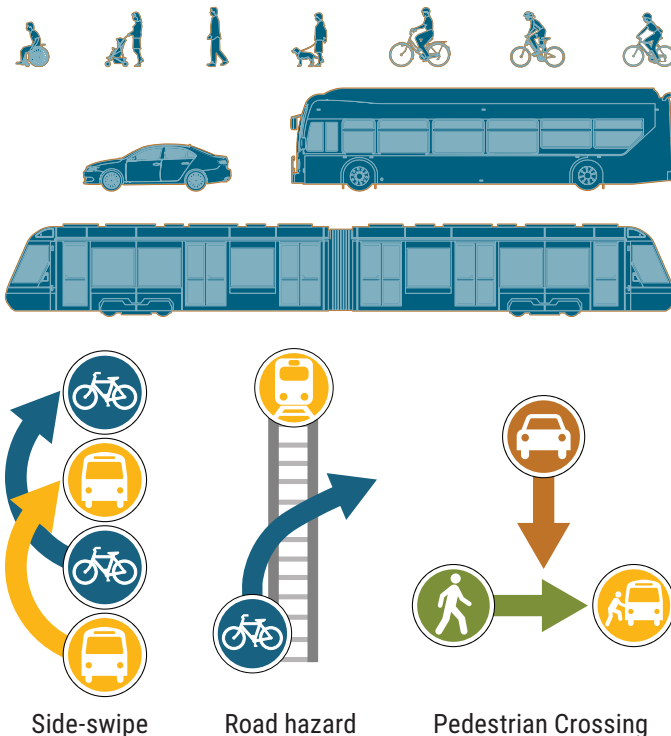
Transportation networks in all land use settings enable people to walk, bike, and/or take transit to and from their destinations. A single trip may consist of using multiple transportation modes, for example walking to a bus stop, riding the bus downtown, and bicycling the last half mile to the office on bike share. Each transportation mode should operate safely and efficiently without negatively impacting others.

Transit conflicts can be a broad topic. This design topic focuses on conflicts between transit vehicles, such as buses and streetcars, and vulnerable road users, such as pedestrians, bicyclists, and pedestrians accessing bus stops. These principles and strategies can be applied to other modes such as bus rapid transit, subways, or heavy railroad stations.

Conflicts between transit vehicles and vulnerable road users can consist of a bus accessing a stop by crossing a standard bike lane, a bicyclist traveling across or along rail tracks, or a pedestrian or bicyclists passing a bus stop with waiting passengers. Conflicts also occur between pedestrians and motor vehicles when accessing or departing from a bus stop.

Transit conflicts may be addressed through designs that clearly delineate the path for each mode and maximize predictability between users.

COMMON USERS IN CONFLICT AND TYPICAL CRASH TYPES



GUIDING PRINCIPLES TO REDUCE CONFLICTS

SAFETY

Roadways should allow safe operation of transit vehicles and vulnerable road users by minimizing potential crashes.

ACCOMMODATION AND COMFORT

The design should provide a sense of comfort to vulnerable road users and transit passengers while accommodating transit operations.

COHERENCE

The path of travel for each mode should be clearly delineated through design, pavement markings, and signs.

PREDICTABILITY

The design should create predictable behaviors that allow transit vehicles, motorists, bicyclists, and pedestrians to have clear right-of-way assignments.

CONTEXT SENSITIVITY

Designs should respond to typical users and conflict types in a manner that complements community character and supports community health, economic, and livability goals.

EXPERIMENTATION

Designers should consider innovative solutions to reducing bicycle hazards at streetcar tracks

DESIGN STRATEGIES

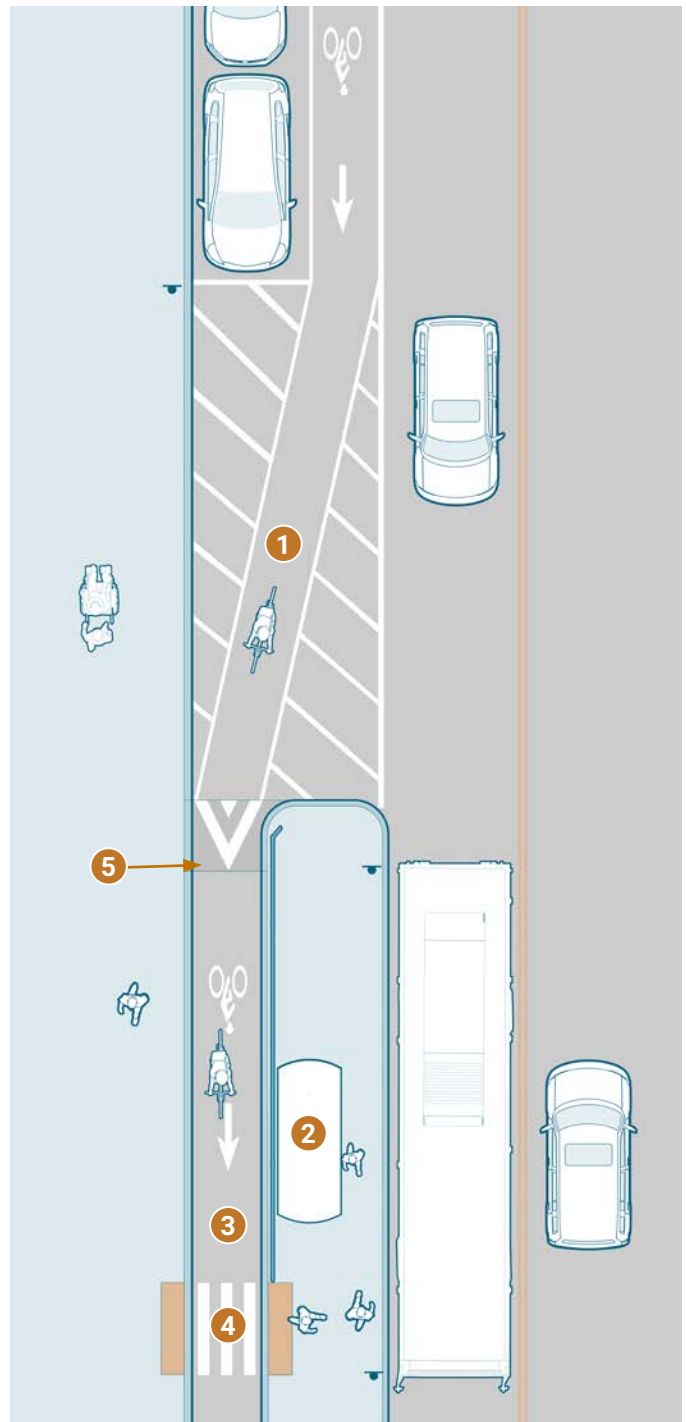
BUS AND BIKE CONFLICTS

A common conflict between buses and bicyclists is referred to as bus-bike leapfrogging. Bus-bike leapfrogging occurs when a bus and bike are traveling on a roadway in the same direction and pass each other at multiple places. The bicyclist is traveling at a constant speed with the bus passing, pulling into a stop, departing the stop, passing the bicyclist, and traveling to the next stop. This crossing of users can create multiple instances where conflicts can occur.

Bus-bike leap-frogging is uncomfortable for bicyclists as well as for bus drivers and passengers as it can impact bus schedules. On one-way streets it may be feasible to avoid transit conflicts entirely by locating bicycle facilities on the other side of the street. Otherwise, implementation of a floating bus stop can eliminate leap-frogging, improving bicyclist's comfort and bus operation.

CONSIDERATIONS

- Provide clear indication of the purpose and operations of the floating bus stop for pedestrians and bicyclists.
- Provide adequate tapers for bicyclists to transition from bicycle lane to behind the bus stop. **1**
- Provide bus stop passengers amenities such as shelters, benches, and trash barrels outside of bicycle travel. **2**
- Maintain accessible pedestrian access to stop amenities, sidewalk, and boarding areas.
- Provide continuous separated bicycle facility behind the boarding area. For more information, refer to the design topic on **Separated Bike Lanes** **3** (FHWA Separated Bike Lane Guide 2015, pp. 92–96).
- Provide clearly marked crosswalks from the island to the adjacent sidewalk **4** (FHWA Separated Bike Lane Guide 2015, pp. 92–96).
- Consider a raised crosswalk across the bicycle facility **5** (FHWA Separated Bike Lane Guide 2015, pp. 92–96).
- Consider yield or stop lines and YIELD [or STOP] HERE FOR PEDESTRIANS (R1-5) signs to alert bicyclists of the passenger crosswalks (MUTCD 2009, Sec. 2B.11).

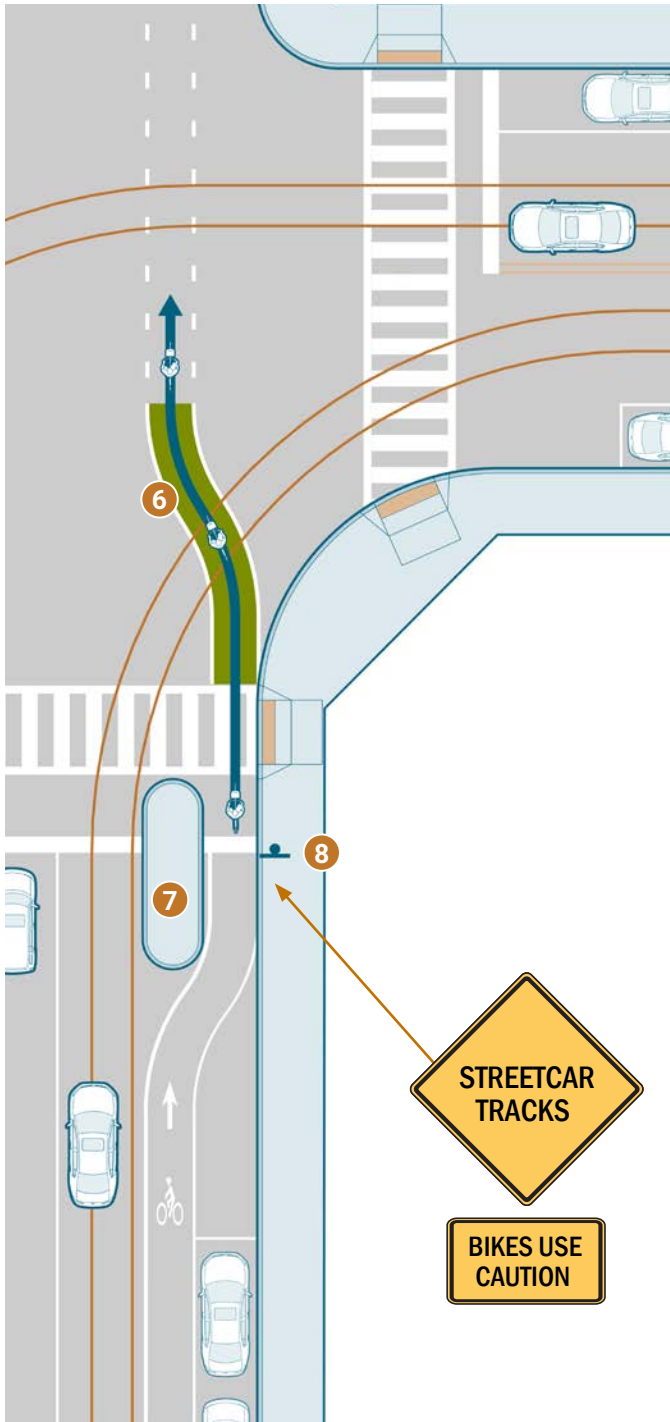


NETWORK

Connected networks for pedestrians and bicyclists allow convenient access to and from transit facilities including stations and bus stops. Factor in desire lines when installing new transit facilities. For more information, refer to the design topic on **Network Connectivity**.

EDUCATION

Educating transit vehicle drivers to be aware and cautious around vulnerable users can help reduce conflicts. Drivers should receive trainings, ideally through driving simulators, on how to operate when bicyclists and pedestrians are present. Bus drivers should be alert that the exiting passengers may cross in front of the bus. Educating bicyclists to be cautious and courteous at transit stops can help reduce conflicts. Consider installing educational signs at strategic locations such as on buses and shelters.



TRACK AND BIKE CONFLICTS

Cities are competing to provide multimodal transportation networks that focus on complete streets and public transportation options. Some have reintroduced light rail and streetcar vehicles to their transit systems. Light rail transit or streetcars, also known as trolley cars, are short public transit vehicles that run on rails on a regular schedule. Light rail transit typically operates within its own exclusive space and streetcars operate in a travel lane along a roadway. Boston, Portland, Seattle, and San Francisco are a few examples of cities that operate light rail and streetcars as part of their transportation systems.

Between the resurgence of light rail and streetcars and increases in bicycling, conflicts between bicyclists and tracks may become more common. Tracks typically contain a gap, called the flangeway, which can be a hazard for bicycle tires. In wet conditions, tracks may be slippery, causing bicyclists to lose control.

CONSIDERATIONS

- Consider using the best track surface material for safe bicycle travel especially when the surface may be regularly wet.
- Consider reducing the flangeway or using a flangeway filler product.
- Provide pavement markings such as bike lane lines, bike symbols, and green colored pavement surfaces to direct bicyclists to cross the tracks between 60 and 90 degrees to reduce the risk of getting bicycle tires caught in the tracks.

6

(AASHTO Bike Guide 2012, p. 4-38)

- Consider a median to force deflection of bicyclist to cross the tracks at the appropriate angle and prevent illegal parking by motorists.
- Provide advance track warning signs to alert bicyclists of the tracks ahead.

8

BUS STOP PLACEMENT

Bus stop placement is a key component of reducing conflicts between bus passengers, pedestrians, bicyclists, and motorists. Bus stops should be located at appropriate distances based on the context of the area. For example, bus stop spacing in central business districts is less than 400 feet. Bus stops should complement the sidewalk and bicycle facilities to connect passengers with the surrounding pedestrian and bicycle networks. At intersections, bus stops can be provided on the near- or far-side of the intersection. Far-side bus

stops are preferred when feasible as near-side bus stops can block visibility between turning vehicles and pedestrians. At midblock bus stop locations, depending on the proximity of other crosswalks, a midblock crossing may be necessary and may require enhanced crossing treatments. For more information, refer to the **design topics on Enhanced Crossing Treatments, Bus Stops, and Midblock Path Intersections**.

(AASHTO Transit Guide 2014, p. 5-11–5-13)

CASE STUDIES

DIRECTING BIKES ACROSS STREETCAR TRACKS BOSTON, MA

With the number of bicyclists increasing in Boston, the City has seen an increase in bicycle crashes resulting from the presence of in-street rail lines. The City decided to address the issue of bicyclist interaction with in-street rail through pavement markings and green colored pavement.

At intersections where track angles were creating challenges for bicyclists, dashed white lane lines with green colored pavement were added to help bicyclists position themselves to cross the tracks at near 90-degree angles.

Boston also has streetcars that run along the center of streets that are too narrow for exclusive bike lanes. To encourage bicyclists to stay in the right lane, the City installed shared lane markings and left-turn queue boxes to assist bicyclists in making left turns.



FLOATING BUS STOP SEATTLE, WA

The City of Seattle has installed bus stop floating islands at a majority of bus stops along Dexter Avenue, a major bicycle commuting corridor that has peak bicycle volumes of over 300 bicyclists per hour. This 1.5-mile corridor carries buses at 10 minute headways during peak periods. The bus stop floating islands allow buses to stop in-lane, decreasing bus delay and allowing buses to easily re-enter traffic without waiting for a gap in passing motorists. The buffered bike lane is routed behind the bus stop, which prevents conflicts between bicyclists and stopped buses. The bus stop floating islands are accessible, with curb ramps and detectable warning surfaces. Some of the bus stops include railings across the back of the bus islands to encourage pedestrians to cross the bike lane at a designated point.



FOR MORE INFORMATION

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Federal Highway Administration. *Separated Bike Lane Planning and Design Guide*. 2015.

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FREIGHT INTERACTION

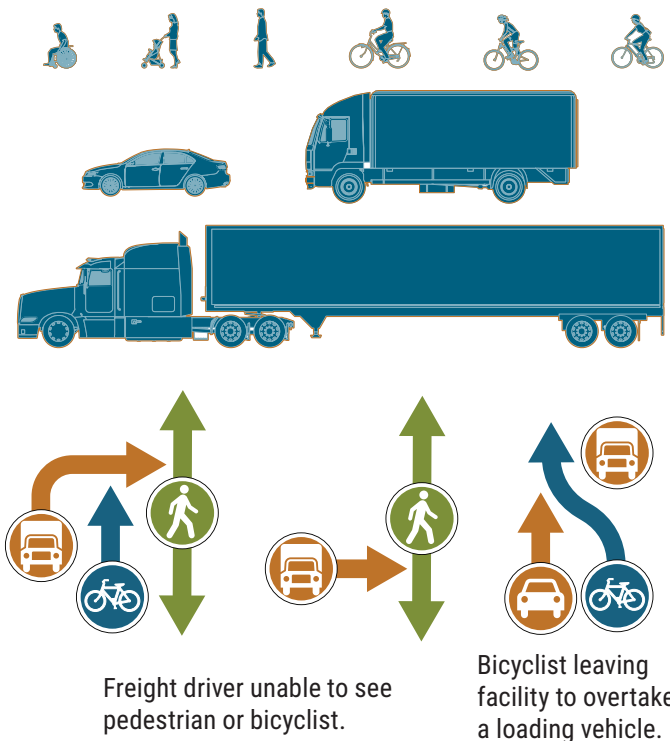


Freight movement is essential for a strong economy. Freight vehicles range from single unit box trucks to large tractor-trailer combinations. These large vehicles are wider, have larger turning radii, and more blind spots than typical passenger vehicles.

Freight vehicles have significant mass, creating the potential for serious or fatal injuries when involved in a bicycle or pedestrian collision. Data from the National Highway Traffic Safety Administration indicates that among crashes involving large trucks, 11 percent of people killed were non-occupants such as pedestrians or bicyclists (**Traffic Safety Facts: Large Trucks, 2015, p. 2**).

Conflicts between freight vehicles and bicyclists and pedestrians generally occur at intersections; however, midblock conflicts can also occur and are typically due to loading activities. Through roadway design, conflicts can be mitigated and the behavior of all users can be made more predictable. Education of all road users can improve the understanding of how each mode operates on roadways.

COMMON USERS IN CONFLICT AND TYPICAL CRASH TYPES



GUIDING PRINCIPLES TO REDUCE CONFLICTS

SAFETY

Through engineering, education, and enforcement, roadway designers and the freight industry should consider an approach to reduce the severity and likelihood of crashes.

ACCOMMODATION AND COMFORT

The design should provide a sense of comfort for vulnerable road users where freight vehicles are present and accommodate freight needs specific to each corridor.

COHERENCE

The path of travel for pedestrians and bicyclists should be clearly delineated for freight vehicles to recognize.

PREDICTABILITY

The design should maximize predictability and reduce conflicts between vulnerable road users and freight vehicles.

CONTEXT-SENSITIVITY

The design should support community health and livability goals while maintaining and growing the economy.

EXPERIMENTATION

Freight vehicles should consider innovative technologies that can alert drivers of potential conflicts with other roadway users.

INTERSECTION GEOMETRY

Designers should consider mountable truck aprons where turning movements by large vehicles are common. Mountable aprons discourage smaller vehicles from making turns at high speeds while still allowing trucks to turn without entering the pedestrian zone or adjacent vehicle lanes. They help reduce off-tracking risks to pedestrians with visual disabilities. Additional strategies for accommodating large vehicles at intersections include setting back stop lines and allowing large vehicles to encroach into adjacent lanes when turning. For more information, refer to the design topic on [Intersection Geometry](#).

SIGNAL PHASING

Signal phases can be used to separate or give a head start to bicycle and pedestrian movements from conflicting freight movements. Separate signal phases can be used where a primary freight route turns and a bicycle route continues straight, at intersections with a high number of freight and bicycle or pedestrian crashes, and at intersections with separated bike lanes. When using separate signal phases, the intersection must be designed so that tractor-trailer combinations can safely make a turn without encroaching on the bike lane, preferably with curb separation between the bike lane and the travel lane. To give a head start, a leading pedestrian or bicycle interval can be used to increase visibility and reduce conflicts. For more information, refer to the design topic on [Signalized Intersections](#).

SIGNS

Dynamic warning signs may be used to alert freight vehicles when bicyclists are present. Dynamic signs use a loop detector to detect a bicyclist. When a bicyclist is detected, the dynamic sign illuminates to alert any potential turning vehicles to yield to the bicyclist. Signs should comply with the [2009 MUTCD](#). For more information, refer to the design topic on [Turning Vehicles](#).

2015 SEATTLE PEDESTRIAN, BICYCLE, AND FREIGHT ASSESSMENT

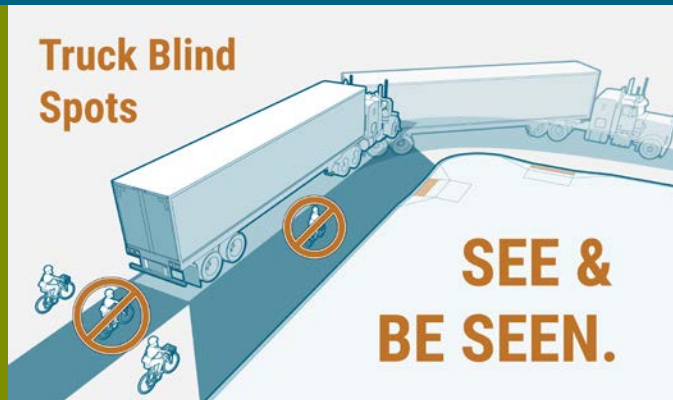
The United States Department of Transportation (U.S. DOT) and its Federal Motor Carrier Safety Administration held a pedestrian and bicycle safety assessment focusing on freight in Seattle assessment in Seattle, Washington on May 7, 2015. The purpose of the assessment was to identify issues and conflict points involving the movement of freight vehicles and bicyclists. Throughout the day, participants were able to ride in buses and trucks, learn about the operating characteristics of various roadways users, and share their experiences as bicyclists, bus drivers, and freight operators.

A key theme in the assessment was user education. While separated bike lanes along roadways with heavy freight traffic are ideal, participants acknowledged that a cohesive network of such infrastructure would take many years to construct. In the meantime, participants agreed that education of all road users on the operational characteristics and needs of each mode is a key tool in reducing crashes between bicyclists, pedestrians, and heavy vehicles.

Participants also recognized that a variety of other components play a part including improvements in both equipment and infrastructure. Turning movements often create conflicts between freight vehicles and bicyclists. Equipment enhancements such as sideguards and audible messaging systems were presented to address this situation. Infrastructure improvements may also decrease the number and severity of conflicts between buses, freight vehicles, and bicyclists by eliminating conflicts where feasible and minimizing speed differentials. The use of bike signals to time-separate the two modes was discussed as an example infrastructure improvement.

EDUCATION

Education is an important component of reducing conflicts between freight and bicycles and pedestrians. Large vehicles need more room to make turning maneuvers than passenger vehicles and the rear wheels do not track along the same line as the front wheels. Educating bicyclists about truck movements and blind spots, as well as educating truck drivers about common bicycle and pedestrian movements, is a key component of sharing the road safely.



CASE STUDIES

OFF-HOUR DELIVERY PROGRAM NEW YORK CITY, NY

In 2009–2010, the New York City (NYC) Department of Transportation implemented an Off-Hour Truck Delivery Pilot Program. Twenty participants shifted their delivery windows to between 7pm and 6am. Receivers had no major issues with the switch; some reported increased staff productivity because staff did not have to be available to receive deliveries while they were serving customers. Carriers reported more efficient operations, fewer parking tickets, and potential to reduce fleet size by balancing day and night operations. With the success, the program, now called NYC deliverEASE, has continued to grow where team members train participants on how to make quiet deliveries and use low noise technologies.



Source: Jason Kuffer (Creative Commons)

TRUCK SIDEGUARDS BOSTON, MA

A literature review performed by the Volpe National Transportation Systems Center found a 61-percent drop in bicyclist fatalities and 20-percent drop in pedestrian fatalities from side-impact truck collisions in the United Kingdom after sideguards were mandated (**Truck Side Guards Resource Page 2015**). In 2014, the City of Boston mandated sideguards for all city-contracted vehicles. Vehicles over 10,000 pounds and tractor-trailers over 26,000 pounds combined must have sideguards, convex mirrors, cross-over mirrors (which eliminate the truck's front blind spot), and blind-spot awareness decals. The improvements cost approximately \$1,800 (2015) per vehicle.



Source: Kristopher Carter, City of Boston

FOR MORE INFORMATION

American Association of State Highway and Transportation Officials. *Guide for the Development of Bicycle Facilities*. 2012.

Federal Highway Administration. *Manual on Uniform Traffic Control Devices*. 2009.

Federal Highway Administration. *Separated Bike Lane Planning and Design Guide*. 2015.

National Association of City Transportation Officials. *Urban Street Design Guide*. 2013.

National Highway Traffic Safety Administration. *Traffic Safety Facts: Large Trucks*. 2015.

Safety Recommendations, issued by National Transportation Safety Board to the National Highway Traffic Safety Administration, April 3, 2014. <http://www.nts.gov/safety/safety-recs/recletters/h-14-001-007.pdf>.

Volpe National Transportation Systems Center. "Truck Side Guards Resource Page." Last modified September 23, 2015. <http://www.volpe.dot.gov/our-work/truck-side-guards-resource-page>.

ACCESSIBILITY

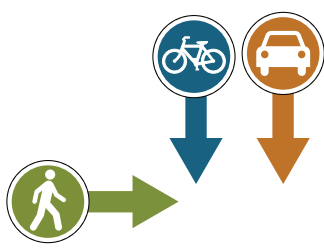
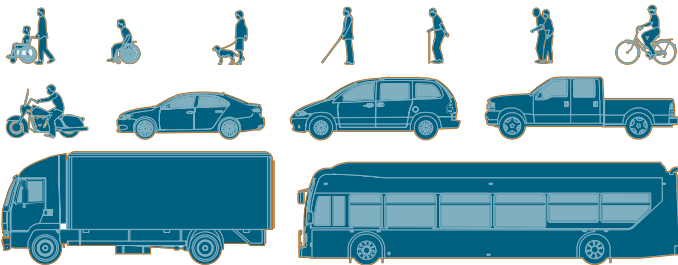


Accessible pedestrian facilities improve the quality of life for those with mobility, visual, hearing, or other disabilities by reducing barriers to services, opportunities, and social activities. Pedestrian access routes, which provide continuous and clear pedestrian pathways, enhance mobility and encourage independence by increasing transportation choice.

Nearly one in five adults under the age of 65 have difficulty traveling due to a disability, with difficulty walking cited as the most common problem (**Committee on Disability in America 2007, p. 522**). Often the built environment is a primary reason for this difficulty because it has historically been designed for people who do not have a disability. Design details for surfaces, streetscape furniture, sidewalks, signals, street crossings, and transit stops may render pedestrian facilities inaccessible. As a result, pedestrians with disabilities may be forced to walk in the street or otherwise be placed in direct conflict with motor vehicles or bicycles.

The Rehabilitation Act of 1973 prohibits agencies receiving Federal financial assistance from discriminating on the basis of disability. Since 1990, the Americans with Disabilities Act (ADA) has required pedestrian facilities in the public right-of-way to be accessible. Accessible street designs minimize multimodal conflicts by eliminating barriers for pedestrians, communicating street crossing information, and promoting predictable behavior for all roadway users.

COMMON USERS IN CONFLICT AND TYPICAL CRASH TYPES



Accessible facilities guide pedestrians to safe and predictable crossing points, reducing their risk of being struck at intersections.



Accessible facilities eliminate barriers, allowing pedestrians to travel on the sidewalk and away from the roadway.

GUIDING PRINCIPLES TO REDUCE CONFLICTS

SAFETY

Designs should eliminate conflicts by maintaining an access route on pedestrian circulation paths, which includes sidewalks, curb ramps, street crossings, and connections to accessible facilities.

ACCOMMODATION AND COMFORT

Designs should eliminate barriers for people with mobility, visual, hearing, or other disabilities.

COHERENCE

Accessible pedestrian routes must provide a continuous clear width free of obstructions and protrusions.

PREDICTABILITY

Designs should provide accessible elements with consistent characteristics and in a logical arrangement to communicate the pedestrian access route.

CONTEXT-SENSITIVITY

Designs should accommodate pedestrians with disabilities in a manner that complements community character and supports community health, economic, and livability goals.

EXPERIMENTATION

Pedestrian access routes must meet Federal standards.

DESIGN STRATEGIES

Providing, maintaining, and connecting to pedestrian access routes is the central concept of the **U.S. Access Board's 2011 Proposed Guidelines for Pedestrian Facilities in the Public Right-of-Way (PROWAG)**. A pedestrian access route must provide a 4-foot minimum continuous clear width, a maximum grade consistent with the road grade, a maximum 2-percent cross slope, and a "firm, stable, and slip resistant" surface (**PROWAG 2011, R302**). Accessibility requirements greatly influence the design and construction strategies for sidewalks, street crossings, curb ramps, signals, street furniture, transit stations, on-street parking, loading zones, shared use paths, and more. For more information on the relationship between the current enforceable ADA Standards and PROWAG, see p. 6.

At the network level, connecting pedestrian access routes reduces conflicts by providing access across barriers. This enables safe and comfortable walking trips from beginning to end for pedestrians of all abilities. For more information, refer to the design topic on **Network Connectivity** for network-level design strategies including small blocks, road diets, safe crossings, and gap connectivity.

SIDEWALKS

Sidewalks comprise the bulk of pedestrian access routes. They should provide a continuous circulation path and connect pedestrians to accessible elements, spaces, and facilities. **1** Where narrower than 5 feet, a 5-by 5-foot minimum passing space is required at 200-foot maximum intervals (**PROWAG 2011, R302.4**). To increase maneuverability, additional space should be provided at "turns or changes in direction, transit stops, recesses and alcoves, building entrances, and along curved or angled routes, particularly where the grade exceeds 5 percent" (**PROWAG 2011, Advisory R302.3**).

Streetscape furniture cannot be placed within the pedestrian access route (i.e., pedestrian through zone) and any nearby obstructions in the frontage and street furniture zones should be detectable by cane. **2** For more information on sidewalk zones, refer to the **NACTO Urban Street Design Guide 2013, p. 38**. Protruding objects, such as wall- or pole-mounted items, must be limited because they can be difficult to detect and avoid (**PROWAG 2011, R402**).

STREET CROSSINGS

Street crossings maintain the pedestrian access route across travel lanes at intersections. A variety of striping may be used to denote the pedestrian crossing (**MUTCD 2009, Sec. 3B.18**). High-visibility ladder style crosswalks with longitudinal lines are recommended. **3**

Ensure that adequate roadway sight distance is provided in advance of the pedestrian crossing to enhance the visibility for approaching motorists and bicyclists. As motor vehicle speeds increase, additional sight distance should be provided.

Consider additional treatments at intersections that minimize multimodal conflicts by reducing motorist turning speeds and improving motorist yielding rates. Curb extensions **4** shorten crossing distances, prevent illegal stopping/parking

in close proximity of the crosswalk, and further increase visibility of pedestrians to motorists, particularly on roadways with on-street parking. Raised crossings **5** enhance visibility and provide an additional traffic calming benefit to encourage motorist yielding behavior. Crossing islands **6** break up long crossings and help pedestrians manage directional conflicts. For more information, refer to the design topics on **Traffic Calming and Design Speed** and **Enhanced Crossing Treatments**.

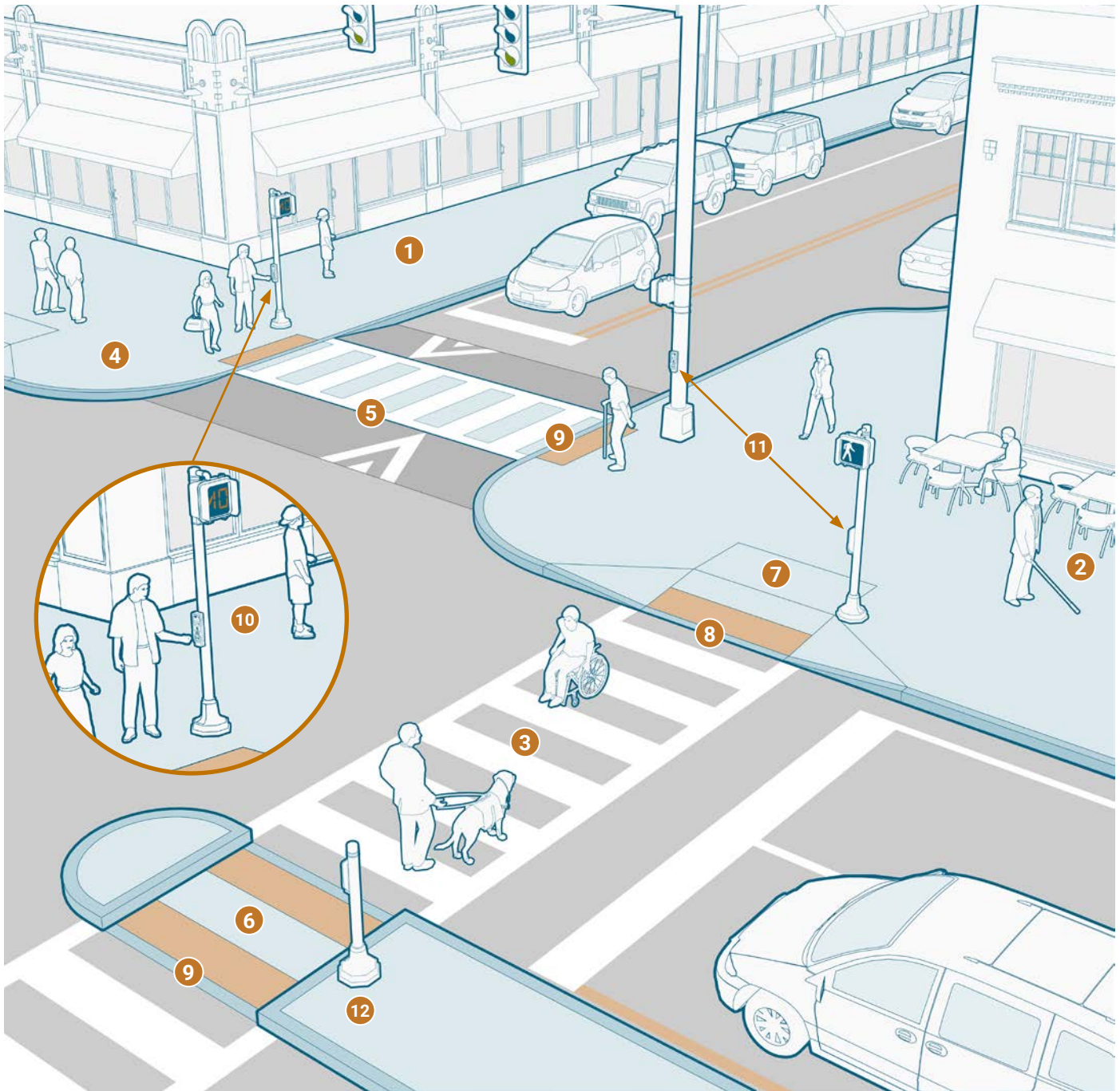
CURB RAMPS

Curb ramps facilitate pedestrian access between sidewalks and street crossings, and between sidewalks and accessible on-street parking. Curb ramps may be perpendicular or parallel to the pedestrian access route, or a combination of both, with a maximum running slope of 8.3 percent. **PROWAG** allows for different maximum cross slopes depending on the traffic control in place at the crossing (**2011, R302.6**). Ramps should align with pedestrian crossings; the use of apex curb ramps (i.e., diagonal ramps) should be a last resort, as these ramps direct pedestrians into the intersection and away from the crosswalk.

Each curb ramp must include a landing/turning space **7** for wheelchair maneuverability and a detectable warning surface **8** to alert pedestrians with a visual disability that they are entering or exiting the roadway. Detectable warning surfaces must include truncated domes to provide tactile feedback and must exhibit visual contrast with adjacent surfaces (e.g., light on dark or dark on light). Place detectable warning surfaces at the back of the curb, unless otherwise specified by **PROWAG (2011, R305.2)**. Detectable warning surfaces are also needed at blended transitions (i.e., crossings with a running slope less than 5 percent) raised crossings, and at pedestrian crossing islands. **9**

SIGNALS

At signalized intersections, accessible pedestrian signals communicate the location of the pedestrian pushbutton and the direction and timing of WALK and DON'T WALK intervals in a non-visual format. **10** The **MUTCD** defines non-visual as one or more "audible tones, speech messages, and/or vibrating surfaces" (**2009, Sec. 4E.09**), whereas **PROWAG** defines non-visual as both "audible tones and vibrotactile surfaces" (**2011, R209**). Designers should separate pedestrian pushbuttons by at least 10 feet **11** and locate each near a level landing or a blended transition to "make it obvious which pushbutton is associated with each crosswalk" (**MUTCD 2009, Sec. 4E.08**). Consider slower walking speeds (less than 3.5 feet per second) when determining pedestrian clearance times to accommodate the elderly and pedestrians with disabilities (**MUTCD 2009, Sec. 4E.06**). Signal timing should allow pedestrians to cross both sides of the street during a single cycle. Designers should place a pushbutton at pedestrian crossing islands for slower moving pedestrians to call the signal if they cannot cross the street in a single cycle. **12**



SURFACE TREATMENTS

PROWAG requires planar and smooth pedestrian access route surfaces. Uneven unit pavers, rough bricks, and hand-tooled concrete control joints cause uncomfortable or even painful vibrations for people using wheeled mobility devices. Minimize vertical discontinuities between unit pavers, vault frames, gratings, and where materials intersect (refer to **PROWAG 2011, R302.7**, for specifications for vertical discontinuities and horizontal openings). Saw-cut concrete control joints and wire-cut bricks help reduce vibrations.

MAINTENANCE

Proper maintenance of pedestrian access routes is essential to keeping pedestrians on the sidewalk and out of the roadway. The clear width should remain free and clear of obstructions, including signs, café seating, snow, ice, debris, and other clutter. Inspect pushbutton responsiveness and pedestrian signal indications on a routine schedule to avoid a lapse in functionality. Public reporting applications can further help identify maintenance needs.

CASE STUDIES

BERKELEY 2010 PEDESTRIAN MASTER PLAN BERKELEY, CA

The City of Berkeley is regarded as one of the most accessible cities in the U.S. for its early and continued efforts to provide accessible public rights-of-way. It has more than 30 years of experience incorporating accessible elements into street design, starting several years before the introduction of national ADA legislation. Both its Disability Compliance Program (BDCP) within Public Works and its Commission on Disability ensure a culture of accessibility within City government. The City retrofits approximately 100 existing curb ramps per year to contemporary design standards, and continues to install accessible elements at locations with identified safety and accessibility deficiencies. Its most recent 2010 Pedestrian Master Plan recommends accessible facilities training for all Public Works and Planning staff, a system to track ongoing efforts, and expanded oversight for the BDCP.



OREGON STATE UNIVERSITY ACCESSIBILITY PLAN CORVALLIS, OR

Oregon State University (OSU) is striving to create a universally accessible campus through a holistic approach to barrier removal using the 2010 ADA Standards and best practice performance standards. OSU's plan (considered a "draft" document because the campus is always changing) identified five key objectives, including identifying an Accessible Travel Grid (ATG) in collaboration with the community and the OSU Accessibility Committee. The ATG is a pedestrian access route that will connect all campus facilities with at least one accessible access point. Focusing on the ATG allowed OSU to initially prioritize 1,134 barriers for resolution (out of 5,029 total barriers identified in the exterior environment), significantly reducing the implementation timeframe and overall cost of achieving an interconnected campus.

COMPREHENSIVE ACCESSIBILITY PLAN FOR THE BUILT ENVIRONMENT (DRAFT)

SUMMER 2013



FOR MORE INFORMATION

American Association of State Highway and Transportation Officials. *A Policy on the Geometric Design of Highways and Streets*. 2011.

Committee on Disability in America. *The Future of Disability in America, Part G: Transportation Patterns and Problems of People with Disabilities*. 2007.

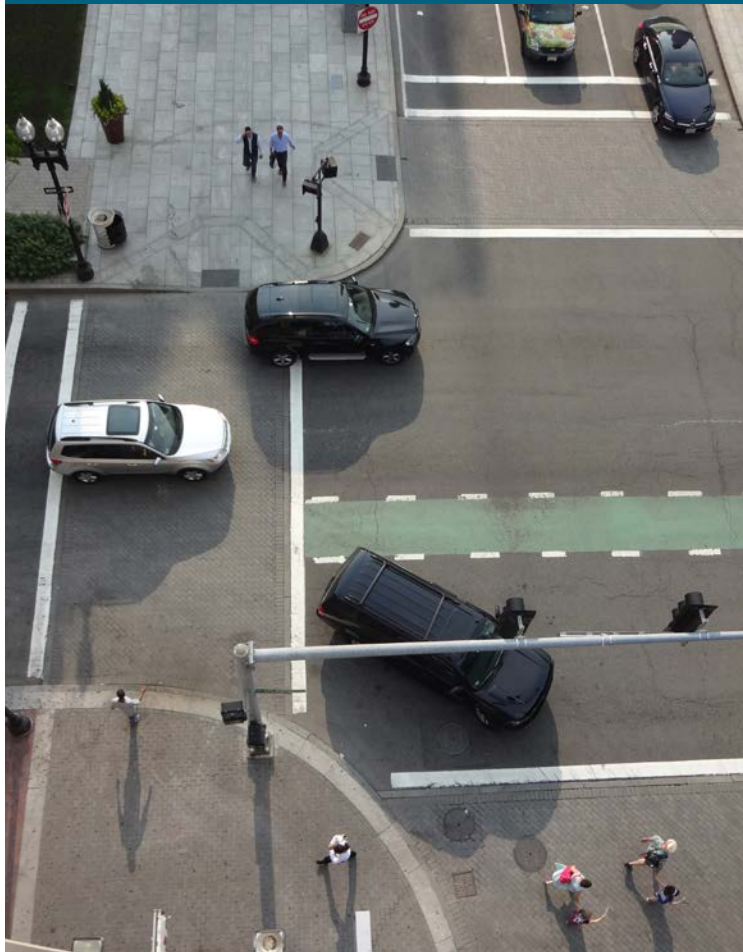
Federal Highway Administration. "Americans with Disabilities Act (ADA)/Section 504 of the Rehabilitation Act of 1973 (504)." Last modified December 1, 2015. <http://www.fhwa.dot.gov/civilrights/programs/ada.cfm>.

Federal Highway Administration. *Manual on Uniform Traffic Control Devices*. 2009.

Transportation Research Board. "Web-Only Document 117A: Accessible Pedestrian Signals: A Guide to Best Practices." Submitted June 2007. http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_w117a.pdf

United States Access Board. *Proposed Guidelines for Pedestrian Facilities in the Public Right-of-Way*. 2011.

TURNING VEHICLES



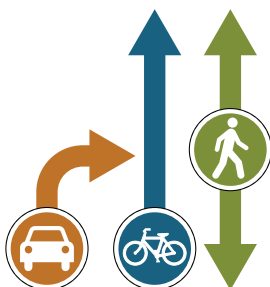
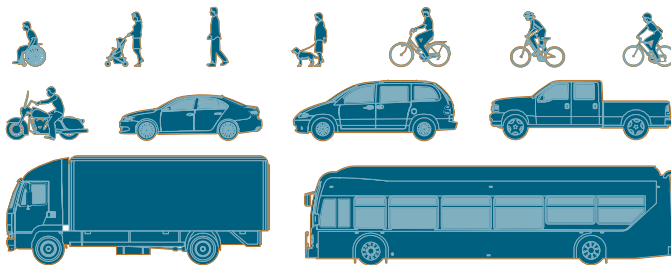
Motor vehicles making turns at intersections can be a hazard for pedestrians and bicyclists. Data from the National Highway Traffic Safety Administration indicate that 20 percent of fatal pedestrian crashes and 34 percent of fatal bicyclist crashes occur at intersections, predominantly in urban areas (**Traffic Safety Facts: Pedestrians, 2015, p. 2; Traffic Safety Facts: Bicyclists and Other Cyclists, 2015, p. 2**). In a 2015 study, the City of Seattle found that the most significant crash type at both signalized and unsignalized intersections was a turning motorist crossing the path of a through bicyclist or pedestrian. Left-turning motorists accounted for 19 percent of bicyclist crashes and 31 percent of pedestrian crashes at all intersection types. Right-turning motorists accounted for 15 percent of bicyclist crashes and 17 percent of pedestrian crashes at all intersection types.

Research has found that left-turning motorists on two-way streets are focused primarily on finding gaps in oncoming traffic, and a high percentage of motorists are not looking for crossing pedestrians or bicyclists. Scanning and awareness becomes more difficult for motorists on roadways with higher speeds and multiple travel lanes.

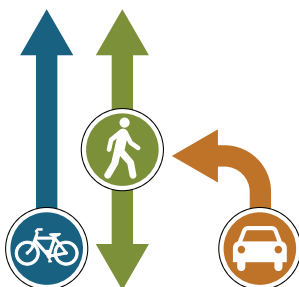
Generally, right-turning motorists have an easier time scanning for bicyclists or pedestrians since they are less focused on finding gaps in traffic. Conflicts often result from failure to yield or bicyclists approaching from the rear in a driver's blindspot.

Turning movement conflicts may be addressed through designs that reduce motor vehicle speeds, minimize speed differentials at conflict points, maximize visibility and predictability, raise awareness, and separate movements through time and space.

COMMON USERS IN CONFLICT AND TYPICAL CRASH TYPES



Right-turning vehicles crossing through bicyclists or pedestrians is known as a "right hook" crash type.



"Left hooks" are similar, where left-turning vehicles come into conflict with opposing traffic traveling straight.

GUIDING PRINCIPLES TO REDUCE CONFLICTS

SAFETY

The design should proactively address known safety issues caused by turning vehicles.

ACCOMMODATION AND COMFORT

Intersections should be designed to be accessible for all users and maximize comfort to the greatest extent practicable.

COHERENCE

Intersections should provide adequate sight distance between turning vehicles and vulnerable road users.

PREDICTABILITY

The design should provide clear right-of-way to increase predictable behavior.

CONTEXT SENSITIVITY

The design should incorporate and support community resources, the natural environment, and adjacent land uses.

EXPERIMENTATION

Intersections should use innovative solutions to increase sight distance and decrease conflicts between turning vehicles and vulnerable road users.

DESIGN STRATEGIES

SIGNALIZED INTERSECTIONS

Traffic signals may be installed at locations where the continual flow of vehicles on one roadway results in excessive delay or hazard to crossing vehicles, bicyclists, or pedestrians. The decision to install a signal should be based on an engineering study which considers the warrants outlined in the **MUTCD**. Accessible pedestrian signals with countdown timers should be provided at signalized intersections to inform pedestrians when they may enter the roadway and how much time remains for their crossing (**MUTCD 2009, Sec. 4E.07**). A minimum pedestrian walk interval of 10 seconds should be provided except in rare circumstances where pedestrian volume is negligible (**ITE Traffic Control Devices Handbook 2009, p. 381**). For more information on accessible pedestrian signals, see the design topic on **Accessibility**.

Reducing left and right hooks can be achieved through partially or fully separating vehicle turning movements from conflicting pedestrian or bicycle movements. ① Partially separated movements are called leading intervals. A leading interval increases visibility and allows pedestrians or bicyclists to assert their right-of-way by providing a head start into the intersection before turning vehicles. Leading intervals are typically a minimum of 3–8 seconds in advance of the green phase for turning motor vehicles. Accessible pedestrian signals should be considered when adding leading intervals. Fully separated movements may require longer signal cycle lengths, which may result in reduced user compliance with signal indications and therefore increased potential for conflict. Cycle lengths should be minimized to reduce delay and maximize compliance. Designers should consider partially or fully separating bicycle movements from motor vehicles. At locations where conflicts are high and the provision of separate phases is not feasible or desirable, restricting vehicular turns should be considered when alternative motor vehicle routes are available. ② For more information, refer to the design topic on **Signalized Intersections**.

CROSSINGS

Bicycle and pedestrian crossings should be separate unless designated as a shared use path crossing. ③ A 6-foot minimum crossing island can be added to provide a refuge for pedestrians and to slow left-turning vehicle speeds. ④ Consider wider crossing islands to accommodate bicycles with

trailers, which cumulatively measure at least 9.75 feet long (**AASHTO Bike Guide 2012, p. 3-4**).

PAVEMENT MARKINGS

Pavement markings improve the predictability of movements and raise awareness of potential conflicts. For bicyclists, this may be accomplished with dotted bicycle lane lines on an intersection approach to indicate a motorist merge area ⑤, or dotted extension lines through the intersection. The dotted lines are typically 6 inches or wider and could be supplemented with green colored pavement to improve visibility. ⑥ Two-stage turn boxes are used to simplify turning for bicyclists. They may require FHWA approval. ⑦ For pedestrians, high-visibility ladder-style crosswalks maximize visibility of the crossing (**MUTCD 2009, Sec. 3B.18**). ⑧

SEPARATED BIKE LANES

Providing additional separation between bicyclists and motorists can improve the visibility of bicyclists to turning motorists. ⑨ For more information, refer to the design topic on **Separated Bike Lanes at Intersections**.

SIGNS

The TURNING VEHICLES YIELD TO (or STOP FOR) PEDESTRIAN (R10-15) sign can be installed at intersections to alert motorists of their requirement to yield or stop for pedestrians or bicyclists within the crossing. In cases where motorists need to be alert to a potential conflict with pedestrians and bicyclists, the sign can be modified to include both a pedestrian and bicycle symbol. The sign can be located at the near- or far-side of the intersection. Engineering judgment should be used to determine a location that is conspicuous to the turning driver. ⑩ (**MUTCD 2009, Sec. 2B.53**).

INTERSECTION GEOMETRY

Intersection geometry has a significant impact on the safety of pedestrians and bicyclists. Ideal intersection geometry should induce yielding by slowing turning vehicles to minimize speed differentials at conflict points. Techniques include installing curb extensions, installing raised crossings, or reducing the curb radii. ⑪ Consider roundabouts as an alternative to traffic signals and at intersections with complicated geometry. For more information, refer to the design topic on **Intersection Geometry** and **NCHRP Report 672**.

EDUCATION

Education campaigns can help to inform users about where to travel to be most visible to other users, where to expect other users to be traveling, and the blind spots of different users. Best practices include educational programs through Safe Routes to School, bicycle and pedestrian curriculum in driver's education and licensing tests, and educational materials such as signs and fliers sent to residents or available at public events.

No Regrets When You DRIVE WITH CARE

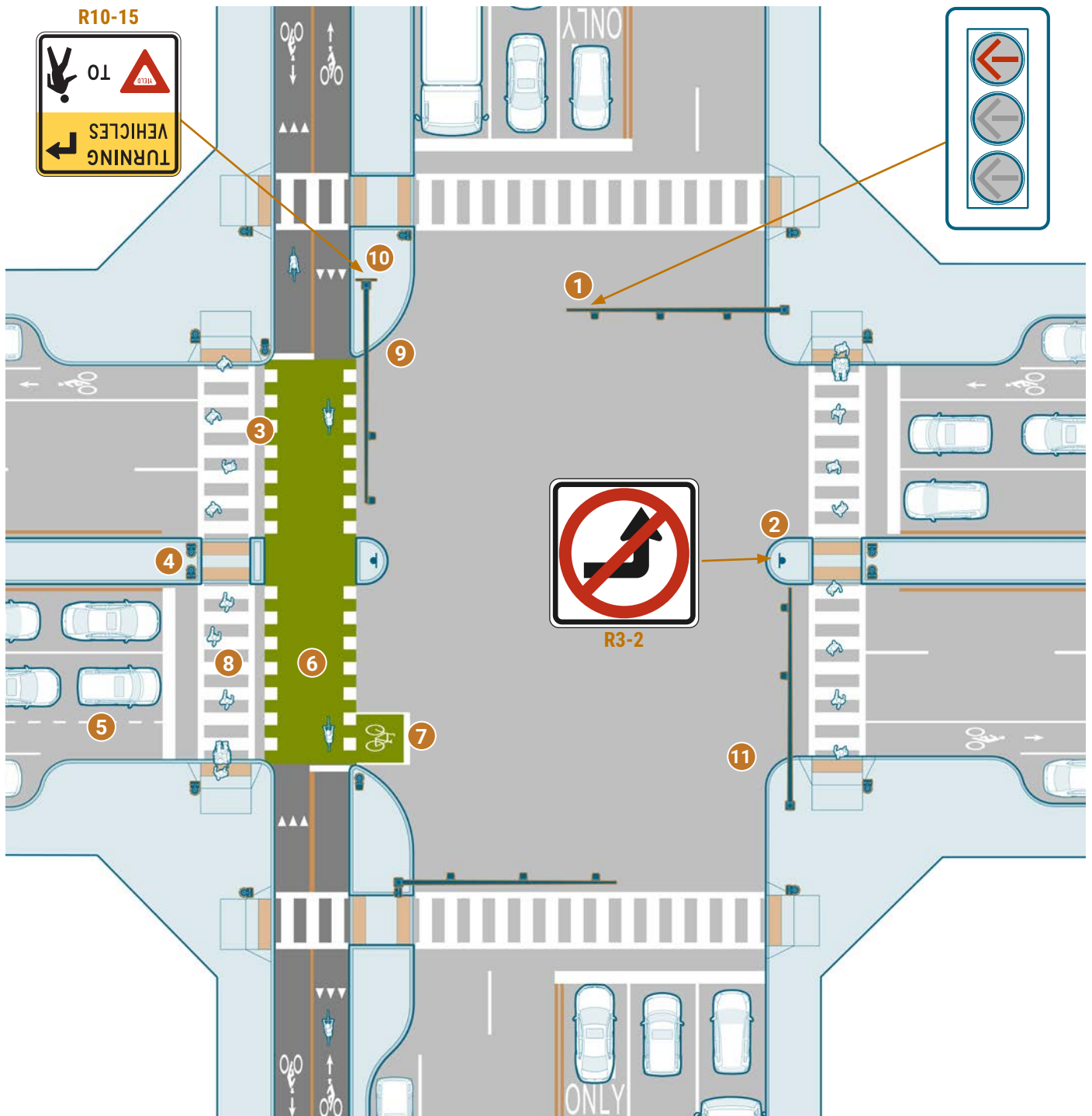
- Stop for pedestrians crossing at every intersection.
- Stop before turning right on red.
- Look in all directions before making a turn.
- Do not pass a vehicle that is stopped for pedestrians.
- Obey the traffic laws, signals and speed limits.



Funded by FDOT

PHONE DOWN↓ BUCKLE UP↑

Source: Florida Department of Transportation District Two



ACCESS MANAGEMENT

Access management techniques can be applied to reduce the frequency of turning movement conflicts caused by driveways or streets. Typical strategies include driveway consolidation, continuous medians, directional islands to restrict left turns, and driveway or street closures. Access management techniques may be particularly beneficial to reduce crashes caused by left turning motorists. Street sections with limited driveway openings maximize comfort and safety for bicyclists and pedestrians.

FREIGHT

Freight vehicles range in size and require large turning radii. Freight vehicles also have blind spots creating challenges for vulnerable road users. For more information, refer to the design topic on **Freight Interaction**.

CASE STUDIES

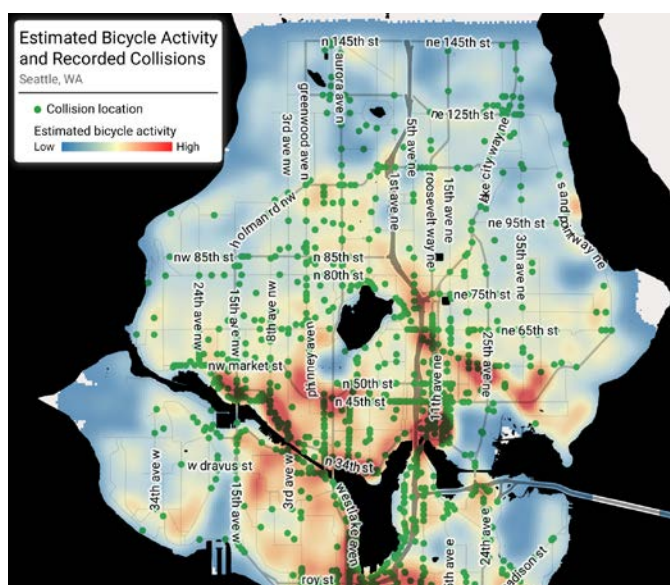
MASSACHUSETTS AVENUE AT BEACON STREET BOSTON, MA

In 2015, at the intersection of Massachusetts Avenue and Beacon Street in Boston, a through bicyclist was struck and killed by a right turning truck. As part of their Vision Zero Initiative to reduce traffic injuries and fatalities, the City of Boston quickly implemented short-term intersection improvements. By obtaining the latest three years of crash data, the City was able to respond with countermeasures to reduce crash patterns at the intersection. Improvements included removing a right turn lane to provide a separated bike lane, optimizing signal timings, providing leading pedestrian intervals, extending bicycle lanes through the intersection with high visibility green-colored pavement markings, adding a bicycle box, and adding signs for motorists to yield to pedestrians. The City will continue to monitor the intersection and plans to develop long-term recommendations to improve safety along the entire corridor.



BICYCLE AND PEDESTRIAN SAFETY ANALYSIS SEATTLE, WA

Seattle is undertaking a robust collision and roadway data analysis to identify the factors that contribute most significantly to pedestrian and bicycle collisions. The findings of this analysis are anticipated to help Seattle proactively address safety issues through systemic improvements and uniform street design approaches. Preliminary results indicate that relatively few combinations of driver and bicyclist or pedestrian actions account for most crashes. The most prevalent—and most likely to be severe—crash type for bicyclists occurred between a bicyclist riding with traffic and a left-turning driver. The most prevalent and severe pedestrian crash type was when a pedestrian crossing a signalized intersection was hit by a driver turning left. The City is developing countermeasures for improvements, along with a tool to analyze future collision data for key factors of interest.



FOR MORE INFORMATION

- American Association of State Highway and Transportation Officials. *Guide for the Development of Bicycle Facilities*. 2012.
- American Association of State Highway and Transportation Officials. *Guide for the Planning, Design, and Operation of Pedestrian Facilities*. 2004.
- Federal Highway Administration. *Manual on Uniform Traffic Control Devices*. 2009.
- Federal Highway Administration. *NCHRP Report 672. Roundabouts: An Informational Guide*. 2010.
- Federal Highway Administration. *Separated Bike Lane Planning and Design Guide*. 2015.
- Institute of Transportation Engineers. *Traffic Control Devices Handbook*. 2009.
- National Highway Traffic Safety Administration. *Traffic Safety Facts: Bicyclists and Other Cyclists*. 2015.
- National Highway Traffic Safety Administration. *Traffic Safety Facts: Pedestrians*. 2015.

SEPARATED BIKE LANES AT INTERSECTIONS

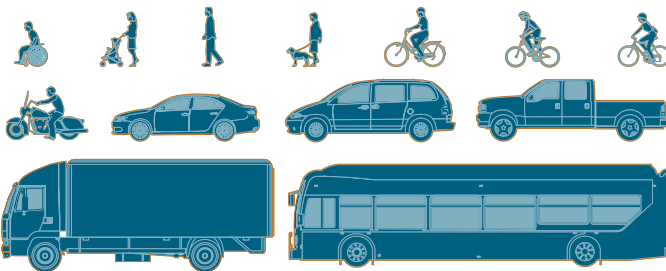


Separated bike lanes reduce stressful interactions between people bicycling and driving by physically separating these users with a horizontal buffer and vertical element. Research shows that they encourage more bicycling, enhance safety for all road users, and are more comfortable for bicyclists and motorists compared to standard bike lanes and shared lanes.

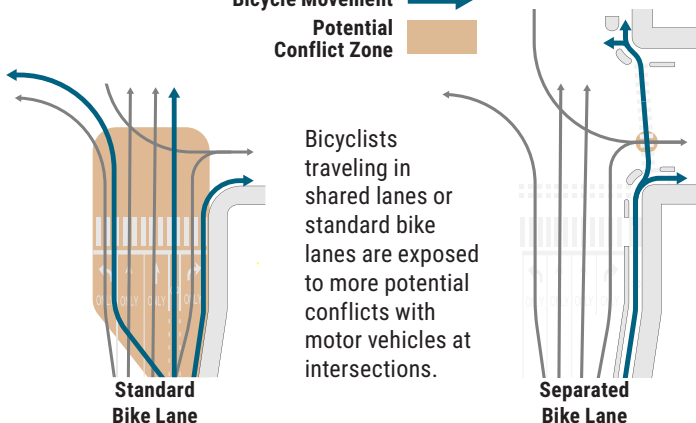
Bicyclists are inherently vulnerable as they have considerably less mass and travel at slower speeds than motorists. This increases the likelihood of serious injury or death in the event of a collision with a motor vehicle. Most conflicts occur at intersections where turning motorists must merge within or turn across a bicyclist's path of travel. Intersection geometry has an influence on the turning speed of a motorist and the approach geometry has an influence on a motorist's merging speed across a bicyclist's path.

At intersections, geometric and signalization strategies for separated bike lanes can reduce conflict areas, clearly communicate the right-of-way for all users, and heighten visibility and lower speeds at crossings. Continuous separated bike lanes along corridors and through intersections serve a primary role in the design of low-stress bicycle networks that appeal to people of all ages and bicycling abilities.

COMMON USERS IN CONFLICT AND CONFLICT ZONES



Vehicle Movement →
Bicycle Movement →
Potential Conflict Zone



GUIDING PRINCIPLES TO REDUCE CONFLICTS

SAFETY

Minimize bicyclist exposure to motor vehicles, decrease the speed differential at conflict points, and provide adequate sight distance for all roadway users.

ACCOMMODATION AND COMFORT

Preserve the separated bike lane up to the cross street to create an environment that appeals to bicyclists of all ages and abilities.

COHERENCE

Clearly delineate the path of travel at conflict points.

PREDICTABILITY

Design pavement markings, signs, geometric elements, and signal phasing strategies to encourage predictable behaviors.

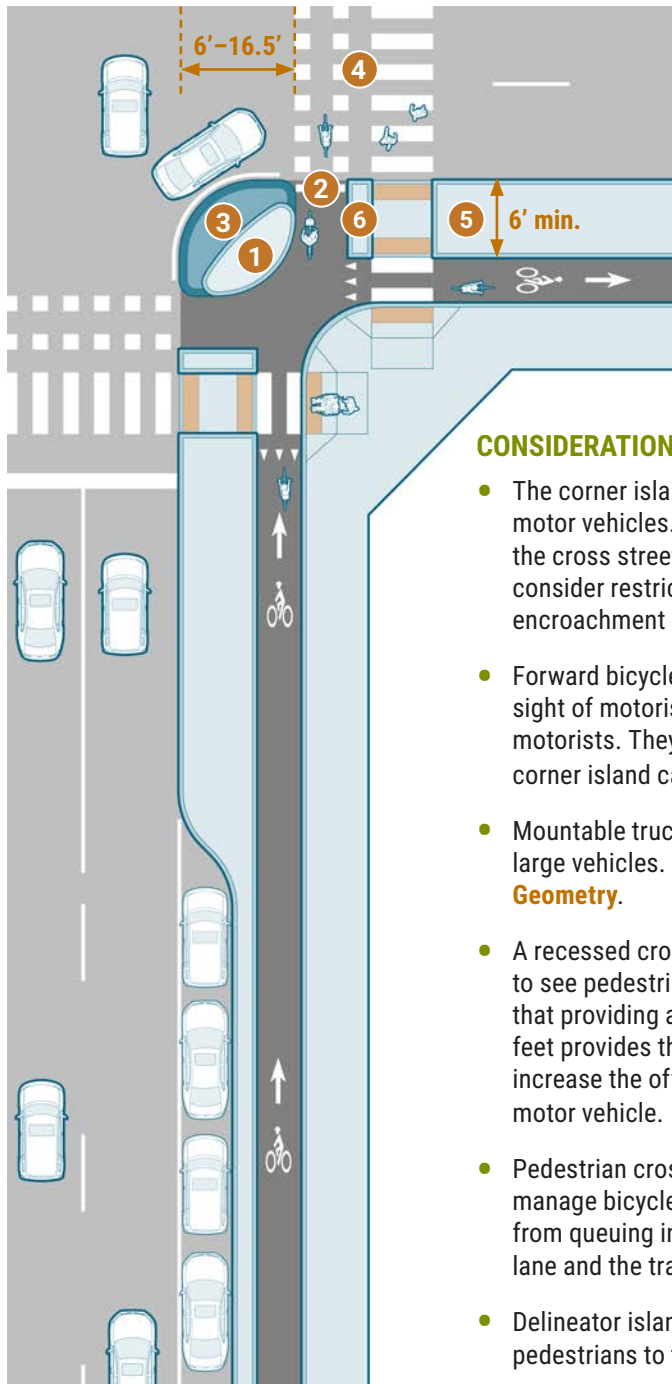
CONTEXT-SENSITIVITY

Consider community character and aesthetics when selecting separated bike lane elements.

EXPERIMENTATION

Utilize innovative solutions such as the provision of bicycle signals for protected-phase crossings or truck aprons to slow turning vehicles.

DESIGN STRATEGIES



PROTECTED INTERSECTIONS

Protected intersections preserve the separated bike lane up to and through intersections. By maintaining physical separation, they eliminate shared spaces with turning and merging vehicles, limiting bicyclist exposure to a single point where the motorist turns across the bike lane and adjacent pedestrian crossing. The speed of the conflict is controlled through geometric design and sight distance is improved by recessing the crossings. Protected intersections are compatible with one- and two-way separated bike lanes; however, contraflow bicycle movements may require signal-phase separation in some situations.

CONSIDERATIONS

- The corner island protects bicyclists by controlling the speed of right-turning motor vehicles. It also allows the crossing to be located at a narrower part of the cross street, minimizing exposure to turning traffic. **1** Designers should consider restricting right turns on red at protected intersections to reduce vehicle encroachment into the crossings.
- Forward bicycle queuing areas allow stopped bicyclists to wait in direct line of sight of motorists and allow bicyclists to enter the intersection before turning motorists. They should be at least 6 feet long to fit a typical bicycle. Enlarging the corner island can create additional queuing space for bicyclists. **2**
- Mountable truck aprons can be used to slow turning vehicles while accommodating large vehicles. **3** For more information, refer to the design topic on **Intersection Geometry**.
- A recessed crossing creates motor vehicle yielding space and allows motorists to see pedestrians and bicyclists without relying on mirrors. Research shows that providing a bicycle crossing offset from the parallel roadway by 6- to 16.5 feet provides the greatest safety benefit. Enlarging the corner island can further increase the offset to the cross street and create additional yielding space for a motor vehicle. **4** (**Schepers 2011, pp. 853–861**)
- Pedestrian crossing islands reduce crossing distances, allow pedestrians to manage bicycle and motor vehicle conflicts separately, and discourage pedestrians from queuing in the bike lane. They must provide at least 6 feet between the bike lane and the travel lane and include detectable warning surfaces. **5**
- Delineator islands separate bicycle and pedestrian crossings and help guide pedestrians to the crossing island and crosswalk. **6**

SIGHT DISTANCE

For sight distance at intersections and driveways, refer to the **AASHTO Green Book 2011**. Restrict parking and vertical objects near the intersection by at least 20 feet to provide a clear approach area (**FHWA Separated Bike Lane Guide 2015, p. 90**). Higher design turning speeds require additional clear area for motorists to identify and react to potential conflicts.

SIGNALS

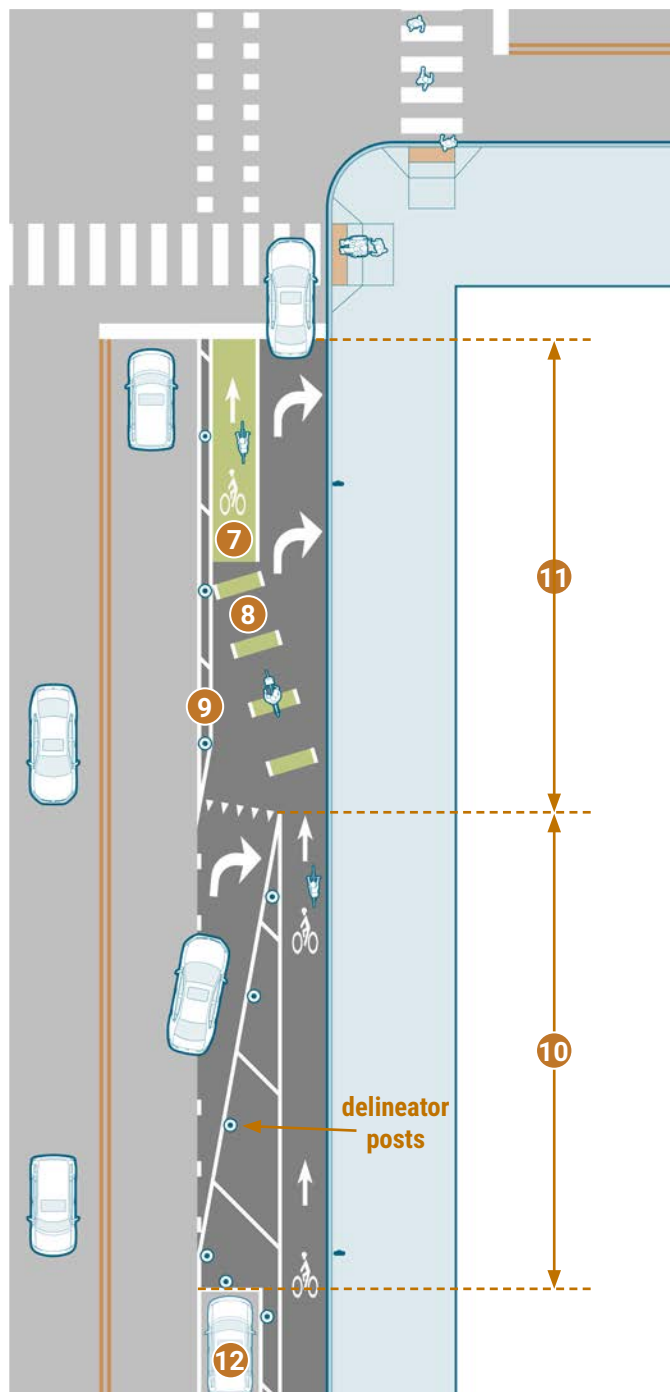
Separated bike lanes are offset from motor vehicle traffic, therefore bicycle signals should be considered to provide consistent, predictable, and easy to understand guidance for bicyclists at signalized locations. Bicycle signals will be necessary at locations where protected or leading bicycle phases are provided. For more information on interval adjustments and signal phasing and coordination, refer to **FHWA Separated Bike Lane Guide 2015, pp. 115–121**.

MIXING ZONES

A mixing zone requires turning motor vehicles to merge into the separated bike lane at a defined location in advance of an intersection. Unlike a standard bike lane where a motorist can merge across at any point, a mixing zone design limits bicyclist exposure to motor vehicles by defining a limited merge area for the turning motor vehicle. They are compatible with one-way separated bike lanes only.

CONSIDERATIONS

- Mixing zones should be limited to constrained locations where maintaining physical separation is infeasible with a maximum of 50–150 turning motor vehicles in the peak hour (**FHWA Separated Bike Lane Guide 2015, p. 107**). Consider signal separation at constrained locations with higher turning volumes.
- Bike lanes should be continuous through the mixing zone where space permits **7**, otherwise shared lane markings should be used.
- Designers should consider a green bike lane or shared lane markings **8** for conflict areas to highlight the conflict point and raise awareness of bicyclists.
- Designers should provide a buffer **9** with a vertical element to separate the turn lane from through lanes, where space permits (**FHWA Separated Bike Lane Guide 2015, p. 83**).
- Motor vehicle speeds should be reduced at the merge point to 20 mi/h or less through the use of reduced taper lengths. **10**
- The length of the mixing zone should be minimized to 60–100 **11** feet to maximize comfort for bicyclists and to minimize speed differential with motorists.
- Where parking is present, it may be necessary to restrict some parking in advance of the merge point **12** to increase approach sight distance.



MARKINGS, SIGNS, & MAINTENANCE

Pavement markings and signs can be used to alert motorists of potential conflicts. For more information, refer to the design topic on **Turning Vehicles**.

Providing a safe and rideable surface through all seasons can reduce conflicts by providing an exclusive space for bicyclists year-round. Designers should consider compatibility with maintenance activities and equipment when designing separated bike lanes. For more information see **FHWA Separated Bike Lane Guide 2015, pp. 64–65**.

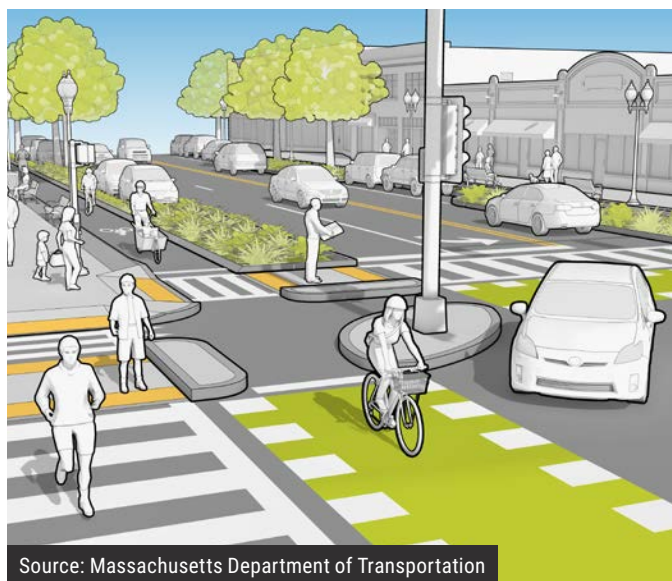
INTERSECTION GEOMETRY

Roadway geometry can assist in reducing conflicts at intersections, especially with separated bike lanes. For more information, refer to the design topic on **Intersection Geometry**.

CASE STUDIES

SEPARATED BIKE LANE PLANNING & DESIGN GUIDE MASSACHUSETTS

The Massachusetts Department of Transportation (MassDOT) Separated Bike Lane Planning & Design Guide presents strategies and criteria for the planning, design, and maintenance of separated bike lanes. MassDOT recognizes the Guide as a critical tool in support of its Complete Streets approach to project development and its goal to provide healthy transportation options. The Guide provides clarification on when separated bike lanes are appropriate and identifies typical separation strategies and configurations while addressing key design criteria for reducing conflicts between all modes. The document provides design guidance for intersections, signalization, transit stops, loading zones, on-street parking, drainage, stormwater management, and landscaping, among others. Notably, it introduces the first set of guidelines for protected intersections, bringing international best practice to the U.S.



PROTECTED INTERSECTION DAVIS, CA

In August 2015, Davis, CA completed the construction of a new intersection design for bicyclists at Covell Boulevard and J Street. The intersection design, referred to as a protected intersection, created corner islands for bicyclists to maneuver around the intersection with physical separation from motorists. The intersection is reported to be functioning well with the various roadway users able to follow their path without explanation. The design reduced the crossing distances for bicyclists and pedestrians and improved visibility between turning vehicles with bicyclists and pedestrians.



FOR MORE INFORMATION

American Association of State Highway and Transportation Officials. *Guide for the Development of Bicycle Facilities*. 2012.

American Association of State Highway and Transportation Officials. *A Policy on the Geometric Design of Highways and Streets*. 2011.

Federal Highway Administration. *Manual on Uniform Traffic Control Devices*. 2009.

Federal Highway Administration. *Separated Bike Lane Planning and Design Guide*. 2015.

Massachusetts Department of Transportation. *Separated Bike Lane Planning & Design Guide*. 2015.

National Association of City Transportation Officials. *Urban Bikeway Design Guide*. 2014.

Schepers et al. "Road factors and bicycle—motor vehicle crashes at unsignalized priority intersections." *Accident Analysis & Prevention*. Volume 43, Issue 2, 2011.

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SHARED USE PATHS



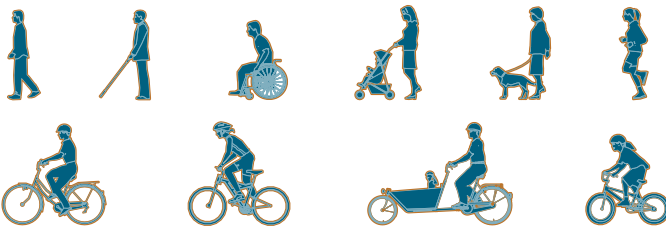
Whether traveling by foot, wheelchair, bicycle, skateboard, or other ways, well-designed shared use paths can provide direct and comfortable routes to places of employment, recreation, education, and other destinations. They can enhance the efficiency of transit systems by making transit stops more accessible. They can also provide a way to engage in physical activity.

As paths attract a wide range of user types, multimodal conflicts can occur. Conflicts on shared use paths most often derive from 1) high volumes of users, 2) path users traveling at different speeds, 3) path users overtaking other users, 4) sharp curves, 5) vertical objects near the path, and 6) surface defects that effectively narrow the usable width.

Increasing use of paths should be expected over time as more people become aware of them and walking and bicycling rates grow. The design of a path should follow best practices and industry standards and consider future growth patterns.

Through careful planning and design, shared use paths can be built to reduce conflicts between users of different types and speeds for current and future path volumes.

COMMON USERS IN CONFLICT AND TYPICAL CRASH TYPES



Insufficient path width can contribute to crashes associated with overtaking and passing maneuvers.



Surface defects can cause bicyclists to become unstable or lose control.



Insufficient path width can contribute to crashes with objects adjacent to path.

GUIDING PRINCIPLES TO REDUCE CONFLICTS

SAFETY

The path width should be designed to accommodate the peak volume of users with proper maintenance to ensure the path is usable throughout the year.

ACCOMMODATION AND COMFORT

Separation of bicyclists and pedestrians should be considered where high volumes of pedestrians are anticipated.

COHERENCE

It should be clear to each mode where and how they are to use the path.

PREDICTABILITY

The design should encourage predictable behaviors of path users throughout and clearly identify where and when users are intended to be separated.

CONTEXT-SENSITIVITY

The path should support the natural environment, adjacent land uses, community health, economic, and livability goals.

EXPERIMENTATION

Path lighting, user education, maintenance operations, and segregation techniques may be warranted to address conflicts.

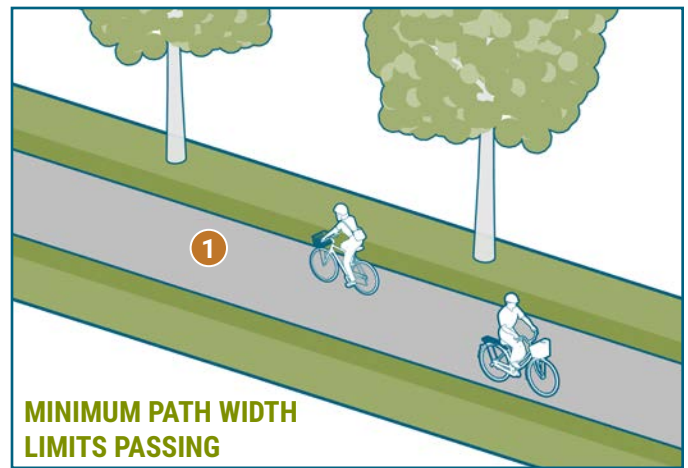
DESIGN STRATEGIES

PATH WIDTH

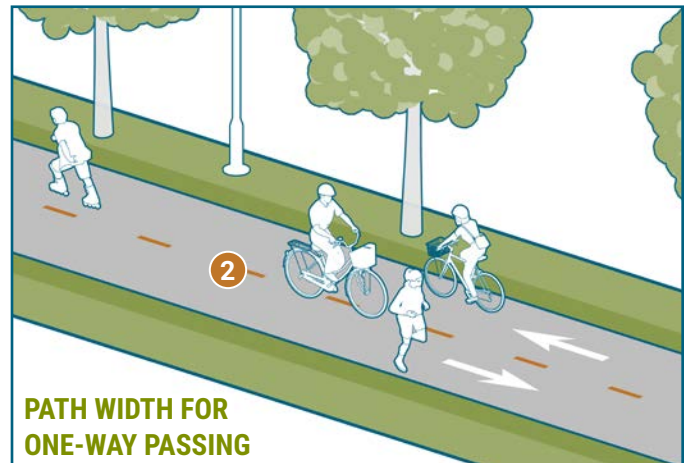
Path width should be determined based on three main characteristics: the number of users, the types of users, and the differences in their speeds. For example, a path that is used by higher-speed bicyclists and children walking to school may experience conflicts due to their differences in speeds. By widening the path to provide space to accommodate passing movements, conflicts can be reduced.

CONSIDERATIONS

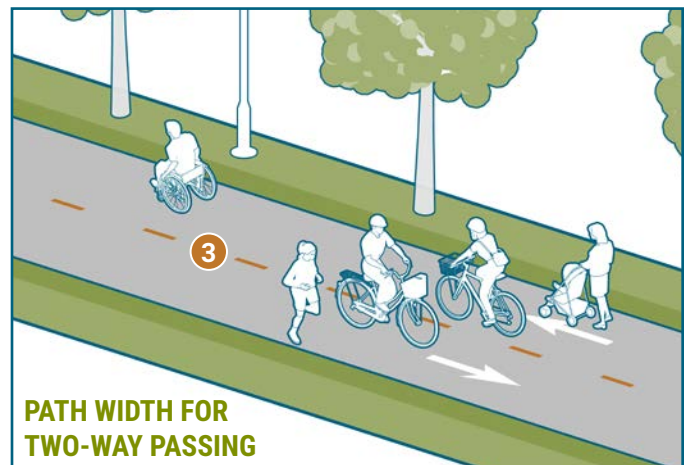
- Design path widths based on anticipated user types, speeds, and volumes.
- Use the **FHWA Shared Use Path Level of Service Calculator**, which recommends path widths based on the predicted number and types of path users.
- A minimum path width of 10 feet is recommended. A width of 8 feet may be used where path volumes are expected to be low and predominantly one user type. **1** (AASHTO Bike Guide 2012, p. 5-3)
- Depending on path volume and user types, consider a path width of 11 feet to allow one person to overtake another while avoiding a path user traveling in the opposite direction. **2** (AASHTO Bike Guide 2012, p. 5-3)
- Wider pathways are recommended in areas with higher user volumes and where a high percentage of pedestrians are expected. **3** (AASHTO Bike Guide 2012, p. 5-3)
- In urban areas where high use is anticipated, the desired path width is a minimum of 14 feet.



**MINIMUM PATH WIDTH
LIMITS PASSING**



**PATH WIDTH FOR
ONE-WAY PASSING**

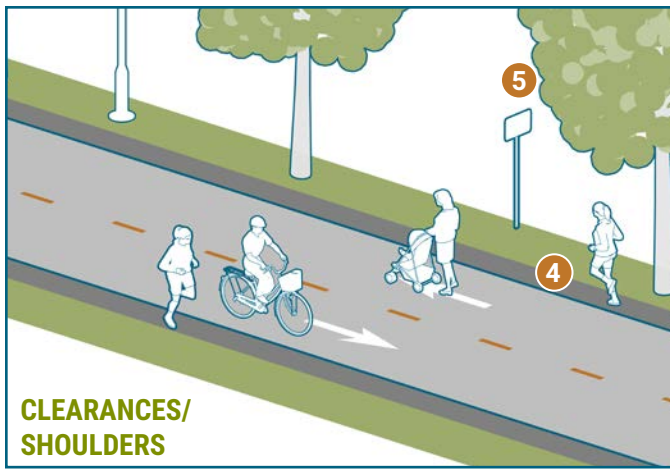


**PATH WIDTH FOR
TWO-WAY PASSING**

EDUCATION AND ETIQUETTE

Reminding users of proper path etiquette, such as announcing when passing someone, may further assist in reducing conflicts between users. Strategies may include additional signs such as etiquette reminders, providing the path rules on maps, and conducting outreach campaigns to path users.

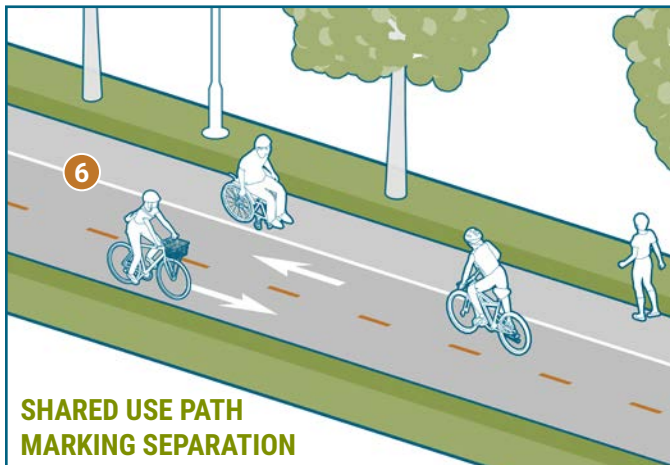




CLEARANCES/SHOULDERS

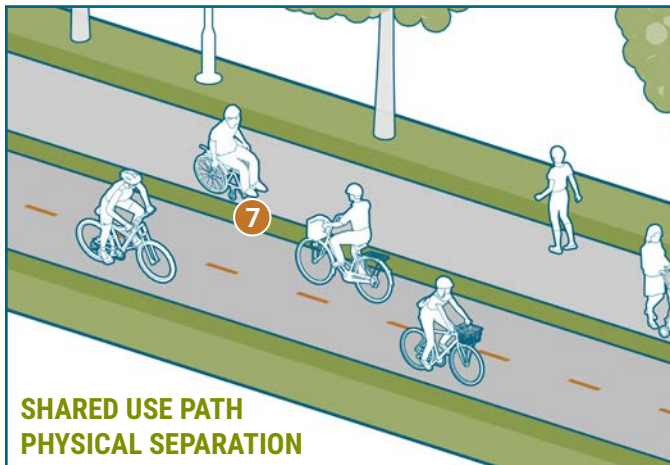
On hard surface paths (asphalt or concrete), it can be useful to include soft surface parallel paths (crushed stone), which are preferred by some users, such as runners. 4 When including parallel running paths, be sure to consider clearance recommendations as highlighted below.

Path clearances are an important element in path design and reducing user conflicts. Vertical objects close to the path edge risk endangering users and reducing the comfortable usable width of the path. 5 Along the path, vertical objects should be set back at least two feet from the edge of the path. Path shoulders may also reduce conflicts by providing space for users who step off the path to rest, allow users to pass one another, or offer a viewing area at scenic vistas (AASHTO Bike Guide 2012, p. 5-5).



SEPARATION

A path may benefit from the separation of users by user speed, type, or direction. Common separators include line markings 6, pavement variations, and landscaping. 7 Separation by user type and speed is typically accomplished by separating bicyclists and pedestrians. When separating users by speed, consider the path width and paving material preferred by each user. A minimum pedestrian path of 6 feet is recommended to allow pedestrians to walk side-by-side and to allow passing.



TURNING MOVEMENTS

Designing paths with sharp turns can also increase conflicts. Sharp turns (typically less than a 30-foot radius) lead users to encroach on other users' path of travel, increasing the potential for conflicts. If a larger radius is not possible, the path should be widened at turn locations to minimize conflicts.

(AASHTO Bike Guide 2012, p. 5-14)

INTERSECTIONS

Additional shared use path conflicts occur where paths and roadways intersect. For more information, refer to the design topic on **Midblock Path Intersections**.

LIGHTING AND MAINTENANCE



Lighting increases the transportation utility of paths, reduces risk of falls and crashes, and improves users' personal security. Paths used for transportation purposes should be open and lit at all times.

A smooth path surface is essential to year-round path user safety. Routine and seasonal maintenance should be performed to eliminate uneven and slippery surfaces due to tree roots, potholes, ponding, snow, and ice. Maintain sight lines along the path and at intersections by routinely trimming vegetation.

CASE STUDIES

SEPARATED PATHS PINELLAS TRAIL, FL

The 47-mile Pinellas Trail in Pinellas County, FL includes separate paths for users where space exists within the former railroad right-of-way. One pathway is wider and a hard surface. The other pathway is narrower and predominately crushed stone. Of the 70,000 monthly users, people on bicycles typically use the hard surface trail while people walking use the crushed stone, decreasing conflicts along the path. However, groups of users, whether pedestrians or bicyclists, typically prefer the wider path as it allows socializing. In addition, some pedestrians prefer hard surfaces for walking. Separated paths can mitigate user conflicts, but it is important to recognize the unique needs of each trail user type.



Source: Pinellas Trail, Inc.

MARKED SEPARATION MINNEAPOLIS, MN

The Midtown Greenway is a 5.7-mile separated trail in the heart of Minneapolis. The trail runs east-west on a former sunken railroad corridor, providing a direct and uninterrupted path for bicyclists to traverse the city. The majority of the trail is below grade, passing underneath bridges and allowing users a traffic-free route. The Greenway features two one-way bike lanes and one two-way walking path. A dashed yellow line separates the two bike lanes, allowing passing for bicyclists. A solid white line separates the walking path from the bike lanes. In some areas, the paths narrow due to space constrictions. The Greenway is well-lit at night, and is open 24 hours per day. Several thousand trail users enjoy the Greenway every day. During the winter, the Greenway is cleared of snow and ice.



FOR MORE INFORMATION

American Association of State Highway and Transportation Officials. *Guide for the Development of Bicycle Facilities*. 2012.

American Association of State Highway and Transportation Officials. *Guide for the Planning, Design, and Operation of Pedestrian Facilities*. 2004.

Federal Highway Administration. *Manual on Uniform Traffic Control Devices*. 2009.

Federal Highway Administration. "Shared-Use Path Level of Service Calculator." Last modified April 4, 2012. <https://www.fhwa.dot.gov/publications/research/safety/pedbike/05138>

United States Access Board. *Proposed Guidelines for Pedestrian Facilities in the Public Right-of-Way*. 2011.

United States Access Board. *Proposed Guidelines for Pedestrian Facilities in the Public Right-of-Way: Shared Use Paths*. 2013.

MIDBLOCK PATH INTERSECTIONS



People of all ages and abilities engage in walking, bicycling, and other activities on shared use paths. Most paths cross roadways at some point, and these locations have the potential to be the most challenging locations for path users.

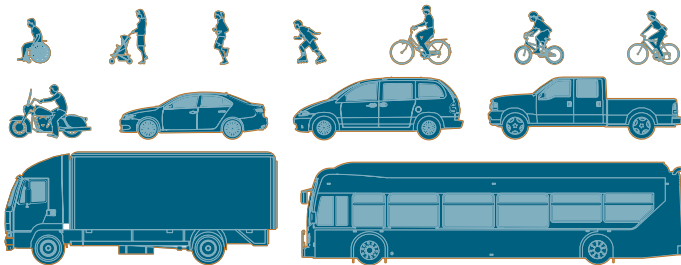
When paths cross roadways midblock, conflicts between path users and roadway users may arise. Roadway users include motorists as well as people bicycling and walking along the road. Much like typical roadway intersections, midblock path and roadway intersections should be designed with sound intersection design principles.

Where inappropriate midblock roadway crossing treatments are applied along shared use paths, path and roadway users may be less likely to comply with traffic controls. For example, the use of stop control where sight lines are adequate may result in non-compliance, when yield control would be more appropriate and match user behavior more closely.

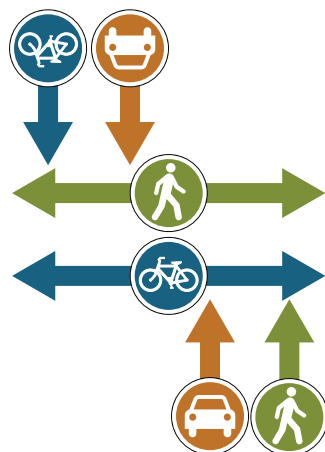
Other potential conflicts may occur where paths intersect roadways at angles, creating challenging sight lines between path and roadway users. Intersection angles should be as close as possible to 90 degrees, providing adequate stopping distances and sight lines for all users.

By designing path and roadway intersections with these principles in mind, many conflicts can be minimized or avoided.

COMMON USERS IN CONFLICT AND TYPICAL CRASH TYPES



Poorly designed path and roadway intersections can contribute to crashes.



GUIDING PRINCIPLES TO REDUCE CONFLICTS

SAFETY

Midblock path intersections should be designed to reduce the likelihood and severity of crashes between path users and between path users and motor vehicles.

ACCOMMODATION AND COMFORT

The intersection should be comfortable for path users of all ages and abilities.

COHERENCE

It should be clear to each mode where and how they are to navigate the intersection.

PREDICTABILITY

The design should be easy-to-understand through predictable behaviors and clear right-of-way assignments.

CONTEXT-SENSITIVITY

The design should support the natural environment, community health, and livability goals.

EXPERIMENTATION

Midblock path intersection traffic controls should be appropriate based on the intersection conditions, path volumes, and roadway volumes.

DESIGN STRATEGIES

An initial assessment of the crossing location should include reviewing the roadway characteristics such as number of lanes, vehicular speeds and volumes, and sight lines. If conditions are extremely challenging for a path crossing, consider adding features to facilitate the crossing such as signalization, re-aligning the path, or providing grade separation.

This design topic addresses paths crossing roadways midblock. These strategies can be applied to similar midblock intersections near schools, transit stations, and at other high pedestrian desire lines. For more information, refer to the design topics on **Network Connectivity**, **School Access**, **Multimodal Access to Existing Transit Stations**, and **Multimodal Access to New Transit Stations**.

PRIORITY AND CONTROL ASSIGNMENTS

Intersection controls often stop path users, even when stopping might be unnecessary or inappropriate. The proliferation of stop signs on paths has led to a lack of compliance by path users in many communities and may actually diminish safety if ignored where truly needed. Therefore, the least restrictive control that is effective should be used (**MUTCD 2009, Sec. 2B.06**). For example, the **MUTCD** recommends that “STOP signs should not be used where YIELD signs would be acceptable” (**2009, Sec. 9B.03**).

Yield controls may be most appropriate when sight lines are adequate to assess the crossing facility and users may slow or stop to avoid a conflict. Yield control can allow path users to maintain momentum and may result in better compliance.

To assess which crossing approach (the path or the roadway) should have priority, examine relative volumes and facility hierarchy in the transportation network to determine which approach should be made to yield or stop.

When priority is assigned, the least restrictive control that is appropriate should be placed on the lower priority approaches. The **MUTCD** provides the following guidance on control devices: “When placement of STOP or YIELD signs is considered, priority at a shared use path and roadway intersection should be assigned with consideration of the following:

- Relative speeds of shared use path and roadway users,
- Relative volumes of shared use path and roadway traffic, and
- Relative importance of shared use path and roadway.

Speed should not be the sole factor used to determine priority, as it is sometimes appropriate to give priority to a high volume shared use path crossing a low volume street, or to a regional shared use path crossing a minor collector street.” (**2009, Sec. 9B.03**)

CONSIDERATIONS

- A stop-controlled approach should have STOP signs (R1-1) and a stop line.
- A yield-controlled approach should have YIELD signs (R1-2) and yield lines. **1**

- The uncontrolled approach should have warning signs **2** and warning pavement markings. **3**

(**AASHTO Bike Guide 2012, pp. 5-38–5-42**)

INTERSECTION DESIGN

At intersections, paths and roadways should meet as close to 90 degrees as possible. Skewed intersections reduce visibility, maneuverability, and increase crossing distances. The faster the user, the longer the distance needed for that user to slow or stop. The fastest users at the intersection are typically the motor vehicle and bicyclist. These users should determine the needed sight line.

People walking and bicycling along the roadway and wishing to access the path should also be considered. Pedestrians and novice bicyclists will often access a path via an intersecting sidewalk **4**, whereas more experienced bicyclists will often access a path via the roadway. **5** Good intersection design will accommodate all user types who wish to access the path via the intersection by providing ramps and adequate room to turn, or a raised crossing that also functions as a speed table for the roadway.

CROSSING TREATMENTS

A variety of other treatments can enhance the safety and comfort of path intersections. These include traffic calming techniques such as raised crossings or chicanes, pedestrian crossing islands **6**, curb extensions to improve visibility and shorten crossway distances, or widening the path at the crossing to accommodate queuing of path users.

For more information, refer to the design topics on **Enhanced Crossing Treatments** and **Traffic Calming and Design Speed**.

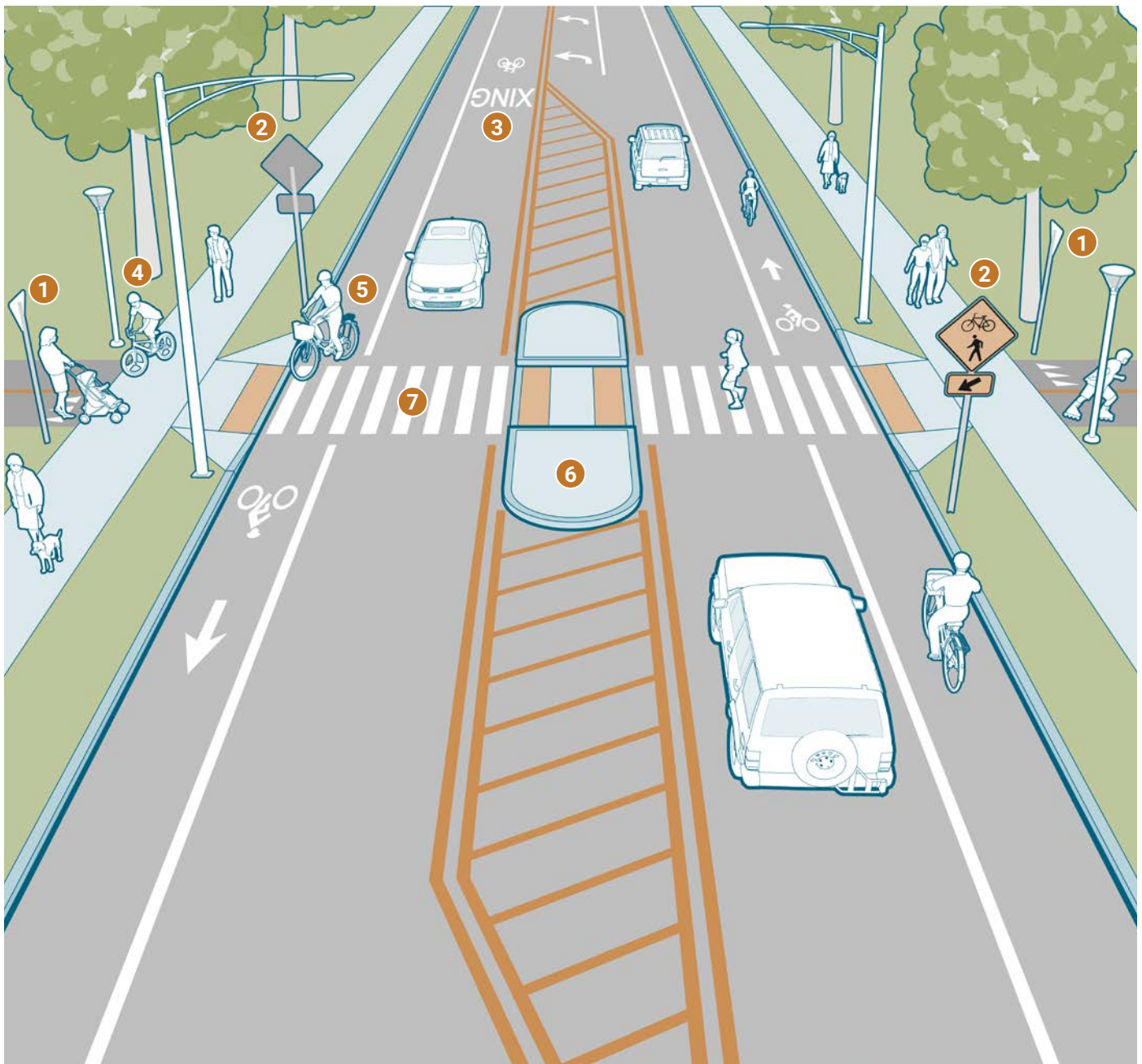
MARKINGS AND SIGNS

Pavement markings and signs can alert roadway and path users to crossings and should be coordinated closely with the crossing control markings and signs. High-visibility crosswalks can improve visibility. **7** Paired with advanced stop or yield lines, high-visibility crosswalks are useful when paths cross roadways with multiple travel lanes to improve sight lines between path users and vehicles in the second or third lane. Additional treatments such as Rectangular Rapid Flashing Beacons or pedestrian hybrid beacons may be justified at some crossings.

Wayfinding signs can be used at intersections to inform path users of the roadway ahead or of key destinations in the vicinity. All wayfinding signs should comply with the **MUTCD**.

PATH WIDTH

Shared use paths can experience conflicts due to the width of the path. For more information, refer to the design topic on **Shared Use Paths**.



OBSTRUCTIONS

Objects that may destabilize or distract path users should not be used at intersections since path users must be able to focus their attention on intersecting traffic. Particularly at intersections, path surfaces should be well-maintained and smooth. The intersection approach should be free of obstructions such as bollards, vegetation, and signs.

LIGHTING AND MAINTENANCE

Sufficient lighting is key to ensuring visibility of all modes. Lighting is especially important at unsignalized midblock intersections so pedestrians are visible where the potential for conflict exists. Consideration should be given to lighting for activities during non-daylight hours.

Maintenance should be performed routinely to eliminate uneven surfaces and trim vegetation.

CASE STUDIES

RAISED TRAIL CROSSING BURKE-GILMAN TRAIL SEATTLE, WA

The midblock crossing of 30th Avenue NE and the Burke-Gilman Trail in Seattle, WA was rebuilt in 2014 and included several new design treatments. The trail crossing location is extremely busy with approximately one million trail users per year, which increases the importance for safety and quality design. The key feature of the redesign was a raised trail crossing on 30th Avenue NE, that allows bicyclists to cross the roadway at the same grade as the Burke-Gilman Trail and signifies that trail users are prioritized. The raised intersection was designed to reduce vehicle speeds, create greater visibility, and reduce conflicts between motorists and trail users. The project also included widened sidewalks, new street and trail signs, new curb ramps, and a landscaped buffer between the sidewalk and roadway.



PRIORITIZED PATHWAY CAPITAL CITY TRAIL MADISON, WI

The Capital City Trail is a popular shared use path in Madison, Wisconsin's densely-developed downtown isthmus. The City has made the path crossings safer at many intersections by adding curb extensions, high-visibility crosswalk markings, and warning signs to alert roadway users of the path crossing. The path's permanent bike counters display bicycle volumes in real time. These volumes typically range from 2,500–4,000 bicyclists per day, depending on the day of the week. Currently, bicyclists on the Capital City Trail must yield or stop to motorists at most crossings, but given the path's popularity several crossings have been changed to require motorists to stop for path users. Future path crossings being planned by the City will prioritize path users.



FOR MORE INFORMATION

American Association of State Highway and Transportation Officials. *Guide for the Development of Bicycle Facilities*. 2012.

American Association of State Highway and Transportation Officials. *Guide for the Planning, Design, and Operation of Pedestrian Facilities*. 2004.

Federal Highway Administration. *Guidance Memorandum on Promoting the Implementation of Proven Safety Countermeasures*. 2012.

Federal Highway Administration. *Manual on Uniform Traffic Control Devices*. 2009.

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SHARED STREETS



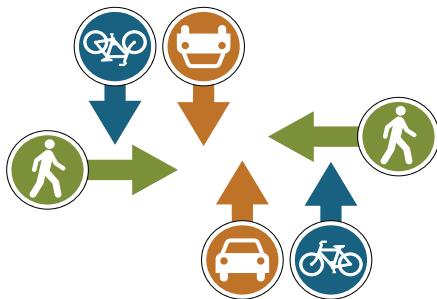
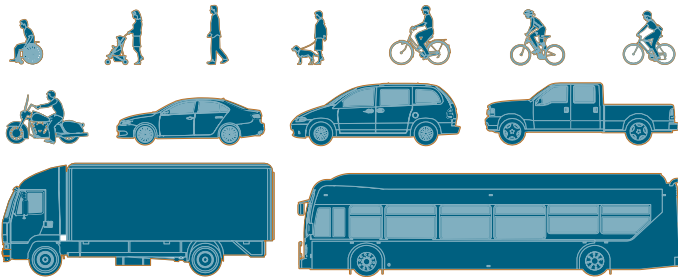
Source: Payton Chung (Creative Commons)

Shared streets, also called flush streets or woonerfs, prioritize pedestrian and bicycle movement by slowing vehicular speeds and communicating clearly through design features that motorists must yield to all other users. Shared streets use various design elements to blur the boundary between pedestrian and motor vehicle space. The design should create conditions where pedestrians and bicyclists can walk or ride on the street and cross at any location, as opposed to at designated locations. This encourages cautious behavior on the part of all users, which in turn reinforces slower speeds and comfortable walking and bicycling conditions.

By slowing the travel speed of all modes, shared streets encourage social interaction and lingering. They support a variety of adjacent land uses including commercial and retail, entertainment venues, restaurants, offices, and residences, while still accommodating commercial loading and transit operations. Shared streets have also been shown to increase economic vitality and vibrancy.

FHWA encourages additional research and best practice review for shared streets, specifically relating to accessibility. Potential topics include existing European planning and guidance, design techniques to distinguish pedestrian-only and shared space, effects of surface materials (e.g., pavers, cobblestones, etc.), interpretation of hard versus soft edges, and impacts of grates, slopes, and crossing treatments.

COMMON USERS IN CONFLICT AND TYPICAL CRASH TYPES



Poor communication to all users on shared streets can contribute to crashes.

GUIDING PRINCIPLES TO REDUCE CONFLICTS

SAFETY

The design, operations, and maintenance of shared streets should encourage lower vehicle speeds, reducing the likelihood and severity of crashes.

ACCOMMODATION AND COMFORT

Shared streets should communicate clearly that motorists are guests on the street and must proceed slowly and cautiously.

COHERENCE

Design details should communicate clearly that the shared street is a multimodal environment where pedestrians are given priority.

PREDICTABILITY

On shared streets, the lack of predictability of all users heightens awareness, thereby creating lower vehicle speeds and reducing conflicts.

CONTEXT-SENSITIVITY

The shared street should support adjacent land uses and support economic and livability goals.

EXPERIMENTATION

Shared street design should use creative means to delineate space for pedestrians with vision disabilities.

DESIGN STRATEGIES

DESIGN SPEED

Shared streets are considered self-enforcing roads, designed and operated primarily for pedestrian traffic. Designs for shared streets should lead to slow vehicular speeds. The maximum design speed should not exceed 20 mi/h. However, the preferred design speed is between 10 and 15 mi/h. For more information, refer to the design topics on **Traffic Calming and Design Speed** and **Slow Streets**.

VOLUME CONSIDERATIONS

Local access streets with relatively high pedestrian demands tend to be good candidates for shared street treatments. Shared streets should have no more than 100 vehicles during the peak hour for pedestrians to feel comfortable sharing the road with motorists (**FHWA Pedestrian Safety Guide and Countermeasure Selection System 2013**). If volumes exceed this threshold, designers can consider restricting access for specific vehicle types to reduce volumes. If vehicular volumes are too high, pedestrians will avoid the middle part of the street. Depending on the role of the shared street in the transportation network, personal vehicles may be directed to alternative routes; while taxis and freight and transit vehicles are allowed. Emergency access should be maintained on shared streets.

INTERSECTION CONSIDERATIONS

At intersections, designers should consider traditional marked crosswalks and detectable warning surfaces in order to alert pedestrians of potential vehicular conflicts. Consider alerting drivers entering the shared street of the intended use of the space and the appropriate speed by using gateway features such as signs, raised crossings ①, raised intersections, or curb extensions. For more information, refer to the design topic on **Intersection Geometry**. Signs should be warning signs with the wording such as SHARED STREET. ② An advisory speed plaque can supplement the warning sign. Signs should comply with the **MUTCD**.

ALLEYWAYS

Alleyways are typically narrow streets behind buildings providing service access. They feature relatively low vehicular volumes and may operate unofficially as shared streets. Shared alleyways make the space more accessible for all users. Removing curbs and adding gateway treatments can help alert users of the shared space. Designers can also use paving treatments such as permeable pavements to assist with stormwater management. All paving surfaces must meet pedestrian accessibility requirements. ③

MULTIPURPOSE SHARED STREETS

Shared streets offer a great deal of flexibility in how the space is designed and used. Without vertical curbs, the street can be closed to offer space for events, or more comfortably provide outdoor seating space for cafés and restaurants. Designers have several options for drainage design and the delineation of space. Through the thoughtful use of urban design principles, these streets can enhance the sense of place and emphasize the pedestrian and bicycle priority of the street.

A multipurpose shared street allows different uses of the space on different days of the week, times of day, or seasons, extending the public space at times of celebration, special events, or festivals. Sidewalks, parking, and vehicle travel lanes can be available at various times. Movable planters, metal barricades, or signs can regulate the use of the space on a temporary or regularly scheduled basis. ④

REMOVING VERTICAL CURBS

Typically, shared streets do not use vertical curbs—the entire street surface is flush, with minimal separation between sidewalks and the travel way. While vertical curbs discourage motor vehicle encroachment, they have limited ability to prevent a vehicle from driving onto the sidewalk. There are several techniques available to designers to control drainage and help delineate the roadway edge, which are typical uses of curbs.

CONSIDERATIONS

- Surface or pavement materials of varying textures, patterns, and colors provide visual cues for each mode. Trench grates can provide a visual and tactile distinction between pedestrian-only space and space where motorists may be present. Vertical elements such as lighting, bollards, street trees, planters, and furnishings can also delineate the space.
- Stormwater can be captured without vertical curbs through proper grading and drainage techniques. A valley gutter can be provided along a flush curb, such as between parking and the travel way. Valley gutters can convey stormwater to inlets or to green infrastructure such as tree pits or rain gardens that may also provide shade and vegetation.





3 ALLEYWAY



4 MULTIPURPOSE STREET

ACCESSIBILITY

Shared streets should be designed carefully for people with disabilities. This can be done by providing a frontage zone along buildings where a traditional sidewalk is located. The frontage zone can be delineated with different paving treatments, drainage infrastructure, trees, street furniture, art, or parking. Paving textures in the frontage zone should be smooth and vibration free, with a minimum of 5 feet clear space. For more information, refer to the design topic on **Accessibility**.



CASE STUDIES

WINTHROP STREET CAMBRIDGE, MA

Many streets in Cambridge were first constructed centuries ago in constrained rights-of-way with narrow sidewalks that do not meet accessibility standards. As a result, pedestrians tend to walk within the roadway on these streets. The City's regulations allow for shared streets in which vehicular traffic mixes with bicyclists, pedestrians, and loading activity. These streets are designed for motorists to yield to pedestrians, use caution, and travel slowly. Winthrop Street is designed so that the sidewalk and roadway are flush. Pedestrian-only space is delineated from space where vehicles are permitted by different-colored pavers, flush curbing, bollards, and planters. Movable planters are also used to close the street to vehicular traffic at certain times of day.



FIRST STREET NORTH JACKSONVILLE BEACH, FL

First Street is a beachfront destination, running parallel to the Atlantic Ocean and providing access to Jacksonville Beach, residences, restaurants, shops, and hotels. The City of Jacksonville Beach decided to implement the shared street concept by removing road markings and putting vehicles at the same plane as pedestrians. The street has pedestrians, vehicles, and bicyclists on even footing, with equal rights to the street. This causes drivers to slow and give way to other users.

As an additional benefit of the flush condition, the street creates universal access without the need for designated curb ramps. The City felt this was an important feature for accessibility as well as for those visiting the beach with coolers, chairs, and strollers.



FOR MORE INFORMATION

American Association of State Highway and Transportation Officials. *A Policy on the Geometric Design of Highways and Streets*. 2011.

American Association of State Highway and Transportation Officials. *Guide for the Planning, Design, and Operation of Pedestrian Facilities*. 2004.

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United States Access Board. *Proposed Guidelines for Pedestrian Facilities in the Public Right-of-Way*. 2011.

CONCLUSION

CONCLUSION

This resource provides practical real-world planning and design information to help communities achieve connected pedestrian and bicycle networks. These networks help people of all ages and abilities get where they need to go, including to and from jobs, school, grocery stores, health care, recreation, and transit. Complete multimodal networks enhance access to opportunity for everyone and help reconnect communities.

The techniques highlighted in this resource draw from a broad range of existing national design guidelines and references. They improve safety for all roadway users, and at the same time make walking and biking for transportation more comfortable, thereby encouraging more people to view these modes as viable transportation choices.

The Federal Highway Administration encourages its partners and stakeholders to use this information not only to inform the planning and project design process at the local, regional, and State level, but also to update national design guidelines and references.



For More Information:

Visit http://www.fhwa.dot.gov/environment/bicycle_pedestrian

FHWA-HEP-16-055