2024 AASHTO Bike Guide 5th Edition

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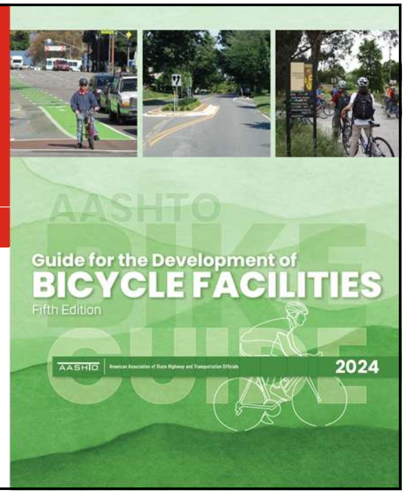
apbp ASSOCIATION OF PEDESTRIAN & BICYCLE PROFESSIONALS Expertise for Active Transportation



1

A Historical Perspective on the AASHTO Guide and the Impact of the Vehicular Cycling Movement

Bill Schultheiss, Rebecca Sanders, and Jennifer Toole

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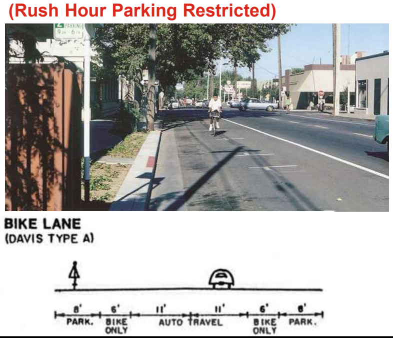
1967 – 1972 Davis California

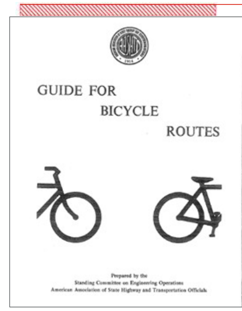
3rd Street Bike Lane
(Rush Hour Parking Restricted)

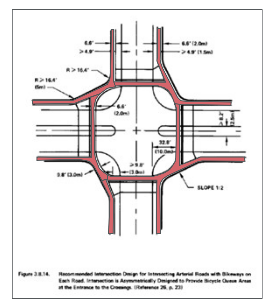


Sycamore Street
Barrier/Parking Protected Bike Lane

3

1974 AASHTO Bike Guide





Protected Bike Lanes & Intersections

Davis, California 1967

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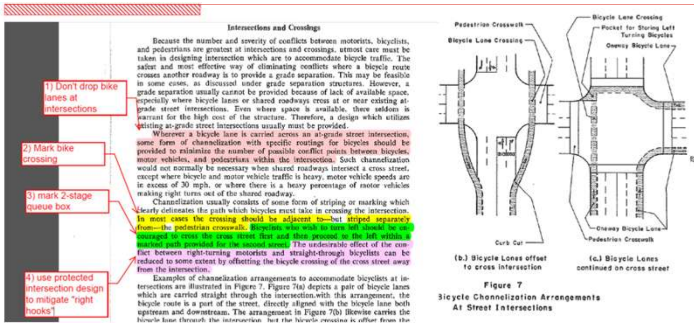
1974 AASHTO Bike Guide



Intersections and Crossings

Because the number and severity of conflicts between motorists, bicyclists, and pedestrians are greatest at intersections and crossings, utmost care must be taken in designing intersection which are to accommodate bicycle traffic. The safest and most effective way of eliminating conflicts where a bicycle route crosses another roadway is to provide a grade separation. This may be feasible in some cases, as discussed under grade separation structures. However, a grade separation usually cannot be provided because of lack of available space, especially where bicycle lanes or shared roadways cross at or near existing at-grade street intersections. Even where space is available, there seldom is warrant for the high cost of the structure. Therefore, a design which utilizes existing at-grade street intersections usually must be provided.

Wherever a bicycle lane is carried across an at-grade street intersection, some form of channelization with specific routings for bicycles should be provided to minimize the number of possible conflict points between bicycles, motor vehicles, and pedestrians within the intersection. Such channelization would not normally be necessary when shared roadways intersect a cross street, except where bicycle and motor vehicle traffic is heavy, motor vehicle speeds are in excess of 30 mph, or where there is a heavy percentage of motor vehicles making right turns out of the shared roadway.

Channelization usually consists of some form of striping or marking which clearly delineates the path which bicycles must take in crossing the intersection. In most cases the crossing should be adjacent to—but striped separately from—the pedestrian crosswalk. Bicyclists who wish to turn left should be encouraged to cross the cross street first and then proceed to the left within a marked path provided for the second street. The undesirable effect of the conflict between right-turning motorists and straight-through bicyclists can be reduced to some extent by offsetting the bicycle crossing of the cross street away from the intersection.

Examples of channelization arrangements to accommodate bicyclists at intersections are illustrated in Figure 7. Figure 7(a) depicts a pair of bicycle lanes which are carried straight through the intersection.with this arrangement, the bicycle route is a part of the street, directly aligned with the bicycle lane both upstream and downstream. The arrangement in Figure 7(b) likewise carries the bicycle lane through the intersection, but the bicycle crossing is offset from the

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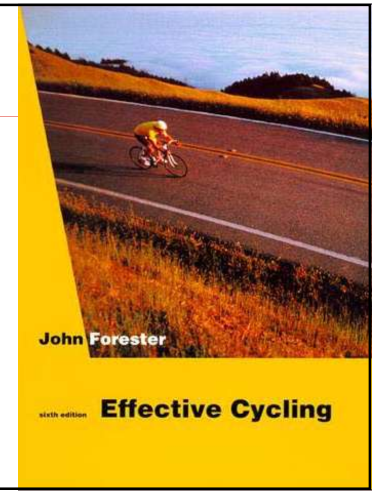
1975 Effective Cycling

"Cyclists fare best when they act and are treated as drivers of vehicles"



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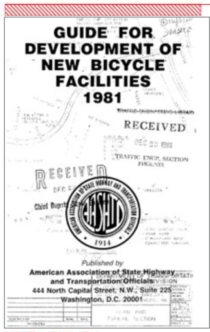
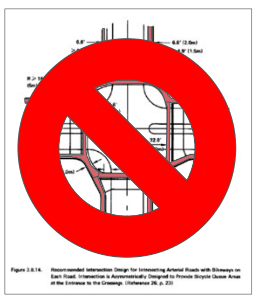
1981 AASHTO Bike Guide



GUIDE FOR DEVELOPMENT OF NEW BICYCLE FACILITIES 1981

RECEIVED

Published by American Association of State Highway and Transportation Officials 444 North Capitol Street, N.W., Suite 225 Washington, D.C. 20001



Protected Bike Lanes & Intersections

Davis, California 1967

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"Communities across the country are all different, but the AASHTO Bike Guide allows each of those communities to learn how to grow, maintain, and operate their bicycle infrastructure – allowing for more transportation options for those who cannot or choose not to drive"

AASHTO Executive Director Jim Tymon

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Who should the default design user be?

Experienced & Confident Bicyclist
AASHTO 1981 - 2012

Interested but Concerned Bicyclist
AASHTO 2024

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2012 Guide compared to 2024 Guide

2012 Guide	2024 Guide	Notable Changes of 2024 compared to 2012
Chapter 1. Introduction	1. Introduction	REWRITE with new discussion of design range concept
Chapter 3. Bicycle Operation and Safety	2. Bicycle Operation & Safety	REWRITE of former Chapter 3
Chapter 2. Bicycle Planning	3. Bicycle Planning	REWRITE and NEW CONTENT added to former Chapter 2
	4. Facility Selection	NEW CHAPTER with a few items carried from Chapter 2
	5. Elements of Design	NEW CHAPTER with some content pulled from Chapters 4 and 5
Chapter 5. Design of Shared Use Paths	6. Shared Use Paths	REVISION of Chapter 5
	7. Separated Bike Lanes	NEW CHAPTER with new content
	8. Bicycle Boulevards	NEW CHAPTER with new content
Chapter 4. Design of On-Road Facilities	9. Bike Lanes & Shared Lanes	REVISION of Chapter 4
	10. Traffic Signals and Active Warning Devices	NEW CHAPTER with new content
	11. Roundabouts, Interchanges, and Alternative Intersections	NEW CHAPTER with new content
	12. Rural Area Bikeways	NEW CHAPTER with some content pulled from Chapter 4
	13. Structures	NEW CHAPTER with some content pulled from Chapter 5
	14. Wayfinding	NEW CHAPTER with some content pulled from Chapter 4
Chapter 7. Maintenance and Operations	15. Maintenance & Operations	REVISION of chapter 7
Chapter 6. Bicycle Parking Facilities	16. Parking, Bike Share, & End of Trip Facilities	REVISION of chapter 6

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Chapter 1 – Introduction

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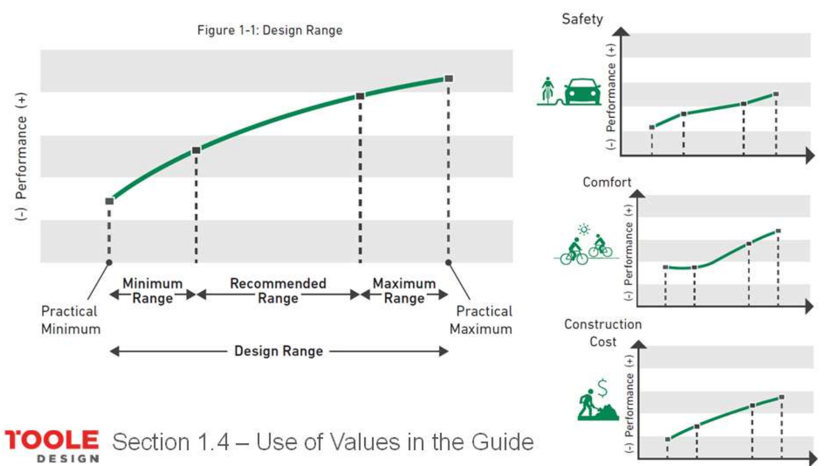

TOOLE DESIGN Section 1.4 – Use of Values in the Guide

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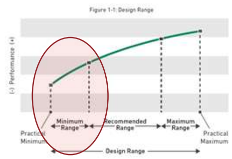
Section 1.4 – Use of Values in the Guide

1.4.1. Minimum Range

The use of **values within the minimum range should be minimized** because they are likely to diminish mobility, safety, and comfort



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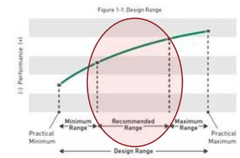
Section 1.4 – Use of Values in the Guide

1.4.2. Recommended Values Range

The use of **values within the recommended range should be chosen** to maximize mobility, safety and comfort benefits for bicyclists as well as other users.

These values were determined by research or established best practice.



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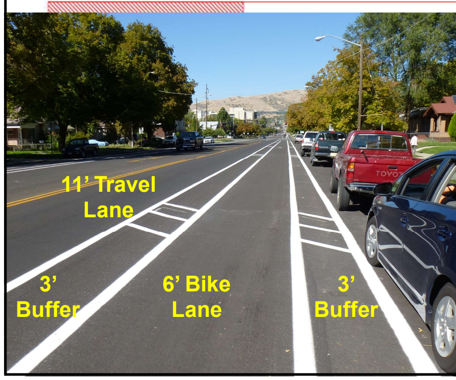
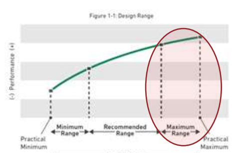
Section 1.4 – Use of Values in the Guide



1.4.3. Maximum Range

The use of **values within the practical maximum range should only be considered when:**

- there are clear benefits to all users and
- bicyclist volumes are high.



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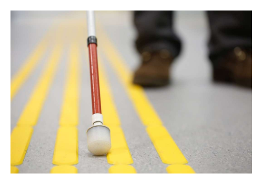
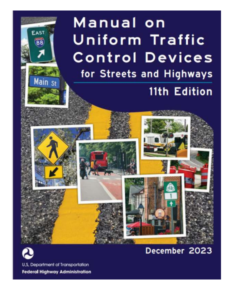
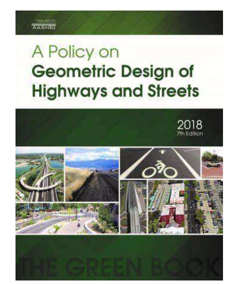
Section 1.6 - Relationship to Other Manuals



Accessibility Guidelines for Pedestrian Facilities in the Public Right-of-Way (PROWAG)





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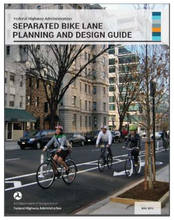
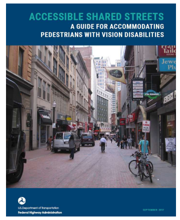
Section 1.6 - Relationship to Other Manuals



FHWA Separated Bike Lane Planning and Design Guide
May 2015

FHWA Achieving Multimodal Networks
August 2016



FHWA Accessible Shared Streets
September 2017

NACTO Urban Bikeway Design Guide
January 2025

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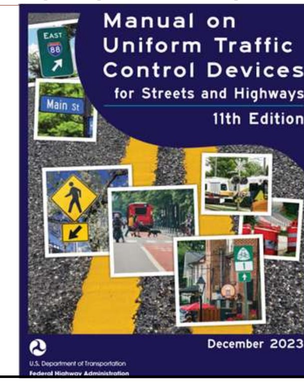
1.6.1. Manual on Uniform Traffic Control Devices for Streets and Highways (MUTCD)

MUTCD defines design and application of traffic control devices (TCDs).

2024 Bike Guide conforms to MUTCD 11th Edition

Includes some TCDs that require experimental approval by FHWA (located at the end of their respective section)

AASHTO expands upon the application of TCDs



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Experimental Treatments in AASHTO Bike Guide

Regulatory Sign

Detection Confirmation Lights

Green-Backed Shared Lane Markings

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Section 1.8 - Definitions

Bicyclist Design User Profile – A **generalized profile of different types of bicyclists based on their comfort when bicycling with motor vehicle traffic**, as well as their bicycling skills and experience. Profiles range from Highly Confident to Somewhat Confident to Interested but Concerned.

Bicycle Facilities – **A general term** denoting provisions to accommodate or encourage bicycling, including bikeways, bicycle boulevards, bicycle detection, in addition to parking and storage facilities.

Bikeway – Any road, path, or facility intended for bicycle travel which **designates separate space for bicyclists distinct from motor vehicle traffic or a bicycle boulevard designed for bicyclist travel priority**. A bikeway does not include shared lanes, sidewalks, signed routes, or shared lanes with shared lane markings.

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Chapter 2 - Bicycle Operation and Safety

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2.2.1. Relationship between Perceived Comfort and Substantive Safety

Research has found a significant relationship between

- how safe and comfortable people feel bicycling,
- whether and how often they bicycle,
- preferences for facility types, and the provision of those facilities.

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2.2.1. Relationship between Perceived Comfort and Substantive Safety

Crashes and near-crash experiences influence perceived bicycling safety and comfort
(Lee et al., 2015; Sanders, 2015; Aldred & Crossweller, 2015)

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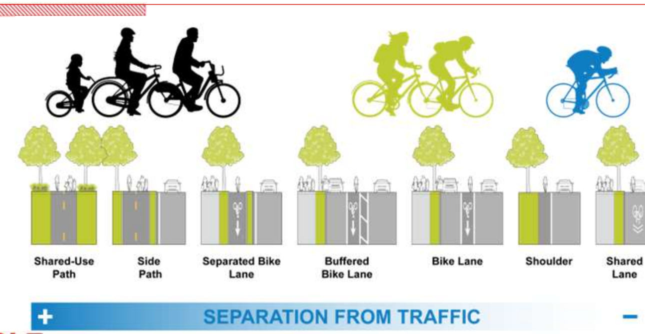
Comfort Increases with Separation



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2.2.2. Safety in Numbers

Bicyclist risk does not increase proportionately to their increased volume, but actually **decreases as the number of bicyclists increases.**

Example
15th Street, NW
Washington DC

Shared Lane
2010: <100 cyclists /day

Separated Bike Lane
2017: 2,500 cyclists /day

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2.3. Bicyclist Design User Profiles

Comfort Typology of Bicyclists				
Design User Profile	Non-Bicyclist	Interested but Concerned	Somewhat Confident	Highly Confident
Bicycling Preferences	Uncomfortable bicycling in any condition, have no interest in bicycling, or are physically unable to bicycle.	Often not comfortable with bike lanes; may bike on sidewalks even if bike lanes are provided. Prefer off-street or separate bicycle facilities or quiet or traffic-calmed residential roads. May not bike at all if bicycle facilities do not meet needs for perceived comfort.	Generally prefer more separated facilities, but comfortable riding in bicycle lanes or on paved shoulders if need be.	Comfortable riding with traffic; will use roads without bike lanes.
Percent of Population	31–37%	51–56%	5–9%	4–7%

Figure 2-2: Comfort Typology of Bicyclists (See Chapter 2 References: Dill and McNeill, 2016)

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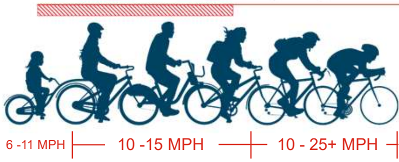
Section 2.4 – Safety and Performance Characteristics by Age



6 -11 MPH — 10 -15 MPH — 10 - 25+ MPH

Children: 6.5 – 11.5 mph

Adults:
- Median Speed: 9.7 mph
- Design Speed: 15 mph

Reaction Time:
- 1.5 seconds (expected stop)
- 2.5 seconds (unexpected stop)

Typical Adult Upright Bicyclist Performance Characteristics		
Feature	Value	Recommended Default Design Value
Speed, paved level terrain	8.0–15.0 mph	15 mph design speed 8.0 mph (intersection crossing speed) 11 mph (intersection approach speed)[b]
Speed, downhill[c]	For every 1% increase in downhill grade, speed is increased by 0.53 mph.	—
Speed, uphill[c]	For every 1% increase in uphill grade, speed is reduced by 0.90 mph.	—
Perception reaction time	1.0–2.5 s	1.5 s[a] (expected stop) 2.5 s[a] (unexpected stop)[b]
Acceleration rate[d]	2.0–5.0 ft/s²	2.5 ft/s²
Coefficient of friction for braking, dry level pavement	0.1–0.8	0.32[e]
Coefficient of friction for braking, wet level pavement	0.16	0.16
Deceleration rate (dry level pavement)[e]	8.0–10.0 ft/s²	10.0 ft/s²
Deceleration rate for wet conditions	2.0–5.0 ft/s²	5.0 ft/s²

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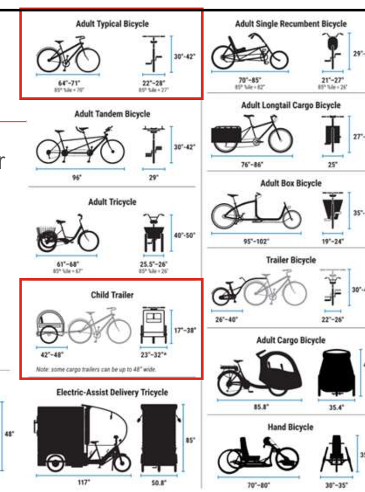
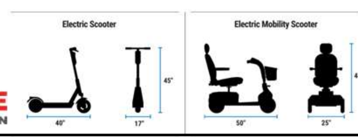
2.5. Types of Bikes

- Typical Design Vehicle: Adult bike + Trailer
- 10' Length for Refuge
- 10'-15' Turn Radius – 5' Minimum
- Recommendations will accommodate scooters and most other micromobility





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2.5.3 Bicyclist Spaces

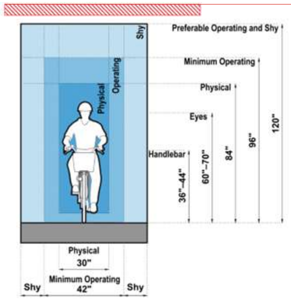

Figure 2-5: Typical Adult Bicyclist Operating Space

Table 2-5: Bicyclist Lateral Shy Distance to Physical Elements

Physical Element	Shy Distance (in.)	
	Practical Minimum	Recommended Range
Intermittent Elements (such as tree, flex post, pole)*	0	24–36
Traffic Signs and Supportive Posts on Curbed Roadways	12	24–36
Traffic Signs and Supportive Posts adjacent to Shared Use Paths	24	36–48
Continuous Elements (such as fence, railing, planter)	12	24–36
Vertical Curbs	6	12–24
Mountable or Sloping Curbs	0	6–12

** To reduce crash risks, eliminating the shy distance is not preferable as any additional shy distance will be beneficial.*

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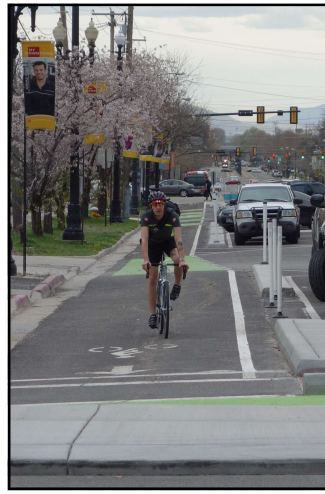

2.7 Guiding Principles for Bicyclist Safety

Reduced injury risk for SBL compared to bike lanes and shared lanes
(Lusk et al., 2013; Lusk et al., 2011; NYCDOT, 2014; Winters et al., 2013)

SBL preferred over striped or shared lanes by both cyclists and motorists
(Monsere et al., 2014; Monsere et al., 2012; Sanders, 2014)

One-way generally safer than two-way
(Schepers et al., 2011; Thomas & DeRobertis, 2013)

Two-way SBLs on one-way roads, preferable on right side
(Schepers et al., 2011; Zangenehpour et al., 2015)

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Chapter 3: Bicycle Planning

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Bicycle Planning Principles

3.2.1. Safety – reduce frequency and severity of crashes by separating bicyclists from higher speed and volumes of motorists

3.2.2. Comfort – do not deter use due to safety concerns

3.2.3. Connectivity – direct, complete and continuous

3.2.4. Legibility – easy to recognize and intuitive to use

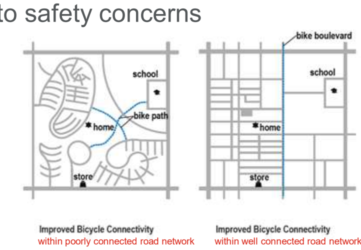

Figure 3-1: Examples of Contrasting Connectivity

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3.9.2. Quality of Service and Bicycle Level of Service Tools

3.9.2.2 Level of Traffic Stress

objective and quantitative method of classifying road segments and bikeway networks based on how comfortable bicyclists

Table 3-4: Levels of Traffic Stress[32]

Levels of Traffic Stress (LTS)	
LTS 1	Presenting little traffic stress and demanding little attention from cyclists, and attractive enough for a relaxing bike ride. Suitable for almost all cyclists, including children trained to safely cross intersections. On links, cyclists are either physically separated from traffic, or are in an exclusive bikeway next to a slow traffic stream with no more than one lane per direction, or are on a shared road where they interact with only occasional motor vehicles (as opposed to a stream of traffic) with a low speed differential. Where cyclists ride alongside a parking lane, they have ample operating space outside the zone into which car doors are opened. Intersections are easy to approach and cross.
LTS 2	Presenting little traffic stress and therefore suitable to most adult cyclists but demanding more attention than might be expected from children. On links, cyclists are either physically separated from traffic, or are in an exclusive bicycling zone next to a well-confined traffic stream with adequate clearance from a parking lane, or are on a shared road where they interact with only occasional motor vehicles (as opposed to a stream of traffic) with a low speed differential. Where a bike lane lies between a through lane and a right-turn lane, it is configured to give cyclists unambiguous priority where motor vehicles cross the bike lane and to keep speeds in the right-turn lane comparable to bicycling speeds. Crossings are not difficult for most adults.
LTS 3	More traffic stress than LTS 2, yet markedly less than the stress of integrating with multilane traffic, and therefore welcome to many people currently riding bikes in American cities. Offering cyclists either an exclusive bikeway next to moderate-speed traffic or shared lanes on streets that are not multilane and have moderately low speed. Crossing may be longer or across higher-speed roads than allowed by LTS 2, but still considered acceptably safe to most adult bicyclists.
LTS 4	A level of stress beyond LTS 3. Bicyclist mix with motor vehicle traffic. Generally uncomfortable for most adults.

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Chapter 4 - Guidance for Choosing a Bikeway Type

- 4.1 Introduction
- 4.2 Project Performance Goals and Objectives
- 4.3 Selecting the Preferred Bikeway Type
- 4.4 Strategies to Achieve the Preferred (or Next Best) Design
- 4.5 Evaluating Design Alternatives and Trade-offs to Select a Bikeway

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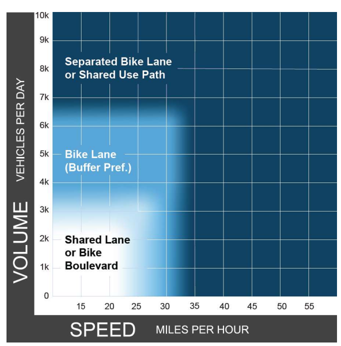
Section 4.3.1 – Streets in Urban, Suburban and Rural Town Contexts

Identifies the **preferred** bikeway type assuming:

Design User = Interested but Concerned bicyclist

Analysis = Level of Traffic Stress



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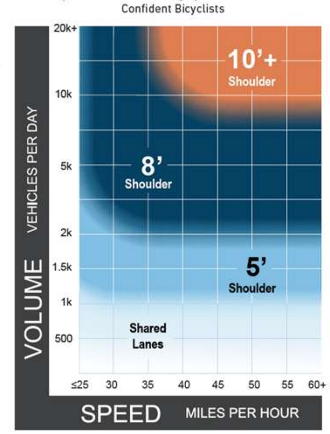
Section 4.3.2 – Rural Roadways

Identifies the **preferred** shoulder width assuming:

Design User = Confident bicyclist

Analysis = Bicycle LOS

Figure 4-2: Preferred Paved Shoulder Widths for Rural Roadways to Accommodate Highly Confident or Somewhat Confident Bicyclists



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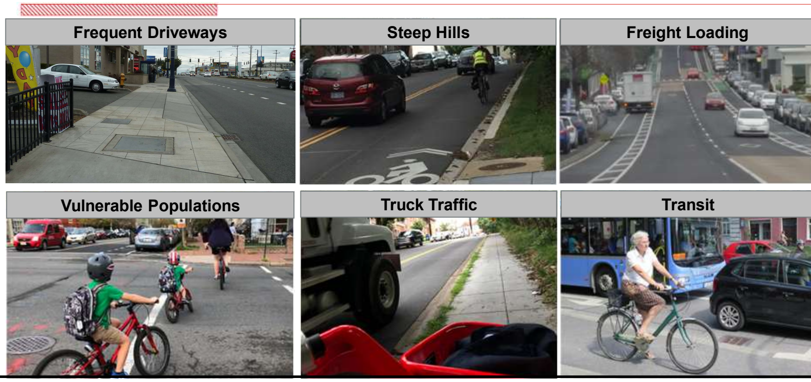
Section 4.3.3 – Conditions Where Increasing Separation from Motor Vehicles is Appropriate



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4.4.2. Example Strategies for Constrained Rights-of-Way

4.4.2.1 Traffic Analysis Approach
4.4.2.2 Narrowing Travel Lanes
4.4.2.3 Removing Travel Lanes
4.4.2.4 Reorganizing Street Space
4.4.2.5 Making Changes to On-Street Parking
4.4.2.6 Reducing Bikeway Widths
4.4.2.7 Reducing Motor Vehicle Traffic Volumes and Speeds

4.5.2. Example of Trade-off Considerations Between Common Bikeway Types

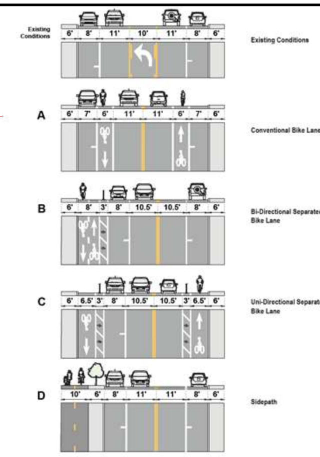

Figure 4-3: Common Bikeway Options within a 48-ft Cross Section

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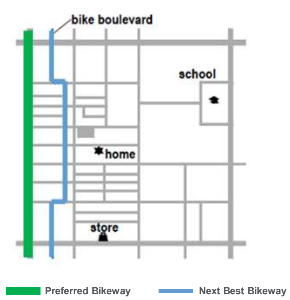
4.5.3. Selecting the Next Best Facility When the Preferred Bikeway Is Not Feasible

Alternative Route

If no other design improvements are feasible, it is necessary to consider alternative parallel routes.

Research indicates that for an alternative low-stress route to be viable, **the increase in trip length should be less than 30 percent.**

Broach, J., Dill, J., and J., Gliebe. Where Do Cyclists Ride? A Route Choice Model Developed with Revealed Preference GPS Data



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Chapter 5 – Elements of Design

5.1 Introduction
5.2 Design User
5.3 Design Speed
5.4 Understanding Assignment of Right of Way
5.5 Sight Distance
5.6 Surface and Geometric Design Elements
5.7 Characteristics of Intersections
5.8 Intersection Design Objectives
5.9 Evaluating Bicycle and Pedestrian Roadway Crossings
5.10 Geometric Design Treatments to Improve Intersection Safety
5.11 Warning and Regulatory Traffic Control Devices
5.12 Pavement Markings
5.13 Bicycle Travel Near Rail Lines
5.14 Other Design Features

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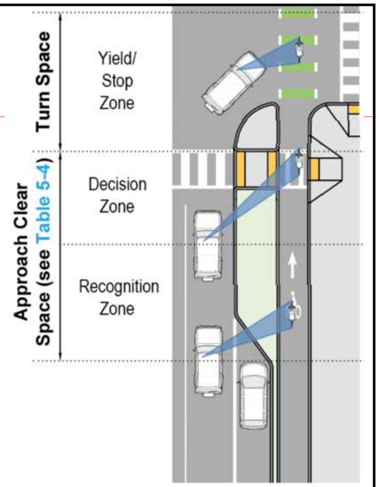
Section 5.4 – Understanding Assignment of Right of Way

All street users need opportunity for Mutual Identification because:

- Motorists & bicyclists must yield to pedestrians in crosswalks
- Pedestrians cannot suddenly leave the curb if vehicles too close to stop
- Motorists must exercise due care to avoid colliding with bicyclists/peds

The approach to a conflict point is composed of three zones.



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5.5.2. Stopping Sight Distance

Tables provided for:

- Unexpected Conflict, 2.5 second PRT
- Expected Conflict, 1.5 second PRT

Table 5-2: Minimum Bicyclist Stopping Sight Distance vs. Grades for Various Design Speeds—2.5-Second Reaction Time

Stopping Sight Distance (ft) Based on Speed and Grade for a 2.5-Second Perception-Reaction Time											
Speed (mph)	Grade (Positive indicates ascending)										
	–10%	–8%	–6%	–4%	–2%	0	2%	4%	6%	8%	10%
10				65	61	58	55	53	52	51	50
11				74	69	66	63	61	59	57	56
12				84	78	74	71	68	66	64	62
15			130	118	109	102	97	93	89	86	84
18	246	201	174	156	143	134	126	120	115	111	108
20	296	240	207	185	169	157	148	140	134	129	
25	440	353	300	266	241	222	208	196	187		
30	611	486	411	361	325	298	277	260			

Note: Calculations are assumed under wet conditions.

Table 5-3: Minimum Bicyclist Stopping Sight Distance vs. Grades for Various Design Speeds—1.5-Second Reaction Time

Stopping Sight Distance (ft) Based on Speed and Grade for a 1.5-Second Perception-Reaction Time											
Speed (mph)	Grade (Positive indicates ascending)										
	–10%	–8%	–6%	–4%	–2%	0	2%	4%	6%	8%	10%
10				50	46	43	41	39	37	36	35
11				58	53	49	47	44	43	41	40
12				66	61	56	53	50	48	46	45
15			108	96	87	80	75	71	67	64	62
18	220	175	148	130	117	107	100	94	89	85	81
20	267	211	178	155	139	128	118	111	105	100	
25	403	316	264	229	204	185	171	159	150		
30	567	442	367	317	281	254	233	216			

Note: Calculations are assumed under wet conditions.

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5.5.4.1 Sight Distance and Approach Clear Space for Bikeways at Roadway Intersections

- **Turning Motorist Yields to (or Stops for) Through Bicyclists:** When a through moving bicyclist that arrives or will arrive at the crossing prior to a turning motorist, the motorist must stop or yield.
- **Through Bicyclist Yields to (or Stops for) Turning Motorist:** When a turning motorist arrives or will arrive at the crossing prior to a through moving bicyclist, the bicyclist must stop or yield.
- **User with Right-of-Way Yields to (or Stops for) Another User:** Sometimes the user with the right-of-way will instead yield the right-of-way.
- **APPROACH CLEAR SPACE ALLOWS THIS TO FUNCTION!**

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5.5.4.1.1 Case S – Right-Turning Motorist Across Separated Bike Lane or Side Path

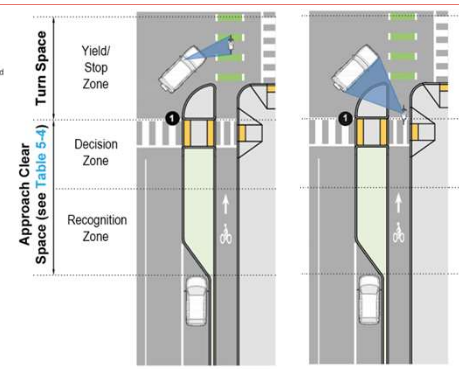
Table 5-4: Recommended Intersection Approach Clear Space by Vehicular Turning Design Speed

Effective Vehicle Turning Radius	Vehicular Turning Speed	Recommended Approach Clear Space
<18 ft	<10 mph[a]	20 ft
18 ft	10 mph	40 ft
25 ft	15 mph	50 ft
30 ft	20 mph	60 ft
>30 ft	25 mph	70 ft

[a] Most low-volume driveways and alleys

legend

line of sight



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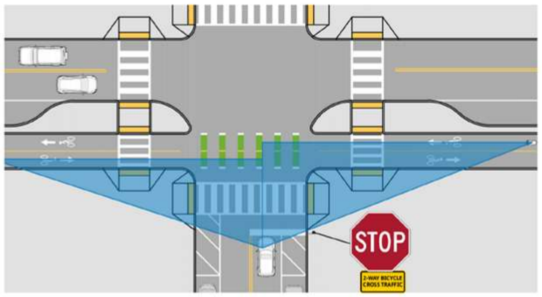
5.5.4.1.3 Case U1 – Through Motorist Crossing of a Separated Bike Lane or Shared Use Path



at a minimum the **provision of stopping sight distance for bicyclists** (Section 5.5.2) **should be provided** to allow a bicyclist to slow or stop if a vehicle encroaches into the separated bike lane or side path

legend
Case U1 sight triangles

Figure 5-3: Intersection Sight Distance: Case U1

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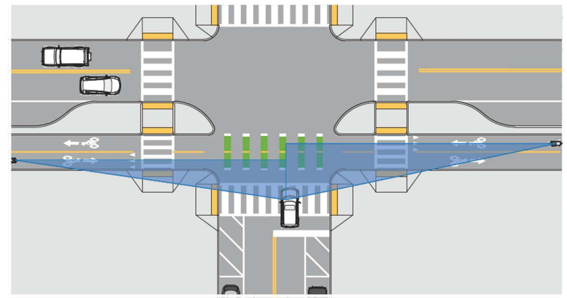
7.9.5 Case U1 – Multistep Variant



Chapter 7 sight distance

- Driver looks for pedestrians, then moves forward
- Driver looks for bicyclists, then moves forward
- Driver looks for other motorists, then proceeds

legend
Case U1 sight triangles
AASHTO *Green Book* Case B sight triangles

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5.5.4.1.3.3 U3 – Mid-Block Shared Use Path Crossing of an Uncontrolled Roadway

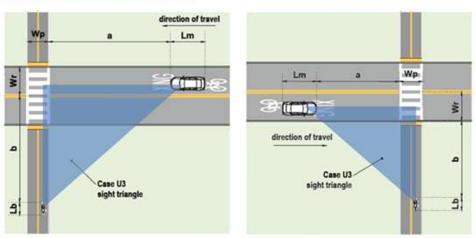

Figure 5-5: Sight Triangle for Uncontrolled Mid-Block Path Crossing of an Uncontrolled Roadway: Case U3

Table 5-8: Length of Path and Roadway Sight Triangle for Uncontrolled Crossings: Case U3

Length of Path and Roadway Sight Triangle (ft) - Case U3

Bike Speed (mph)	Roadway Speed (mph) 15 (a / b)	20 (a / b)	25 (a / b)	30 (a / b)	35 (a / b)	40 (a / b)
10	96 / 58	128 / 59	160 / 63	192 / 68	224 / 74	255 / 81
11	97 / 64	129 / 65	162 / 69	194 / 75	226 / 82	258 / 89
12	98 / 70	131 / 70	164 / 75	197 / 82	230 / 89	262 / 97
15	105 / 87	140 / 88	174 / 94	209 / 102	244 / 111	279 / 122
18	112 / 105	150 / 106	187 / 113	225 / 122	262 / 134	300 / 146
20	118 / 116	157 / 117	197 / 125	236 / 136	275 / 149	315 / 162
25	133 / 145	178 / 147	222 / 156	266 / 170	311 / 186	355 / 203
30	149 / 174	199 / 176	249 / 188	298 / 204	348 / 223	398 / 244

a = sight distance (ft) along roadway
b = sight distance (ft) along path

Assumptions: Bicycle reaction time = 1.5 seconds
Width of path = 10 ft to 11 ft
Width of road lane = 11 ft to 12 ft
Length of bicycle = 6 ft
Length of motor vehicle = 18 ft
Grade = –2 percent to +2 percent

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5.5.4.3 Sight Distance at Horizontal Curves

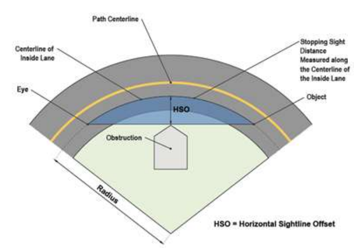

Figure 5-10: Diagram Illustrating Components for Determining Horizontal Sightline Offset

Table 5-11: Horizontal Sightline Offset Look-Up

Minimum Lateral Clearance (Horizontal Sightline Offset or HSO) for Horizontal Curves (ft)

R (ft)	S = Stopping Sight Distance (ft) 40	60	80	100	120	140	160	180	200	220	240	260	280	300
25	7.6	15.0												
50	3.9	8.7	15.2	23.0	31.9	41.5								
75	2.7	5.9	10.4	16.1	22.8	30.4	38.8	47.8	57.4	67.2				
100		4.5	7.9	12.2	17.5	23.5	30.3	37.8	46.0	54.6	63.8	73.3	83.0	92.9
125		3.6	6.3	9.9	14.1	19.1	24.7	31.0	37.9	45.4	53.3	61.7	70.6	79.7
150		3.0	5.3	8.3	11.8	16.0	20.8	26.2	32.1	38.6	45.5	52.9	60.7	69.0
175		2.6	4.6	7.1	10.2	13.8	18.0	22.6	27.8	33.5	39.6	46.1	53.1	60.5
200			4.0	6.2	8.9	12.1	15.8	19.9	24.5	29.5	34.9	40.8	47.0	53.7
225			3.5	5.5	8.0	10.8	14.1	17.8	21.9	26.4	31.3	36.5	42.2	48.2
250			3.2	5.0	7.2	9.7	12.7	16.0	19.7	23.8	28.3	33.1	38.2	43.7
275			2.9	4.5	6.5	8.9	11.6	14.6	18.0	21.7	25.8	30.2	34.9	39.9
300			2.7	4.2	6.0	8.1	10.6	13.4	16.5	19.9	23.7	27.7	32.1	36.7
350				3.6	5.1	7.0	9.1	11.5	14.2	17.1	20.4	23.9	27.6	31.7
400				3.1	4.5	6.1	8.0	10.1	12.4	15.0	17.9	20.9	24.3	27.8
450				2.8	4.0	5.4	7.1	9.0	11.1	13.4	15.9	18.7	21.6	24.8
500				2.5	3.6	4.9	6.4	8.1	10.0	12.1	14.3	16.8	19.5	22.3
600					3.0	4.1	5.3	6.7	8.3	10.1	12.0	14.0	16.3	18.7
700					2.6	3.5	4.6	5.8	7.1	8.6	10.3	12.0	14.0	16.0
800						3.1	4.0	5.1	6.2	7.6	9.0	10.5	12.2	14.0
900						2.7	3.6	4.5	5.6	6.7	8.0	9.4	10.9	12.5
1000							3.2	4.0	5.0	6.0	7.2	8.4	9.8	11.2

Table 5-12: Horizontal Sightline Offset for Horizontal Curves Equation

Horizontal Sight Line Offset for Horizontal Curves Equation

$$HSO = R\left[1 - \cos\left(\frac{28.65S}{R}\right)\right]$$

$$S = \frac{R}{28.65}\left[\cos^{-1}\left(\frac{R - HSO}{R}\right)\right]$$

Where:

S	=	stopping sight distance (ft)
R	=	radius of centerline of lane (ft)
HSO	=	horizontal sightline offset, distance from centerline of lane to obstruction (ft)

Note: Angle is expressed in degrees.

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5.8. Intersection Design Objectives

5.8.1. Minimize Exposure to Conflicts
5.8.2. Reduce Speeds at Conflict Points
5.8.3. Communicate Right-of-Way Priority
5.8.4. Providing Adequate Sight Distance
5.8.5. Transitions to Other Facilities
5.8.6. Accommodating Persons with Disabilities

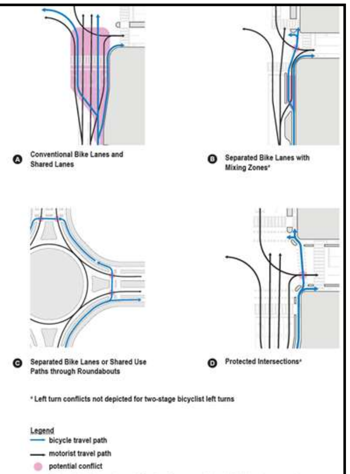

Figure 5-13: Comparison of Bicyclist Exposure to Motor Vehicles at Intersections

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5.9.2. Evaluations of Uncontrolled Roadway Approaches to Bicycle Crossings

5.9.2.1 Factors That Impact Motorist Yielding Rates

5.9.2.2.1 Recommended Crossing Opportunities

Table 5-14: Recommended Minimum Range of Hourly Crossing Opportunities

Major Street Crossings (opportunities per hour)	
Recommended	≥120
Practical Minimum	60 to <120

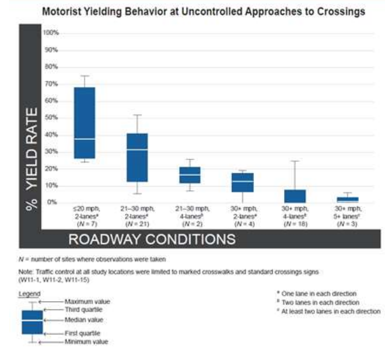

Figure 5-14: Motorist Yielding at Uncontrolled Crossings Based on Roadway Characteristics

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5.9.2.3 Apply Countermeasures to Improve Yielding

Tier 1: Signing & Markings

Tier 2: RRFB & Geometric Improvements

Tier 3: PHB, Signal, or Grade Separation

Table 5-15: Uncontrolled Crossing Evaluation

Uncontrolled Crossing Countermeasure Evaluation Table

Roadway Type	Vehicle ADT < 9,000			Vehicle ADT 9,000 - 12,000			Vehicle ADT 12,000 - 15,000			Vehicle ADT > 15,000		
Number of Travel Lanes and Median Type	Speed Limit (mph)											
	≤30	35	40≥[a]	≤30	35	40≥[a]	≤30	35	40≥	≤30	35	40≥
2 Lanes[b]	1	1	2	1	1	2	1	1	3	1	2	3
3 Lanes with Raised Median[b]	1	1	2	1	1	2	1	2	3	2	2	3
3 Lanes without Raised Median[b,d]	1	1	2	1	2	2	2	3	3	2	3	3
4 Lanes with Raised Median[c,d]	1	1	2	1	2	2	2	3	3	3	3	3
4+ Lanes without Raised Median	1	2	3	2	2	2	3	3	3	3	3	3

Notes:
[a] Where the speed limit exceeds 40 mph, Tier 3 should be considered.
[b] 1 lane in each direction.
[c] Raised medians must be at least 6 ft wide to serve pedestrians. See Figure 2-4 for different bicycle lengths to serve bicyclists. Where median width is less than these values, review category of 4+ lanes without raised median.
[d] 2 lanes in each direction.

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Section 5.10 – Geometric Design Treatments to Improve Intersection Safety

5.10.1 Medians and Pedestrian Refuge Islands; Hardened Centerlines
5.10.2 Curb Extensions
5.10.3 Curb Radius
5.10.4 Mountable Truck Aprons
5.10.5 Raised Crossings
5.10.6 Multiple Threat Crossing Treatments
5.10.7 Bike Ramps
5.10.8 Directional Indicators

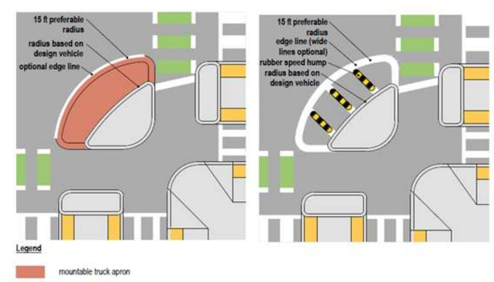

Figure 5-18: Mountable Truck Apron

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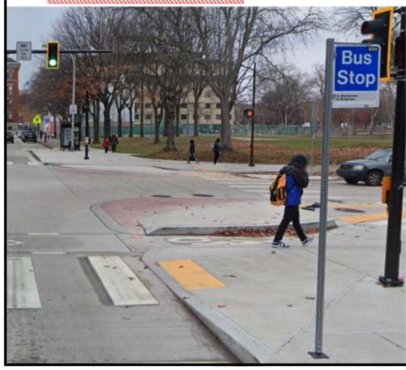
5.10.4 Mountable Truck Aprons



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Section 5.10 – Geometric Design Treatments to Improve Intersection Safety

5.10.1 Medians and Pedestrian Refuge Islands; Hardened Centerlines
5.10.2 Curb Extensions
5.10.3 Curb Radius
5.10.4 Mountable Truck Aprons
5.10.5 Raised Crossings
5.10.6 Multiple Threat Crossing Treatments
5.10.7 Bike Ramps
5.10.8 Directional Indicators

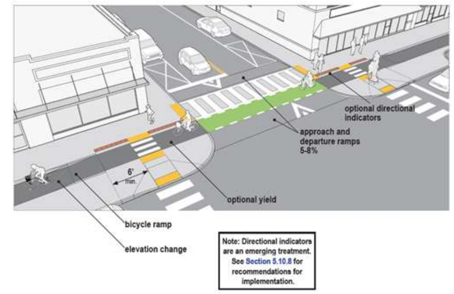

Figure 5-20: Raised Side Street Crossing

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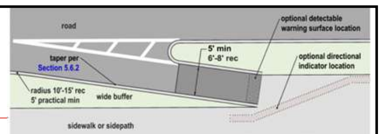
Section 5.10 – Geometric Design Treatments to Improve Intersection Safety



Detail 1—Preferred bicycle ramp alignment with wide sidewalk buffer

5.10.1 Medians and Pedestrian Refuge Islands; Hardened Centerlines
5.10.2 Curb Extensions
5.10.3 Curb Radius
5.10.4 Mountable Truck Aprons
5.10.5 Raised Crossings
5.10.6 Multiple Threat Crossing Treatments
5.10.7 Bike Ramps
5.10.8 Directional Indicators

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5.10.8 Directional Indicators

Per ISO 23599 the width of the directional indicator (DI) can vary based on use:

- If perpendicular to the pedestrian path of travel (for example to direct a pedestrian towards a mid-block crossing or transit stop), it must be a minimum width of 2 ft to be detectable.
- If parallel to the pedestrian path of travel, it can be as narrow as 1 ft.
- At some locations (such as near intersections) pedestrian paths may interact with directional indicators both parallel and perpendicular, and in these situations the wider width should be used.

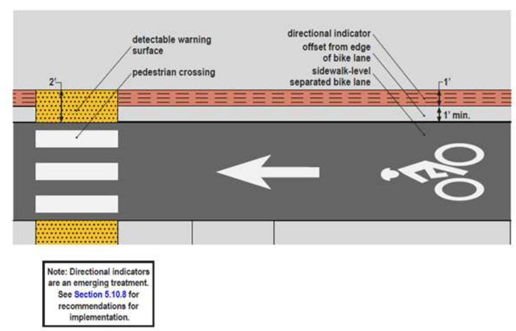

Figure 5-24: Sidewalk-Level Separated Bike Lane with Directional Indicator

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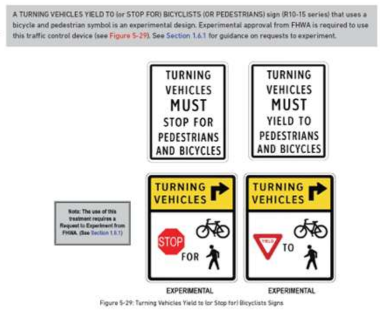
5.11.5. Turning Vehicles Yield to Pedestrians/Bicyclists Signs

The use of the sign should be limited to the following:

- Crossings where turning motor vehicle volumes exceed 50 vehicles/hour.
- Locations where there is a documented problem with motorists failing to yield.
- Locations with inadequate sight lines and other mitigations are not feasible.
- New installations of left side bicycle lanes or two-way bikeways where counterflow bicycle travel may be unexpected.



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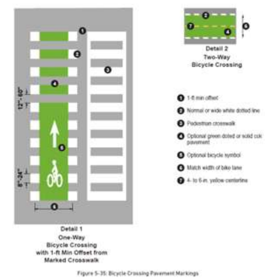
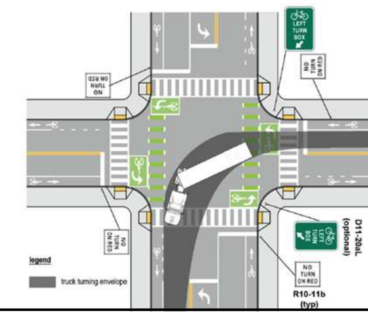
5.12 Pavement Markings

5.12.7.2 Bicycle Crossings with Parallel Pedestrian Crossings



5.12.9. Two-Stage Bicycle Turn Box



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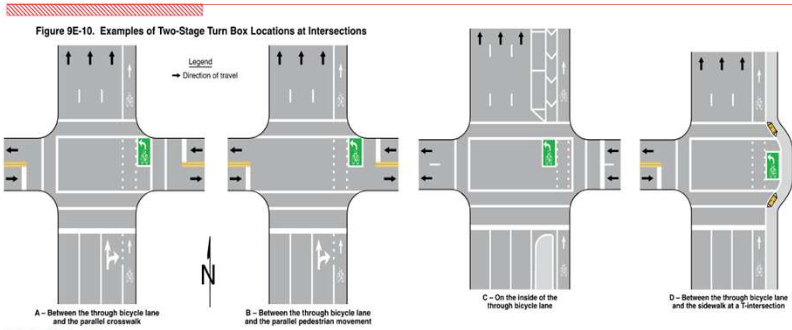
Pavement Markings (MUTCD)



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Chapter 6 – Shared Use Paths

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Chapter 6
SUP Width (Two-way)

6.4.3. Recommended Shared Use Path Widths

Table 6-3: Recommended Shared Use Path Widths* to Achieve SUP LOS "C"

Shared Use Path Operating Widths and Operational Lanes*					
SUPLOS "C" Peak Hour Volumes	Recommended Operational Lanes	Practical Minimum	Recommended Lower Limit	Recommended Upper Limit	Practical Maximum
150 to 300	2	8 ft	10 ft	12 ft	13 ft
300 to 500	3	11 ft	12 ft	15 ft	16 ft
500 to >600	4	15 ft	16 ft	20 ft	None

*Typical Mode Split is 55% adult bicyclists, 20% pedestrians, 10% runners, 10% in-line skaters, and 5% child bicyclists

11' wide provides three (3) operational lanes

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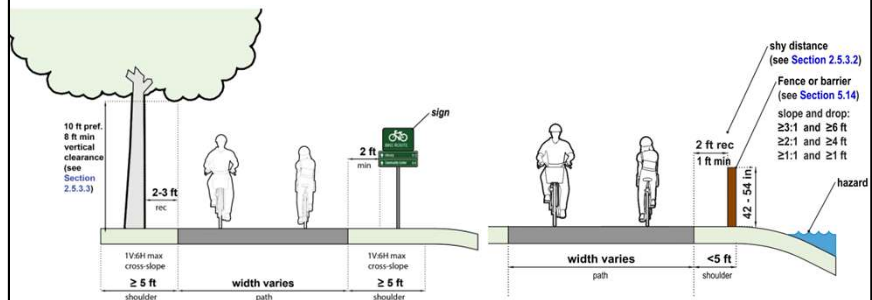
Section 6.3.1 – Width and Shy Space Considerations



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6.4.2. Shared Use Path Level of Service

Table 6-1: Shared Use Path Operating Conditions Based on Level of Service Criteria

Shared Use Path Level of Service (SUPLOS) and Operating Conditions	
SUPLOS	Peak Operating Conditions
A. Excellent	A significant ability to absorb more users across all modes is available.
B. Good	A moderate ability to absorb more users across all modes is available.
C. Fair	Path is close to functional capacity with minimal ability to absorb more users.
D. Poor	Path is at its functional capacity. Additional users will create operational and safety problems.
E. Very Poor	Path operating beyond its functional capacity resulting in conflicts and people avoiding the path.
F. Failing	Path operating beyond functional capacity resulting in significant conflicts and people avoiding the path.

Table 6-2: Shared Use Path Level of Service Look-Up Table, Typical Mode Split

Shared Use Path Level of Service Look-Up Table, Typical Mode Split*										
Shared Use Path Peak Hour Volume	Shared Use Path Width (ft)									
	8	10	11	12	14	15	16	18	20	≤ 25
50	B	B	B	B	B	A	A	A	A	A
100	D	C	B	B	B	A	A	A	A	A
150	D	C	B	B	B	A	B	A	A	A
200	D	D	C	B	B	A	B	A	A	A
300	E	D	C	C	C	B	B	B	B	A
400	F	E	D	D	C	C	C	B	B	A
500	F	F	D	D	D	C	C	C	C	A
600	F	F	E	E	E	D	D	C	C	A
800	F	F	F	F	F	E	E	E	E	A
1,000	F	F	F	F	F	E	F	F	F	A
≥ 1,200	F	F	F	F	F	F	F	F	F	A

*Assumptions:

1. Mode split is 55 percent adult bicyclists, 20 percent pedestrians, 10 percent runners, 10 percent in-line skaters, and 5 percent child bicyclists.
2. An equal number of trail users travel in each direction (the model uses a 50 percent–50 percent directional split).
3. Trail volume represents the actual number of users counted in the field (the model adjusts this volume based on a peak hour factor of 0.85).
4. Trail has a centerline.

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6.4.4. Separation of Pedestrians and Bicyclists

6.4.4.1 Land Use Considerations Where Separation is Desirable

6.4.4.2 Volume Thresholds Where Separation is Desirable

Should be considered when:

- Level of Service is projected to be at or below level "C."
- Pedestrians can reasonably be anticipated to be 30% or more of the volume

6.4.4.3 Separation Strategies

6.4.4.4 Accessibility Considerations

Figure 6-3: Burke-Gilman Shared Use Path (2008) and Separated Paths (2021), Seattle, WA

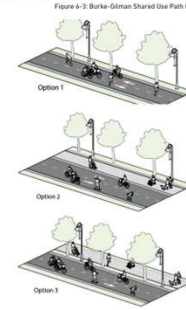

Figure 6-4: Options for Separating Bicyclists and Other Wheeled Users from Pedestrians

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6.6. General Design Considerations

6.6.1. Shy Distance, Clearances, and Shoulders

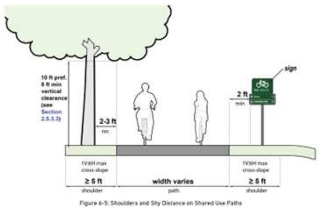

Figure 6-5: Shoulders and Shy Distance on Shared Use Paths

6.6.3. Horizontal Alignment

Table 6-5: Minimum Radii for Horizontal Curves at 20-Degree Lean Angles

Design Speed (mph)	Minimum Radii (ft) for Horizontal Curves at 20-Degree Lean Angles
8	12
10	18
12	27
14	36
16	47
18	60
20	74
25	115
30	166

6.6.4. Vertical Alignment

Table 6-7: Length of Crest Vertical Curve to Provide Sight Distance Equations

Length of Crest Vertical Curve to Provide Sight Equations		
when $S > L$		$L = 2S - \frac{200(\sqrt{h_1} + \sqrt{h_2})^2}{A}$
when $S < L$		$L = \frac{AS^2}{100(\sqrt{2h_1} + \sqrt{2h_2})^2}$
where:		
L	=	minimum length of vertical curve (ft)
A	=	algebraic grade difference (percent)
S	=	stopping sight distance for flat grade (ft)*
h_1	=	eye height (3.83 ft for a typical recumbent bicyclist)
h_2	=	object height (0 ft)

*See Tables 5-2 and 5-3.

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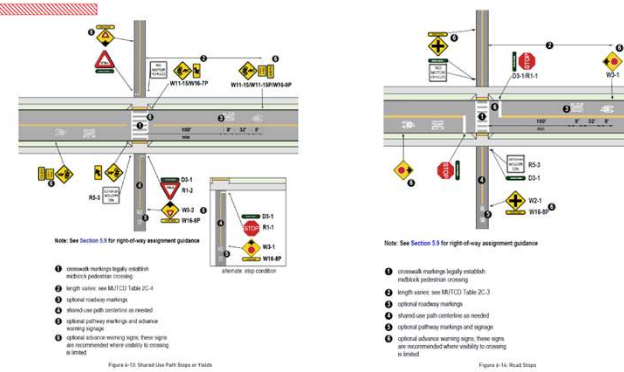
6.7. Shared Use Path Intersections and Transitions



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Chapter 7 – Separated Bike Lanes and Side Paths

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7.2. General Design Considerations

The cross section of a separated bike lane comprises three distinct zones (see Figure 7-1):

1. **Bike lane**—The bike lane is the space in which the bicyclist operates. It is located between the street buffer and the sidewalk buffer.
2. **Street buffer**—The street buffer separates the bike lane or side path from motor vehicle traffic.
3. **Sidewalk buffer**—The sidewalk buffer separates the bike lane from the sidewalk.

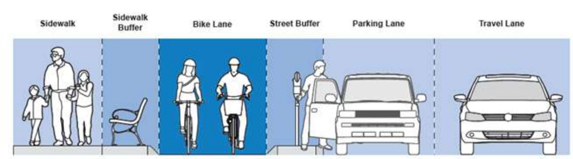

Figure 7-1: Separated Bike Lane Zones

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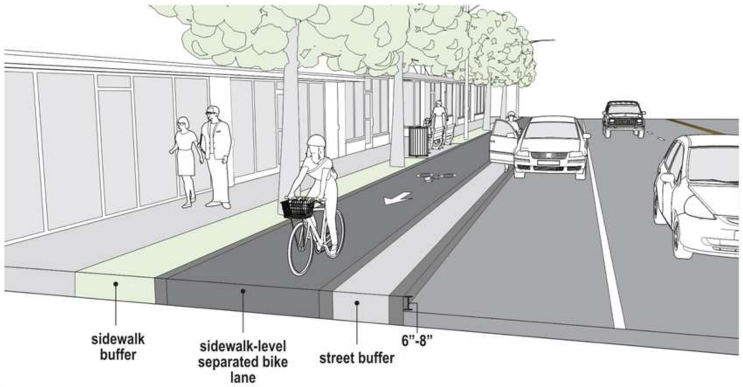
Section 7.2.2 – Sidewalk-Level Separated Bike Lanes



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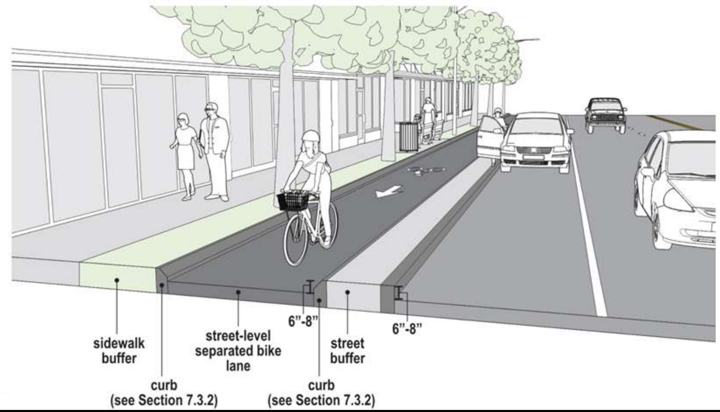
Section 7.2.2 – Street-Level Separated Bike Lanes



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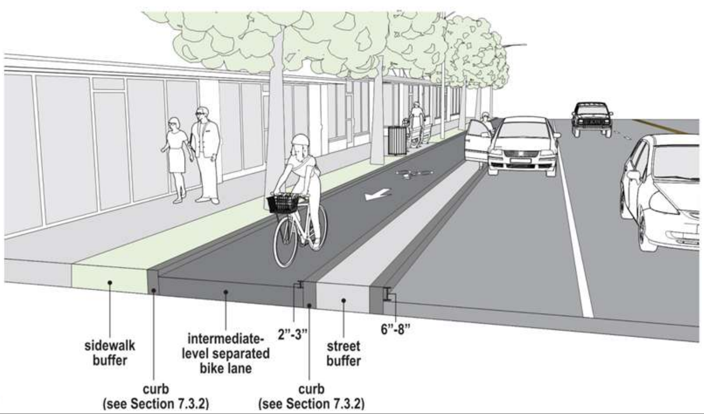
Section 7.2.2 – Intermediate-Level Separated Bike Lanes



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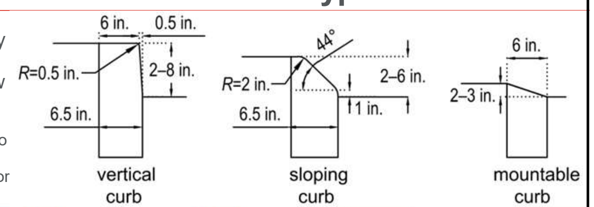
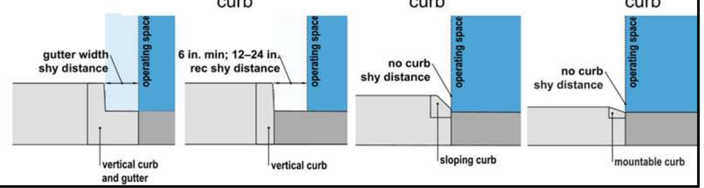
Section 7.3.2 – Bikeway Width: Consider The Curb Types

Shy distances and bikeway widths are intertwined

curb reveal of 2-3 in. below sidewalk elevation is recommended to:

- provide vertical separation to the adjacent sidewalk, and
- provide a detectable edge for pedestrians with vision disabilities





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Section 7.3.4 – SBL Width (One-way)

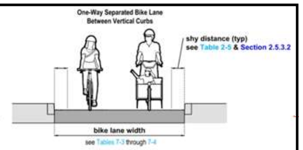


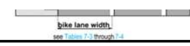
Table 7-3: One-Way Separated Bike Lane Widths Based on Existing or Anticipated Volumes

Peak Hour Directional Bicyclist Volume	One-Way Separated Bike Lane Width (ft) Recommended Values		
	Between Vertical Curbs without Gutter	Adjacent to One Vertical Curb	Between Sloped Curb, at Sidewalk Level, or Adjacent to Curb with Gutter
<150	6.5–8.5	6–8	5.5–7.5
150–750	8.5–10	8–9.5	7.5–9
>750	≥10	≥9.5	≥9
Practical Minimum*	4.5	4	4

*Peak Hour Directional Bicyclist Volume not applicable

Low end of width will accommodate occasional passing

Practical Minimum width does not accommodate passing. Only recommend for limited distances.



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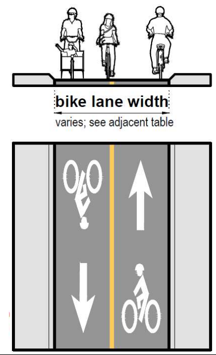
Section 7.3.4 – SBL Width (Two-way)



Peak Hour Directional Bicyclist Volume	Two-Way Separated Bike Lane Width (ft) Recommended Values		
	Between Vertical Curbs without Gutter	Adjacent to One Vertical Curb	Between Sloped Curb, at Sidewalk Level, or Adjacent to Curb with Gutter
<150	10–12	9.5–11.5	9–11
150–350	12–16	11.5–15.5	11–15
>350	≥16	≥15.5	≥15
Practical Minimum*	8.5	8	7.5

*Peak Hour Directional Bicyclist Volume not applicable

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7.7.1. Drainage and Stormwater Management

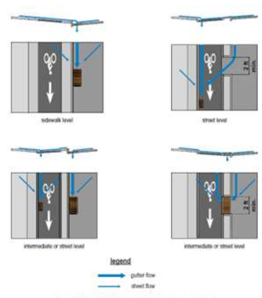

Figure 7-11: Examples of Separated Bike Lane Drainage Options

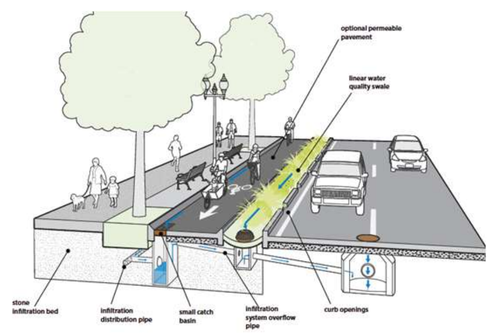

Figure 7-10: Green Stormwater Infrastructure in an Urban Street Context

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7.9. Separated Bike Lane and Side Path Intersection Design

- 7.9.1. Minimizing Exposure to Conflicts
- 7.9.2. Reducing Speeds at Conflict Points
- 7.9.3. Transitions between Elevations
- 7.9.4. Right-of-Way Priority
- 7.9.5. Sight Distance
- 7.9.6. Restricting Motor Vehicles

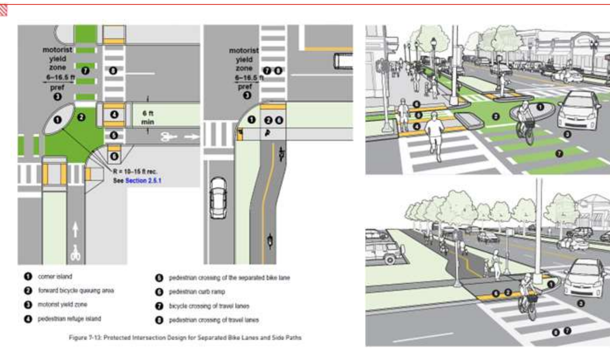

Figure 7-13: Protected Intersection Design for Separated Bike Lanes and Side Paths

TOOLE DESIGN

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7.9.7.1 Corner Island

Benefits:

- forward bicycle queuing area
- space for turning vehicles to wait
- reduces crossing distances
- reduces motorist turning speeds
- can reduce bicyclist speeds by adding deflection to the bike lane or side path

Figure 7-15: Corner Island with Flexible Delineator Posts (Source: Carl Sundstrom, PE, Office of Bicycle and Pedestrian Programs, New York City Department of Transportation)

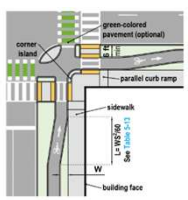

Figure 7-16: Bend-Out Example

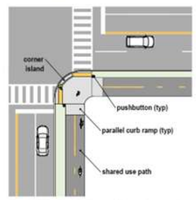

Figure 7-17: Side Path Curb Ramps at Constrained Intersection

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7.9.9. Intersection Design with Mixing Zones NOTE: see NCHRP 1125 for selection process

Reduce speeds of motor vehicles entering the merge point to 20 mph or less:

- Minimize merge area length
- Locate merge point as close to the intersection
- Minimize length of the storage portion of the turn lane
- Provide buffer and physical separation (e.g., flexible delineator posts) from the adjacent through lane after the merge area, if feasible
- Highlight the conflict area with a green-colored pavement and dotted bike lane markings or shared lane markings

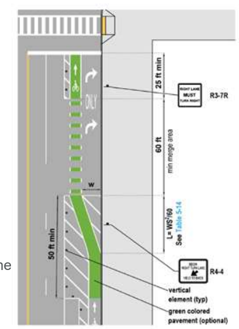

Figure 7-20: Angled Crossing Mixing Zone with Bike Lane

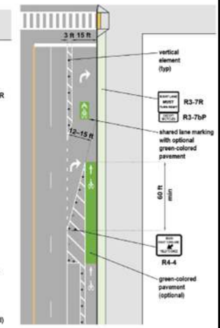

Figure 7-21: Angled Crossing Mixing Zone with Shared Lane

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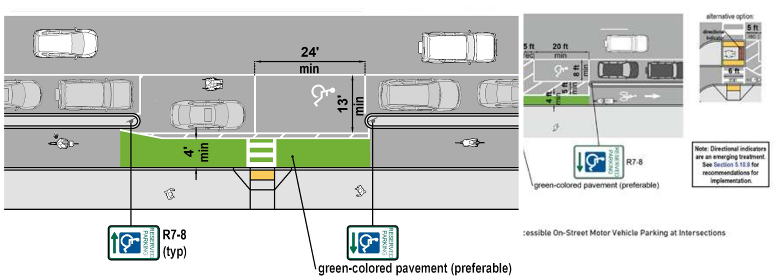
7.9.12.1 Accessible Motor Vehicle Parking



:essible On-Street Motor Vehicle Parking at Intersections

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7.9.14. Transit Stops

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7.9.14. Transit Stops

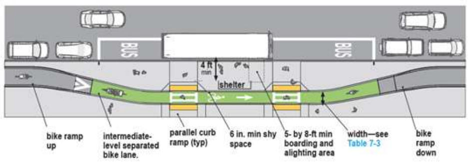

Figure 7-26: Example Configuration: Floating Transit Stop (Mid-Block)

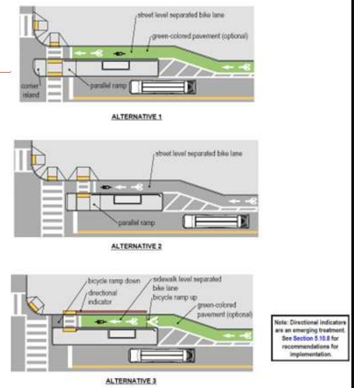

Figure 7-31: Example Configurations: Floating Transit Stop (Near-Side)

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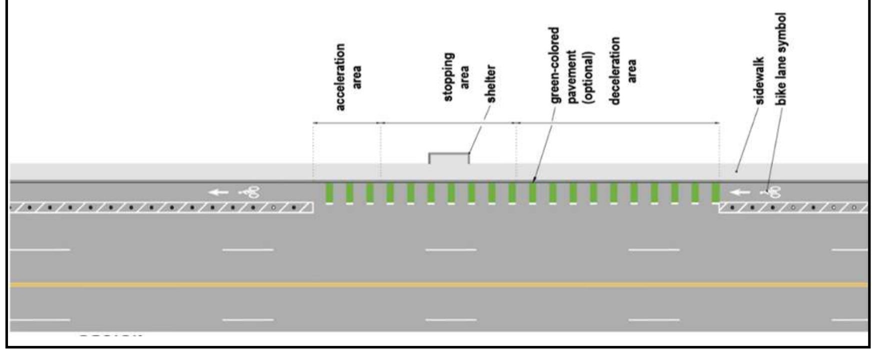
7.9.14. Transit Stops



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7.10. Transitions between Facilities

In general, it is preferable for a transition from a separated bike lane to a standard bicycle lane or shared lane to occur on the far side of the intersection.

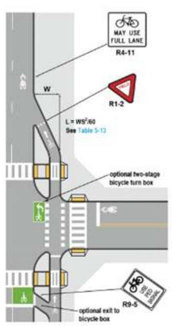

Figure 7-32: Transition to Shared Lane

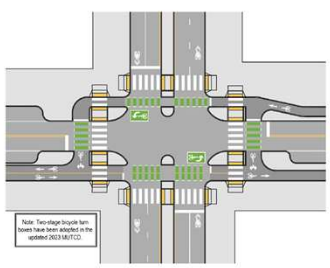

Figure 7-35: Transition from One-Way to Two-Way Separated Bike Lanes at Protected Intersection

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7.11. Raised Bike Lanes

Table 7-5: Raised Bike Lane Widths

Raised Bike Lane Widths				
Bike Lane Context	Practical Minimum (ft)	Recommended Lower Limit (ft)	Recommended Upper Limit (ft)[2]	Practical Maximum (ft)[2]
Intermediate level or sidewalk level raised bike lane[1]	5	6.5	8	10

[1]Raised bike lane widths are exclusive of the gutter unless the gutter is integrated into the full widths of the bike lane.

[2]Separated bike lane with a street buffer may be preferable to a curb-attached, wide raised bike lane.

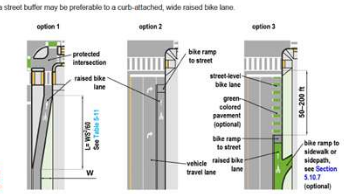

Figure 7-40: Raised Bike Lane Transitions at Intersections

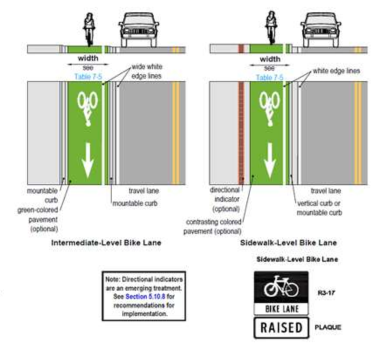

Figure 7-39: Intermediate-Level and Sidewalk-Level Raised Bike Lanes

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Chapter 8 – Bicycle Boulevard Planning and Design

- 8.1 Introduction
- 8.2 Bicycle Boulevard Principles
- 8.3 Bicycle Boulevard Minimum Design Elements
- 8.4 Traffic Calming Strategies (Speed Management)
- 8.5 Traffic Diversion Strategies (Volume Management)
- 8.6 Traffic Control for Minor Street Crossings
- 8.7 Traffic Control for Major Street Crossings

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Section 8.2 – Bicycle Boulevard Principles

Bicycle Boulevards are not just signed bike routes.

Principles that set them apart from local streets include:

- 8.2.1. Manage motorized through traffic volumes and speeds
- 8.2.2. Prioritize right-of-way at local street crossings
- 8.2.3. Provide safe and convenient crossings at major streets

Minimize Motorized Through Traffic Volumes and Speed Differential

	Hourly Traffic Volume	Daily Traffic Volume	Speed
Preferred	50 vehicles/hr	1,000 ADT	15 mph
Acceptable	75 vehicles/hr	2,000 ADT	20 mph
Maximum	100 vehicles/hr	3,000 ADT	25 mph

Major Street Crossings (opportunities per hour)	
Preferred	120
Minimum	60

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8.4. Traffic Calming Strategies (speed management)

Figure 8-5: Example of a Chicane Treatment on a Two-Way Street Created by a Median and Curb Extensions

Figure 8-6: Example of a Chicane Treatment Created by Alternating Parking from One Side of the Street to the Other

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8.5. Traffic Calming Strategies (volume management)

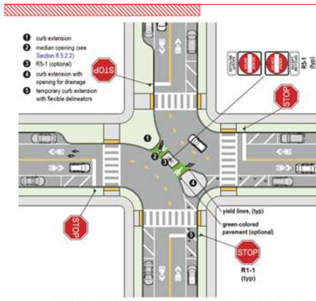

Figure 8-12: Example of a Median Used to Create a Diagonal Diverter at Intersection of Two Local Streets

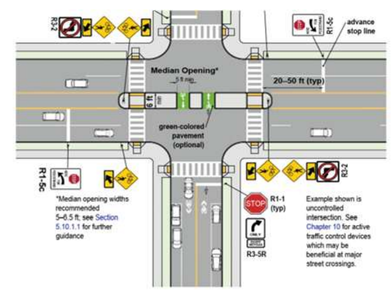

Figure 8-11: Example of a Median Used to Divert Traffic at a Major Street Crossing

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8.7. Traffic Controls for Major Street Crossings

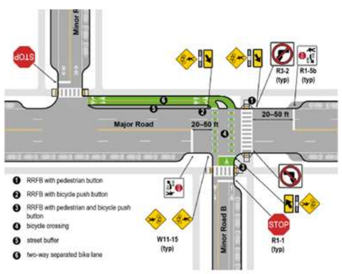

Figure 8-15: Example of Connecting Offset Bicycle Boulevard Segments Using a Two-Way Separated Bike Lane

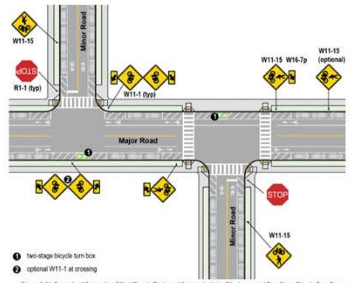

Figure 8-14: Example of Connecting Offset Bicycle Boulevard Segments Using Bike Lanes and Two-Stage Bicycle Turn Boxes

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Chapter 9 – Shared Lanes and Bicycle Lanes

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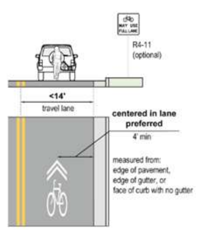
9.3.2. Limited Effectiveness of Wide Outside Lanes

Figure 9-1: Shared Lane Conditions (Rural Context, Suburban Context, Urban Context)

Rural Roadway

Suburban Arterial

Figure 9-3: Shared Lane Marking Lateral Placement in Travel Lanes < 14 Feet Without Parking



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9.4.1. Bicycle Lane Widths
9.5 Buffered Bicycle Lanes

Table 9-1: One-Way Standard Bicycle Lane Widths

One-Way Standard Bike Lane Widths				
Bike Lane Context	Practical Minimum (ft)	Recommended Lower Limit (ft)	Recommended Upper Limit (ft)	Practical Maximum (ft)
Adjacent to edge of Pavement	4[1]	5	7	8[3]
Adjacent to curb (exclusive of gutter)	5[1]	6	7	8[3]
Between through lanes and turn lanes[2]	5[1]	6	7	8[3]
Between buffers	4	5	7	8[3]
Adjacent to parking	5	6	7	8[3]
To allow occasional passing or side-by-side bicycling[4]	6.5	8[3]	10[3]	11[3]

Notes

[1]Shoulders should be provided in lieu of narrow bicycle lanes to avoid confusion below the practical minimum width.

[2]Buffers are desirable where bicycle lanes are located between through lanes and turn lanes, especially as motorist speeds exceed 30 mph.

[3]Buffered bike lanes or separated bike lanes should be considered in lieu of wider bicycle lanes to avoid confusion with a parking or travel lane.

[4]A minimum of 6.5 ft is necessary for occasional passing and 8 ft or more for comfortable side-by-side bicycling.

9.5. Buffered Bicycle Lanes

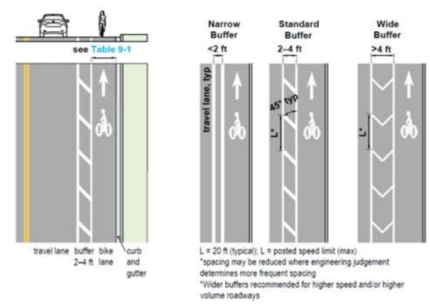

Figure 9-9: Buffer Design Options

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9.6.4. Bicycle Lanes Adjacent to Parallel Parking and Loading

9.6.4.1 Minimum Width Bike Lane Considerations

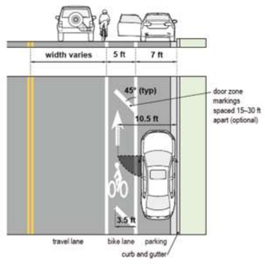
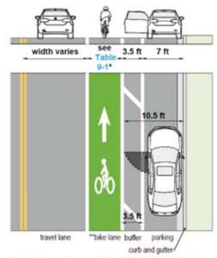


Figure 9-10: Constrained Bike Lane Adjacent to Parking Example



*bike lane may be a minimum of 4 ft if located adjacent to a buffer
**optional green-colored pavement

Figure 9-11: Bike Lane with a Door Zone Buffer adjacent to Parking

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9.8. Advisory Bicycle Lanes (Experimental)

Advisory bicycle lanes are continuously-dotted bicycle lanes which permit motorists to temporarily enter the bicycle lane, allowing opposing motor vehicle traffic sufficient space to pass (see Figures 9-15 and 9-16). They are an experimental design treatment for streets with lower traffic speeds and volumes where it is not feasible to provide standard-width travel lanes and bicycle lanes. They are designed to improve bicyclist comfort while also providing a traffic calming benefit. This is the same procedure for motorists operating on yield streets where motorists must move to the right side of the road, into unoccupied parking spaces or driveways, to permit oncoming traffic to pass (see Section 8.4.1).

Figure 9-15: Example of an Advisory Bicycle Lane in Alexandria, VA

Groundbreaking to include experimental treatments and emerging concepts

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9.12.3 Right Turn Lane Considerations

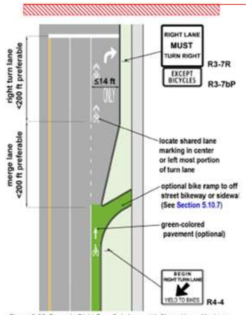

Figure 9-22: Example Right-Turn Only Lane with Shared Lane Markings

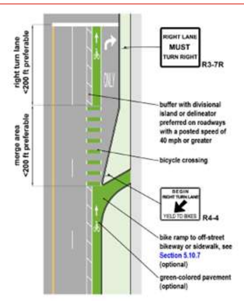

Figure 9-24: Example Bike Lanes on Streets >40 mph or Right-Turn Lanes >200 ft

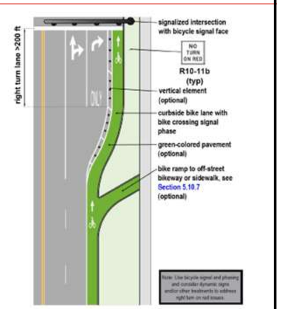

Figure 9-26: Example Bike Lane Approach to a Through-Right and a Right-Turn Only Lane

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Chapter 10 – Traffic Signals and Pedestrian Hybrid Beacons

10.1 Introduction
10.2 Design Guidance for Traffic Signal Control
10.3 Traffic Signal Phasing for Managing or Reducing Conflicts
10.4 Traffic Signal Timing for Bicyclists
10.5 Bicycle Signal Design Consideration
10.6 Detection for Bicycles
10.7 Design Guidance for Pedestrian Hybrid Beacons
10.8 Toucan Crossings with Traffic Signals

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10.2.4. Traffic Signal Indication Options for Bicyclists

Bike signal head warrant:
- Leading or protected phasing
- Contra-flow movements
- Signal heads beyond cone of vision

Bike signal head application:
- Can only be used without conflicting vehicle turns

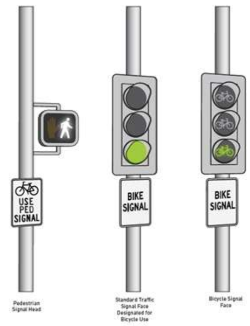

Figure 10-2: Examples of Signal Indication Options for Bicyclists

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10.3.5. Signal Phasing Schemes for Reducing Conflicts

Table 10-1: Recommended Hourly Turning Traffic Thresholds for Time-Separated Bicycle Movements

	Left Turn Crossing One Vehicle Lanes	Left Turn Crossing Two Vehicle Lanes
One-Way Bike Lane	≥ 100 / ≥ 150*	≥ 50 / ≥ 150*
Two-Way Bike Lane	≥ 50 / ≥ 100*	ANY / ≥ 100*

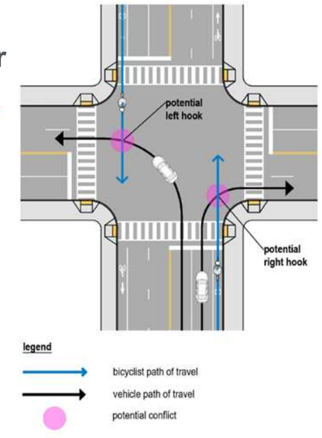

Figure 10-3: Left-Hook and Right-Hook Graphic

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10.3.5. Signal Phasing Schemes for Reducing Conflicts (NCHRP 1125)

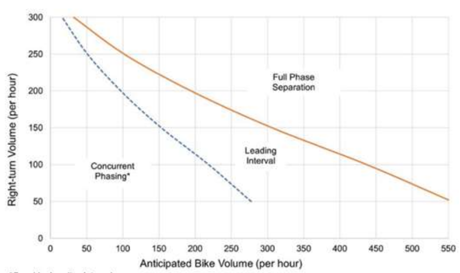

Figure 7. Protected corner signal phasing thresholds.

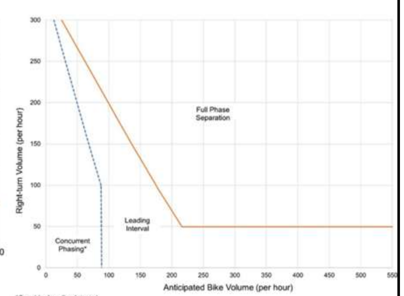

Figure 8. Separated bicycle lanes at intersection signal phasing thresholds.

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10.6. Detection for Bicycles
10.6.1.1 Pushbuttons for Bicyclists

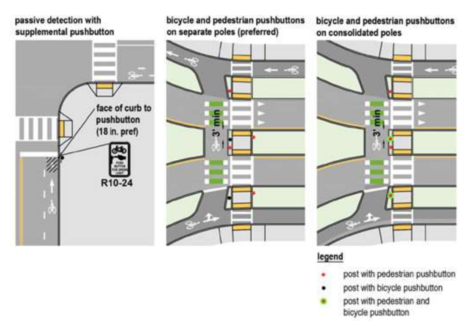

Figure 10-12: Pushbutton Locations

Figure 10-13: Example of Curbside Bicycle Pushbutton

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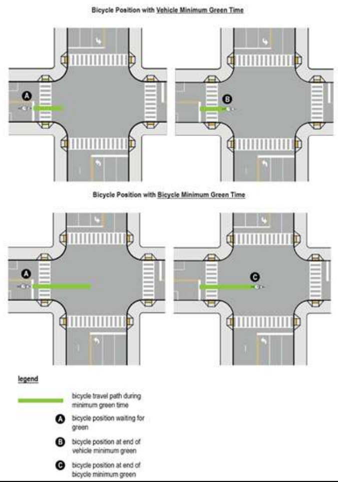
10.4.1. Green Time, Change Interval and Clearance Intervals for Bicyclists

Vehicle Minimum Green
- vs -
Bicycle Minimum Green

Table 10-2: Bicycle Minimum Green Time Equation

Bicycle Minimum Green Time Equation		
$G_{min} = t + \frac{1.47v}{2a} + \frac{d+L}{1.47v}$		
Where:		
G_{min}	=	bicycle minimum green time (s)
v	=	attained bicycle crossing speed (assumed 8 mph)
t	=	perception reaction time (generally 1.5 s)
a	=	bicycle acceleration (assumed 2.5 ft/s²)
d	=	distance from stop bar to middle of the intersection (ft)
L	=	typical length of a bicycle (6 ft)



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10.4.1. Red Clearance Interval

Time needed for bikes to clear an intersection

Table 10-5: Bicycle Red Clearance Equation

Bicycle Red Clearance		
$R_{bike} = \frac{D+L}{1.47v} + \left(t + \frac{1.47v}{2a}\right) - y$		
Where:		
D	=	width of intersection from stop bar to far side of travel lane
L	=	length of bike (6 ft)
v	=	speed of bicyclist (8 mph)
t	=	reaction time (1 sec)
a	=	bike deceleration (10 ft / s²)
y	=	vehicle yellow time

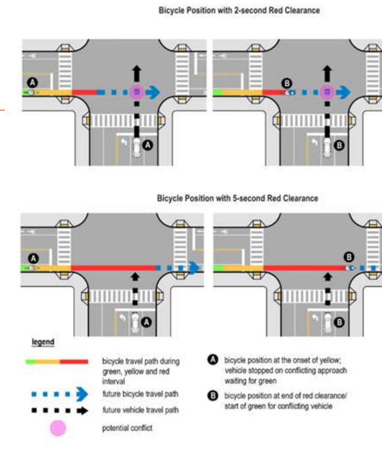

Figure 10-9: Bicycle Position During Red Clearance

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Chapter 11: Bicycle Facility Design at Interchanges, Alternative Intersections, and Roundabouts

11.1 Introduction
11.2 Basic Design Principles
11.3 Exit and Entrance Ramps
11.4 Multiple-Threat Conditions
11.5 Motorist Left Turns
11.6 Designs that Place Bicyclists in Constrained Areas
11.7 Conflicts between Bicyclists and Pedestrians in Shares Spaces
11.8 Channelized Right-Turn Lanes
11.9 Alternative Intersection Design Considerations
11.10 Roundabouts

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11.3. Exit and Entrance Ramps

- On-road and off-road options
- Bike ramp to access to sidewalk
- Sidewalk becomes shared use path
- Perpendicular crossings

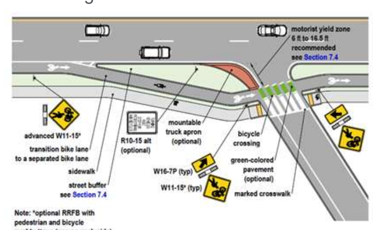

Figure 11-4: Entrance Ramp with Truck Apron and Separated Bike Lane

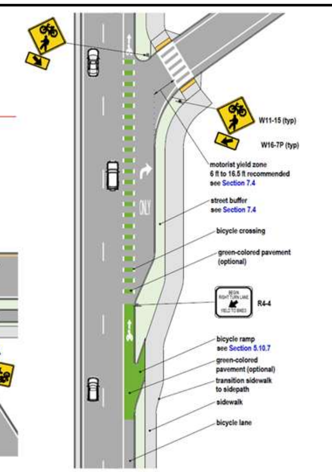

Figure 11-5: Entrance Ramp with Right-Turn Lane, Bike Lane, and Side Path

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11.3.3. Merging and Weaving Areas

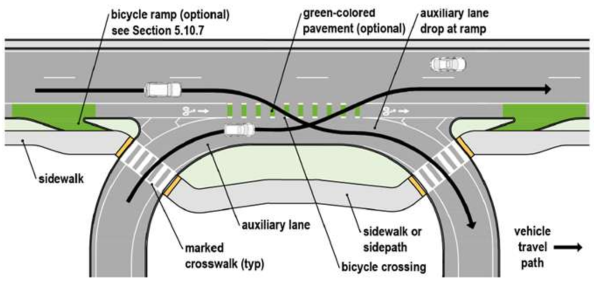

Figure 11-9: Bike Lane Positioned in High-Exposure Weaving Area

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11.7. Conflicts between Bicyclists and Pedestrians in Shared Space

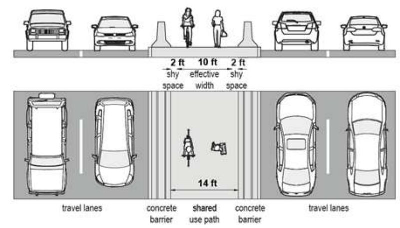

Figure 11-11: Constrained Median Shared Use Path (10 ft wide) with Concrete Barrier Buffers

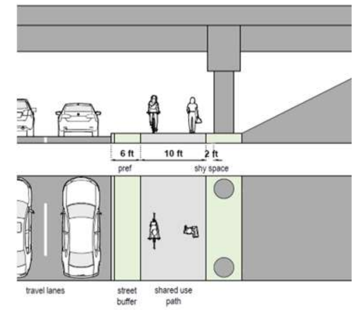

Figure 11-12: Side Path between Travel Lanes and Bridge Piers with Preferred Buffers

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11.8. Channelized Right-Turn Lanes

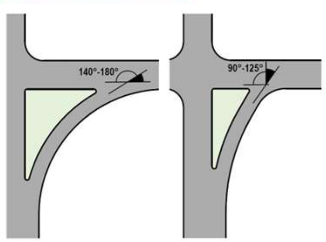

Figure 11-13: Channelized Right-Turn Lane Approach Angles

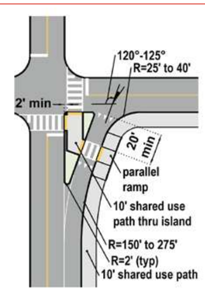

Figure 11-14: Channelized Right-Turn Refuge Island

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11.10. Roundabouts

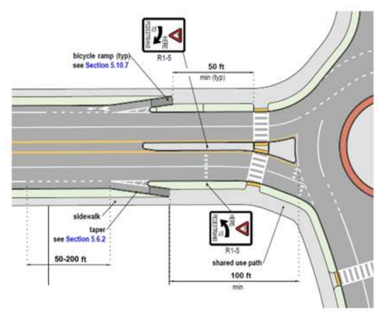

Figure 11-16: Typical Layout of Bike Lane Transitions to Shared Use Path at Multilane Roundabout with Bike Ramps

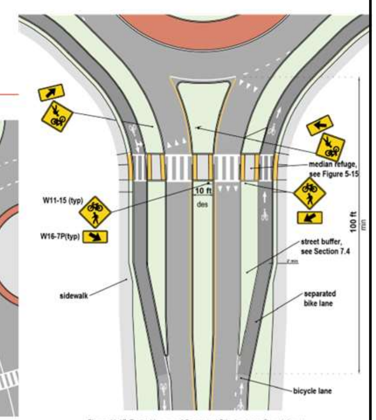

Figure 11-17: Typical Layout of Separated Bike Lanes at Roundabout

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Chapter 12 – Rural Area Bikeways and Roadways

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12.4.3.2 Widths of Paved Shoulders

Table 12-1: Paved Shoulder Widths for Bicycling (see Chapter 12 References: FHWA, 2016b)

Paved Shoulder Widths Exclusive of Rumble Strips[i] for Bicycling				
Design Year Average Daily Traffic (ADT) and Posted Speed (MPH) Thresholds	Practical Minimum[ii]	Recommended Range		Practical Maximum
		Lower Limit[ii]	Upper Limit	
< 2,000; all speeds	2 ft	3 ft	5 ft[ii]	10 ft
2,000 - 6,000; all speeds	2 ft	4 ft	6 ft[ii]	10 ft
6,000 - 10,000; all speeds	4 ft	6 ft	8 ft[ii]	10 ft
> 10,000; ≤ 35 mph	5 ft	6 ft	8 ft[iii]	12 ft[iii]
> 10,000; > 40 mph[iv]	5 ft	6 ft	10 ft[iii]	12 ft[iii]

Notes
[i]See Section 12.5.1 for rumble strip design considerations.
[ii]Where roadside barriers, walls, or other vertical elements are present, they should be offset a minimum of 2 ft from the outer edge of the rideable shoulder to provide minimum shy distance to bicyclists (see Section 2.5.3.2.)
[iii]Where >10 percent of traffic consists of trucks.
[iv]Shared use paths are preferred.

Figure 12-3: Shoulder Widening on Uphill Section of Roadway to Accommodate Bicycling

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Section 12.3 - Design User Profiles

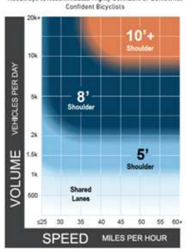
Design User:

Between Towns & Villages
- *Highly Confident*

In Towns & Villages
- *Interested but Concerned*

Figure 12-10: Sidepath along a Rural Road

Figure 4-2: Preferred Paved Shoulder Widths for Rural Roadways to Accommodate Highly Confident or Somewhat Confident Bicyclists



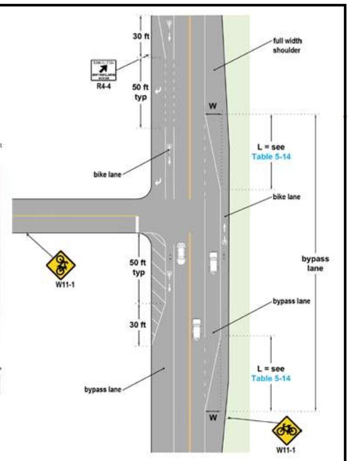


Figure 12-6: Bypass Lane with Paved Shoulder

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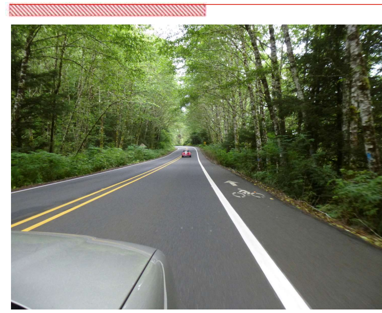
Rural Road Bike Lanes and Sidepaths



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12.4.4. Advisory Shoulders (Experimental)

12.4.4. Advisory Shoulders (Experimental)

Similar to advisory bike lanes (see Section 9.8), advisory shoulders are an experimental design treatment for roads with lower traffic speeds and volumes where it is not feasible to provide standard bike lanes or shoulders for bicycle travel. When motor vehicles traveling in opposite directions meet, motorists may need to enter the advisory shoulder to create sufficient space to pass (see Figure 12-7). Experimental approval from FHWA is required to use this traffic control treatment. Where sidewalks are not present and it is desired for pedestrians to walk within the advisory shoulders, the advisory shoulder should be accessible to and usable by individuals with disabilities (see Section 1.6.3). See Section 1.6.1 for guidance on requests to experiment. See Section 9.8 and the FHWA Small Town and Rural Multimodal Networks Guide (see Chapter 12 References: FHWA, 2016b) for additional design guidance.

Note: The use of this treatment requires a Request to Experiment from FHWA. (See Section 1.6.1)

Figure 12-7: Example of Advisory Shoulders in Hanover, NH

Advisory shoulders may be considered in rural contexts on roads with the following characteristics:

- Low operating speeds
  - < 25 mph preferable
  - < 35 mph maximum
- Low to moderate motor vehicle volumes
  - < 3,000 vehicles/day preferable
  - < 6,000 vehicles/day maximum
- Infrequent heavy vehicles
- Adequate passing sight distance for motorists
- Regular bicycle traffic

If an advisory shoulder is being considered on a low-volume roadway with operating speeds above 35 mph, traffic calming treatments should be implemented to promote operating speeds at or below 35 mph.

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12.4.4. Advisory Shoulders (Experimental)

Yarmouth, ME
Population: 9K

Hanover, NH
Population: 11K
Photo Credit: FHWA

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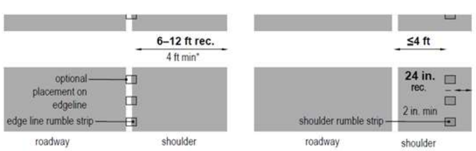
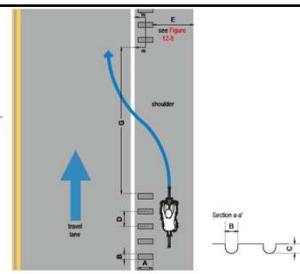
12.5.1. Rumble Strip Placement and Design



* 5 ft minimum if adjacent curb, guardrail, vertical element, or obstacle

Figure 12-8: Rumble Strip Placement Options



Definitions	
Length (A)	Dimension of rumble strip measured lateral to the travel lane
Width (B)	Dimension of rumble strip measured parallel to the travel lane
Depth (C)	Vertical distance measured from top of pavement surface to bottom of a rumble strip pattern
Spacing (D)	Dimension between rumble strip patterns
Clear Path (E)	Distance from outside (for example, right) edge of rumble strip to oustide edge of paved shoulder
Gap (G)	Distance measured parallel to roadway, between groups of rumble strip patterns

*Note: Figure not to scale.

Figure 12-9: Rumble Strip Minimum Gap Illustration

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Chapter 13 – Structures

13.1 Introduction
13.2 General Design Principles for Structures
13.3 Design Details for Bridges
13.4 Design Details for Underpasses
13.5 Options for Retrofitting Existing Structures
13.6 Connections to Nearby Facilities

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13.2. General Design Principles for Structures

Figure 13-1: Bikeway along the Interstate 90 Bridge over Lake Washington, WA

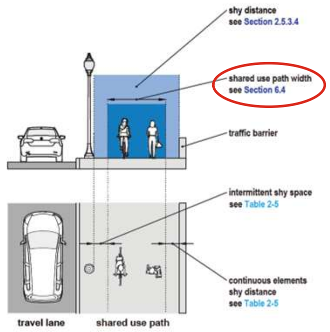

Figure 13-5: Horizontal Clearances for Shared Use Paths on Bridges Along Roads

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Chapter 14 – Wayfinding Systems for Bicyclists

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14.6. Bicycle Wayfinding Sign Assemblies

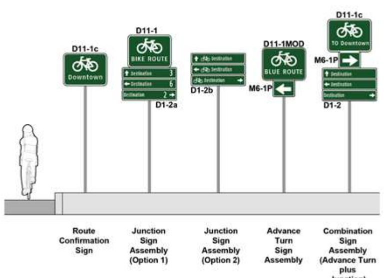

Figure 14-4: Examples of Confirmation, Decision, and Turn Sign Assemblies

Table 14-1: Mileage Rounding Guidelines

Mileage Rounding Guidelines	
Distance (mi)	Guideline
< 0.2	Do not include mileage; blocks are appropriate, if necessary
0.2 - 5.0	Round mileage to the nearest tenth of a mile
> 5.0	Round mileage to the nearest whole mile

Figure 14-7: Example of Community Wayfinding

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Chapter 15 – Maintenance and Operations

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15.2. Maintenance Policy and Programs

Figure 15-1: Examples of Debris, Faded Markings, and Snow Clearing

Figure 15-4: Fog Sealing a Shared Use Path

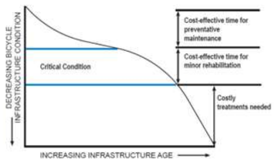

Figure 15-2: Bicycle Infrastructure Life Cycle

Table 15-1: Maintenance Equipment Types

Maintenance Equipment Types				
Type of Equipment	Corresponding Design Vehicle[a]	Width (ft)[b]	Height (ft)	Uses
3-Axle Single Unit Truck	SU-40	8	11-13	highway snow plowing, heavy construction, emergency vehicles
2-Axle Single Unit Truck	SU-30	8	11-13	ambulance, snow plowing, construction, routine maintenance
Pickup Truck	N/A	6-8	6-7	snow plowing, routine maintenance, law enforcement
Typical Skid-Steer Loader	N/A	5.5	6.5	snow plowing, routine maintenance, sweeping
Specialty Equipment	N/A	Varies by manufacturer		Varies

[a] For detailed information on vehicle geometry and turning radius, refer to Chapter 2 of AASHTO's *A Policy on Geometric Design of Highways and Streets* (See Chapter 15 References: AASHTO, 2018).
[b] Width of attachments such as sweeper brooms or snowplow blades may exceed the width of the vehicle.

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Chapter 16 – Bicycle Parking, Bike Share Siting, and End of Trip Facilities

Figure 16-1: Directional Signage for Bicycle Parking

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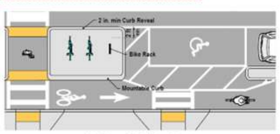
16.3. Short-Term Parking

16.3.4. Example Designs with Unique Considerations



Bike Parking on Raised Median Adjacent to Accessible Car Parking Space

Figure 16-2: On-Street Bicycle Corrals

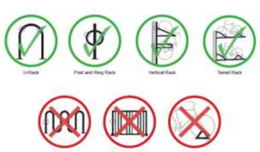


Figure 16-4: Examples of Recommended and Not Recommended Racks

Table 16-1: Sample Short-Term Bicycle Parking Quantity Requirements

Short-Term Parking Quantities		
Types of Activity	Sample Bicycle Parking Quantities[a]	
	Most Contexts	Urbanized or High Bicycle Mode Share Areas
Multi-unit residential dwellings	0.05 spaces per bedroom	0.10 spaces per bedroom
Libraries and government buildings	One space per 10,000 square ft of floor area	One space per 8,000 square ft of floor area
Church, theatres, stadiums, parks, beaches	Spaces for 2 percent of maximum expected attendance	Spaces for 5 percent of maximum expected attendance
Schools (K-12)	One space per 20 students	1.5 spaces per 20 students
Colleges and universities	One space per 10 students of planned capacity	One space per 10 students of planned capacity
Rail or bus terminals and stations and airports	Spaces for 1.5 percent of a.m. peak passengers	Spaces for 2 percent of a.m. peak passengers
Retail- groceries	One space per 2,000 ft² of floor area	One space per 2,000 ft² of floor area
Retail- general	One space per 5,000 ft² of floor area	One space per 5,000 ft² of floor area
Office	One space per 20,000 ft² of floor area	One space per 20,000 ft² of floor area

[a] A minimum of two bike parking spots is recommended in all cases

Adapted from Anderson et al. (2010); see Chapter 16 References.

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KEY TAKEAWAYS

- AASHTO Bike Guide is a resource for all communities
  - Representative of all state DOTs (including your state DOT)
  - It's vetted and approved by your state DOT!
  - Guidance applicable to your community: Urban, suburban, and rural
  - Research and data-supported solutions
- Advocate for it's use!
  - By practitioners (agencies, consultants, etc.)
  - Get a copy in your local library for advocates

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Thank you!
Questions?
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Multimodal Design Practice Lead
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