Complete Streets Training for Prince George's County

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Jeremy Chrzan, PE, PTOE – Multimodal Design Practice Lead

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Meet your instructors!

Jeremy Chrzan, PE, PTOE, LEED AP

Cipriana Patterson, PE, PTOE

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Toole Design is the nation's leading planning, engineering, and landscape architecture firm specializing in multimodal transportation.

We've worked on 500+ active transportation projects and designed 1,000's of miles of bikeway and streetscape projects built in the last twenty years.

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What Will Be Covered

- Introductions
- Complete Streets Planning, Policies, and Resources
- Designing for Walking, Biking, and Transit
- Intersection Design Considerations
- Altering Driver Behavior through Street Design
- Applying Lessons Learned to Regional Roadways

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Introductions

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What brings you to this training?

- Please share your:
  - Name
  - Organization
  - Role
  - What you hope to get out of this training?

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Complete Streets Planning, Policies, and Resources

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Why do we need to think about "Complete Streets"

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1. Urbanized Streets are different

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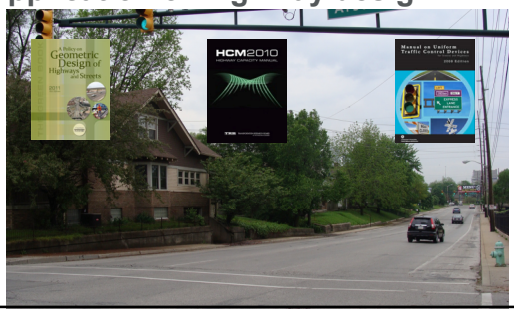
2. Misapplication of Highway design



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3. Emergence of New Policy Framework & Priorities

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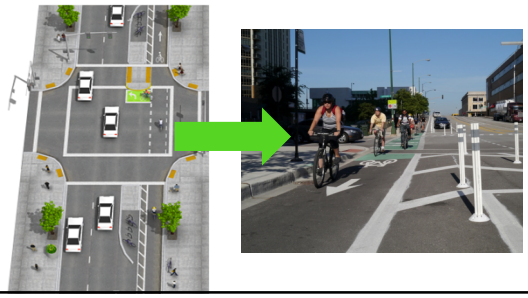
4. Increased use of Bicycles



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5. Emergence of Local Design Guides

New York City Street Design Manual, 2010

Boston Complete Streets Guidelines, 2012

Prince George's County, 2017

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6. Consider the Uses of Public Space

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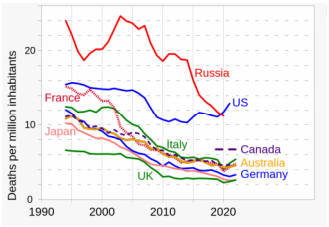
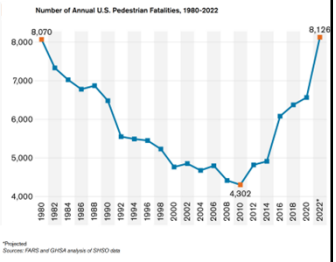
7. The Public Safety Crisis





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Complete Streets Policies

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Prince George's County

- 2012 Complete Streets Policy
  - *Complete Street means a public street that safely and adequately accommodates motorized and non-motorized users, including pedestrians, bicycles, motor, freight, emergency and transit vehicles, in a manner appropriate to the function and context of the facility*
  - *All planned County financed and approved road, sidewalk, trail and transit related projects shall include environmental site design and facilities for motor, emergency and freight vehicles, transit, bicycles and pedestrians, except when cost shall be disproportionate to the projected need or when such facilities would be inappropriate due to the nature of the project, including the context and character of the neighborhood or area.*

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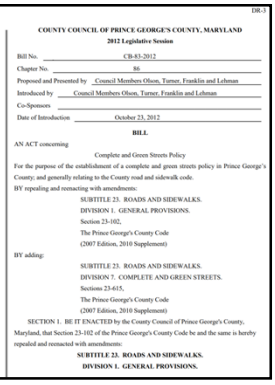

DR-3

COUNTY COUNCIL OF PRINCE GEORGE'S COUNTY, MARYLAND
2012 Legislative Session

Bill No. CB-83-2012
Chapter No. 86
Proposed and Presented by Council Members Olson, Turner, Franklin and Lehman
Introduced by Council Members Olson, Turner, Franklin and Lehman
Co-Sponsors
Date of Introduction October 23, 2012

BILL

AN ACT concerning
Complete and Green Streets Policy
For the purpose of the establishment of a complete and green streets policy in Prince George's County; and generally relating to the County road and sidewalk code.
BY repealing and reenacting with amendments:
SUBTITLE 23. ROADS AND SIDEWALKS.
DIVISION 1. GENERAL PROVISIONS.
Section 23-102,
The Prince George's County Code
(2007 Edition, 2010 Supplement)
BY adding:
SUBTITLE 23. ROADS AND SIDEWALKS.
DIVISION 7. COMPLETE AND GREEN STREETS.
Sections 23-615,
The Prince George's County Code
(2007 Edition, 2010 Supplement)
SECTION 1. BE IT ENACTED by the County Council of Prince George's County, Maryland, that Section 23-102 of the Prince George's County Code be and the same is hereby repealed and reenacted with amendments:
SUBTITLE 23. ROADS AND SIDEWALKS.
DIVISION 1. GENERAL PROVISIONS.

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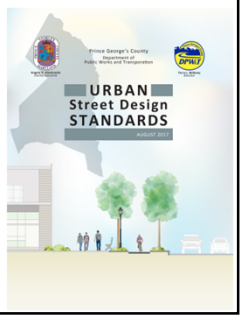
Prince George's County

- Urban Street Design Standards are intended for use in designing new and retrofit streets in Regional Transit Districts and Local Centers, as established by Plan Prince George's 2035
- Key elements include:
  - Slower speeds
  - Shorter crossing distances
  - Reduced curb radii
  - Wider sidewalks
  - More bicycle facilities
  - Pedestrian amenities
- Established Urban Street Typology and Widths



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Prince George's County

- 2023 update
  - Formalizes 15' as default turning radius and 25' for buses and trucks
  - Streets shown are 4 lanes max
  - Prohibits the use of slip lanes
  - Deviations from the standards only allowed by the Director, who may authorize:
    - Reduction in number of travel lanes
    - Reduction in width of travel lanes
    - Reduction in width or elimination of median
    - Reduction in width or elimination of center turn lane
    - Replacement of an off-street bicycle facility with a barrier- or parking-separated on street facility
    - Reduction in width or elimination of on-street parking.

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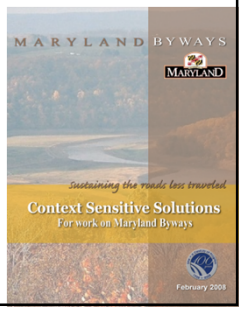
SHA Context Sensitive Solutions

- **Policy Framework**
  - Context Sensitive Solutions is a collaborative, interdisciplinary approach to developing and implementing transportation projects, involving all stakeholders to ensure that transportation projects are in harmony with communities and preserve and enhance environmental, scenic, aesthetic and historic resources while enhancing safety and mobility
- **Mobility and Safety**
  - SHA will develop projects that enhance mobility and safety for users of all modes.



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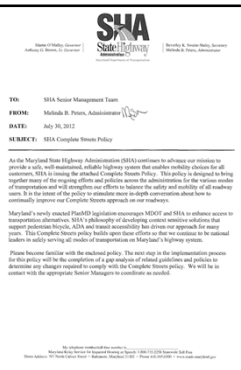
SHA Complete Streets

- The SHA **shall** follow a Complete Streets Approach that promotes the MDOT's overarching mission to *"Enhance the quality of life for Maryland's citizens by providing a balanced and sustainable multimodal transportation system for safe, efficient passenger and freight movement."*



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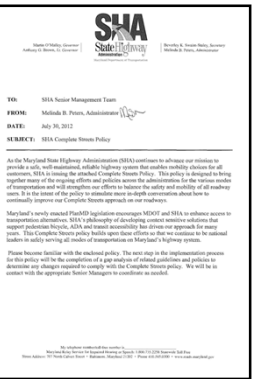
SHA - Pedestrians

- Sidewalks
- Ramps
- Median Treatments
- Driveway Crossings
- Protruding Objects
- Cross Walks
- Midblock Crossings
- Stop Lines
- Signals
- Accessible Pedestrian Signals
- Detectable Warning Devices



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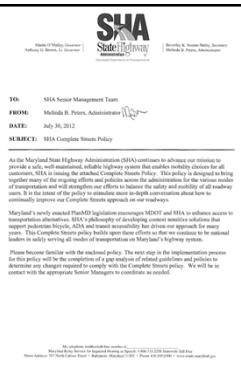
SHA - Bicyclists

- Bike lanes
- Sharrows
- Bike Signs
- Sub-standard lane treatments
- pocket lanes
- cycle tracks
- shared use path
- intersection striping



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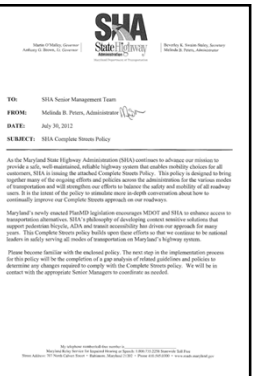
SHA - Transit

- Bus stop locations
- bus signal prioritization
- bus pull out areas
- dedicated bus lanes
- bus rapid transit typical sections



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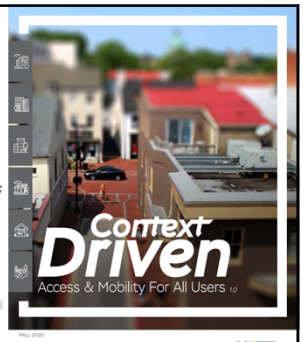
SHA Context Driven

- Address different land use contexts

"Engineers are encouraged to seek out innovative design treatments, especially in areas where there are needs or challenges that cannot be easily addressed by standard elements."



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Resources

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SHA Context Driven Toolkit

- Barrier Separated Bike Lanes
- Continental Crosswalks
- Green Pavement for Bike Lanes
- Hardened Centerlines
- In-Lane Floating Bus Stops
- Lane Width Reduction
- Leading Pedestrian Intervals
- Midblock Crosswalks
- No Turn on Red
- Pedestrian Hybrid Beacon
- Posted Speed Limit Reduction
- Protected Intersections
- Rectangular Rapid Flashing Beacon

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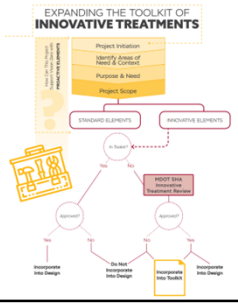

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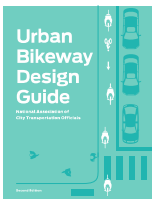
Design Resources



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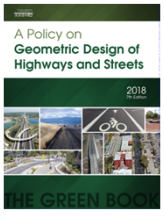
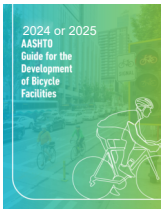
Design Resources





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Look beyond your borders for inspiration

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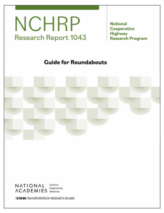
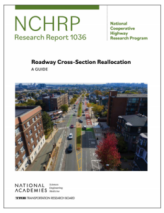
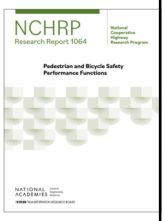
Stay Informed







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Designing for Walking, Biking, and Transit

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Pedestrian Accommodations

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Pedestrian Crash Types & Locations

Common pedestrian crash types:

- Pedestrians crossing midblock
- Walking along a roadway
- At an intersection

92% of pedestrian-involved crashes occurred in the Baltimore and Washington metropolitan areas.

Prince George's County accounted for the greatest number of crashes resulting in a fatality (24%).

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Importance of Pedestrian Facilities

- We are all pedestrians as some point every day
- Dedicated pedestrian facilities make streets safer for everyone
  - Paved shoulders reduces pedestrian crashes by 70% (CRF)
  - Sidewalks reduce pedestrian crashes by 88% (CRF)
- Walking improves livability and public health
- Quality pedestrian facilities provide access to and support local businesses
- Many people do not drive

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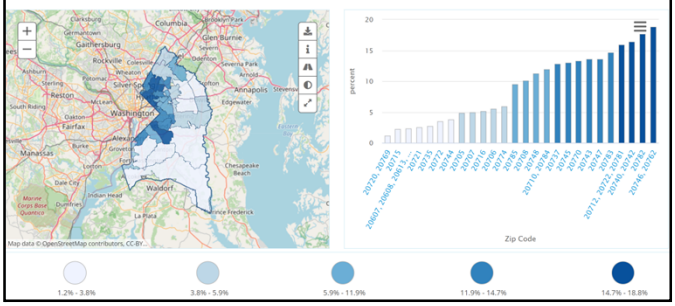
Households without a vehicle



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Pedestrian Facility Needs

Land Use Context Classifications	Sidewalk/Walkway
Rural	Paved shoulders
	Shared Streets
	Shared use paths
Suburban	Sidewalks on both sides of the roadway
	Shared use paths
Urban Core, Urban, and Rural Town	Sidewalks on both sides of the roadway
	Shared Streets
	Shared Use Path

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Types of Pedestrian Facilities

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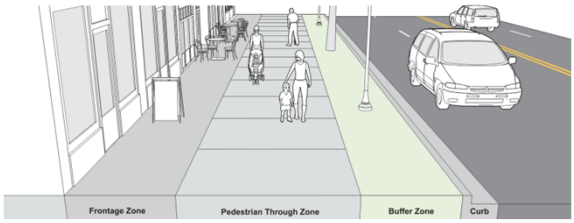
Pedestrian Zone Framework

Curbed Roadways



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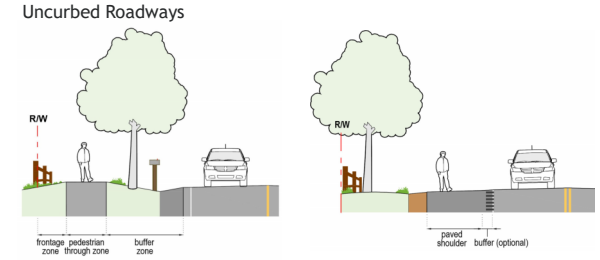
Pedestrian Zone Framework

Uncurbed Roadways



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Understanding Pedestrian Through Zone Widths

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Understanding Pedestrian Through Zone Widths

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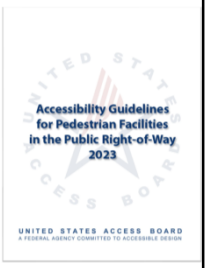
Compliance with PROWAG

- Accessibility Guidelines for Pedestrian Facilities in the Public Right-of-Way
- Minimum accessibility guidelines for pedestrian facilities in the public right-of-way
- Applies to existing facilities when altered
- Ensure pedestrian facilities in the public right-of-way are readily accessible and usable



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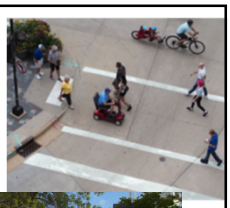
Why PROWAG Matters

- PROWAG to become first national-level enforceable guidance for accessibility in the public right-of-way
- Consistency and predictability in design
- 26% of US population has a long-term disability
- Most people experience a temporary disability
- Access to education, jobs, healthcare, shopping, recreation, etc.
- Benefits people who do not have disabilities



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Topics Covered

- Pedestrian access routes
- Alternate pedestrian access routes
- Protruding objects and vertical clearance
- Sidewalks
- Street furniture
- Curb ramps and blended transitions
- Detectable warning surfaces
- Crosswalks
- Accessible pedestrian signals
- Pedestrian signal timing
- Pedestrian overpasses and underpasses
- Transit stops and transit shelters
- On-street marked or metered parking
- Passenger loading zones
- Stairs and escalators
- Handrails
- Street furniture, including public toilets, tables, counters, benches, drinking fountains
- Pedestrian signs
- At Grade Rail Crossings

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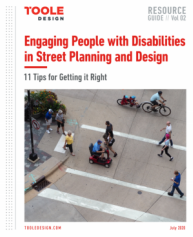
Topics Not Covered or Not Covered In-Depth

- Separated bike lanes, floating bus stops, shared spaces, electric vehicle charging stations, and other street design innovations
- Quick build projects, e.g., flex post curb extensions and pedestrian crossing islands
- Tactile walking surface indicators other than detectable warning surface, e.g., tactile direction indicator
- People with intellectual and developmental disabilities
- Engaging people with disabilities



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Alterations Projects

- *Change to, or an addition of, pedestrian facility in existing developed public right-of-way*
- Must comply to the maximum extent feasible where existing physical constraints make compliance technically infeasible
- Existing ROW width is not a physical constraint
- Not tied to funding sources

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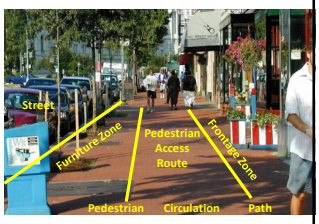
Key Terms

- Pedestrian Access Route: *An accessible, continuous, and unobstructed path of travel for use by pedestrians with disabilities within a pedestrian circulation path.*
- Pedestrian Circulation Path: *A prepared exterior or interior surface provided for pedestrian use in the public right-of-way.*
  - May or may not contain a pedestrian access route; required for new construction



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Surface Characteristics

- Surface must be firm, stable, and slip resistant

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Protruding Objects

- Objects 27” to 80” above ground are not detectable by cane
  - Objects in furniture or frontage zones must not protrude more than 4”
    - Handrails can protrude 4-1/2” max
  - Protruding objects may be protected by a barrier or curb that is at least 2-1/2” high

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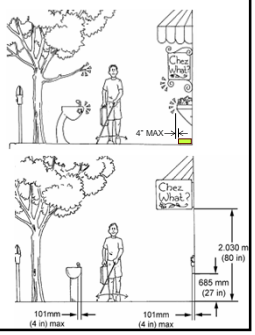

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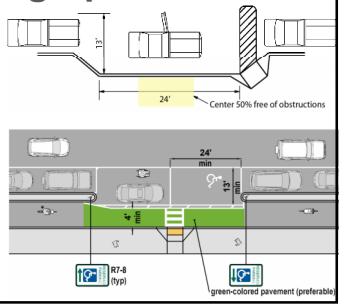
Accessible Parking Spaces

- Accessible parallel parking spaces must be 13’ wide x 24’ long
  - Exception 1: Adjacent PAR not altered then width may match other parallel parking widths.
  - Exception 2: Insufficient ROW (9’ from curb to ROW) in alteration project
  - For exceptions, parking spaces must be located nearest crosswalks
- Middle 50% of parking spaces must be free of obstructions
- Angled parking spaces must be 11’ wide



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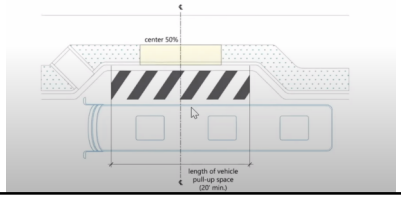
Passenger Loading Zones

- Similar to parking requirements
  - 8’ wide pull up space, 20’ length
  - 5’ wide accessible aisle at the same elevation as loading zone
  - Same center 50% obstruction free requirement along sidewalk



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Roundabouts and Channelized Turn Lanes

- At multi-lane segments of roundabouts and multi-lane channelized turn lanes, one or more off the following is required:
  - Traffic control signal with pedestrian signal head
  - Pedestrian hybrid beacon (PHB)
  - Rectangular rapid flashing beacon (RRFB)
  - Raised crosswalk

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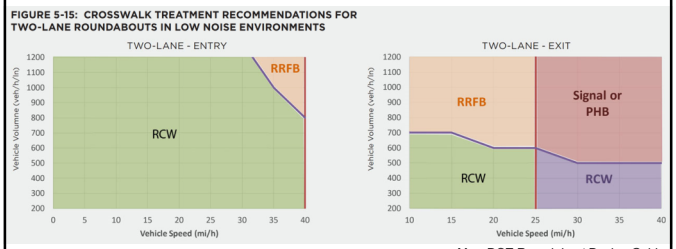
Roundabouts and Channelized Turn Lanes



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MassDOT Roundabout Design Guide (modified by Toole Design)

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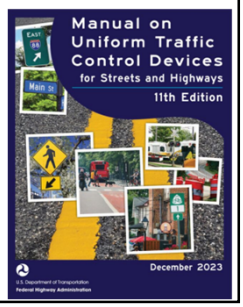
Manual on Uniform Traffic Control Devices

- Effective January 18, 2024
- States have 2-years to adopt or provide their own in substantial conformance



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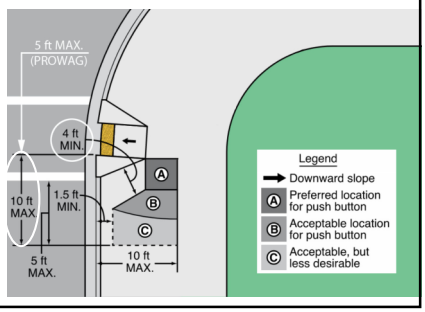
Push Buttons

- 5' vs 10' from Curb Ramp



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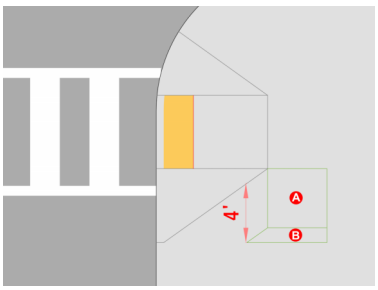
Push Buttons

- 5' vs 10' from Curb Ramp
- Placement in relation to ramp



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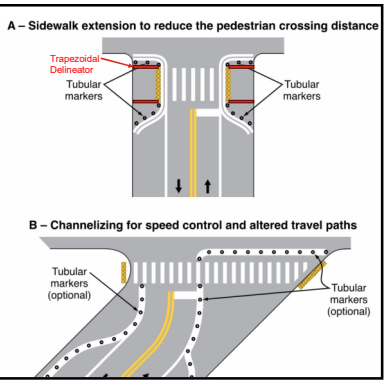
Quick-Build Curb Extension



TOOLE DESIGN

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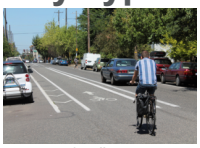
Bicyclists

61

Bicycle Facility Types


Shared Lanes

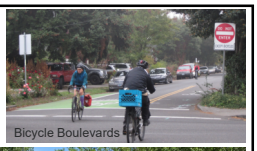

Bike Lanes & Buffered Bike Lanes

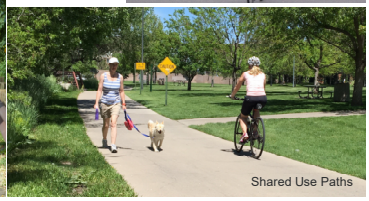

Separated Bike Lanes

62

Bicycle Facility Types

Sidepaths


Bicycle Boulevards


Shared Use Paths

63

What Type of Bikeway Would You Choose?

a. Shared Lanes
b. Bike Lane
c. Bike Boulevard
d. Buffered Bike Lane
e. Separated Bike Lane
f. Sidepath

64

What Type of Bikeway Would You Choose?

a. Shared Lanes
b. Bike Lane
c. Bike Boulevard
d. Buffered Bike Lane
e. Separated Bike Lane
f. Sidepath

65

What Type of Bikeway Would You Choose?

a. Shared Lanes
b. Bike Lane
c. Bike Boulevard
d. Buffered Bike Lane
e. Separated Bike Lane
f. Sidepath

66

What Type of Bikeway Would You Choose?

a. Shared Lanes
b. Bike Lane
c. Bike Boulevard
d. Buffered Bike Lane
e. Separated Bike Lane
f. Sidepath

TOOLE DESIGN

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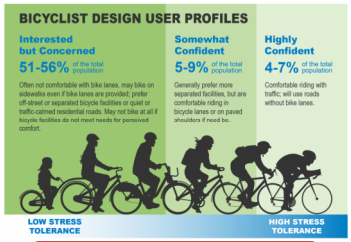
Bicycle Design User Profiles



AUDIENCE POLL
What Type of Bicyclist are You?

The Design User is selected based on the context of the area:

Urban, Suburban, Rural Town Contexts

- Design User Assumption: Interested but Concerned*

Rural Context

- Design User Assumption: Highly Confident

** When we design for the Interested but Concerned User, the design also accommodates the Somewhat Confident and Highly Confident Riders.*

TOOLE DESIGN

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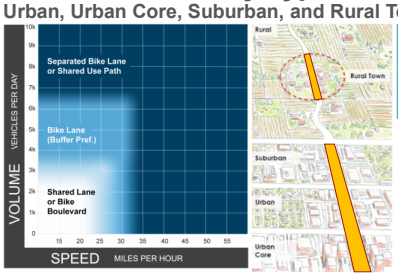
Preferred Bikeway Type

Urban, Urban Core, Suburban, and Rural Town Contexts



Design User Assumption: Interested But Concerned Bicyclist

Analysis: Bicycle Level of Traffic Stress (LTS)

Notes

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

TOOLE DESIGN

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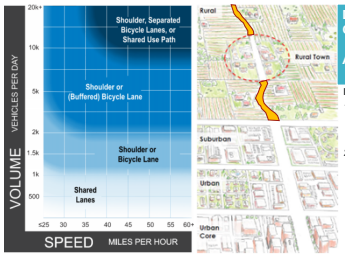
2.5.2 Preferred Bikeway Type

Rural Context



Design User Assumption: Confident Bicyclists

Analysis: Bicycle Level of Service (BLOS)

Notes

1. *Chart assumes operating speeds are similar to posted speeds. If they differ, use operating speed rather than posted speed.*
2. *If the percentage of heavy vehicles is greater than 10%, consider providing a wider shoulder or a separated pathway.*

TOOLE DESIGN

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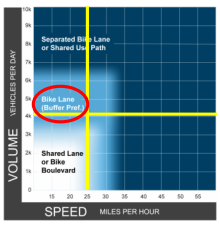
How did your choice compare?

Context Urban → Design User Profile: Interested but Concerned
Posted Speed = 25 mph
Vehicle Volume = 4,000 AADT
40' Road Width, 12' Lane Width, 8' Parking Lane

Urban, Urban Core, Suburban, and Rural Town Contexts



TOOLE DESIGN

71

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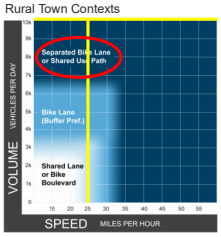
How did your choice compare?

Context: Urban → Design User Profile: Interested but Concerned
Posted Speed = 25 mph
Vehicle Volume = 14,000 AADT
40' Road Width, 12' Lane Width, 8' Parking Lane

Urban, Urban Core, Suburban, and Rural Town Contexts



TOOLE DESIGN

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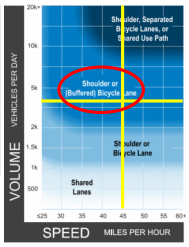
How did your choice compare?

Context: Rural
Posted Speed = 45 mph
Vehicle Volume = 4,000 AADT
28' Road Width, 12' Lane Width, 2' Shoulder

Design User Profile:
Confident Bicyclists

Rural Contexts



TOOLE DESIGN

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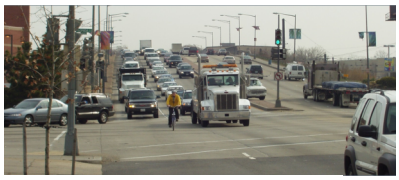
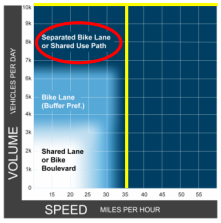
How did your choice compare?



Context Suburban
Posted Speed = 35 mph
Vehicle Volume = 34,000 AADT
70' Road Width, 10' Lane Widths, No Parking

Design User Profile:
Interested but Concerned

Urban, Urban Core, Suburban, and Rural Town Contexts



TOOLE DESIGN

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Assess & Refine: Conditions for Increasing Separation

TOOLE DESIGN

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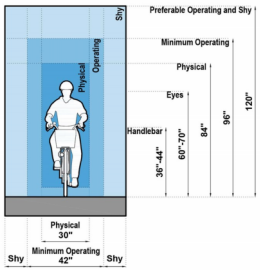
Bicycle Physical, Operating, and Shy Space

Vertical Element	Shy Space (in.)	
	Minimum	Constrained
Bicycle Traffic	12	6
Intermittent (tree, flex post, pole, etc.)	12	0
Continuous (fence, railing, planter etc.)	24	12
Vertical Curb	12	6
Mountable / Sloping Curb	0	0



TOOLE DESIGN

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Bicycle Lanes

Bicycle Lanes Adjacent to On-Street Parking

If parking lane is narrow and turnover is high, separated bike lane is preferred

If a separated bike lane is not feasible, an interim solution is needed or parking turnover is low, a buffered bike lane should be considered

TOOLE DESIGN

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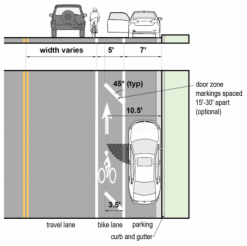
Bicycle Lanes

Bicycle Lanes Adjacent to On-Street Parking



If a buffered bike lane is not feasible, designers should consider the following options in the order stated:

1. Reduce travel lane and parking lane widths where possible
2. Consolidate or remove parking
3. Narrow bike lane, buffer and parking lane widths may be considered
4. Shared lane markings may be used but likely will not accommodate the IBC bicyclists
5. Constrained bicycle lane, buffer, and parking lane dimensions may be used as shown.

TOOLE DESIGN

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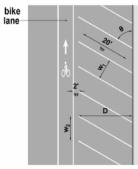
Bicycle Lanes

Bicycle Lanes Adjacent to On-Street Parking



Back in Angle Parking			
θ (Degrees)	W_t (feet)	W_s (feet)	D (feet)
0°	7-10	20	7-10
30°	8-9	16-18	16.9-17.8
45°	8-9	11.3-12.7	19.8-20.5
60°	8-9	9.2-10.4	21.3-21.8

W_t =stall width
W_s =striping width
D=depth to face of curb
θ=angle

TOOLE DESIGN

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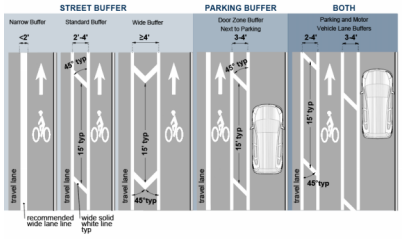
Buffered Bicycle Lanes

- Buffered bike lanes may be provided on any roadway to increase the comfort of bicyclists and are beneficial for the Interested but Concerned Bicyclist as traffic volumes and speeds increase
- See bicycle lane design for lane width dimensions
- Buffer marking style depends on width, roadway speed, and location in relation to the bicycle lane



TOOLE DESIGN

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Separated Bicycle Lanes

Configuration on a One-Way Street

Corridor-level Planning Considerations	One-way SBL	Counterflow SBL	One-way SBL Plus Counterflow SBL	Two-way SBL
Access to Destinations	Limited access to other side of street		Full access to both sides of street	Limited access to other side of street
Network Connectivity	Does not address demand for counterflow bicycling, may result in wrong way riding	Requires bicyclists traveling in the direction of traffic to share the lane (may result in wrong way riding in the SBL); counterflow progression through signals may be less efficient	Accommodates two-way bicycle travel, but counterflow progression through signals may be less efficient	
Crash Risk	Lower because pedestrians and turning drivers expect concurrent bicycle traffic	Higher because pedestrians and turning drivers may not expect counterflow bicycle traffic		
Intersection Operations	May use existing signal phases; separate bicycle phase may be required depending on vehicle volumes	Typically requires additional signal equipment; separate bicycle phase may be required depending on vehicle volumes		

Configuration on a Two-Way Street

Corridor-level Planning Considerations	One-way SBL Pair	Two-way SBL	Median Two-way SBL
Access to Destinations	Full access to both sides of street	Limited access to other side of street	Limited access to both sides of street
Network Connectivity	Accommodates two-way bicycle travel		
Crash Risk	Lower because pedestrians and turning drivers expect concurrent bicycle traffic	Higher because pedestrians and turning drivers may not expect counterflow bicycle traffic	Higher because pedestrians and turning drivers may not expect counterflow bicycle traffic; but median refuge may improve visibility and create opportunities to separate conflicts
Intersection Operations	May use existing signal phases; separate bicycle phase may be required depending on vehicle volumes	Typically requires additional signal equipment; separate bicycle phase may be required depending on vehicle volumes	

TOOLE DESIGN

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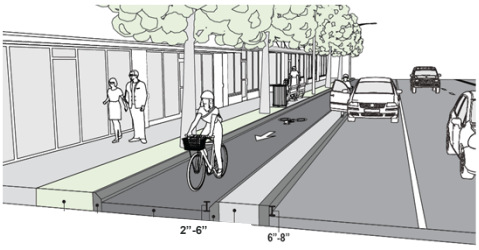
Separated Bicycle Lanes Elevation



TOOLE DESIGN

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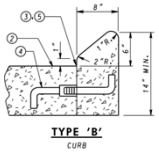
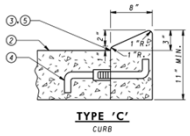
Separated Bicycle Lane Curbing

The following curb types are recommended for separated bicycle lanes:

- Curb Type B - Sloping Curbs are preferred along any separated bike lane to reduce pedal strike hazards and to ease access to the sidewalk.
- Curb Type C - Mountable curbs are traversable by bicyclists, reduce pedal strike hazards, and are preferred along intermediate level separated bicycle lanes. (Recommend modification to remove the 1" fillet at gutter line for bikeways)





Peak Hour Directional Bicyclist Volume	One-Way Separated Bike Lane Width (ft)		
	Between Vertical Curbs	Adjacent to One Vertical Curb	Between Sloped Curb or at Sidewalk Level
<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
Constrained Condition*	4.5	4	3.5

*Peak Hour Directional Bicyclist Volume not applicable

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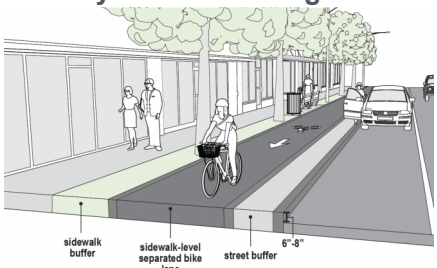
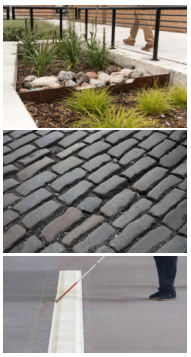
Sidewalk Buffer – Reliably Detectable Edge





TOOLE DESIGN

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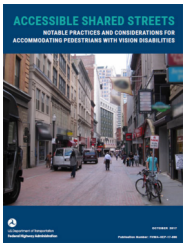
Accessibility at Sidewalk Level Separated Bicycle Lanes

"When a separated bike lane is raised to sidewalk level, sidewalk buffers need to include a delectable edge so pedestrians with vision disabilities can distinguish between the bike lane and the sidewalk."



Recommendations for Detectable Sidewalk Buffer:

- Detectable underfoot and with a white cane
- A 'non-walkable surface' is preferred
- A curb with a reveal of at least 2"

TOOLE DESIGN

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Sidewalk Buffer – Detectable Edge?

POLL

TOOLE DESIGN

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Sidewalk Buffer – Detectable Edge?

POLL

TOOLE DESIGN

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Sidewalk Buffer – Detectable Edge?

POLL

TOOLE DESIGN

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Shared Use Path General Design

Path widths **less than 11 ft.** in width **do not provide space** for people to travel side-by-side and be passed by other users approaching from the opposite direction without **increasing the potential for conflicts**.

For this notable reason, 11 ft widths should be used where possible.

TOOLE DESIGN

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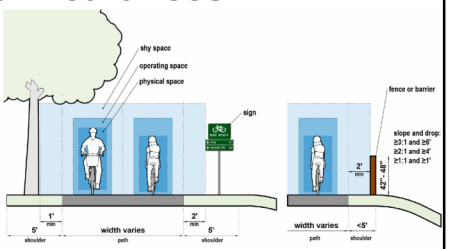
Widths and Clearances

Shoulder Design Criteria:

- Width ≥ 5ft.
- Cross Slope 6:1 max
- Shy Spaces need to be considered



TOOLE DESIGN

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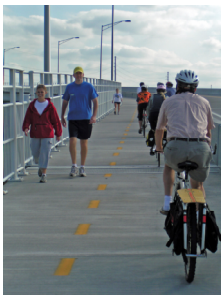
Bridges and Underpasses for Paths

- The clear width of a shared use path on a bridge or in an underpass should account for the necessary operating space and shy spaces.
- The paved width of the path (barrier-to-barrier or wall- to-wall width) should allow 2 ft. of shy space on each side of the shared use path.
  - Under constrained conditions the shy space may be reduced to 1 ft.



TOOLE DESIGN

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Transit

TOOLE DESIGN

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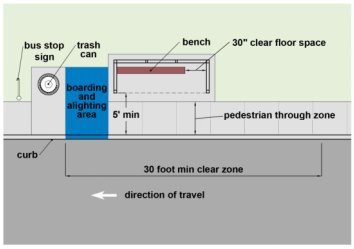
Accommodating Transit Users

- Pedestrian Access
- Bicycle Access
- Boarding and Alighting Area Accessibility
- Passenger Waiting Area
- Bus Stop Amenities



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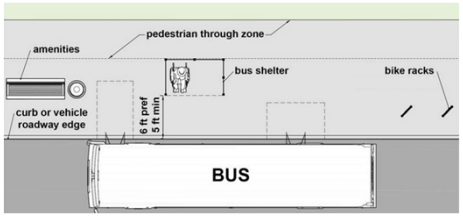
Accessibility at Transit Facilities

- PROWAG identifies the dimensions required for pedestrian access and maneuverability at bus stops



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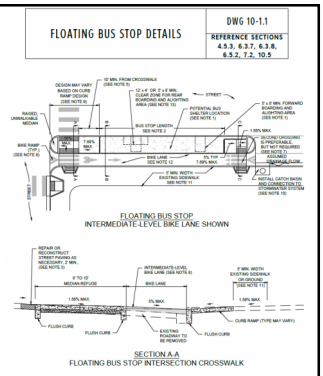
Integrating Bicycle Facilities with Transit



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Transit Stops & Transit Shelters

- PROWAG requires alternate transit stops if accessible transit stops are temporarily not accessible, e.g., due to construction

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Transit Resources

TOOLE DESIGN

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Intersection Design Considerations

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Intersections and Crossings for Multimodal Streets

- Visibility
- Frequency of Crossing Opportunities
- Minimal exposure to conflicts with motorists
- High motorized yielding rates
- Minimized vehicle speeds and conflicts

TOOLE DESIGN

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Intersections and Crossings for Multimodal Streets

- **Visibility**
- Frequency of Crossing Opportunities
- Minimal exposure to conflicts with motorists
- High motorized yielding rates
- Minimized vehicle speeds and conflicts

TOOLE DESIGN

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Intersections and Crossings for Multimodal Streets

- Visibility
- **Frequency of Crossing Opportunities**
- Minimal exposure to conflicts with motorists
- High motorized yielding rates
- Minimized vehicle speeds and conflicts

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

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Intersections and Crossings for Multimodal Streets

- Visibility
- Frequency of Crossing Opportunities
- **Minimal exposure to conflicts with motorists**
- High motorized yielding rates
- Minimized vehicle speeds and conflicts

TOOLE DESIGN

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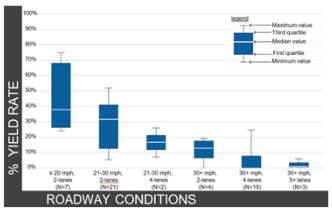
Intersections and Crossings for Multimodal Streets

- Visibility
- Frequency of Crossing Opportunities
- Minimal exposure to conflicts with motorists
- **High motorized yielding rates**
- Minimized vehicle speeds and conflicts



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Crossing Treatments to Improve Motorist Yielding

- Crosswalk and Yield Markings
- Crossing Islands and Medians
- Curb Extensions
- Raised Crossings
- RRFBs & PHBs
- Illumination

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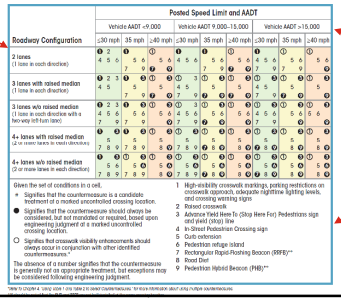
Selecting Pedestrian Crossing Treatments

Roadway Configuration

Posted Speed Limit & AADT

Pedestrian Crash Countermeasures



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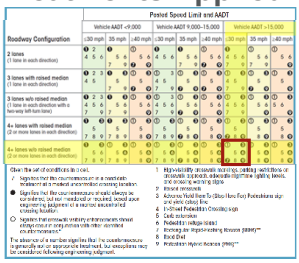
Selecting Pedestrian Crossing Treatments Applied



TOOLE DESIGN

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Intersections and Crossings for Multimodal Streets

- Visibility
- Frequency of Crossing Opportunities
- Minimal exposure to conflicts with motorists
- High motorized yielding rates
- **Minimized vehicle speeds and conflicts**

TOOLE DESIGN

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Large Radius

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Small Radius / Protected Intersection

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Minimizing Turning Speeds

Design Controls & Evaluation:
Intersection Design and Check Vehicles
Turning Vehicle Design Speed
Actual and Effective Curb Radius

Treatments for Minimizing Turning Speeds
Truck Aprons
Turning Lanes and Channelized Islands
Median Islands and Hardened Centerlines

Designing Intersection and Driveway Corner Radii (to Minimize Turning Speeds)

TOOLE DESIGN

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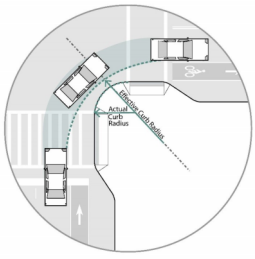
Design & Control Evaluation

- Choose most appropriate motorized design and check vehicle for the location
- Smallest feasible curb radius should be selected for corner designs based upon the design vehicle's effective turning radius



TOOLE DESIGN

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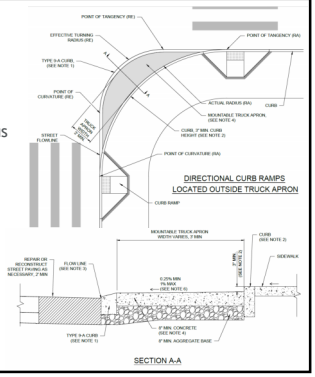
Designing Intersection and Driveway Corner Radii

Where pedestrians or bicyclists are expected and the effective turning radius exceeds 15 ft., consider the following:

- Provide a truck apron to increase the effective radius of larger vehicles, including SU-30, while providing a smaller effective radius for the majority of vehicles (e.g., passenger car)
- Consider a raised crossing to slow turning vehicles.



TOOLE DESIGN

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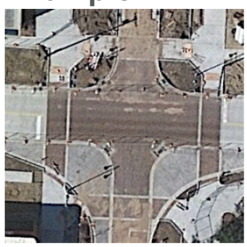
Mountable Truck Apron Example



TOOLE DESIGN

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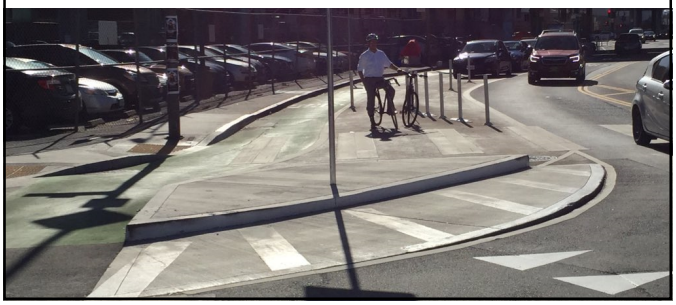
Mountable Truck Apron Example

TOOLE DESIGN

114

Mountable Truck Apron Example



115

Mountable Truck Apron Example

116

Mountable Truck Apron Example

117

Bicycle Lanes Intersection Design

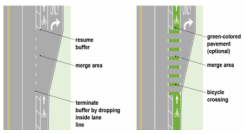
General Design Principles:

- Communicate where motorist are expected to yield to bicyclists.
- Bicycles should not operate between turning lanes and moving lanes with traffic operating over 30 mph on either side of them for distances longer than 200 ft.
- Bicycle crossings of weaving or merging movements by motor vehicles operating over 20 mph should be avoided or minimized to a length of 200 ft. or less.
- Motorists merging and crossing movements across bike lanes should be confined to a location where motor vehicles are likely to be traveling at speeds less than 20 mph.
- Bicycle crossings of intersections should be marked.

TOOLE DESIGN

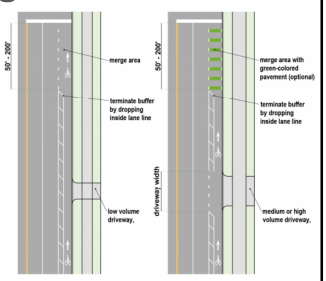
118

Approach Markings



Dotted lane lines should be used to delineate conflict areas within the bike lane at locations where:

- intersections are signalized and bicyclists and motorists operate concurrently
- where right turn lanes are not provided and turning motorist volumes are high
- buses frequently cross the bike lane at transit stops



TOOLE DESIGN

119

Intersection Pavement Markings

Intersection Type	Condition	Separated Bicycle Lane	Conventional/ Buffered Bike Lane	Bicycle Boulevard
Signalized	Turn Conflict			No Markings
	No Turn Conflict			No Markings
	Bikeway Corridor Turns Left			

TOOLE DESIGN

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Hennepin Ave

Intersection Type	Condition	Separated Bicycle Lane	Conventional/ Buffered Bike Lane	Bicycle Boulevard
Signalized	Turn Conflict			No Markings
	No Turn Conflict			No Markings
	Bikeway Corridor Turns Left			

TOOLE DESIGN

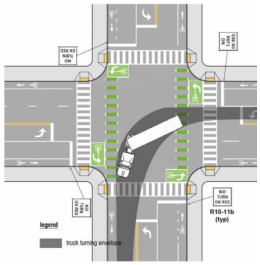
121

Hennepin Ave – Markings

TOOLE DESIGN

122

Intersection Pavement Markings



Intersection Type	Condition	Separated Bicycle Lane	Conventional/ Buffered Bike Lane	Bicycle Boulevard
Signalized	Turn Conflict			No Markings
	No Turn Conflict			No Markings
	Bikeway Corridor Turns Left			

TOOLE DESIGN

123

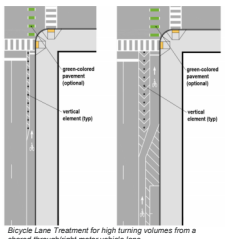
Hennepin Ave – Facilitating Turns

TOOLE DESIGN

124

Bicycle Lanes Intersection Design

- **Shared Through/Right Motor Vehicle Lanes**
- Right Turn Only Lanes
  - Transition to Separated Bike Lane
  - Bicycle Lane Adjacent to a Right Turn Only
  - Through Lane Transitions to a Right Turn Only Lane
  - Bike Lane Ends to Develop a Right Turn Lane
  - Dual Right Turn Only Lanes



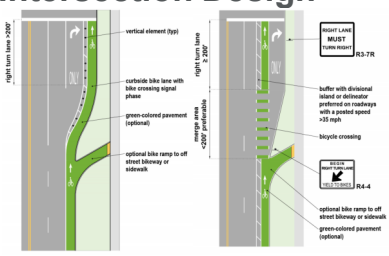
Bicycle Lane Treatment for high turning volumes from a shared through/right motor vehicle lane

TOOLE DESIGN

125

Bicycle Lanes Intersection Design

- Shared Through/Right Motor Vehicle Lanes
- Right Turn Only Lanes
  - **Transition to Separated Bike Lane**
  - **Bicycle Lane Adjacent to a Right Turn Only**
  - Through Lane Transitions to a Right Turn Only Lane
  - Bike Lane Ends to Develop a Right Turn Lane
  - Dual Right Turn Only Lanes



TOOLE DESIGN

126

Example of Right Turn Lane

TOOLE DESIGN

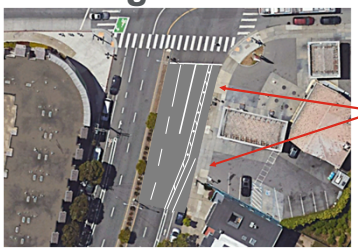
127

Example of Right Turn Lane

TOOLE DESIGN

128

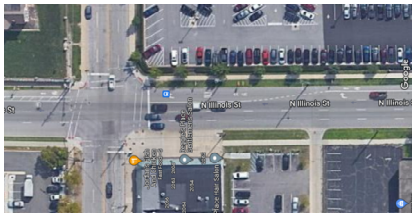
Example of Right Turn Lane

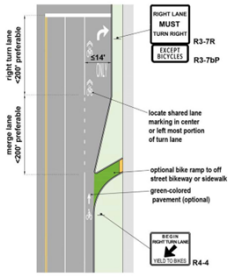


TOOLE DESIGN

129

How could we improve this transition?

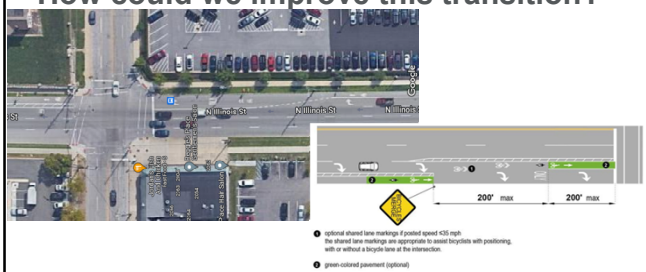




TOOLE DESIGN

130

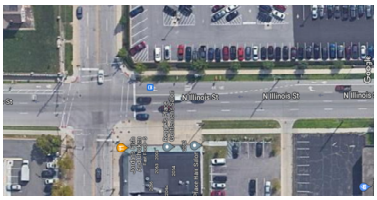
How could we improve this transition?

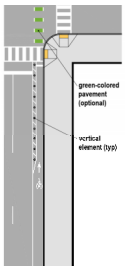


TOOLE DESIGN

131

How could we improve this transition?

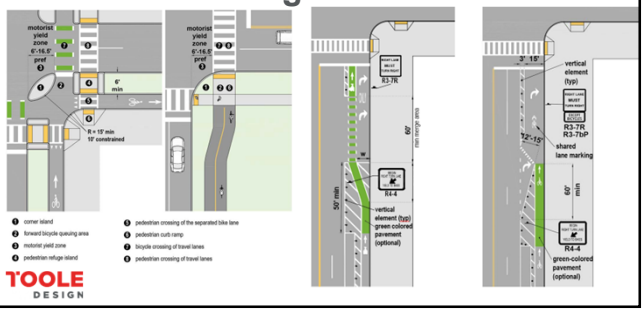




TOOLE DESIGN

132

Separated Bike Lanes at Intersection Design



TOOLE DESIGN

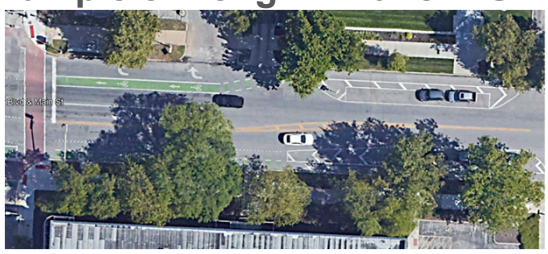
133

Example of Long RT Lane- KS

TOOLE DESIGN

134

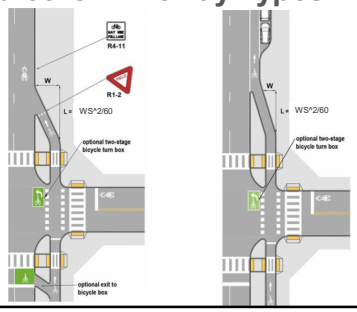
Example of Long RT Lane -KS



TOOLE DESIGN

135

Transitions between Separated Bicycle Lanes and other Bikeway Types

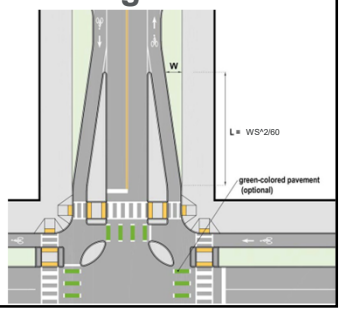


TOOLE DESIGN

136

Transitions on Intersecting Street

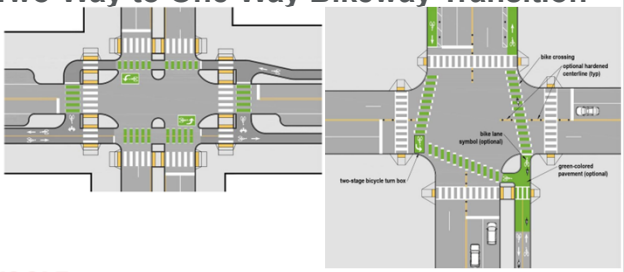
- Maintain protection through intersection where possible
- Restrict parking near intersection to maintain sight distance
- Taper bike lane



TOOLE DESIGN

137

Two-Way to One-Way Bikeway Transition



TOOLE DESIGN

138

How could we improve this transition?

TOOLE DESIGN

139

How could we apply these tools to improve this intersection?

140

Intersection Design: Pedestrian Traffic Signals and Signal Phasing

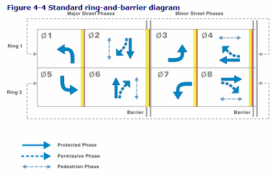
TOOLE DESIGN

141

Signal Terminology Refresher

Terminology Refresher:

- Interval – period during which a signal indication does not change (e.g. green signal)
- Phase – the green, yellow change, and red clearance intervals for a given movement or group of movements
- Signal Cycle – the combination of all movement or group of movements phases



TOOLE DESIGN

142

Evaluation of Traffic Control Signal or Pedestrian Hybrid Beacon

Consider pedestrian signal or pedestrian hybrid beacon (PHB) installation at crossing locations where one or more of the following conditions occur:

- Where one or more traffic signal warrants or PHB guidelines are met;
- Sight distance is restricted, based on prevailing motor vehicle speeds;
- Motor vehicle approach speeds exceed 30 mph;
- There are four or more through lanes of major street traffic;
- There are insufficient crossing opportunities (including crossings of two through lanes) within about a quarter of a mile from the location in question.

TOOLE DESIGN

143

Traffic Control Signal Warrants

Designers have the flexibility to **estimate future demand in the absence of a signal or PHB** if existing conditions limit vulnerable user crossing opportunities.

At bicycle boulevards and shared use paths crossings] there is **an implied understanding that a higher level of care has been taken to ensure bicyclists and pedestrians can safely navigate these routes**, as families commonly use such facilities with children.

TOOLE DESIGN

144

Signal Design Guidance for Pedestrian Facilities

(Visual) Pedestrian Signals

Audible Pedestrian Signals

Image Source: MODOT

Detection

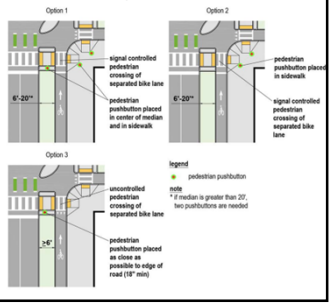
TOOLE DESIGN

145

Pedestrian Push Button Placement Considerations at Separated Bicycle Lanes

- Controlled Crossings - Option 1 & 2
- Uncontrolled Crossings Option 3

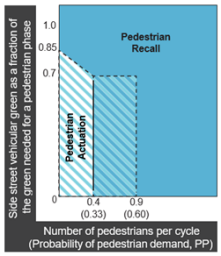
Controlled crossings are preferred.



TOOLE DESIGN

146

Pedestrian Recall and Actuation



Recall should be a priority in populated areas where tends to be significant pedestrian volume and relatively short cycle lengths.

Signal timing plans can vary based on the time of day or day of week.

TOOLE DESIGN

147

Signal Cycle Length & Pedestrian Phase Timing

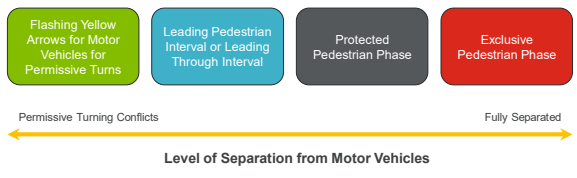
Signal Cycle Length

Pedestrian Signal Phase Timing

TOOLE DESIGN

148

Signal Phasing for Managing or Reducing Conflicts



TOOLE DESIGN

149

Concurrent Pedestrian Phase with Permissive Vehicle Turns

MARYLAND ISSUES!

TOOLE DESIGN

150

Leading Pedestrian Intervals (LPI) & Leading Through Interval (LTI)

Warrant	Turning Vehicles Volume (A)	Pedestrian Volume (B)
Vehicle Peak Hour	≥130 per hour	≥25 per hour
Pedestrian Peak Hour	≥100 per hour	≥50 per hour
4-Hour Vehicular and Ped Volume	≥105 per hour	≥30 per hour
8-Hour Vehicular and Ped Volume	≥100 per hour	≥25 per hour
School Crossing	≥50 per hour	

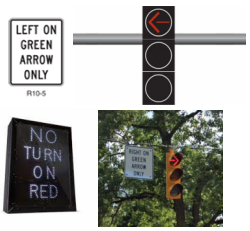
TOOLE DESIGN

151

Protected Pedestrian Phase and Turn Restrictions

Consider turn restrictions or protected pedestrian phases when one or more of the following criteria are met:

- High volume of conflicting turning vehicles
- High volume of total approaching traffic (greater than 2000 veh/hr for all approaches)
- High pedestrian volumes (pedestrians are 30% of vehicle volumes or 300 peds/hour)
- Crash patterns at the study location or nearby locations with similar geometry support the use of separating motor vehicle and pedestrian phasing
- The available sight distance is less than the minimum stopping sight distance criteria
- The intersection geometry is unusual (streets intersect at acute/obtuse angles or streets have significant curvature approaching the intersection), which may result in unexpected conflicts and/or visibility issues
- An intersection in close proximity to senior housing, elementary schools, recreational areas, playgrounds, and/or health facilities



TOOLE DESIGN

152

Exclusive Pedestrian Phases

TOOLE DESIGN

153

Intersection Design: Bicycle Traffic Signals, Timing, & Detection

TOOLE DESIGN

154

Bicycle Signal Indication Options

Standard Traffic Signal Designated for Bicycle Use

Bicycle Signal Face (FHWA Interim Approval)

Pedestrian Signal Head + Bikes Use Ped Signal Sign

TOOLE DESIGN

155

When to direct bicyclist to follow the pedestrian signal?

The instances where it may be acceptable are bikeways where:

- Traveling in the same direction as the closest motor vehicle travel lane and the pedestrian signal is well oriented for bicyclists to see,
- Locations where an LPI is provided and allowing bicyclists to follow the pedestrian signal means they are provided a protected time to cross without turning vehicles, and
- Projects with insufficient funding to provide separate bicycle signals, such a quick-build (rapid implementation) projects or those implemented as part of a resurfacing project where signal work is not part of the project scope.

Pedestrian Signal Head

TOOLE DESIGN

156

When to use a bicycle signal?

A bicycle signal is typically used in the following situations:

- Where the bikeway is a one-way or two-way separated bike lane;
- Where bicyclists' position in the bikeway does not allow them to see motor vehicle or pedestrian signals that may otherwise be able to control their movement, and;
- Where intersection complexity is such that signals may be helpful, as determined by engineering judgment.

Traffic signal indications for a bicyclist along a corridor should be as uniform as possible.

TOOLE DESIGN

157

FHWA Optional Use of Bicycle Signal Faces

- Allowable Applications:
  - Can only be used without conflicting vehicle turns
  - Any deviations require formal Request to Experiment (RTE)

The requirement for phase separation DOES NOT apply to Standard Traffic Signal + BIKE SIGNAL sign.

TOOLE DESIGN

158

Bicyclist Detection

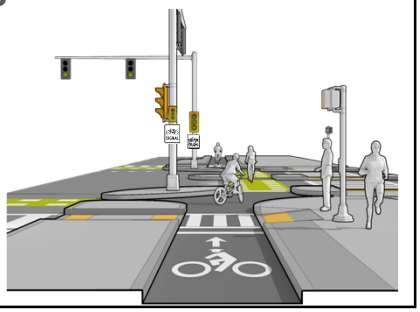
- Detection considerations include:
  - Technology Options
  - Location/ Placement
  - Signing and Markings

TOOLE DESIGN

159

Signal Design Considerations

- Size and Layout of Displays
- Number of Displays
- Visibility
- Mounting Height
- Considerations for Placement with Pedestrian Signal Equipment



TOOLE DESIGN

160

Signal Timing and Reducing Bicycle Delay

- Signal Cycle Length
- Bicycle Minimum Green
- Yellow Change Interval
- Red Clearance Interval
- Bicycle Green Extension
- Signal Coordination Considerations

TOOLE DESIGN

161

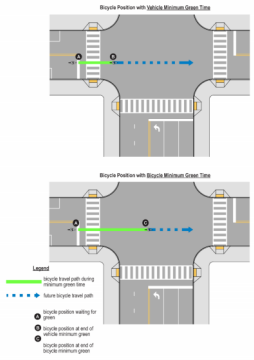
Bicycle Minimum Green

Bicycle Minimum Green Time Equation

$$G_{min} = t + \frac{1.47v}{2a} + \frac{D+L}{1.47v}$$

Where:

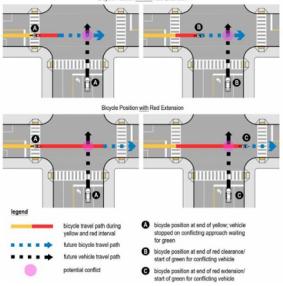
G_{min}	=	bicycle minimum green time (s)
v	=	attained bicycle crossing speed (assumed 8 mph)
t	=	perception reaction time (generally 1.5 s)
a	=	bicycle acceleration (assumed 2.5 ft/s²)
D	=	distance from stop bar to middle of the intersection (ft)
L	=	typical length of a bicycle (6 ft)



TOOLE DESIGN

162

Yellow Change & Red Clearance Interval



TOOLE DESIGN

163

Signal Cycle Length and Coordination Considerations

TOOLE DESIGN

164

Bicycle Signal Phasing for Managing and Reducing Conflicts

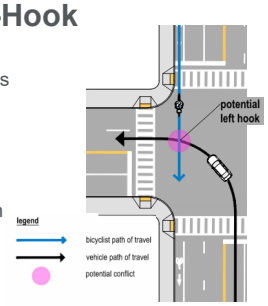
TOOLE DESIGN

165

Turning Conflicts: Left-Hook

During permissive left-turns:

- Drivers are focused on finding gaps in vehicular traffic
- May not detect crossing cyclists or pedestrians
- Crashes tend to be more severe than right-hook due to acceleration through intersection



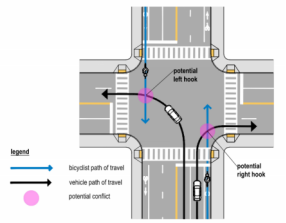
TOOLE DESIGN

166

Turning Conflicts: Right-Hook

Most common right-hook crashes are a result of:

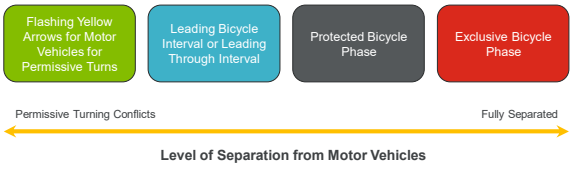
- Motorist failing to yield
- Bicyclist isn't visible
- Right-turning vehicle volumes are very high



TOOLE DESIGN

167

Signal Phasing For Managing Conflicts



TOOLE DESIGN

168

Thresholds for Protected Bicycle Phase

Hourly Volume Thresholds for Separate Turn Phases		
	Left Turn Crossing One Oncoming Lane	Left Turn Crossing Two Oncoming Lanes
One-Way Separated Bike Lane	≥ 100 ≥ 150*	≥ 50 ≥ 150*
Two-Way Separated Bike Lane or Sidepath	≥ 50 ≥ 100*	ANY ≥ 100*

*Threshold also applies to left turns on one-way streets

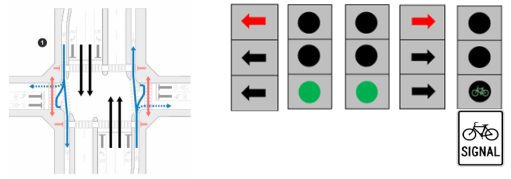
In addition to locations that meet hourly volume thresholds, designers shall consider providing separate signal phases for the following situations:

- Locations with multiple left or right turn lanes;
- Where sight obstructions limit bicycle visibility;
- At locations where bicycle volumes and/or parallel pedestrian volumes are high and turning motorists are unable to find appropriate gaps;
- At locations where more than 5% of the turning traffic volume is heavy vehicles;
- Locations where motorists may turn across the bikeway at speeds over 30 mph or on roads with posted speeds of 35 mph or greater.

TOOLE DESIGN

169

Signal Phasing for Bicyclists: Concurrent Protected Bicycle Phase



Permissive Turning Conflicts — Fully Separated

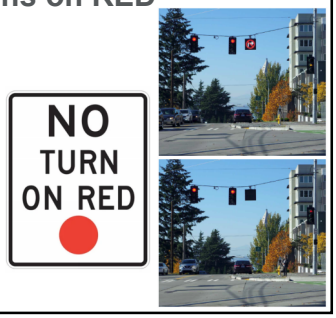
Level of Separation from Motor Vehicles

TOOLE DESIGN

170

Restricting Right Turns on RED

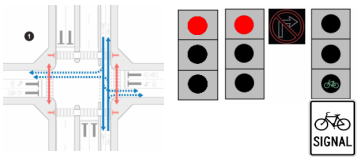
- Restrict motor vehicle right turns on red to reduce conflicts
- Necessary for protected phases
- Option to use static sign or blank out signs



TOOLE DESIGN

171

Signal Phasing for Bicyclists: Exclusive Bike Phase



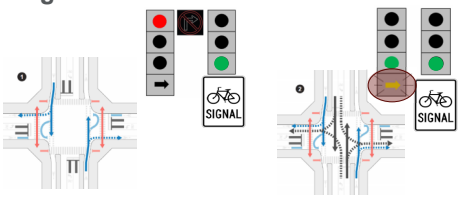
Permissive Turning Conflicts — Fully Separated

Level of Separation from Motor Vehicles

TOOLE DESIGN

172

Signal Phasing for Bicyclists: Leading Bike Interval



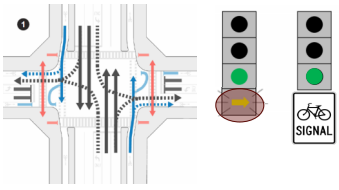
Permissive Turning Conflicts — Fully Separated

Level of Separation from Motor Vehicles

TOOLE DESIGN

173

Signal Phasing for Bicyclists: Permissive Vehicle Turns



Permissive Turning Conflicts — Fully Separated

Level of Separation from Motor Vehicles

TOOLE DESIGN

174

Altering Driver Behavior through Street Design

175

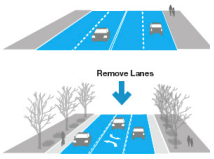
Traffic Calming

- Traffic calming makes roadways safer by reducing dangerous driving speeds and movements
- Types of traffic calming:
  - Street Width Reduction
  - Horizontal Deflection
  - Vertical Deflection
  - Diversions

176

Street Width Reduction

Road Diets



Narrow (Yield) Streets

One-Lane Pinch Points

177

Wider Lanes are Required, Right?

11' to 14' lanes historically favored to be more forgiving to drivers, especially on high-speed roads

AASHTO Green Book allows 9' to 12'

- Allows 10' for "low-speed" roads (45mph or less)

FHWA no longer requires design exceptions for lane width as a controlling criteria

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Needed to Accommodate Vehicle Widths?

Design Vehicle Dimensions

Vehicle	Vehicle Length	Vehicle Width	Operating Width[1]
Passenger Cars and Light Trucks	19.0 feet	7.0 feet	9.0 ft
School Bus	36.0 feet	8.0 feet	10.0 ft
Transit Bus	40.0 feet	8.5 feet	10.5 ft
Single Unit Truck[2]	30.0 feet	8.0 feet	10.0 ft
Tractor-Trailer	55.0 feet	8.5 feet	10.5 ft

Source: *A Policy on the Geometric Design of Streets and Highways*, AASHTO, 2004. Chapter 2 Design Controls and Criteria
1 Assuming one-foot clearance on both sides of vehicle
2 The SU-30 design vehicle is commonly used to model emergency response vehicle operations

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Narrow Lanes – Safety Concerns?

Travel lanes of 10-feet as part of a thoughtful design of arterials and collectors do not negatively affect motorist safety.

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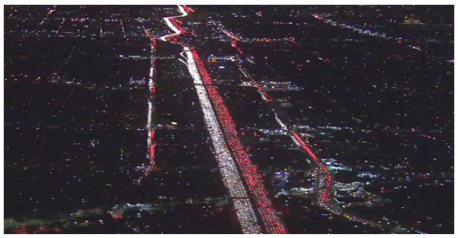
Narrow Lanes – Congestion Concerns?



Travel lanes of 10-feet as part of a thoughtful design of arterials and collectors have no measurable effect on capacity.

TOOLE DESIGN

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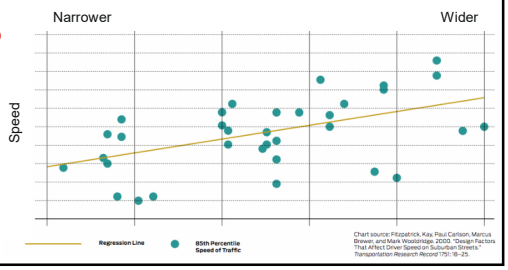
Narrow Lanes Can Reduce Speeds

"Narrow lanes can contribute to lower speeds when integrated as part of an urban street design."
- FHWA



TOOLE DESIGN

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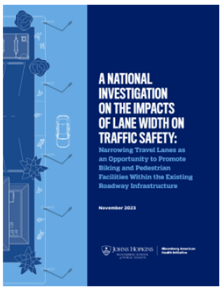
Narrow Lanes Are Allowed and Are Safer



- Our survey of AASHTO member state DOTs indicate that the majority of state DOTs prefer to follow the conventional design standards adopted by their DOT, and the context-sensitive design approach has not been widely used within their jurisdiction.
- In practice we are far from implementation of the context-sensitive design solutions by most state DOTs. The design exception for lane width reduction projects seems to be a rare event in most state DOTs that participated in our survey.
- In the speed class of 20—25 mph, the driving speed is slow enough that drivers do not notice changes in lane widths. This hypothesis was confirmed by our findings that there is no significant difference in terms of the number of non-intersection crashes between 9-foot, 10-foot, 11-foot, 12-foot, or even 13-foot lanes.
- On the other hand, street sections with 10-foot, 11-foot, and 12-foot lanes have significantly higher numbers of non-intersection crashes than their counterparts with 9-foot lanes in the speed class of 30—35 mph.
- In other words, in the speed class of 30—35 mph, wider lanes not only are not safer, but exhibit significantly higher numbers of crashes than 9-foot lanes, after controlling for geometric and cross-sectional street design characteristics of street sections.

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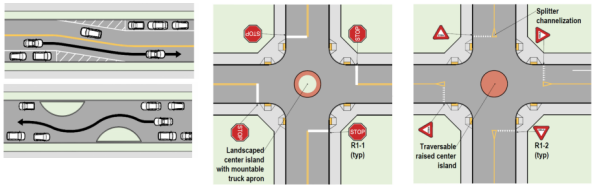
Horizontal Deflection

Lateral Shifts & Chicanes | Traffic Circles | Mini and Modern Roundabouts



TOOLE DESIGN

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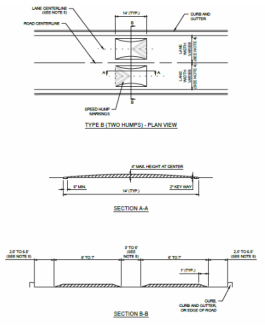
Vertical Deflection

Vertical deflection as a traffic calming measure is appropriate on streets where posted speeds are less than 35 mph and where roadway grades do not exceed 8%.

Options include:

- Speed Humps
- Raised Crossings
- Speed Tables



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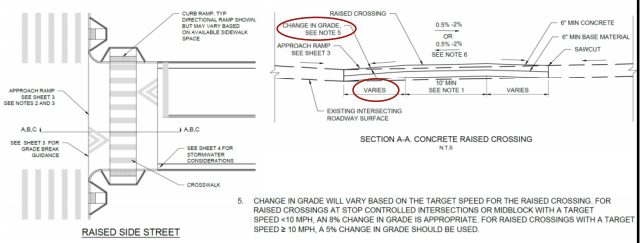
Raised Crosswalk / Speed Table Guidance



5. CHANGE IN GRADE WILL VARY BASED ON THE TARGET SPEED FOR THE RAISED CROSSING. FOR RAISED CROSSINGS AT STOP CONTROLLED INTERSECTIONS OR MIDBLOCK WITH A TARGET SPEED <10 MPH, AN 8% CHANGE IN GRADE IS APPROPRIATE. FOR RAISED CROSSINGS WITH A TARGET SPEED ≥ 10 MPH, A 5% CHANGE IN GRADE SHOULD BE USED.

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Routing Restrictions & Diversions

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Applying Lessons Learned to Regional Roadways

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Central Ave & Addison Road

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Questions? Thank you!

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