Pedestrian and Bicycle Transportation Design Best Practices

June 27, 2019
Laramie, Wyoming
Introductions

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What type of organization do you represent?
What is your primary role?
What is the most challenging part of implementing pedestrian and bicycle infrastructure?
What do you hope to gain from today’s training?
## Agenda

<table>
<thead>
<tr>
<th>Time</th>
<th>Topic</th>
</tr>
</thead>
<tbody>
<tr>
<td>9:15 am</td>
<td>Pedestrian Design Training (Part 1)</td>
</tr>
<tr>
<td>10:30 am</td>
<td>Break</td>
</tr>
<tr>
<td>10:45 am</td>
<td>Pedestrian Design Training (Part 2)</td>
</tr>
<tr>
<td>11:45 am</td>
<td>Pedestrian Design Group Activity</td>
</tr>
<tr>
<td>12:15 pm</td>
<td>Lunch</td>
</tr>
<tr>
<td>12:45 pm</td>
<td>Bicycle Design Training (Part 1)</td>
</tr>
<tr>
<td>2:00 pm</td>
<td>Break</td>
</tr>
<tr>
<td>2:15 pm</td>
<td>Bicycle Design Training (Part 2)</td>
</tr>
<tr>
<td>3:15 pm</td>
<td>Bicycle Design Group Activity</td>
</tr>
<tr>
<td>3:45 pm</td>
<td>Wrap-up</td>
</tr>
</tbody>
</table>
Wyoming Context
Population Trends

- Slow population growth (2.3% compared to 5.8% nationally)
- 50th in total population
- 49th in population density (10th largest state)

Source: American Community Survey
Transportation System

- 29,024 miles of roadways (42nd)
  - 14% federal
  - 23% state
  - 50% county
  - 8% city
  - 4% private/institutional

Source: USDOT Bureau of Transportation Statistics

- **Pedestrian fatalities**
  - 48 (50\(^{th}\))
  - 3.7% of all traffic fatalities

- **Bicyclist fatalities**
  - 10
  - 0.8% of all traffic fatalities

Sources: NHTSA Fatality Analysis Reporting System, Smart Growth America Dangerous By Design 2019
Commute Mode Share

Source: American Community Survey 2017

- Drive alone: 88.2%
- Work from home: 4.6%
- Other: 1.1%
- Take transit: 1.3%
- Walk: 4.0%
- Ride a bicycle: 0.8%
Commute Trips are Only a Fraction

19% Work

It’s more than just work trips.
Commuter Trips are Only a Fraction

- 20% Recreation
- 19% Work
- 21% Shopping
- 19% Errands
- 7% Social
- 10% School

It’s more than just work trips.
The Role of Design
Why should we plan and design for pedestrians and bicyclists?
What role does design play in transportation safety?
What is our responsibility as transportation practitioners?
Have special concern for the long-range consequences of present actions.

AICP Code of Ethics
Hold paramount the safety, health, and welfare of the public.

NSPE Code of Ethics Fundamental Canons
Principles of Pedestrian Design
Principles of Pedestrian Design

- Manage speeds
- Reduce conflicts
- Separate modes
- Provide a connected network

Source: Karl Jilg, Swedish Road Administration
Available Resources
Available Resources
Available Resources

Guide for Improving Pedestrian Safety at Uncontrolled Crossing Locations

Urban Street Design Guide

Small Town and Rural Multimodal Networks
Sidewalks
Pedestrians can get by without sidewalks on quiet streets
Paved shoulders reduce pedestrian crash risk by 70%
Sidewalks reduce pedestrian crash risk by 88%
But too often the sidewalk ends
Or sidewalks are only provided on one side of the street.
Sidewalk Zones
Residential Sidewalk Zones

- Curb Zone
- Street Buffer Zone
- Frontage Zone
- Pedestrian Zone

Speed Limit 25

[Image of a residential street with a sidewalk, curb, street buffer zone, frontage zone, and a speed limit sign.]
Commercial Sidewalk Zones

- Curb Zone
- Street Buffer Zone
- Pedestrian Zone
- Frontage Zone
Curb Zone
Sidewalk Zone
ADA Requirements for Sidewalks

- 3’ unobstructed width; 4’ proposed
- Smooth surface
- 2% maximum cross-slope, including at driveways
A sidewalk should be as wide as needed to serve anticipated pedestrian use (use HCM Pedestrian LOS).
Street Buffer Zone
Frontage Zone
Reducing Building Setbacks
Interim Sidewalks
Interim Sidewalks

Concrete Curb and Posts
Wood Curb and Packed Stone
Plastic Curb and Posts
Driveways
Driveways built like intersections encourage high-speed turns.
Driveways built like driveways encourage slow-speed turns
cross-slope exceeds 2%
Solution for Narrow Sidewalks

Fully Lowered Sidewalk
Solution for Narrow Sidewalks

Route Behind Driveway Apron
Crossings
General Principles

1. Pedestrians want and need to cross streets safely.
2. Drivers need to understand pedestrians’ intent.
3. Short crossings reduce exposure.
4. Lower speeds reduce crash risk and severity.
5. Pedestrians will cross where it’s convenient.
Pedestrians want and need to cross the street safely.
Drivers need to understand pedestrians’ intent
Long Crossings

- Increase exposure time
- Increase vehicle-pedestrian conflict
- Require long pedestrian phases which increase vehicle delay
- Decrease the ability of slower pedestrians to cross
Speed Matters

13% Likelihood of fatality or severe injury
40% Likelihood of fatality or severe injury
73% Likelihood of fatality or severe injury

Source: Tefft, Brian C. Impact speed and a pedestrian’s risk of severe injury or death. Accident Analysis & Prevention. 50. 2013.
Pedestrians will cross where it’s most convenient.
Crosswalk Markings
Function of Crosswalk Markings

- Indicate to pedestrians where to cross
- To indicate to drivers where to expect pedestrians
- At mid-block location, legal establish the crosswalk
Locations for Installation

- Commonly used to guide pedestrians and alert other road users of pedestrians at signalized locations and approaches controlled by STOP or YIELD signs.
- An engineering study should be performed before crosswalk markings are installed at locations away from traffic signals or STOP signs. (MUTCD Section 3B.18)
Do marked crosswalks actually increase safety or do they provide a false sense of security?
Marked Crosswalks

- Do not decrease safety on two-lane roads
- Should be accompanied by crash countermeasures on multilane roadways where
  - ADT > 12,000 without median
  - ADT > 15,000 with median
  - Speeds > 40 mph
New marked crosswalks alone, without other measures designed to reduce traffic speeds, shorten crossing distances, enhance driver awareness of the crossing, and/or provide active warning of pedestrian presence, should not be installed across uncontrolled roadways where the speed limit exceeds 40 mph or either:

- Has 4 or more lanes without a raised median or island and ADT of 12,000 or more, or
- Has 4 or more lanes with raised median island and ADT of 15,000 or more
When considering marked crosswalks at uncontrolled locations, the question should not be simply, ‘Should I provide a marked crosswalk or not?’
Regardless of whether marked crosswalks are used, there remains the fundamental obligation to get pedestrians safely across the street.
In all cases, the final design must accomplish the goal of getting pedestrians across the road safely.
The design question is, ‘How can this task [getting pedestrians across the road safely] best be accomplished?’
Place longitudinal markings to avoid wheel tracks, reducing wear and tear
Crosswalk Crash Countermeasures
### Table 1. Application of pedestrian crash countermeasures by roadway feature.

<table>
<thead>
<tr>
<th>Roadway Configuration</th>
<th>Posted Speed Limit and AADT</th>
<th>Vehicle AADT &lt; 9,000</th>
<th>Vehicle AADT 9,000–15,000</th>
<th>Vehicle AADT &gt; 15,000</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>≤30 mph</td>
<td>35 mph</td>
<td>≥40 mph</td>
<td>≤30 mph</td>
</tr>
</tbody>
</table>
| 2 lanes  
(1 lane in each direction) | 1 2 3 4 5 | 6 | 7 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 |
| 3 lanes with raised median  
(1 lane in each direction) | 1 2 3 4 5 | 6 | 7 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 |
| 3 lanes w/o raised median  
(1 lane in each direction with a two-way left-turn lane) | 1 2 3 4 5 | 6 | 7 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 |
| 4+ lanes with raised median  
(2 or more lanes in each direction) | 1 2 3 4 5 | 6 | 7 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 |
| 4+ lanes w/o raised median  
(2 or more lanes in each direction) | 1 2 3 4 5 | 6 | 7 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 |

**Given the set of conditions in a cell,**

- **High-visibility crosswalk markings, parking restrictions on crosswalk approach, adequate nighttime lighting lanes, and crossing warning signs**
- **Raised crosswalk**
- **Advance Yield Here to (Stop Here For) Pedestrians sign and yield (stop) line**
- **In-Street Pedestrian Crossing sign**
- **Curb extension**
- **Pedestrian refuge island**
- **Rectangular Rapid Flashing Beacon (RRFB)**
- **Road Diet**
- **Pedestrian Hybrid Beacon (PHB)**

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1. Cite references for the countermeasures listed above.
2. Note that the countermeasures are generally not an appropriate treatment, but exceptions may be considered following engineering judgment.
FHWA Step Guide

Table 1. Application of pedestrian crash countermeasures by roadway feature.

<table>
<thead>
<tr>
<th>Roadway Configuration</th>
<th>Posted Speed Limit and AADT</th>
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<tbody>
<tr>
<td></td>
<td>Vehicle AADT &lt; 6,000</td>
</tr>
<tr>
<td></td>
<td>≤30 mph</td>
</tr>
<tr>
<td>2 lanes</td>
<td>4 5 6</td>
</tr>
<tr>
<td>(1 lane in each direction)</td>
<td>0 1 2</td>
</tr>
<tr>
<td>3 lanes with raised median</td>
<td>2 3 4</td>
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</tr>
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</tr>
</tbody>
</table>

Given the set of conditions in a cell:
- □ Signifies that the countermeasure is a candidate treatment of a marked uncontrolled crossing location.
- ■ Signifies that the countermeasure should always be considered, but not mandated or required, based upon engineering judgment of a marked uncontrolled crossing location.
- ○ Signifies that crosswalk visibility enhancements should always occur in conjunction with other identified countermeasures.

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

1. High-visibility crosswalk markings, parking restrictions on crosswalk approach, adequate nighttime lighting lanes, and crossing warning signs
2. Raised crosswalk
3. Advance Yield Here To (Stop Here For) Pedestrians sign or yield (stop) line
4. In-Street Pedestrian Crossing sign
5. Curb extension
6. Pedestrian refuge island
7. Rectangular Rapid-Flash Beacon (RRB)**
8. Road Diet
9. Pedestrian Hybrid Beacon (PHB)**
Raised Crosswalks
Raised Crosswalks
Advanced Stop/Yield Markings
A - Two-way roadway

B - One-way roadway

Note: If Stop Here for Pedestrians signs are used instead of Yield Here to Pedestrians signs, stop lines shall be used instead of yield lines.
In-Street Signs
In-Street Signs

User Guide for R1-6 Gateway Treatment for Pedestrian Crossings

Prepared by:
Western Michigan University
T.Y. Lin International
December 2015
Crossing Islands
Crossing Islands
Crossing Islands
Table 1. Application of pedestrian crash countermeasures by roadway feature.

<table>
<thead>
<tr>
<th>Roadway Configuration</th>
<th>Posted Speed Limit and AADT</th>
<th>35 mph</th>
<th>40 mph</th>
<th>40 mph</th>
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<tr>
<td>Vehicle AADT &lt; 9,000</td>
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<td></td>
<td></td>
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<tr>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 lanes (1 lane in each direction)</td>
<td></td>
<td>1 4 5 6</td>
<td>5 6 7 8</td>
<td>5 6 7 8</td>
</tr>
<tr>
<td>3 lanes with raised median (1 lane in each direction)</td>
<td></td>
<td>1 2 3 4 5 6</td>
<td>5 6 7 8 9 10</td>
<td>5 6 7 8 9 10</td>
</tr>
<tr>
<td>4 lanes with raised median (2 or more lanes in each direction)</td>
<td></td>
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9. Pedestrian Hybrid Beacon (PHB)**

FHWA Step Guide

TOOLE DESIGN
A center turn lane is not a refuge.
Rectangular Rapid Flash Beacons
Rectangular Rapid Flash Beacons

- Motorist yield rates increase from 20% to 80%
- Beacon is yellow, rectangular, and has a rapid “wig-wag” flash
- Beacon located between the warning sign and the arrow plaque
- Must be pedestrian activated (pushbutton or passive)
Beacons required on both the right side and on the left side or in a median if practical.
Pedestrian Hybrid Beacons
PHB Display Sequence

1. Dark Until Activated
2. Flashing Yellow Upon Activation
3. Steady Yellow
4. Steady Red During Pedestrian Walk Interval
5. Alternating Flashing Red During Pedestrian Clearance Interval
6. Dark Again Until Activated

Legend:
- SY: Steady yellow
- FY: Flashing yellow
- SR: Steady red
- FR: Flashing red
Crosswalk Lighting
Crosswalk Lighting

Traditional midblock crosswalk lighting layout

Preferred midblock crosswalk lighting layout
Intersections
Intersection Geometry and Operations

- Pedestrian signals/phases
- Accessible push buttons
- Leading Pedestrian Interval (LPI)
- Restriction RTOR
- Permissive vs. protected lefts
- Curb radii
- Curb ramp configuration/design
Small, tight intersections are best for pedestrians.
Large intersections can work for pedestrians, with mitigation.
Turn Radii
Design Vehicle

Control Vehicle
- Infrequent large user of street
- Permitted to turn very slowly
- Permitted to make wider turn onto receiving street

Design Vehicle
- Frequent user of a given street
- Dictates the minimum required turning radius
- Design to allow turning from one approach lane to one receiving lane
Must consider design vehicle, but don’t choose larger vehicle than necessary
We shouldn’t design for the exceptional vehicle at the expense of pedestrian safety.
Curb Radius

- Calculate effective radius if travel lanes are offset from curb with parking, bike lane, etc.
Effective Turn Radius

- At large intersection, assume truck may use inside receiving lane
Truck Aprons
*Corner with no possible turn
Crossing Islands
Crossing Islands

- Separate conflicts & decision points
- Reduce crossing distance
- Improve signal timing
- Reduce crashes
High speed, head turner = low visibility of pedestrians

Slow speed, good angle = good visibility of pedestrians

Tighter angle

40°

55 to 60 degree angle between vehicle flows
Crossing Islands

- Move crosswalks in
- Move stop bars in
Intersection Operations
Turn movements often result in conflicts
MUTCD Signal Warrants

- 8-hour vehicle volume
- 4-hour vehicle volume
- Peak hour
- Pedestrian volume*
- School crossing*
- Coordinated signal systems
- Crash experience*
- Roadway network
- Hybrid Beacon

*Note: 20 pphp applies as the lower threshold volume
2009 MUTCD Pedestrian Volume Warrant for Speeds Greater than 35 mph

**Easier to meet on streets with high vehicle volumes**

**More difficult to meet on streets w/ low vehicle volumes**

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**Old minimum ped volume:** 190

**Minimum ped volume:** 93

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Figure 4C-8. Warrant 4, Pedestrian Peak Hour (70% Factor)
Restricting Right Turn on Red
When Children/Pedestrians Present

- Difficult to enforce
By Time of Day

- Limits most RTOR
Via Pedestrian Actuation or Controller

- Note: An on-demand NTOR sign can be used to improve the effectiveness of a Leading Pedestrian Interval (LPI)
At All Times
Proper Pushbutton Placement
Proper Pushbutton Placement

- MUTCD Figure 4E-3
Signs Accompanying Pedestrian Pushbuttons

- Combination of sign legends and pushbutton placement shall clearly indicate which crosswalk signal is activated by each pushbutton.

MUTCD Sec. 2B.52 and Section 4E.08
Pedestrian Signals
Pedestrian Signals

- Use signals wherever pedestrians may be present (if in doubt, install them)

2009 MUTCD
Section 4E.03
Ped head should be placed here.
Lack of pedestrian signals on one way street: the pedestrian may not notice the signal.

Ped head should be placed here:
Place ped head here, not here

Poor example

Good example
Pedestrian Phases

- 7 sec walk, 4 sec option
- Ped clearance time (flashing hand) calculated at 3.5'/sec curb-to-curb
- Example: 60’ crosswalk
  - 60’ / 3.5 ‘/sec = 17 sec clearance
  - 7 sec walk + 17 sec clearance = 24 sec total
- Additional test for walk plus clearance time: calculate travel time from push button (or 6’ feet from curb if no button) to curb on other side at 3’/sec
- Example: 6’ + 60’ crosswalk = 66’
  - 66’ / 3 ’/sec = 22 sec
  - 24 sec > 22 sec; passes test
Countdown pedestrian signal tells pedestrians how much time remains for crossing
Group Activity
Group Activity

- Select an appropriate crossing treatment
- Draft an intersection redesign to improve walking environment
Select an Appropriate Crossing Treatment
Select an Appropriate Crossing Treatment

3,000 ADT
25 mph
2-lane with parking
Select an Appropriate Crossing Treatment

- 28,000 ADT
- 35 mph
- 4-lane with raised median
- Excessive vehicle speeds
Select an Appropriate Crossing Treatment

13,000 ADT
30 mph
2-lane
Poor yielding
Sketch Intersection Redesign to Improve Walking Environment
Sketch Intersection Redesign to Improve Walking Environment
Bikeway Planning and Design
- Vulnerable roadway user
- Sensitive to speeds, volumes, trucks, terrain, and lateral separation
- Crashes in urban areas highest at intersections
- Operating speed and acceleration rates vary
Background

- What is AASHTO?
  - Mission: “provides technical services to support states in their efforts to efficiently and safely move people and goods”

- Some history
  - 5th Edition is expected in 2020; currently undergoing review

- Standards vs. guidance
All Ages and Abilities

Interested and Concerned  Enthused and Confident  Strong and Fearless
All Ages and Abilities

1% Experienced and confident
9% Casual and somewhat confident

All Ages and Abilities

1% Experienced and confident
9% Casual and somewhat confident
60% Interested but concerned

lower stress tolerance
higher stress tolerance

Perceptions vs. Statistics

perceptions

reported crashes

BICYCLE CRASH FREQUENCY
ALL REPORTED BICYCLE CRASHES
2004-2012

Spot / Route Improvement
Comments

source: Cambridge Community Development Department
Low-stress Network Principles

Safety:
- Minimize conflicts
- Encourage yielding
- Delineate space
- Provide consistency

Comfort:
- Separate modes
- Balance delay
- Accommodate passing bicyclists

Connectivity:
- Provide direct, seamless transitions
- Integrate into multimodal network
Street Level Separated Bike Lane

- Provide physical separation from moving vehicles
- Are comfortable for less confident users
Sidewalk Level Separated Bike Lane
What is in the NACTO Guide?

- Bike lanes
- Separated Bike Lanes
  - Street level
  - Raised cycle tracks
  - Two-way cycle tracks
- Bike boxes
- Colored pavement material guidance
- Bicycle boulevards
Bike Lanes vs. Wide Outside

“The provision of wide outside lanes should also be weighed against the likelihood that motorists will travel faster in them…, resulting in decreased level of service for bicyclists and pedestrians.”

- 2012 AASHTO Guide for the Development of Bicycle Facilities
# Shared Lane Widths

<table>
<thead>
<tr>
<th>Lane Width (not including gutter)</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>13 Feet or Less</td>
<td>Motorists will likely encroach into next lane</td>
</tr>
<tr>
<td>14 Feet</td>
<td>Allows motorists to pass without encroaching into next lane</td>
</tr>
<tr>
<td>15 Feet</td>
<td>Allows more maneuverability for cyclists for drainage grates, raised delineators, on-street parking, etc.</td>
</tr>
<tr>
<td>16 Feet or More</td>
<td>May encourage the undesirable operation of two motor vehicles side by side in congested areas</td>
</tr>
</tbody>
</table>
MARKED SHARED LANES

- Not appropriate in paved shoulders or bike lanes
- Should not be used on roadways with speed limits over 35 mph
- Have not been studied to determine effectiveness
- May be beneficial for wayfinging
- **NO MINIMUM LANE WIDTH** for SLM’s
Application of Shared Lane Signs in Different Contexts

Share the Road?

Bikes May Use Full Lane

Narrow Lanes
Shared Lanes – Rural Conditions

- Suitable where:
  - Good sight distance
  - Low traffic volumes
  - Speeds 55 mph or less

- May comprise high % of:
  - Local bicycle routes
  - State bicycle routes
  - US bicycle routes
Wayfinding
Bicycle Guide Signs/Wayfinding

Used to:

- Provide wayfinding guidance
  - Designate a system of routes
  - Designate a continuous or preferred route
  - Provide location specific guidance

They are NOT a bike facility
Paved Shoulders
Paved Shoulders vs. Shared Lanes

- “when sufficient width is available to provide bike lanes or paved shoulders, they are the preferred facilities on major roadways”

- Overtaking and rear end crashes:
  - Large proportion of rural crashes
  - Often fatal
Paved Shoulders

- Bike lanes are travel lanes → no parking
- Paved shoulders are not travel lanes → parking ok
- 4-foot minimum width when no curb is present
- 5-foot minimum
  - curb, guardrail, or other barrier
- Additional width:
  - Improves BLOS
  - 50 mph
  - Heavy trucks
Paved Shoulders at Intersections

- Paved shoulders typically stay to right of right turn lane
- To avoid conflicts with right turn lanes, bike lanes may be added at intersections to serve through-cyclists
Paved Shoulders at Intersections

- Shoulder transitions to bike lane
- Bike lane placed on left side of right turn lane
Paved Shoulders at Intersections

- Shoulder with bike lane
Paved Shoulder Spot Widening

- Constrained roadways
- Spot widening can improve safety:
  - on inside of horizontal curves
  - over crest of steep vertical curves
  - on steep grades where only space for lane in one direction (place uphill)

Source: http://vermonthills.wordpress.com/
Paved Shoulder Spot Widening

- Over crest of steep vertical curves
Paved Shoulders at Intersections

- 4-foot minimum shoulder width at shoulder bypass lanes
Rumble Strips
Rumble Strips – Design and Placement

- Maintain a 4-ft min. clear path width with no curb present; 5-ft with curb
- Use gaps to allow cyclists to move across rumble strips as needed
- Centerline rumble strips may lead motorists to shy away from the centerline and move closer to bicyclists
Rumble Strips – Design and Placement

- Desired shoulder width with rumble strips
Bike Lanes
Bike Lane Widths

- Bicyclists preferred operating width is at least 5 feet
- Widths should be determined by context and anticipated use
- Measure to center of line
Bike Lane Markings and Signs

- Both symbols or the words “BIKE LANE”
- Symbols spaced between 100 feet and 1,000 feet
- Place close to locations motorists will cross bike lanes
Bike Lane Markings and Signs

- Bike lane line and bike symbol **required**
- Parking line **recommended**
- Bike lane signs **optional**
Bike Lane Widths

- 4 foot minimum where there is no gutter, curb or parking
Bike Lane Widths
no parking, no gutter, with curb

- 5 foot is typical
- 4 foot allowed
  - Constrained, low speed roads
  - No gutter
  - All other lanes should be narrowed first
- Additional width improves comfort and safety
Bike Lane Widths with gutter and curb

- 5 foot minimum with 12-inch gutter
- 6 foot minimum with 24-inch gutter and high speeds
- Additional width improves comfort and safety
Bike Lane Widths adjacent to parallel parking

- 5 foot minimum
- 6 or 7 foot width adjacent to high turnover parking
- Parking lane width:
  - 7 foot minimum
  - 8 foot desirable
Narrow arterial lanes up to 10 feet acceptable.

Research shows that 10’ and 11’ travel lanes don’t increase crash rates in urban and suburban contexts.
Bike Lane Widths
Bike lanes adjacent to parallel parking

- Combined bike and parking lane width should be 13 feet where parking line is not used
Bike Lane Widths
Bike lanes adjacent to parallel parking – low turnover

- Combined bike/parking lane width may be 12 feet
- Use only where cross-section is constrained and travel lanes cannot be narrowed
- Parking turn-over is low
Dooring Issues
Designs to Reduce Doorzing

- Wider Bike Lanes
- Wider Parking Lanes
Designs to Reduce Dooring

- Buffered door zone
Bike Lanes and Angled Parking

- “Bike lanes should normally not be placed adjacent to conventional front-in diagonal parking…”
Bike Lanes and Angled Parking
Bike Lanes and Angled Parking

The use of back-in diagonal parking can mitigate the conflicts normally associated with front-in parking.
Striped buffers may be used to provide increased separation to parking or travel lanes.
Bike Lanes at Intersections
Bike Lanes at Intersections

- Principles for good design:
  - Minimize free-flowing movements
  - Provide guidance to bicyclists and motorists
  - Direct, logical routing
  - Signal accommodations provided
- May use dotted or solid lines on approaches
Solid Lane Lines vs. Dotted

- Solid lane lines discourage crossing or merging
- Dashed lane lines encourage crossing or merging
- Consider state and local laws for motorists turning at intersections
Bike Lane Widths at Intersections

- 4 foot minimum
- 5 feet or wider preferred
Dotted Bike Lane Lines

- Dotted lane line provide positive guidance for right turn lane transition
Solid Lane Lines

- Solid lane lines across alleys and driveways
Right Turn Considerations

- Bike lane may be dotted, or dropped
- Solid or dotted?
  - Volume of right turning vehicles
  - Bus stops
  - Motor vehicle speed
  - State or local law
- Incorporate R4-4 sign at start of right turn lane
Dotted Lines Through Intersections

- Establishes bike lane through the intersection
- Alerts drivers to potential conflict with right turn movement
Green Colored Bike Lanes

- Green Lane FHWA interim approval

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**Memorandum**

**Subject:** INFORMATION: MUTCD – Interim Approval for Optional Use of Green Colored Pavement for Bike Lanes (IA-14)

**From:** Jeffrey A. Landis
Associate Administrator for Operations

**To:** Federal Lands Highway Division Engineers
Division Administrators

**Date:** APR 15 2011

**In Reply Refer To:** HOTO-1

**Purpose:** The purpose of this memorandum is to issue an Interim Approval for the optional use of green colored pavement in marked bicycle lanes and in extensions of bicycle lanes through intersections and other traffic conflict areas. Interim Approval allows interim use, pending official rulemaking, of a new traffic control device, a revision to the
Colored Pavement
Dotted Lines and Colored Pavement

- Green can be dotted to match dotted lines
Bike Box
### FHWA Status of Bikeway Treatments


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Bicycles at Roundabouts
Bicycles at Roundabouts

- Crash reduction benefits for bicyclists if designed for slow speed
  - Single-lane are preferred
  - Design to widen to two lanes for “future traffic” if it comes
- Bicyclists should “take the lane” or use ramps to access the sidewalk

Source: Cyclicious
Roundabouts – Taking the Lane

- End bike lane 100’ in advance of edge of circulatory roadway
- Use 7:1 taper (for 20 mph speed) to narrow the roadway
- Dash bike lane for 50-200’
- Add shared lane markings
- Resume bike lane as soon as width is available
Roundabouts: Using the Sidewalk

- Used for multi-lane, high speed, and complex roundabouts
- Provide wide sidewalks to function as shared-use path
  - Consider separate bicycle only path parallel to sidewalk
- Provide ramp minimum of 50’ prior to crosswalk
  - Angle (35-45 deg), steeper slope, and placement to reduce confusion to vision impaired pedestrians
- Detectable warnings should be placed on the ramps
  - At top (sidewalk side) of ramp if buffer is present
  - At bottom of ramp (roadway side) if no buffer is present
Railroad Grade Crossings
Railroad Grade Crossings

- Crossing angle
  - 60-90 degree angle
- Crossing surface
  - Smooth
  - Concrete is best
- Bikeway Width
  - 6’ minimum
- Minimize flange opening
Railroad Grade Crossings
Bicycle Signals
Bike Signals

- FHWA Issued Interim Approval for use of bike signal face - December 2013
- Limited to:
  - Midblock trail crossings
  - Protected bike phases on streets
Signal Timing Practices

- AASHTO Bicycle guide describes 2 conditions:
  - Standing bicycle minimum green (start from stop)
  - Rolling bicycle minimum green (arrive moving)
- Children aged 10 to 19 over-represented in “trap” type crashes

Speed: 10 mph
Acceleration: 1.5 ft/s²
Deceleration: 5 ft/s²
Perception-Reaction Time: 1 s
Shared Use Paths
All Ages and Abilities

1% Experienced and confident
9% Casual and somewhat confident
60% Interested but concerned

lower stress tolerance  higher stress tolerance

Not all Paths are low stress

- Low Volume Pedestrians Low Conflict
- Separate Uses Low Conflict
- High Volume Pedestrians High Conflict

Evaluate with FHWA Shared-Use Path Level of Service Calculator
Shared Use Path Users

- Bicyclists
  - Upright adults, children
  - Recumbent bicyclists
  - Bicyclists pulling trailer/bikes
  - Tandem bicyclists

- Pedestrians
  - Walkers, Runners
  - People with disabilities
  - People with strollers
  - People walking dogs

- Inline/roller skaters
- Kick scooter users
Shared Use Path Basics

- Primary design user: adult bicyclist
- Guide instructs for adjustments if another user type is primary
- Paths frequently used by children:
  - Children’s design speed are accommodated in the Guide
  - Use engineering judgment to modify other values
Guidance on Centerline Striping

- Provides space for directional travel
- Solid where passing is not permitted
- Broken where passing is permitted
- Along entire length of trail or only where operational challenges exist
Separation of Users Allowed

- Bi-directional walking lane for pedestrians with directional lanes of travel for cyclists
  - 5 ft min width for pedestrians
  - At least 10 feet for bicyclists
Separation of Users

- In areas with “extremely heavy pathway volumes”
Separation of Users

- When pedestrians outnumber bicyclists, they are less likely to follow the rules.
Sidepaths

- New term in guide
  - Sidepath = shared-use path that runs along a roadway
- Not a substitute on-road bicycle facilities
- Provides separation from motor vehicles
- Guide defines potential conflicts at intersections
Street Level Separated Bike Lane

- Sidepaths 2.0 =
- Separated Bike Lanes
Sidewalk Level Separated Bike Lane
Sidepaths

- Along a high-speed roadway, a sidepath should have 5 feet or more separation or a crashworthy barrier
Sidepath with no buffer
Shared Use Path Design
Bicyclists Physical and Operating Space on Shared Use Paths
Width and Clearance

- 10 ft = minimum width
- 11 ft is needed for passing
- 10-14 ft width is typical
  - Wider path accommodates higher volumes or more varied user groups
  - Guide sets forth specific scenarios where a wider path is warranted

8 ft is acceptable only in rare circumstances
Intersection Design Principles

- Good geometric design
- Thorough understanding of behaviors and operating characteristics of all users
  - Pedestrians
  - Bicyclists
  - Motorists
- Appropriate assignment of right-of-way
Shared Use Path Crossing Types

- Mid-block roadway crossings
  - Outside the functional area of an adjacent intersection
  - Can be considered a four-leg intersection
- Sidepath roadway crossings
  - Within functional area of intersection
  - Grade-separated
Shared Use Path Crossing Types

- **Mid-block roadway crossings**
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Shared Use Path Crossing Types

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Figure 5-13. Mid-Block and Sidepath Crossings Relative to Intersection Functional Area
Shared Use Path Crossing Types

- Mid-block roadway crossings
- Sidepath roadway crossings
Grade Separated
Sidepath/Separated Bike Lane Crossings
Sidepath Crossings at Signalized Intersections

Pathway should be integrated into the intersection controls following principles of pedestrian crossings.
Priority at Crossings

- Marked bicycle crossings
- Marked pedestrian crossings of separated bike lane
- Signage
- Raised crossing (if appropriate)
Visibility at Conflict Points

protected intersection  conventional bike lane
Visibility

motorist’s view at conventional bike lane

motorist’s view at separated bike lane
Recessed Crossings

1. Corner refuge island
2. Forward bicycle queuing area
3. Motorist yield zone
4. Pedestrian crossing island
5. Pedestrian crossing of separated bike lane
6. Pedestrian curb ramp
Recessed Crossings
Sidepath Crossings at Driveways

- High speed roadways (>50 mph)
  - Move crossing back from roadway
- Lower speed roadways
  - Crossing should be close to the parallel roadway so motorists can better detect sidepath users
Recessed Crossings

- Crash reduction benefits when crossing set back 6’ – 16.5’ from the roadway
Example Intersections in the US

Salt Lake City, UT

Chicago, IL

Austin, TX

Davis, CA
Paths Crossing Other Paths
Mid-block Crossings
Crosswalk Mutual Yielding Context

- Mutual yielding
  - Driver must stop/yield to pedestrians in crosswalk
  - Bicyclists/pedestrian must stop/yield to motorists if the motorist can’t stop in time (can’t disregard traffic)
Crosswalk Mutual Yielding Context

- **Legal Crossings**
  - Mid-block: marked crosswalks required to create a legal crossing
  - Sidepath: crosswalks exists regardless of marking

- **Consider state laws**
  - How are bicyclists treated? (bicyclist = pedestrian in x-walk?)
Mutual Yielding Implications

- Bikes vs. peds
  - Cyclists can operate up to 30 mph, desire momentum
  - Pedestrians operate up to 12 mph
- Mutual yielding
  - Works well with peds
  - Doesn’t work well where bicyclists approach at higher speeds
Geometric Alignment and Terrain Considerations
Assess Roadway Characteristics

- What type of crossing treatment is needed?
Evaluate Sight Triangles for Yield Control Scenario

- Approach speeds determined by fastest users:
  - Bicyclists (12-30mph)
  - Motorists (15-80mph)

- Departure speed determined by slowest users (typically pedestrian):
  - 3.0 – 3.5 feet/second
Choose the least restrictive – but effective – control

- Unwarranted controls will not be respected by users
- Poor bicyclist compliance with unnecessary stop signs is well documented
- Tend to treat them as a yield condition
Determine Which Leg Has Priority

- Consider relative volumes, speeds, and system hierarchy
  - Local street vs. regional trail
  - Low volume road vs. high volume trail
- Apply least restriction that is effective
Stop Controlled Roadway
Evaluate Sight Triangles to Pedestrian Sidewalks/Crossings

- Clear sight triangle at least 15 feet along walkway
  - Provides 2.5 second reaction time for a pedestrian moving at up to 6 feet per second (running) to stop
Crossing Islands

- Lower crash rates
- Beneficial at:
  - High roadway volumes
  - Wide crossings
  - Crossing 3 or more lanes
- Widths
  - Minimum width: 6 feet
  - Preferred width: 10 feet
    - consider platoons

\[ L = \text{Taper Length} \]
\[ X = 6 \text{ ft (1.8 m) min.} \]
\[ W = \text{Offset Width} \]
\[ Y = 6 \text{ ft (1.8 m) min.} \]
Warning Signs and Markings

Should not use where roadway is stop, signal, or yield controlled
Signalized and Active Warning Crossings

- Reference MUTCD for guidance
- Signalized shared use path crossings: design for slowest user (pedestrian)
  - Accessible push button
  - Pedestrian signal timing
  - Automated detection
Lighting

- Where nighttime use is permitted
- Pedestrian scale fixtures
- Consider 0.5 to 2 foot candles
- Higher illumination at crossings
Speed Control on Paths

- Introduces concept of using geometric design to reduce user speeds
- Recommends centerline stripe to reduce speeds and conflicts
- Depends on site specific context
Restricting Motor Vehicle Access

- “The routine use of bollards...to restrict motor vehicle traffic is not recommended.”

- “Barriers such as bollards, fences, or other similar devices create permanent obstacles...and can cause serious injury.”
Bollard Considerations

- If bollards must be used:
  - Retroreflectorized
  - Bikes can pass w/o dismounting
  - Provide adequate sight distance
  - Stripe an envelope at approach
  - Use flexible delineators
  - Vehicles should not be able to pass
  - Use an odd number of bollards
  - Set back min, 30 ft from road
  - Flush hardware in ground
Restricting Motor Vehicle Access
Bridges, Viaducts, and Tunnels

- On long (1/2 mile+) bridges consider providing a shared-use path on each side separated by barriers
Group Activity
Group Activity

- Re-design the cross-section of a street to provide a buffered bike lane (E Harney St.)
- Identify improvements needed for a shared use path + on-street connection (Laramie River Greenbelt)
Group Activity

- Redesign the cross-section to provide buffered bike lanes
- Assume:
  - Speed 30 mph
  - Moderate parking turn-over.
E Harney St

- Recommended cross-section?
- Cross-section Dimensions
- Placement of Buffer
Laramie River Greenbelt Trail – W Garfield St Crossing
Laramie River Greenbelt Trail Connections

West side trail entrance

East side trail entrance
Recommend routing in each direction for trail users
Identify needed improvements including signs and markings