What is a Complete Street?

A Complete Street is safe, comfortable & convenient for travel via automobile, commercial vehicle, foot, bicycle, & transit.
Complete Streets policies provide for all users

What is a Complete Streets policy?
Ensures that the entire right-of-way is designed for all users

Make the needs of all users the default:
- No need to prove ped, bike, transit, & freight facilities are needed
- Rather, it's assumed they're needed unless proven otherwise

Why have a Complete Streets policy?
- To shift transportation investments
- Create better streets opportunistically
  - Planning
  - Construction
  - Operations, and
  - Maintenance activities
An Ideal Complete Streets Policy

1) Sets a vision
2) Includes all users and modes
3) All projects and phases
4) Clear, accountable exceptions
5) Connected network
6) Other jurisdictions involved in the process
7) Inclusive design guidelines - flexible
8) Is context-sensitive
9) Sets performance measures
10) Includes implementation steps

What does a Complete Street look like?

One size doesn’t fit all: Complete Streets doesn’t mean every street has sidewalks, bike lanes, and transit

There is no magic formula

The Many Types of Complete Streets

Shoulders on Rural Roads

The Many Types of Complete Streets

A Slow-Speed Shared Street
The Many Types of Complete Streets

Commercial Neighborhood with Mid-Block Crossing

The Many Types of Complete Streets

High Density Neighborhood with Mid-Block Crossing

The Many Types of Complete Streets

Historic Main Street

The Many Types of Complete Streets

Transit Route on an Urban Arterial
The Many Types of Complete Streets

- High Density Neighborhood with One-way Protected Bike Lane, Parking, and Sidewalk

- A Two-Way Protected Bike Lane Through Downtown

- A Roundabout with Space for Over-size Trucks

- A Natural Drainage System as Part of a Complete Street
Treasure Valley Perspective

Wangfujing Street

Chengfu Street
Why do we have cities?

To minimize travel and maximize exchange
How have we built our cities?

To facilitate longer travel distances

Reducing Travel Demand Through Land Use

- The problem:
  - Commercial activities concentrated in auto-dominated corridors.
  - Segregated land uses
- Result: long travel distances, not conducive to walking

Potential solutions?
1. Allow small-scale retail in neighborhoods
2. Create neighborhood parks
3. Site school closer to residences & parks

Neo-traditional Development

Destinations are close to residential area

Manufacturing District

- Prevent encroachment of incompatible land uses
- Buffer sub-zones
- Performance criteria for each zone
Context zones categorize a corridor by typical land uses and development intensities rather than just “urban” or “rural”

- Rural in Transition
- Suburban
- General Urban
- Undeveloped
- Developing
- Developed

Land Use and Transportation Planning

Complete Network

- Network for each mode
- Not all users are prioritized on all corridors
- Always provide access:
  - Across low-comfort corridors
  - Along key links

Source: Cambridge Systematics, Inc., 2010

Source: METRANS Transportation Center
What is Multimodal Connectivity?

- **Networks** are accessible, interconnected transportation facilities that allow all users to safely and conveniently get where they want to go.
- **Connectivity** is the extent to which users can make comfortable trips from beginning to end when traveling to destinations throughout a community.

Measure Multimodal Connectivity

www.fhwa.dot.gov/environment/bicycle_pedestrian/publications/multimodal_connectivity

City of Baltimore

- What does connectivity assessment look like in a robust network?
- Focus on accessibility

Map credit: Lowry 2016

City of Baltimore
Caltrans District 4

Route Directness Index (RDI) used to assess the crossing quality and opportunity at regular points along the corridor.

Caltrans District 4

- Plan assesses network need for crossing improvements by overlaying:
  - Potential bicycle demand
  - Supply and quality of bicycle access
  - Safety
  - User comments

Caltrans District 4

- Route Directness Index (RDI) used to assess the crossing quality and opportunity at regular points along the corridor.

Corridor: I-680, Contra Costa County

Out of Direction Travel
- < 1/3 Mile (High Permeability)
- 1/2 Mile to 1 Mile
- 1 1/2 Mile to 2 Miles
- > 1 1/2 Miles (Low Permeability)

Existing Bicycle Network
- Facility Type
  - Class I Bike Path
  - Class II Bike Lane
  - Class III Bike Route/Shared Lane
Connected Streets Lollipop pattern

- 3 left turns!

Connectivity creates a walkable street system by:
- Reducing travel distances;
- Offering more route choices on quiet local streets;
- Dispersing traffic – reducing reliance on arterials for all trips

Restoring Connectivity

Can you increase connectivity with paths, greenways?
- Reduces walking distances: **YES**
- Offers more route choices: **YES**
- Disperses traffic: **NO**

Maintaining Pedestrian and Bicyclist Connectivity

- Dedicate ROW to link culs-de-sac with linear parks
- Schools located next to parks

Connecting Pedestrian & Bicyclist Routes
Connecting Pedestrian & Bicyclist Routes

Source: Bike SLO County

High Connectivity
Moderate Connectivity
Low Connectivity

Travel Lanes Required

Lack of Connectivity

Overly wide streets

Designing for Pedestrian Safety 11 coke
Lack of Connectivity

Fewer, but larger, intersections

Freight Network: City of Seattle

Major Truck Street
- Arterial street that has significant truck traffic
- Also includes some State and US Routes
- Criterion for
  - Design
  - Traffic management
  - Pavement
  - Repairs

City of Seattle

Policies to manage freight operations:
- Reserve some on-street parking for commercial vehicles
- Require permits for over-size trucks
- Require new developments to provide off-street truck loading areas
- Retain alleys for truck delivers and garbage/recycling collection
- Provide signage for truck drivers to identify appropriate routes and note prohibitions
- Provide businesses with information regarding route closures and detours early enough for them to adjust routes or delivery schedules if required
- Provide real-time information about incidents that will disrupt traffic operations
Complete Streets 4/16/19

Transit Networks

- Public Works/DOT Responsibility
- Transit Stop
- Transit Route
- Transit Responsibility

Access to Transit

- Connections to transit routes
- Access to transit stop
- Access at transit stop

Catchment Area

- The catchment area is defined as the area served by transit
- Transit access considers elements within catchment area
- In general, people are willing to:
  - Walk ¼ mile to access local bus
  - Walk ½ mile to BRT or rail transit
  - Bike 1-3 miles
  - Drive 15 miles

Catchment Area

- Bus Stop
- Bus Stop Catchment Area
- Corridor Catchment Area
**Planning & Design**

- Continuity & Connectivity
  - Desire lines
  - Demand
  - Accessibility
  - Convergence of modes
  - Visibility
  - Lighting
  - Available information/guidance

**Agency Considerations**

- High-use Locations (Ridership)
  - Busy corridors
  - Busy stops near key generators or high transfer activity

- Infrastructure Gaps/Needs
  - Sidewalks
  - Crossings
  - ADA compliance
  - Placement relative to intersections

- Safety
  - High incident locations

**Passenger Demand**

- Waiting space should meet passenger demand
- This may change as routes change and land use changes

**Key Generators**

- Understand activities and locations that generate demand
- Understand pedestrian paths
Transfer Activity

- Understand passenger travel patterns and the effect on pedestrian paths

Evaluate All Aspects

- Transit ridership
- Transit stop inventory (ADA compliance and other design elements)
- Crashes

Site-specific

- Transit ridership
- Transit stop inventory (ADA compliance and other design elements)
- Crashes

Priority Corridor

- Transit ridership
- Transit stop inventory (ADA compliance and other design elements)
- Crashes
Evaluate All Aspects

- Transit ridership
- Transit stop inventory (ADA compliance and other design elements)
- Crashes

Secondary Corridor

Evaluate All Aspects

- Transit ridership
- Transit stop inventory (ADA compliance and other design elements)
- Crashes

System-wide

Site Design

- Set-backs
- Walkable access to store front
- Driveways
- Parking (cars, bikes, & sharing economy)
- Commuter services
  - Repair stations
  - Showers
- Off-street transit stops
- Off-street loading

Bringing Buildings Closer to the Street

Creates a street where drivers know to expect pedestrians
**Bringing Buildings Closer to the Street**

Building at the back of the sidewalk is a pedestrian-oriented design.

---

**Growing All Modes to Street**

- Parking between sidewalk and building is not pedestrian-friendly

---

**Connecting All Modes to the Street**

- Fast food typically favors drive-thru over walk-ins
- Pedestrians must cross drive-thru lane
Connecting All Modes to the Street

- Still providing parking and drive-thru

Portland, OR

Connecting All Modes to the Street

- Even a gas station/convenience store can be built with pedestrian friendly design, at back of sidewalk

Milwaukee, WI

Connecting All Modes to the Street

- Pedway retrofitted from sidewalk to building, through parking lot

Corvallis, OR

Connecting All Modes to the Street

- Same principles apply to large-scale developments
- Provide direct, safe, and convenient access

Complete Streets 4/16/19
Site Design

- These goals are achieved by local ordinances, which must be enforced.
- They are beyond the scope of road designers, yet contribute greatly to the safety, comfort, and aesthetics.

Planning Concepts

- Land use
- Complete network
- Network connectivity
- Site design

Along the Road

- Speed
- Context
- Pedestrian zone system
- Bicycle facilities
- Street crossings

Along the Road

- Speed
- Context
- Pedestrian zone system
- Bicycle facilities
- Street crossings
Along the Road

- Speed
- Context
- Pedestrian zone system
- Bicycle facilities
- Street crossings

Selecting Facility for Context

- Speed
- Context
- Pedestrian zone system
- Bicycle facilities
- Street crossings

Average US walking trip: 1.2 mi
- (50% are < 0.5 mi)

Average US bicycling trip: 4.0 mi
- (50% are < 2.0 mi)
Shoulders Benefit All Users

- Pedestrians—a place to walk
- Bicyclists—a place to ride
- Motorists and Trucks—room to avoid crashes
- Transit—boarding and alighting

Along the Road

- Speed
- Context
- Pedestrian zone system
- Bicycle facilities
- Street crossings

Sidewalk Zones

The sidewalk corridor extends from the edge of roadway to the right-of-way and is divided into four zones:

- Curb zone
- Furniture zone
- Pedestrian zone
- Frontage zone

Curb Zone

- Typically 6 inches
- Vertical Curb less likely to be mounted
- Mountable curbs are inappropriate on local streets
Furniture Zone

- Local or collector streets 2 to 4 ft
- Arterial or major streets 4 to 6 ft
- Place for all the “stuff”
- Buffer from vehicles

Pedestrian Zone

- Local or collector streets — 2 to 4 ft
- Arterial or major streets — 4 to 6 ft
- Place for all the “stuff”
- Buffer from vehicles

Frontage Zone

- Doors, planters, signs, etc. — 3 feet
- Café seating — 8 feet
- An interesting façade makes narrow sidewalks feel wider

Along the Road

- Speed
- Context
- Pedestrian zone system
- Bicycle facilities
- Street crossings
**Level of Traffic Stress**

- Comfortable for children
- Comfortable for most adults
- Typical of most U.S. facilities
- "Strong and fearless" or those who absolutely have to

**Level of Traffic Stress**

- Increased bicyclist comfort leads to increased ridership

**Shared Roadway**

- Unless prohibited, all roads have shared lanes
- No special features for:
  - Minor roads
  - Low volumes (< 1000 vpd)
  - Speeds vary (urban v. rural)
- 85% or more of a well-connected grid

**Shared Lane Marking**

- More than 1 lane
- Downhill or level
- Short segment to fill gap in bikeway
- Speed < 30 mph
- High bicycle use

- Single lane
- Uphill
- Parallel route option
- Long segment
- Speed > 40 mph
- Low bicycle use
Shared Lane Marking

- Center in lane
  - Prevent “dooring”
  - Prevent passing too closely
  - Keep bicyclist visible

Shared Road Signs

- Reminder for motorists

Bike Boulevard

Yield Roadway
**Yield Roadway**

- Two-way Center Travel Lane
- Yield to Bicyclists
- Contrasting Paving Materials
- Permissive broken lane - line

**Edina, MN**

Population: 49,300

---

**Shoulder Bikeway**

<table>
<thead>
<tr>
<th>Functional classification</th>
<th>Volume (AADT)</th>
<th>Speed (mi/h)</th>
<th>Recommended Minimum Paved Shoulder Width</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minor Collector</td>
<td>up to 1,000</td>
<td>35 (55 km/h)</td>
<td>5 ft (1.5 m)</td>
</tr>
<tr>
<td>Major Collector</td>
<td>up to 2,600</td>
<td>45 (70 km/h)</td>
<td>6.5 ft (2.0 m)</td>
</tr>
<tr>
<td>Minor Arterial</td>
<td>up to 6,000</td>
<td>55 (90 km/h)</td>
<td>7 ft (2.1 m)</td>
</tr>
<tr>
<td>Principal Arterial</td>
<td>up to 8,500</td>
<td>65 (100 km/h)</td>
<td>8 ft (2.4 m)</td>
</tr>
</tbody>
</table>
Bike Lanes

- Low stress on wide/low-speed streets
- Access to major destinations
- Mobility on arterials
- Guide bicyclist behavior
- Improve visibility

Bike Lane Width

The minimum dimensions should NOT be your default!

Buffered Bike Lane

- Shy distance
- Bike passing
- Door zone
- Wider w/out confusing motorists
- More comfortable

Level of Traffic Stress for Different Bike Lanes

- **LTS 1**
  - Wide or buffered bike lanes
- **LTS 2**
  - 5 ft bike lane/30 mph
- **LTS 3**
  - 5 ft bike lane/35 mph
- **LTS 4**
  - 5 ft bike lane/40 mph
### Pavement Markings
- Shared-lane markings
- Bike lane extension lines
- Bike lane arrow and symbol
- Green pavement

### Separated Bike Lanes
- Exclusive bike facility
- Adjacent to or on roadway
- One-way or contra-flow
- Separated from traffic by vertical element

### Separated Bike Lane Zones

<table>
<thead>
<tr>
<th>Sidewalk</th>
<th>Sidewalk Buffer</th>
<th>Bike Lane</th>
<th>Street Buffer</th>
<th>Street</th>
</tr>
</thead>
</table>

### SBL Elevation
- Considerations
  - Ped/bike encroachment
  - Usable bike lane width
  - Accessibility
  - Frequency of transition ramps
  - Drainage
  - Maintenance
**SBL Width**

Widths vary by peak hour volume
- 6.5-10 ft recommended
- 5-8 ft minimum
- 4’ allowable at bus stops or accessible parking

<table>
<thead>
<tr>
<th>Same Direction Bicyclists/ Pedestrian</th>
<th>Bike Lane Width (ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;250</td>
<td>6.5</td>
</tr>
<tr>
<td>250-750</td>
<td>8.0</td>
</tr>
<tr>
<td>&gt;750</td>
<td>10.0</td>
</tr>
</tbody>
</table>

**Street Buffer Width**

- 6’ preferred
- 2’ when constrained
- 1’ along raised SBL
- 6-16.5’ optimum for intersections

**SBL Width**

Widths vary by peak hour volume
- 10-14 ft recommended
- 8-11 ft minimum

<table>
<thead>
<tr>
<th>Bidirectional Bicyclists/ Peak Hour</th>
<th>Bike Lane Width (ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;1&lt;00</td>
<td>10.0</td>
</tr>
<tr>
<td>1&lt;50-400</td>
<td>11.0</td>
</tr>
<tr>
<td>&gt;400</td>
<td>14.0</td>
</tr>
</tbody>
</table>

**Parking**
**Accessible Parking**

- Opposite side of street
- Guide passengers
- Two crossings
- Communicate to bicyclists
- Floating bus stop
- In-lane bus operation

**Loading Zones**

**Flexibility in Motor Vehicle Lane Width**

Lane Widths AASHTO Green Book 7th Edition

- 4.3 Lane Width
  - 9 to 12 ft generally used
  - 12 ft predominant on most high-speed, high-volume highways.
- 7.2.11.2 Lane Widths
  - In rural town contexts with low-speed conditions and low percentage of trucks, 10-ft lanes may be satisfactory
- 7.3.3.2
  - Lane widths of 10ft may be used in more constrained areas where truck and bus volumes are relatively low and speeds are less than 35mph.
  - 11ft are used quite extensively for urban arterial street designs.
Flexibility in Motor Vehicle Lane Width

Lane Widths NACTO

- 10 feet appropriate urban areas
- Designated truck or transit routes one travel lane of 11 feet may be used in each direction.
- Select cases narrower travel lanes (9-9.5 ft) can be effective as through lane in conjunction with a turn lane.

Along the Road

- Speed
- Context
- Pedestrian zone system
- Bicycle facilities
- Street crossings

Marked vs. Unmarked Crosswalks at Uncontrolled Locations

Marked vs. Unmarked Analysis

Speeds < or = to 40 mph

- Two-lane roads: No significant difference in crash rate
- Multilane roads (3 or more lanes)
  - Under 12,000 ADT: no significant difference in crash rate
  - Over 12,000 ADT w/o median: crashes marked > crashes unmarked
  - Over 15,000 ADT & w/ median: crashes marked > crashes unmarked

Marked vs. Unmarked Analysis

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  - Over 15,000 ADT & w/ median: crashes marked > crashes unmarked

One explanation of higher crash rate at marked crosswalks: multiple-threat crash

1st vehicle stops and “masks” visibility for driver in 2nd lane
Solution: advance stop bar (we’ll discuss later...)
FHWA Guide

- Provides guidance and suggested process for selecting countermeasures
- Assists agencies in developing a policy to support the installation of countermeasures at uncontrolled pedestrian crossing locations

Countermeasure Selection Process

Following the process suggested in the guide offers countermeasure options based on road conditions, crash causes, and pedestrian safety issues.
STEP’s Spectacular Six

- Crosswalk Visibility Enhancements
- Raised Crosswalks
- Pedestrian Refuge Islands
- Rectangular Rapid Flashing Beacon
- Pedestrian Hybrid Beacon (PHB)
- Road Diets

Crosswalk Visibility Enhancements
Crosswalk Visibility Enhancements

Raised Crosswalks

Pedestrian Refuge Islands

Rectangular Rapid Flashing Beacon
Pedestrian Hybrid Beacons (PHB)

1. Blank for drivers
2. Flashing yellow
3. Steady yellow
4. Steady red
5. Wig-Wag

Return to 1

Road Diet:

Before

After

Mid-Block or Intersection?

~300 ft from Signalized Intersection to Mid-block Crossing

Street View
**Crosswalk Visibility Enhancements**

**High Visibility Crosswalk**

What Pedestrians See

[Photo source: all 4 Michael Ronkin]

What Drivers See

---

**In-street pedestrian crossing signs**

Tampa FL

R1-6  
R1-6a  
MUTCD signs

Yield or Stop depends on state law

2009 MUTCD Section 2B.12 and Figure 2B-2

---

**In-Street Pedestrian Sign**

**MUTCD Some Standards**

- Shall be placed in the roadway at the crosswalk location on the center line, on a lane line, or on a median island
- Shall not be post-mounted on the left-hand or right-hand side of the roadway
- Unless placed on a physical island, the sign support shall be designed to bend over and then bounce back to its normal vertical position when struck by a vehicle
- Shall be a maximum of 4 feet above the pavement surface. Top of sign placed in an island shall be a maximum of 4 feet above the island surface


---

**Crosswalk Visibility Enhancements**

**Pedestrian Crossing signs**


2009 MUTCD Sec. 2C.50 & Fig. 2C-11
Multiple Threat Crash Problem
• 1st car stops to let pedestrian cross, blocking sight lines
• 2nd car doesn’t stop, hits pedestrian at high speed

Multiple Threat Crash Solution
Advance stop or yield line
• 1st car stops further back, opening up sight lines
• 2nd car can be seen by pedestrian

Signing to go along with markings
R1-5  R1-5a  R1-5b  R1-5c
(Use where local law says yield to pedestrians)  (Use where local law says stop for pedestrians)

Rectangular Rapid Flashing Beacon
New IA-21
• Must request and receive permission to use this new Interim Approval (IA-21) even if prior approval had been given for Interim Approval 1A-11
• A State may request Interim Approval for all jurisdictions in that State.
**Interim Approval - Allowable Uses**

- Function as pedestrian-actuated conspicuity enhancement
- Shall only be used to supplement post-mounted Pedestrian, School, Trail Crossing warning sign with diagonal downward arrow, plaque, or overhead-mounted warning sign located at or immediately adjacent to an uncontrolled marked crosswalk
- If deemed necessary by the engineer, in event of sight distance, additional RRFB may be installed in advance of crosswalk. Shall supplement not replace.

**Crosswalk Visibility Enhancements**

- Curb Extensions
- Corner Radii
- Brief mention here but further discussed in Intersection Geometry

**Lighting Over Crosswalks**

- Recommended lighting level: 20 lux at 5’ above pavement
**Raised Crosswalks**

- Typically installed on 2-lane or 3-lane roads
- Speed limits of 30 mph or less
- AADT below about 9,000
- CRF: 45%

**Raised Crosswalk**

Traffic Calming ePrimer

- [https://safety.fhwa.dot.gov/speedmgt/traffic_calm.cfm](https://safety.fhwa.dot.gov/speedmgt/traffic_calm.cfm)

**Pedestrian Refuge Islands**

- Breaks complex crossing into two simpler crossings

**Raised median- Breaks complex crossing into two simpler crossings**
Pedestrian Hybrid Beacons (PHB)

CRF: Vehicle/Pedestrian 69%

Excerpts from 2009 MUTCD Chapter 4F For Pedestrian Hybrid Beacons

The CROSSWALK STOP ON RED sign shall be used

There are Guidelines (similar to signal warrants) for Pedestrian Hybrid Beacons – variables include:
- Pedestrian volume
- Traffic speeds
- Traffic volumes
- Crosswalk length

Road Diet / Roadway Reconfiguration

- Reduce crossing distance
- Eliminate / reduce “multiple threat” crash types
- Install crossing island to cross in 2 simple steps
**Road Diet / Roadway Reconfiguration**

- Reduce top end travel speeds
- Buffer sidewalk from travel lanes (parking or bike lane)
- Reclaim street space for “higher and better use” than moving peak hour traffic

**Road Diet Informational Guide & Road Diet Case Studies**


**Intersections**

- Signal timing or phasing changes at intersections to optimize operations and safety benefits
- Single Lane Roundabouts
  - ~20,000 ADT

**STEP’s Spectacular Six**

- Crosswalk Visibility Enhancements
- Raised Crosswalks
- Pedestrian Refuge Islands
- Rectangular Rapid Flashing Beacon
- Pedestrian Hybrid Beacon (PHB)
- Road Diets
Along the Road
• Speed
• Pedestrian zone System
• Bicycle facilities
• Street crossings

Intersections
• Intersection Control Evaluation
• Roundabouts
• Intersection Geometry
• Signals
• Bicycle Conflicts
• Protected Intersections

Intersection Control Evaluation (ICE)
Tiered process for developing and evaluating intersection improvement alternatives
Intersections

- Intersection Control Evaluation
- **Roundabouts**
- Intersection Geometry
- Signals
- Protected Intersections

---

Essential Roundabout Characteristics

- Slow speed exit = yield
- Slow speed entry = yield
- Truck apron
- Crosswalk 1 car length back
- Separated sidewalks direct peds to crosswalks
- Lots of deflection = slow speeds throughout

---

Roundabouts Are Safer for All Users

- Pedestrian crashes:
  - CMF = 0.73 (CRF = 27%)
- Conversion from Two-way stop control:
  - All crashes: CMF = 0.56 (CRF = 44%)
  - Injury crashes: CMF = 0.18 (CRF = 82%)
- Conversion from signal control:
  - All crashes: CMF = 0.52 (CRF = 48%)
  - Injury crashes: CMF = 0.22 (CRF = 78%)

---

Fewer Conflict Points

- Vehicles: 32 to 8
- Pedestrians: 16 to 8
- Bicyclists: depends on whether sharing lane or using crosswalks
**Advantages for Pedestrians**

- Reduced vehicle speeds
- Reduced number of conflict points
- Shorter crossing distances
- Splitter island provides a refuge – pedestrian crosses one direction of traffic at a time
- Crosswalk is placed one car length back

**Making Roundabouts Work for Bicyclists**

- Slow speeds
  - Deflection
  - Truck apron
  - NO BIKE LANES
- Simple
  - Single lane
  - NO BIKE LANES
- Splitter islands
- Bike ramps

**Safety Benefits for Vehicles**

- Low travel speeds
  - Typically 15 to 20 miles per hour
  - Low severity collisions
- No signal
  - Continuous flow of traffic
  - Drivers only yield—no stopping if no traffic
  - No incentive to speed up to “beat the light”
- One-way travel
  - Deflection and curvature calms traffic
  - Eliminates severe head-on and T-bone conflicts

**Works for Large Trucks and Oversize Loads**

- Calms traffic
- Eliminates severe head-on and T-bone conflicts
Intersections

Intersection Geometry Affects:
- Crossing distance
- Signal timing
- Turning speeds
- Number of conflict points
- Curb ramp design
- Marked crosswalks placement

Intersection Design Principles:
- Reduce speed
- Minimize exposure to conflicts
- Communicate right-of-way priority
- Provide adequate sight distance
- Accommodate motor vehicle turning
- Accommodate pedestrian needs
  - Minimize crossing distance
  - Ramps for wheelchairs
  - Detectible warnings
- Accommodate bicyclist needs

Large Curb Radius
- Increases crossing distance & time
- Makes crosswalk & ramp placement more difficult
- Indirect crossing
- Increased crossing setback
- Increased vehicle speed
Large Curb Radius

... and makes it hard to figure out where to cross

Small Corner Radii

Benefits:

• Smaller, more pedestrian-scale intersections
• Reduced pedestrian crossing distance and crossing time
• Slower vehicular turning speeds
• Better geometry for installing perpendicular ramps for both crosswalks at each corner
• Simpler, more appropriate crosswalk placement, in line with the approaching sidewalks

Effective Curb Radius

The effective corner radius controls turning speeds and the ability of large vehicles to turn (Credit: Michele Weisbart)
Small corner radii allow two ramps, shortest crosswalks, direct travel paths.

Crosswalks at shortest crossing = longer walking distance
Right & left-turning drivers don’t see crosswalk.

Balancing the goals works best
Note: 3" curb exposure between ramps allows them to be close together
Note: Crosswalk length and setback are greater with large radii than with small radii

Curb extensions
Most focus is on reduced crossing distance

Other advantages:
- Better visibility between pedestrians and motorists
- Traffic calming
- Room for street furniture

Curb extensions should be the width of the parking lane and not encroach on bike lanes or travel lanes.
Before: road looks and feels wide

After: curb extension integral to sidewalk
Street looks narrow even with no parked cars

- Curb extension integrated into sidewalk

Pedestrian Islands

Benefits:
- Separate conflicts & decision points
- Reduce crossing distance
- Improve signal timing
- Reduce crashes
Right-turn Slip Lane: Design for Pedestrians

Old Way

- High speed, head turn = low visibility of pedestrians

New way

- Slow speed, good angle = good visibility of pedestrians

Right-turn Slip Lane - Details

- Cut through medians and islands for pedestrians
- 55° to 70° between vehicular flows.
- 25° to 40° radius depending on design vehicle
- Crosswalk one car length back
- Long radius followed by short

Island Design Details

- Cut-through preferred over ramps
- Truncated domes at cut-throughs

Minimize Curb Radius w/Truck Apron
Left-turn Conflicts and Countermeasures

Two-stage Left Turn Box IA-20

• Required design elements include:
  • Bicycle symbol
  • Turn arrow
  • Solid white line on all sides
  • Turn on red prohibition
  • Passive detection of bicycles
  • Queued bicyclists outside path of moving traffic
  • Avoid crosswalk conflicts
  • Size to prevent conflicts

Bike Box IA-18

• Reduced conflicts between bicyclists and turning vehicles
• Reduced avoidance maneuvers
• Reduced encroachment into crosswalks
• Use clearly understood by motorists and bicyclists
Shoulder Riding at Intersection

- Shoulder not a travel lane
- Modify shoulder striping
- Opportunity to switch to shared lanes OR
- Add bike lane thru intersection

Shoulder Striping

Intersection with Shared Lanes

- Additional/all lanes are shared at intersection

Bike Lane Thru Intersection
Extension Thru Intersection

Highlight Conflict Zone

Stop Bars Placed for Forward Queueing

Stop Bars Placed for Forward Queueing
Bike Lane at Drop Lane

Bike Lane at Drop Lane

Bike Lane at Drop Lane

Transition Considerations

• What happens at termini?
• What happens when bicycle facility type changes?
• Have you stranded or created a barrier to the less confident user?
• How many stops will bicyclist have to make to traverse transition?
• Will bicyclists cross from the right side of the street to the left to continue on their path?
**Example Transitions**

- Into a two-way separated bike lane

**Freeway Interchanges**

Recommended Design Guidelines to Accommodate Pedestrians and Bicycles at Interchanges

ITE 2016

**Guiding Principles for Pedestrians**

- Ramp geometry
- Locate crosswalk
  - Best visibility
  - Before acceleration
  - Short and direct
- Crosswalk short w/out excessive deviation
- Widen sidewalks shared with bicyclists
Guiding Principles for Bicyclists

- Buffer where bicyclists are between moving vehicles more than 200 ft
- Provide bike “exit” option ahead of on-ramps
- Define a weaving area

Signalized Intersections

- Signal timing & walking speeds
- Countdown signals
- Turning vehicle conflicts
  - Protected left turns
  - Flashing yellow arrow
  - Restricting right turn on red
  - LPI/LBI
- Bicyclist signals

Intersections

- Intersection Control Evaluation
- Roundabouts
- Intersection Geometry
- **Signals**
  - Protected Intersections

Use Short Signal Cycle Length

- Long wait causes stacking: pedestrians wait in street, or don’t wait and cross against the signal
**Pedestrian Walking Speeds**

2009 MUTCD:
- 7 sec walk, 4 sec option (no change)
- Ped clearance time (flashing hand) calculated at 3.5’/sec curb-to-curb.
- Example: 60’ crosswalk requires 17 sec
  - 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’ requires 22 sec
    - 24 sec > 22 sec; passes test.

**Pedestrian Conflicts with Turning Vehicles**

- Countermeasures
  - Protected vs. permissive turns
  - No turn on red
  - Exclusive pedestrian phase
  - Leading pedestrian interval

**Signs: Remind Turning Drivers to Yield to Peds**

- R10-15 in 2009 MUTCD
- Older local variations, using MUTCD-approved lettering and symbols:
  - Leesburg, FL
  - Juneau, AK

**Protected Vs. Permissive Left Turns**

- CMF = 0.3 (CRF 70%) (all crashes) converting permissive left turns to protected only left turns
Permissive Left Turns

- Pedestrians cross at the same time as left-turning car.
- Drivers turning left on a green ball don’t look for pedestrians.

Protected Left Turns

- Pedestrians cross after left-turning car, with thru-traffic.
- Pedestrian and car not in conflict.

Protected/Permissive Left Turns

- Pedestrians cross after most left-turning cars (protected phase).
- Pedestrian and remaining cars are in conflict (permissive phase).

Protected/Permissive Left Turns: Solutions

1. Provide protected-permissive phasing by default, but revert to protected-only when pedestrian button is pushed or based on time of day.
2. Flashing Yellow Arrow (details on the next slide).
Flashing Yellow Arrow during steady green ball warns drivers: yield to pedestrians and oncoming vehicles.

Restricting Turns on Red

Consider No Turn on Red signs where there is:
- Poor sight distance between vehicles and peds
- An unusual number of ped conflicts with turns on red (compared to turns on green)
- An exclusive pedestrian phase
- A leading pedestrian or bicyclist interval
- Two-stage turn box
- Bike box
- Two-way separated bike lane

1. At all times
2. When pedestrians are present

Difficult to enforce

3. By time of day
4. Changeable message sign—activated by push button or by controller

Note: A dynamic NTOR sign can be used to improve the effectiveness of a Lead Pedestrian Interval.
EDC5 STEP’s Spectacular Seven

- Crosswalk Visibility Enhancements
- Raised Crosswalks
- Pedestrian Refuge Islands
- Rectangular Rapid Flashing Beacon
- Pedestrian Hybrid Beacon (PHB)
- Road Diets
- Leading Pedestrian Interval

LPI = Lead Pedestrian Interval

MUTCD Sec. 4E.06 paragraphs 19-23

WALK comes on at least 3 seconds prior to the green signal; pedestrians enter crosswalk before turning vehicles arrive there.

These peds waited 3 cycles before turning drivers let them cross as legally required. LPI would give them a head start.

CMF = 0.95 (CRF: 5%)
Safer Signals for Bicyclists

- Bikes start-up and travel slower than cars
  - Differentiating bike detection to optimize signals
  - Set initial and gap times to accommodate bikes
- Leading Bike Interval
- Segregate conflicting movements

Bicycle Signal Face

**Application for:**
- Bicyclist non-compliance
- Provide a leading or lagging bicycle interval
- Continue the bicycle lane on the right-hand side of an exclusive turn lane
- Augment the design of a segregated counter-flow
- Unusual or unexpected arrangements of the bicycle movement through complex intersections, conflict areas, or signal control.

Bicycle Detection

- Buttons
- Loops
- Video
- Microwave
- Radar
- Infrared

Loop Detection

- Square
- Quadrupole
- Diamond
- Diag. Quadrupole

Grand Prairie, Alberta

Portland, OR
Loop Detection

MUTCD standard for signal loop marking for bicyclists (Section 9C.05)

Proper Pushbutton Placement

The MUTCD recommends these dimensions

Proper Pushbutton Placement

MUTCD Recommendations:
• In line with crosswalk;
• Buttons at least 10' apart;
• Between 1.5' and 6' from curb
• Button face parallel to x-walk

5 ft MAX

1.5 ft MIN

6 ft MAX

1.5 ft MAX

Behind guardrail

Behind vegetation
Proper Pushbutton Placement

- On side of pole
- At top of ramp

Accessible Pedestrian Signals (APS)

- Provide ped signal information in audible and vibrotactile format
- Benefit all pedestrians by providing redundancy
- The 2009 MUTCD describes the features of APS, but does not require them
- Future accessibility standards and future MUTCD editions will likely require APS for all ped signals

Protected Intersection

- Intersection Control Evaluation
- Roundabouts
- Intersection Geometry
- Signals
- Protected Intersections
Protected Intersections Video

Visibility at Conflict Points

- Motorist's view at conventional bike lane
- Motorist's view at separated bike lane

Visibility at Conflict Points

- Corner refuge island
- Forward bicycle queuing area
- Motorist yield zone
- Pedestrian crossing island
- Pedestrian crossing of separated bike lane
- Pedestrian curb ramp

Protected Intersections
Slow Right Turning Speeds

- Design for \( \leq 10 \text{ mph} \) vehicle turns
- Mountable truck apron
- 3' max
- Visually distinct
- Large radii reduces bicycle, pedestrian queuing areas

Indianapolis, IN

Chicago, IL

Chicago, IL
Complete Streets

- **Networks** are accessible, interconnected transportation facilities that allow all users to safely and conveniently get where they want to go.
- **Connectivity** is the extent to which users can make comfortable trips from beginning to end when traveling to destinations throughout a community.

**Intersections**
- Intersection Control Evaluation
- Roundabouts
- Intersection Geometry
- Signals
- Bicycle Conflicts
- Protected Intersections

**References**
### Levels of Traffic Stress (LTS)

<table>
<thead>
<tr>
<th>Levels of Traffic Stress</th>
<th>LTS 1</th>
<th>LTS 2</th>
<th>LTS 3</th>
<th>LTS 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Physically separated from traffic or low-volume, mixed-flow traffic at 25 mph or less</td>
<td>• Bicycle lanes 5.5 ft wide or less, next to 30 mph auto traffic</td>
<td>• Bicycle lanes next to 35 mph auto traffic, or mixed-flow traffic at 30 mph or less</td>
<td>• No dedicated bicycle facilities</td>
<td>• Traffic speeds 40 mph or more</td>
</tr>
<tr>
<td>• Bike lanes 6 ft wide or more</td>
<td>• Unsignalized crossings of up to 5 lanes at 30 mph</td>
<td>• Comfortable for most current U.S. riders</td>
<td>• Comfortable for “strong and fearless” riders (vehicular cyclists)</td>
<td>• Comfortable for most adults</td>
</tr>
<tr>
<td>• Intersections easy to approach and cross</td>
<td>• Typical of bicycle facilities in Netherlands</td>
<td>• Typical of bicycle facilities in U.S.</td>
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<tr>
<td>• Comfortable for children</td>
<td></td>
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</tbody>
</table>

### Recommendations from Model Design Manual for Living Streets

- **Shared Lane Marking**
  - Supporting Characteristics:
    - More than 1 lane Downhill or level
    - Short segment to fill gap in bikeway
    - Speed < 30 mph
    - High bicycle use
  - Nonsupporting Characteristics:
    - Single lane
    - Uphill
    - Parallel route option
    - Long segment
    - Speed > 40 mph
    - Low bicycle use

- **Shoulder Bikeway**
  - Functional classification:
    - **Minor Collector**: up to 1,000 vehicles/day, 35 mph (55 km/h), 5 ft (1.5 m)
    - **Major Collector**: up to 2,600 vehicles/day, 45 mph (70 km/h), 6.5 ft (2.0 m)
    - **Minor Arterial**: up to 6,000 vehicles/day, 55 mph (90 km/h), 7 ft (2.1 m)
    - **Principal Arterial**: up to 8,500 vehicles/day, 65 mph (100 km/h), 8 ft (2.4 m)
Pavement Markings

Bike lane Width for One-Way

- Widths vary by peak hour volume
  - 6.5-10 ft recommended
  - 5-8 ft minimum
  - 4' allowable at bus stops or accessible parking

<table>
<thead>
<tr>
<th>Same Direction</th>
<th>Bike LANE Width (ft)</th>
<th>Rec.</th>
<th>Min.</th>
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<tbody>
<tr>
<td>&lt;180</td>
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<td>6.5</td>
<td>5.0</td>
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<tr>
<td>180-750</td>
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<td>8.0</td>
<td>6.5</td>
</tr>
<tr>
<td>&gt;750</td>
<td></td>
<td>10.0</td>
<td>8.0</td>
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</tbody>
</table>

Shy Distance

- Lateral offset
  - Height < 36” no offset
  - Height > 36” 6” offset

- Vertical clearance
  - 100”
Street Buffer Width

- 6' preferred
- 2' when constrained
- 1' along raised SBL
- 6-16.5' optimum for intersections

Countermeasure Selection

<table>
<thead>
<tr>
<th>Objective Type</th>
<th>Shared Boulevards</th>
<th>On-Road Bicycle Facilities</th>
<th>Interaction Treatments</th>
<th>Make Travel Safer</th>
<th>Traffic Calming</th>
<th>Trails</th>
<th>Shared Paths</th>
<th>Markings, Signs &amp; Signals</th>
<th>Other Measures</th>
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</thead>
<tbody>
<tr>
<td>Safe on-street facilities</td>
<td>X</td>
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<tr>
<td>Provide off-road bike paths or trails</td>
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<td>X</td>
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<td>Provide and maintain quality surfaces for bicyclists</td>
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<tr>
<td>Provide safe intersections for bicyclists</td>
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<tr>
<td>Improve pedestrian and bicyclist behavior and safety</td>
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*These countermeasures make up the 3M countermeasures: 1. Missing visibility enhancements. 2. Multiple countermeasures may be implemented at a location as part of overall visibility enhancements.
Small Corner Radii Benefits:

- Smaller, more pedestrian-scale intersections
- Reduced pedestrian crossing distance and crossing time
- Slower vehicular turning speeds
- Better geometry for installing perpendicular ramps for both crosswalks at each corner
- Simpler, more appropriate crosswalk placement, in line with the approaching sidewalks

Road Diets

- Considerations
  - Safety
  - Operations
    - Peak Hour
  - Design
    - Signalized Intersection Adjustments
    - Resurfacing
    - Context Sensitive Solutions/Complete Streets