Lecture 9
Pedestrian Characteristics & Facility Design and Operation

Design and Operation of Bicycle and Pedestrian Infrastructure

Christopher Monsere, Associate Professor
Department of Civil and Environmental Engineering
Portland State University

Nick Foster, Graduate Research Assistant
Outline

• Design Characteristics of Pedestrians
  – Types
  – Performance and Behavior

• Facility Design
  – Sidewalks
  – Midblock Crossings
  – Intersections

• Traffic Signals
General Types of Pedestrians

- **Purpose**: Utilitarian vs. recreational users
- **Age range**: Children to elderly
- **Abilities**: Fully ambulatory vs. visual/physical/auditory limitations
- **Social use**: Single pedestrians vs. groups of pedestrians vs. congregating pedestrians
Pedestrian Trip Types

<table>
<thead>
<tr>
<th>Reasons for Walking</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Personal Errands</td>
<td>38%</td>
</tr>
<tr>
<td>Exercise or Health</td>
<td>28%</td>
</tr>
<tr>
<td>Recreation/Leisure</td>
<td>21%</td>
</tr>
<tr>
<td>Commuting to School/Work</td>
<td>5%</td>
</tr>
<tr>
<td>Work-related Trip</td>
<td>4%</td>
</tr>
<tr>
<td>Other</td>
<td>3%</td>
</tr>
</tbody>
</table>

2002 National Survey of Pedestrian and Bicyclist Attitudes and Behaviors
## Age vs. Mode Share

<table>
<thead>
<tr>
<th>Walking Trips, as a percentage of all trips, By Age</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 to 15</td>
<td>15.2</td>
</tr>
<tr>
<td>16 to 24</td>
<td>9.3</td>
</tr>
<tr>
<td>25 to 39</td>
<td>9.2</td>
</tr>
<tr>
<td>40 to 64</td>
<td>7.8</td>
</tr>
<tr>
<td>65 and over</td>
<td>8.9</td>
</tr>
<tr>
<td>All</td>
<td>9.6</td>
</tr>
</tbody>
</table>

*Source: Pucher and Renne. 2003. Socioeconomics of Urban Travel: Evidence from the 2001 NHTS.*
## Perceived Safety

<table>
<thead>
<tr>
<th>Why Felt Threatened</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Motorists</td>
<td>62%</td>
</tr>
<tr>
<td>Dogs/Other Animals</td>
<td>36%</td>
</tr>
<tr>
<td>Crime Potential</td>
<td>36%</td>
</tr>
<tr>
<td>Uneven Walking Surface</td>
<td>28%</td>
</tr>
</tbody>
</table>

2002 National Survey of Pedestrian and Bicyclist Attitudes and Behaviors
# Self-Reported Trip Length

<table>
<thead>
<tr>
<th>Most Recent Trip Length</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;1 Mile</td>
<td>50%</td>
</tr>
<tr>
<td>1 Mile</td>
<td>13%</td>
</tr>
<tr>
<td>&gt;1 – 2 Miles</td>
<td>17%</td>
</tr>
<tr>
<td>&gt;2 – 3 Miles</td>
<td>8%</td>
</tr>
<tr>
<td>&gt;3 Miles</td>
<td>7%</td>
</tr>
</tbody>
</table>

*2002 National Survey of Pedestrian and Bicyclist Attitudes and Behaviors*
## Characteristics by Age

<table>
<thead>
<tr>
<th>Age</th>
<th>Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-4</td>
<td>• Learning to walk&lt;br&gt;• Requires supervision&lt;br&gt;• Developing abilities</td>
</tr>
<tr>
<td>5-8</td>
<td>• Still require some supervision&lt;br&gt;• Poor depth perception</td>
</tr>
<tr>
<td>9-13</td>
<td>• Poor judgment&lt;br&gt;• “Dart out” potential</td>
</tr>
<tr>
<td>14-18</td>
<td>• Improved awareness&lt;br&gt;• Poor judgment</td>
</tr>
<tr>
<td>19-40</td>
<td>• Fully aware and active</td>
</tr>
<tr>
<td>41-65</td>
<td>• Slowing reflexes</td>
</tr>
<tr>
<td>65+</td>
<td>• Vision/hearing loss&lt;br&gt;• Slower movement&lt;br&gt;• More susceptible to fatal injury</td>
</tr>
</tbody>
</table>

Older Pedestrian Considerations

• Simple Designs
• Minimize Crossing Distance
• Use Lower Walking Speeds
• Lighting/Glare
• Increased Sign Size
• Enhanced Markings
Mobility Impaired Pedestrians

• **Wheelchair/Scooter Users**
  – Firm/stable surface
  – Curb ramps
  – Minimize cross slopes/grades (<2%)
  – Wider travel/turning paths

• **Walking-Aid Users**
  – Eliminate large cracks/grates
  – No slippery/uneven surfaces
  – Wider travel/turning paths
  – Slower walking speeds
Mobility Impaired Pedestrians (contd.)

• Prosthesis Users
  – Slower walking speeds
  – Minimize cross slopes/grades

• Hearing Impairments
  – Visual / sight distance is critical
Mobility Impaired Pedestrians (contd.)

• Vision Impairments
  – Detectable warnings
  – Physical barriers
  – Directional guidance
  – Cues for multiple senses
  – Visual and textile consistency

• Cognitive Impairments
  – Signs with universal symbols, pictures, and colors
Walking Speed

- **Range:**
  - 2.5 – 6.0 ft/sec
- **MUTCD**
  - 3.5 ft/sec
- **Influential factors:**
  - Age
  - Weather
  - Time of day
  - Trip purpose
  - Grade
  - Congestion

![Table 18. Walking speed by gender and age group.](image)

*Improving Pedestrian Safety and Unsignalized Crossings, NCHRP 562/TCRP 112 (2006)*
NCHRP 562

Figure 22. Older than 60 (Old) and 60 and younger than 60 (Young) walking speed distribution.
Spatial Requirements

• Width:
  – 4.67 Ft – 2 People Walking Side-By-Side
  – 5 Ft – 2 Wheelchairs

• Spatial Bubbles

Figure 5. Spatial dimensions for people with disabilities (4).
Activity: Calculate out of direction travel time for pedestrians, then convert to distance equivalent for vehicles assuming 35 mph speed.
Bikes vs. Pedestrians

• Similarities
  – Exposure
  – Competition for Space
  – Age
  – Licensing

• Differences
  – Slower
  – Shortcuts
  – Maneuverability
  – ADA Requirements
  – Everyone’s a Pedestrian
Facility Design
General Considerations

- Accessibility
- Continuity
- Social Space
- Shortest Path
- Obstructions
Types of Walkways

• SIDEWALKS
  – located along roadways, separated with a curb and/or planting strip or swale, have a hard, smooth surface. Sidewalks in residential areas are sometimes used by bicyclists, but cities may ban bicycle riding on sidewalks.

• PATHS
  – typically used by pedestrians, cyclists, skaters and joggers (shared-use). It is not realistic to plan and design a path for exclusive pedestrian use, as others will be attracted to the facility.

• SHOULDERS
  – which serve pedestrians in many rural areas. The ODOT-recommended shoulder widths are usually adequate to accommodate pedestrians.

Source: ODOT 2011 Bicycle and Pedestrian Design Guide
Sidewalk Zones

• Context
  – Urban streets
  – Rural roads (sometimes)

• Zones
  – Curb
  – Furniture (“Buffer”)
  – Pedestrian
  – Frontage

Source: ODOT 2011 Bicycle and Pedestrian Design Guide
Curbs

• On most urban streets with sidewalks
• Helps with drainage
• Recommend “barrier” curb rather than mountable
  – Prevents Parking/Driving
  – Not Mountable

Source: ODOT 2011 Bicycle and Pedestrian Design Guide
Furniture/Buffer Area

• Paved or Landscaped
• Benefits
  – Greater Separation
  – Clear Walking Area
  – Aesthetics
  – ADA Compatibility
  – Drainage

Source: ODOT 2011 Bicycle and Pedestrian Design Guide
Furniture/Buffer Area Design

• Desirable Widths (Landscaped)
  – Local/Collector Streets – 2-4 Ft.
  – Arterial Streets – 5-6 Ft.
  – No Bike Lane/Parking – 6 Ft.

• Desirable Total Widths (Paved)
  – Residential Local/Collector Streets – 6 Ft.
  – Commercial and Arterial Streets – 8 Ft.
Walking Zone

• General Considerations
  – Obstruction-free
  – Smooth, even surface
  – Distinguish from paved buffers

Source: ODOT 2011 Bicycle and Pedestrian Design Guide
Walking Zone Widths

• ODOT
  – 6 Ft. – Standard
  – 5 Ft. – Minimum
    • Requires Justification
  – 4 Ft. – Absolute Minimum for Pinch Points

• Other Situations
  – 6-10 Ft. – Arterials
  – 10+ Ft. – CBDs/High Activity Areas
Frontage Zone

- **Context**
  - Adjacent Building/Barrier

- **Uses:**
  - Street Furniture
  - Window Shopping
  - Enter/Exit Buildings

- **Width:**
  - 2 Ft. - Recommended
  - 1 Ft. – Minimum
  - 4+ Ft. - CBDs

Source: ODOT 2011 Bicycle and Pedestrian Design Guide
Activity

• In a group, brainstorm the following:
  – 1 excellent pedestrian sidewalk
  – 1 poor sidewalk facility

• We’ll try to Google Streetview it!
Sidewalks – Other Situations

• No Curb/Gutter
  – Rural Roads with Ditch
  – 6 Ft. Recommended/5 Ft. Min.

• Bridges
  – Both Sides
  – 7 Ft. Min. Width
    • Not Narrower Than Approach
Sidewalks – ADA Guidelines

• Min. Width – 4 Ft.
  – Below ODOT Standard
  – Requires 5 ft. Passing Spaces
  – No Obstructions

• Grade – Same as Adjacent Road
  – 5% Max. If Not by Road

• Cross Slope – 2% Max.
A maximum grade of 12:1 (8.33%) is acceptable for a rise of no more than 2.5 feet if a 5 foot long level landing is provided after each 2.5 foot rise but this creates a “choppy” effect.
Cross-slopes

• The maximum allowable cross-slope (needed for drainage) for the pedestrian access route portion of a walkway is 2%.

• Across driveways, curb ramps and road approaches (in crosswalks, marked or unmarked), a 4 foot minimum wide area must be maintained at 2%.
Driveways

Figure 4-21: Furniture zone maintains sidewalk continuity

Figure 4-22: Curb tight sidewalk wraps to the back of driveway

Figure 4-23: Entire sidewalk dips at driveway, but beware the roller coaster effect

Figure 4-25: Minimum pedestrian access route maintained level at driveway
Consolidate Driveways!

Figure 5-3: Access management techniques such as raised medians and consolidated driveways reduce conflict points
Types of Ramps

Figure 4-28: Parallel curb ramp

Figure 4-29: Perpendicular ramp

Figure 4-31: Combination curb ramp

Parallel curb ramp

Perpendicular Curb Ramp

Combination curb ramp
Placement of Ramps

• These rules should be followed:
  – Ramps must be wholly contained within the crosswalk lines (flares may fall outside the crosswalk);
  – Two ramps per corner should be provided, where feasible;
  – Ramps should be placed as close to the intersection as possible; this is made easier by keeping the curb radius tight, and the curb height between two adjacent ramps to no more than 3 inches; and
  – Drainage grates should be provided upstream of ramps to prevent water ponding.
Truncated Domes

To illustrate the importance of color and contrast in ramp treatments, researchers from WisDOT and the city of Madison took digital photographs through low-vision goggles at distances of (left) approximately 9.8 meters (32 feet) and (right) 1.5 meters (5 feet).

Photos: Duane Sippola.

Source: FHWA, Public Roads, Sept/Oct 2004 Vol. 68 · No. 2
Intersection Basics

• Crossings Across All Legs
• Direct Paths
• Minimize Length
  – Refuge Islands
  – Small Corner Radii
    • Know the Design Vehicle
  – Curb Extensions
Curb Radius

ace for pedestrians, move

cult for pedestrians to sec
turning vehicles may

Exhibit 3-20.
Effective Turning Radius (24).

is used at all four

Exhibit 3-21.
Advantage of Smaller Curb Radii
(11).

Curb Radius, $R$

<table>
<thead>
<tr>
<th>Curb Radius, $R$</th>
<th>Increased Crosswalk Distance*</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 m [16 ft]</td>
<td>1 m [3 ft]</td>
</tr>
<tr>
<td>10 m [33 ft]</td>
<td>7 m [23 ft]</td>
</tr>
<tr>
<td>15 m [49 ft]</td>
<td>12 m [39 ft]</td>
</tr>
</tbody>
</table>

* Measured along centerline of sidewalk/crosswalk as compared to curb-to-curb width.
Is Crossing the Street a Crime?

• “Jaywalking” is not a legally defined term in Oregon law. It does not mean crossing a street midblock.

• The Oregon Vehicle Code states that it is illegal for pedestrians to:
  – Cross a street against a traffic signal;
  – Cross the street outside of a crosswalk without yielding to vehicular traffic;
  – Cross the street outside of a crosswalk at an intersection; and
  – Proceed in a crosswalk in a manner that causes an immediate hazard to an approaching motor vehicle.
Midblock Crossings

• Considerations
  – Motor Vehicle Traffic
  – Crossing Demand
    • Land Use
    • Transit
    • Trail
  – Distance to Nearest Crossing
  – Sight Distance
Midblock Crossing Types

• Marked Crosswalk
• Enhanced
• Active
• Red Signal/Beacon
• [Half Signal]
• Traffic Signal
Crossing Type Guidelines

- NCHRP Report 562
  - 20+ Crossings/Hour Min. for Control
  - Worksheets to Identify Treatments Based on Pedestrian Delay and Expected Motorist Yielding

Source: NCHRP Report 562
Motorist Yielding By Treatment

Abbreviations: Msig=midblock signal; Half=half signal; Hawk=HAWK signal beacon; InSt=in-street crossing signs; Flag=pedestrian crossing flags; OfPb=overhead flashing beacons (pushbutton activation); Refu=median refuge island; HiVi=high-visibility signs and markings; OfPa=overhead flashing beacons (passive activation)

Figure 24. Site average and range for motorist yielding by crossing treatment.
Marked Crosswalks

• Continental Striping Preferred
  – Consider Advance Stop Lines on Multi-lane Roads

• FHWA Safety Study
  – Only Marking Crosswalks May Increase Crash Risk
  – <12,000 ADT, < 35 MPH, 2 Lanes
    • A Marked Crosswalk OK
  – 15,000 ADT, 40+MPH and/or Multi-lane
    • Consider Substantial Improvements
Types of Crosswalk Markings

- Standard
- Continental
- Diagonal

Figure 32a  Crosswalk Types
MUTCD Crosswalk Markings

- Section 3B.18 Crosswalk Markings
- Support:
  - Crosswalk markings provide guidance for pedestrians who are crossing roadways by defining and delineating paths on approaches to and within signalized intersections, and on approaches to other intersections where traffic stops. In conjunction with signs and other measures, crosswalk markings help to alert road users of a designated pedestrian crossing point across roadways at locations that are not controlled by traffic control signals or STOP or YIELD signs. At non-intersection locations, crosswalk markings legally establish the crosswalk.
- Standard:
  - When crosswalk lines are used, they shall consist of solid white lines that mark the crosswalk. They shall not be less than 6 inches or greater than 24 inches in width.
- Guidance:
  - If transverse lines are used to mark a crosswalk, the gap between the lines should not be less than 6 feet.
  - If diagonal or longitudinal lines are used without transverse lines to mark a crosswalk, the crosswalk should be not less than 6 feet wide.
  - Crosswalk lines, if used on both sides of the crosswalk, should extend across the full width of pavement or to the edge of the intersecting crosswalk to discourage diagonal walking between crosswalks (see Figures 3B-17 and 3B-19).
  - At locations controlled by traffic control signals or on approaches controlled by STOP or YIELD signs, crosswalk lines should be installed where engineering judgment indicates they are needed to direct pedestrians to the proper crossing path(s).
  - Crosswalk lines should not be used indiscriminately. An engineering study should be performed before a marked crosswalk is installed at a location away from a traffic control signal or an approach controlled by a STOP or YIELD sign. The engineering study should consider the number of lanes, the presence of a median, the distance from adjacent signalized intersections, the pedestrian volumes and delays, the average daily traffic (ADT), the posted or statutory speed limit or 85th-percentile speed, the geometry of the location, the possible consolidation of multiple crossing points, the availability of street lighting, and other appropriate factors.
- 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 and either:
  - A. The roadway has four or more lanes of travel without a raised median or pedestrian refuge island and an ADT of 12,000 vehicles per day or greater; or
  - B. The roadway has four or more lanes of travel with a raised median or pedestrian refuge island and an ADT of 15,000 vehicles per day or greater.
Figure 3B-17. Examples of Yield Lines at Unsignalized Midblock Crosswalks

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.

Legend

→ Direction of travel
ODOT Standard

Figure 32d  Typical Mid-Block Crosswalk Markings

ODOT Traffic Line Manual
June 2011

Portland State University
Median Refuge Islands

- **Context**
  - Any Crossing, Especially Multi-Lane Roads
- **Shortens/Simplifies Crossing**
- **May Slow Traffic**
- **Driver Yielding Rate** –
  - 7-75% (29-34% Average)
- **Design Guidance**
  - 5+ Ft. Wide Cut Through
    - Can Be offset
  - 6+ Ft. Island Width
    - 8+ Ft. if Bikes Expected
- **Can Impact Turning Movements**

Photo: N. Foster
Raised Crosswalks

• Context
  – Local/Collector Streets
• Increases Visibility
• Slows Traffic
• Design Guidance
  – Level with Sidewalk
  – 10-12’ Wide
  – Mark/Color Approach/Edge

Photo: Dan Burden, www.pedbikeimages.org
Curb Extensions

• Context
  – Streets with On-Street Parking

• Increase Visibility
  Sight Distance

• Slows Traffic

• Shortens Crossing

• Design Guidance
  – Full Width of Parking Lane, Not Into Bike Lane

Photo: Dan Burden, www.pedbikeimages.org
In-Street Signs

• Improve Visibility
• Reminds Drivers of State Law
• Driver Yielding Rates:
  – 44-97% (77-90% avg.)
  – 25-30 MPH Road
• Placement
  – In Roadway At Crosswalk
    • Centerline, lane line, or median island
• Bounce-back Design
  – Maintenance

Source: 2009 MUTCD
High Visibility Signs and Markings

- Only in school zones
- Improve Visibility
- At or In Advance of Crossing
- Signs
  - Fluorescent Yellow-Green
  - Higher Reflectivity
- Markings
  - Higher Conspicuity/Reflectivity
In-Roadway Warning Lights

• Improve Visibility
• Pedestrian Activated
• Not > ¾” Above Surface
• Limited Effectiveness in Daylight
  – Not a Recommended Treatment

Source: Google Maps
Crossing Flags

• Improve Visibility
• Warn Drivers
• Driver Yield Rates –
  – 46-80% (65-74% Avg.)
• Inexpensive
• Considerations
  – Require Regular Replacement
  – May Be Missing From One Side

Photo: Dan Burden, www.pedbikeimages.org
Overhead Beacons

• Passive or Active
  – Driver Yield Rates (Passive) – 25-73% (31-67% avg.)
  – Driver Yield Rates (Active) – 29-92% (47-52% avg.)

• Improve Visibility
  – Warn Drivers, if Active

Photo: FHWA
Rectangular Rapid Flash Beacon

• Improve Visibility
• Warn Drivers
  – Pedestrian Activated
  – Irregular Flashing
• Driver Yield Rates
  – 75% - 88% (avg.)
• Relatively inexpensive
• FHWA Interim Approval
Pedestrian Hybrid Beacon

• Context
  – Multi-lane, high-speed/volume crossings
• Pedestrian Activated
• Red Control
  – Flashing Red Reduces Driver Delay
• Driver Yield Rates –
  – 94-100% (97-99% avg.)
• MUTCD Warrant
  – Min. 20 Crossings/Hour
• Cheaper Than a Signal
Pedestrian-Hybrid Beacon

Figure 4F-3. Sequence for a Pedestrian Hybrid Beacon

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
Pedestrian Hybrid Signal Sequence

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

Slide Credit: Peter Koonce, City of Portland
Pedestrian-Hybrid Beacon Volume Guidelines

Figure 4F-1. Guidelines for the Installation of Pedestrian Hybrid Beacons on Low-Speed Roadways

- Speeds of 35 mph or less
- Speeds of more than 35 mph

*T Note: 20 pph applies as the lower threshold volume

Portland State University
Half-Signals

• In revising MUTCD in 1987, taken out of MUTCD:
• Motorists on the minor road, facing the inability to cross the major stream of traffic, could utilize the pedestrian signal, may not come to a complete stop, and not give adequate attention to pedestrians crossing the street.
• Left-turning vehicles from the minor road that enter the intersection because they see that major road traffic is stopped could potentially become trapped in the intersection as the signal changes back to green. In this situation, there would be no clearance interval for the minor road traffic.
• Half-signals violate driver expectancy with vehicles at the stop controlled minor leg making left turns in front of drivers who see a green ball from the traffic signal on the major road.

Half-Signalized Intersection, NE Glisan, Portland, OR
Traffic Signal

• Context
  – High Crossing Demand AND
  – Multi-lane, high speed/volume

• Pedestrian Activated
  – “Hot” Response Desirable
  – Coordinated with Other Signals

• Driver Yield Rates
  – 91-100% (95-99% avg.)

• MUTCD Warrant
  – 75-133 Crossings/Hour Min.
If the posted or statutory speed limit or the 85th-percentile speed on the major street exceeds 35 mph, or if the intersection lies within the built-up area of an isolated community having a population of less than 10,000,
Selecting Pedestrian Crossing Treatments

Step 1. Select worksheet based on (1) posted or statutory speed limit or the 85th percentile speed on the major street and (2) other conditions present:
   a) Worksheet 1 - 35 mph (55 km/h) or less
   b) Worksheet 2 - Exceeds 35 mph (55 km/h) or locations where the community has a less than 10,000 population or where a major transit stop is present

Step 2. Does the crossing meet minimum peak-hour pedestrian volumes to be considered for a traffic control device type of treatment?
   NO
   Consider median refuge islands, curb extensions, traffic calming, etc. as feasible. No traffic control devices are recommended.
   YES
   Go to Step 3

Step 3. Does the crossing meet the warrant for a traffic signal?
   NO
   Go to Step 4
   YES
   Warrant met, consider traffic signal if site is not within 300 ft (91 m) of another signal.

Step 4. Estimate pedestrian delay.

Step 5. Select treatment based upon total pedestrian delay and expected motorist compliance.

Figure A-1. Flowchart for Guidelines for Pedestrian Crossing Treatments.
Activity

• Complete in-class analysis @ 2700 Block Elm Street
Delay and Crossing Behavior

Table 8. HCM LOS criteria for pedestrians at unsignalized intersections. (23)

<table>
<thead>
<tr>
<th>Level of Service</th>
<th>Average Delay/Pedestrian (s)</th>
<th>Likelihood of Risk-Taking Behavior*</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>&lt; 5</td>
<td>Low</td>
</tr>
<tr>
<td>B</td>
<td>≥ 5 – 10</td>
<td>Moderate</td>
</tr>
<tr>
<td>C</td>
<td>&gt; 10 – 20</td>
<td>Moderate</td>
</tr>
<tr>
<td>D</td>
<td>&gt; 20 – 30</td>
<td>High</td>
</tr>
<tr>
<td>E</td>
<td>&gt; 30 – 45</td>
<td>Very High</td>
</tr>
<tr>
<td>F</td>
<td>&gt; 45</td>
<td>Very High</td>
</tr>
</tbody>
</table>

* Likelihood of acceptance of short gaps.

• Most studies state that pedestrians become more likely to take extra risks at longer delays, i.e., above a delay of around 30 s, pedestrians are more likely to accept shorter gaps in traffic through which to cross
Pedestrian LOS at TWSC Intersections

• **Before Conditions:**
  – 4-lanes, undivided
  – 44 foot crossing distance
  – 2,000 vehicles per hour
  – 10% yield rate (based on standard marked crosswalk)
  – *Results: Delay = 600s, LOS = F*

• **Conversion to 3-lane section with median island:**
  – 2-lanes, divided
  – 11 foot crossing distance (x2 for each stage)
  – 1,000 vehicles per hour (x2 for each stage)
  – 10% yield rate
  – *Results: Delay = 15s, LOS = C*

• **Conversion to 3-lane section with Median Island (plus Rapid Flash Beacon):**
  – 2-lanes, divided
  – 11 foot crossing distance (x2 for each stage)
  – 1,000 vehicles per hour (x2 for each stage)
  – 80% yield rate (based on rapid flash beacon research)
  – *Results: Delay = 4s, LOS = A*

• *Note: actual pedestrians would not wait 10 minutes to cross here. They would likely walk to the nearest signal, pick a small gap in traffic and run, or cross "frogger-style" where they do not wait for the entire roadway is clear to begin crossing. The point is that any of these results are extreme inconveniences to pedestrians, and potential safety hazards.*

Examples and spreadsheet by Jamie Parks, City of Oakland
Traffic Signals
Signal Design Topics

• Pedestrian Signal Heads
• Pedestrian Detection
  – Active
  – Passive (Push-Buttons)
• Phasing and Timing
Oregon DOT Policy

• The following points shall be considered regarding the design and operation of crosswalks at signalized intersections:
  – **Crosswalks shall be marked** for all approaches of signalized intersections unless the crosswalk is closed by official action and signs are posted.
  – **Pedestrian signal heads shall be provided** for all marked crosswalks at signalized intersections.
  – For all new installations, **countdown pedestrian signal heads shall be installed**.
  – **Pedestrian detection/activation shall be provided where pedestrian signal heads are provided** except when the pedestrian phase is recalled at all times, as is the case at signalized intersections in a central business district.
Pedestrian Indications

Figure 4E-1. Typical Pedestrian Signal Indications

A - With countdown display

B - Without countdown display
Pedestrian Signal Heads

- Mounting Heights
  - Bottom of signal housing
  - Not less than 7 ft
  - Not more than 10 ft
  - Clearly Visible

- Symbols
  - Must be at least 6 inch
  - If more than 100 ft crossing, symbols 9 inch high

- Physical separation if on same support as vehicle heads
MUTCD Pushbutton Location Area

• Push Button Placement (if necessary)
  • 10 Ft. or Less From Curb
  • 42 In. High
  • Adjacent to Crosswalk
  • Accessibility Features

Figure 4E-3. Pushbutton Location Area

Notes:
1. Where there are constraints that make it impractical to place the pedestrian pushbutton between 1.5 feet and 6 feet from the edge of the curb, shoulder, or pavement, it should not be further than 10 feet from the edge of curb, shoulder, or pavement.
2. Two pedestrian pushbuttons on a corner should be separated by 10 feet.
3. This figure is not drawn to scale.
4. Figure 4E-4 shows typical pushbutton locations.
Typical Push Button Locations

Figure 4E-4. Typical Pushbutton Locations (Sheet 1 of 2)

A - Parallel ramps with wide sidewalk

B - Parallel ramps with narrow sidewalk

C - Parallel ramps with narrow sidewalk and tight corner radius

D - Perpendicular ramps with crosswalks far apart

Notes:
1. This figure is not drawn to scale.
2. These drawings are intended to describe the typical locations for pedestrian pushbutton installations. They are not intended to be a guide for the design of curb cut ramps.
3. Figure 4E-3 shows the recommended area for pushbutton locations.

Figure 4E-4. Typical Pushbutton Locations (Sheet 2 of 2)

E - Perpendicular ramps with crosswalks close together

F - Perpendicular ramps with sidewalk set back from road with crosswalks far apart

G - Perpendicular ramps with sidewalk set back from road with crosswalks close together

H - Perpendicular ramps with sidewalk set back from road with continuous sidewalk between ramps

Notes:
1. This figure is not drawn to scale.
2. These drawings are intended to describe the typical locations for pedestrian pushbutton installations. They are not intended to be a guide for the design of curb cut ramps.
3. Figure 4E-3 shows the recommended area for pushbutton locations.
Accessible Pedestrian Detectors

- **Pushbutton Locator tones**
  - Shall have a duration of 0.15 seconds or less, and shall repeat at 1-second intervals.
  - Shall be intensity responsive to ambient sound, and be audible 6 to 12 feet from the pushbutton, or to the building line, whichever is less

- **Vibro-tactile buttons**
  - Tactile arrows shall be located on the pushbutton,
  - Have high visual contrast (light on dark or dark on light)
  - Aligned parallel to the direction of travel on the associated crosswalk.

- **Audible Walk indication**
  - Audible walk indication shall be a percussive tone.
  - Audible tone walk indications shall repeat at eight to ten ticks per second.
  - Audible tones used as walk indications shall consist of multiple frequencies with a dominant component at 880 Hz.
  - Speech optional

- **If pushbuttons are located closer than 10 feet**
  - A speech walk message for the WALKING PERSON (symbolizing WALK) indication, and
  - A speech pushbutton information message.
Pedestrian Signal Timings

- Pedestrians: WALK → Flashing DON'T WALK
- Vehicles: MIN GREEN → PASSAGE GAP → MAX GREEN
- Bicycles: PREEMPTION or PRIORITY
- Special: YELLOW CHANGE AND RED CLEARANCE
Pedestrian phase

• Consists of three intervals:
  – Walk
    • WALKING PERSON
  – Pedestrian clearance, commonly referred to as flashing don’t walk (FDW)
    • UPRAISED HAND (FLASHING)
  – Solid don’t walk
    • UPRAISED HAND
## Pedestrian walk interval duration

<table>
<thead>
<tr>
<th>Conditions</th>
<th>Walk Interval Duration (PW), s</th>
</tr>
</thead>
<tbody>
<tr>
<td>High pedestrian volume areas (e.g., school, central business district, sports venues, etc.)</td>
<td>10 to 15</td>
</tr>
<tr>
<td>Typical pedestrian volume and longer cycle length</td>
<td>7 to 10</td>
</tr>
<tr>
<td>Typical pedestrian volume and shorter cycle length</td>
<td>7</td>
</tr>
<tr>
<td>Negligible pedestrian volume</td>
<td>4</td>
</tr>
<tr>
<td>Conditions where older pedestrians are present</td>
<td>Distance to center of road divided by 3.0 feet per second</td>
</tr>
</tbody>
</table>

Source: Traffic Signal Timing Manual (FHWA)
Pedestrian Clearance

• When the pedestrian clearance interval begins, pedestrians should either complete their crossing if already in the intersection or refrain from entering the intersection until the next pedestrian walk interval is displayed.

• The MUTCD currently stipulates that the pedestrian clearance interval must be calculated assuming the distance from the curb to the far side of the opposing travel way, or to a median of sufficient width for pedestrians to wait.

Source: Traffic Signal Timing Manual (FHWA)
Pedestrian Clearance Times

<table>
<thead>
<tr>
<th>Pedestrian Crossing Distance, ft</th>
<th>Walking Speed, ft/s</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>3.0</td>
</tr>
<tr>
<td>40</td>
<td>13</td>
</tr>
<tr>
<td>60</td>
<td>20</td>
</tr>
<tr>
<td>80</td>
<td>27</td>
</tr>
<tr>
<td>100</td>
<td>33</td>
</tr>
</tbody>
</table>

1. Note: Clearance times computed as $PCT = \frac{D_c}{v_p}$, where $D_c =$ pedestrian crossing distance (in feet) and $v_p =$ pedestrian walking speed (in feet per second).

Source: Traffic Signal Timing Manual (FHWA)
Some agencies require that the pedestrian clearance time conclude with the onset of the yellow change interval. This approach provides additional time (equal to the change period) for pedestrian clearance—time that is sometimes of benefit to pedestrians who walk slower than average. The pedestrian clearance interval duration for this practice is computed using Equation 5-3.

Other agencies allow a portion of the pedestrian clearance time to occur during the change period (i.e., yellow change or yellow change plus red clearance intervals). This practice minimizes the impact of pedestrian service on phase duration and allows it to be more responsive to vehicular demand. This pedestrian clearance interval duration is computed using Equation 5-4.

The practice of excluding the change and clearance intervals may place pedestrians at risk if a concurrent permissive left turn movement is receiving a yellow and the vehicles from that movement are expected to clear the intersection during the yellow interval. Some agencies using flashing yellow applications choose to omit the permissive left turn portion of a protected-permissive left-turn movement during a pedestrian call.

Source: Traffic Signal Timing Manual (FHWA)
Minimum Green for Pedestrian Crossing Time

• The minimum green duration must satisfy pedestrian crossing needs for through phases that are not associated with a pedestrian push button but have a pedestrian demand. Under these conditions

\[ G_p = PW + PC \]

Where:
- \( G_p \) is the minimum green interval duration needed to satisfy pedestrian crossing time,
- \( PW \) is the walk interval duration, and
- \( PC \) is the pedestrian clearance interval duration, s (all values in seconds).
Pedestrian Recall

• The pedestrian recall parameter causes the controller to place a continuous call for pedestrian service on the phase, resulting in the controller timing its walk and flashing don’t walk operation.

• There are at least two common applications of pedestrian recall:
  – Pedestrian detection is not present or is out of service.
  – High pedestrian demand: Pedestrian recall is sometimes used to activate the Walk and Pedestrian clearance intervals for phases and time periods that are likely to have high pedestrian demand. This is a common application during periods of high pedestrian activity in downtown environments or at intersections near schools as students are arriving or leaving school for the day.

Source: Traffic Signal Timing Manual (FHWA)
Figure 4E-2. Pedestrian Intervals

Pedestrian Signal Display

<table>
<thead>
<tr>
<th>Pedestrian Intervals</th>
<th>Walk Interval</th>
<th>Pedestrian Change Interval</th>
<th>Buffer Interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steady</td>
<td></td>
<td>Flashing with countdown*</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Steady</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Steady</td>
<td></td>
</tr>
</tbody>
</table>

“Zero” point of countdown display

7 seconds MIN.**

Calculated pedestrian clearance time*** (see Section 4E.06)

3 seconds MIN.

Relationship to associated vehicular phase intervals:

Yellow Change Interval = Buffer Interval

Red Clearance Interval = Buffer Interval

Associated Green Interval extends beyond end of Buffer Interval

Legend

G = Green Interval
Y = Yellow Change Interval (of at least 3 seconds)
R = Red Clearance Interval
Red = Red because conflicting traffic has been released

* The countdown display is optional for Pedestrian Change Intervals of 7 seconds or less.
** The Walk Interval may be reduced under some conditions (see Section 4E.06).
*** The Buffer Interval, which shall always be provided and displayed, may be used to help satisfy the calculated pedestrian clearance time, or may begin after the calculated pedestrian clearance time has ended.
Signal Timing

• Ped-Friendly Timing Strategies:
  – Pedestrian Progression
  – Recall Phasing (ped phase served every time)
  – Short Cycles (delay)
  – Leading Pedestrian Interval
  – Protected Left-Turns
  – Lagging pedestrian interval
  – Exclusive pedestrian phase (also “pedestrian scramble” or “Barnes’ Dance”)
Signal Operations with Peds

• There are several options available in the controller software, which may provide safer and more efficient operations of pedestrian crossings including:
  – Push and hold for extended walk (allows for a longer walk time)
  – Flashing yellow left-turn arrow “not-ped” mode
  – Right turn overlap “not-ped” mode
Closing Crosswalks