



# **Designing Traffic Signals for Pedestrians**

**John N. LaPlante, PE, PTOE  
T.Y. Lin International**

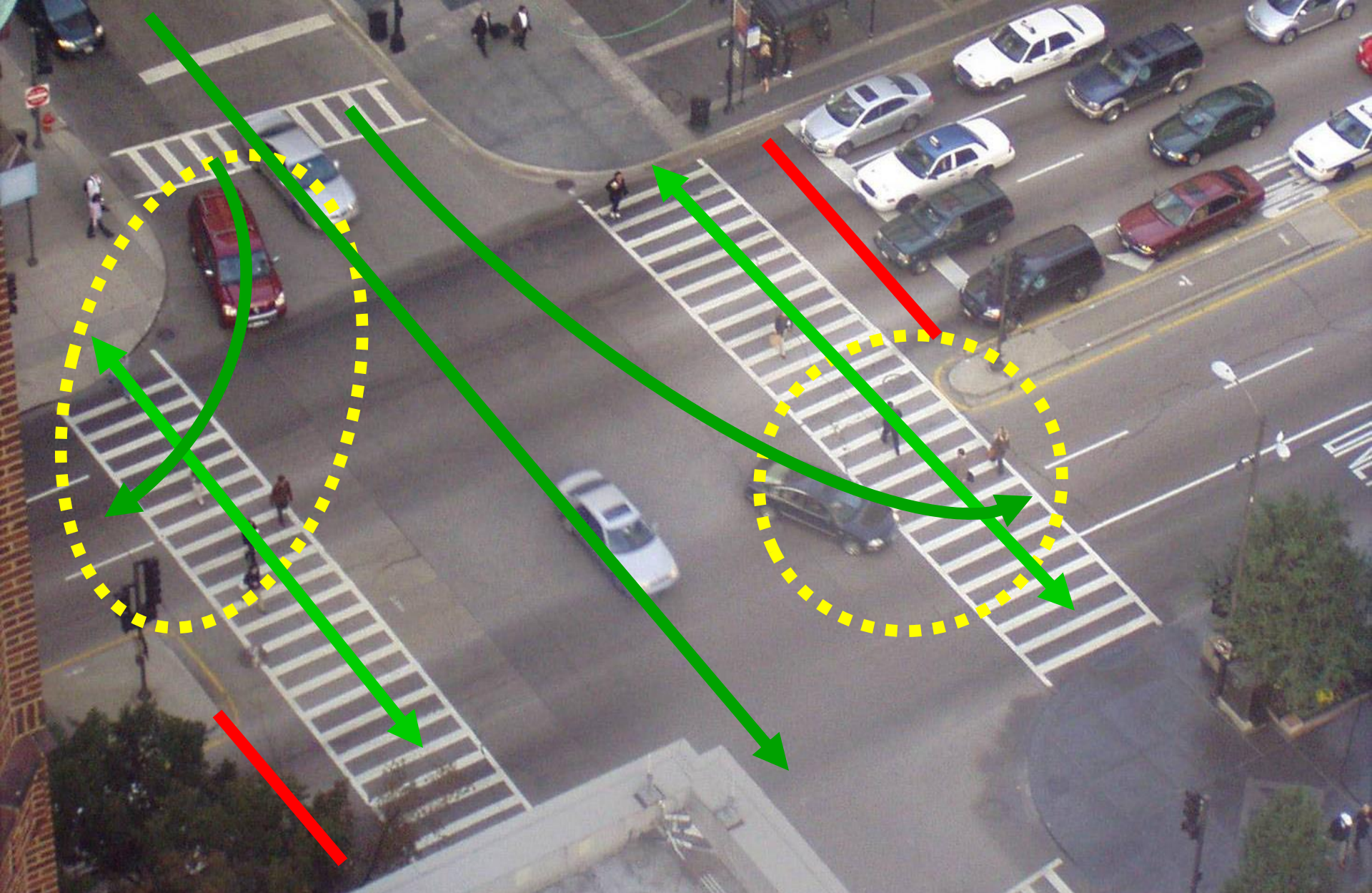
**Prepared for:**

**TRB Workshop on Accommodating Pedestrians  
at Signalized Intersections  
Marriott Hotel – Washington, DC  
January 11, 2009**

# Traffic signals assign the of right of way, regulate the flow of traffic and create gaps



Traffic signals do **not** guarantee safety – in fact, signalized intersections have more crashes than non-signalized



Turn movements often result in conflicts

# Traffic signals don't ensure protection



Peds routinely ignore the light (*usually quite safely*)

# Traffic signals don't ensure protection



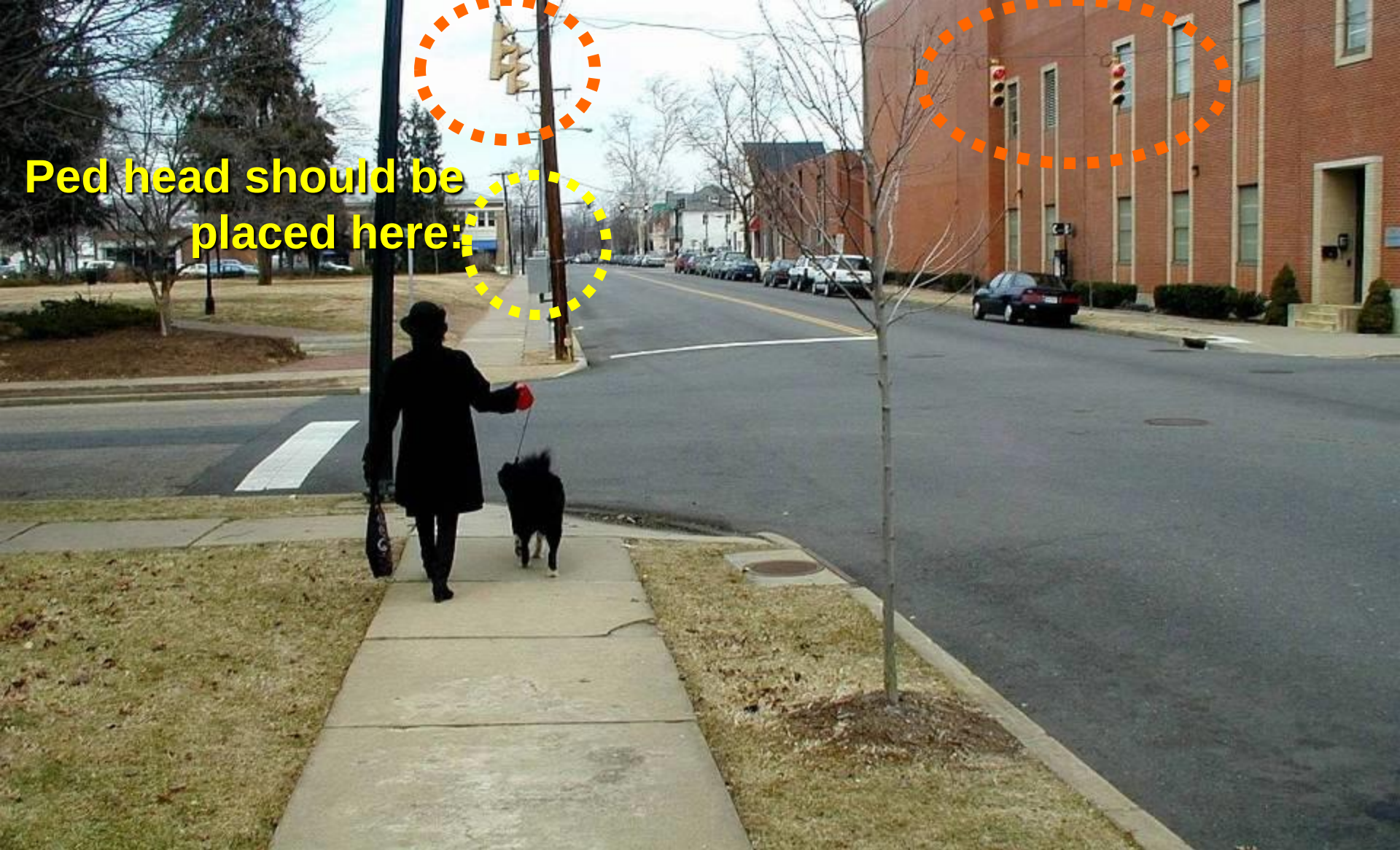
Pedestrians will cross where it's convenient

# Traffic signals don't ensure protection



Pedestrians are at risk when crossing with the light

# Placing Pedestrian Heads Where They Can Be Seen



Ped head should be placed here:

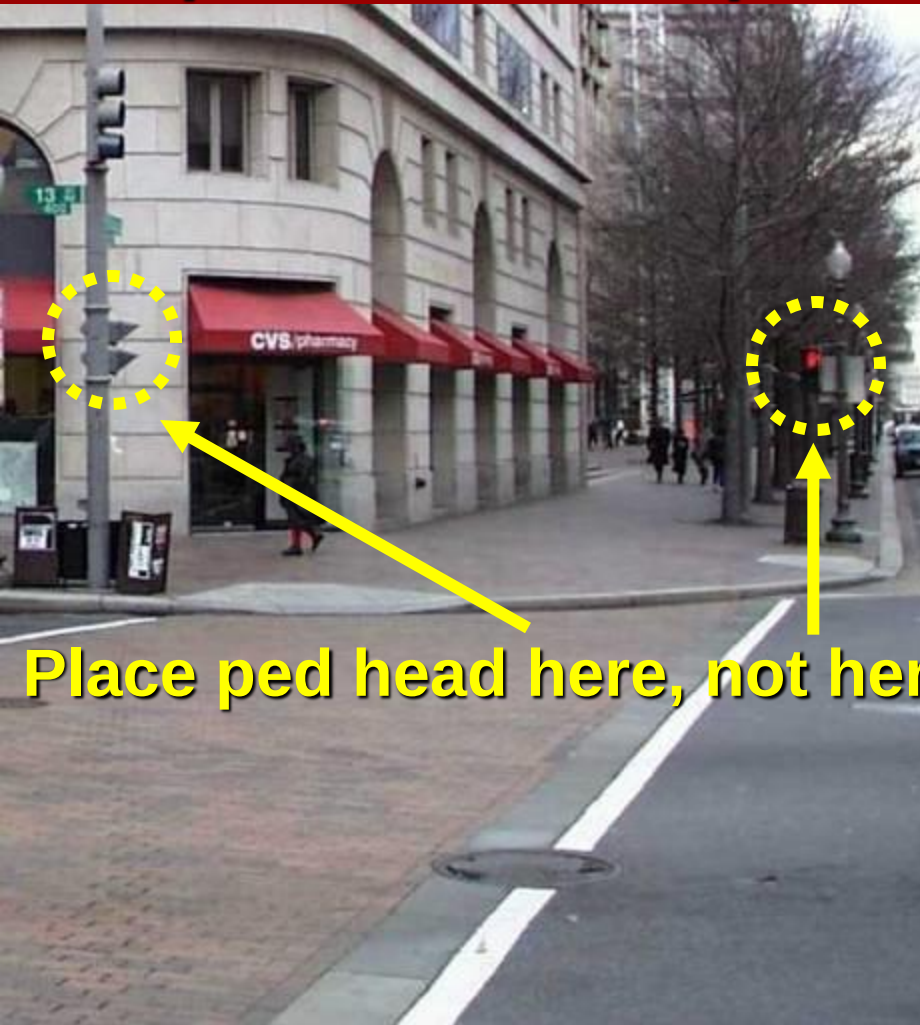
Pedestrian signals should be provided,  
Otherwise pedestrians don't know when to cross



Ped head should be placed here:

Lack of pedestrian signals on one way street:  
The pedestrian cannot see the signal

# Ped head placement: close to crosswalk, visible to pedestrians, especially with long crosswalk



Poor example



Good example

# Two-step signals: ensure pedestrians don't see conflicting signals



These pedestrians kept walking, against light

# Are ped heads always needed?

In general, **YES**

## Possible exceptions:

- Narrow street
- High ped use
- Simple intersections/simple signal phasing
- Appropriate vehicular signal heads are readily visible in both directions
- Ped clearance time can be accommodated by vehicular yellow plus all-red



# **Pedestrian Walking Speed Requirements**

# Background



- Every traffic engineer receives complaints:  
“I don’t have enough time to cross the street.”

Partly this is because 50% of pedestrians in the U.S. do not understand that “Flashing Don’t Walk” really means it is OK to continue walking

So we put signs like this to “correct” the problem



# Countdown Clocks



Pedestrian count-down signals tell pedestrians how much crossing time is left

# Countdown Clocks



- Pedestrians understand how it works
- Even though more pedestrians start to cross during clearance phase...
- Fewer peds begin walking late in clearance phase
- No peds left in crosswalk in steady don't walk phase

# Countdown Clocks



Results from San Francisco:  
25% Crash Reduction Factor after countdown  
signals installed

# Countdowns in New MUTCD

- The existing option of using pedestrian countdown displays will now be a requirement **for all new ped installations**
- All existing pedestrian signal installations should be upgraded with countdown clocks **within 10 years**
- Only exception is where the duration of the pedestrian change interval (flashing Don't Walk) is less than 7 seconds

# Proposed Change for 2009 MUTCD

New meaning of flashing hand when countdown pedestrian signals are present:

- Pedestrians may leave the curb if they are out of the traveled way by the time a conflicting vehicular movement is allowed to proceed.



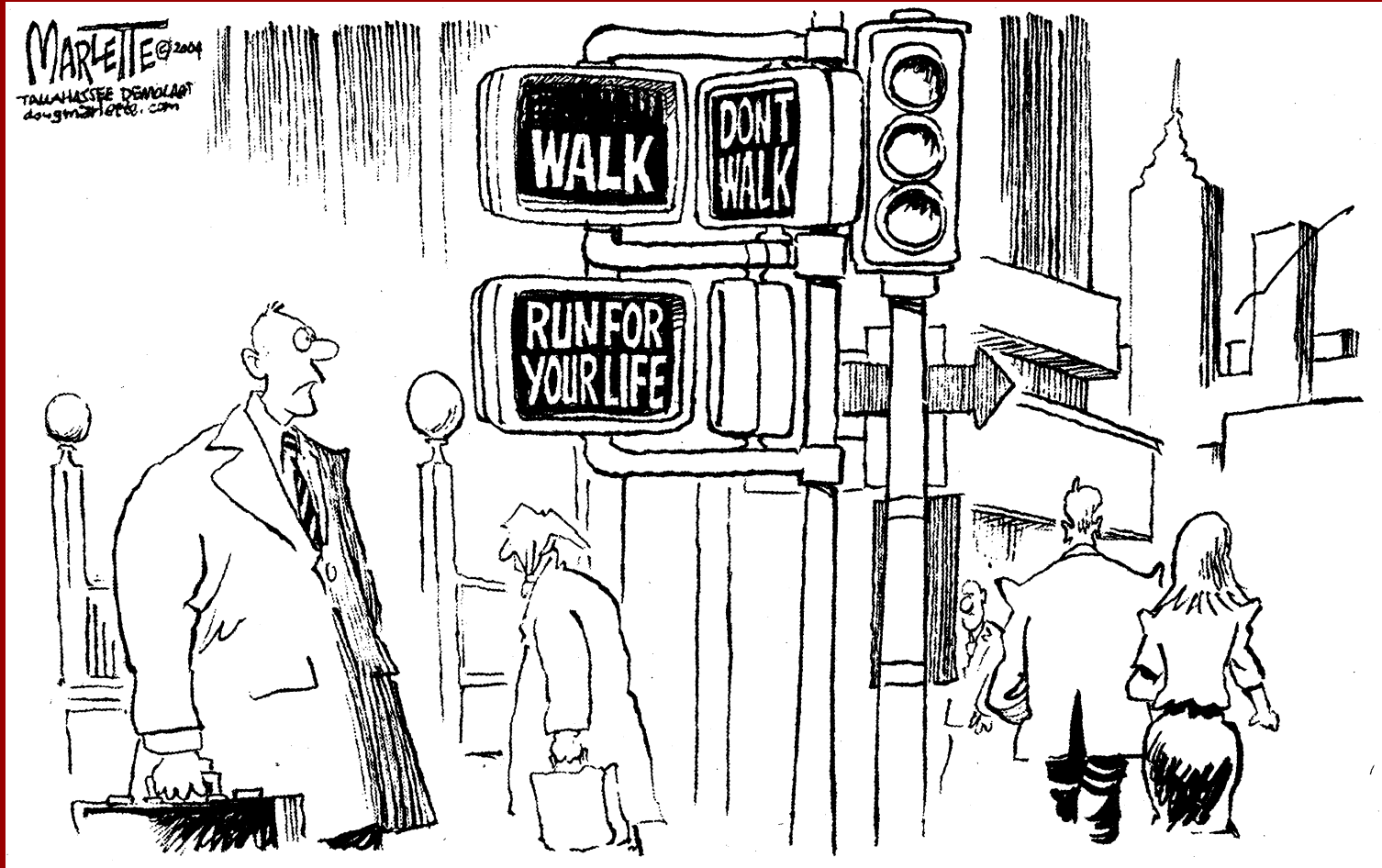
*Note: For this to apply, state or local laws must be updated with this provision*

# Role of Walking Speed

- Current MUTCD says Pedestrian Clearance Time should be based on 4.0 ft/sec walking speed
- “Where pedestrians who walk slower than normal, or pedestrians who use wheelchairs, *routinely* use the crosswalk, a walking speed of less than 4 feet per second should be considered . . . .”

# Role of Walking Speed

- Is this enough?



# PROWAAC Draft Guidelines

- In 2002, Public Rights-of-Way Access Advisory Committee (PROWAAC) released draft guidelines for public comment. They included:
  - Universal maximum ped walking speed of 3.0 fps
  - Crossing distance to include crosswalk length plus length of curb ramp

# PROWAAC Draft Guidelines

- TY Lin International asked by US Access Board to:
  - Determine history of current walking speed values
  - Estimate effect of recommended change on traffic operations

# Brief Walking Speed History

## 1948 MUTCD

- General language about the need to provide sufficient time for “most” peds to cross street
- “. . . the period during which it is not possible to start and complete a crossing at the *normal* walking speed should always be recognized . . . to prevent pedestrians from being stranded in the middle of the street.”

# Brief Walking Speed History

- 1952 John Exnicios' unpublished Yale master's thesis indicated:
  - Average walking speed of 4 fps for all crossing peds (3.5 fps as 15<sup>th</sup> percentile)
  - For elderly peds, average speed about 3.5 fps (15<sup>th</sup> percentile about 3.0 fps)

# Brief Walking Speed History

## 1961 MUTCD

- “A pedestrian clearance interval . . . shall be sufficient to allow a pedestrian to leave the curb and travel to the center of the farthest traveled lane . . . (*Normal* walking speed is assumed to be 4 feet per second.)”

# Brief Walking Speed History

## 1978 and 1988 MUTCD

- Similar to the 1961 version, with only minor differences with respect to the definition of ped clearance interval
- “Duration *shall* be . . .” was changed to “Duration *should* be . . .”

# Brief Walking Speed History

## Millennium Edition MUTCD

- Notes the need to consider peds who may move slower than the “normal” 4 fps walking speed
- “Where pedestrians who walk slower than normal, or pedestrians who use wheelchairs, *routinely* use the crosswalk, a walking speed of less than 4 feet per second should be considered . . . .”

# Brief Walking Speed History

## 2003 MUTCD

- Altered the crossing distance to be considered when determining ped crossing time from the *center* of the furthest traveled lane to the *far side* of the traveled way

# Recent Research

- 2005 TCRP/NCHRP study by TTI indicated 3.77 fps as 15th percentile speed for all pedestrians, and 3.03 fps as 15<sup>th</sup> percentile speed for older pedestrians
- It also reviewed past studies, and recommended 3.5 fps for all peds and 3.0 fps for older peds as 15<sup>th</sup> percentile speeds

# PROWAAC Recommendations

## New MUTCD Requirements

- Calculate pedestrian signal clearance phase timing using 3.5 ft/sec pedestrian walking speed
- Also calculate total walk crossing time (Walk plus Flashing Don't Walk) using 3.0 ft/sec
- Include the length of the crosswalk and one curb ramp for calculating crossing distance

# Impact on Timing and Capacity

- 2005 Study by Kim and Hunter (TRR 1920) examined the effect of walking speeds, crossing distances, varying critical volume ratios, and cycle lengths on delay



# Impact on Timing and Capacity

- Effect on intersection performance most significant at low cycle lengths
- Where the discrepancy between critical lane volumes on the main street and cross street increased, the impact of pedestrian green times on vehicular delay also increased
- When cycle lengths increased to account for pedestrian constraints, optimal delay rarely increased by more than a few seconds



# Wide Street Design Options

- Check to ensure number of through and/or turning lanes are really needed

# Roadway Capacity Analysis

- Always design urban roadways to LOS D
- Designing to LOS C for peak hour means:
  - Unnecessary pavement, waste of tax dollars
  - Increased ped crossing times, thus reducing vehicular movement times
  - Increased operating speeds for other 22 hours



# Wide Street Design Options

- Check to ensure number of through and/or turning lanes are really needed
- Check lane widths to see if narrower lanes are an option

# Narrower Travel Lanes

- 70 mph lane widths not needed to handle 30 mph traffic



# Narrower Travel Lanes

**News Flash!** 10 and 11-foot lanes are just as safe as 12-foot lanes on urban arterials with posted speeds less than 45 mph



# Wide Street Design Options

- Check to ensure number of through and/or turning lanes are really needed
- Check lane widths to see if narrower lanes are an option
- Check corner radii to see if crossing widths can be reduced

A photograph of a street intersection. A silver sedan is partially on the sidewalk, angled towards the curb. A pedestrian is walking across the street in the background. Two other pedestrians are standing on the sidewalk in the foreground, looking towards the car. The scene is set in an urban environment with various cars and buildings in the background.

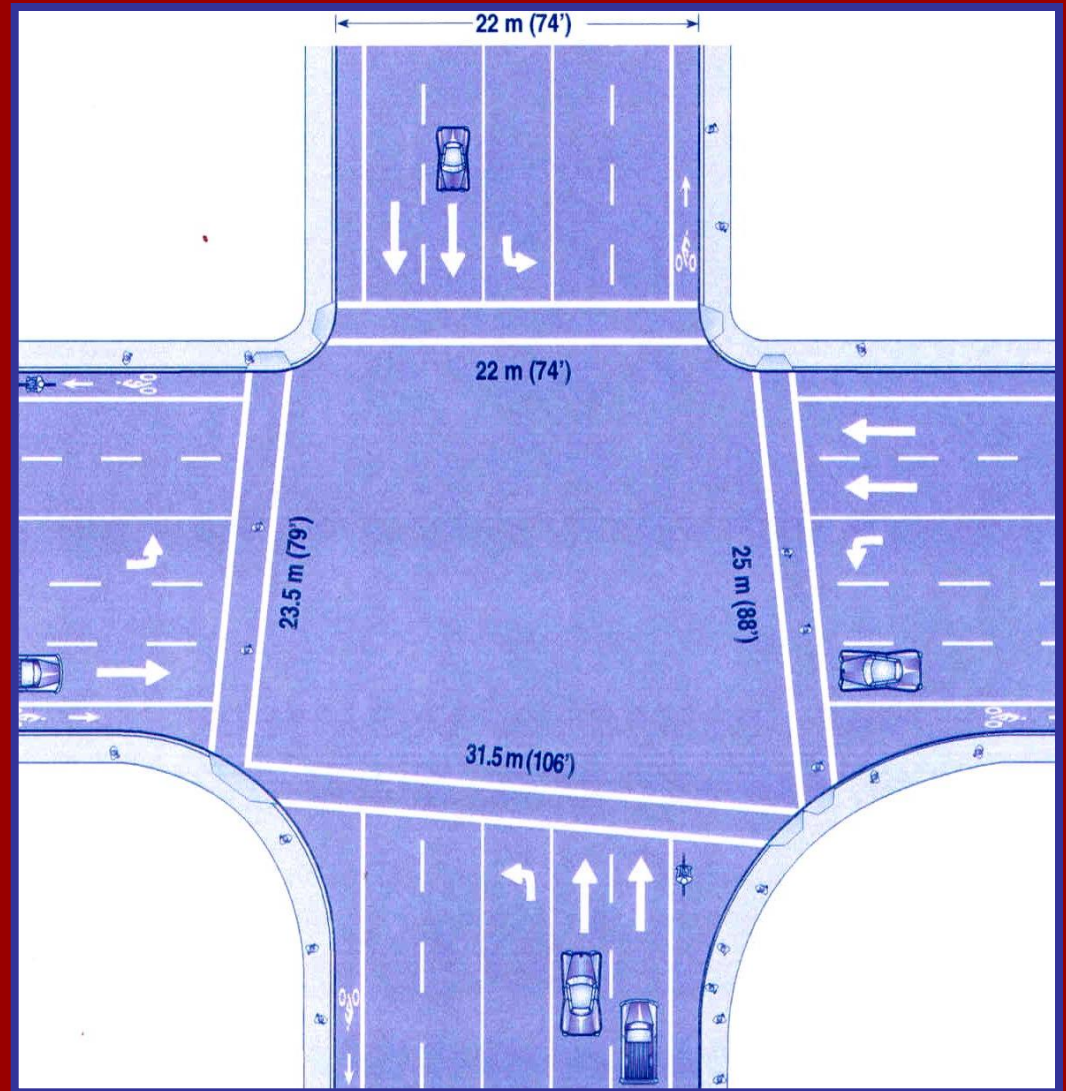
**Effect of large radius on drivers**

**They drive fast,  
ignoring pedestrians**

# Tighten Corner Curb Radii

Intersection  
geometry:

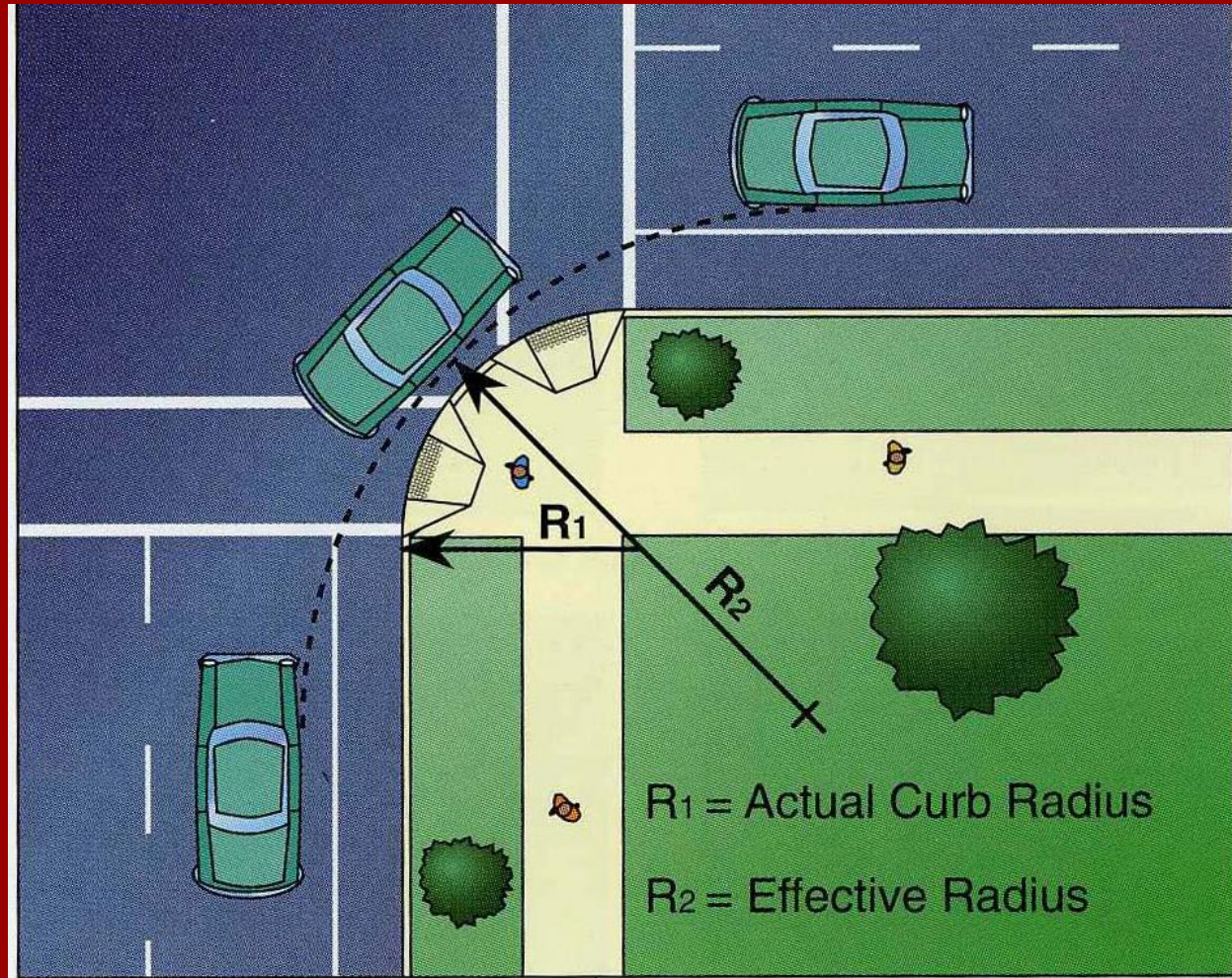
Large radii increase  
crossing distance,  
and affect  
crosswalk & ramp  
placement



# Tighten Corner Curb Radii

Actual curb  
radius (R1)

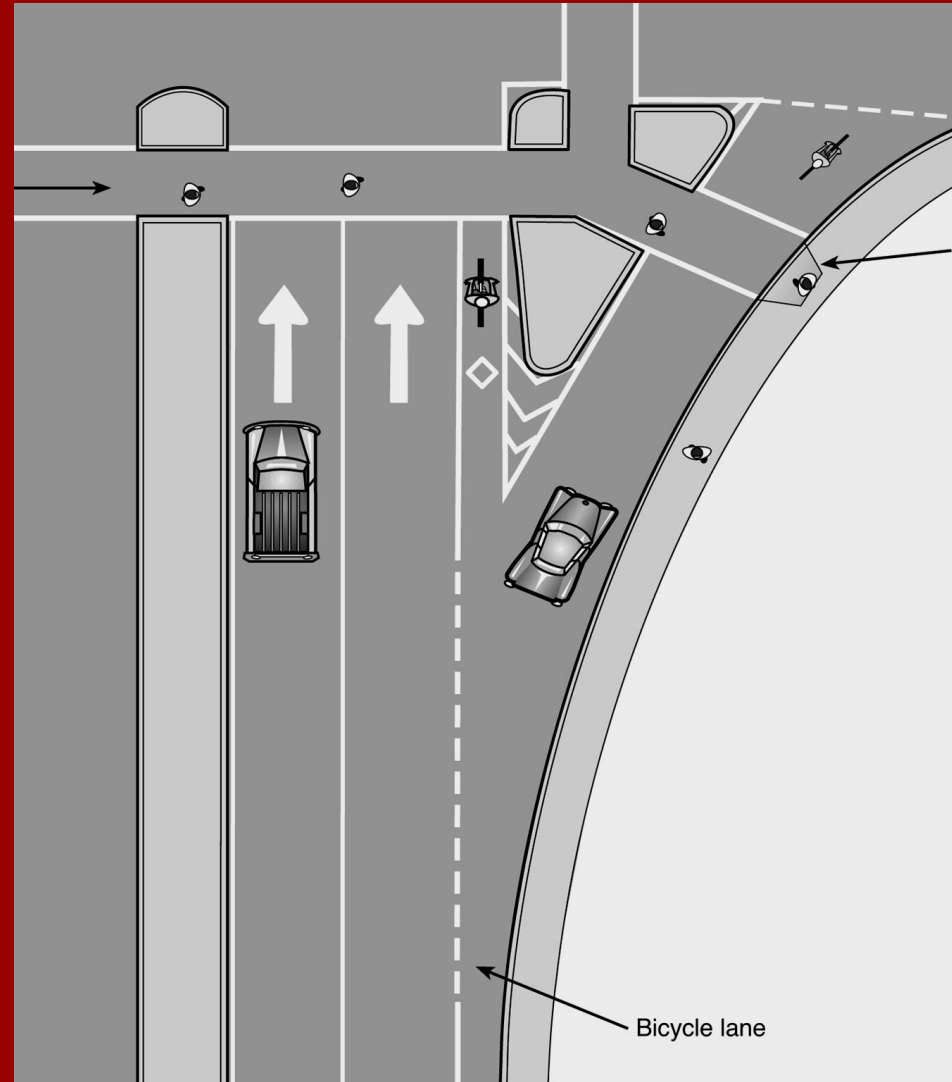
Effective  
radius (R2)



# Corner “Pork Chop” Islands

## Benefits:

- Separate conflicts & decision points
- Reduce crossing distance
- Improve signal timing
- Reduce crashes

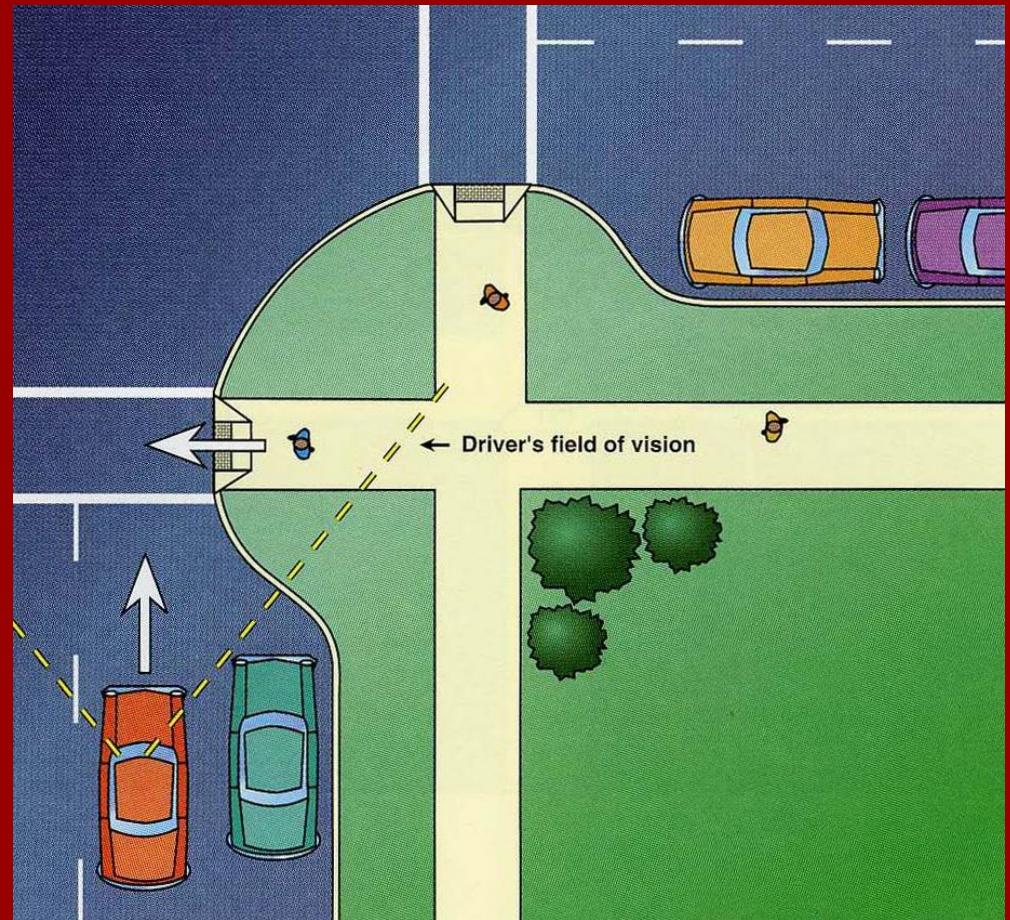


# Wide Street Design Options

- Check to ensure number of through and/or turning lanes are really needed
- Check lane widths to see if narrower lanes are an option
- Check corner radii to see if crossing widths can be reduced
- Where parking exists, use curb bulbs to shorten the crosswalk

# Curb Bulb-outs

- Reduce crossing distance
- Improve sight distance and sight lines
- Prevent encroachment by parked cars
- Create space for curb ramps and landings



# Wide Street Design Options

- Check to ensure number of through and/or turning lanes are really needed
- Check lane widths to see if narrower lanes are an option
- Check corner radii to see if crossing widths can be reduced
- Where parking exists, use curb bulbs to shorten the crosswalk
- Install extended time push button to get more walk time and retain 4.0 ft/sec as default setting



- In this example a high-tech signal was used to help slower pedestrians cross the street with minimal delay to traffic.
- A slower crossing speed would delay traffic significantly



Microwave sensors are aimed at the crosswalks to track peds



Pedestrian clearance  
is timed @ 4 ft/sec



The sensor tracks peds  
as they cross the street

- The controller adds 4 seconds crossing time if pedestrian hasn't finished crossing (8 seconds maximum)
- In this case, the walk phase was prolonged in 20% of crossings, reducing unnecessary traffic delay the other 80% of crossings.

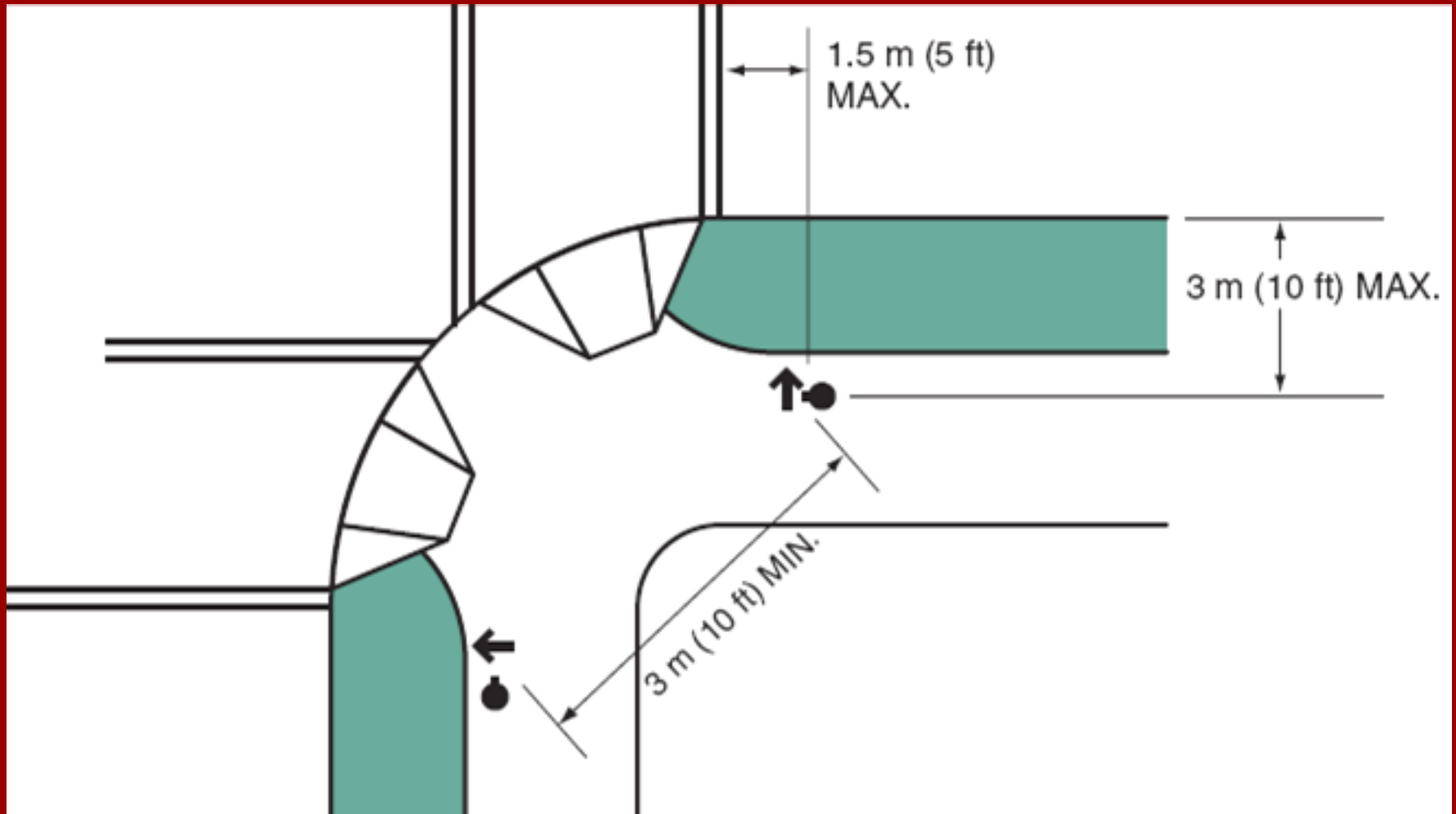


# Wide Street Design Options

**Or, just learn to live with lower  
LOS for peak hour traffic to  
ensure pedestrian safety!**

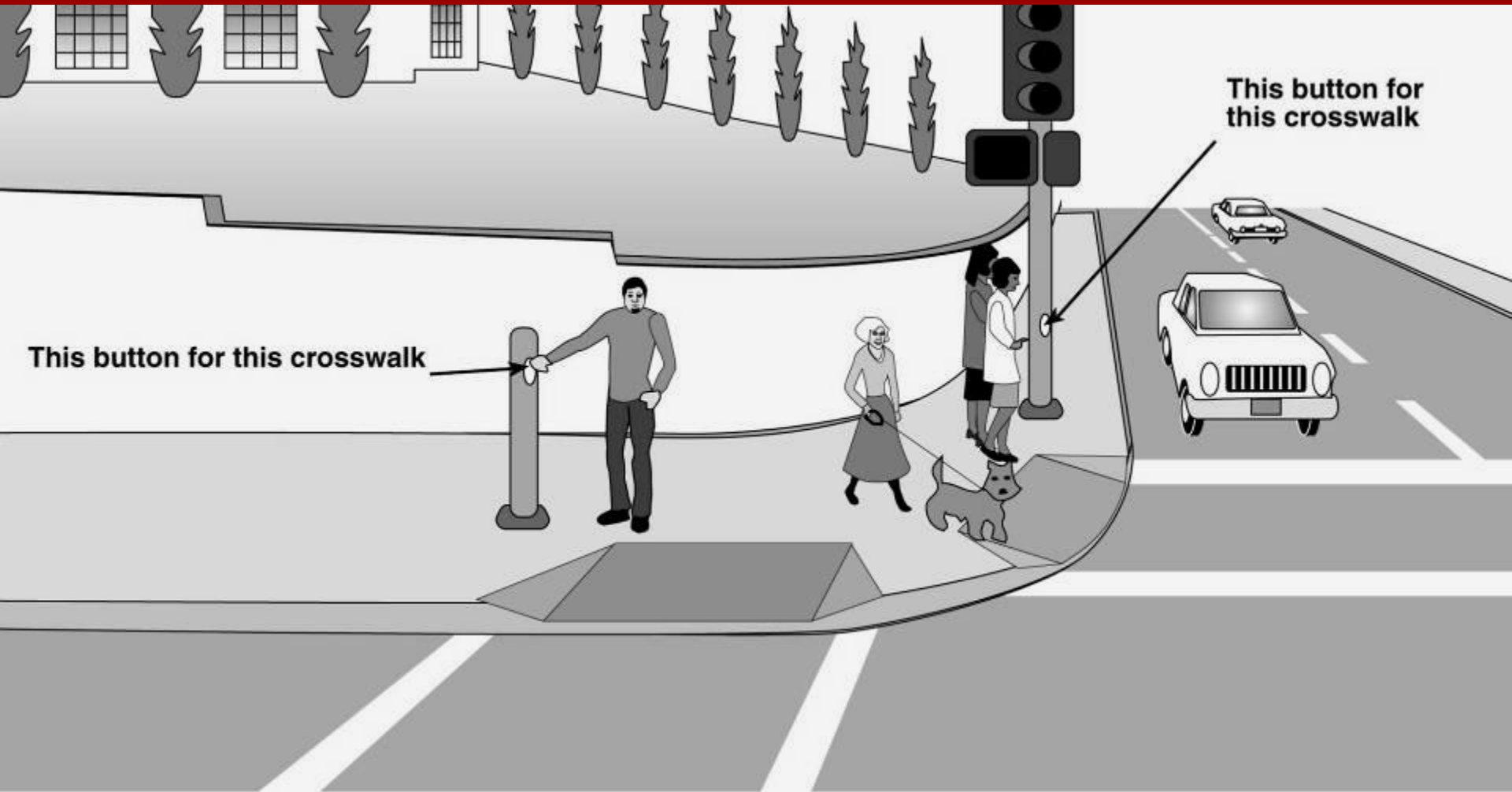
# Placing Push-buttons In Convenient Locations

# Proper Push-button Placement



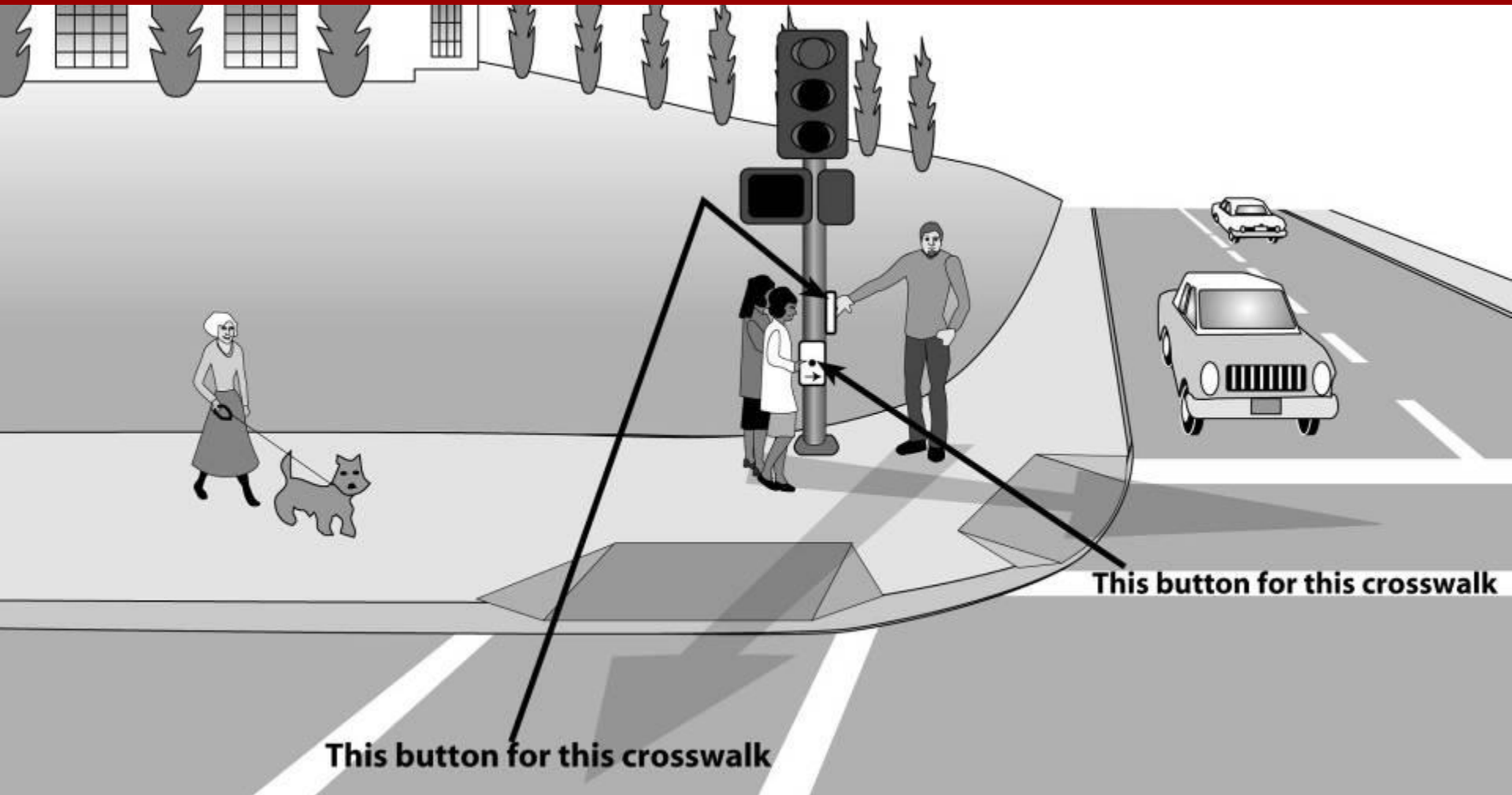
Use MUTCD accessible signal (APS) standard so pedestrians will understand which button to push

# Preferred push-button placement: 2 separate buttons



Always next to landing at top of ramp,  
in line with crosswalk

# Alternate push-button placement: 2 on single pole



Always next to landing at top of ramp,  
in line with crosswalk

# Poor Push-button Placement

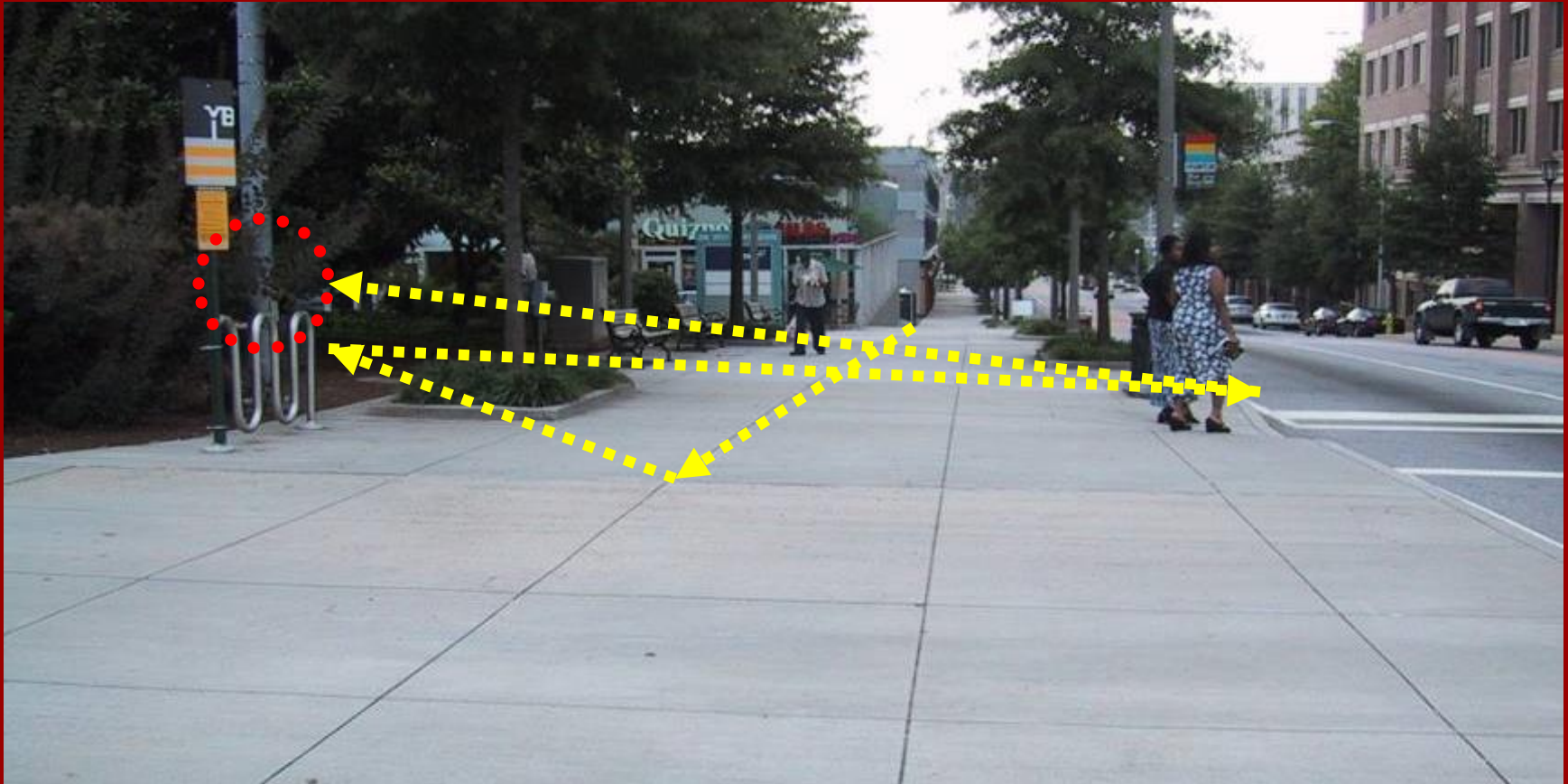


Inconspicuous



Too far from ramp

# Poor Push-button Placement



Find the pushbutton. Now line up to cross.  
Missed your chance? Do it again...

# Poor Push-button Placement



Behind guardrail



Behind vegetation

# Poor Push-button Placement



At back of pole



In front of pole

# Proper Push-button Placement

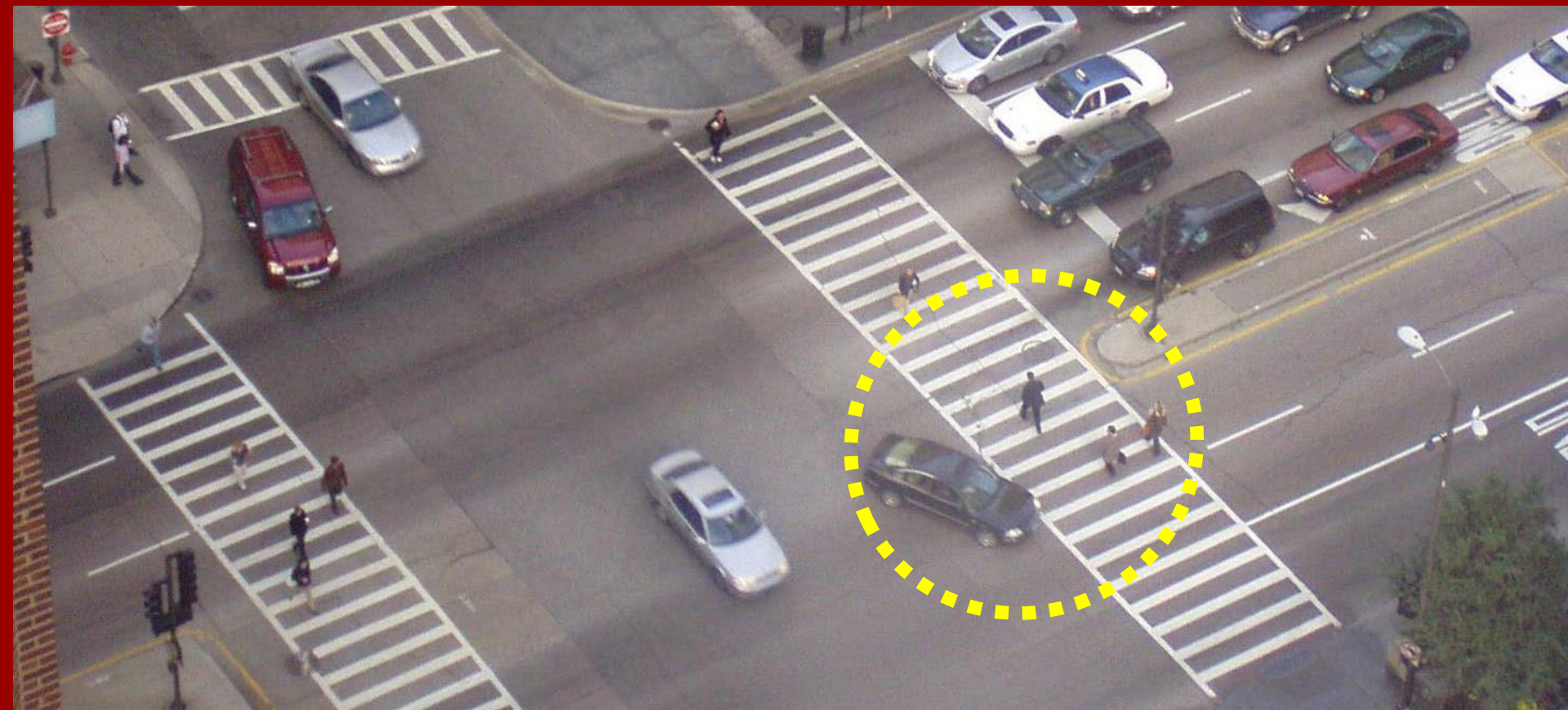


On side of pole



At top of ramp

# Reducing Pedestrian & Left-Turning Vehicle Conflicts



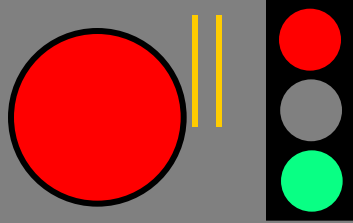
# Protected Vs. Permissive Left Turns



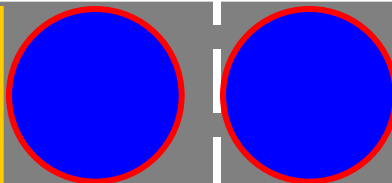
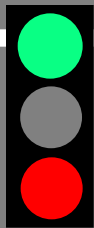
At signals, turning movements account for most of ped crashes; Left/right turn ped crash ratio is roughly 2:1

*\* CRF 70% (all crashes) converting permissive left turns to protected only left turns*

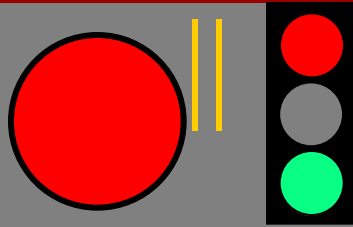
# Permissive Left Turns



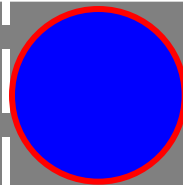
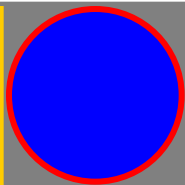
**Pedestrians cross at same  
time as left-turning car;  
Drivers turning left on a green  
ball don't look for pedestrians.**



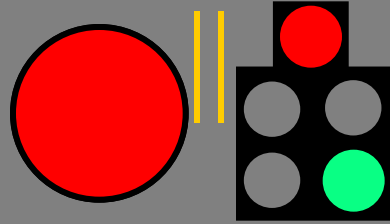
# Protected Left Turns



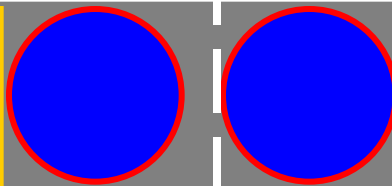
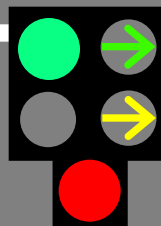
Pedestrians cross after left-turning car, with thru-traffic;  
Pedestrian and car not in conflict



# Protected/permissive Left Turns

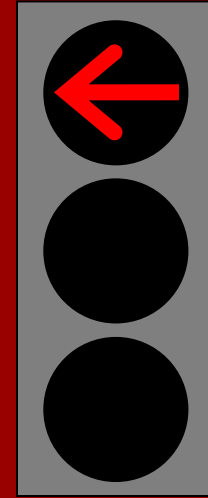


Pedestrians cross after most left-turning cars (protected phase);  
Pedestrian and remaining cars are in conflict (permissive phase)

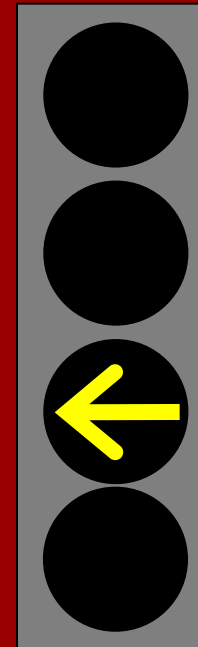


# Protected/permissive Left Turns: Solutions

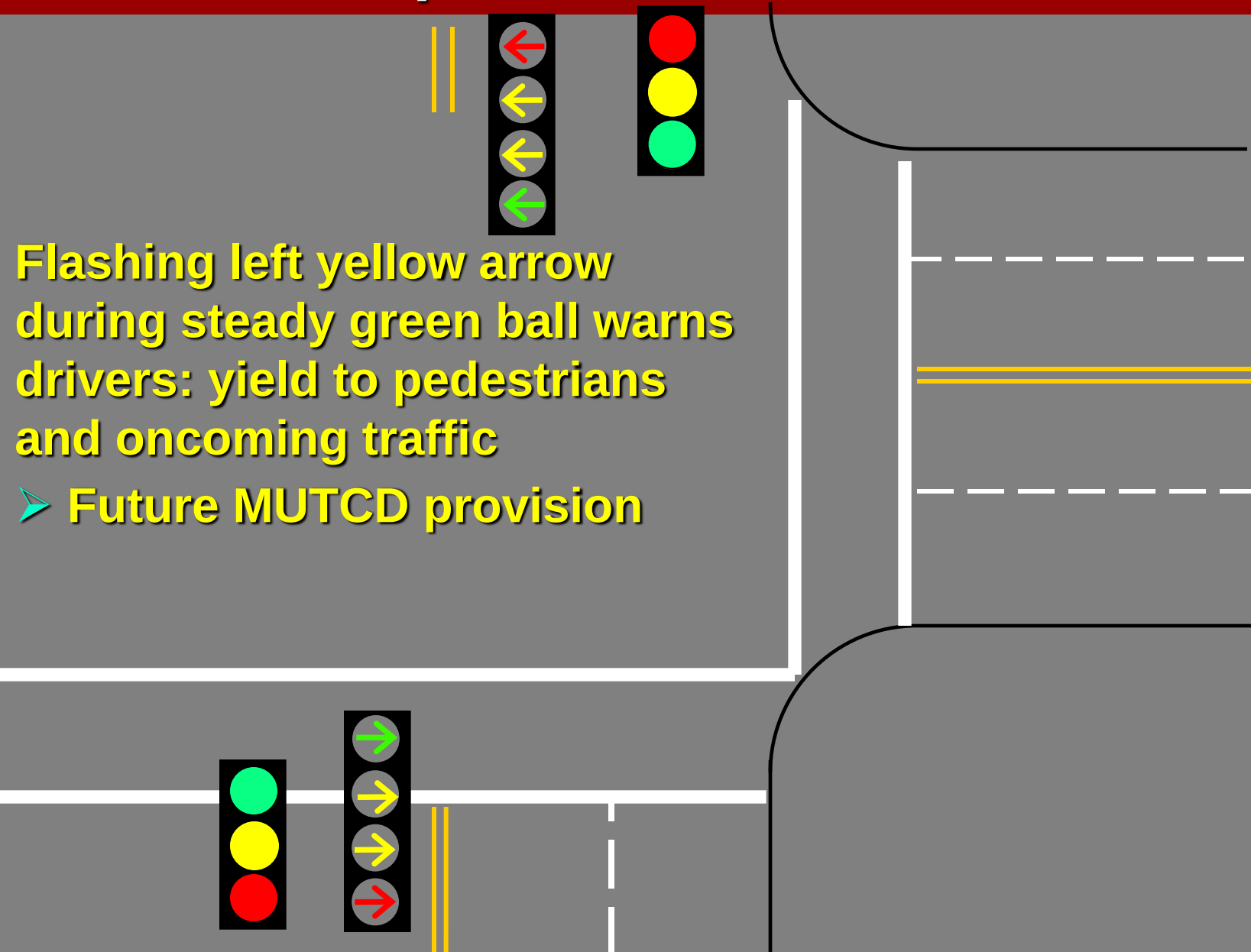
1. Provide protected-permissive phasing by default, but revert to protected-only when pedestrian button is pushed



2. Flashing Yellow Arrow  
(details on the next slide)



# Protected/permissive Left Turns: Solution



# Signal Timing To Minimize Pedestrian Delay & Conflicts



# Use Short Signal Cycle Length

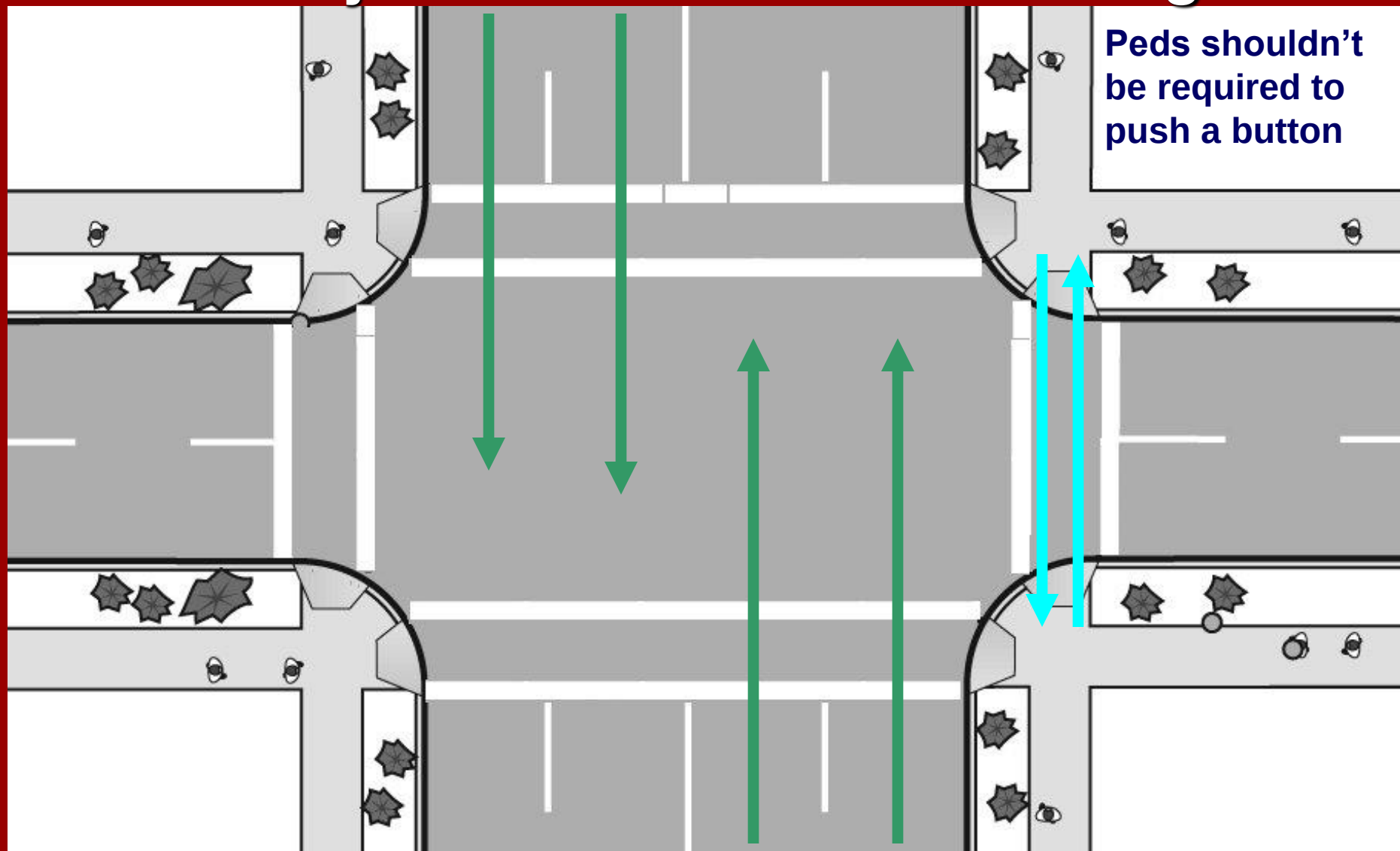


Long wait causes stacking: pedestrians wait in street, or don't wait and cross against the signal



At high-use crosswalks,  
pedestrians should get a signal at every cycle

# Set pedestrians to recall to WALK when major street is set to recall to green



# LPI

**LPI = Lead Pedestrian Interval**

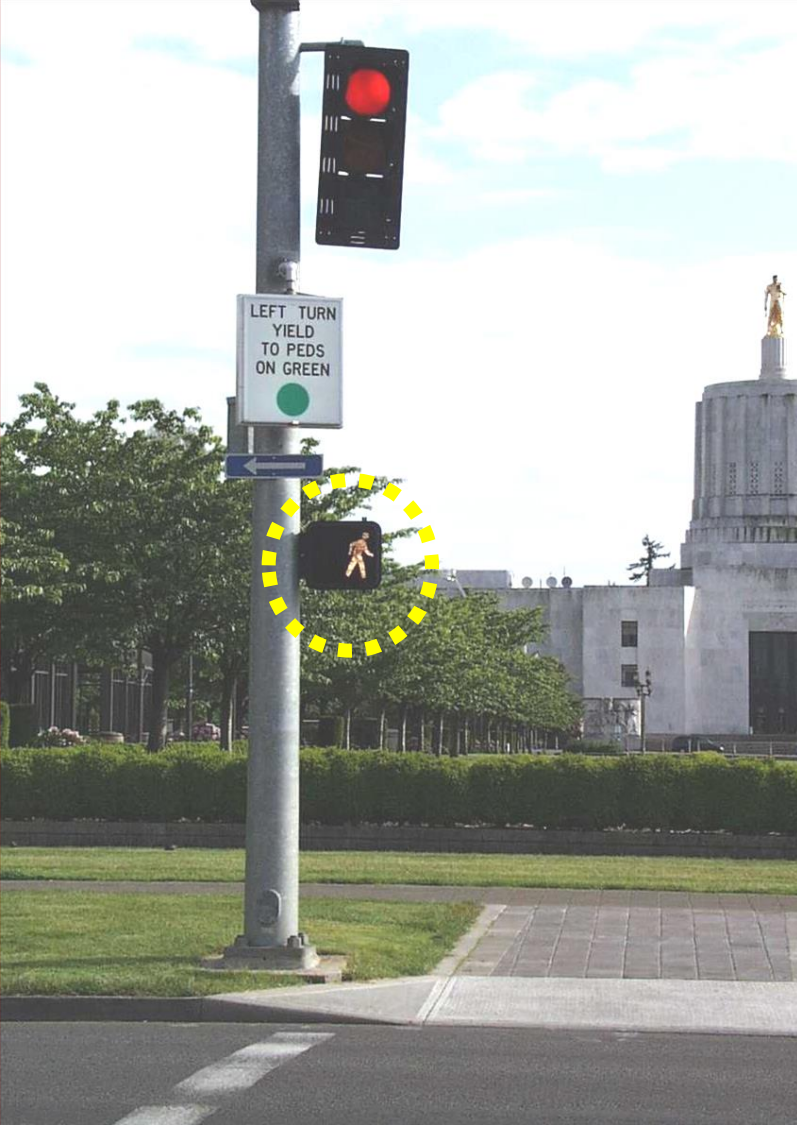
***LPI gives pedestrians a head start***

**Looks like a regular signal to  
drivers**



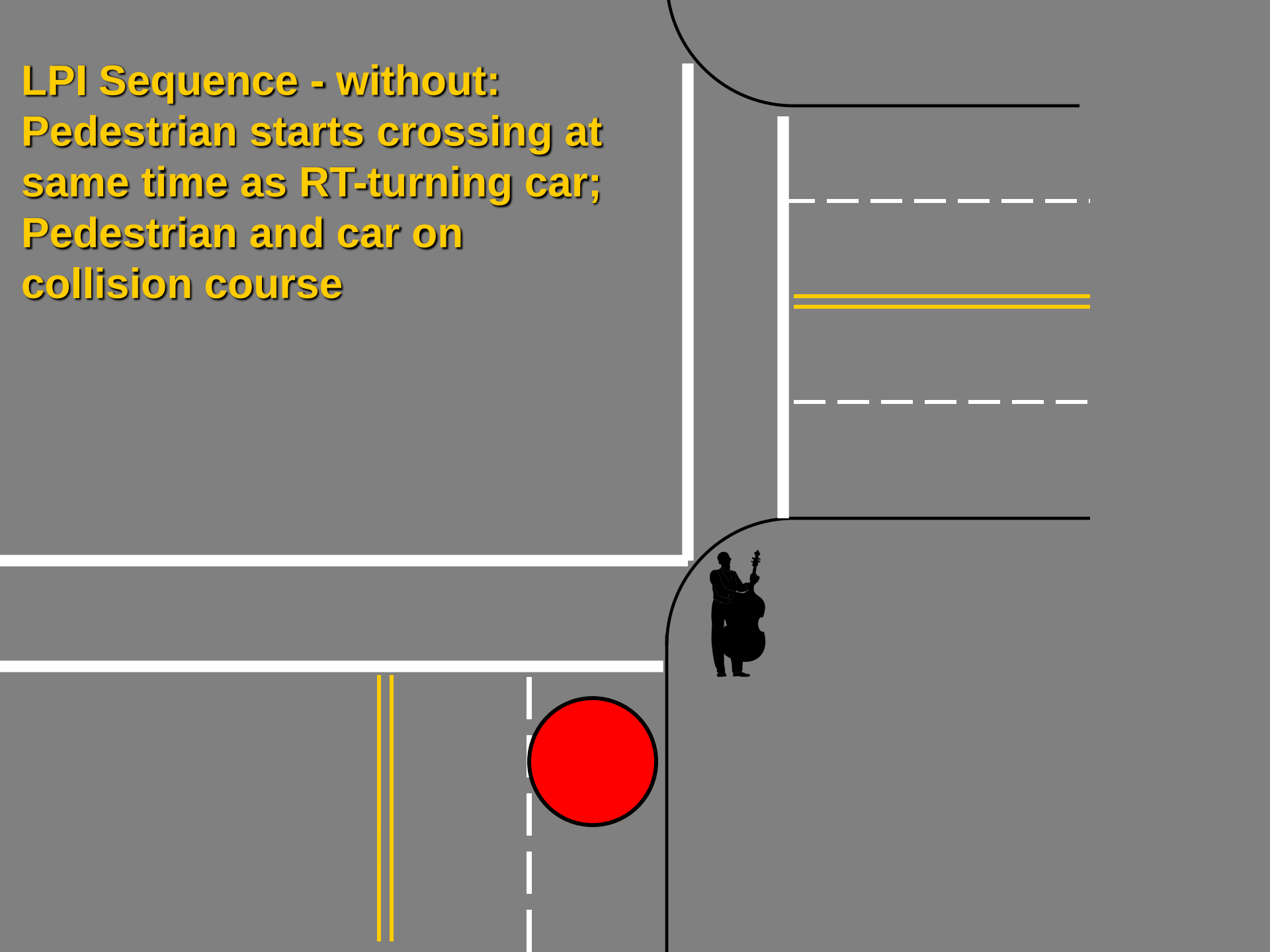
Looks like a regular signal to drivers: *green-yellow-red*



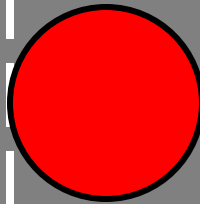


*LPI : WALK comes on 2 to 5 seconds prior to the vehicular green; pedestrians enter crosswalk before turning vehicles arrive there.*

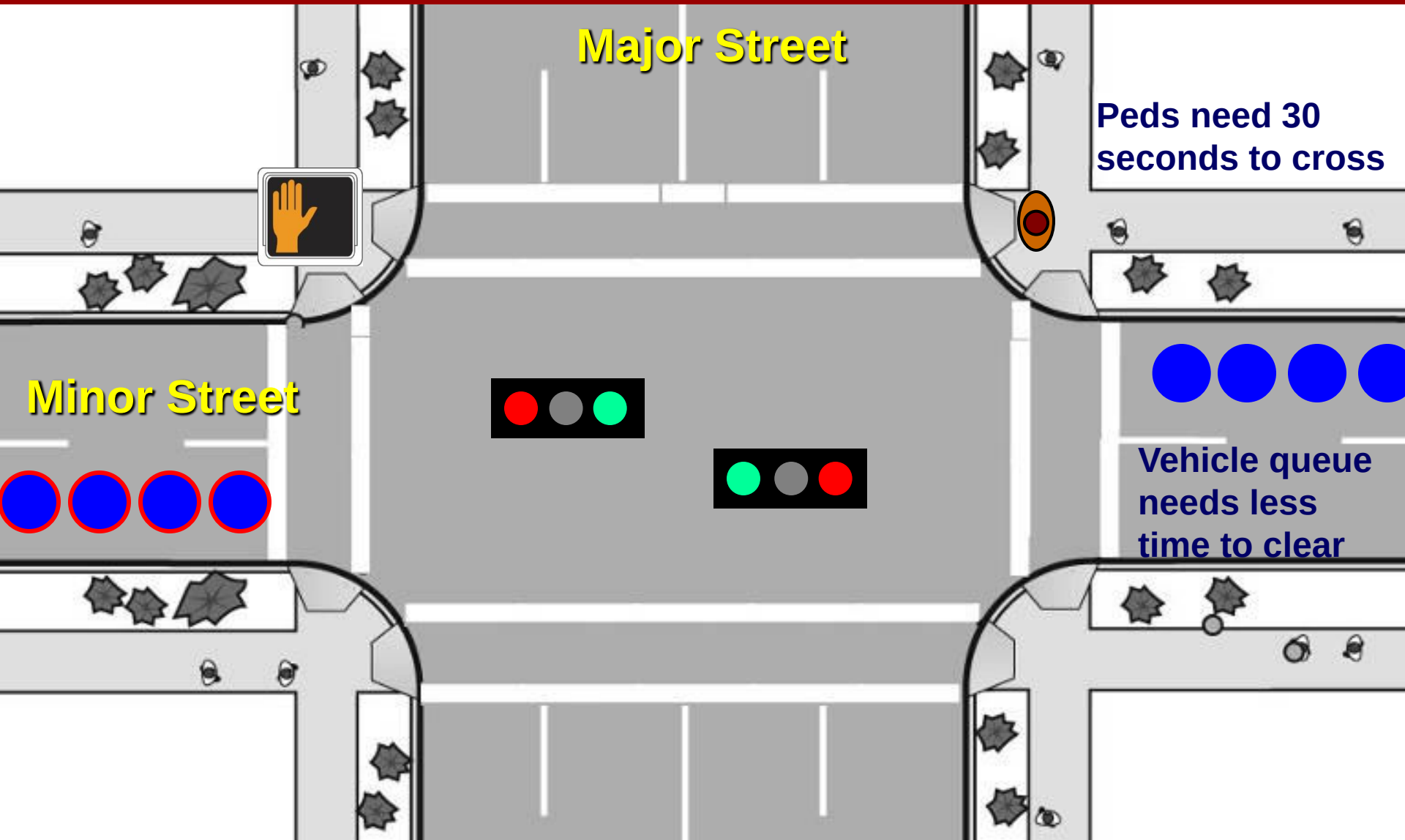
**LPI Sequence - without:  
Pedestrian starts crossing at  
same time as RT-turning car;  
Pedestrian and car on  
collision course**



**LPI Sequence - with:**  
**Pedestrian starts crossing**  
**before RT-turning car;**  
**Pedestrian gets head start**  
**and driver sees ped before**  
**entering crosswalk**



# Where do the extra 3-5 seconds come from?





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

**CRF: 5%**

# **Simple & Innovative Ideas To Minimize Pedestrian Conflicts**

# Signs: Remind Turning Drivers to Yield to Peds



Revised R10-15 in  
draft 2009 MUTCD

Local variations, using  
MUTCD-approved lettering  
and symbols:



New York



Alaska

# Restricting Right Turns on Red:

1. At all times



# Restricting Right Turns on Red:

1. At all times
  2. When pedestrians are present
- Difficult to enforce*



# Restricting Right Turns on Red:

1. At all times  
*Difficult to enforce*
3. By time of day  
*Limits most RTOR*



# Restricting Right Turns on Red:

1. At all times
2. When pedestrians are present

*Difficult to enforce*

3. By time of day

*Limits most RTOR*

4. When ped pushes button or as set by controller



Note: An on-demand NTOR sign can be used to improve the effectiveness of a Lead Pedestrian Interval

# Pedestrian Scramble (Barnes Dance)



Popular because all traffic stops and pedestrians can cross in any direction (*must ban turns on red*)



Pedestrians pay a price in delay:  
Pedestrians wait for traffic in one direction



Pedestrians wait for traffic in other direction



**Pedestrian scramble increases safety  
(CRF 34%)  
but decreases efficiency of intersection  
Use where there are high ped volumes  
and many turning vehicles**

**Reward: Pedestrians can cross in any direction**

# HAWK Pedestrian Hybrid Signal



HAWK (High Intensity Activated Crosswalk)

Drivers see  
Beacon



Peds see  
Pedhead





At rest, blank



Flashing then steady yellow



Steady red



Wig-wag red

# HAWK Pedestrian Hybrid Signal



**1**

**Blank for  
drivers**



**4**

**Steady  
red**



**2**

**Flashing  
yellow**



**5**

**Wig-Wag**



**3**

**Steady  
yellow**



**Return  
to 1**



## HAWK Sequence

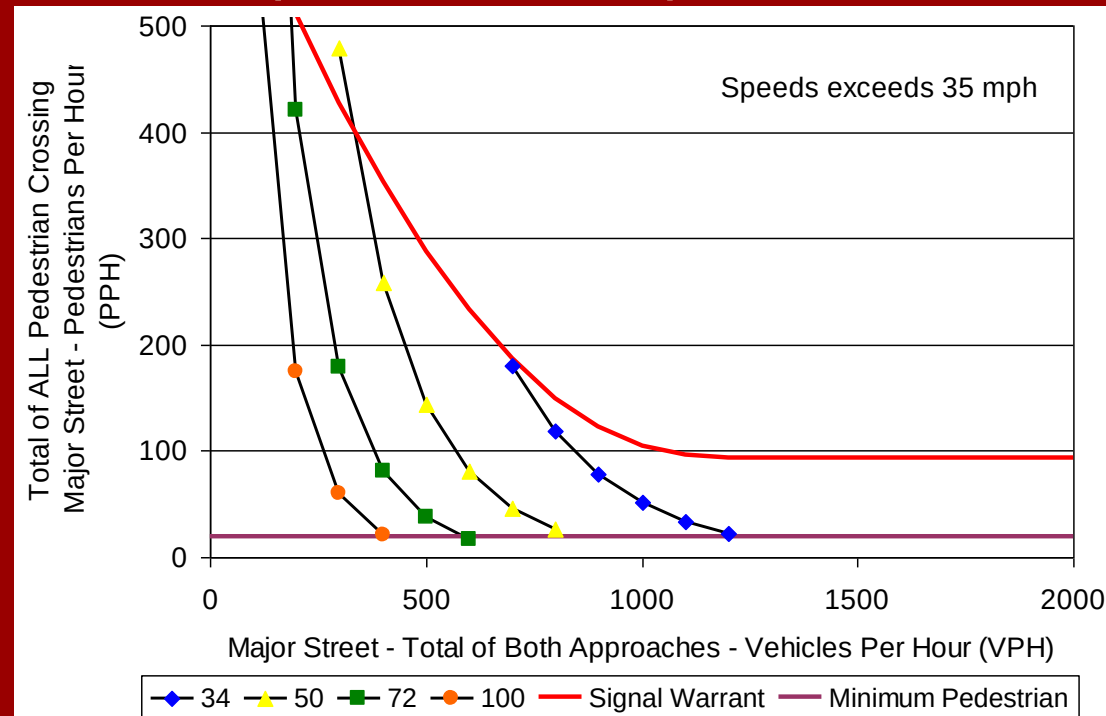
# HAWK Pedestrian Hybrid Signal

Hawk  
effectiveness

| Crossing Treatment                               | TCRP D-08/NCHRP 3-71 Study              |           |             |                                                     |           |             |
|--------------------------------------------------|-----------------------------------------|-----------|-------------|-----------------------------------------------------|-----------|-------------|
|                                                  | Compliance – Staged Pedestrian Crossing |           |             | Compliance – General Population Pedestrian Crossing |           |             |
|                                                  | # of Sites                              | Range (%) | Average (%) | # of Sites                                          | Range (%) | Average (%) |
| <b>Red Signal or Beacon</b>                      |                                         |           |             |                                                     |           |             |
| Midblock Signal                                  | 2                                       | 97 to 100 | 99%         | 4                                                   | 91 to 98  | 95%         |
| Half Signal                                      | 6                                       | 94 to 100 | 97%         | 6                                                   | 96 to 100 | 98%         |
| <b>HAWK Signal Beacon</b>                        | 5                                       | 94 to 100 | <b>97%</b>  | 5                                                   | 98 to 100 | <b>99%</b>  |
| <b>Active When Present</b>                       |                                         |           |             |                                                     |           |             |
| In-Roadway Warning Lights                        | NA                                      | NA        | NA          | NA                                                  | NA        | NA          |
| Overhead Flashing Beacon (Pushbutton Activation) | 3                                       | 29 to 73  | 47%         | 4                                                   | 38 to 62  | 49%         |
| Overhead Flashing Beacon (Passive Activation)    | 3                                       | 25 to 43  | 31%         | 3                                                   | 61 to 73  | 67%         |

# Pedestrian Hybrid Signals Can Significantly Improve Accessibility for Blind Pedestrians

- Pedestrians with visual impairments have difficulty crossing at unsignalized locations
- Normal pedestrian signal warrants are hard to meet (red line is 2009 MUTCD warrant for – minimum 93 peds/hr)
- Hybrid Signal allows much lower ped volumes (varies on street width but minimum 20 peds/hr)
- Minimum values are for high vehicle volumes



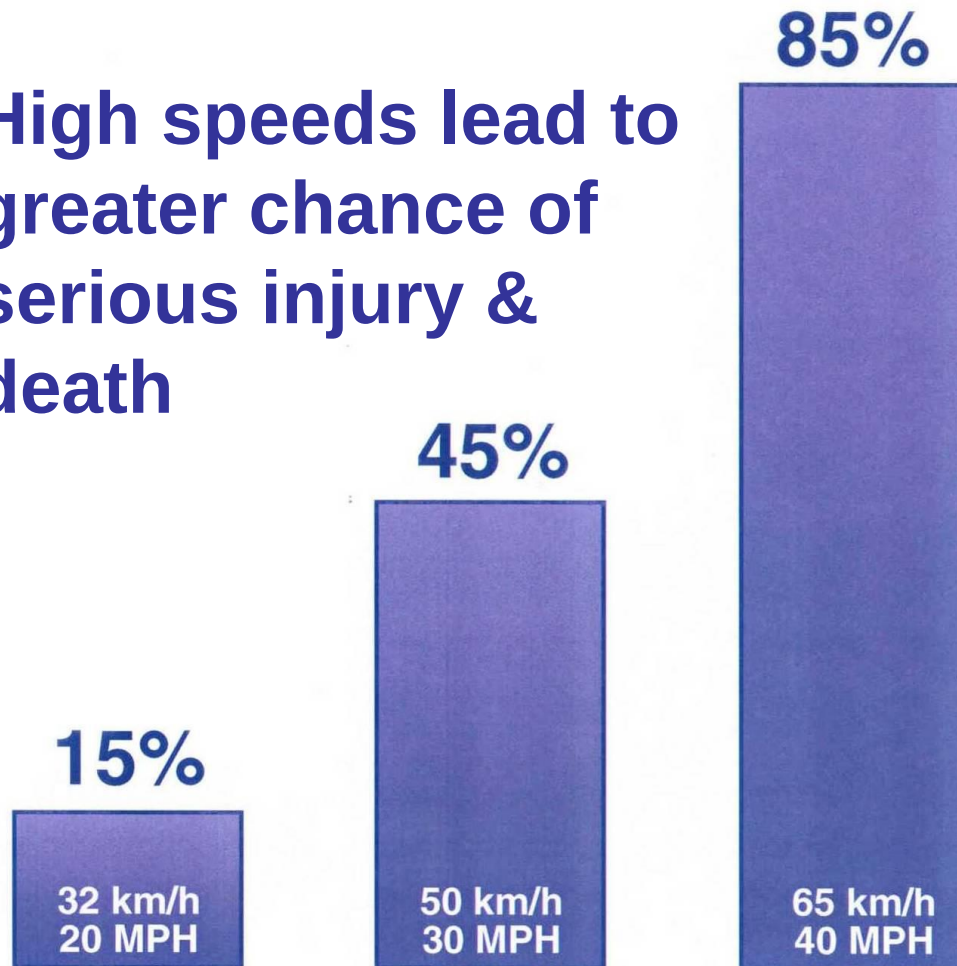
# HAWK Pedestrian Hybrid Signal

- A new Chapter added to describe the application, design, and operation of pedestrian hybrid signals.
- Vehicular signal rests in blank
- Ped signal rests in Don't Walk (except when used with roundabouts where they can rest in blank)

# Using Traffic Signals to Control Speeds

# Speed Matters

High speeds lead to  
greater chance of  
serious injury &  
death



**Pedestrians' chances of death if hit by a motor vehicle**

SOURCE: *Killing Speed and Saving Lives*, UK Department of Transportation

# Child dart-out: speed is a factor!



150'

# First scenario: Speed 25 MPH

100' = distance covered in 2.5 sec. perception/reaction time

Driver applies brakes



100'

150'



# First scenario: Speed 25 MPH

Driver applies  
brakes

50' stopping distance  
(wet pavement)



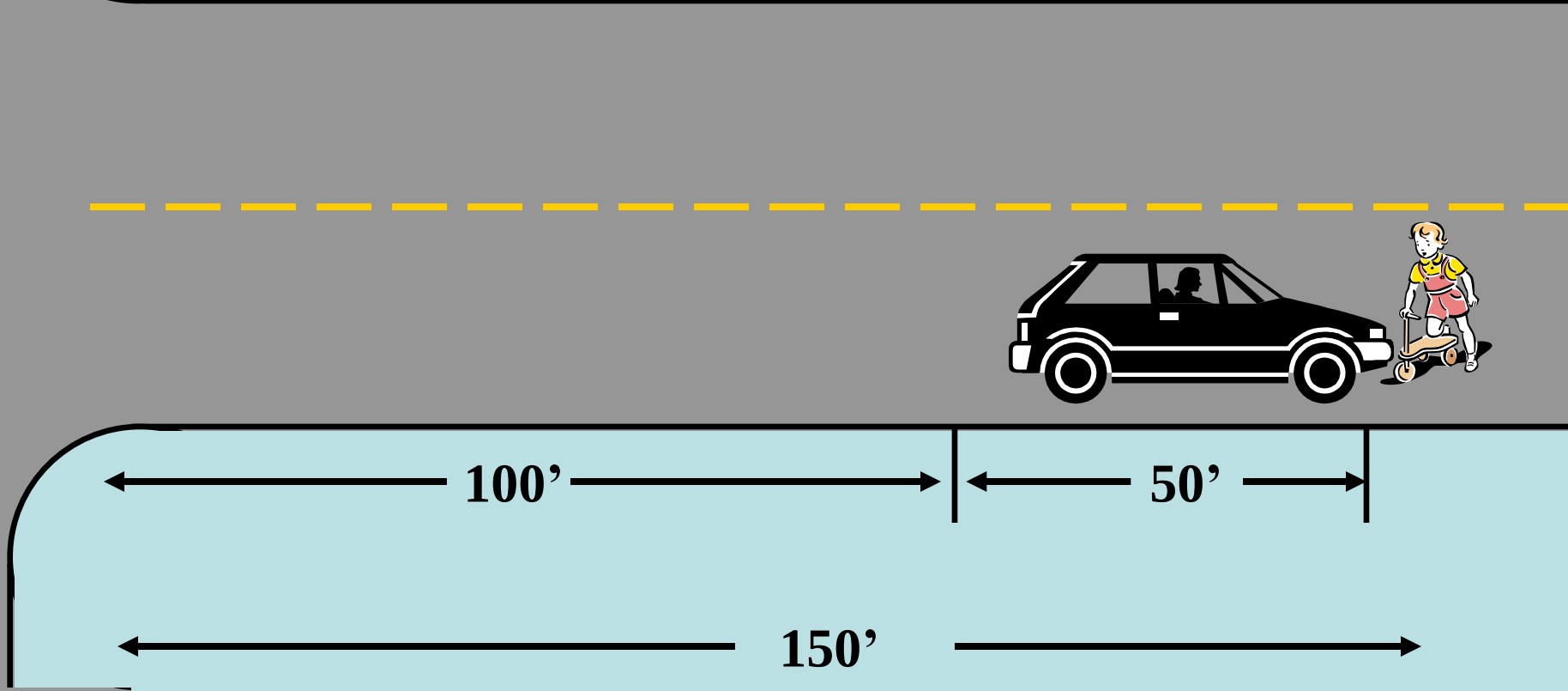
100'

50'

150'

# First scenario: Speed 25 MPH

**Result: Nothing happens beyond  
one scared child, driver & parent!**



# Second scenario: Speed 38 MPH

140' = distance covered in 2.5 sec. perception/reaction time

Driver applies brakes



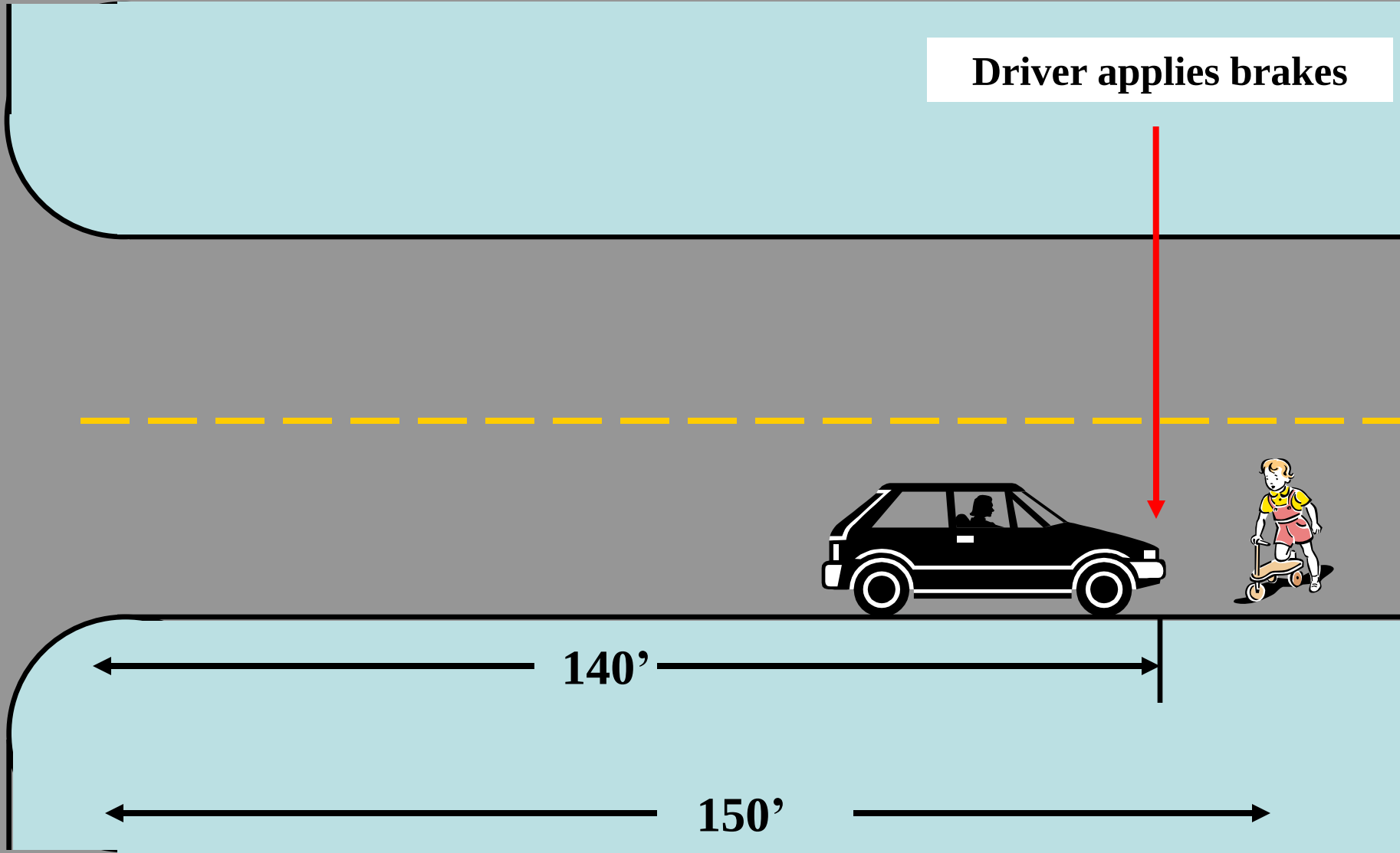
140'

150'



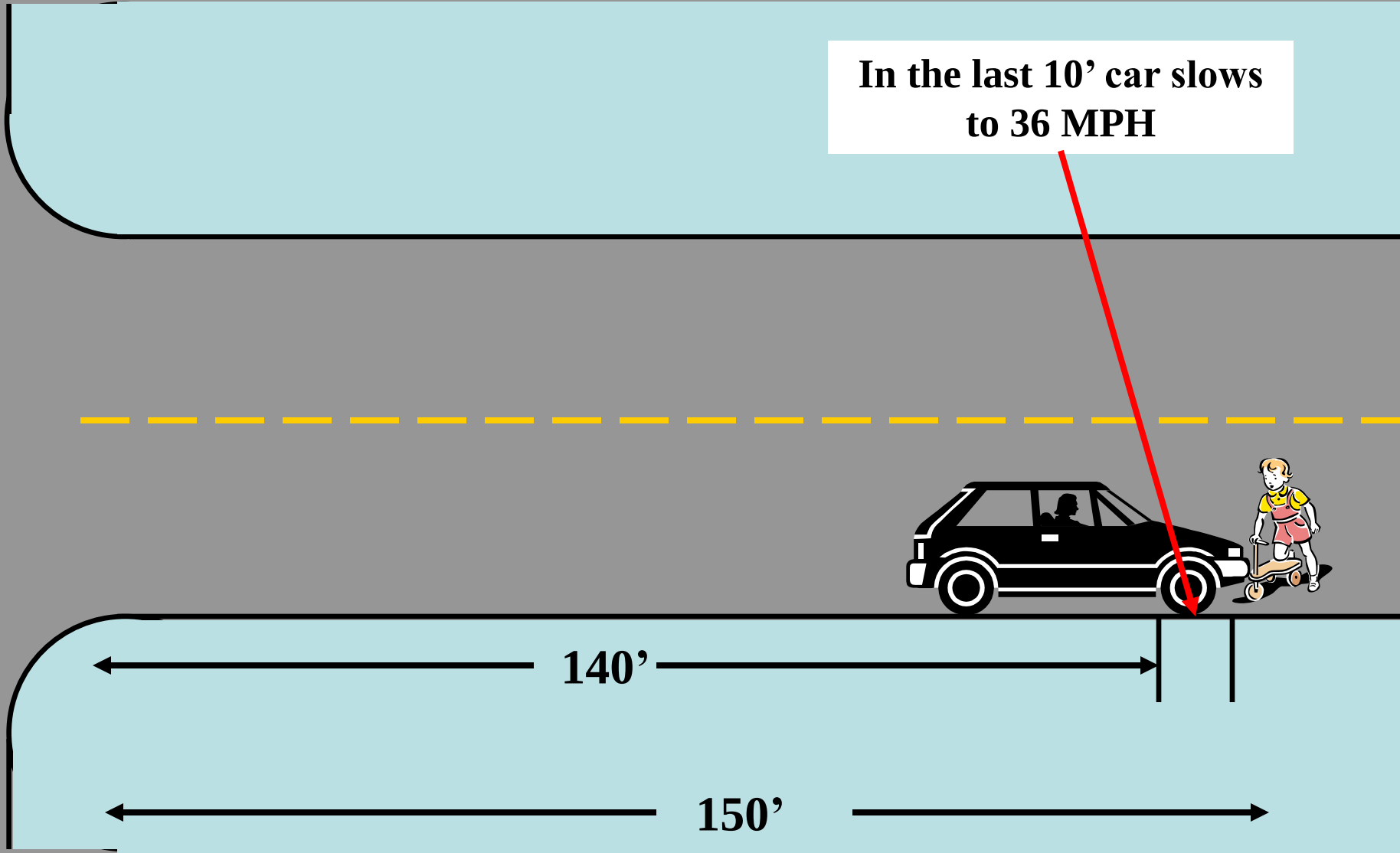
# Second scenario: Speed 38 MPH

Driver applies brakes



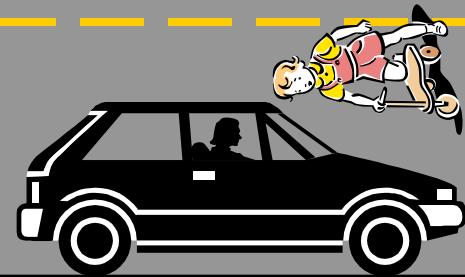
# Second scenario: Speed 38 MPH

In the last 10' car slows  
to 36 MPH



## Second scenario: Speed 38 MPH

**Result: a high speed crash**

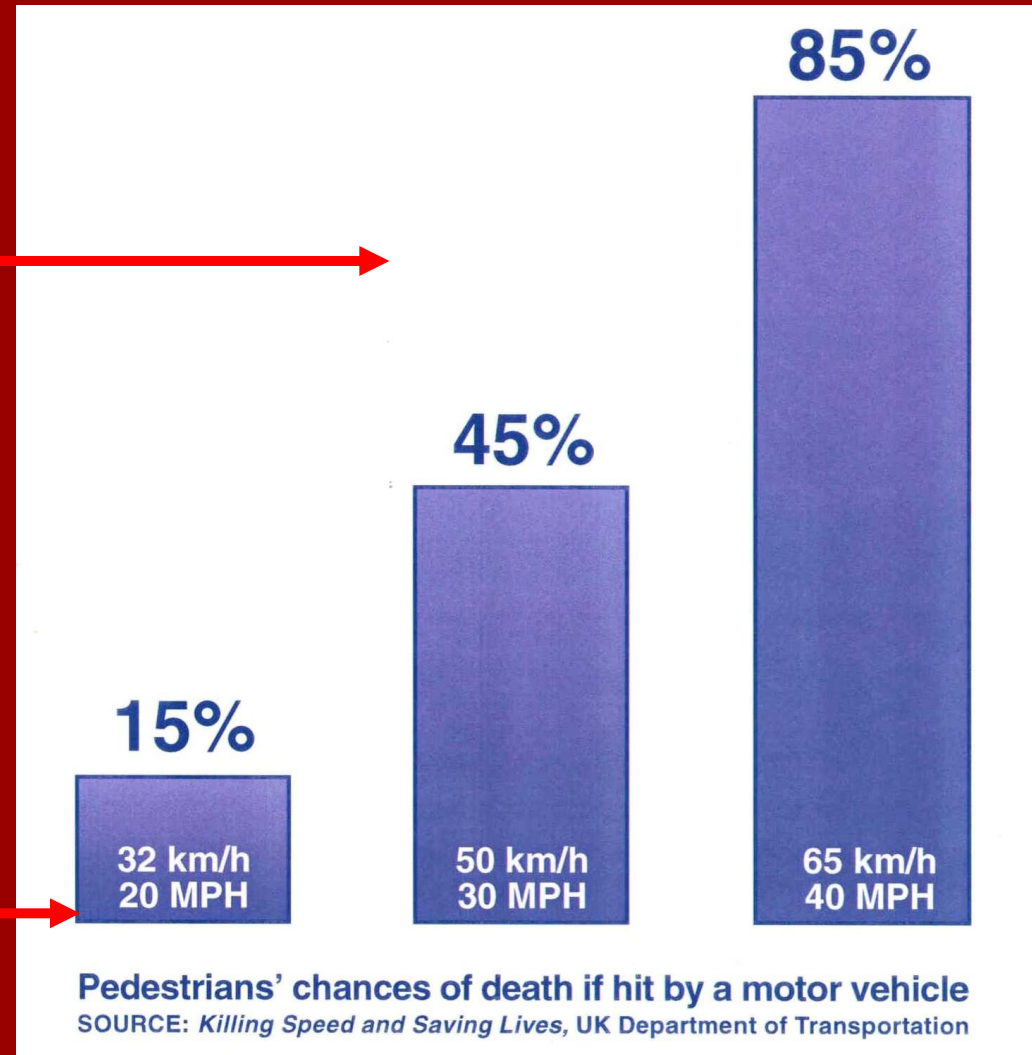


150'

# Where do these two scenarios lie on the pedestrian fatality risk scale?

Second scenario:  
Crash speed 36 MPH

First scenario:  
no crash



# Defining Mobility



- Typical experience:
  - 45 mph speed
  - 2 min wait at signal



# Defining Mobility

- Viable alternative:
  - 2-way progression set for 30 mph



# Benefit/Cost Analysis

- Reducing speed from 45 mph to 30 mph
  - For a 5-mile trip, a 3.33-minute delay
  - Assume 30,000 ADT and \$20/hr driver cost
  - \$12.5 million in loss to economy, right?
- **Wrong!**
  - Delay for each person is still under 4 minutes
  - Less time than their daily stop for Starbucks
- Community benefit
  - Slower operating speeds
  - Safer and more comfortable ped crossings



# QUESTIONS?