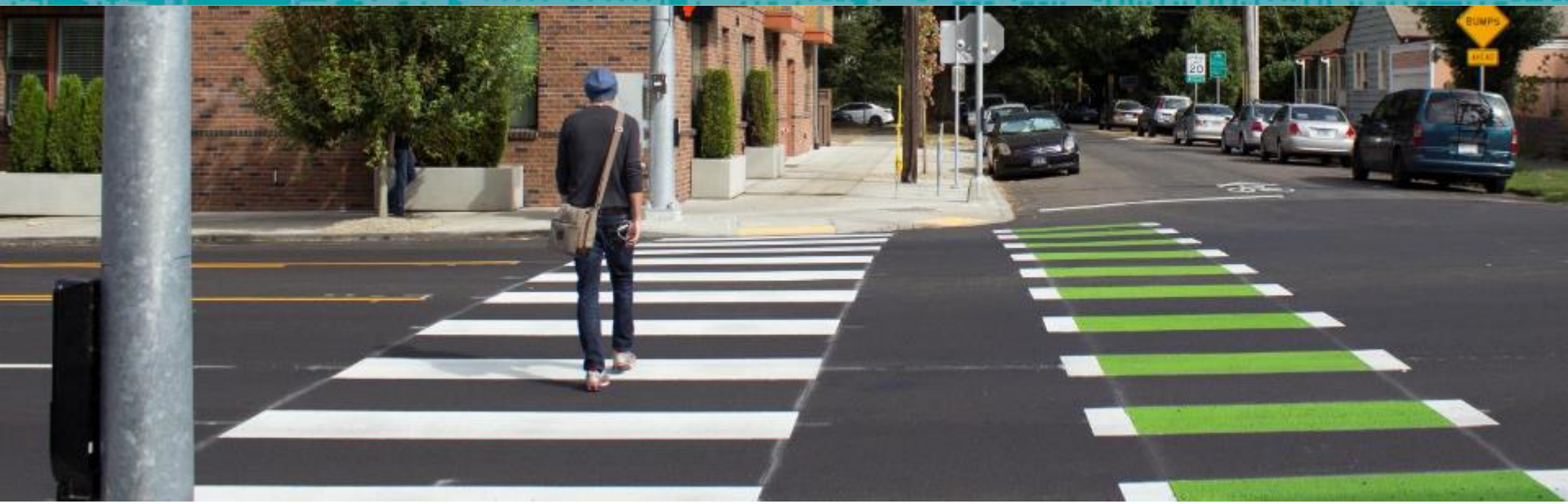
Changing Traffic Signals for Safer Crossings



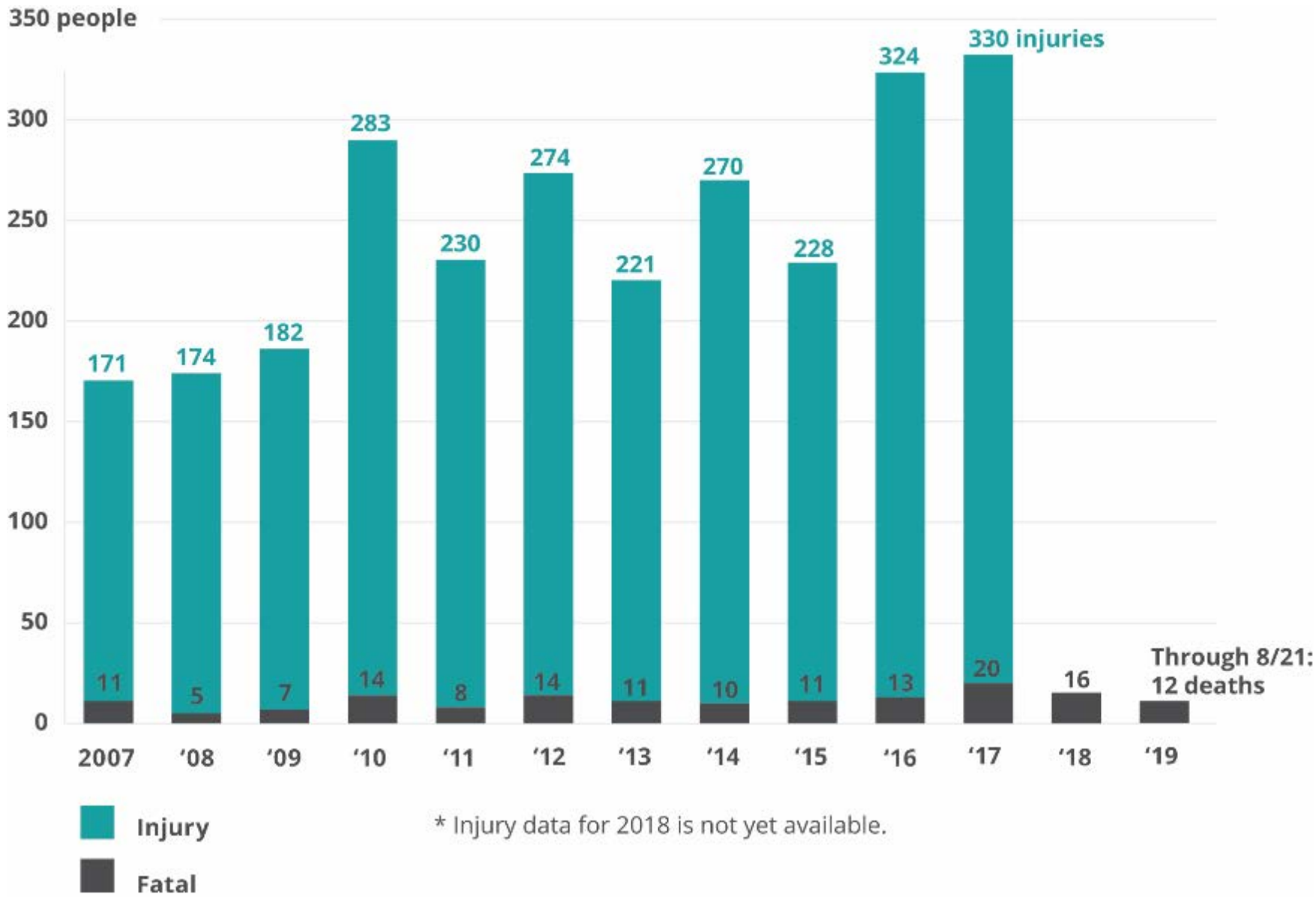
APBP Conference, Portland OR

August 27, 2019

PBOT
PORTLAND BUREAU OF TRANSPORTATION

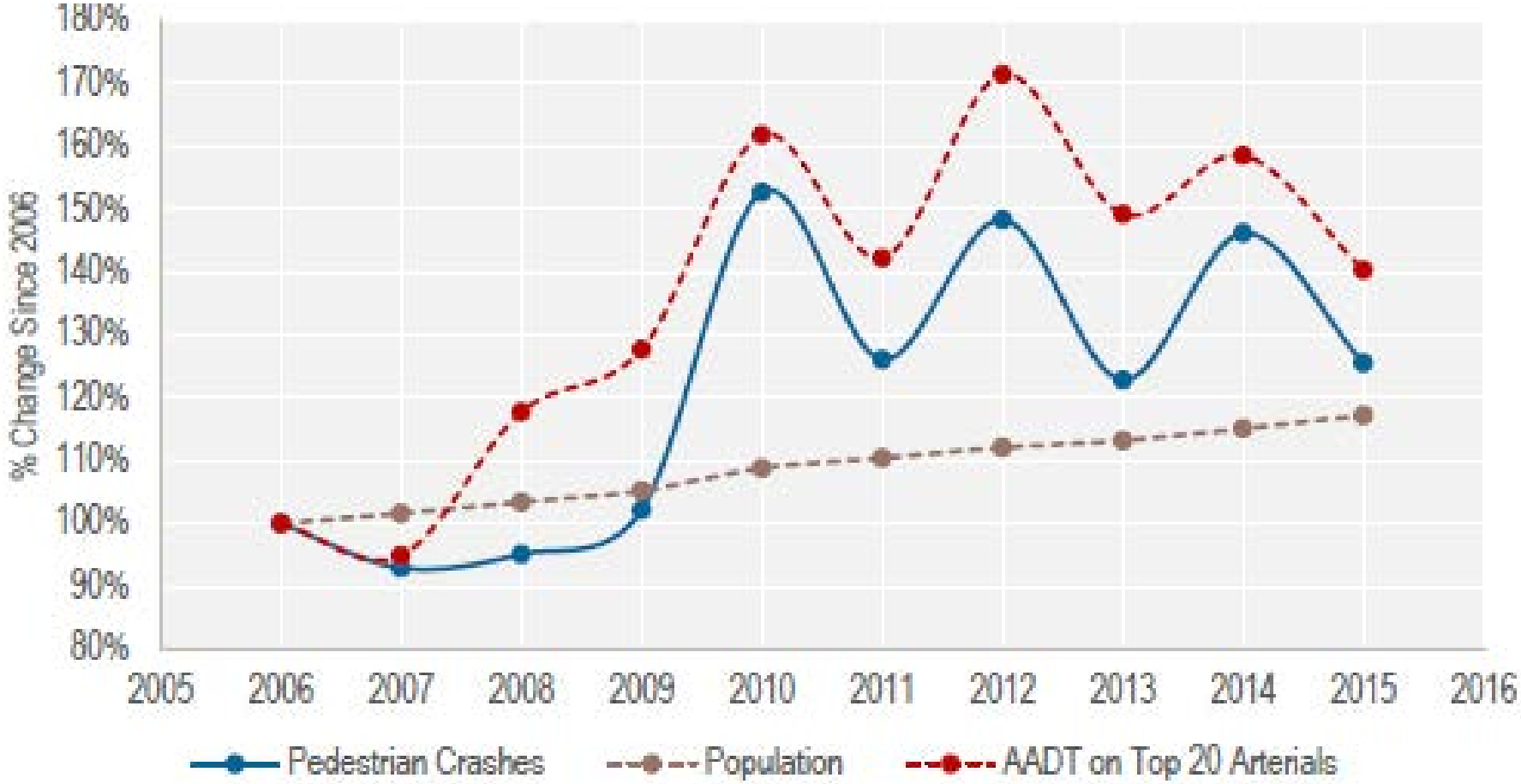
PedPDX is Portland's Citywide Pedestrian Plan. It prioritizes sidewalk and crossing improvements and other investments to make walking safer and more comfortable across the city. The plan identifies the key strategies and tools we will use to make Portland a great walking city for everyone.

PedPDX citywide pedestrian crash analysis



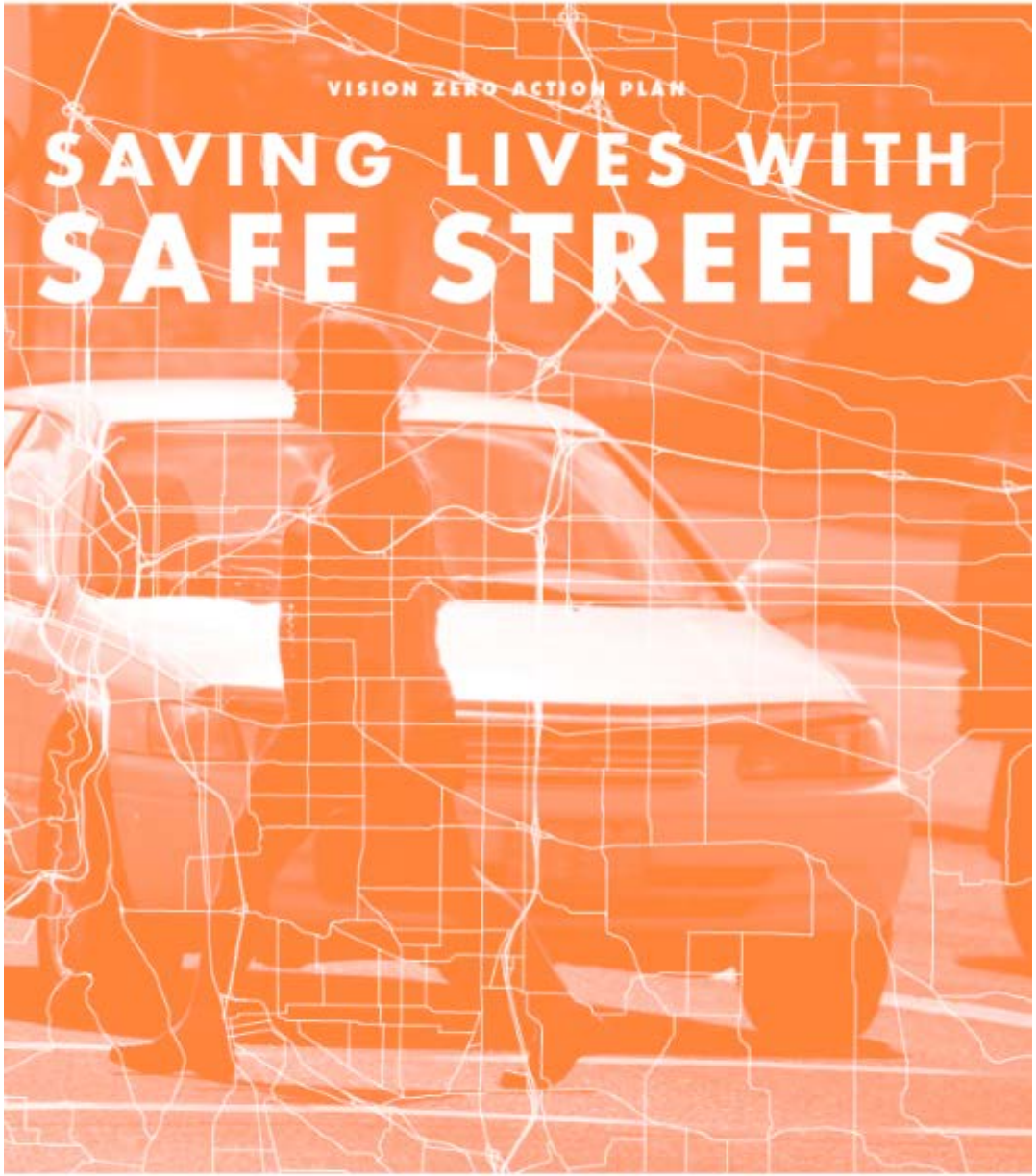
* Injury data for 2018 is not yet available.

Annual Pedestrian Crash Growth Relative to Pop and AADT Growth



THE CITY OF PORTLAND

DECEMBER 2016



VISION ZERO ACTION PLAN

SAVING LIVES WITH SAFE STREETS

VISION ZERO

STRATEGY

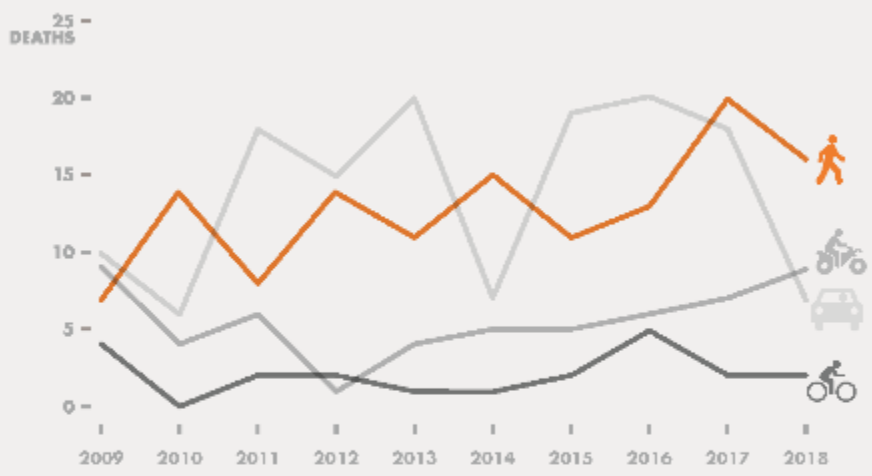
PROTECT PEDESTRIANS

Out of 34 traffic deaths in 2018, 16 were people walking. This reflects a continuing trend: during the past five years, on average 39% of traffic deaths have been pedestrians.

What the data tells us about pedestrian crashes

- 71% of all pedestrian crashes occur at intersections, with 44% at signalized intersections.
- 20% of pedestrian crashes result from left-turning drivers failing to yield to pedestrians in the crosswalk at signalized intersections.

PORTLAND TRAFFIC DEATHS
2009–2018
Source: PBOT



Where are crashes happening?

Table 3: Pedestrian Crash Location Type Summary (2006-2015)

LOCATION TYPE	NUMBER OF CRASHES	PERCENT OF CRASHES	NUMBER OF KSI* CRASHES	PERCENT OF KSI* CRASHES	PROBABILITY OF A KSI* CRASH
Signalized Intersections	971	43.5%	97	33.4%	13.1%
Unsignalized Intersections	614	27.5%	127	25.5%	15.8%
Mid-block	567	25.4%	148	38.9%	26.1%
Driveway	78	3.5%	8	2.1%	10.3%
Total	**2,230**	**100%**	**380**	**100%**	**17.0%**

** KSI = Killed or Serious Injury Crash*

Source: The City of Portland provided the crash data for this analysis, which it received from the Oregon Department of Transportation (ODOT) Crash Analysis and Reporting Unit.

Where are crashes happening?

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OVER

40% of pedestrian crashes

AND

30% of severe/fatal crashes citywide

OCCUR AT SIGNALIZED INTERSECTIONS

Crash types

Pedestrian Crash Type	Criteria Description	Count	% of Crashes	% of Type Resulting in a KSI
Signalized Intersections	**Crash at signalized intersection location (per reported Intersection field and geographic proximity to traffic signal)**	**971**	**43.5%**	**13.1%**
Left turning driver fails to yield to pedestrian	▪ Vehicle turning left preceding collision ▪ Driver assigned error code	453	20.3%	8.6%
Right turning driver fails to yield to pedestrian	▪ Vehicle turning right preceding collision ▪ Driver assigned error code	184	8.3%	9.2%
Pedestrian crossing against signal or outside of crosswalk	▪ Pedestrian assigned error code ▪ Error code = Disregarded traffic signal or crossing at intersection – traffic signal present	160	7.2%	25.0%
Driver going straight fails to yield	▪ Vehicle traveling straight preceding collision ▪ Driver assigned error code	88	3.9%	21.6%
Other	▪ All other crashes at signalized intersections	86	3.9%	14.0%
Unsignalized Intersections	**Crash at non-signalized intersection location (per reported Intersection field and no geographic proximity to traffic signal)**	**614**	**27.5%**	**15.8%**
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Left turning driver fails to yield	▪ Vehicle turning left preceding collision ▪ Driver assigned error code	159	7.1%	6.3%
Pedestrian crossing did not have the right-of-way	▪ Pedestrian assigned error code ▪ Non-motorist action indicated pedestrian crossing	135	6.1%	25.2%
Right turning driver fails to yield to pedestrian	▪ Vehicle turning right preceding collision ▪ Driver assigned error code	70	3.1%	7.1%
Other	▪ All other crashes at unsignalized intersection	61	2.7%	16.4%
Mid-block	**Crash at mid-block location (per reported Intersection field)**	**567**	**25.4%**	**26.1%**
Pedestrian crossing between intersections	▪ Non-motorist action – crossing between intersection	420	18.8%	24.5%
Other	▪ All other crashes at midblock locations	147	6.6%	30.6%
Driveway	**Crash located at driveway (per Road Character field)**	**78**	**3.5%**	**10.3%**
Driveway	▪ All crashes located at driveway	78	3.5%	10.3%
Total	**All collisions**	**2,230**	**100.0%**	**17.0%**

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Figure 24 Pedestrian Crashes in Relation to the High Crash Network Streets, Location Type, and Vehicle Movement

Relation to High Crash Network (HCN)	Signalized Intersection				Unsignalized Intersection				Mid-Block				Driveway				Totals
	Straight	Turning Left	Turning Right	Other	Straight	Turning Left	Turning Right	Other	Straight	Turning Left	Turning Right	Other	Straight	Turning Left	Turning Right	Other	
Driver Along HCN Segment | **Pedestrian** Across HCN Segment	102	0	0	0	154	0	0	0	231	0	0	0	0	0	0	102	**487**
Driver Turning On To HCN Segment | **Pedestrian** Across HCN Segment	0	204	37	0	0	23	5	0	0	3	0	1	0	8	0	0	**281**
Driver Turning Off Of HCN Segment | **Pedestrian** Along HCN Segment	0	81	40	0	0	36	11	0	0	0	1	2	0	2	0	0	**173**
Driver Across HCN Segment | **Pedestrian** Along HCN Segment	59	0	0	0	12	0	0	0	26	0	0	0	2	0	0	59	**99**
Driver Turning On To HCN Segment | **Pedestrian** Along HCN Segment	0	11	33	0	0	4	22	0	0	0	1	0	0	6	10	0	**88**
Driver Along HCN Segment | **Pedestrian** Along HCN Segment	17	0	0	0	15	0	0	0	19	0	0	0	0	0	0	17	**51**
Driver Turning Off Of HCN Segment | **Pedestrian** Across HCN Segment	0	8	24	1	0	4	6	0	0	0	0	4	0	3	0	0	**50**
Other	16	1	3	3	4	0	1	1	22	0	0	2	0	2	1	16	**56**
Totals	**194**	**305**	**137**	**4**	**185**	**67**	**45**	**1**	**298**	**3**	**2**	**9**	**2**	**21**	**11**	**1**	**1,285**

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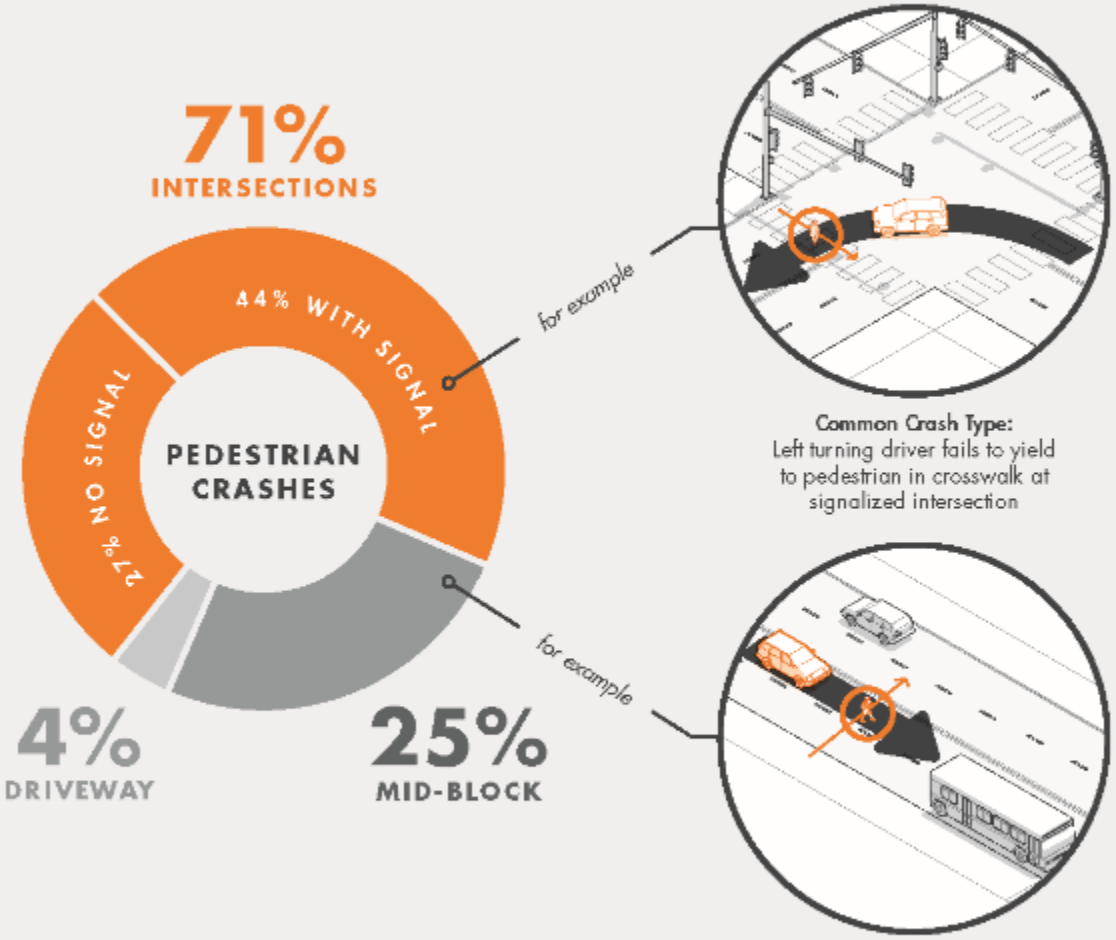
PEDESTRIAN CRASHES BY LOCATION

2006–2015

Source: ODOT



Common Crash Type:
Left turning driver fails to yield to pedestrian in crosswalk at signalized intersection

Common Crash Type:
Pedestrian crossing between intersections at mid-block location

THE PEDPDX TOOLBOX

The Implementation Toolbox is the programmatic work plan to advance the vision and mission of PedPDX.

Strategy 1
Address gaps in the Priority Pedestrian Network

ACTION 1.3

Explore options to enabl pedestrian improvemen

PBOT's Development Review group reviews all street and frontage improvements assoc with private development. In Portland, priva development is typically required to make st frontage improvements along the property a of a development project. This includes prov improving sidewalks in a manner consistent City's Pedestrian Design Guide. A large prop new sidewalks constructed or improved in P time have been provided in conjunction with development activities.

Current City Code only requires developers t the sidewalk frontage directly adjacent to th There are no mechanisms in place to encour enable private developments to provide ped infrastructure beyond the immediate proper including crossing enhancements that could future tenants, or sidewalk extensions beyo property to connect to new development to neighborhoods.

The PBOT PBOT Policy, Innovation, and Regi Collaboration will work with Development R City Attorney, and City Council to explore m for encouraging off-site pedestrian improve in conjunction with private development. Op to explore include offering SDC credits or ot development fee waivers for voluntary prov off site crossing or sidewalk improvements, updating PBOT's multi-modal level-of-servic criteria to require off site pedestrian mit gat appropriate.

Strategy 2
Improve visibility of pedestrians at crossings

ACTION 2.4

Provide high visibility cros crossings when restriping crosswalks.

The PedPDX Safety Analysis found that signalize intersections are not preventing pedestrian cra in Portland. Over 40% of pedestrian crashes an of severe/fatal crashes citywide occur at signali intersections. Over a quarter of all crashes invol turning driver failing to yield when the person w has the right of way at the signal.

OVER **40%** of pedestri crashes

AND **30%** of severe/f crashes city

OCCUR AT SIGNALI INTERSECTIONS

Improving the visibility of pedestrian crosswalk at signalized intersections may help make cross pedestrians more visible to people driving. PBO Traffic Design Manual has historically called for crosswalk markings with two transverse lines (running perpendicular to oncoming traffic) at signalized intersections. In contrast, high visibili "continental") crosswalks with longitudinal lines to traffic flow allow drivers to see the marked c from a greater distance. This increased visibility drivers more time to safely stop for a pedestrian waiting to cross. The PBOT Traffic Design Manua currently requires these high-visibility "continen crosswalk markings at uncontrolled crossings a school crossings where increased visibility is ne

Strategy 3
Reduce turning movement conflicts at intersections

PEDPDX OBJECTIVES ADDRESSED

ACTION 3.2

Develop a pilot to study prohibiting "turn-on-red" within Pedestrian Districts and at High Pedestrian Crash Intersections.

Allowing rights on red is common throughout the city. Left turns on a red light are also allowed when the driver is turning onto a one-way street, which is common downtown. To make these movements, drivers must pull forward into the crosswalk to look for a gap in on-coming traffic, into and across the path of pedestrians who have a "walk" signal. This can create a dangerous situation if the driver does not see a pedestrian entering the crosswalk. It is particularly dangerous for blind pedestrians, who do not receive visual clues (through signals or eye contact with the driver) that the driver intends to turn against the signal. Furthermore, drivers looking for gaps in traffic to make the turn do not always look the opposite direction to check for crossing pedestrians before making the turn against the signal.

As part of the PedPDX public outreach, members of Portland's disability community in particular have expressed strong support for eliminating "turn-on-red." Engineering studies show a significant increase in pedestrian crashes where "right-on-red" is permitted [1,2]. The City Traffic Engineer, PBOT Signals and Street Lighting, and Vision Zero staff will develop a pilot to study prohibiting "turn-on-red" in high pedestrian demand districts and/or at pedestrian high crashes intersections. The pilot study will establish evaluation criteria and based on the findings of the pilot the City Traffic Engineer may consider permanent prohibitions on "turn-on-red" at key locations.

No Turn on Red

Considerations

A pilot study will allow PBOT to monitor what impact prohibiting "turn-on-red" might have on pedestrian safety and automobile congestion. It will also offer an opportunity to monitor driver compliance. The pilot study should be coupled with education about the safety concerns underlying the study, as well as enforcement for non-compliance.

[1] 10% increase in right turn crashes where right turn on red is permitted - Handbook of Road Safety Measures, Elvik, R. and Vaa, T., 2004

[2] ... in ke and vehicle/pedestrian crashes (all severities) – Highway Safety Manual, 1st Edition, 2010

STRATEGY 2

Improve visibility of pedestrians at crossings

The PedPDX Safety Analysis found that citywide, 70% of pedestrian crashes in Portland occur at intersections (in Oregon, every intersection is a legal crosswalk). Making sure pedestrians crossing the street are visible to people driving is a critical factor for increasing pedestrian safety on our roadways. The following actions seek to improve visibility conditions at pedestrian crossings through intersection design, changes to street markings, and by applying vision clearance best practices.

Improved street lighting at intersections and crossings is also a critical tool for improving visibility of pedestrians and will be addressed in greater detail as part of Strategy 6.

ACTION 2.4

Provide high visibility crosswalks at all marked intersections when restriping or providing new crosswalks

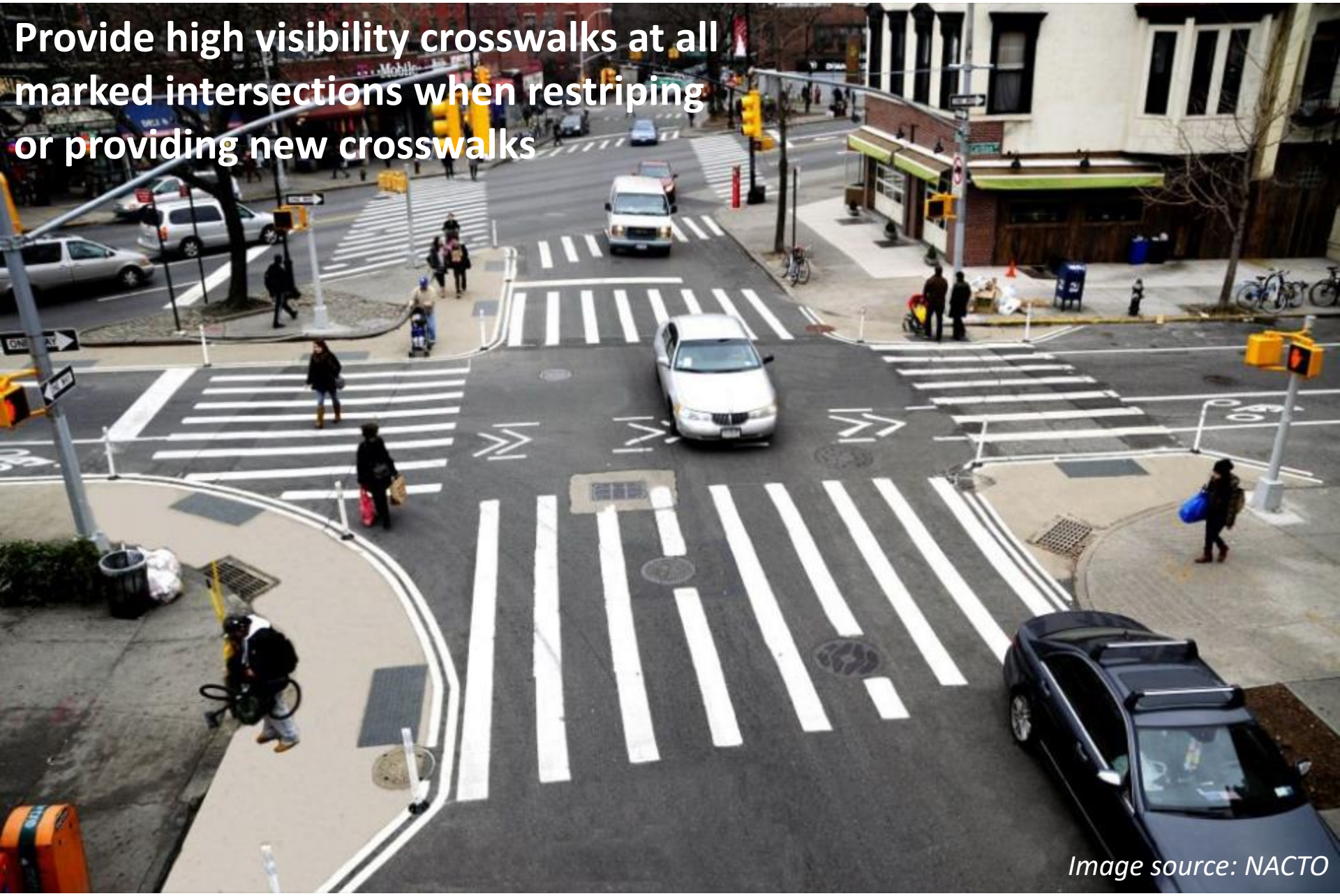


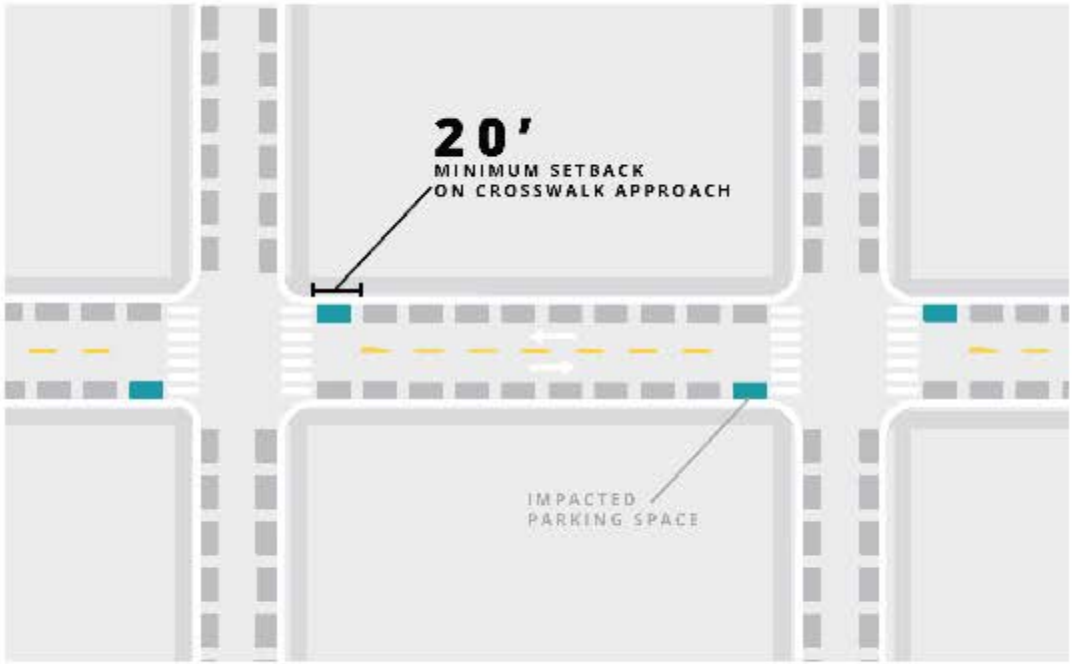
Image source: NACTO

SE Cesar Chavez & Hawthorne

SW 4th & Columbia

NEW CITYWIDE PEDESTRIAN SAFETY GUIDELINES

Vision Clearance Guidelines at Intersections

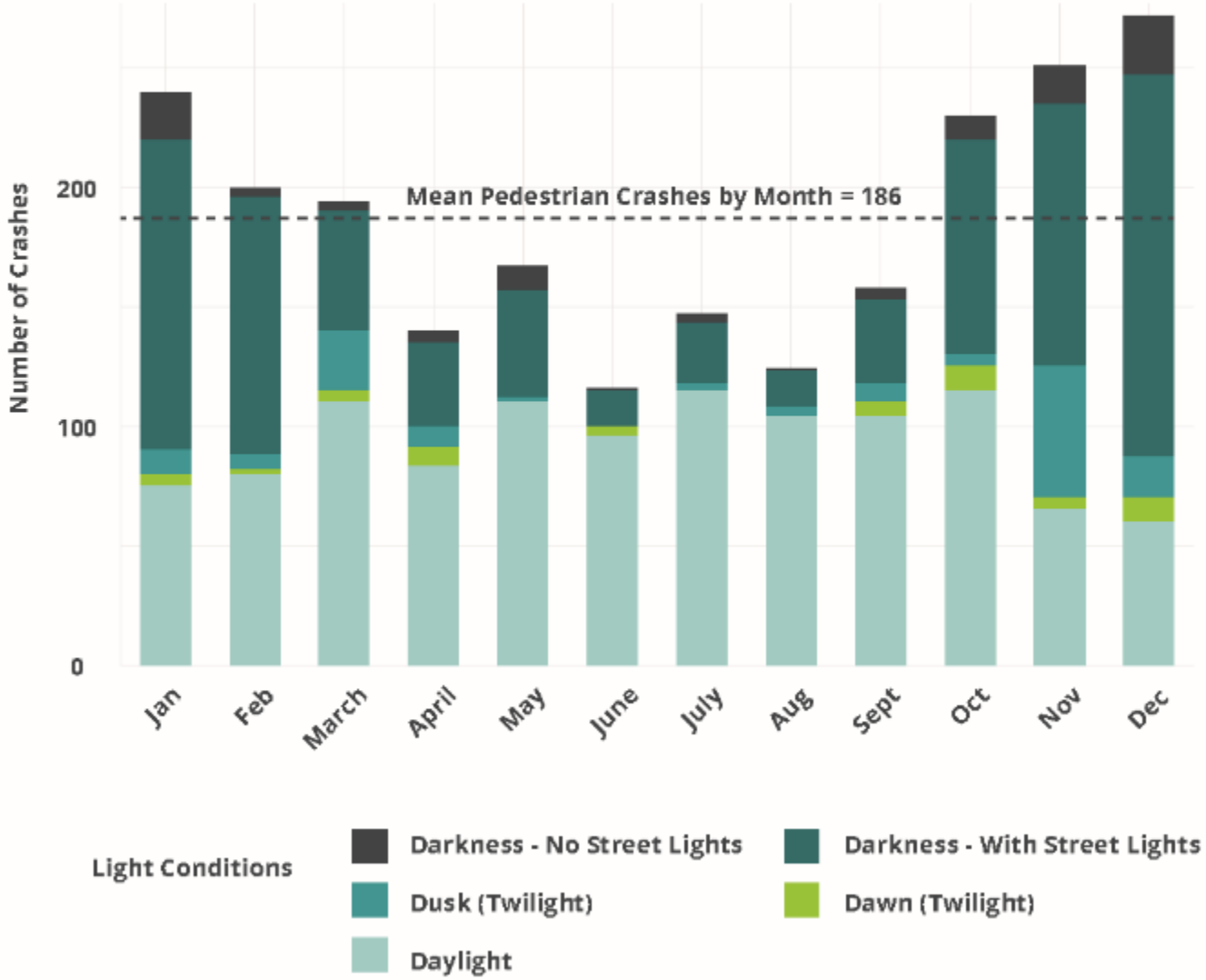


ACTION 2.3

Evaluate the need for vision clearance guidelines at controlled crossings and on local streets

When are crashes happening?

Figure 15: Crashes by Month and Lighting Conditions

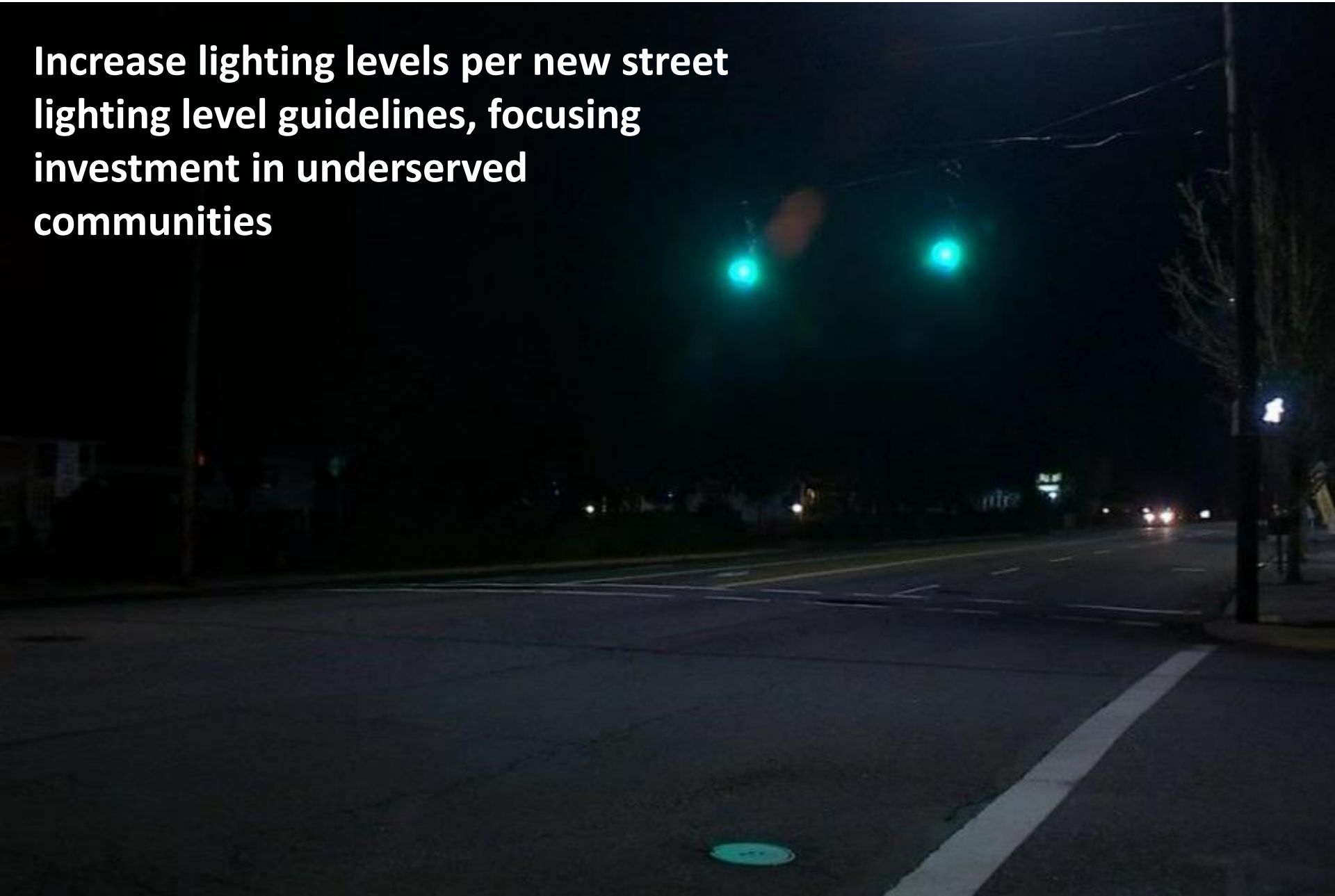


Places to Improve - Average Point Value (from 1-6)

WHAT MAKES WALKING DIFFICULT IN PORTLAND?	WALKING WHILE BLACK	CITYWIDE
Poor Lighting	5.00	3.62
Sidewalks / walking paths missing on BUSY streets	4.94	4.66
People driving too fast on BUSY streets	4.82	4.29
Not enough safe places to cross busy streets	4.78	4.46
People driving too fast on RESIDENTIAL streets	4.74	4.44
Sidewalks / walking paths missing on RESIDENTIAL streets	4.71	4.29
Drivers not stopping for pedestrians crossing the street	4.47	4.29
Buckled / cracked / uplifted sidewalks, or other tripping hazards	4.47	3.46
Missing curb ramps at intersections	4.00	3.22
Not enough time to cross the streets	3.91	3.08

Figure 1. Which kinds of places are the most important to improve for walking in Portland?

ACTION 12.1



Increase lighting levels per new street lighting level guidelines, focusing investment in underserved communities

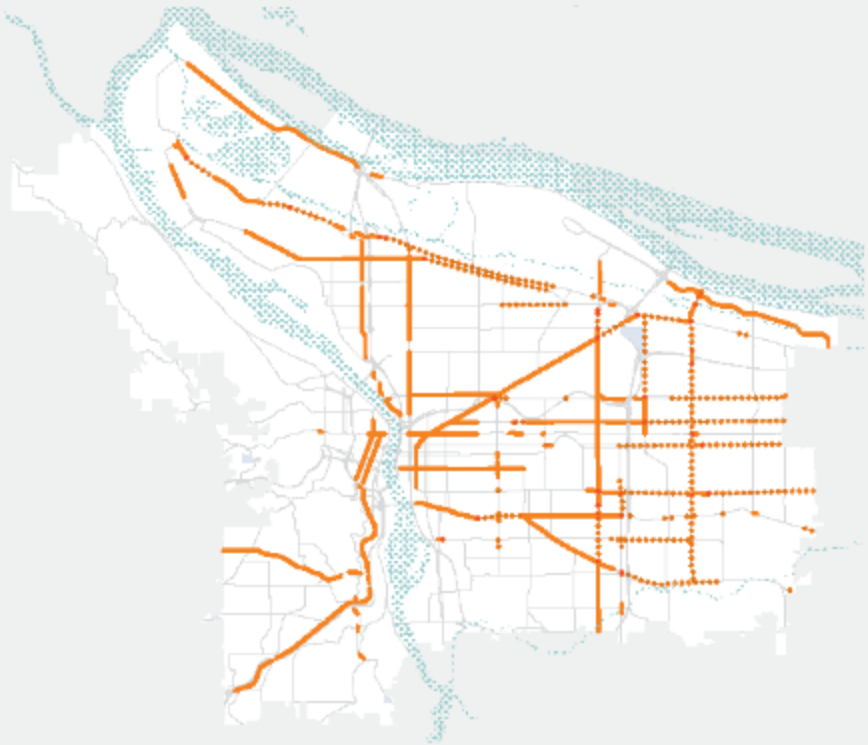
ADDRESSING DISPARITIES

Lighting needs are greatest in East Portland

49% of Portland's pedestrian crashes occur in dark or low-light conditions. By City guidelines, streets wider than 48′ should have two-sided lighting. Citywide, 61% of High Crash Network streets wider than 48′ have lighting on two sides. By contrast, only 22% of wide High Crash Network streets in East Portland have two-sided lighting.

STREETS 48 FEET OR WIDER

Source: PBOT



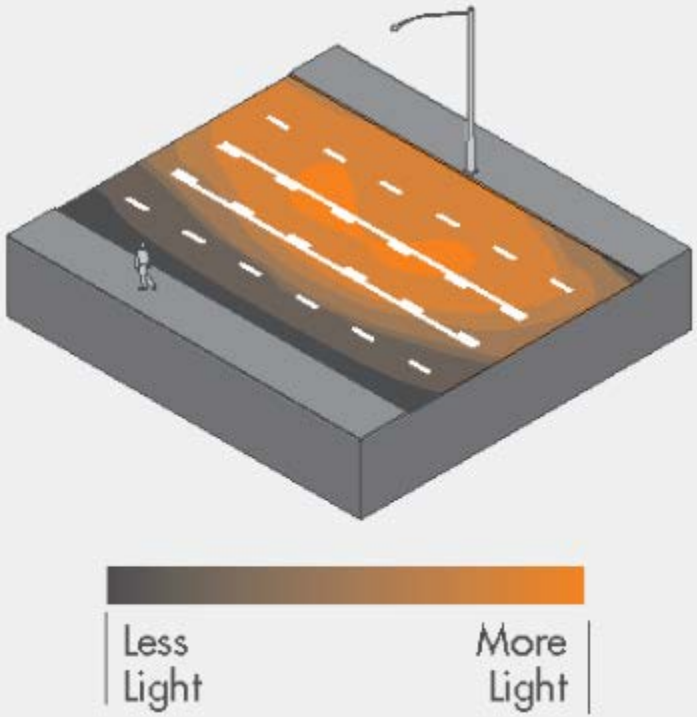
LIGHTS ON BOTH SIDES OF STREET

LIGHTS ON ONE SIDE OF STREET

STREET LIGHTING

WIDE STREET, SUCH AS SE STARK, WITH LIGHTING ON ONE-SIDE ONLY

Source: PBOT



Left turn calming

LEFT TURN CALMING
PILOT PROJECT

SPEED LIMIT 30
BIKES
PET-MART

STRATEGY 3

Reduce turning movement conflicts at intersections

Intersections are where pedestrians are most likely to be killed or seriously injured. This strategy aims at protecting pedestrians trying to cross at a "WALK" signal from turning cars, a problem shown in the PedPDX Safety Analysis and heard in the Disability Focus Group. Intersection design focused on turning movements can facilitate safe turning and improve pedestrian safety.

Strategy 3

Reduce turning movement conflicts at intersections

PEDPDX OBJECTIVES ADDRESSED

ACTION 3.2

Develop a pilot to study prohibiting "turn-on-red" within Pedestrian Districts and at High Pedestrian Crash Intersections.

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As part of the PedPDX public outreach, members of Portland's disability community in particular have expressed strong support for eliminating "turn-on-red." Engineering studies show a significant increase in pedestrian crashes where "right-on-red" is permitted [1,2]. The City Traffic Engineer, PBOT Signals and Street Lighting, and Vision Zero staff will develop a pilot to study prohibiting "turn-on-red" in high pedestrian demand districts and/or at pedestrian high crashes intersections. The pilot study will establish evaluation criteria and based on the findings of the pilot the City Traffic Engineer may consider permanent prohibitions on "turn-on-red" at key locations.

No Turn on Red

Considerations

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Strategy 3

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Where RTOR is permitted:

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- 69% increase in vehicle/bike and vehicle/ped crashes (all severities) *(Highway Safety Manual, 1st Edition, 2010)*

Strategy 3

Reduce turning movement conflicts at intersections

ACTION 3.1

Develop guidelines and practices for separating vehicle turning movements concurrent with the pedestrian walk phase and incorporate signal timing analysis into capital project scopes.

The PedPDX Safety Analysis found that over 40% of crashes involving pedestrians occur at signalized intersections. Assignments of error for pedestrian crashes show that 8% involve a right-turning driver failing to yield and 20% involve a left-turning driver failing to yield when the person walking has the right of way. Protecting crossing pedestrians from automobile turning phases can help decrease these right and left turn conflicts.

There are a variety of tools for separating pedestrian crossing movements from vehicle turning movements, including protected left turns, protected right turns, all-pedestrian phases, leading pedestrian intervals, and protected-permissive phasing. Protected-permitted left turns area flashing yellow arrows that if concurrent with conflicting walk symbols also create a hazard and should be avoided (this is already PBOT practice). The Oregon Department of Transportation's Crash Reduction Factor Appendix cites a 37% pedestrian and bicycle crash reduction factor for leading pedestrian intervals and a 43% pedestrian crash reduction factor for installing signals with no pedestrian phase with flashing yellow arrows.

The City Traffic Engineer, PBOT Signals and Street Lighting, and Vision Zero staff will develop guidelines and practices for separating vehicle turning phases concurrent with pedestrian walks, including identifying contexts and criteria where various treatments are appropriate and where shared phasing should be eliminated.

In the interim, PBOT Signals and Street Lighting and the City Traffic Engineer will generally not approve permissive left turns at new signals across Major City Walkways (or Bikeways), unless engineering judgment justifies the treatment. PBOT will utilize ODOT guidelines and practices for separating vehicle turning phases from opposing through traffic. PBOT Signals and Street Lighting will continue to use PBOT's Leading Pedestrian Interval (LPI) Guidelines to identify opportunities to provide LPIs.

These guidelines will consider PedPDX classifications and designated pedestrian high crash intersections as a factor. The decision to separate pedestrian crossing phases from vehicle turning phases should largely be a function of where we have seen or predict pedestrian safety concerns.

Once developed, PBOT Complete Streets will incorporate new signal timing guidelines into the PBOT project development checklist to inform project scoping needs.

PEDPDX OBJECTIVES ADDRESSED

20% OF ALL PEDESTRIAN CRASHES involve a **left-turning driver failing to yield** to a person walking who has the right of way

8% OF ALL PEDESTRIAN CRASHES involve a **right-turning driver failing to yield** to a person walking who has the right of way

Considerations

There are a number of trade-offs to be considered when determining how to effectively set signal timing to maximize safety and efficiency for all road users. Giving more walk time to pedestrians will have an impact on traffic flows, including transit vehicles and people biking, increasing the overall length of time it takes for a signal to move through a cycle length will increase wait time for all users, including pedestrians, which can lead to less efficient crossings and non-compliant movements. Turn pockets needed for protected turning phases require sufficient right-of-way width, which is not always available. Changing the signal timing at one location could lead to a ripple impact to dozens of nearby signals.

Tools for separating pedestrian crossing movements from vehicle turning movements:

PROTECTED (OR PROHIBITED) LEFT TURNS: Turning vehicle has a green left-turn signal and pedestrians are not permitted to cross (as opposed to an unprotected turn, when turning vehicles have a green light and must yield to oncoming traffic and pedestrians typically have a "WALK" signal, which creates a potential conflict for pedestrians and turning vehicles). Prohibited left turn movements may be an appropriate tool where there is not adequate space for a left turn pocket.

PROTECTED RIGHT TURNS: Protected right turns are similar to protected left turns in that they hold vehicles from turning right with a red light to provide pedestrians with a "WALK" signal. This prevents pedestrians from sharing a traffic phase with right-turning vehicles. When vehicles have a green right turn arrow, pedestrians are not permitted to cross. The addition of a "NO TURN ON RED" sign may also be used.

ALL-PEDESTRIAN PHASES: Stops all motor vehicle movement and allows pedestrians to cross in any direction at the intersection, including diagonally.

LEADING PEDESTRIAN INTERVALS: Gives pedestrians a 3-10 second head start when entering an intersection.

PROTECTED PERMISSIVE PHASING: Motor vehicles are given two phasings. In a "permissive/protected" mode, the permissive left-turn phase is immediately followed by an exclusive, protected left turn phase, initiated by a green arrow signal indication.

- **Protected (or prohibited) left turns**
- **Protected right turns**
- **Leading pedestrian intervals**
- **Protected permissive phasing**
- **All-way walks**
- **No-turn-on-red**

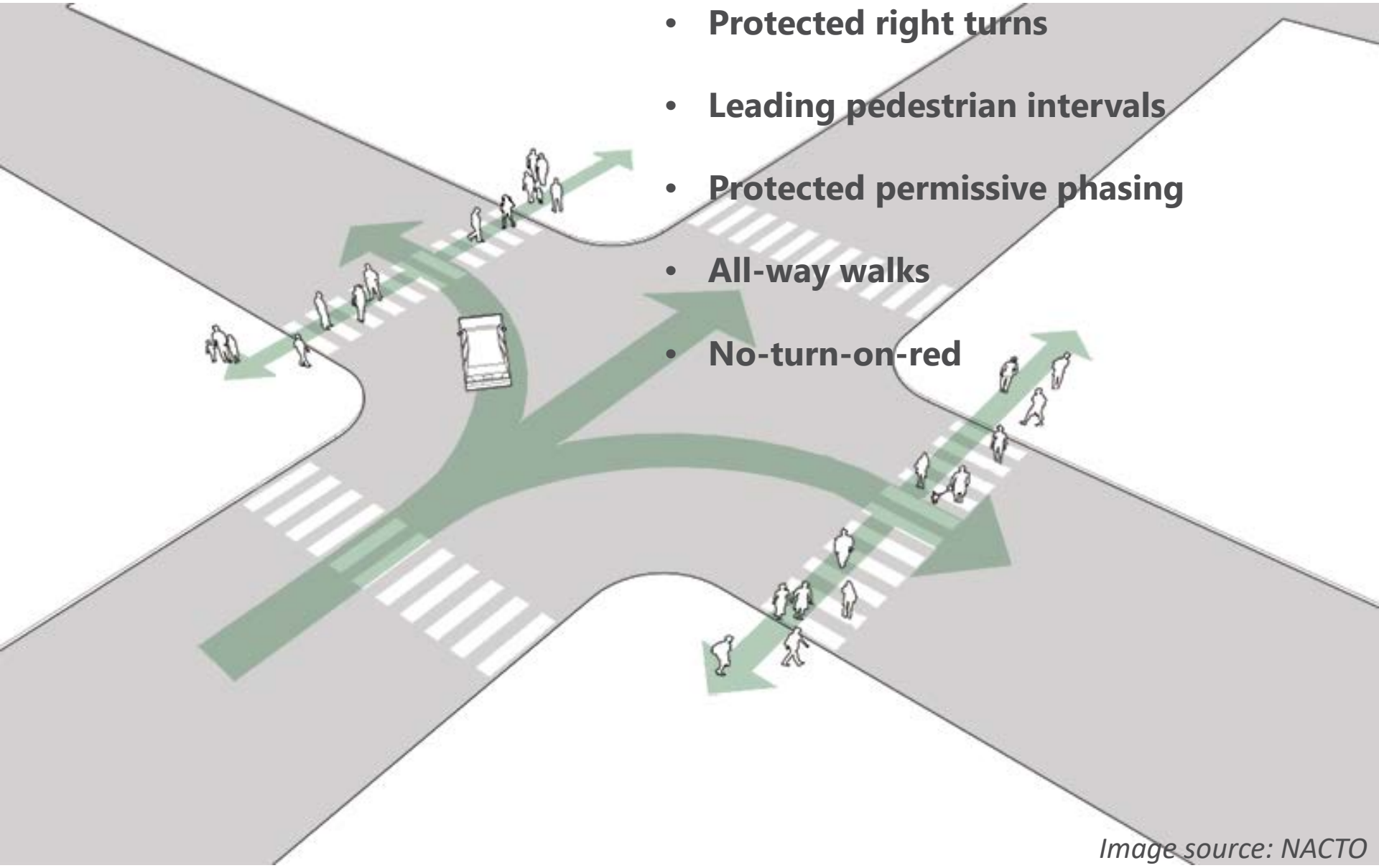

Image source: NACTO

Thank you!

Michelle Marx | Pedestrian Coordinator
Portland Bureau of Transportation
Michelle.Marx@portlandoregon.gov

Actualizing Safer Signals for Walking & Biking

Oliver Smith, Ph.D.
APBP 8.29.19

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Permissive left turn conflicts

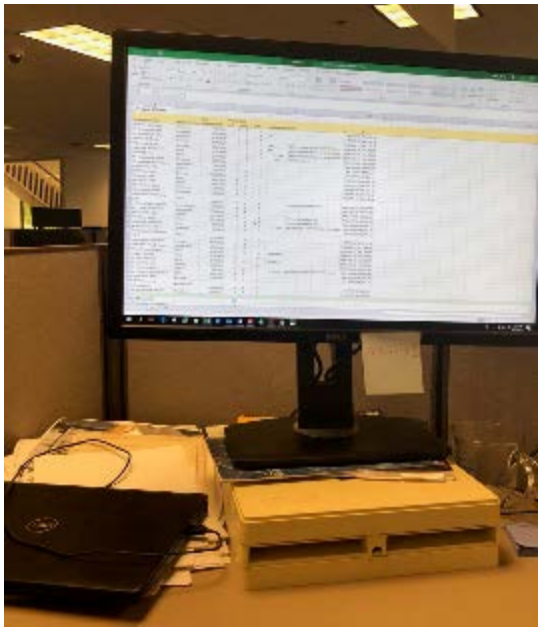
Leading Pedestrian Interval (LPI)

Enter the LPI

Reduces vehicle-ped crashes & conflicts

Crash Modification Factor (CMF) 0.55 - 0.63

Trivial delays



EVALUATE -> IMPLEMENT -> DOCUMENT

City Directive

LPIs will become our default practice at new/upgraded traffic signals on High Crash Network streets... PBOT will add at least ten LPIs/year to existing signals.

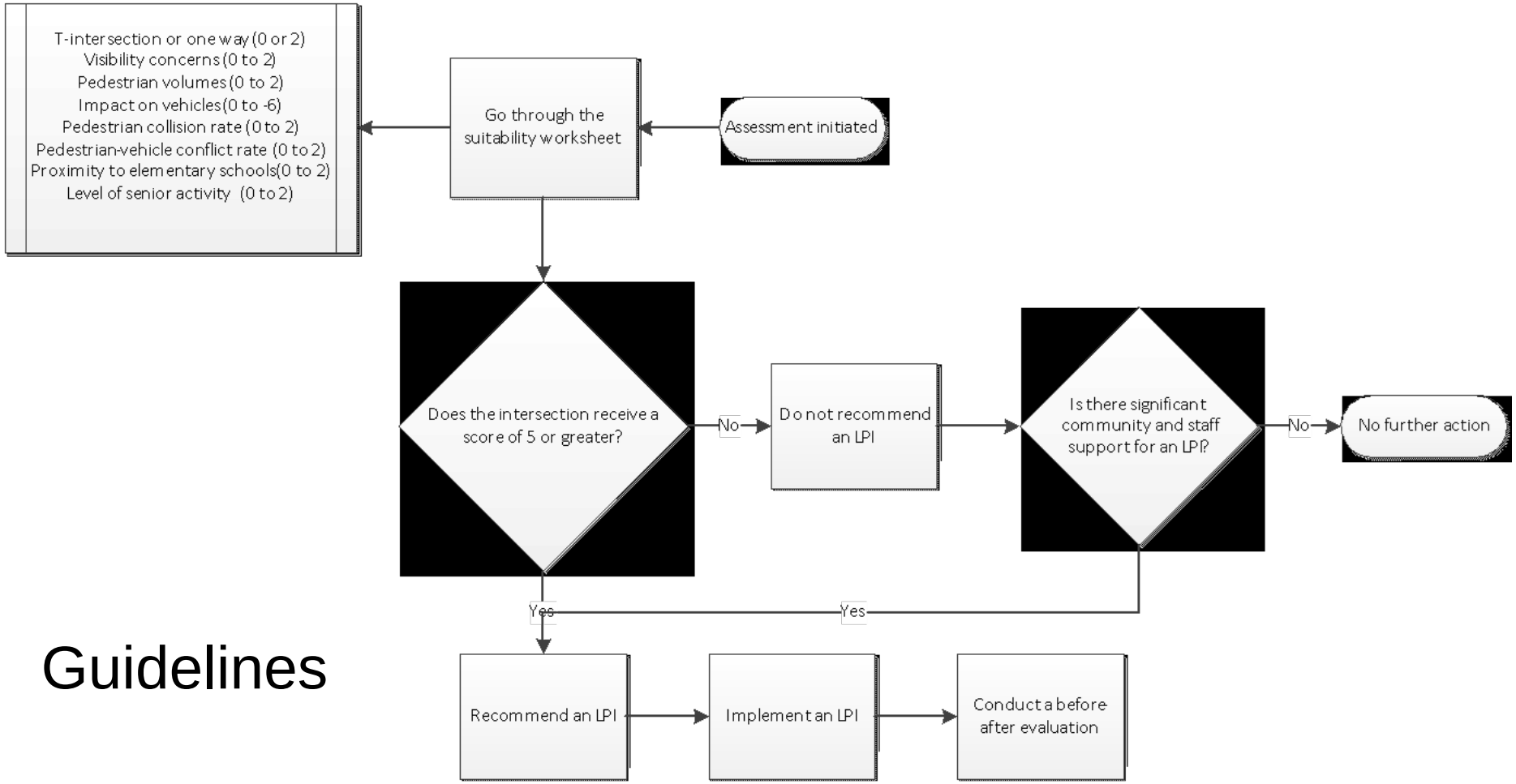
Protected left turns will become default practice at new/upgraded signals on High Crash Network streets. We will install 3+ protected left turns/year at existing signals.

High ped crash locations

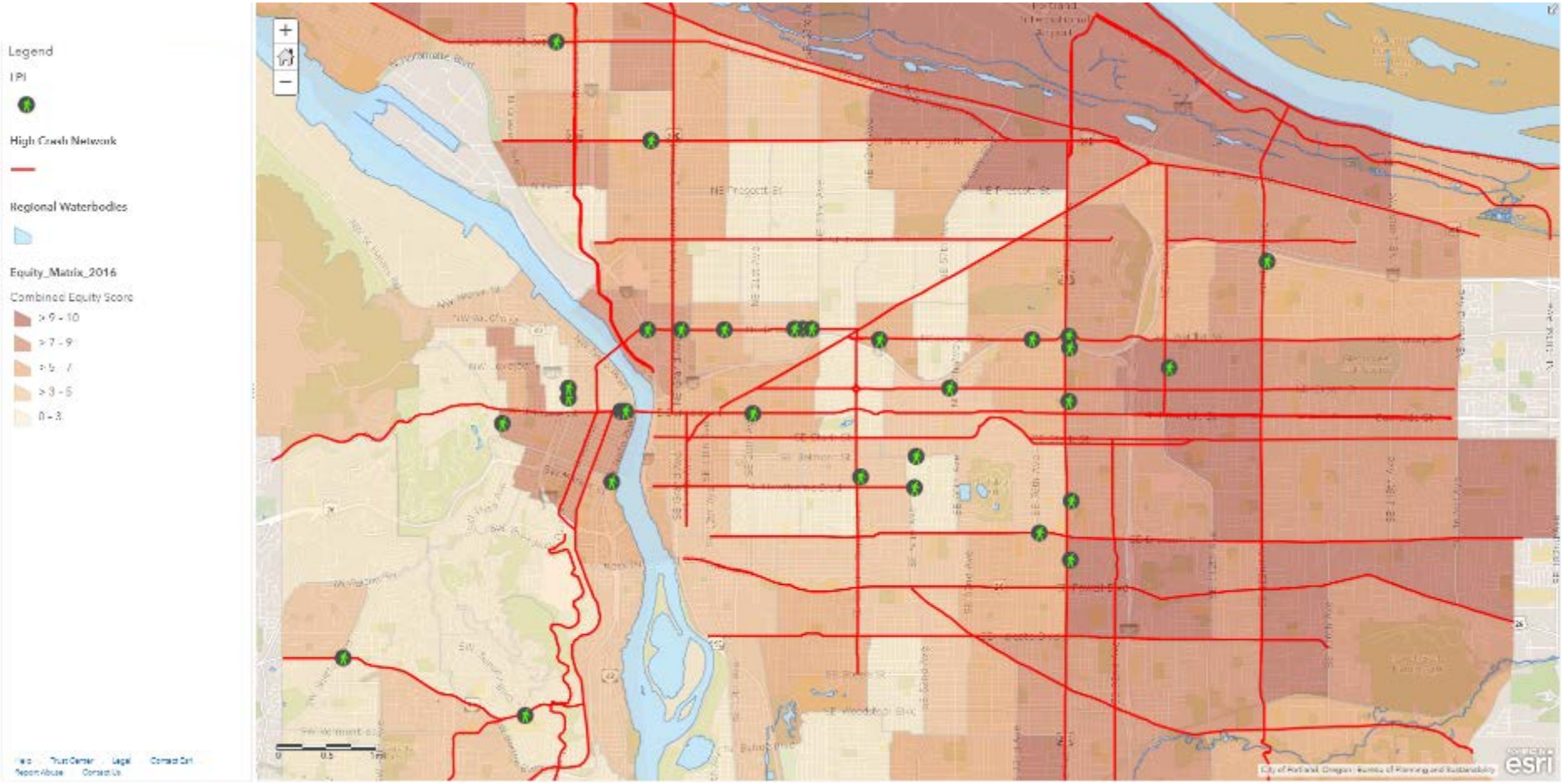
When?

- Ped crossing layout
- Safety concerns
- Ped counts
- Vehicle volumes, including turns
- Crash history
- Presence of schools

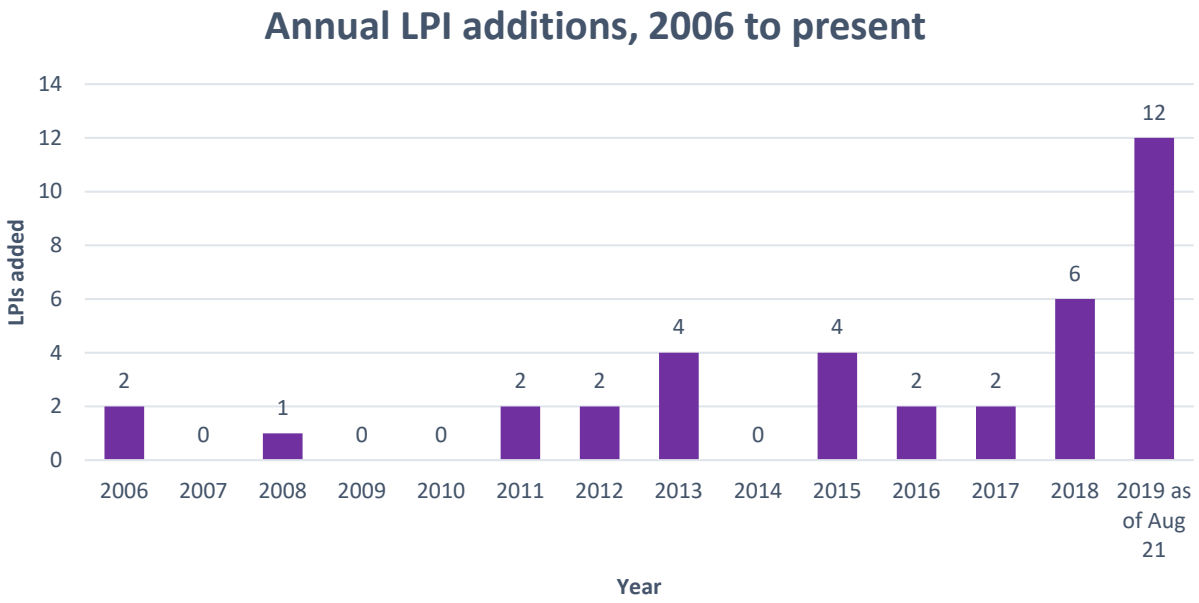
Guidelines

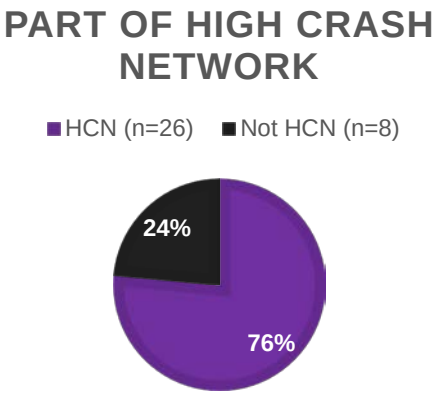

T-intersection or one way (0 or 2)
Visibility concerns (0 to 2)
Pedestrian volumes (0 to 2)
Impact on vehicles (0 to -6)
Pedestrian collision rate (0 to 2)
Pedestrian-vehicle conflict rate (0 to 2)
Proximity to elementary schools (0 to 2)
Level of senior activity (0 to 2)
Go through the suitability worksheet
Assessment initiated
Does the intersection receive a score of 5 or greater?
No
Do not recommend an LPI
Is there significant community and staff support for an LPI?
No
No further action
Yes
Yes
Recommend an LPI
Implement an LPI
Conduct a before after evaluation

Existing LPIs (n=37)

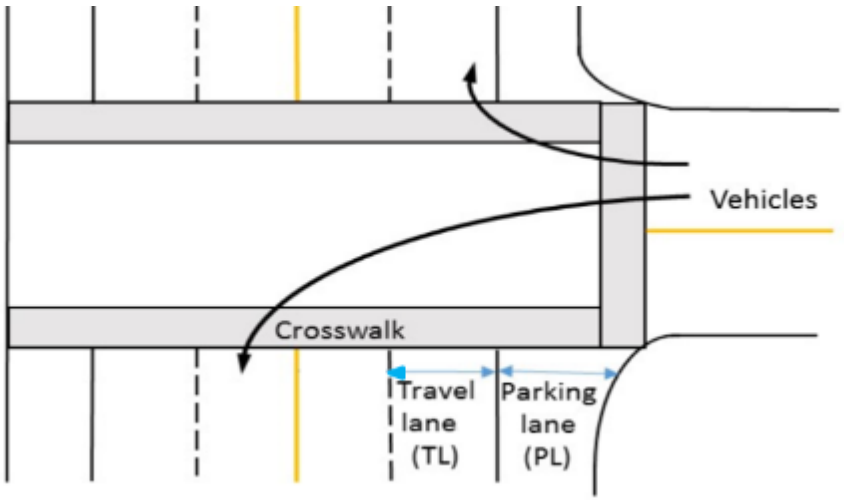


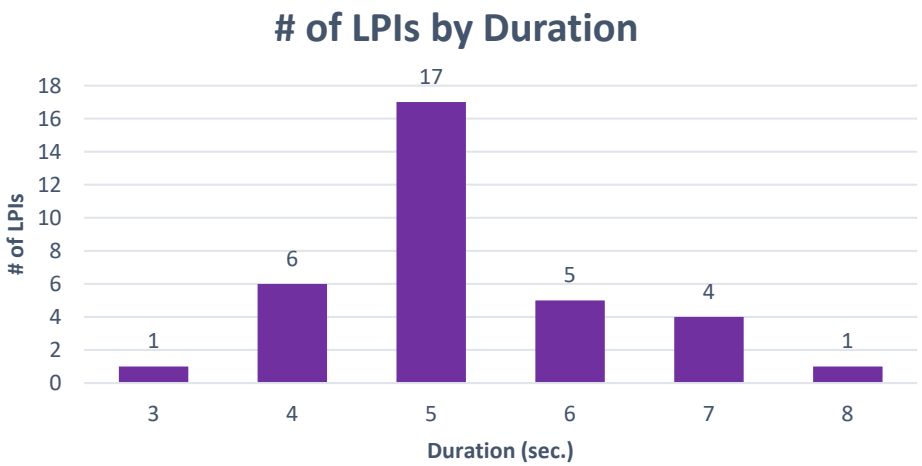
Timeline


Annual LPI additions, 2006 to present
LPIs added
14
12
10
8
6
4
2
0
2
0
1
0
0
2
2
4
0
4
2
2
6
12
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019 as of Aug 21
Year


PART OF HIGH CRASH NETWORK
HCN (n=26)
Not HCN (n=8)
24%
76%

How long?





LPI= (TL+PL)/W

where:

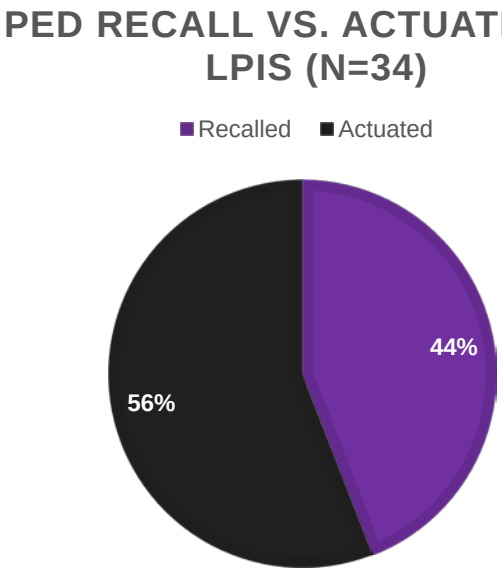
LPI = number of seconds (rounded)

TL = distance to clear width of one moving lane

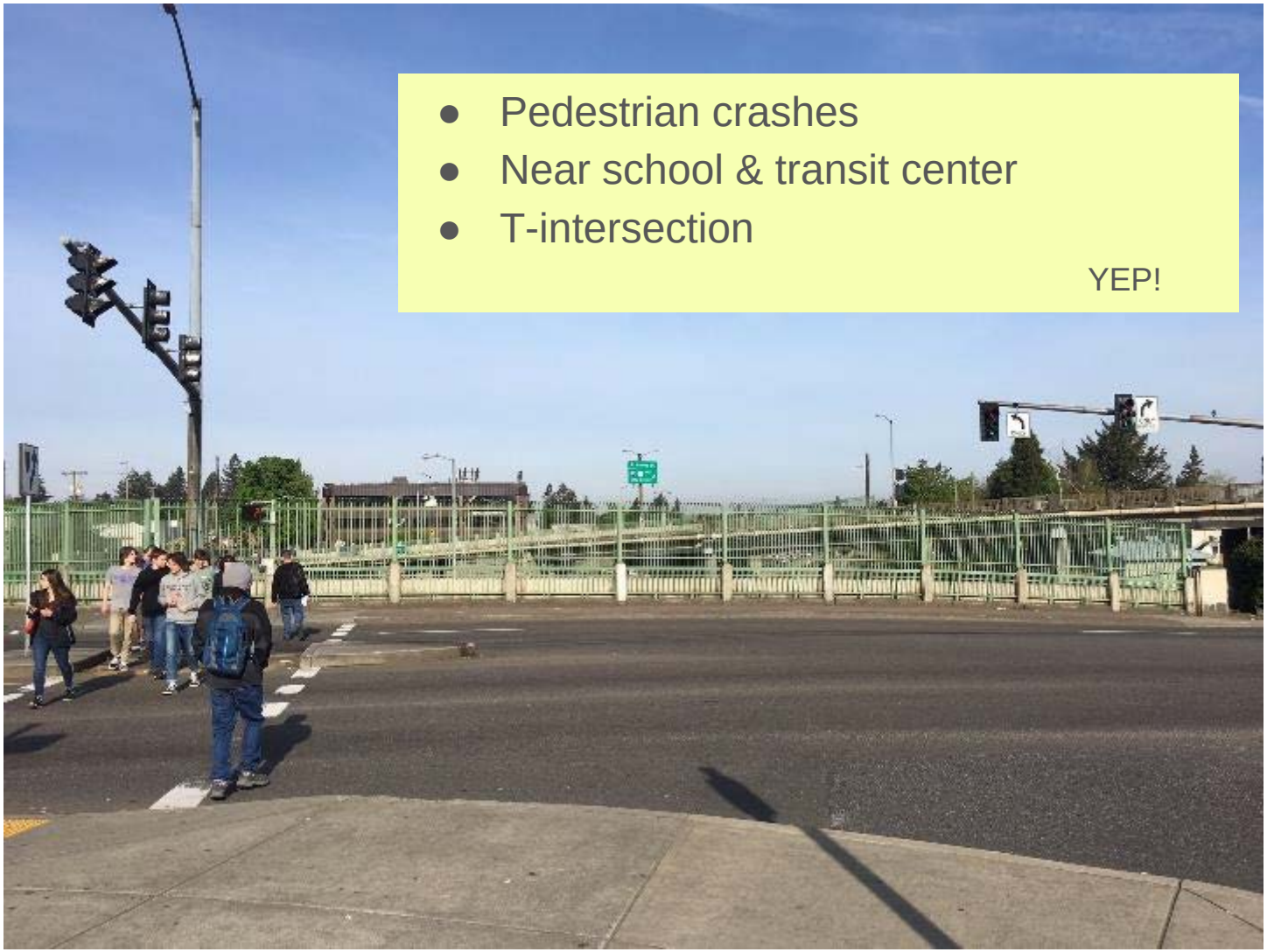
PL = width of parking lane, if any

W = walking speed (3.5 ft/s)

Push Button Considerations



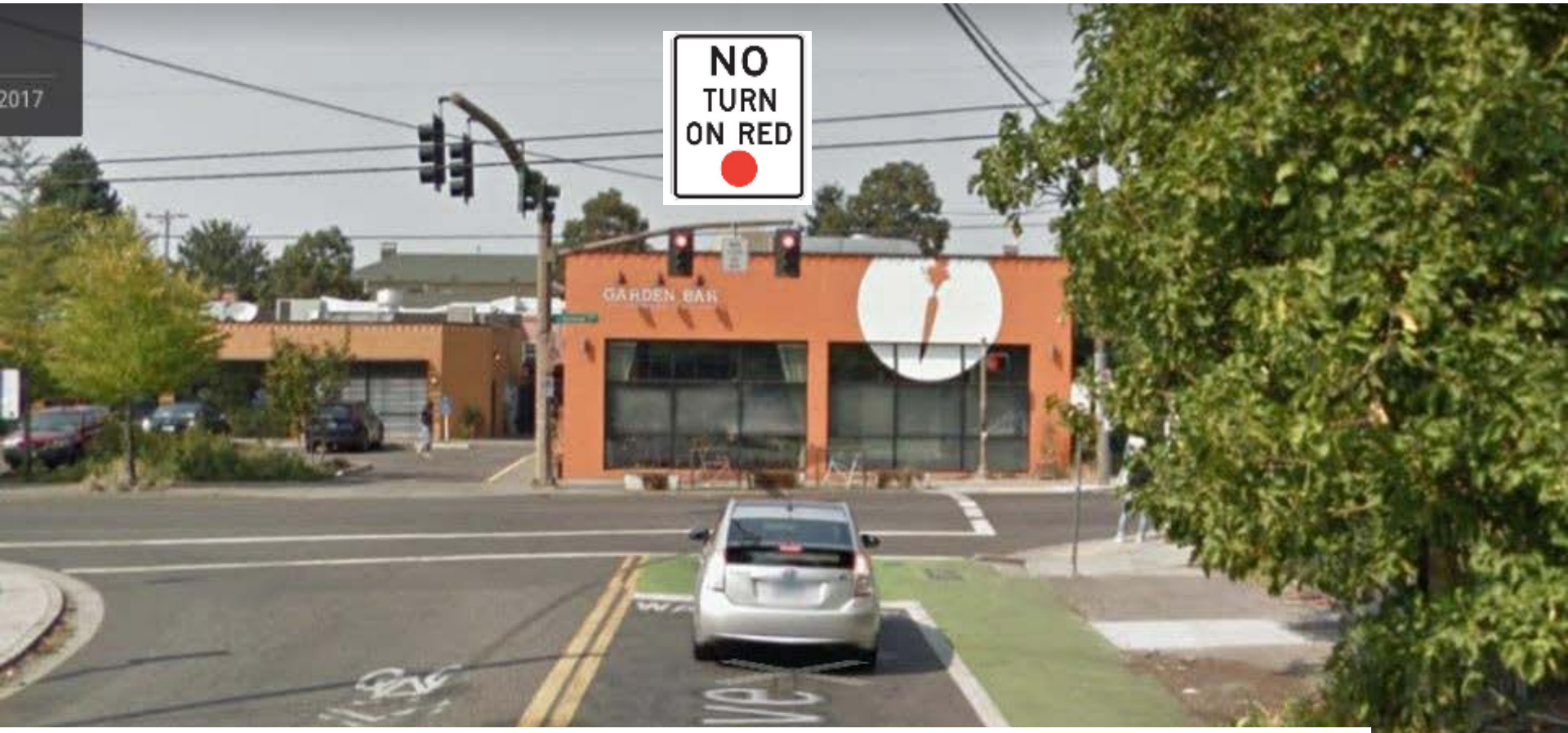
Presence of LPI to prioritize APS installation


Pedestrian crashes
Near school & transit center
T-intersection
YEP!

- Has protected left turns
- Two intersecting major streets

NOPE!

LPIs or Protected Lefts?



Or No Turn on Red

Monitoring

No PDX study

Working with PSU’s Sirisha Kothuri’s NCHRP 17-87 (describe)

Grateful for work others have done

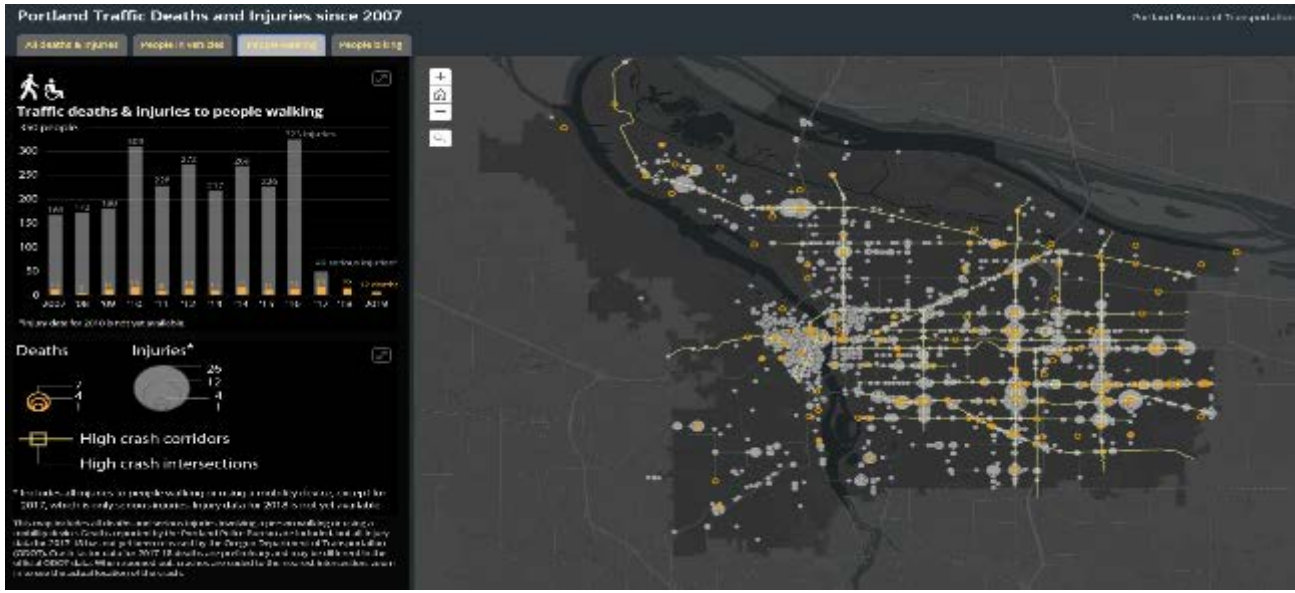
NYC, CHI, Charlotte

Regina
Winnipeg
Vancouver
Victoria
Seattle
WASHINGTON
MONTANA
NORTH DAKOTA
MINNESOTA
Portland
OREGON
IDAHO
WYOMING
SOUTH DAKOTA
Minneapolis
WISCONSIN
MICHIGAN
Toronto
Ottawa
Montreal
Québec City
NEW BRUNSWICK
MAINE
VERMONT
NEW HAMPSHIRE
NEW YORK
MASSACHUSETTS
CT
RI
Detroit
Chicago
IOWA
NEBRASKA
PENNSYLVANIA
New York
Philadelphia
NJ
MARYLAND
ILLINOIS
INDIANA
OHIO
Indianapolis
NEVADA
UTAH
United States
COLORADO
Kansas City
KANSAS
MISSOURI
WEST VIRGINIA
KENTUCKY
VIRGINIA
Sacramento
San Francisco
CALIFORNIA
Las Vegas
Nashville
TENNESSEE
OKLAHOMA
NORTH CAROLINA
Charlotte
ARKANSAS
Los Angeles
ARIZONA
NEW MEXICO
Atlanta
SOUTH CAROLINA
San Diego
Phoenix
Dallas
MISSISSIPPI
ALABAMA
GEORGIA
Tucson
El Paso
TEXAS
BAJA CALIFORNIA
SONORA
Austin
Houston
LOUISIANA
New Orleans
Jacksonville
CHIHUAHUA
San Antonio
Orlando
Tampa
FLORIDA
COAHUILA
NUEVO LEON
Miami
Gulf of California
BAJA CALIFORNIA SUR
SINALOA
DURANGO
Monterrey
Gulf of Mexico
The Bahamas
Mexico
TAMAULIPAS
Havana

A movement

Next steps - High priority locations

- Outside schools
- SRTS (safe routes to school)
- High crash corridors, esp. where the sidestreet volumes are low
- Pedestrian districts
- Dual left turns



Bikes though?

People just do it…

NYC passed bill in May 2019

Questions

- Equity concerns?
- What % of our signals are low-hanging fruit? Goal #?
- At what point do people walking expect them at signals?
- Corridor by corridor approach vs. dispersed?
- Clarify bike use of LPIs?

Conclusion

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NCHRP 03-133: Non-Motorized Users at Traffic Signals

Burak Cesme and Peter Furth

APBP Conference

Portland, Oregon

August 27, 2019

NCHRP 03-133: Traffic Signal Design and Operations Strategies for Non-Motorized Users

- Develop ***toolbox of strategies and treatments*** to make traffic signals work better for peds/bikes

- April 2018 – March 2020

Northeastern

WAYNE STATE UNIVERSITY

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3 “Raises/Razes”

- **Raise** the roof
  - Research and innovation – advance practice
- **Raise** the floor
  - Improve practice – adjust the status quo
- **Raze** the barriers
  - Improve processes for implementation

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SET 1: Basic Treatments to Reduce Pedestrian Delay

1. ***Evaluating Pedestrian and Bicycle Crossing Delay***
2. ***Short Cycle Length***
3. ***Maximizing Walk Interval Length***
   a. *General (Pre-timed Phases)*
   b. ***Rest in WALK***
   c. *Adapting Minimum Green to Demand*
   d. *Adaptive Walk Intervals*
   e. *Changing from actuated to pre-timed*
4. *Permissive Periods for Pedestrian Actuation*
5. *Recall versus Actuation for Pedestrians*

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"Evaluating Pedestrian and Bicycle Crossing Delay"

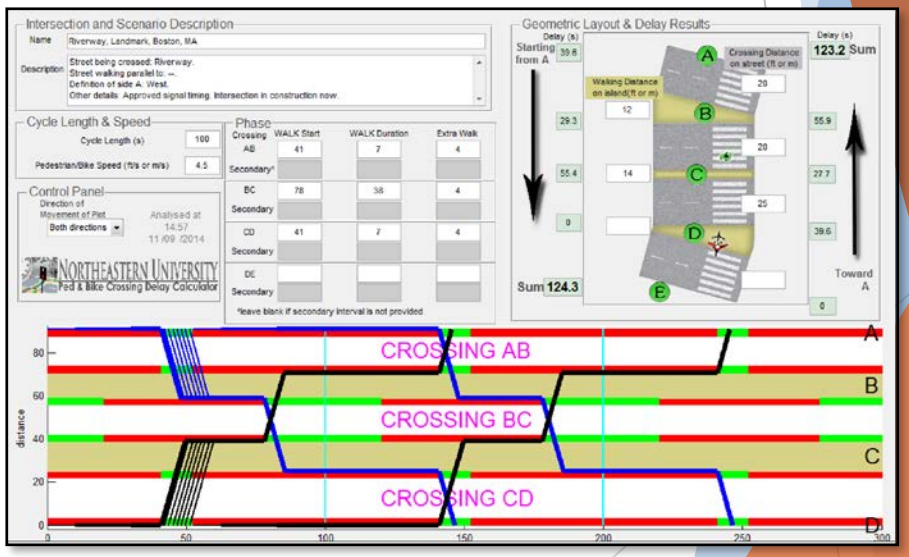
- *Policy: Whenever vehicular delay is reported, ped delay must be reported, too.*

"Only what's measured counts"

Boston Example

Timing Plan 1: 123 s average ped delay

Timing Plan 2: 45 s average ped delay (with 0.5 s increase in vehicular delay)



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"Short Cycle Length"

Amsterdam Policy:

1. Make cycles as short as possible
2. Maximum Cycle = 100 s

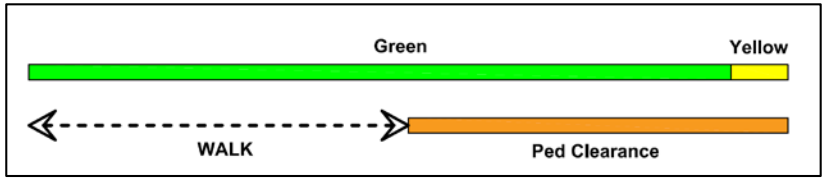
- ❑ Less Pedestrian Delay, Less Transit Delay
- ❑ Better Ped/Bike Compliance
- ❑ Fewer Speeding Opportunities

"Maximizing WALK Interval Length"

Not this:

but this:

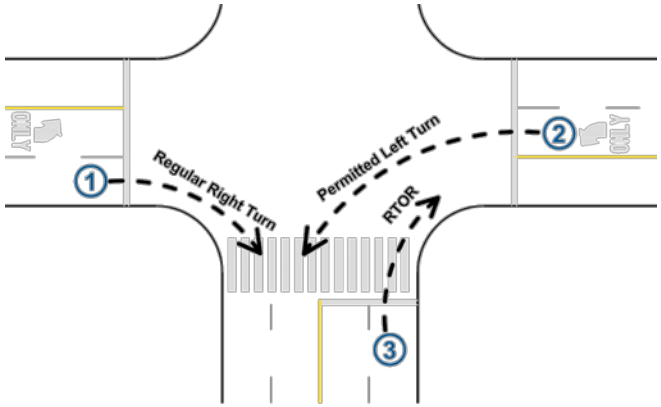
[Make the WALK interval as long as will fit within the parallel vehicular phase]



For coordinated phases, use the setting "Rest in WALK"

SET 2: Eliminating Conflicts with Parallel Traffic Turns

1. *Exclusive Pedestrian Phases*
2. ***Protected Left Turns on Multilane Roads***
3. ***Concurrent Yet Protected Pedestrian Crossings***
4. *Delta Islands for Ped and Bike Crossings*



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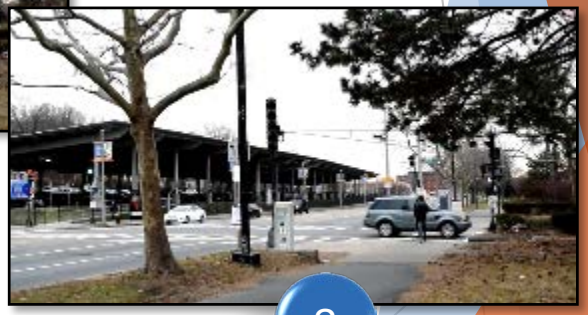
"Protected Left Turns on Multilane Roads"

Amsterdam Policy: On multilane roads, left turns are protected only, never "permitted".



US Guidelines: Permitted lefts are OK unless:

- 50+ mph speed limit
- Crossing 4+ lanes
- Crash experience
  - *Contrary to Vision Zero principles*

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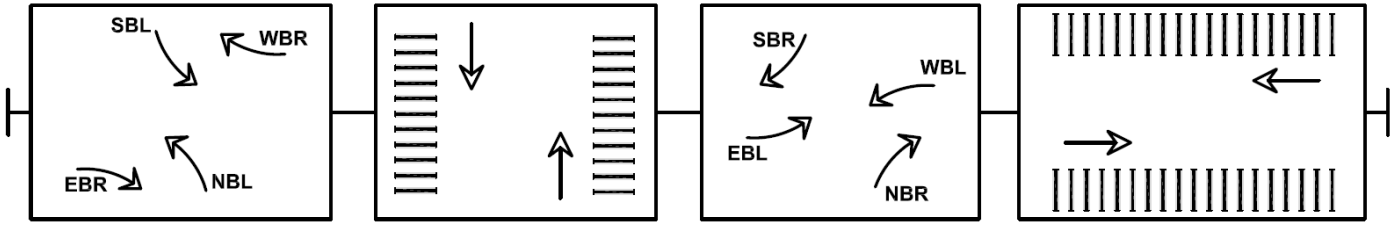
"Concurrent Yet Protected Pedestrian Crossings"

a.k.a. Protected Right Turns, Right-Turn Overlap

Using right turn AND left turn signals to protect crossings from all turn conflicts



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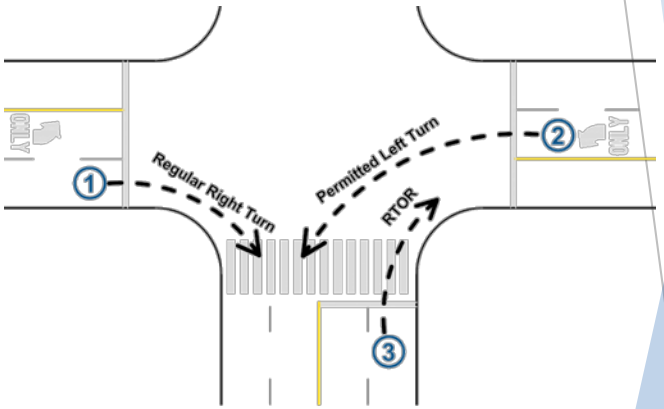
SET 3: Mitigating Conflicts with Parallel Traffic Turns

1. ***Leading Pedestrian Intervals***
2. ***Delayed Turn***
3. ***Flashing Ped/Bike Crossing Warning***



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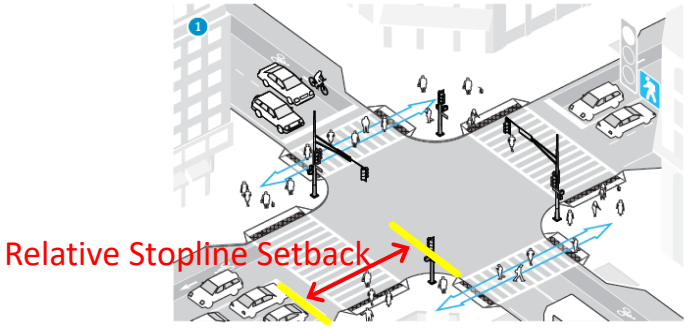
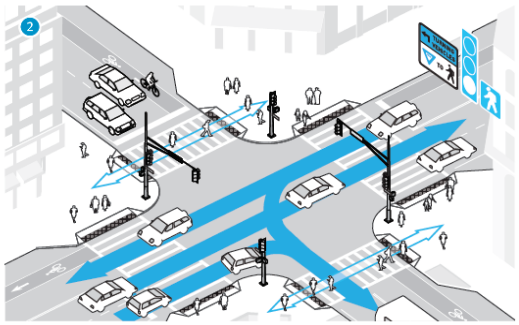
"Leading Pedestrian Intervals"

a.k.a. Pedestrian Head Start



Leading interval (3-7 s): Peds only



Concurrent traffic with turn conflicts

1. Audible signal needed
2. May bikes use it, too?
3. Can make cycle longer – and so in Netherlands:
   - NOT used where "protected intersection" layout gives peds/bikes a head start *in space.*
   - Only used where bike & car have the same stopline

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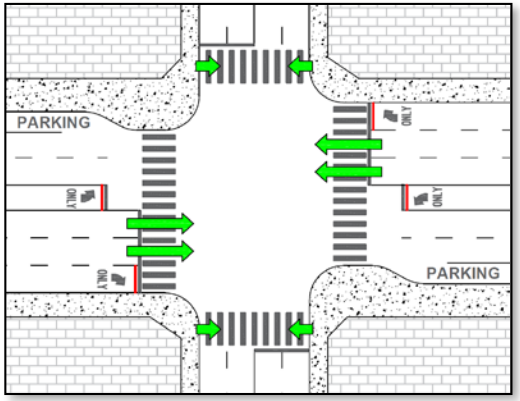
"Delayed Turn"

a.k.a. Leading Bike Interval, Leading Thru Interval, LPI+



Leading interval (10 s or more)

Charlotte ("LPI-Plus")

New York, Charlotte: Only with a right turn lane

Montreal: Without a right turn lane

"Flashing Ped/Bike Crossing Warning"

Flashing Yellow Arrow

"LET OP" = WATCH OUT

Flashing Bike Crossing Warning, Amsterdam

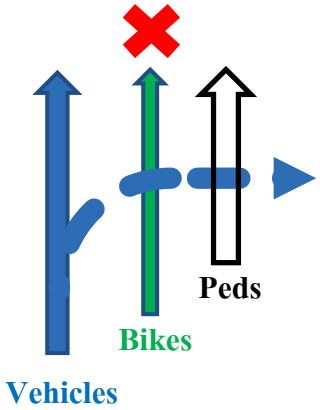
SET 4: Better Crossing Experience

1. *Countdown for WALK + FLASHING DON'T WALK*
2. *Red Period Countdown*
3. *No Turn on Red*
4. *Independently Mounted Pushbuttons*
5. *Accessible Signals without Pushbuttons*
6. *Call Indicators*
7. *Serving Slower Pedestrians*

SET 5: Bicycle Phases and Special Bike Needs

1. ***Indicating Bike Phases***
2. *Detection for Bicycles*
3. *Diagonal Bike Crossing Phases*
4. *Minimum Green and Safety-Based Green Extension for Bikes with Shared Traffic Signals*
5. *Minimum Width Crossing Islands for Bikes, and Single-Stage Bike Crossings next to Two-Stage Crossings for Pedestrians*

"Indicating Bike Phases"



FHWA won't allow bike green if there are permitted turn conflicts

SET 6: Special Phasing Techniques Favoring Peds and Bikes

1. *Multi-Stage Crossings*
   a. *Progression through ped crossings*
   b. *Pedestrian Overlaps with Left Turn Phases and Different Lead-Lag Phasing Sequences*

2. *Pedestrian Phase Overlaps with Each Other, with Bike Phases, and with Vehicular Holds*

3. ***Re-service for the Ped/Bike Phase***

4. *Two-Stage Left Turn Progression for Bikes*

5. *HAWK Signals at Intersections with Minor Streets*

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"Re-service for the Ped/Bike Phase"

***Reservice**: twice per cycle*

***Run free:** on demand, allowing cars 10 s green between ped phases*

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Pedestrian Recall vs. Pushbutton Actuation

- Research Need

Pedestrian Volume	Decision	Medium	Long
Low	Actuation	?	**Recall**
Medium	?	?	**Recall**
High	Recall	Recall	Recall

- Decision involves a tradeoff between
  - Impact on operations (traffic delay, capacity, progression, cycle length)
  - Impact on pedestrians (delay, compliance/safety)

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Research Questions

- When would there be a small traffic impact of putting ped phases on recall?
- Is there a ped volume threshold to set ped phases on recall?
- How is it different for peds crossing major street or side street?

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Research Methodology: Base Model

- Microsimulation on a real arterial in Virginia (Route 1)
- Coordinated-actuated arterial with 110 seconds cycle length
- Focusing on a single (test) intersection that is non-critical (i.e., has slack capacity)
- Modeled both peds crossing main arterial and side street
- Recall was tested only for peds crossing main arterial (7 sec of Walk and 20 sec of FDW)
  - Crosswalk across side street was set to Rest in Walk

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Research Methodology: Scenario Testing and Variables

Probability of pedestrian demand in a given cycle (denoted as "PP")
0.1 (4 peds/hr)
0.3 (12 peds/hr)
0.5 (24 peds/hr)
0.7 (42 peds/hr)
0.9 (80 peds/hr)

Side street vehicle green time required as a fraction of Min Ped Green time required (denoted as "SSG")
0.5
0.6
0.7
0.85
1.0
1.2

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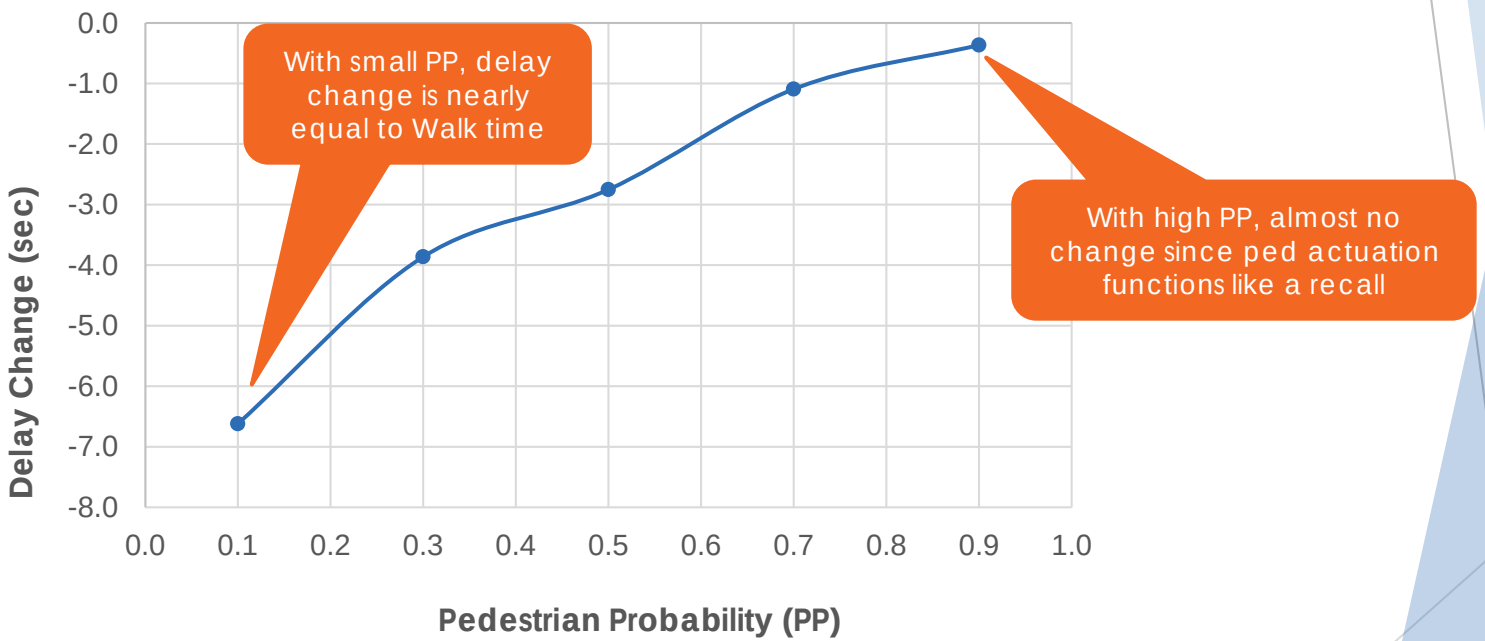
Preliminary Results: Delay Change for Peds Crossing the Main Arterial



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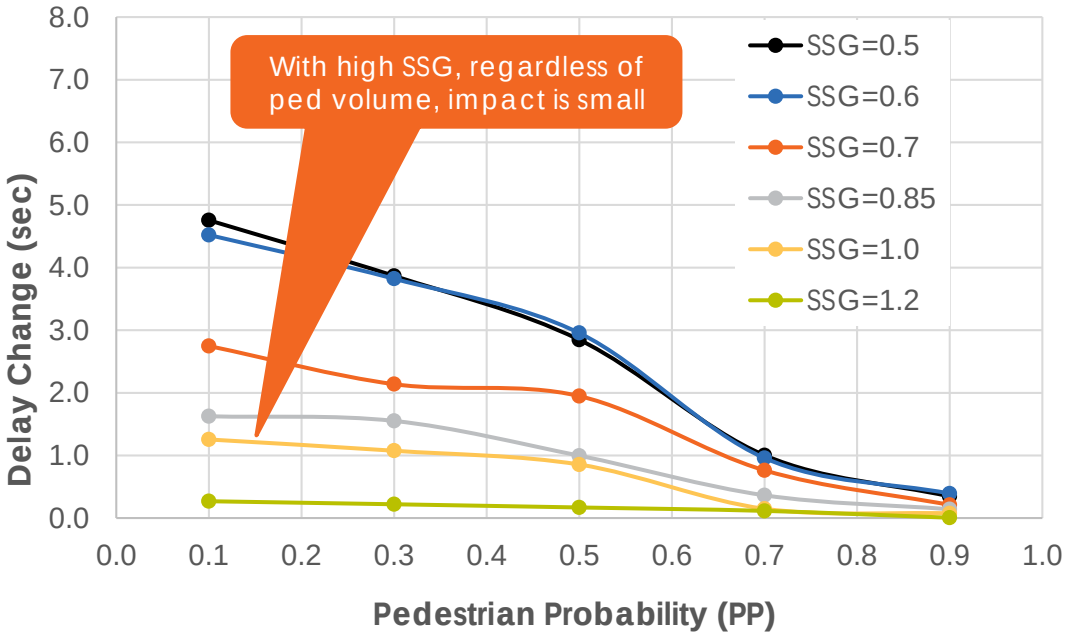
Preliminary Results: Delay Change for Peds Crossing the Side Street



SSG=0.5, PP=0.1 Scenario

Peds Crossing Main Arterial	Peds Crossing Side Street
-7 seconds 59 seconds to 52 seconds	**+5 seconds** 8 seconds to 13 seconds

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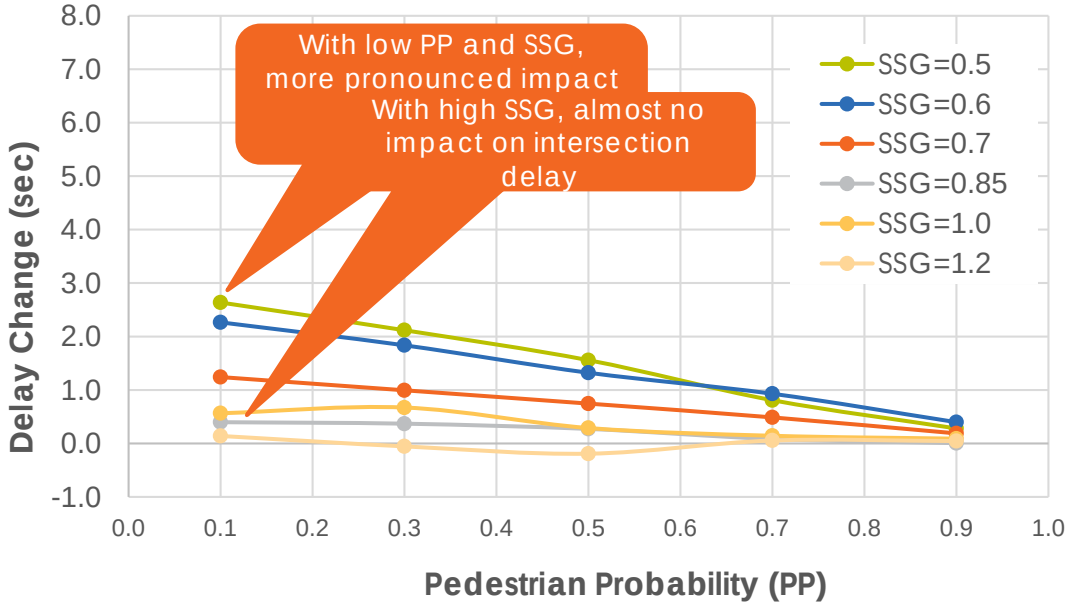
Preliminary Results: Intersection Vehicle Delay



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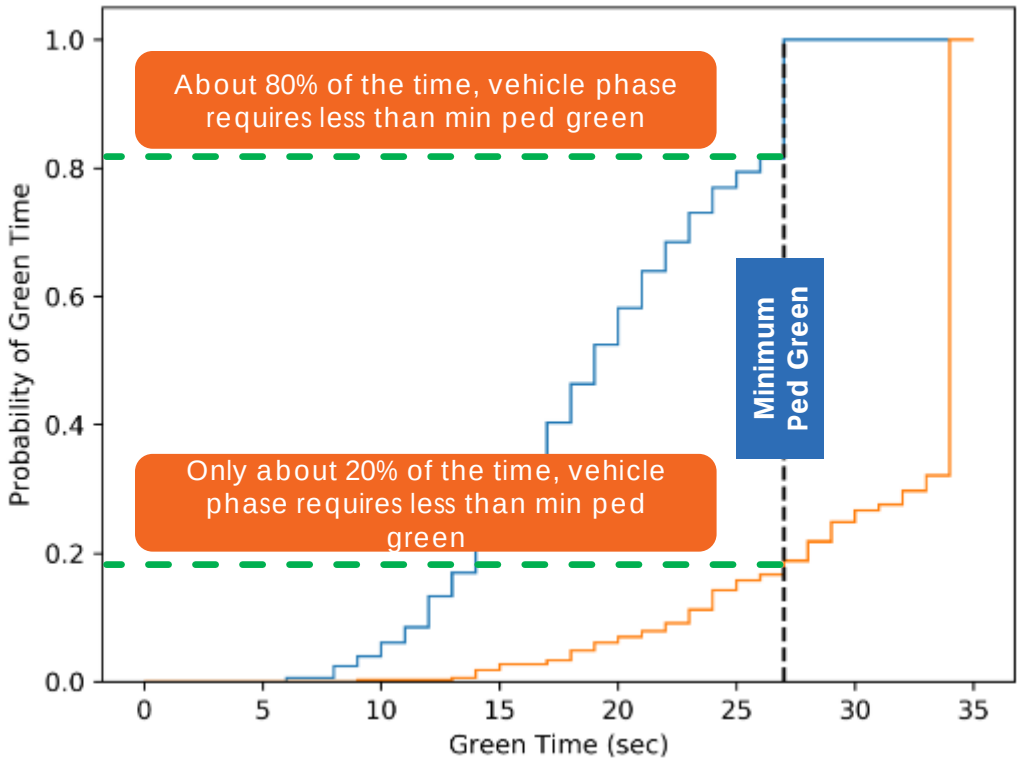
Preliminary Results: Side Street Phase Green Time Distribution



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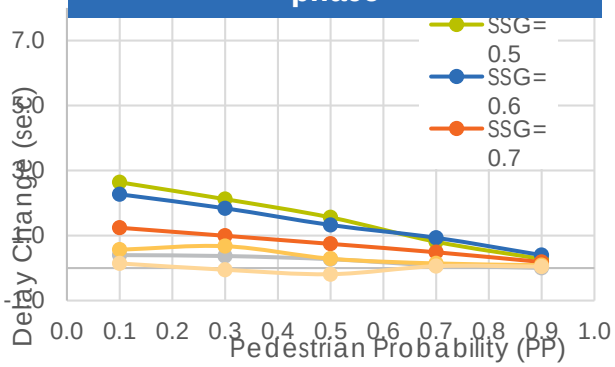
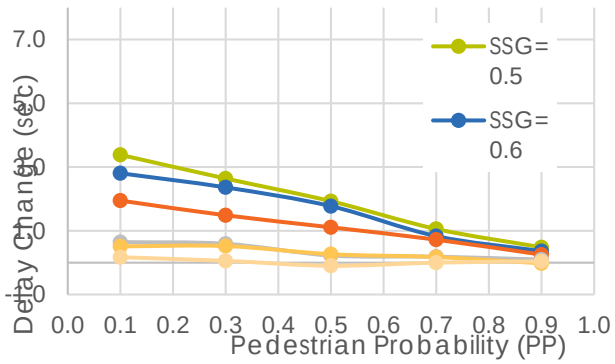
Sensitivity to Progression Band: Intersection Delay

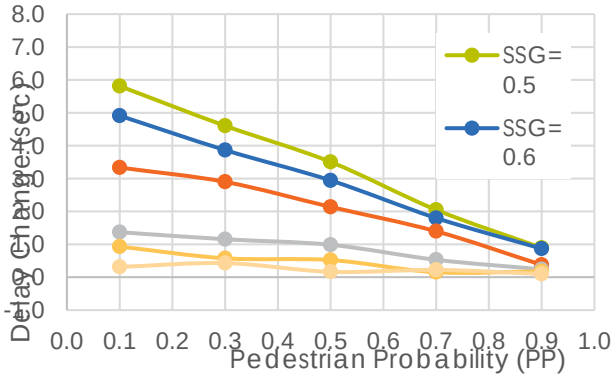
***Scenario A (Original Scenario)*: Platoons arrive towards the middle of the coordinated green phase**



***Scenario B*: Platoons arrive towards the start of the coordinated green phase**



***Scenario C*: Platoons arrive before the start of the coordinated green phase**



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Questions?

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