PBIC Crash Types Series
Left-Turn Crashes Involving Pedestrians

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Thursday, October 25, 2018

PBIC Webinar

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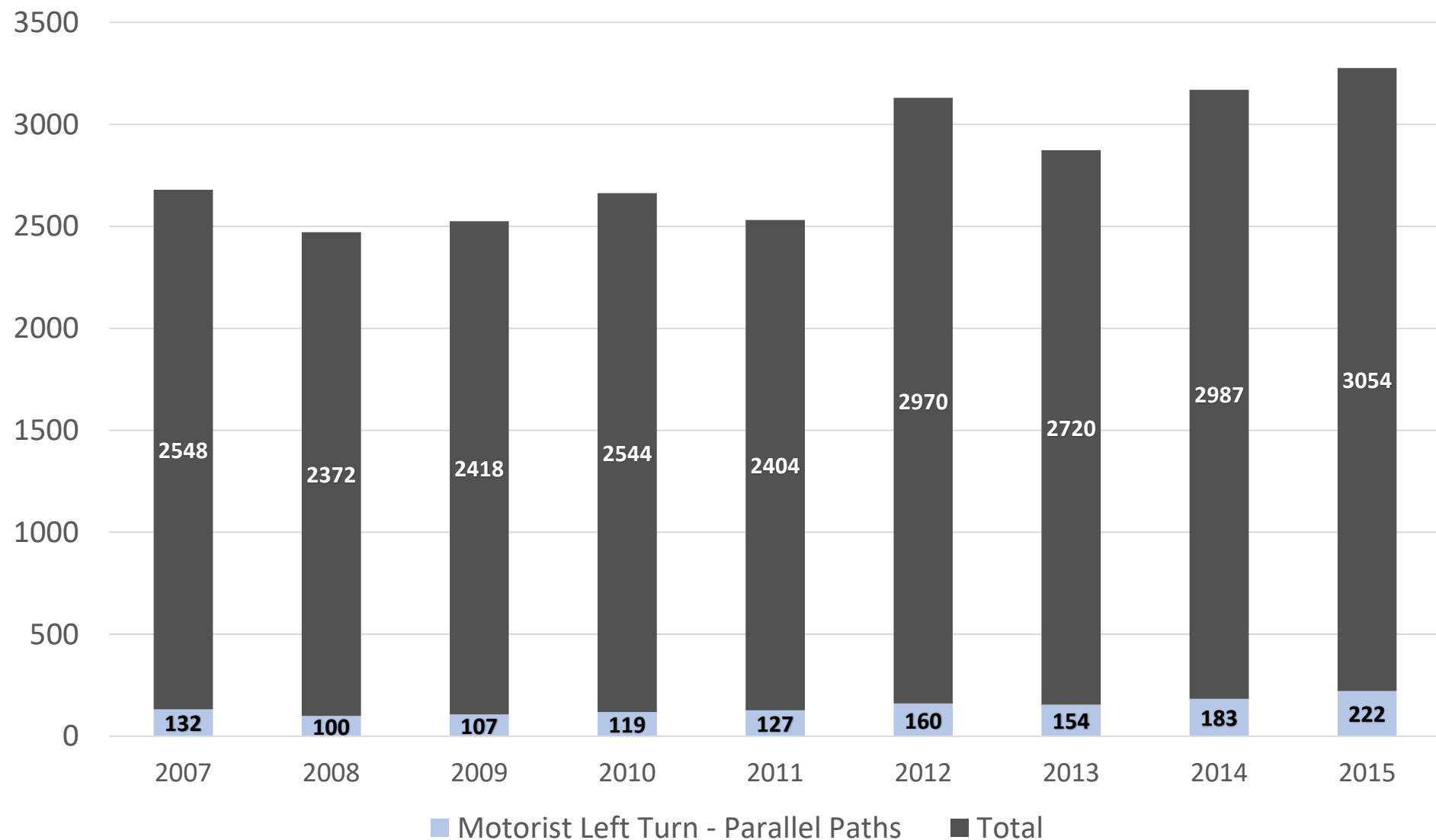# Left-Turn Crashes

Left-Turn Crashes

Left-Turn Crashes

Crash Types Involving Motor Vehicle Left Turns

Libby Thomas
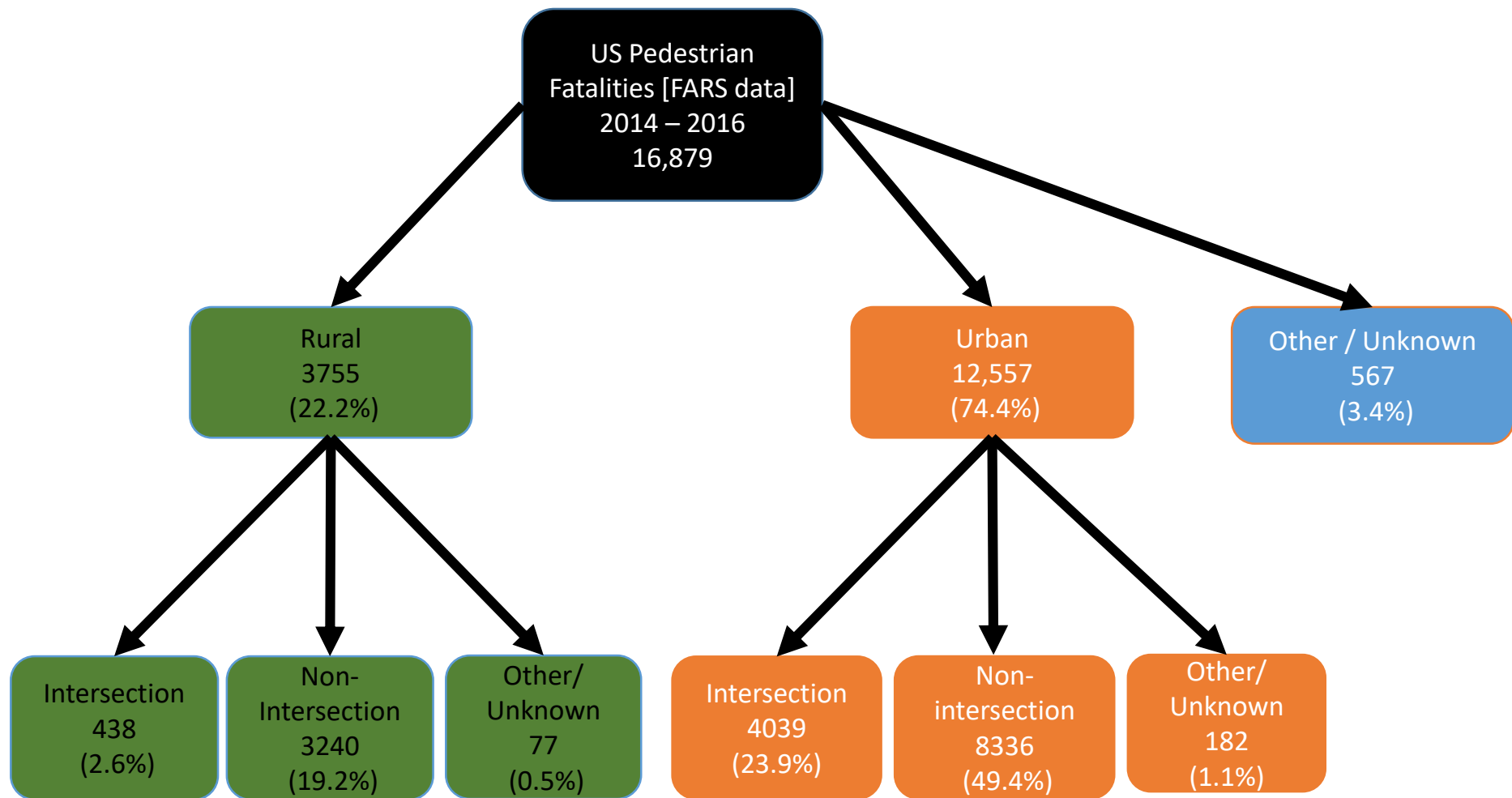University of North Carolina
Highway Safety Research Center

October 25, 2018

Crash Year	Person Type	No Apparent (O)	Possible (C)	Suspected Minor (B)	Suspected Serious (A)	Fatal Injury (K)	Injured, Severity Unknown	Unknown	Total
					Injury Severity of Pedestrians and Cyclists IN Fatal Crashes, Source: FARS data, NHTSA				
2014	Pedestrian	7	73	130	201	4910	2	2	5325
	Bicyclist	2	2	11	15	723	0	0	753
	Other Cyclist	0	0	0	0	6	0	0	6
	Persons on Personal Conveyances	0	0	5	5	158	0	1	169
	Total	9	75	146	221	5797	2	3	6253
2015	Pedestrian	15	63	132	213	5495	4	4	5926
	Bicyclist	1	3	14	18	828	1	0	865
	Other Cyclist	0	0	0	0	1	0	0	1
	Persons on Personal Conveyances	0	4	3	7	160	0	0	174
	Total	16	70	149	238	6484	5	4	6966
2016	Pedestrian	6	74	127	191	5987	7	6	6398
	Bicyclist	2	4	7	17	835	0	0	865
	Other Cyclist	0	0	0	1	5	0	0	6
	Persons on Personal Conveyances	1	5	0	4	169	0	0	179
	Total	9	83	134	213	6996	7	6	7448
All 3 years	Pedestrian	28	210	389	605	16392	13	12	17649
	Bicyclist	5	9	32	50	2386	1	0	2483
	Other Cyclist	0	0	0	1	12	0	0	13
	Persons on Personal Conveyances	1	9	8	16	487	0	1	522
	Total	34	228	429	672	19277	14	13	20667

North Carolina Pedestrian Crash Trends - All Severity

Year	Motorist Left Turn - Parallel Paths	Total
2007	132	2548
2008	100	2372
2009	107	2418
2010	119	2544
2011	127	2404
2012	160	2970
2013	154	2720
2014	183	2987
2015	222	3054

■ Motorist Left Turn - Parallel Paths   ■ Total

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US Pedestrian Fatalities [FARS data] 2014 – 2016 16,879

Rural 3755 (22.2%)

Urban 12,557 (74.4%)

Other / Unknown 567 (3.4%)

Intersection 438 (2.6%)

Non-Intersection 3240 (19.2%)

Other/ Unknown 77 (0.5%)

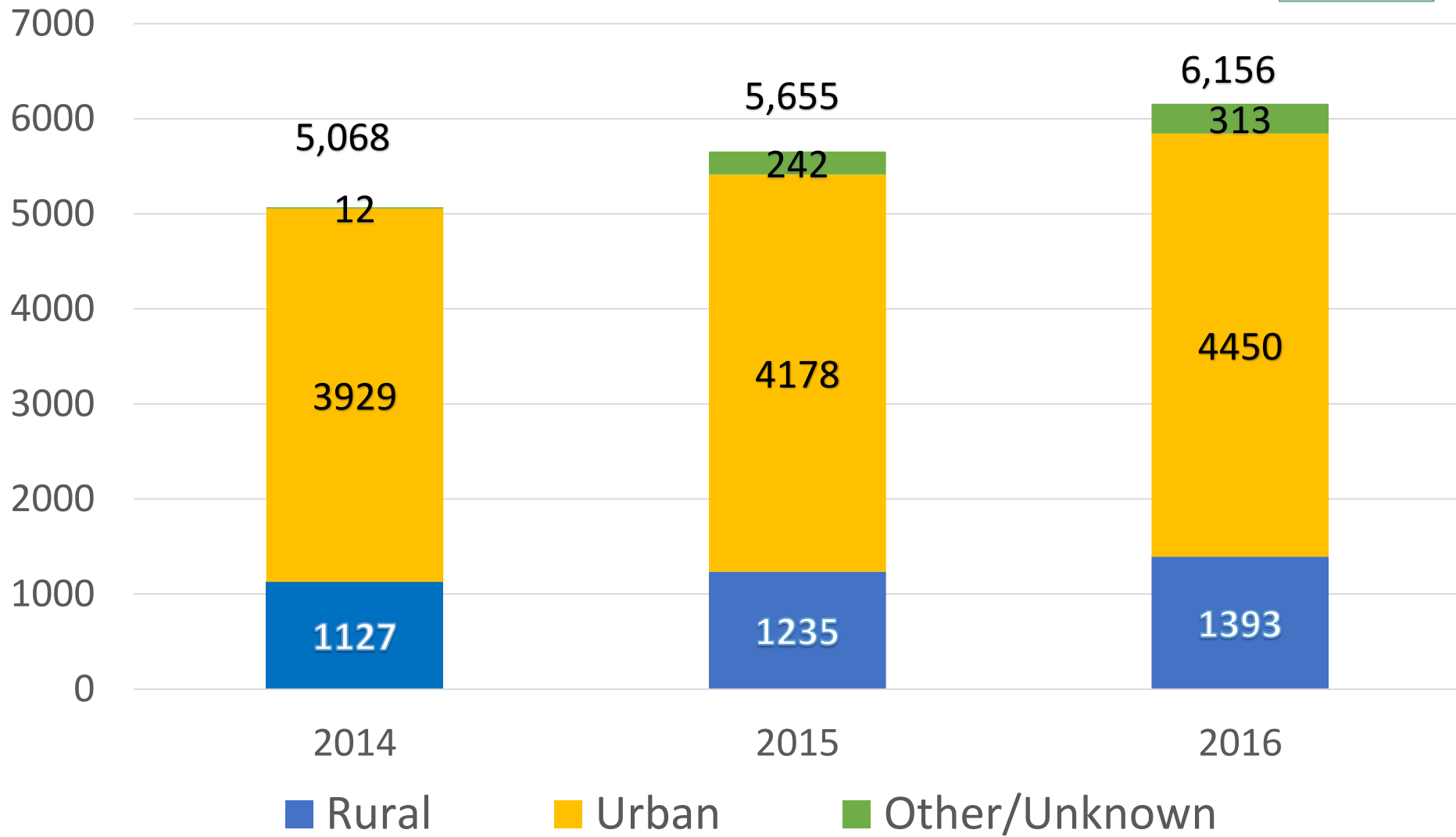Intersection 4039 (23.9%)

Non-intersection 8336 (49.4%)

Other/ Unknown 182 (1.1%)

Overall Location Types, 82.2% of Pedestrian Fatalities were associated with locations with No Traffic Control for the Motorist

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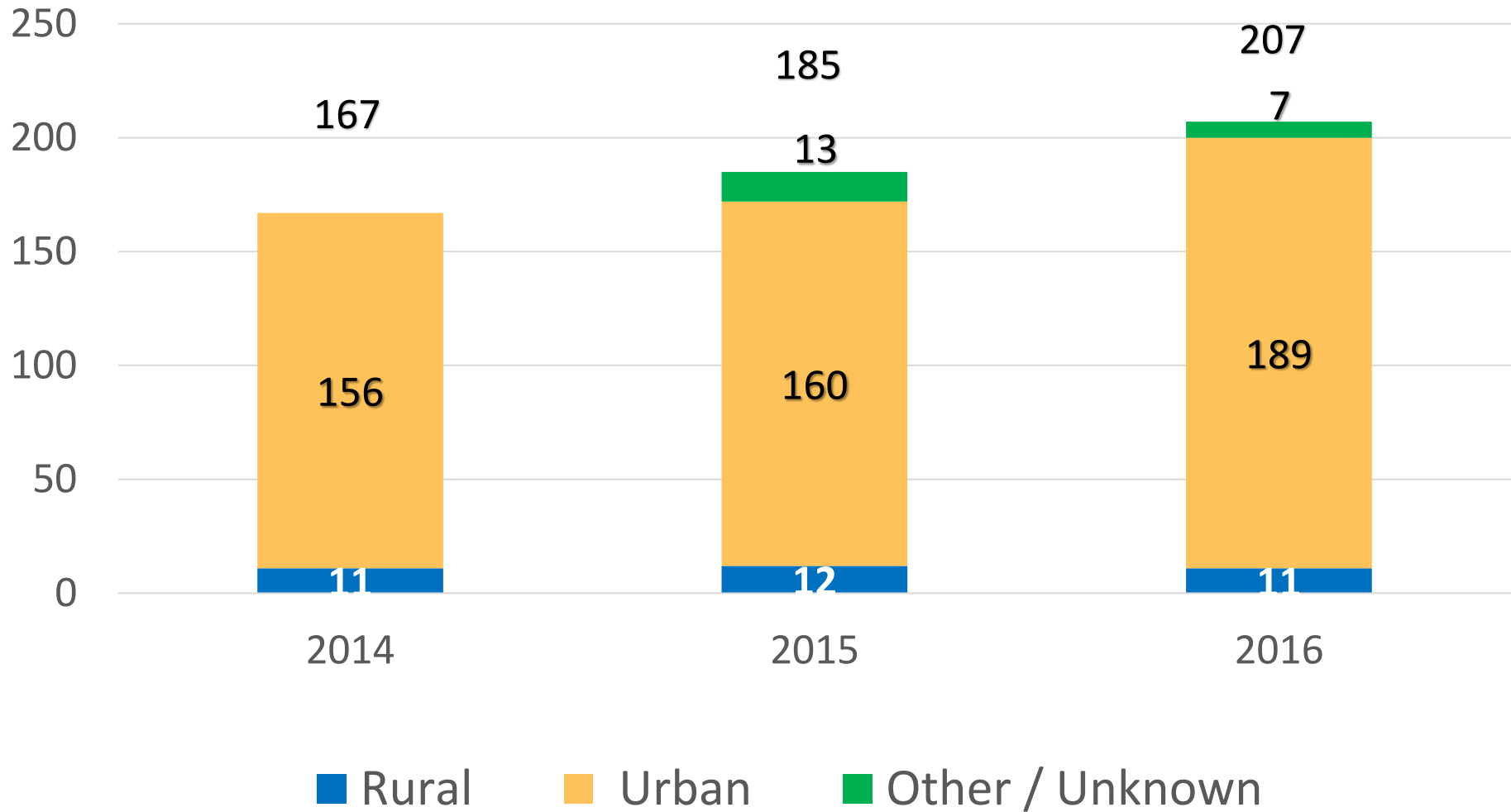pedbikeinfo.org
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U.S. Pedestrian Fatalities

74% Urban

Year	Rural	Urban	Other/Unknown	Total
2014	1127	3929	12	5,068
2015	1235	4178	242	5,655
2016	1393	4450	313	6,156

Legend: Rural, Urban, Other/Unknown

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U.S. Pedestrian Fatalities - Motorist Left Turn

90% Urban

Year	Rural	Urban	Other / Unknown	Total
2014	11	156		167
2015	12	160	13	185
2016	11	189	7	207

Legend: Rural, Urban, Other / Unknown

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Relative Frequencies of Crash Type

	U.S. Fatalities 2014-16			NC All Severity Urban 2007-15			NC All Severity Rural 2007-2015		
	Freq.	Rank	Percent	Freq.	Rank	Percent	Freq.	Rank	Percent
Motorist Left Turn - Parallel Paths	523	10	3.1	1,207	4	6.8	97	17	1.5
Motorist Left Turn - Perpendicular Paths	36	38	0.2	46	43	0.3	10	44	0.2
Total number all types	16,879			17,632			6,385		

Motorist Left Turn – Perpendicular Paths

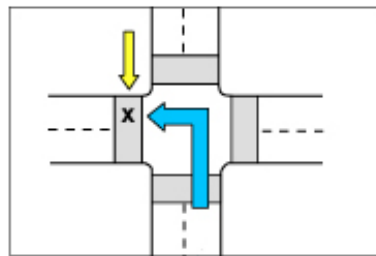6%
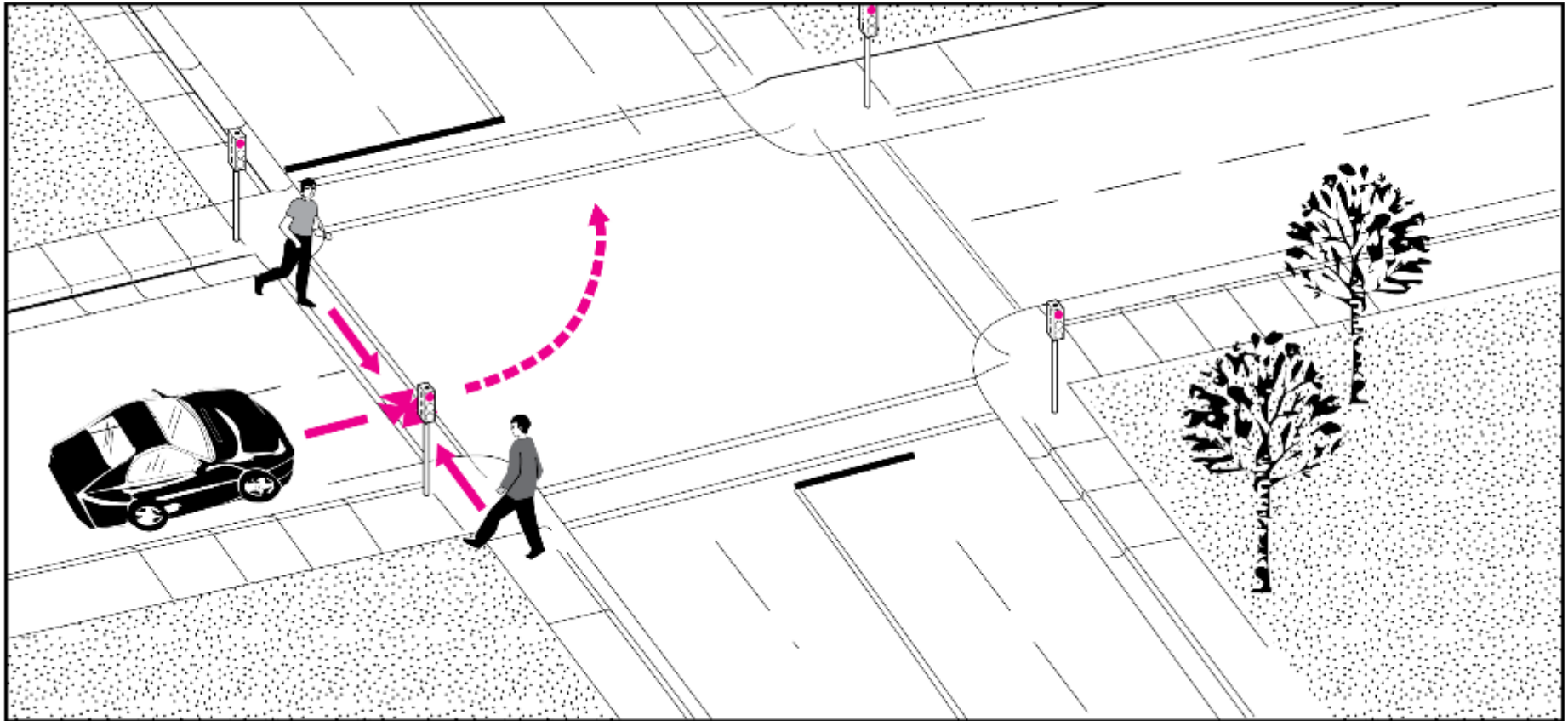
Motorist Left Turn – Parallel Paths
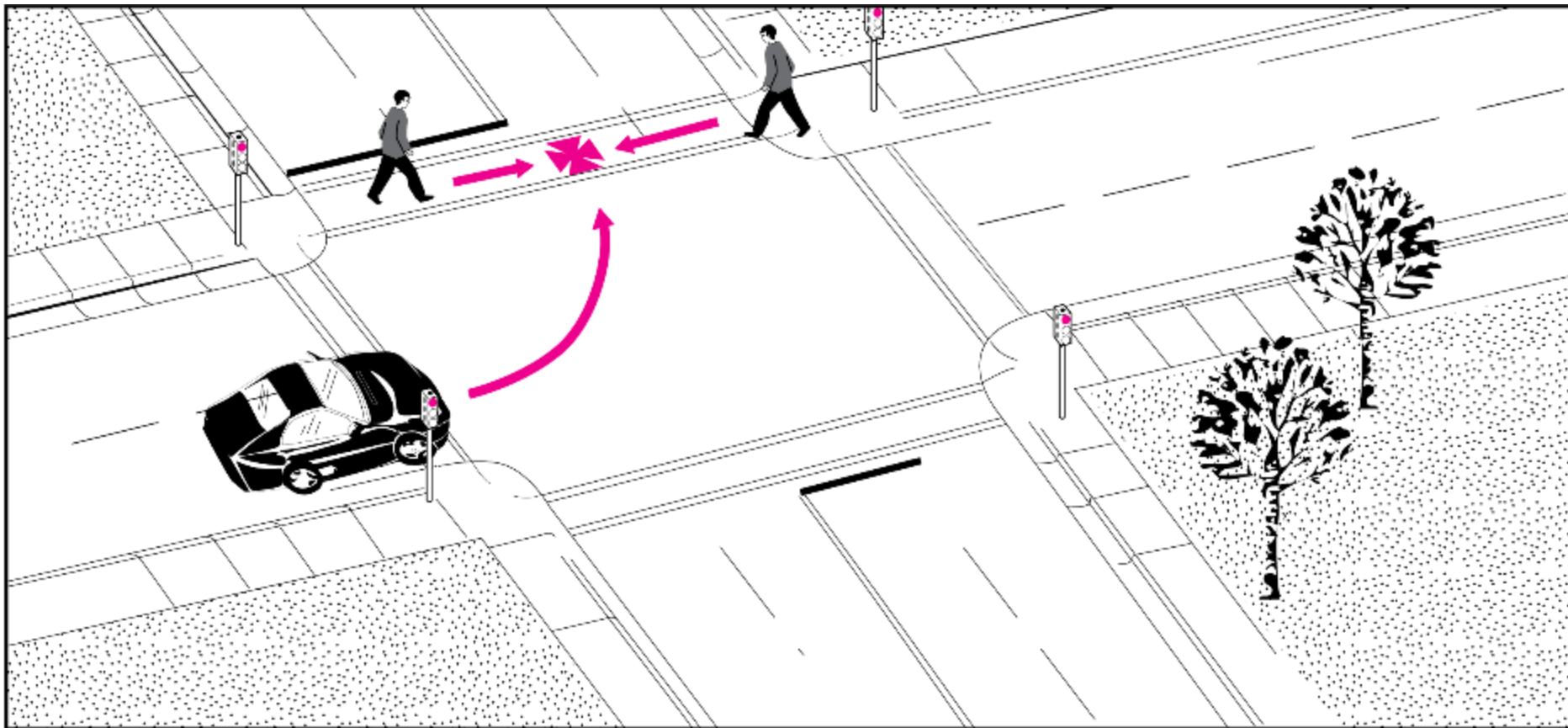
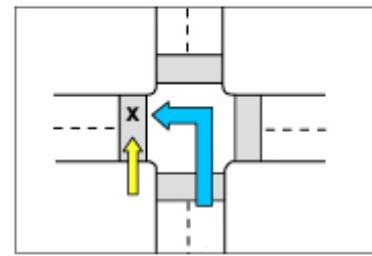| Pedestrian Crash Type	FARS - Motorist Left Turn - Parallel Path Pedestrian	FARS Motorist Left Turn - Perpendicular Path Pedestrian	FARS - All Ped Crossing Types (turning/non-turning m.v.)	NC – All severity Motorist Left Turn - Parallel Path
Intersection %	80	78	31	77
Intersection-related %	13	8	11	12
Traffic Signal %	66	67	22	58
Stop Sign for MV %	15	14	2	22
No Control for MV %	17	19	74	15
Median-divided %	14	22	36	
TWLTL %	6	11	17	
One-Way %	11	3	3	
Two-Way Undiv. %	66	56	42	
Daylight %	72	58	23	68
20 - 25 mph %	37	22	11	27
30-35 mph %	38	28	32	56
40-45 mph %	8	28	36	12
Total frequency (N)	**523**	**36**	**8,148**	**1,304**

Most Frequent Scenarios for Motorists Left Turn – Parallel Path Pedestrian

Pedestrian Crash Scenario – Relative pedestrian directions and position	**11b.** Pedestrian within crosswalk area, approach direction opposite motorist's.	**11a.** Pedestrian within crosswalk area, approach direction same as motorist's.	**12b.** Pedestrian outside crosswalk area, approach direction opposite motorist's.
Percent of total	40% occurred like this	22% like this	8% like this

- Pedestrian traveled from same direction as motorist, outside crosswalk area = 4%
- All others – Unknown or not applicable

Summary

- Most (75%) occur on lower speed roads (up to 35 mph);
- During daylight hours (72%);
- At signalized locations (66%); and
- On Two-way, undivided facilities (66%)

- Motorist turning left across parallel path pedestrian is a common crash type resulting in 3% of all U.S. pedestrian fatalities.
- This type appears to be even more frequent among all severity of pedestrian crashes (7% of reported in urban areas of NC)
- Most common scenario among fatalities involves the pedestrian approaching in a crosswalk from the opposite direction to the turning motorist
- Crash data are insufficient for assessing many types of risk factors (pedestrian facilities/conspicuity/width of crossings; presence of turn lanes/turning traffic volume; opposing traffic volumes; signal phasing, LPIs etc.)

Driver Response at Signalized Intersections Operating the Flashing Yellow Arrow:
Results From a Driving Simulator Experiment

PBIC CRASH TYPES SERIES - LEFT TURN CRASHES INVOLVING PEDESTRIANS

OCTOBER 25, 2018

Speakers:

David Hurwitz, Associate Professor, Co-PI, OSU

Chris Monsere, Professor, Co-PI, PSU

Background: Permissive Left-turns and Human Factors

- A driver facing a permissive left-turn traffic signal indication must yield the right-of-way to opposing traffic (vehicles and bicycles) and conflicting pedestrians in the crosswalk.

- Opposing vehicles are often the focus of the driver search and gap decision-making process.

- In elevated workload, drivers fail to scan for pedestrians while performing permissive left-turns (*Lord et al., 1998*).

- This is an issue where driver expectation of pedestrians is low.

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Motivations for Our Work

- **NOT** about indication type

    - Existing research clearly suggests FYA indication is the most effective display for permitted turn from an exclusive turning bay

- Add to the body of knowledge on driver behavior in response to the FYA in the presence of pedestrians

    - Pedestrian/driver interactions are addressed in a limited way in other aspects of FYA research

- Explore the effect of 4 or 3- section arrangement on driver behavior

    - Little existing work

Three or four section displays for FYA?

- 4-section signal face, required for PPLT (MUTCD 4D.20.03)

- 3-section signal face, allowed

  - permissive-only (4D.18.03)
  - protected-only (4D.19.03)
  - flashing red operations (4D.18.05)
  - when height or lateral restrictions prevent the use of a 4-section display in PPLT (4D.20.03 (H))

- Possible operational issues

  - Each sequence doesn't have own face
  - Driver color blindness
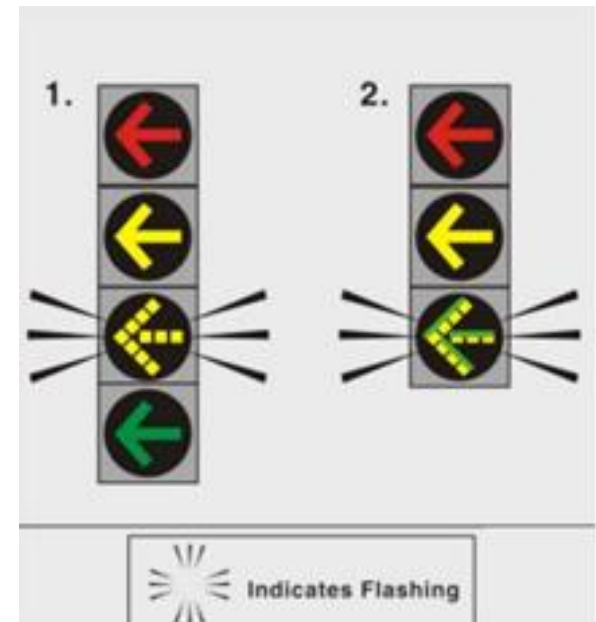
Note: Bi-modal yellow not studied

Oregon State Driving Simulator

Forward Projection

Rear Projection

Operators Station

Simulator in use

Eye Tracking

- Eye movement consists of fixations and saccades

  - Fixations are points that are focused on during a short period of time
  - Saccades are the quick eye movements between fixations
  - The majority of visual data is acquired from fixations

- The Mobile Eye-XG system records a fixation when the subject's eyes have paused in a certain position for more than 100 milliseconds

Scene & Eye Camera

Computer & Control Unit

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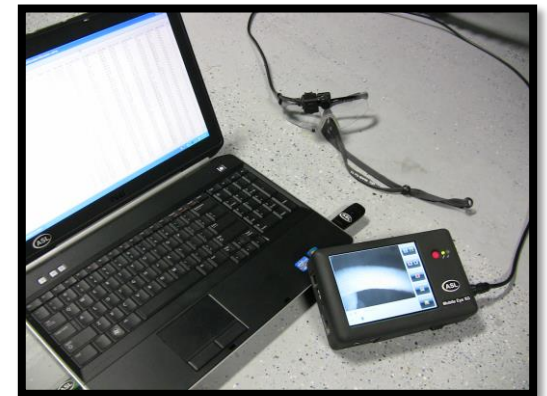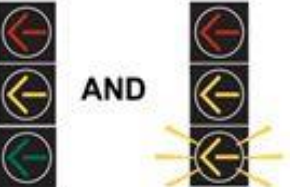
Eye Tracking Raw Video

Independent Variables

Crossing Pedestrians	Opposing Vehicles	FYA Signal Configuration
No pedestrians	No vehicles	3-section dual-arrow vertical
1 pedestrian *toward* the subject	3 vehicles	4-section vertical
1 pedestrian *away* from subject	9 vehicles	-
Four pedestrians (2 each side)	-	-

Presentation Sequence for Drivers

Simulated Environment

1 pedestrian walking away

4 pedestrians, two walking in each direction

No pedestrians

1 pedestrian walking towards

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Simulated Environment
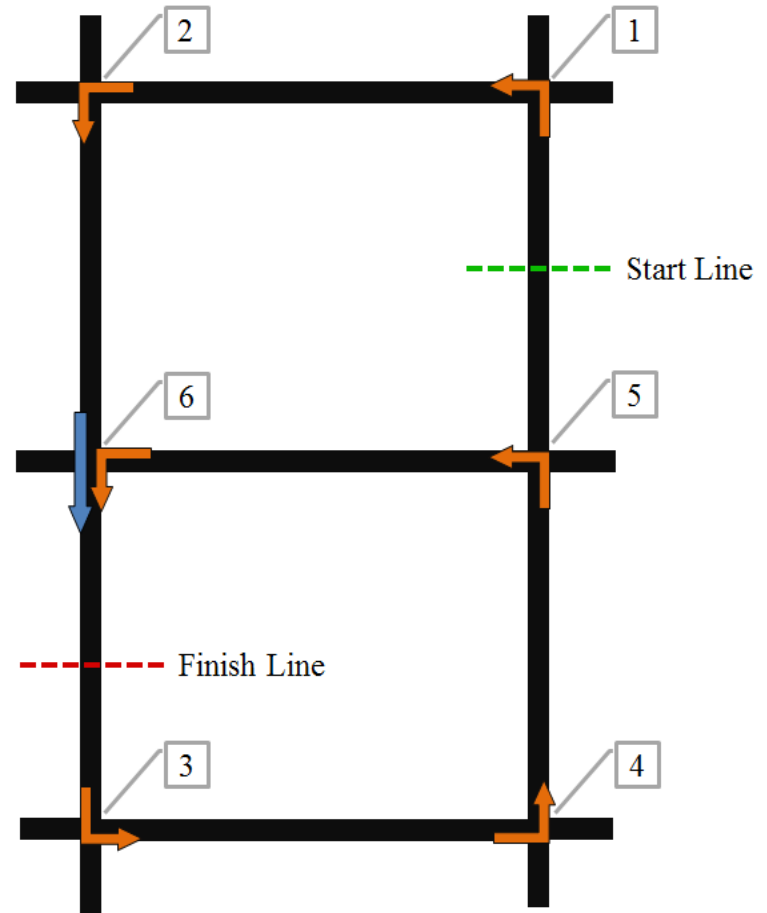
Primary Data: Driver Glance Fixation Duration
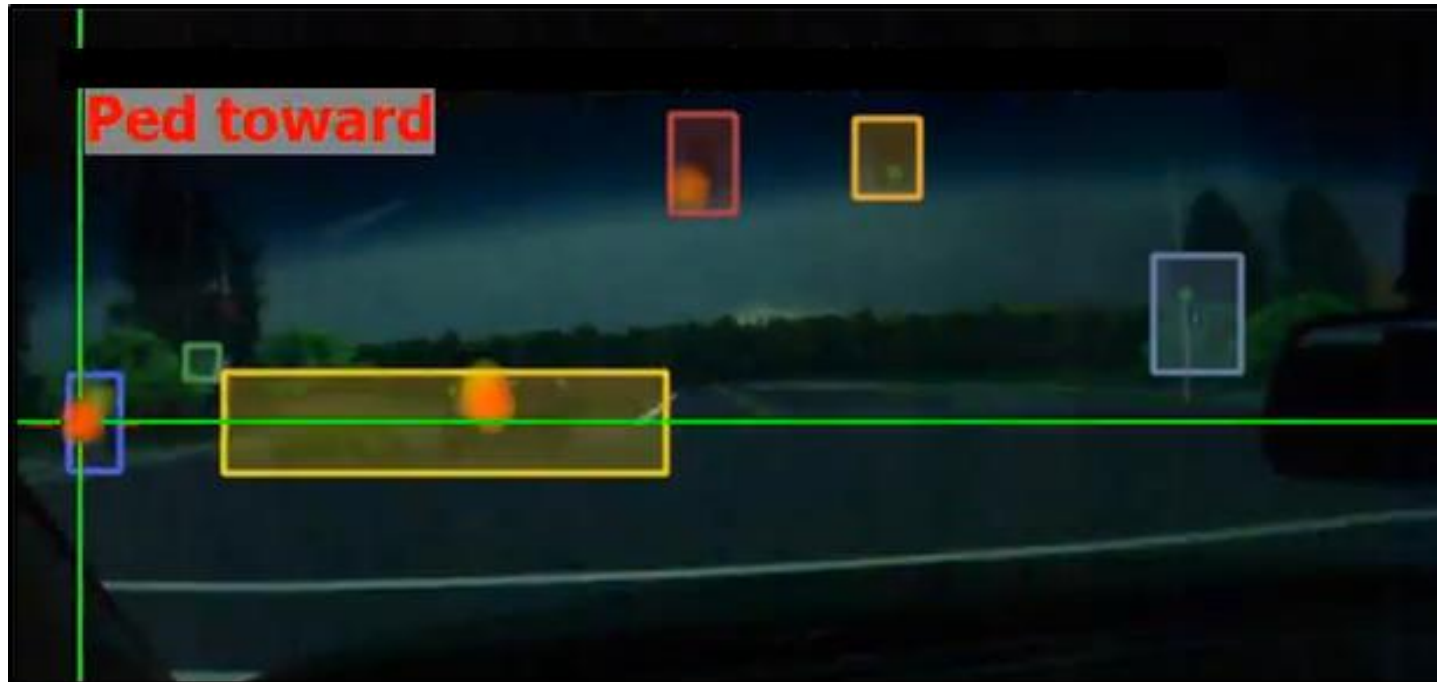
AOI Name	Fixation Count	Total Fixation Duration	Average Fixation Duration	First Fixation Time
Bay	9	3.4	0.378	15.02
FYA	7	3.11	0.444	16.02
Opposing Veh	8	2.72	0.34	24.34
OUTSIDE	27	6.19	0.229	14.29
Ped Towards	1	0.2	0.2	29.72

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Research Hypothesis 1: Fixations on AOIs by Signal Configuration

H_0: *There is no difference in the <u>total duration of driver fixations </u>during permitted left-turn maneuvers at signalized intersections operating the FYA with <u>a 4-section vertical or a 3-section dual-arrow</u> vertical configuration.*

Two Signal Configuration

- 3-Section Dual-Arrow Vertical
- 4-Section Vertical

Seven Areas of Interest (AOI)

- Turn Bay
- Opposing Vehicles
- FYA Signal
- Ped Area
- Ped Both
- Ped Towards
- Ped Away
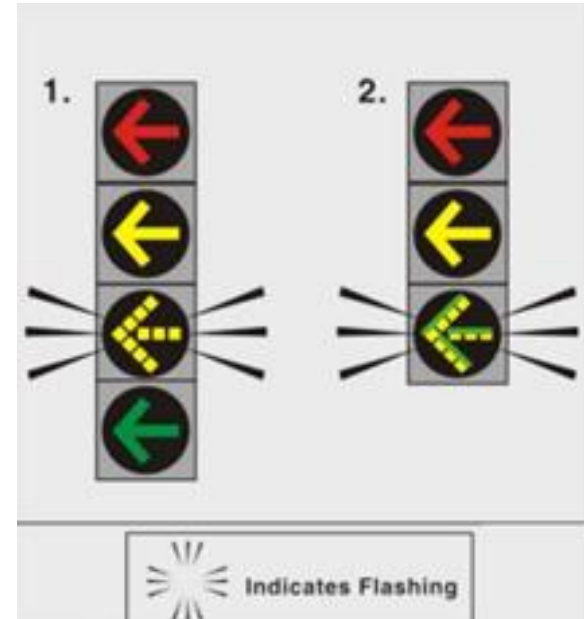
Fixations on FYA by Signal Configuration

Average Total Fixation Duration (secs)

Opposing Vehicles
n=207,207
p=0.37

Ped Both
n=78,309
p=0.59

Turn Bay
n=308,207
p=0.68

Ped Away
n=74,76
p=0.13

FYA Signal
n=308,309
p=0.48

Ped Toward
n=74,78
p=0.97

Ped Area
n=60,56
p=0.93

3-Section
4-Section

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Data Reduction: Pedestrian Location

- A secondary analysis of the data was preformed using the raw video footage from the eye tracking camera.

- The location as described by Pedestrian Lane Number (PLN) was recorded at the moment when the driver initiated a left turn movement

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Research Hypothesis 2: Pedestrian Position by Signal Configuration

H_0: There is no difference in the <u>location of the pedestrian in the crosswalk</u> when the driver initiates a permitted left-turn maneuver at signalized intersections operating the FYA with a <u>4-section vertical or a 3-section dual-arrow vertical</u> configuration.
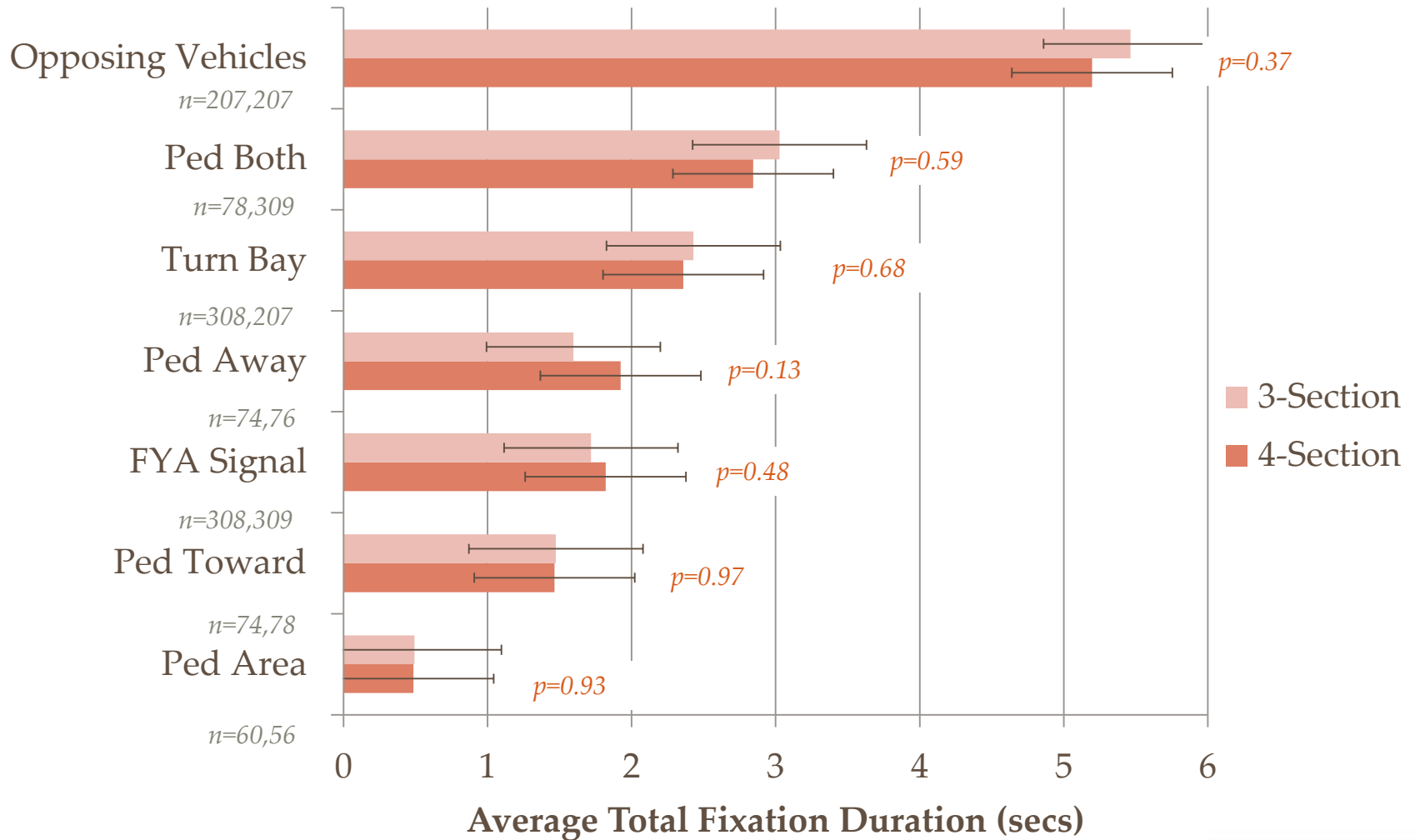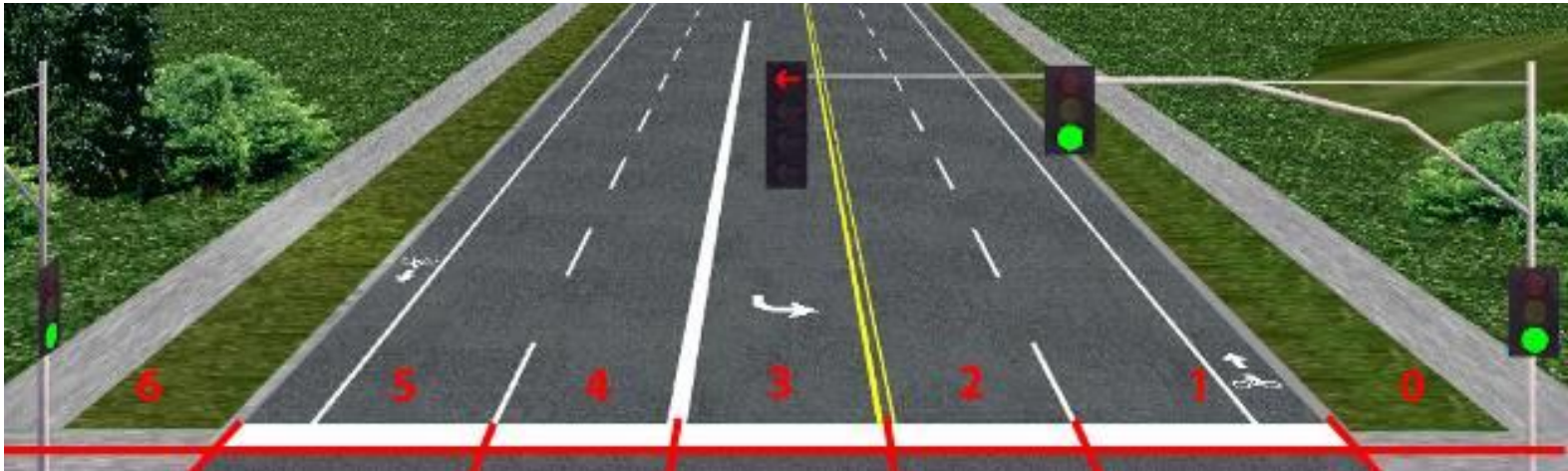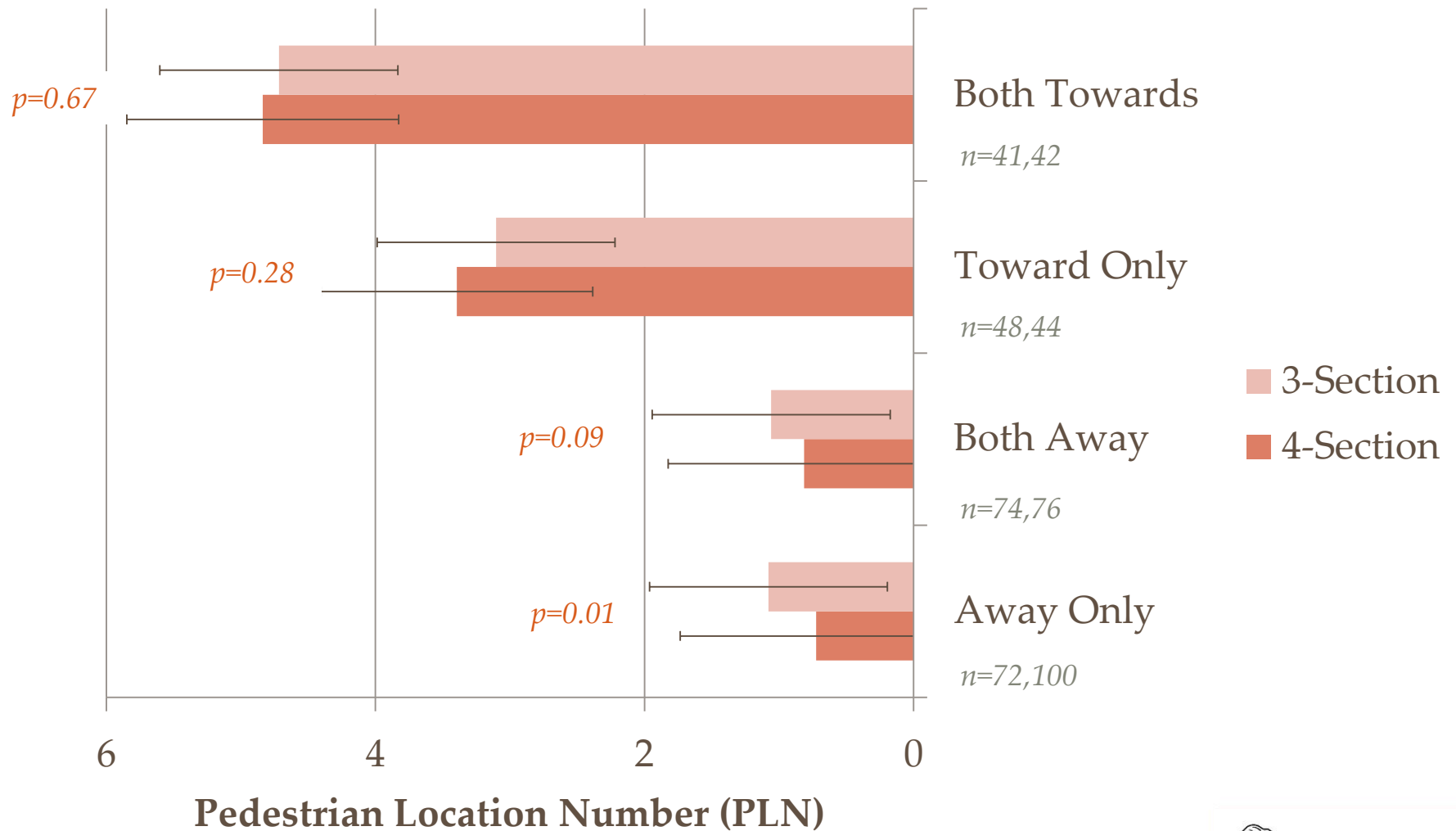
Two Signal Configuration

- 3-Section Dual-Arrow Vertical
- 4-Section Vertical

4 Pedestrian Cases

- Towards Only
- Away Only
- Towards (with peds from both directions)
- Away (with peds from both directions)

Pedestrian Lane Locations by Signal Configuration

Both Towards — n=41,42 — p=0.67

Toward Only — n=48,44 — p=0.28

Both Away — n=74,76 — p=0.09

Away Only — n=72,100 — p=0.01

Legend: 3-Section, 4-Section

X-axis: Pedestrian Location Number (PLN) — 6, 4, 2, 0

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Research Hypothesis 3: Fixations on Pedestrians

H_0: There is no difference in the <u>proportion of drivers who fixate on pedestrians or areas where pedestrians would likely be present</u> during permitted left-turn maneuvers at signalized intersection operating the FYA.

Ped Cases	Total	Did Not Fixate	
Towards	152	10	7%
Away	150	6	4%
Both	309	16	5%

Drivers Failed to fixate on pedestrians in the pedestrians in the conflicting crosswalk 4% to 7% of the time

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Conclusions

- A clear gap exists in the traffic engineering profession with respect to the implications of presenting the FYA in a 3-section or 4-section vertical configuration

- With respect to the vertical position of the flashing yellow arrow display, we observed little difference in the visual search task of drivers

  - No statistical difference was found in average fixation durations on any AOI for 4 or 3 section signal heads

  - The position of the pedestrian in the crosswalk when the driver began the left turn was not statistically different for three of the four pedestrian walking directions presented

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# Possible Signal Timing Countermeasures

- Introduce protected left-turn phasing
  - No turning vehicles when pedestrian walk + clearance active
- Introduce Leading Pedestrian Interval (LPI)
  - Hold turning vehicles, give pedestrians 3 to 7 second head start. Not as effective for late arriving pedestrians or those crossing from curb to behind driver.
- Operate permissive interval as protected/permitted (PPLT) with "pedestrian inhibit" feature
  - Delay or cancel the permissive interval when pedestrians present

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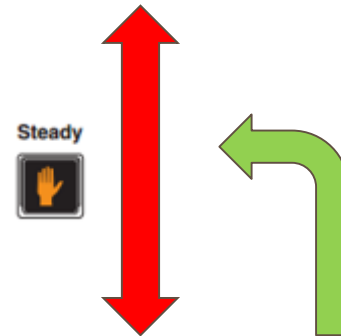# PPLT without (1) and with (2) pedestrian inhibit

1
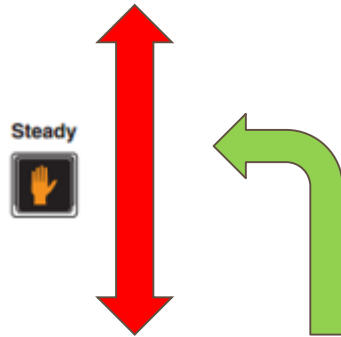
Protected Left Turn
Pedestrian Don't Walk
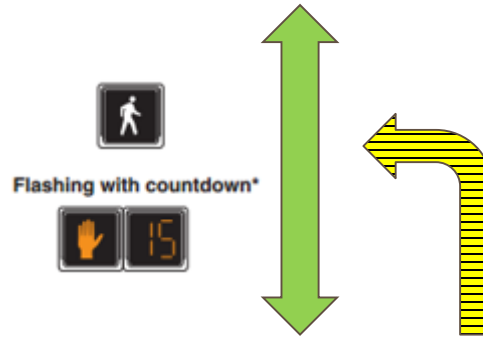
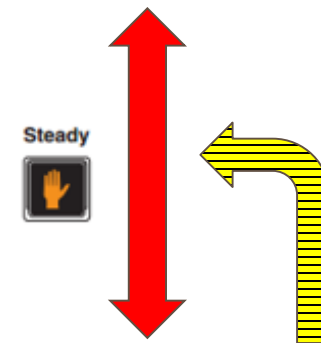Permissive Left Turn Concurrent with
Pedestrian Walk and Clearance

2

Protected Left Turn
Pedestrian Don't Walk

On ped call:
Pedestrian Walk and Clearance
Red Left Turn

No ped call and/or if time remaining:
Permissive Left Turn
Pedestrian Don't Walk

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Acknowledgments

This project was funded by the Oregon Transportation Research and Education Consortium (OTREC).

Washington County Traffic Engineering provided matching funding as well as technical support (Stacy Shetler and Ed Anderson).

Kittelson & Associates, Inc. also provided technical support for the project (Shaun Quayle).

Related Papers and Reports

- Left-turns and pedestrians (FYA):
    - Hurwitz, D., Marnell, P. Monsere, C., Paulsen. K. "*Three- or Four-Section Displays for Permissive Left-Turns?*" Transportation Research Record: Journal of the Transportation Research Board, No. 2463, Transportation Research Board of the National Academies, Washington, D.C., 2014. pp 1-9. DOI 10.3141/2463-01
    - Marnell, P., Tuss, H., Hurwitz, D., Paulsen, K., Monsere, C. "*Permissive Left-Turn Behavior at the Flashing Yellow Arrow in the Presence of Pedestrians,*" 7th International Driving Symposium on Human Factors in Driver Assessment, Training, and Vehicle Design, Bolton Landing, NY, June 2013, 488-494.
    - Hurwitz, D., Monsere, C. "*Improved Pedestrian Safety at Signalized Intersections Operating the Flashing Yellow Arrow*". Final Report, Oregon Transportation Research and Education Consortium, OTREC-RR-13-01, April 2013
- Right-turns and bicycles
    - Jannat, M., Hurwitz, D., Monsere, C., Funk, K. "*The Role of Driver's Situational Awareness on Right-Hook Bicycle-Motor Vehicle Crashes*". Safety Science, Volume 110, Part A, 2018, pp 92-101, DOI: 10.1016/j.ssci.2018.07.025.
    - Warner, J, Hurwitz, D., Monsere, C., Fleskes, K. "*A Simulator-Based Analysis of Engineering Treatments for Right-Hook Bicycle Crashes at Signalized Intersections*" Accident Analysis & Prevention, 2017 https://doi.org/10.1016/j.aap.2017.04.021
    - Hurwitz, D., Monsere, C., Jannat, M., Warner, J, Razmpa, A. "*Towards Effective Design Treatment For Right Turns At Intersections With Bicycle Traffic*". Oregon Department of Transportation SPR Project No. 767, June 2015
- Right-turns and pedestrians (FYA):
    - Hurwitz, Monsere, C., Kothuri, S., H. Jashami, K. Buker, A. Kading . "*Improved Safety and Efficiency Of Protected/Permitted Right-Turns in Oregon*". Oregon Department of Transportation, SPR 789, May 2018.

Contact Information

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Department Chair and Professor
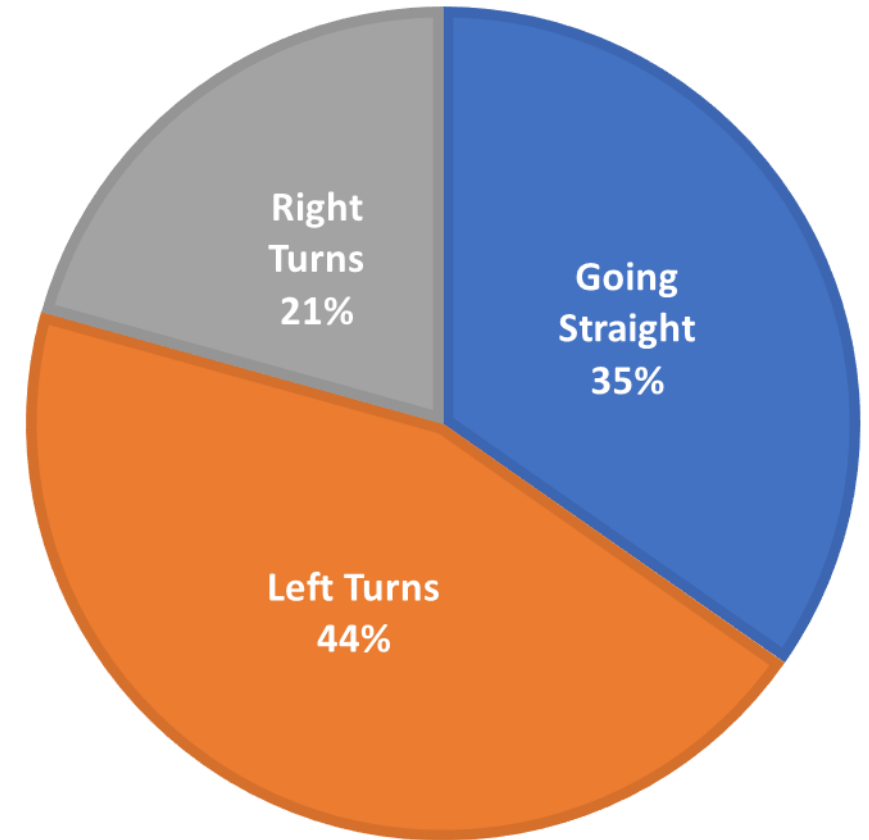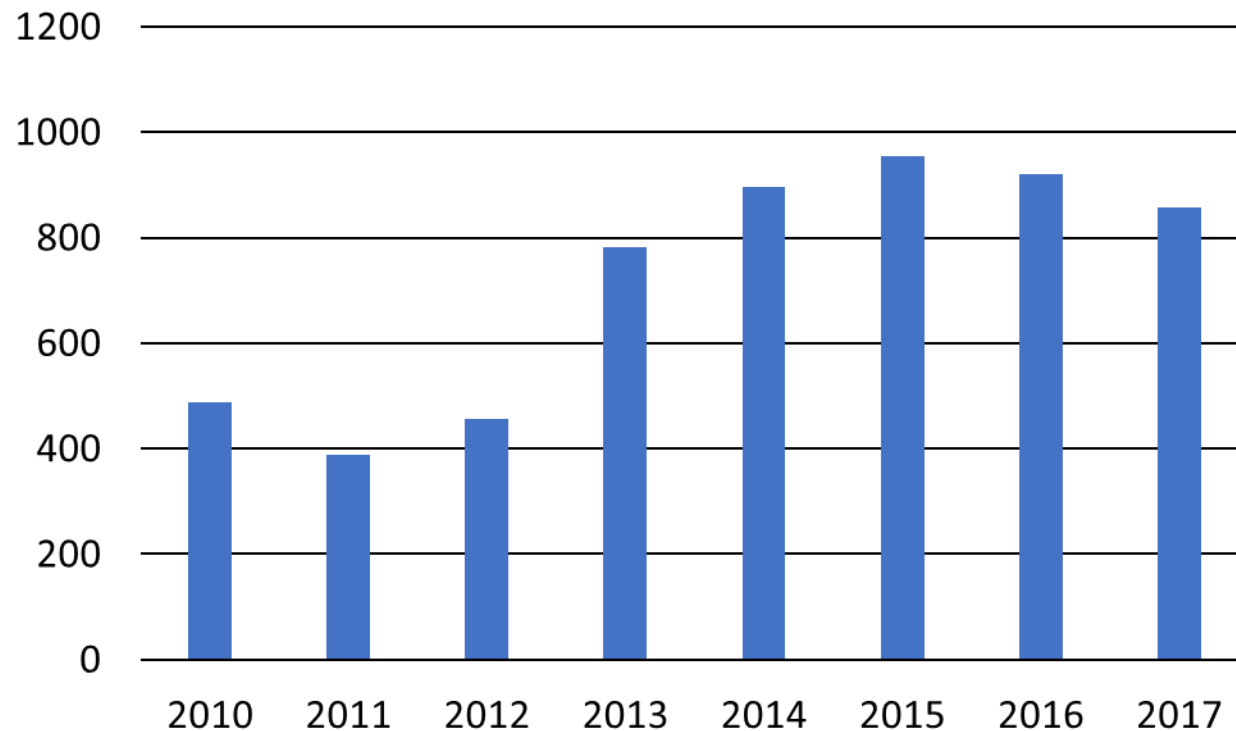Portland State University
Email: monsere@pdx.edu

Left Turn Crashes Involving Pedestrians

Bradley Topol
Senior Capital Projects Coordinator
Seattle Vision Zero Program

City of Seattle

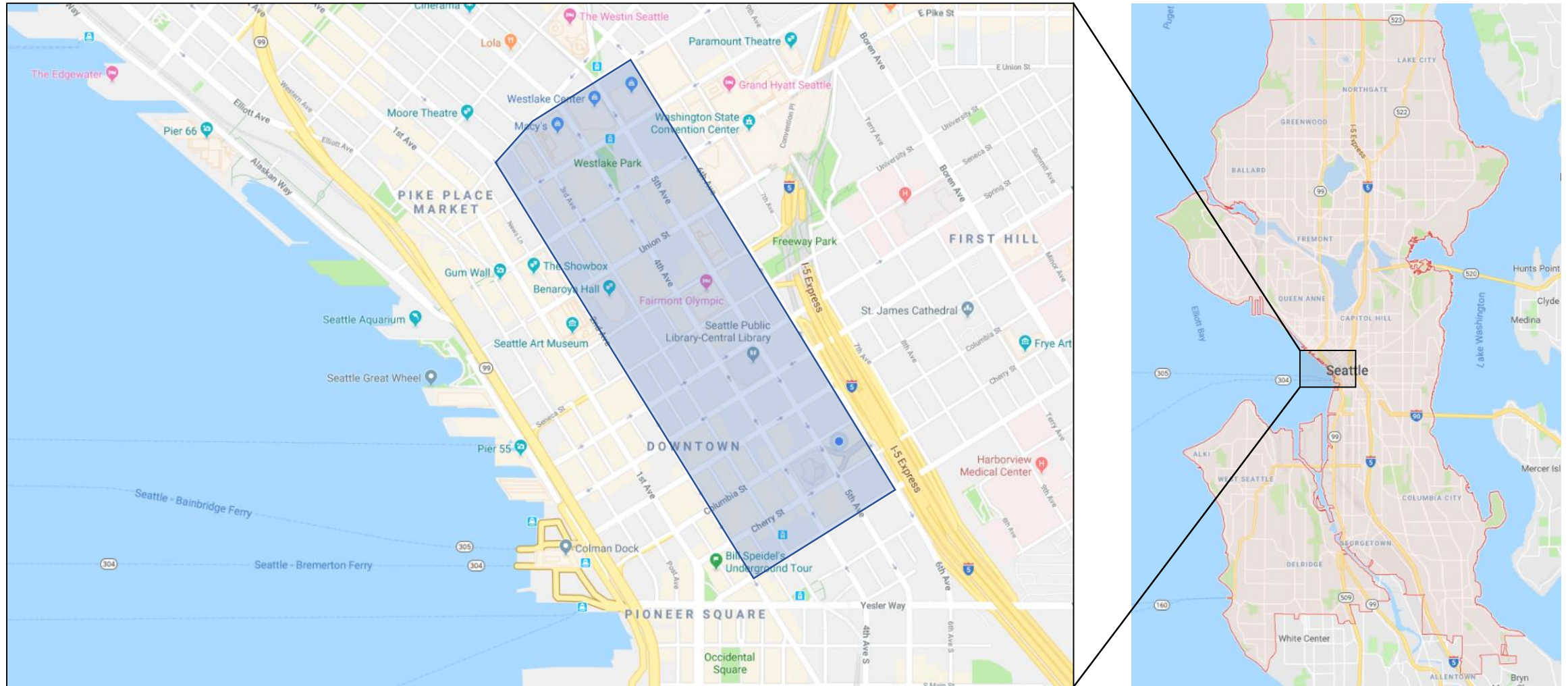# Seattle Pedestrian Intersection Crashes 2010-2017
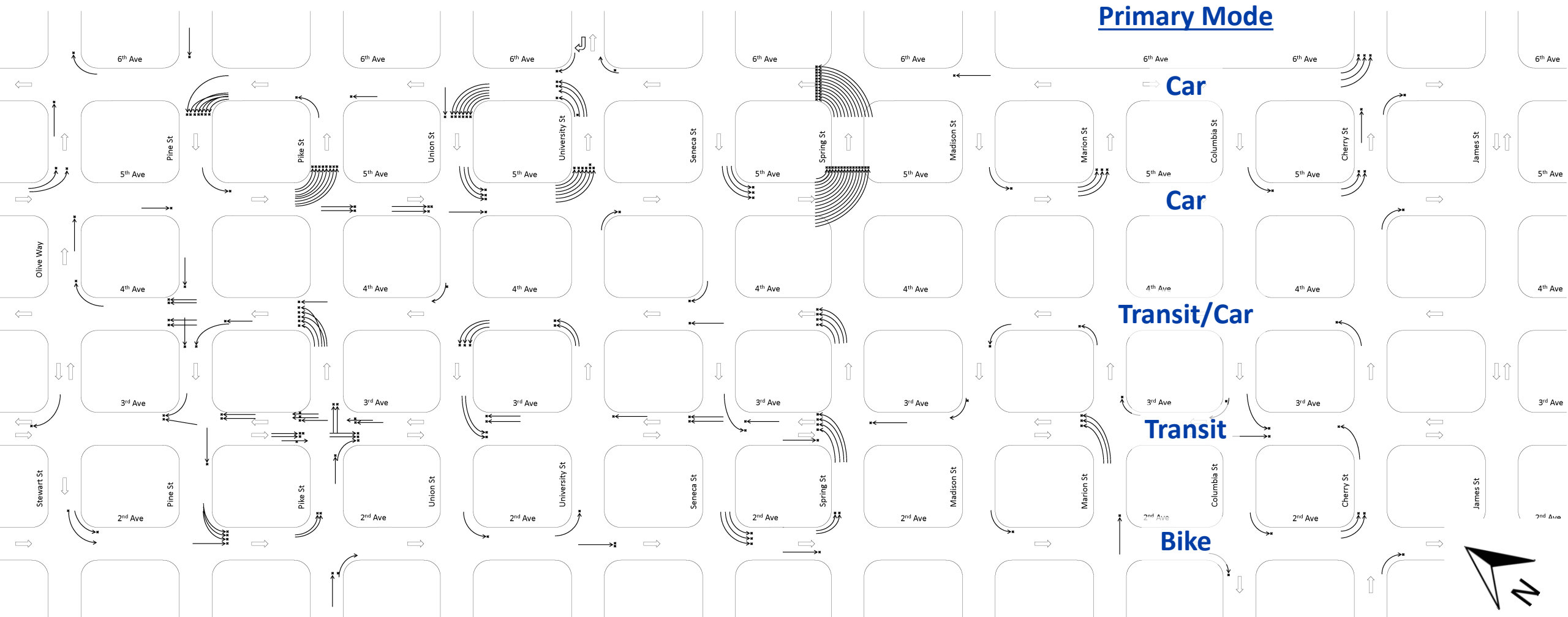
Left Turn Pedestrian Crash Treatments

- Leading Pedestrian Intervals
- Left Turn Signal Separation
- Full Signal Separation
- Addition of Left Turn Lanes
- Turn Restrictions (Major to Minor)
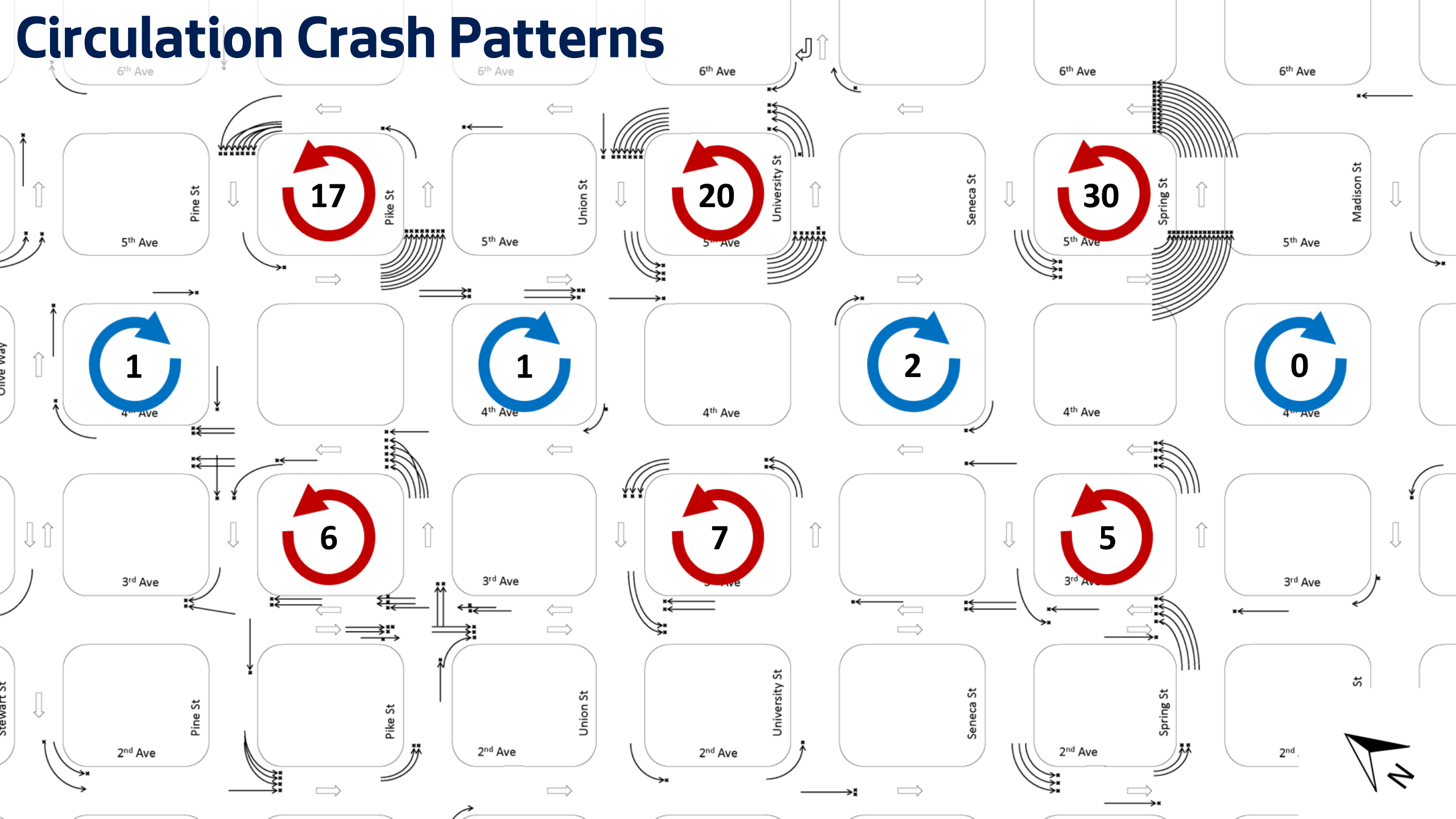- Traffic Circles (Residential)

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Downtown Pedestrian Crash Patterns

City of Seattle

Downtown Pedestrian Crash Patterns

Primary Mode

Car

Car

Transit/Car

Transit

Bike

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Circulation Crash Patterns

Leading Pedestrian Interval (LPI)

Phase 1: Pedestrians only

Phase 2: Pedestrians and vehicles
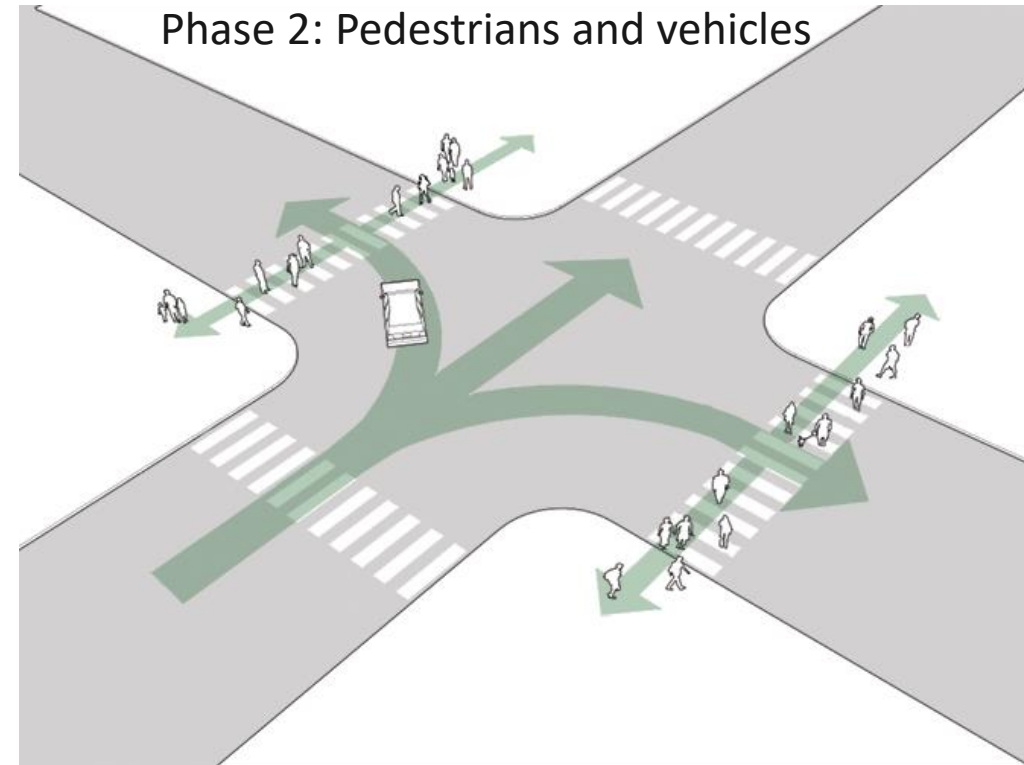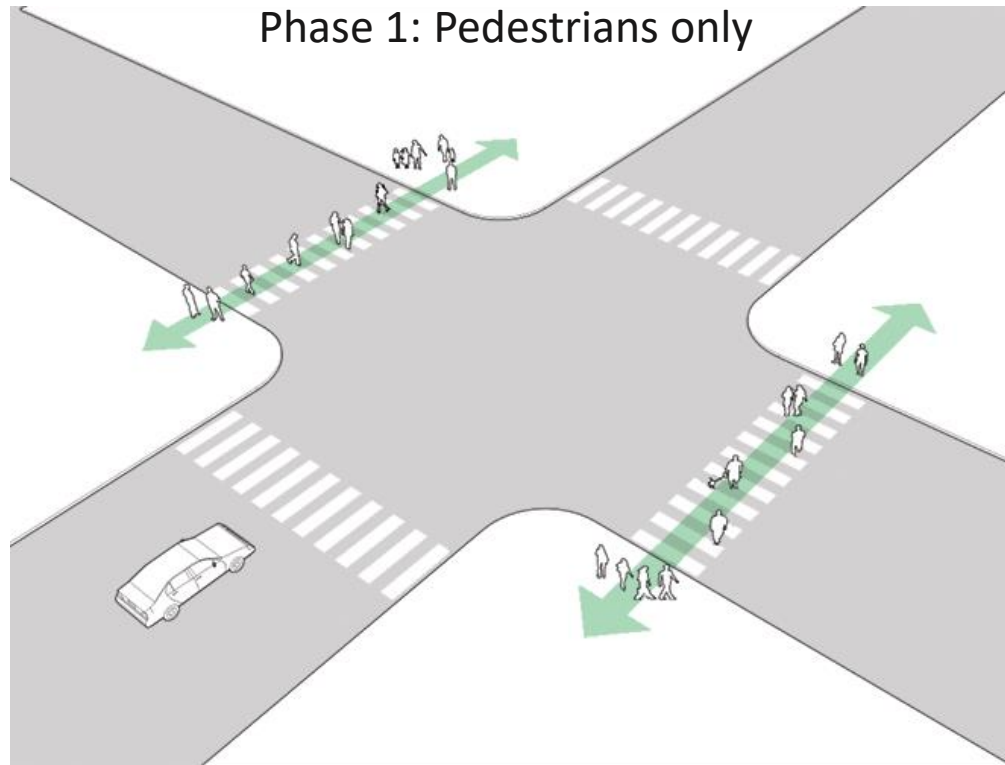
- Activate ped signal 3-7 seconds prior to green light

Leading Pedestrian Interval

- 60% Reduction in Pedestrian-Vehicle Crashes
- Increased visibility
- Reinforce right of way in crosswalks (especially for platoons)

City of Seattle

Existing Results to Date

- 17 locations installed from 2009-2018 (10 this year)

- 40-60% reduction in pedestrian collisions

- Average cost $0-$10k per intersection
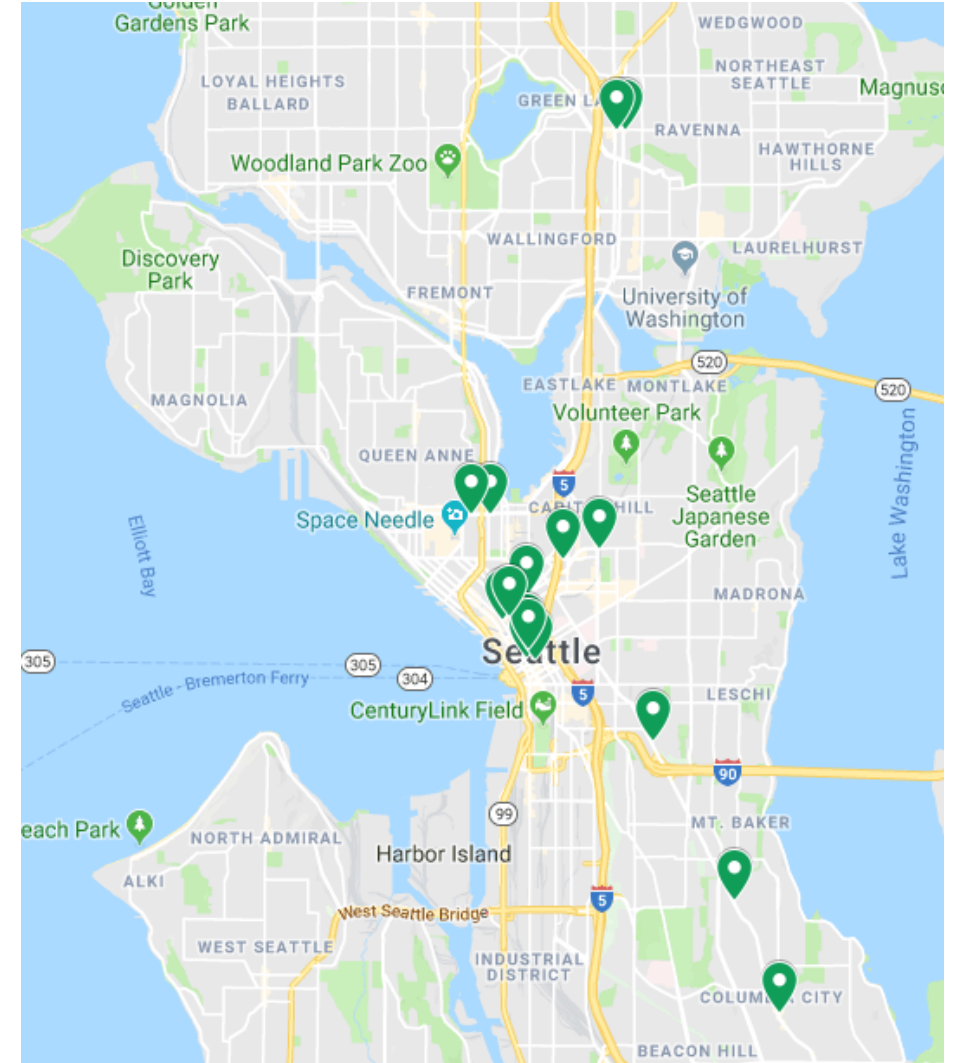
School Crossing – Henderson St & Rainier Ave

- Four schools near intersection

- Three crashes involving four students in 2018

- Three serious injuries

City of Seattle
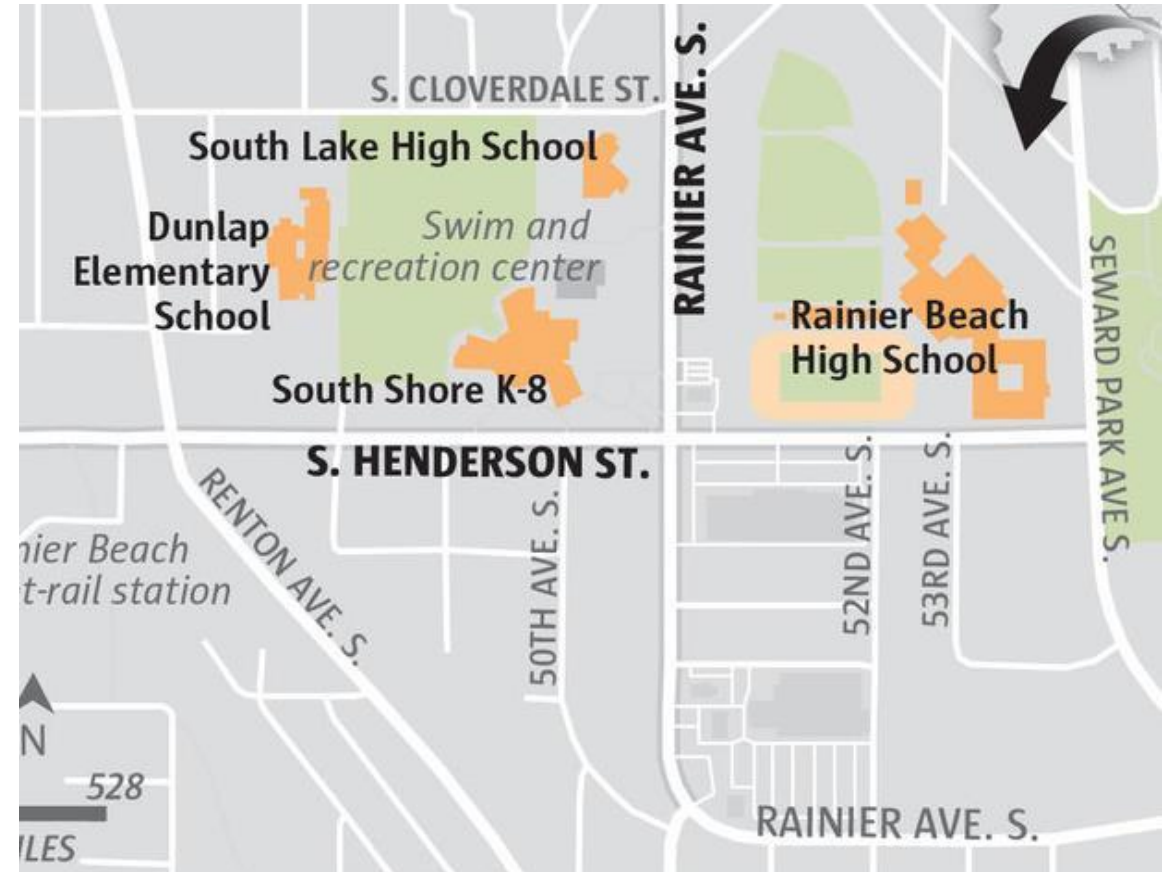
School Crossing – Henderson St & Rainier Ave

- LPI for all legs (3 seconds)

- Set all signals to ped recall

- Widened crosswalks to 16'

- Shortened crossings
  - Right lanes on Henderson converted to turns lanes with curb bulbs on farside

City of Seattle

Left Turn Signal Separation

- Add left turn arrows at signals
- Consider lagging lefts in areas with high pedestrian volumes
- Reduces pedestrian phase time but increases comfort
- Cost: $20,000-$80,000

City of Seattle

School Crossing – 80th St N & Aurora Ave

City of Seattle

School Crossing – 80ᵗʰ St N & Aurora Ave

Previous Conditions

- High left turn volumes from 80ᵗʰ St

- Permissive left turns

- 80ᵗʰ St ADT = 14,000

- Aurora ADT = 35,000

AURORA AVE N

N 80ᵀᴴ ST

Daniel Bagley Elementary

School Crossing – 80ᵗʰ St N & Aurora Ave

Solution

- Push button call separates left turns from ped phase

- No call provides flashing yellow arrow for lefts

City of Seattle

Signal Separation – 2ⁿᵈ Ave Protected Bike Lanes

Previous Condition

- Permissive left turns

- High volume of left turn hook crashes with bikes

City of Seattle

Signal Separation – 2nd Ave Protected Bike Lanes

- Added protected/lagging lefts

- Benefited bikes and peds

- Reduced left turn pedestrian crashes from 2nd Ave by 80%

City of Seattle

Fully Separated Signals – All Way Walk

- Allows diagonal movements during ped only phase

- Also called Barnes Dance or Pedestrian Scramble

- Consider where high ped volumes exist with desire lines in all directions
  - Campuses, business districts, tourist attractions

City of Seattle

Fully Separated Signals – All Way Walk

- Can restrict or allow ped movements during vehicle phases

- Increased pedestrian comfort

- Can increase pedestrian delay

- Consider blended pedestrian ramps for ADA

- Cost: $5,000 - $40,000

City of Seattle

All-Way Walk – 1ˢᵗ Ave and Cherry St

- Installed in 2010
- 1ˢᵗ Ave ADT = 12,000
- 3 injuries prior
- Zero pedestrian injuries since install

City of Seattle

All-Way Walk – 1st Ave and University St

- Installed in 2010
- 1st Ave ADT = 21,000
- 2 injuries prior
- Zero pedestrian crashes since install

All-Way Walk – California Ave and Alaska St

- Installed in 1952
- California Ave ADT = 14,000
- Zero pedestrian crashes since 2003

City of Seattle

Fully Separated Signals – All Walk Phase

- No diagonal pedestrian crossing
- Still utilizes ped only phase
- Consider where diagonal crossing clearance time would be too long
- Cost: $0 - $10,000

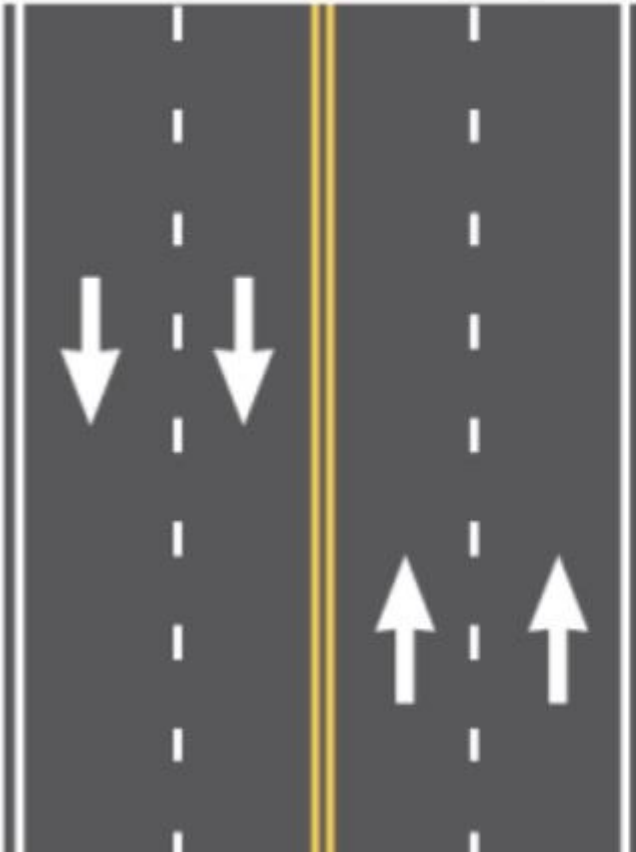Westlake Ave & 9th Ave

City of Seattle

Left Turn Lanes at Uncontrolled Intersections

- Can reduce total crashes by 30-40% (FHWA)

- Reduces stress and pressure on driver

- Consider if there are a high number of driveway cuts

- Road diets can provide corridor wide left turn lanes

City of Seattle

Road Diets

BEFORE

AFTER

Left Turn Restrictions

- Consider for high ADT/speed streets to residential streets
- Utilize hardscape to formalize restrictions
- Consider combining with pedestrian medians (45% ped crash reduction)

City of Seattle

Residential Traffic Circles

- Utilize on low speed residential streets
- Slows left turning speed

City of Seattle

Questions?

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City of Seattle

Discussion

⇨ **Send us your questions**

⇨ **Follow up with us:**

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⇨ **Archive at www.pedbikeinfo.org/webinars**