TREC Webinar Series

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Webinar: Improving Walkability at Signalized Intersections with Signal Control Strategies

Edward J. Smaglik
Northern Arizona University

Sirisha Murthy Kothuri
Portland State University

Improving Walkability at Signalized Intersections with Signal Control Strategies

Contributors:

Sirisha Kothuri, Edward Smaglik, Andrew Kading, Chris Sobie, Peter Koonce, Paul Zebell, Avery Rhodes, Jeffrey Bauman

Organizations:

Portland State University, Northern Arizona University, City of Portland, OR, City of Mesa, AZ and City of Flagstaff, AZ

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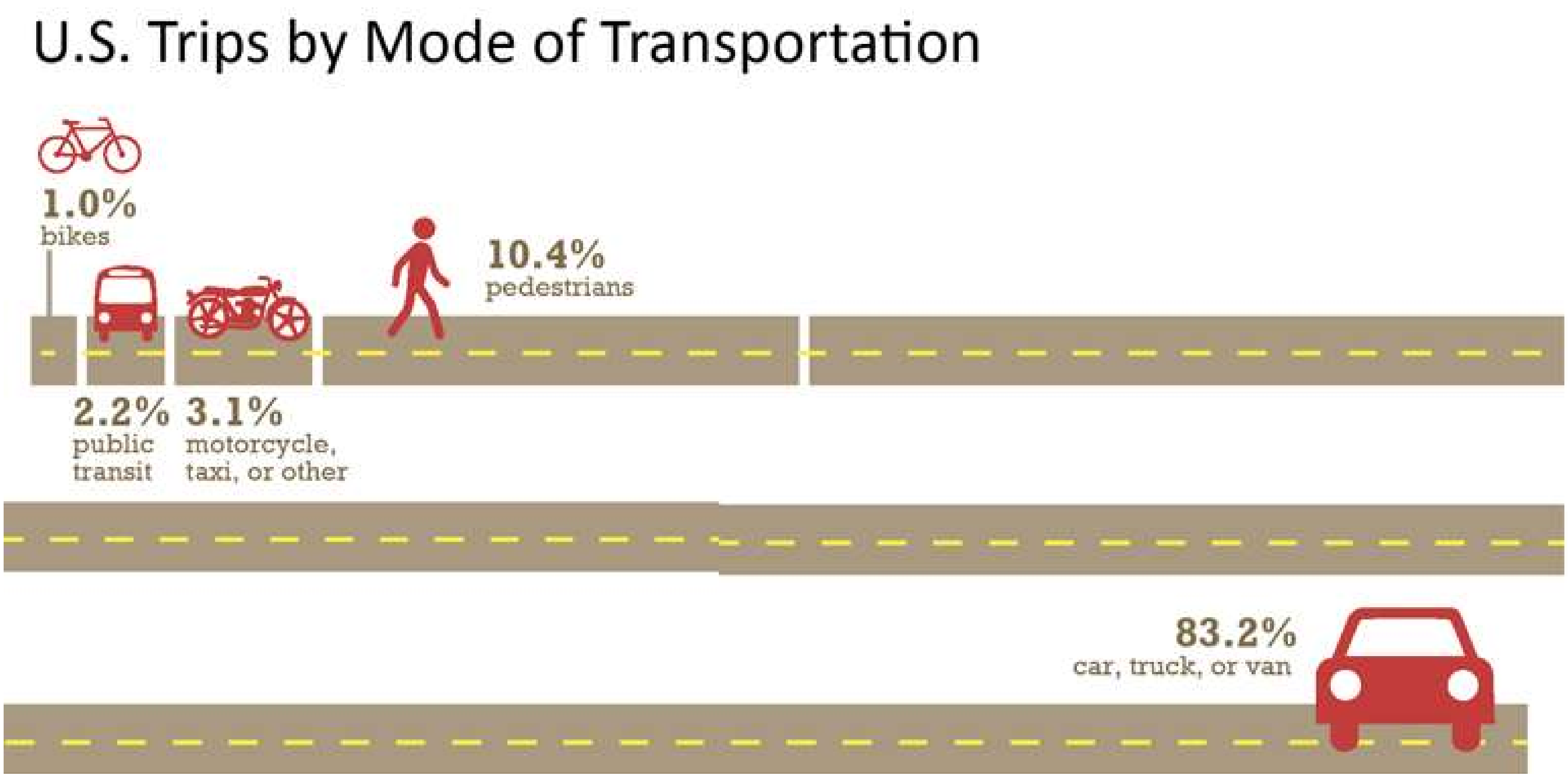
Outline

- Introduction
- Background
- Goals
- Pedestrian Control Strategies
- Pedestrian Priority Algorithm Development & Deployment
- Conclusions and Recommendations

Introduction

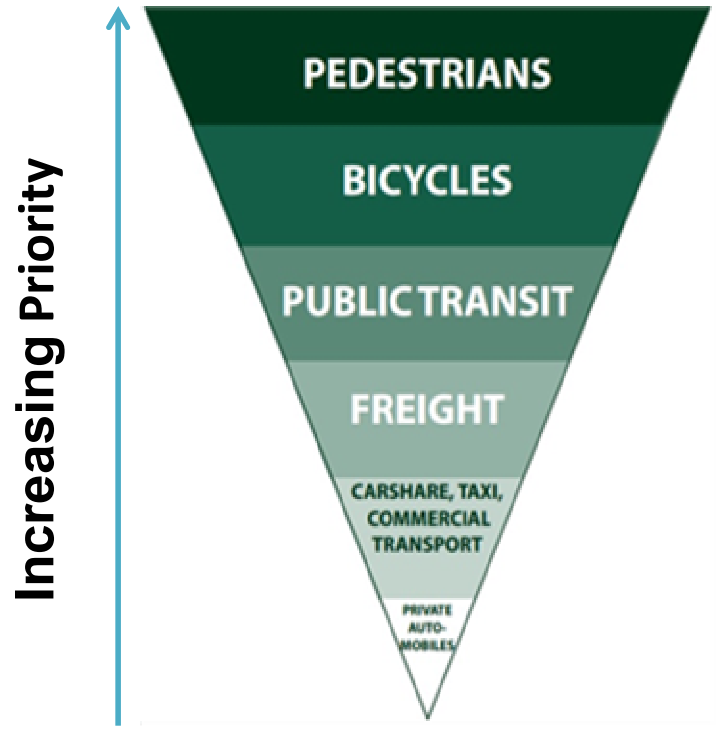


Source: Bicycling and Walking in the United States; 2014 Benchmarking Report

Introduction

- Delays affect pedestrians disproportionately
- "Everyone is a pedestrian"

How do we translate "pedestrian first" policies into specific operational strategies at intersections?



Source: City of Portland, TSP

Background

- Limited knowledge regarding signal control strategies focused on pedestrians
  - Existing strategies typically focus on safety
    - Leading Pedestrian Interval (LPI)
    - Exclusive Pedestrian Phase (Barnes Dance)
  - Other efficiency-focused options
    - Shorter cycle length
    - Actuated-coordinated timing
    - Free operation

Project Goals

- Assess the efficiency impacts of existing strategies
  - Coordination (base case)
  - Leading Pedestrian Interval
  - Exclusive Pedestrian Phase
  - Shorter Cycle Lengths
  - Free Operation
  - Actuated-Coordinated Operation
- Develop and implement a pedestrian priority algorithm

Leading Pedestrian Interval

Leading Pedestrian Interval - Impacts

- Safety Impacts
  - Documented reduction in pedestrian-vehicle crashes at intersections
  - Can provide level of ‘comfort’ to pedestrians
- Efficiency Impacts
  - Increase in overall delays due to lost time
  - Actual magnitude of increase depends on
    - Length of LPI
    - Cycle length
    - Implementation of LPI on major or minor phase

Leading Pedestrian Interval - Implementation

- Implementation should be based on (Sainenejad and Lo, 2015, Sharma et al., 2017)
  - Crash history (frequency, severity)
  - Volume of pedestrians
  - School proximity
  - Activity by elderly residents
  - Impacts on vehicle delay
  - Visibility issues
  - Intersections with special geometry

Exclusive Pedestrian Phase

Exclusive Pedestrian Phase- Impacts

- Safety Impacts
  - Documented reduction in pedestrian-vehicle crashes at intersections
  - Increase in pedestrian signal non-compliance
  - Pedestrians less likely to wait for exclusive phase at low volume intersections
- Efficiency Impacts
  - Significant increase in overall delays due to lost time for all users
  - Actual magnitude of increase depends on
    - Length of EPP
    - Cycle length

Exclusive Pedestrian Phase-Implementation

- Best suited for
  - Intersections with high volume of pedestrians and turning vehicles (e.g. downtown)
  - Locations where traditional pedestrian accommodations do not work well
  - Carefully weigh the costs
    - Increase in overall delays
    - Increase in pedestrian non-compliance

Free Operation

- Each intersection operates independently of adjacent intersections
- Individual intersections can be optimized without consideration of other signals
- Can lead to greater flexibility and responsiveness (Urbanik et al., 2015)
- Good detection is necessary on all approaches for high operational and safety performance (Koonce et al., 2008)

Free Operation - Impacts

- Safety Impacts
  - None quantified in literature
- Efficiency Impacts
  - Can reduce overall delays when major street vehicular volumes are low (v/c < 0.5)
  - Tradeoff between major and minor street user delays with higher volumes
    - Reduction in minor street pedestrian delay
    - Increase in major street vehicle delay
  - Detrimental to coordination

Free Operation - Implementation

- Best suited for
  - Locations with long spacing between adjacent intersections
  - Locations where coordination is not a priority
  - Time of day operation to prioritize pedestrians
    - Off-peak (middle of day)
    - Late night
  - Intersections with balanced volumes on major and minor streets

Short Cycle Lengths

- Cycle length refers to the time taken for a complete sequence of signal indications
- Ped delay is a function of cycle length
- According to the HCM

$$Ped\ Delay = \frac{(C - g_{walk})^2}{2C}$$

Where

C = cycle length

g_{walk} = *effective walk time*

Short Cycle Lengths- Impacts

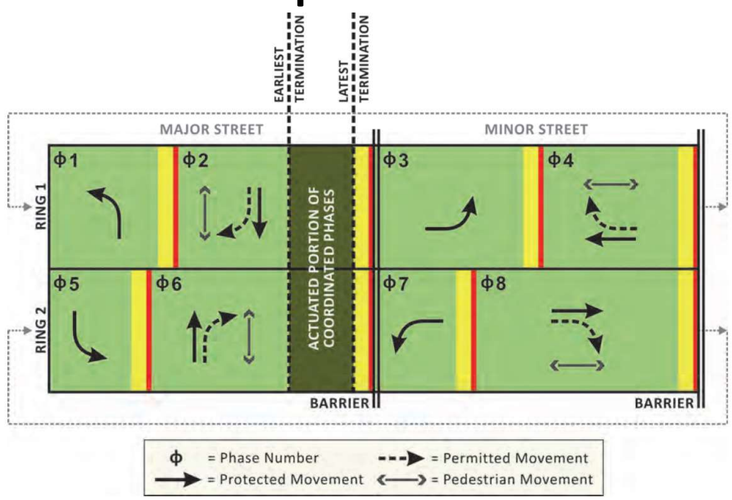
- Safety Impacts
  - None quantified in literature
- Efficiency Impacts
  - Reduce pedestrian delay
  - Encourages signal compliance
  - Increases efficiency of all users, typically

Short Cycle Lengths - Implementation

- Best suited for off-peak and other low vehicular demand periods, when agencies want to keep their signals coordinated
- NACTO's Urban Street Design Guide and PEDSAFE also recommend short cycle lengths to increase compliance and efficiency

Actuated-Coordination

- Actuating the coordinated phase allows
  - Coordinated phases to gap out if there is low demand
  - Signal to be more responsive to field conditions



Source: Signal Timing Manual, 1st Edition

Actuated-Coordination - Impacts

- Safety Impacts
  - None quantified in literature
- Efficiency Impacts
  - Decrease in v/c ratios and fewer occurrences of split failures (Day et al., 2008)
  - Use of fixed force-offs and fully actuated coordination reduced delays for non-coordinated phases (Day et al., 2014)
  - Decreases minor street pedestrian delay (Sobie et al., 2016)

Actuated-Coordination - Implementation

- Best suited for
  - Off-peak and other low vehicular demand periods, when agencies want to keep their signals coordinated
  - Major street demand is low and minor street demand is high
- Presence of mainline detection is necessary
  - Additional detection and maintenance costs

Permissive Length

- Period of time after the yield point where the call on a non-coordinated phase can be serviced without delaying the start of the coordinated phase
- Increasing permissive length can reduce pedestrian and vehicular delays on the minor street movements

Permissive Length- Impacts

- Safety Impacts
  - None quantified in literature
- Efficiency Impacts
  - For low volume conditions, increasing permissive length reduces delays for non-coordinated phases (de Castro-Neto, 2005)
  - Decreases minor street pedestrian delay (Kothuri et al., 2013)

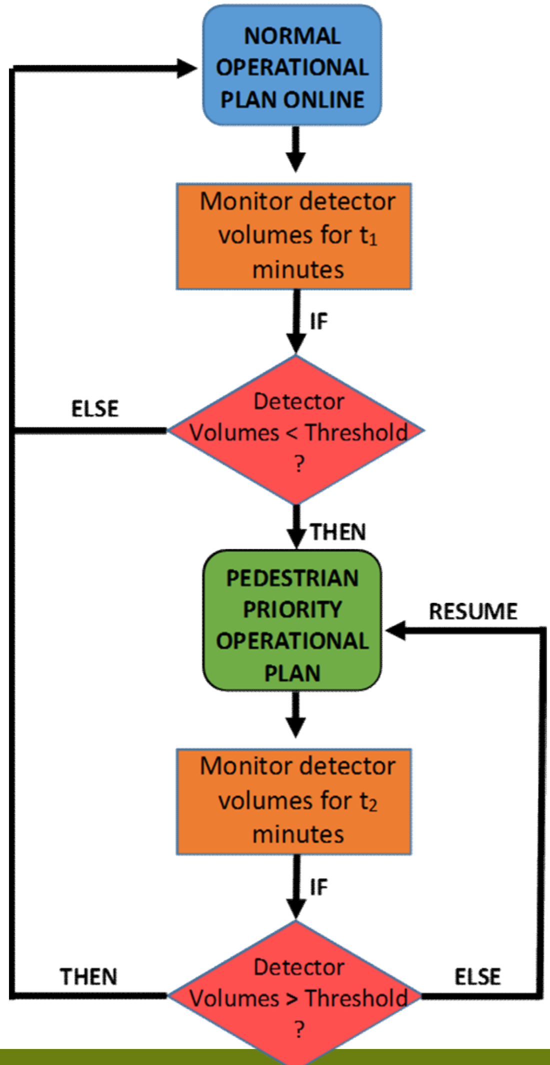
Permissive Length - Implementation

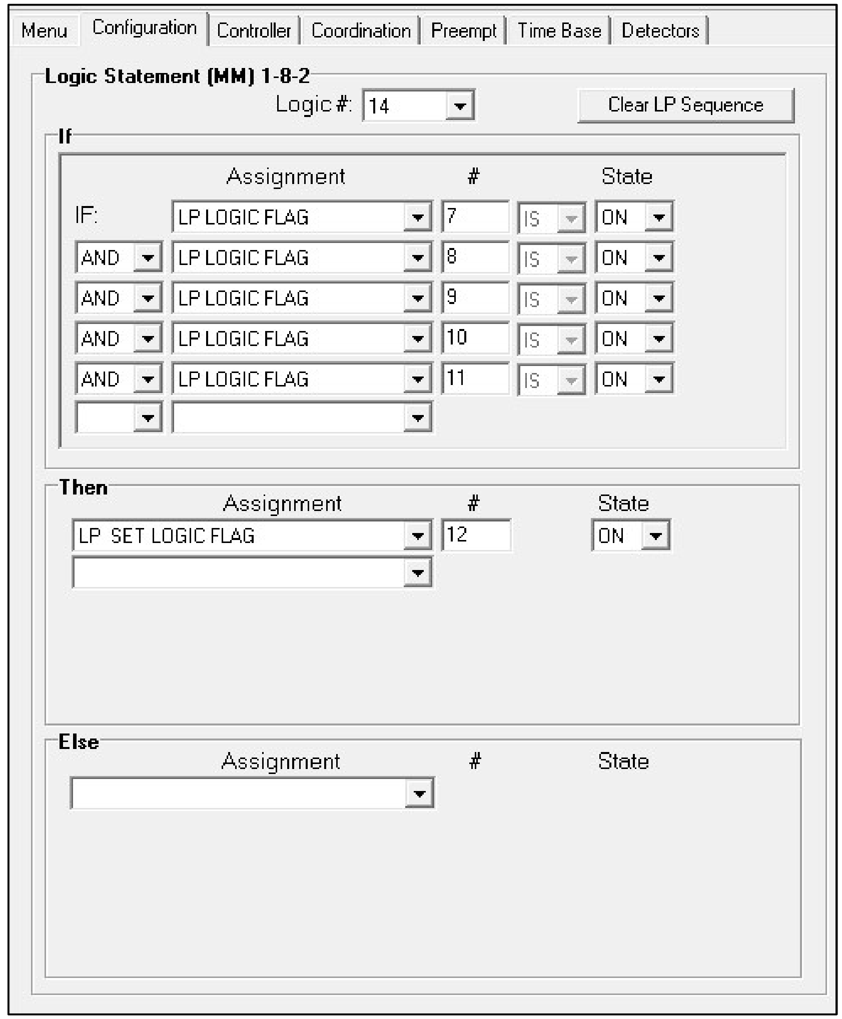
- Best suited for
  - Off-peak and other low vehicular demand periods, when agencies want to keep their signals coordinated
  - Major street demand is low and minor street demand is high

Pedestrian Priority Algorithm

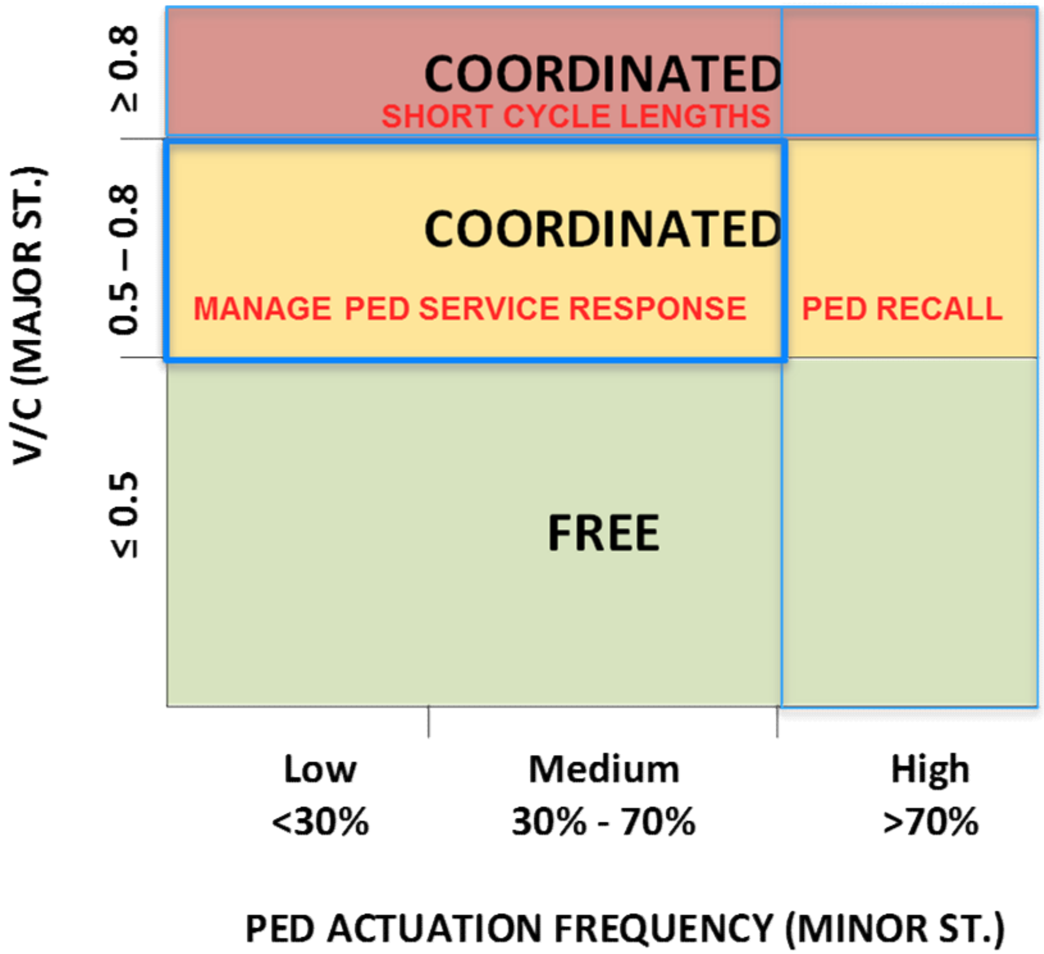
- Goal is to change the operational pattern based on volume input
  - Coordinated above a threshold
  - Pedestrian plan below threshold
    - Select from previously presented options, or other
- Toe the line between vehicular and pedestrian objectives

Pedestrian Priority Algorithm Development

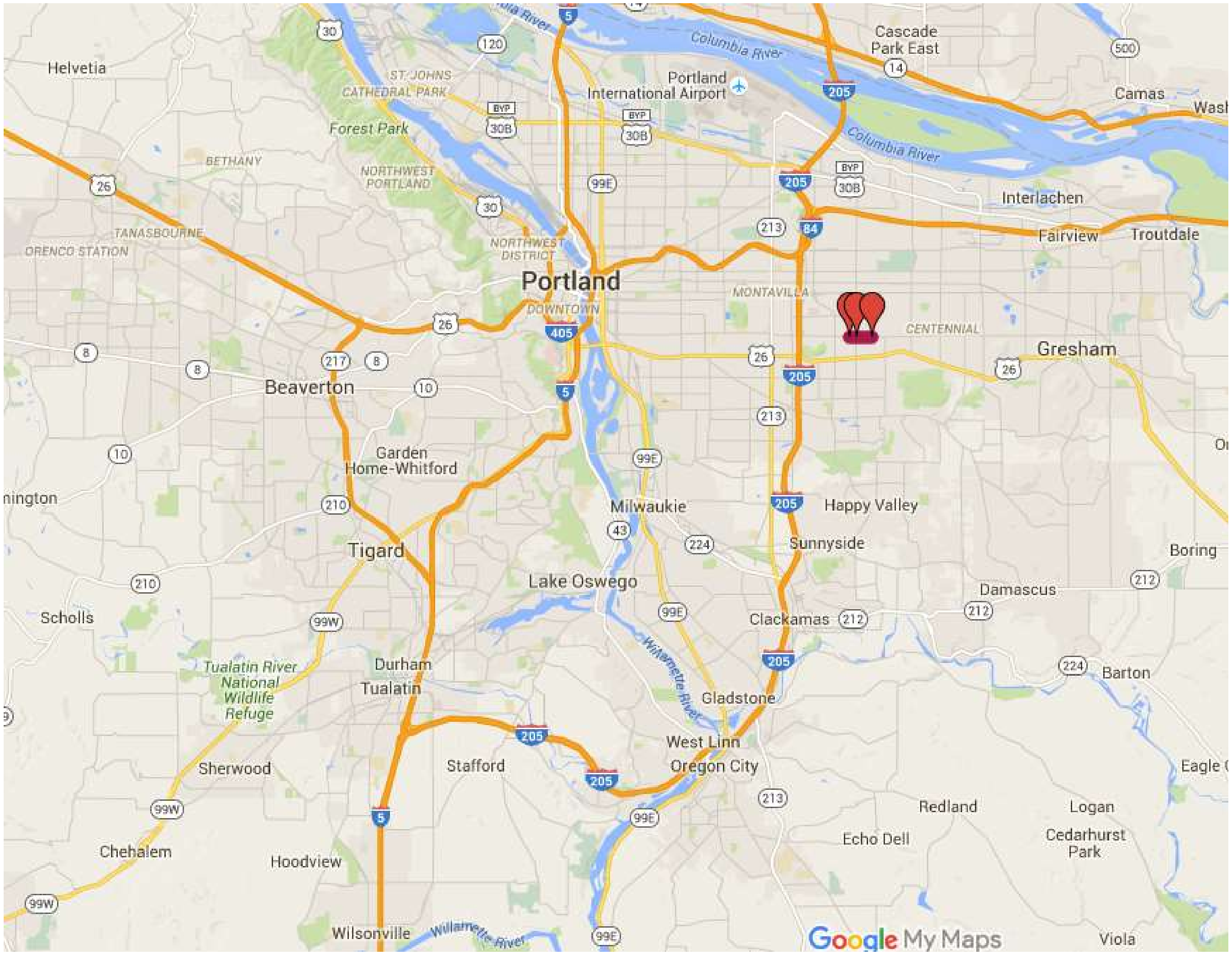




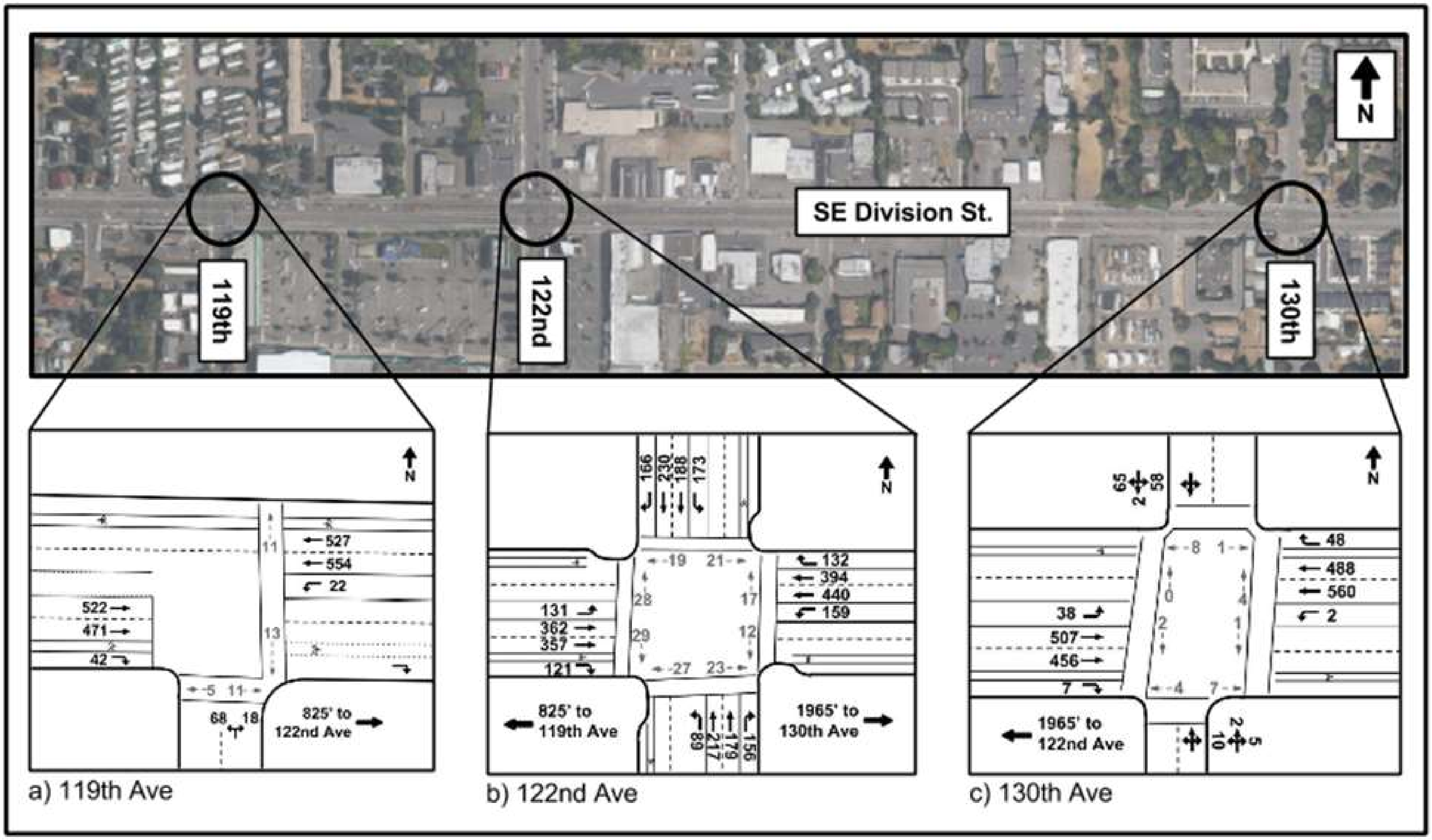
Threshold Determination



Simulated Network



Simulated Network



a) 119th Ave
b) 122nd Ave
c) 130th Ave

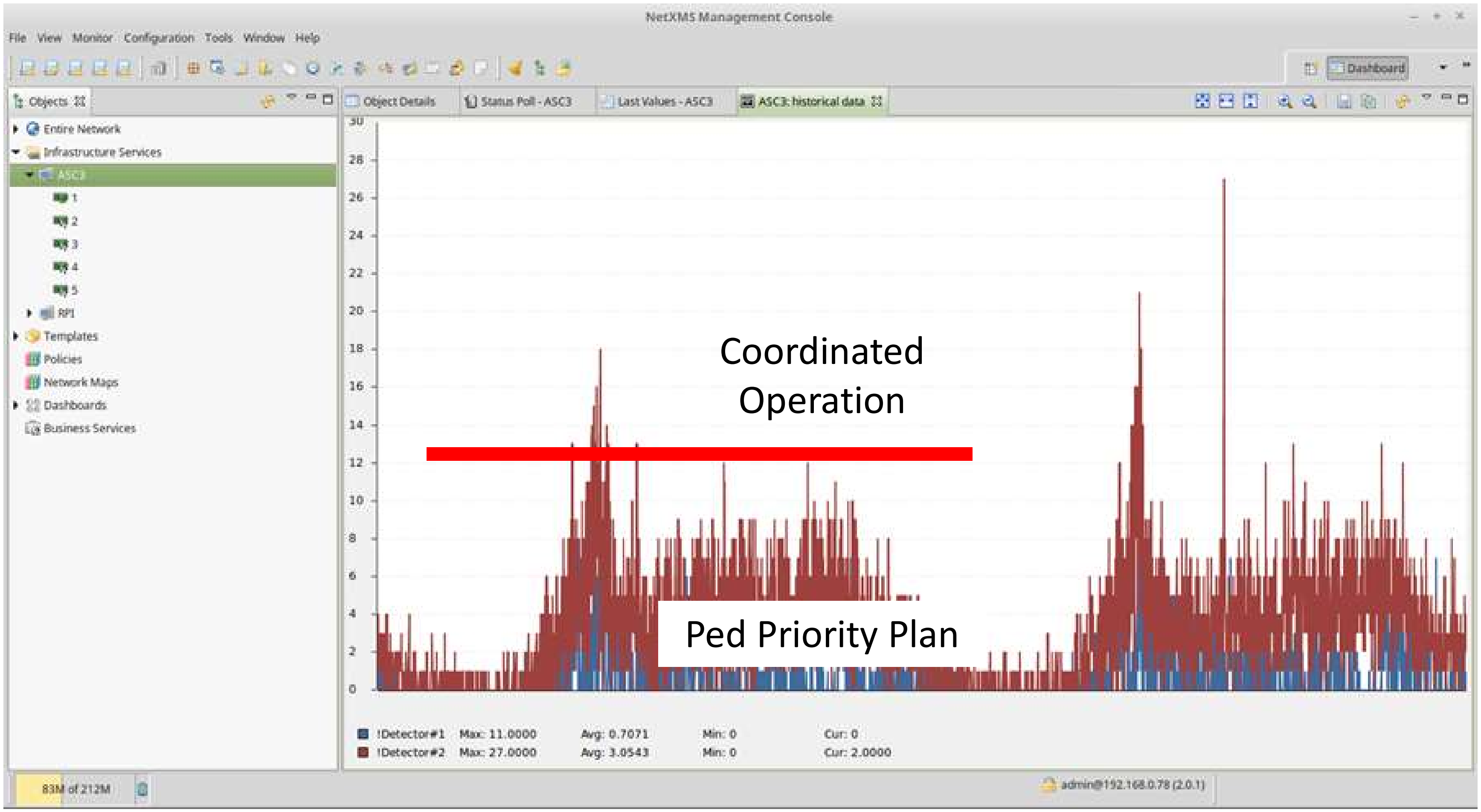
Algorithm Simulation Results

Scenario	Avg. Veh Delay (s)	Avg. Ped Delay 2/6 (s)	Avg. Ped Delay 4/8 (s)	Avg. TT (s) (EB)	Avg. TT (s) (WB)	Avg. TT (s) (NB)	Avg. TT (s) (SB)
Coordinated (Base)	26.55	25.43	44.95	100.71	90.61	94.79	90.77
Actuated - Coordinated	26.73	36.45*	43.45	101.98	90.99	94.81	91.28
Free with Algorithm	25.11*	28.44*	41.28	102.25	99.93*	87.69*	84.39*
Free	22.81*	32.87*	30.25*	104.25*	107.62*	77.73*	74.50*

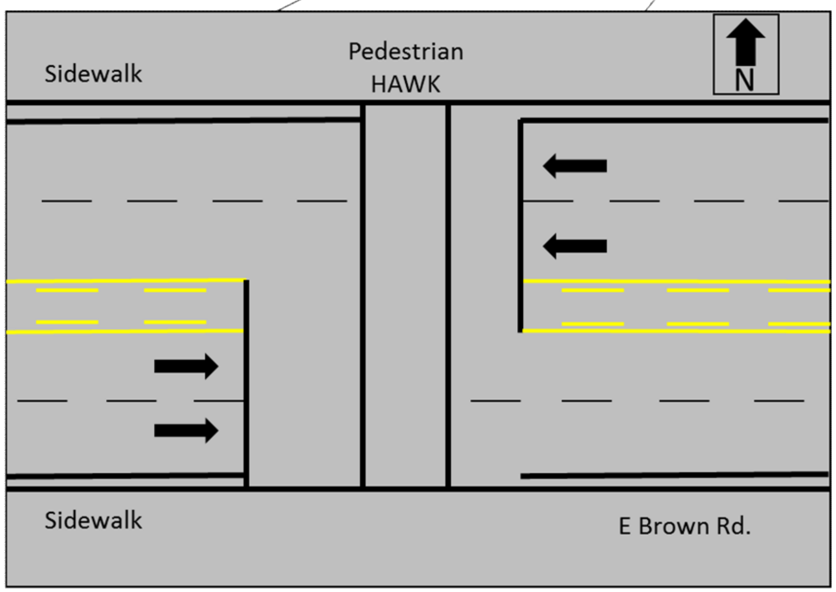
Algorithm Field Deployments

- Field Deployments
  - Raspberry Pi
    - Mesa, AZ
    - Flagstaff, AZ
  - ASC/3 Controller
    - Portland, OR

Threshold Determination



Site 1 – Mesa, AZ (Raspberry Pi)



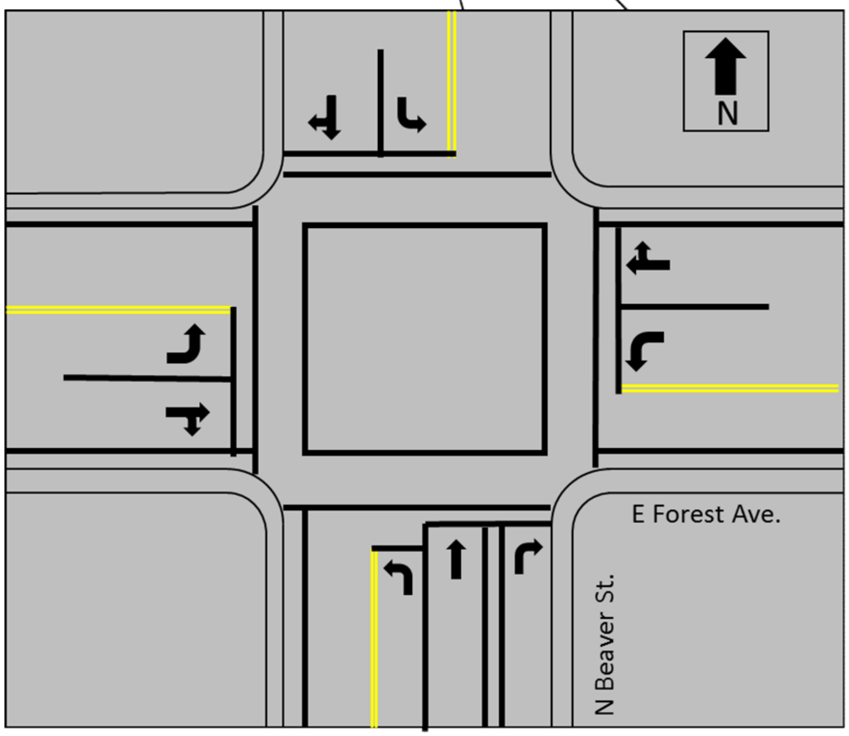
Signalized Intersections

- (yellow) = Brown Rd. and Center St.
- (red) = Pedestrian HAWK
- (yellow) = Brown Rd. and Mesa Dr.

Dots ordered from left to right of picture

- (blue) = Bluetooth Location

Site 2 – Flagstaff, AZ (Raspberry Pi)



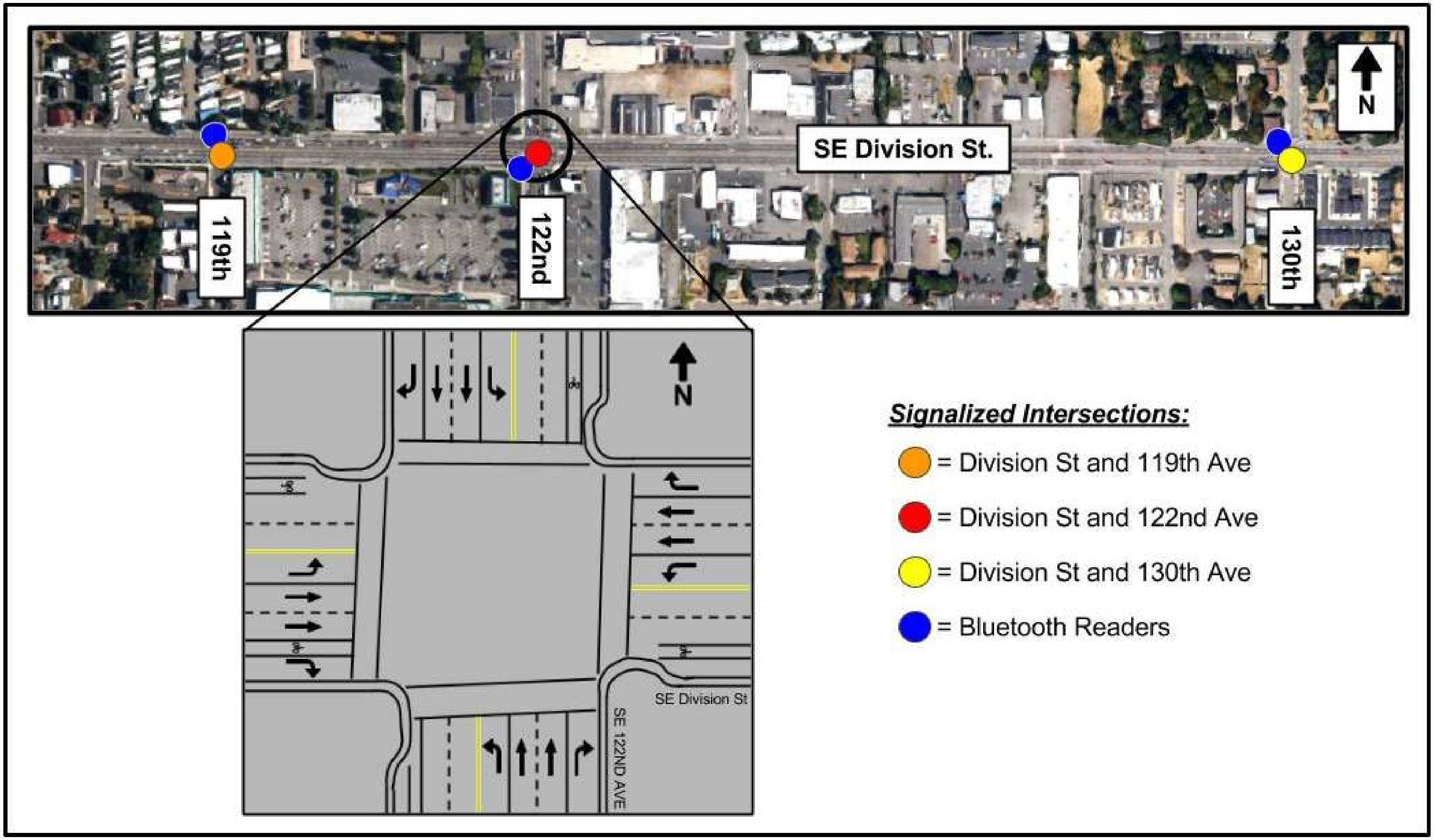
<u>Signalized Intersections</u>

- 🔴 = Forest Ave. and Beaver St.
- 🟡 = Forest Ave. and San Francisco St.
- 🟡 = Forest Ave. and Turquoise Dr.

Dots ordered from left to right of picture

- 🔵 = Bluetooth Location

Site 3 – Portland, OR (ASC/3)



Deployment Outcomes

- Mesa
  - Reductions in pedestrian delay seen during off-peak typically coordinated time periods

	Travel Time				Pedestrian Data	
Two weeks, before (weekdays)	WB		EB			
	Count of Cars	Average Travel Time (s)	Count of Cars	Average Travel Time (s)	Count of Pedestrians Call	Average Pedestrian Delay
0000-0630 (C=90)	145	52.87	162	31.70	13	00:54.1
0630-1500 (C=100)	1780	55.90	1098	58.95	330	00:49.1
1500-1830 (C=110)	809	60.12	959	62.63	200	00:50.9
1830-0000 (C=90)	917	57.50	766	64.00	153	00:44.4

	Travel Time				Pedestrian Data	
Two weeks, after (weekdays)	WB		EB			
	Count of Cars	Average Travel Time (s)	Count of Cars	Average Travel Time (s)	Count of Pedestrians Call	Average Pedestrian Delay
0000-0630 (C=90)	103	43.50	80	47.53	7	00:13.0
0630-1500 (C=100)	1534	50.95	895	56.96	317	00:22.0
1500-1830 (C=110)	768	54.83	827	59.94	169	00:52.0
1830-0000 (C=90)	650	58.51	678	62.70	147	00:26.0

Deployment Outcomes

- Flagstaff
  - Results less clear
  - Reduction in ped delay during weekday off peak, but other numbers are contradictory (PM plan)
  - Detection may have been an issue

One week, before (Weekdays)	Count of Pedestrians Call	Average Pedestrian Delay
0000-0715 (C=Free)	72	0:00:35
0715-0815 (C=90)	140	0:00:23
0815-1630 (C=95)	394	0:00:41
1630-1730 (C=75)	73	0:00:19
1730-0000 (C=Free)	143	0:00:26
One week, after (Weekdays)	Count of Pedestrians Call	Average Pedestrian Delay
0000-0715 (C=Free)	94	0:00:37
0715-0815 (C=90)	78	0:00:40
0815-1630 (C=95)	591	0:00:34
1630-1730 (C=75)	52	0:00:48
1730-0000 (C=Free)	206	0:00:36

Deployment Outcomes

- Portland
  - Minor reductions in ped delay observed
  - Further refinement of threshold, my yield further reduction in ped delay

Results	Ped 4		Ped 8	
	n	Avg. Ped Delay	n	Avg. Ped Delay
Without Algorithm (All Day)	1604	0:00:51	1617	0:00:51
With Algorithm (All Day)	1590	0:00:48	1602	0:00:49
Without Algorithm (10:00 -13:00)	285	0:00:51	283	0:00:53
With Algorithm (10:00 - 13:00)	229	0:00:50	273	0:00:49

Comparison of Strategies

More Delay

- Pedestrian Delay
  - Barnes Dance
  - Coordination
  - Actuated Coordination
  - Leading Pedestrian Interval
  - Short Cycle Lengths
  - Free

- Vehicle Delay
  - Barnes Dance
  - Short Cycle Lengths
  - Leading Pedestrian Interval
  - Actuated Coordination
  - Coordination
  - Free

Less Delay

Conclusions

- LPI and Barnes Dance may improve safety, but increase delays overall
- Free operation and shorter cycle lengths can reduce pedestrian delays, but impacts on safety are not known
- Field deployments corroborate simulation results
- Generally no right solution. Implementation choice based upon operational objectives and intersection characteristics

Recommendations

- Common needs for deployment of specific strategies
  - Barnes Dance: Very high pedestrian or right turning volumes creating need to completely separate modes
  - LPI/Split LPI: Geometry or vehicle volumes that cause issues for pedestrians entering crosswalk
  - Reduced Cycle Length: Satisfy need to operate in coordinated mode while trading green bandwidth for reduced delays for other users

Recommendations

- Common needs for deployment of specific strategies
  - Free: Most aggressive strategy resulting in lower delay for most users at expense at main street traffic
  - Actuated-Coordinated: Can provide earlier minor street Walk if possibility of main street vehicle gap out. Useful for low-moderate pedestrian volumes

Publications

- NITC Final Report
  - http://ppms.trec.pdx.edu/media/project_files/NITC-RR-782_Final_Report.pdf
- Transportation Research Record
  - Sobie, Chris, Smaglik, Edward J., Sharma A., Kading A., Kothuri, S., and Koonce, P. "Managing User Delay with a Focus on Pedestrian Operations" Accepted for publication in Transportation Research Record, in press, 2016.
  - Conference Paper: http://docs.trb.org/prp/16-1487.pdf
- Application Guidebook
  - Still in publication

Acknowledgements

Portland State UNIVERSITY

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NORTHERN ARIZONA UNIVERSITY

CITY OF PORTLAND, OREGON 1851

CITY OF FLAGSTAFF SERVICE AT A HIGHER ELEVATION

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Contact Information

Edward Smaglik
Associate Professor
Civil and Environmental Engineering
Northern Arizona University
Email: Edward.Smaglik@nau.edu
Phone: 928-523-1431

Sirisha Kothuri
Research Associate
Civil and Environmental Engineering
Portland State University
Email: skothuri@pdx.edu
Phone: 503-725-4208