Managing Pedestrian Delay at Signalized Intersections through Timing Strategies

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Christopher Sobie, EIT; Brian Jouflas; Kaiqi Zhang

Other Investigators / Contributors:
Sirisha Kothuri (PI), Chris Monsere, Andrew Kading - PSU
Edward Smaglik – NAU
Peter Koonce, Paul Zebell – Portland, OR
Avery Rhodes, Arthur Dock, Gary Bonner – City of Mesa, AZ
Jeffrey Bauman – City of Flagstaff, AZ
Agenda

- Introduction
- Motivation
- Objectives
- Results
- Outcomes
- Applicability to Practice
- Next Steps
Introduction

- Growing emphasis on active transportation
- Walking ↔ healthy, livable communities
- Increase in walking trips

National Walking Trends

Source: Data from Pucher et al., (2011)

Local Commute Shares - Walk 4%

Source: City of Portland, Climate Action Plan
Motivation

- 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 signal control strategies for pedestrians
  - Typically focused on safety

Leading Pedestrian Interval (LPI)

Image Sources: LPI; STM Ed. 2. Exclusive Ped. Phase; STM Ed. 1
Background

- Exploring Pedestrian Responsive Signal Timing Strategies in Urban Areas

![Diagram showing Coordinated Short Cycle Lengths, Free Ped Act. Frequency (side st.), V/C (major st.), Low (<30%), Medium (30%-70%), High (>70%), Coordinated Manage Ped Service Response, and Ped Recall.](image)
Research in Progress

- Improving Walkability Through Control Strategies at Signalized Intersections
  - Newer treatments (LPI, scramble) improve safety, but peds must still wait their turn
  - Can result in delays much longer than those for vehicles
  - Are there opportunities to improve operations through control strategies?
Simulation Objectives

- Assess the efficiency impacts of various control strategies on all users
  - Free
  - Actuated Coordinated
    - Veh Ext Timer Sensitivity Analysis
  - Coordinated
  - Algorithm

- Develop and implement a pedestrian priority algorithm based on vehicle volumes
Pedestrian Priority Algorithm

- Goal is to change operational pattern based upon volume input
  - Coordinated above a threshold
  - Pedestrian plan below threshold
Pedestrian Priority Algorithm

- Pedestrian Operational Plans
  - Free
  - Actuated-Coordinated
  - Reduced Cycle Length
  - Other Options
Simulation Development
Simulation Scenarios

• First set of simulations (not validated to field)
  – Coordinated (Base) vs:
    • Actuated-Coordinated
    • Free
    • Free w/ Algorithm
  – Sensitivity analysis on vehicle extension parameter

• Second set of simulations (field validated volumes)
  – Comparison of Coordinated (Base) vs:
    • Free
    • Leading Pedestrian Interval
    • Barnes Dance (Exclusive Ped Phase)
### Figure 3 Ring Barrier Diagram for Actuated-Coordinated Operation

**a)** Base ring barrier diagram with several actuated-coordinated parameters

**b)** Gap out termination 5s into extensible period allows for early termination
### Simulation Results (Set 1)

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Avg. Veh Delay (%)</th>
<th>Avg. Ped Delay 2/6 (%)</th>
<th>Avg. Ped Delay 4/8 (%)</th>
<th>Avg. TT (EB) (%)</th>
<th>Avg. TT (WB) (%)</th>
<th>Avg. TT (NB) (%)</th>
<th>Avg. TT (SB) (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Actuated Coordinated</td>
<td>0.7</td>
<td>43.3</td>
<td>-3.3</td>
<td>1.3</td>
<td>0.4</td>
<td>0.0</td>
<td>0.6</td>
</tr>
<tr>
<td>Free with Algorithm</td>
<td>-5.4</td>
<td>11.8</td>
<td>-8.2</td>
<td>1.5</td>
<td>10.3</td>
<td>-7.5</td>
<td>-7.0</td>
</tr>
<tr>
<td>Free</td>
<td>-14.1</td>
<td>29.3</td>
<td>-32.7</td>
<td>3.5</td>
<td>18.8</td>
<td>-18.0</td>
<td>-17.9</td>
</tr>
</tbody>
</table>

All comparisons made with the base case where the intersection is coordinated.
## Simulation Results - Sensitivity Analysis

<table>
<thead>
<tr>
<th>Vehicle Extension Timer %</th>
<th>Avg. Overall Delay %</th>
<th>Avg. Veh Delay %</th>
<th>Avg. Ped Delay 2/6 %</th>
<th>Avg. Ped Delay 4/8 %</th>
<th>Avg. TT % (EB)</th>
<th>Avg. TT % (WB)</th>
<th>Avg. TT % (NB)</th>
<th>Avg. TT % (SB)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0.6%</td>
<td>0.8%</td>
<td>-0.9%</td>
<td>-9.1%</td>
<td>3.8%</td>
<td>0.7%</td>
<td>-0.3%</td>
<td>-0.3%</td>
</tr>
<tr>
<td>0.5</td>
<td>0.6%</td>
<td>0.8%</td>
<td>-0.8%</td>
<td>-9.1%</td>
<td>3.8%</td>
<td>0.7%</td>
<td>-0.3%</td>
<td>-0.3%</td>
</tr>
<tr>
<td>1.0</td>
<td>0.6%</td>
<td>3.7%</td>
<td>-0.7%</td>
<td>-8.9%</td>
<td>3.7%</td>
<td>0.5%</td>
<td>-0.4%</td>
<td>-0.2%</td>
</tr>
<tr>
<td>1.5</td>
<td>0.3%</td>
<td>0.4%</td>
<td>-0.8%</td>
<td>-7.9%</td>
<td>3.0%</td>
<td>0.4%</td>
<td>-0.3%</td>
<td>-0.2%</td>
</tr>
<tr>
<td>2.0</td>
<td>0.5%</td>
<td>0.5%</td>
<td>-0.5%</td>
<td>-6.2%</td>
<td>2.4%</td>
<td>0.3%</td>
<td>-0.2%</td>
<td>0.2%</td>
</tr>
<tr>
<td>2.5</td>
<td>0.7%</td>
<td>0.7%</td>
<td>0.2%</td>
<td>-1.3%</td>
<td>1.8%</td>
<td>0.5%</td>
<td>0.1%</td>
<td>0.1%</td>
</tr>
<tr>
<td>3.0</td>
<td>0.4%</td>
<td>0.4%</td>
<td>0.3%</td>
<td>0.9%</td>
<td>0.9%</td>
<td>0.0%</td>
<td>0.3%</td>
<td>0.2%</td>
</tr>
</tbody>
</table>
Simulation Takeaways

- Free operation most effective method to reduce delay
  - 5 – 14% reduction in average vehicle delays
  - 8 – 33% reduction in average minor street pedestrian delays
- Modifying extension timer of actuated-coordinated phase can:
  - Reduce minor street ped delay (1.3% - 9.1%) with minimal impact on overall vehicle delay
Validated Simulation / Field Deployment

- **Two step approach**
  1. SITL simulation of ped control treatments
     - Shorter cycle lengths
     - Elimination of coordination during certain periods
     - Leading pedestrian intervals, pedestrian scramble
     - Pedestrian priority
  2. Field implementation of pedestrian priority algorithm
     - Portland, OR
     - Flagstaff and Mesa, AZ
Simulation Results (Set 2)

Coordinated vs. Free (Delay)

% Difference: Free vs. Base
"Free has ___% delay than the Base Case"

<table>
<thead>
<tr>
<th>Mode</th>
<th>Delay_All</th>
<th>Delay_Bike</th>
<th>Delay_Ped</th>
<th>Delay_HGV</th>
<th>Delay_Car</th>
</tr>
</thead>
<tbody>
<tr>
<td>%_119th</td>
<td>25%</td>
<td>47%</td>
<td>-47%</td>
<td>27%</td>
<td>33%</td>
</tr>
<tr>
<td>%_122nd</td>
<td>-8%</td>
<td>-9%</td>
<td>-4%</td>
<td>-7%</td>
<td>-9%</td>
</tr>
<tr>
<td>%_130th</td>
<td>-13%</td>
<td>-43%</td>
<td>-9%</td>
<td>-19%</td>
<td>-12%</td>
</tr>
</tbody>
</table>

Mode:
- %_119th
- %_122nd
- %_130th
Exclusive Pedestrian Phase (Barnes Dance)

Exclusive Pedestrian (No vehicle traffic)

Image Sources: LPI; STM Ed. 2. Exclusive Ped Phase; STM Ed. 1
Simulation Results (Set 2)

Coordinated vs. Barnes Dance (Delay)

% Difference in Delay:
Barnes has ___% delay than Base

<table>
<thead>
<tr>
<th>Mode</th>
<th>Difference in Delay:</th>
<th>Delay_All</th>
<th>Delay_Bike</th>
<th>Delay_Ped</th>
<th>Delay_HGV</th>
<th>Delay_Car</th>
</tr>
</thead>
<tbody>
<tr>
<td>%_200</td>
<td></td>
<td>84%</td>
<td>146%</td>
<td>88%</td>
<td>82%</td>
<td>83%</td>
</tr>
<tr>
<td>%_400</td>
<td></td>
<td>89%</td>
<td>149%</td>
<td>86%</td>
<td>82%</td>
<td>83%</td>
</tr>
<tr>
<td>%_600</td>
<td></td>
<td>94%</td>
<td>142%</td>
<td>87%</td>
<td>82%</td>
<td>83%</td>
</tr>
</tbody>
</table>
Leading Pedestrian Interval
Simulation Results (Set 2)

Coordinated vs. LPI (Delay – LPI All approaches)

% Difference _LPI v Base State_ LPI on Both
“LPI is ___ % (more/less) compared to base case

<table>
<thead>
<tr>
<th>% Difference in Delay</th>
<th>All</th>
<th>Bike</th>
<th>Ped</th>
<th>HGV</th>
<th>Car</th>
</tr>
</thead>
<tbody>
<tr>
<td>119th</td>
<td>16%</td>
<td>6%</td>
<td>0%</td>
<td>11%</td>
<td>18%</td>
</tr>
<tr>
<td>122nd</td>
<td>7%</td>
<td>5%</td>
<td>0%</td>
<td>9%</td>
<td>7%</td>
</tr>
<tr>
<td>130th</td>
<td>10%</td>
<td>1%</td>
<td>-2%</td>
<td>-4%</td>
<td>12%</td>
</tr>
</tbody>
</table>
Simulation Results (Set 2)

**Cycle Length Manipulation**

<table>
<thead>
<tr>
<th>Cycle Length (seconds)</th>
<th>02/06</th>
<th>08</th>
<th>Ped 2</th>
<th>Ped 4/8</th>
</tr>
</thead>
<tbody>
<tr>
<td>70</td>
<td>29%</td>
<td>-54%</td>
<td>19%</td>
<td>-44%</td>
</tr>
<tr>
<td>80</td>
<td>22%</td>
<td>-40%</td>
<td>9%</td>
<td>-34%</td>
</tr>
<tr>
<td>90</td>
<td>24%</td>
<td>-28%</td>
<td>10%</td>
<td>-19%</td>
</tr>
<tr>
<td>100</td>
<td>6%</td>
<td>-24%</td>
<td>16%</td>
<td>-11%</td>
</tr>
<tr>
<td>120</td>
<td>7%</td>
<td>16%</td>
<td>10%</td>
<td>11%</td>
</tr>
<tr>
<td>130</td>
<td>-88%</td>
<td>17%</td>
<td>21%</td>
<td>20%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Cycle Length (seconds)</th>
<th>02/06</th>
<th>04/08</th>
<th>Ped 2/6</th>
<th>Ped 4/8</th>
</tr>
</thead>
<tbody>
<tr>
<td>70</td>
<td>15%</td>
<td>-37%</td>
<td>11%</td>
<td>-35%</td>
</tr>
<tr>
<td>80</td>
<td>8%</td>
<td>-35%</td>
<td>0%</td>
<td>-44%</td>
</tr>
<tr>
<td>90</td>
<td>16%</td>
<td>-29%</td>
<td>9%</td>
<td>-28%</td>
</tr>
<tr>
<td>100</td>
<td>6%</td>
<td>-13%</td>
<td>-2%</td>
<td>-6%</td>
</tr>
<tr>
<td>120</td>
<td>1%</td>
<td>13%</td>
<td>2%</td>
<td>11%</td>
</tr>
<tr>
<td>130</td>
<td>2%</td>
<td>20%</td>
<td>-8%</td>
<td>16%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Cycle Length (seconds)</th>
<th>02/06</th>
<th>04/08</th>
<th>Ped 2/6</th>
<th>Ped 4/8</th>
</tr>
</thead>
<tbody>
<tr>
<td>70</td>
<td>26%</td>
<td>-93%</td>
<td>-1050%</td>
<td>-61%</td>
</tr>
<tr>
<td>80</td>
<td>-8%</td>
<td>-37%</td>
<td>-4%</td>
<td>-22%</td>
</tr>
<tr>
<td>90</td>
<td>-56%</td>
<td>-35%</td>
<td>-22%</td>
<td>-26%</td>
</tr>
<tr>
<td>100</td>
<td>-99%</td>
<td>-12%</td>
<td>-20%</td>
<td>-9%</td>
</tr>
<tr>
<td>120</td>
<td>2%</td>
<td>15%</td>
<td>-3%</td>
<td>9%</td>
</tr>
<tr>
<td>130</td>
<td>18%</td>
<td>-48%</td>
<td>-122%</td>
<td>8%</td>
</tr>
</tbody>
</table>
Simulation...still to come

• Set 2:
  – Actuated-Coordinated
  – Ped Priority Algorithm
Field Deployments

• Goal:
  – Deploy algorithm at three different locations
  – Collect travel time and pedestrian delay with and without algorithm implementation
    • Travel time: Bluetooth technology
    • Ped Delay: Time between call and service
  – Compare results to simulation
Pedestrian Delay

<table>
<thead>
<tr>
<th>Event Code</th>
<th>Event Descriptor</th>
<th>Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>45</td>
<td>Pedestrian Call Registered</td>
<td>Phase # (1-16)</td>
<td>Call to service on a phase is registered by pedestrian demand. This event will not be set if a recall exists on the phase.</td>
</tr>
<tr>
<td>21</td>
<td>Pedestrian Begin Walk</td>
<td>Phase # (1-16)</td>
<td>Set when walk indication becomes active.</td>
</tr>
</tbody>
</table>

- Pedestrian delay is time difference between Pedestrian Call Registered and Pedestrian Begin Walk.
Site 1: Flagstaff, AZ (ASC/3 Controller)

**Signalized Intersections**
- = 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 2: Mesa, AZ (ASC/3 Controller)
Site 3: Portland, OR (2070 Controller - Voyage)
Field Deployment – Current Status

• Mesa:
  – Issues with getting algorithm to function in field
    • Believed due to method of uploading controller database used by Mesa
    • Currently building Raspberry Pi based method to employ this month

• Flagstaff
  – Issues with getting algorithm to function in field
    • Unable to pinpoint problem
    • Plan to use Raspberry Pi based method once weather improves (winter!)

• Portland
  – Currently collecting before data
Field Deployment – Raspberry Pi

Programmable Logic Controller (PLC)

Raspberry Pi
Field Deployment – Raspberry Pi
Outcomes thus far

- Simulation results are consistent with expectations
  - Building a comprehensive set of alternatives
- Field deployment has been troublesome
  - Controller challenges
- Strong support from partners for use of this proposed strategy
  - Mesa really likes this idea for their trail crossings
Next Steps

- Complete simulations
- Complete field deployments
- Final Report
- Guidance Document
- Future work
  - Ped-responsive algorithm
Thank you!
Simulation Results (Set 2)

Coordinated vs. Barnes Dance (Delay)

Barnes Dance Results_All ped vol

<table>
<thead>
<tr>
<th>Mode Type</th>
<th>Delay_All</th>
<th>Delay_Bike</th>
<th>Delay_Ped</th>
<th>Delay_HGV</th>
<th>Delay_Car</th>
</tr>
</thead>
<tbody>
<tr>
<td>200 peds/hr</td>
<td>48.88</td>
<td>52.79</td>
<td>75.37</td>
<td>48.43</td>
<td>47.29</td>
</tr>
<tr>
<td>400peds/hr</td>
<td>50.2</td>
<td>53.39</td>
<td>74.78</td>
<td>48.46</td>
<td>47.33</td>
</tr>
<tr>
<td>600peds/hr</td>
<td>51.49</td>
<td>51.8</td>
<td>75.29</td>
<td>48.46</td>
<td>47.32</td>
</tr>
<tr>
<td>Base Case</td>
<td>26.5</td>
<td>21.44</td>
<td>40.17</td>
<td>26.56</td>
<td>25.82</td>
</tr>
</tbody>
</table>
Deployment of Pedestrian Priority

- Three sites
  - Before and after data collection
  - Travel times via Bluetooth
  - Pedestrian delay