Using Hardware-in-the-Loop Simulation to Evaluate Signal Control Strategies for Transit Signal Priority

Christopher A. Pangilinan
Portland State University
Massachusetts Institute of Technology
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Outline

- Introduction
- Objective
- Study Design
- Test Scenarios
- Results
- Conclusions
- Future Research
Introduction

- Transit Signal Priority Concept

- Smart bus knows location and schedule status
- Bus communicates priority request to signal
- Local controller provides priority
Tri-Met Buses

- The “Smart Bus”

**PCMIA Card**

**Control Head**

Schedule deviation
Call for TSP
TSP in Portland, OR

- Conditional Priority with TriMet’s Bus Dispatch System
Priority Framework

Green Extension

Conditional Priority Framework

Red Truncation

1. Is bus within the City of Portland?
   - Yes
   - No

2. Is the bus on its proper route?
   - Yes
   - No

3. Are the bus doors closed?
   - Yes
   - No

4. Has the request already been sent?
   - Yes
   - No

5. Is the bus on schedule?
   - Yes
   - No

6. Is the bus behind schedule?
   - Yes
   - No

Request Priority

Priority Disabled
Objective

• Examine relationship between Transit Signal Priority and bus stop location
• Explore concept of hardware-in-the-loop simulation

Measures of Effectiveness:

• Bus Travel Times
• Bus Intersection Delays
• Side Street Delays
Study Design

Model a single intersection

N. Killingsworth at N. Albina
Study Design

- VISSIM 3.70
- Model 170E Signal Controller
- NIATT Controller Interface Device
- “Hardware-in-the-loop” simulation
Study Design

- TSP Detection Range = 500’
- 12 minute one-way headways
- Dwell times of 20-40 seconds
- 70 second cycle time
  - 31 green, 3 amber, 1 AR

> 

- Green Extension: + 12 seconds
- Red Truncation: - 12 seconds

<table>
<thead>
<tr>
<th>Phase</th>
<th>Volume (veh/hr)</th>
<th>Thru</th>
<th>Right</th>
<th>Left</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 NB</td>
<td>500</td>
<td>70%</td>
<td>15%</td>
<td>15%</td>
</tr>
<tr>
<td>4 EB</td>
<td>500</td>
<td>85%</td>
<td>5%</td>
<td>10%</td>
</tr>
<tr>
<td>6 SB</td>
<td>500</td>
<td>50%</td>
<td>20%</td>
<td>30%</td>
</tr>
<tr>
<td>8 WB</td>
<td>500</td>
<td>80%</td>
<td>15%</td>
<td>5%</td>
</tr>
</tbody>
</table>
## Test Scenarios

### Far Side Transit Stops

<table>
<thead>
<tr>
<th></th>
<th>TSP</th>
<th>No TSP</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Near Side Stop</strong></td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td><strong>Far Side Stop</strong></td>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>

### Near Side Transit Stops
Study Design

- 25-hour real-time simulation runs for each scenario, 2 runs per scenario

- Aggregate data every hour (50 samples)
  - Vehicle/Person delay
  - Travel Times
  - Queue Lengths
  - Much More…
Example: Without TSP
Example: With TSP
Results

Travel Times

<table>
<thead>
<tr>
<th></th>
<th>NearSide without TSP</th>
<th>FarSide without TSP</th>
<th>NearSide with TSP</th>
<th>FarSide with TSP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average Bus Travel Time (Sec.)</td>
<td>79.1</td>
<td>76.8</td>
<td>84.1</td>
<td>68.3</td>
</tr>
</tbody>
</table>

• Far Side Bus Stops: 11% travel time reduction

• Near Side Bus Stops: 6% travel time increase
## Results

### Intersection Delay

<table>
<thead>
<tr>
<th>Bus</th>
<th>NearSide W/o TSP Delay (s)</th>
<th>NearSide w/ TSP Delay (s)</th>
<th>Overall Delay Savings (s)</th>
<th>FarSide w/o TSP Delay (s)</th>
<th>FarSide w/ TSP Delay (s)</th>
<th>Overall Delay Savings (s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average (NB/SB)</td>
<td>27.6</td>
<td>32.5</td>
<td>+4.9</td>
<td>25.2</td>
<td>16.7</td>
<td>-8.5</td>
</tr>
<tr>
<td>Standard Deviation</td>
<td>5.34</td>
<td>5.56</td>
<td></td>
<td>5.18</td>
<td>2.05</td>
<td></td>
</tr>
</tbody>
</table>

- **Far Side Bus Stops:** 33% delay savings
- **Near Side Bus Stops:** 18% delay *increase*
Results

Side Street Delays

<table>
<thead>
<tr>
<th>Side Street</th>
<th>NearSide Delay (s)</th>
<th>Overall Delay Change (s)</th>
<th>FarSide Delay (s)</th>
<th>Overall Delay Change (s)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>w/o TSP</td>
<td>w/ TSP</td>
<td>w/o TSP</td>
<td>w/ TSP</td>
</tr>
<tr>
<td>EB</td>
<td>17.8</td>
<td>21.1</td>
<td>+3.3</td>
<td>17.1</td>
</tr>
<tr>
<td>WB</td>
<td>16.2</td>
<td>18.4</td>
<td>+2.2</td>
<td>16.6</td>
</tr>
<tr>
<td>Average</td>
<td>17.0</td>
<td>19.7</td>
<td>+2.7</td>
<td>16.8</td>
</tr>
</tbody>
</table>

- Minimal delays on side street (non-transit street)
Results

Stop Utilization

0%, 25%, 50%, 75%, 100%
Near Side and Far Side results are similar with 0% stoppage
- Near Side reacts as if it was a Far Side stop
- Near Side delay reductions decrease with higher utilization
- Far side receives benefits regardless of stoppage
Travel Time

- Near Side travel time reduction occurs in every scenario EXCEPT 100% stoppage.
- Far side receives travel time reduction for all scenarios.
- Far Side results have better consistency with TSP.
- Unpredictability of dwell time for Near Side can make call for TSP ineffective.
Conclusions and Future Research

Conclusions

- With no Transit Signal Priority, bus stop location has a negligible effect on delays and travel times.
- With Transit Signal Priority AND a very high stop utilization, far side stops are clearly beneficial.
- Minimal increase in side street delay with short cycle length (70 seconds) and modest volume to capacity ratios.

Future

- Effect of detection length
- Different Transit Signal Priority plans (i.e. no green extensions)
- Traffic volumes
For More Information

http://www.its.pdx.edu/tsp.html

Thank You!