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Webinar: Transit Signal Priority Evaluation and Performance Measures

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Transit Signal Priority Evaluation and Performance Measures

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Portland State University

NITC Webinar - October 26, 2016
Transit signal priority (TSP)* is the process of:
- detecting transit vehicles approaching signalized intersections and
- adjusting the signal phasing in real time to reduce transit delay

TSP Elements

(a) An onboard priority request generator

(b) A detection system that receives the priority request and informs the traffic controller

(c) A priority control strategy at the signal controller
Background—Transit Signal Priority

Why TSP?

Benefits*
- Improve transit reliability
- Allow late bus recovery
- Speed improvements?
- TSP is relatively inexpensive and “easily implemented”

Evaluation? Not so easy...

Background—Transit Signal Priority

Not a comprehensive list!

Evaluation methods

- **Analytic:** Lin (2002); Abdy & Hellinga (2011)
- **Simulation:** Furth & Muller (2000); Dion et al. (2004)
- **Empirical:** Kimpel et al. (2005); Albright & Figliozzi (2012)

Before / after, using bus data and at the corridor level

Performance measures

- Bus travel time
- Schedule adherence
- Headway variability
- Delay for other vehicles
- *Lack of effectiveness and efficiency performance*
Why another study?

Evaluation methods

• Real-world data
• Several intersections
• Integration of:
  – bus data location with
  – signal timing and phases

Performance measures

• At the intersection level
• New PMs to measure TSP effectiveness and efficiency
• Comparison of early green (EG) and green extension (GE) strategies
Study Corridor

Milwaukie  21st  26th  33rd  39th  42nd  50th  52nd  65th  69th  71st, 72nd  82nd

Bus Route 9

Bus Route 66

SE Powell Blvd.

12 SCATS signals

Near-side:
26th EB  33rd EB  42nd EB  72nd EB
26th WB  43rd WB

Far-side:
33rd EB  39th EB  50th EB  52nd EB  65th EB  69th EB  71st EB  72nd EB
39th WB  40th WB  50th WB  52nd WB  65th WB  69th WB  72nd WB

Stop-to-stop segment
Near-side (6)
Far-side (12)
Bus stop-to-stop segments

33rd EB
26th WB
42nd WB
26th EB
72nd EB
42nd EB

6 near-side segments

65th WB
52nd EB
39th WB
69th EB
71st EB
65th EB
50th WB
33rd WB
52nd WB
39th EB
50th EB
72nd WB

12 far-side segments

0 0.1 0.2 0.3 0.4 0.5 mile
TSP in our case study

(a) An onboard priority request generator
TSP request is sent when:
1) on-route,
2) doors are closed, and
3) >30 seconds late.

(b) A detection system that receives the priority request and informs the traffic controller

(c) A priority control strategy at the signal controller determines whether to grant a TSP phase, which TSP phase should be granted, and when the TSP phase should start and end
SCATS: adaptive traffic control

Median Cycle Length, Green phase and red phase duration

Seconds

Intersections / Directions

MKE  21st  26th  33rd  39th  42nd  50th  52nd  65th  69th  71st  72nd

Red
Green
Data Integration

VERY DIFFICULT !!!

Bus ALV/APC Database

SCATS Vehicle Counts Database

SCATS Signal Phase Log Database

Bus Stop-to-Stop Trip Database

Geometry, trajectories

TSP Performance Evaluation

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TSP Phases

• An early green phase truncates a red phase and begins the green phase early to help transit vehicles begin moving early.

• A green extension phase extends a green phase to speed bus passage through an intersection before the signal turns red.
We know bus times and locations before/after crossing the intersection
We do not know bus arrival time at the intersection

We know signal timing and phases
GE Phase: trajectories and probabilities

Arrival time

Departure time

\[ GE_j^e = R_{j+1}^s = t_r \]

\[ GE_j^s \]

Forensic work: many potential cases depending on the stop departure and arrival times, timing of the phases, and bus speed probability distribution
Research Objectives/Questions

• Define performance measures

• Green extension (GE) vs. early green (EG)? Which one is more effective?

• Time savings tradeoffs: buses, passengers, main arterial, and cross streets
Proposed Performance Measures

– TSP Frequency
  • Is TSP working properly?

– TSP Responsiveness
  • Are TSP phases granted after a request?

– TSP Timeliness
  • From the bus point of view
  • What is the probability of benefiting from a TSP phase request?
  • What is the expected time saved per request?

– TSP Efficiency
  • From the traffic signal system point of view
  • What is the expected bus/passenger time saved per phase granted?
  • Normalized to seconds per second of TSP phase duration
TSP Frequency

Is the system working?

**Average number of bus trips per day**
- Blue bars represent requested TSP.
- Red bars represent did not request TSP.

**Average number of TSP phases per day**
- Green bars represent Green Extension (GE).
- Light green bars represent Early Green (EG).

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Responsiveness: Actual Outcomes of TSP Requests

Granted within a cycle

- Neither GE nor EG
- EG
- Both GE and EG
- GE

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18
TSP Timeliness: GE

- d: no GE
- a: late GE
- b: on time GE
- c: early GE

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![Bar chart showing percentage distribution of GE timeliness across different timeframes (39th to 72nd) with categories: d: no GE, a: late GE, b: on time GE, c: early GE.](chart.png)
TSP Timeliness: EG

- **d**: no EG
- **a**: late EG
- **b**: on time EG
- **c**: early EG

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- **d**: no EG
- **a**: late EG
- **b**: on time EG
- **c**: early EG
TSP Effectiveness

Probability that a bus requesting TSP will benefit from a TSP phase

- (Graph showing the probability of on-time EG and on-time GE for different bus stops and near stops)

- EB 39th near
- EB 42nd near
- EB 50th near
- EB 52nd near
- EB 65th near
- EB 69th near
- EB 71st near
- EB 72nd near

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Passengers: avg. time saved per TSP Request

\[
\frac{\sum_i \text{Time saving from GE}_i}{\sum_i \text{TSP request}_i} \quad \frac{\sum_i \text{Time saving from EG}_i}{\sum_i \text{TSP request}_i}
\]

Y axis: average total passenger time savings per TSP request

\( i = \) intersection index
Passengers: Avg. Time Saved per EG phase

Y axis: average total passenger time per second of granted EG phase

\[ \frac{\sum_j \text{Time saving of } EG_j}{\sum_j EG_j} \]
Passengers: Avg. Time Saved per GE phase

NOTE: same scale for the vertical axis

Y axis: average total passenger time per second of granted GE phase

$$\frac{\sum_j Time \ saving \ of \ GE_j}{\sum_j GE_j}$$
Minor streets delay is greatly affected by queue length at the time EG or GE is granted; this is especially important when cross streets have a significant traffic volume.
Summary of Findings

<table>
<thead>
<tr>
<th>TSP performance</th>
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| • Vary significantly across intersections  
| • Opportunity: significant gap between actual and ideal performance  
|  
| Green extension |  
| • Too many late green extension phases  
| • Overall time savings $\approx$ Delay  
|  
| Early green |  
| • Overall time savings $>\ Delay$  

Discussion

• Findings from this study may be site-specific, but the methodology is transferable to other corridors/cities
• Proposed TSP performance measures can help identify problems/improvement opportunities
• Laborious and difficult data integration process
• Importance of synchronization and data accuracy (dealing with a few seconds)
Discussion

- Reliable data transmission, accurate bus location, fast response from the controller
- Impacts of queuing, bus stop location, and signal detection/communication reliability (check in/out)
- Too many GE phases? Better location and data transfer technology may be needed for GE
- SCATS: what is the TSP logic?
- Glass half full or half empty?
Acknowledgements

Steve Callas
David Crout

Willie Rotich
Peter Koonce
References


• Papers can be downloaded from: [http://www.pdx.edu/transportation-lab/publications-by-area](http://www.pdx.edu/transportation-lab/publications-by-area)

• Report can be downloaded from: [http://trec.pdx.edu/research/researcher/Figliozzi/4164/related/products](http://trec.pdx.edu/research/researcher/Figliozzi/4164/related/products)
Questions?