Urban Arterials: Linking Traffic, Transit, and Air Quality Data and Performance Measures

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PSU
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Arterial traffic signal systems: adaptive or fixed-cycle traffic lights?

• Signal timing and cycle lengths can be constant throughout the day or change

• Change:
  – As a function of time of the day (TOD)
  – As a function of detected traffic flows (adaptive)

• Adaptive:
  – Vehicle detection is key
  – $$$: for detection and adaptive control
  – $$$: staff time for maintenance/updating vs. software calibration
Background I

• The City of Portland implemented an adaptive traffic signal system (SCATS) along Powell Boulevard on October 8th, 2011

• SCATS: Sydney Coordinated Adaptive Traffic System

• SCATS adjusts cycle length, phase splits, and offsets to optimize traffic
Background II

• Buses running along this section of Powell Boulevard use TSP (Transit Signal Priority)

• To the best of our knowledge, this is the first time that SCATS and TSP have been integrated in Oregon (and in the USA)
Background III

• Traditional GOALS

• Traditional Goals: a system more responsive to vehicle demand changes; to coordinate traffic flows maintaining the highest acceptable degree of saturation and reducing overall delay ...

... there can be other goals
Adaptive vs. Time of Day Cycle Length

Typical Constraints:
- Maximum cycle length
- Delays/queues for secondary approaches
- Pedestrian requests
- Transit priority

October 26, 2011
Objectives

1. Are there significant improvements in traffic conditions after implementing SCATS?
2. What about transit? Does SCATS affects transit operations?
3. What about TSP (transit signal priority)? How effective is TSP, where, how much?
4. Impacts on air quality and other livability related performance measures?
Data Sources

- **Traffic**
  - Wavetronix radar detection units
  - SCATS Loop detectors
- **Transit**
  - TriMet AVL and APC (automated vehicle location and passenger counting)
  - TSP logs
- **Air Quality**
  - AQ measurements at some key intersections
  - In situ vehicle classification and presence (heavy vehicles)
Background

Powell Boulevard between 10th and 86th Streets

- Urban arterial
- Connects Portland downtown and Gresham via the Ross Island Bridge
- Commuter corridor with peak period congestion

Study area: approx. 5.1 miles, 14 signalized intersections, 54 bus stops.
Traffic Volumes

• Peak Hour
  – Westbound: up to 1,700 vehicles (7-8 am)
  – Eastbound: up to 1,800 vehicles (4-5 pm)

• Daily
  – Westbound: 19,000 – 22,000 vehicles
  – Eastbound: 18,000 – 20,000 vehicles
  – Both directions: approx. 41,000 vehicles
Volume-speed vs. Time of Day

Eastbound Movement (from Portland to Gresham)

Wavetronix unit at 35th @ Powell
Next traffic light at 39th @ Powell

4pm to 7pm (orange)
1pm to 4pm (green)
10am to 1pm (blue)
7am to 10am (red)
7pm to 10pm (black)
Powell @ 26th - Volume Difference – After-Before AM Peak Period - Westbound

% Difference

Volume/5 minutes

Before SCATS Average
After SCATS Average
1. Traffic Evaluation

- *In most cases, statistically significant improvements in travel speeds*
  - With higher traffic volumes after SCATS (statistically significant increases)
  - Accounting for weather conditions
  - Accounting for day of the week and other variables (comparing similar conditions one week before and after SCATS implementation)
2. Transit Performance Measures

• Travel time (corridor)
• Time point reliability (Powell @39th)
• Controlling for...
  – Passenger flows: no statistically significant differences in passenger boarding/hour and passenger load/hour between before and after SCATS
  – TSP requests, time of day, direction of travel, bus driving speed...
Regression Results

- Peak periods: morning 7:30 to 8:30 am (westbound) and afternoon 4 to 6 pm (eastbound)
- Interaction between SCATS, direction and time of day (seconds)

<table>
<thead>
<tr>
<th></th>
<th>Peak Period</th>
<th>Off-Peak Period</th>
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<tbody>
<tr>
<td></td>
<td>West</td>
<td>East</td>
</tr>
<tr>
<td><strong>With SCATS</strong></td>
<td>221</td>
<td>88</td>
</tr>
<tr>
<td><strong>Without SCATS</strong></td>
<td>112</td>
<td>130</td>
</tr>
</tbody>
</table>

- Overall: reduction of 23 seconds on average
2. Transit Evaluation Conclusions

• Mixed Positive Results

• Travel time (corridor)
  – During off-peak improvements in both directions
  – During peak hour improvements only eastbound (not westbound)

• On-time reliability (at 39th @ Powell)
  – During off peak improvements in schedule delay in the westbound direction
  – During peak no improvement in headway delay
3. Transit Signal Priority (TSP) Evaluation

Source: Global Traffic Technologies
3. Effectiveness of Active Transit Signal Priority (TSP)

TSP can *significantly reduce* travel time and *does facilitate* schedule recovery (statistically significant impacts)

BUT *both* priority and driver behavior (bus speed) have significant and discernible effects on travel time.

Schedule recoveries are also affected by many factors and are *intersection* dependent:

- Cross traffic volumes
- Bus Stop Bay characteristics (length, location)
- Bus Stop Location (mid block, far side, near side)
- Time of day
- Direction of travel ...
3. Transit, the big picture

- Approx. 5 miles
- Typical bus travel time (not accounting for stops, loading/unloading passengers) between 500 and 700 seconds
- SCATS decreases travel time 23 seconds on average
- TSP decreases travel time up to 30 seconds (2 seconds per intersection on average)
- Improvements of up to 10% of transit travel time
- As a reference: peak periods add around 90 seconds on average
3. TSP Complexity

Can you have too much of a good thing?

YES! In some cases TSP can facilitate bus bunching

A bus travel time is affected by the number of stops, passenger boardings/alightings, TSP requests...etc... *of the 3 previous buses* (statistically significant impacts)

Current system is myopic (one bus, not system-wide)
4. Air Quality Insights I

• First research to quantify the impacts of traffic signals on vehicle emissions at the sidewalk level

• Clear link between traffic/signal variables (vehicle volumes, vehicle type, queuing, and traffic signal phase durations) with exposure levels

• Overall, SCATS tends to improve air quality per vehicle served by reducing queuing along Powell
4. Air Quality Insights II

• For particulate matter (PM), the impact of heavy duty diesel engines (queuing/idling) at the intersection = hundred or more passenger vehicles

• Some heavy vehicle factors:
  – Angled tailpipe (angled away reduces exposure) (-)
  – Bus engine efficiency (EMP) (-)
  – Idling time is a more significant factor than age/mileage of the bus

• The impact of vehicle presence on particulate matter can take up to 2 minutes (lagged effect)
We are doing a good job measuring performance measures related to...

- Capacity
- Mobility

- Specific Technology Contributions/Understanding (e.g. TSP much more difficult !)

In general, the evaluation of Accessibility & Livability measures have not received much attention:

- Pedestrian/traffic LOS tradeoffs?
- Empirical modeling of air quality/exposure impacts? For example, what are the health impacts of bicycling along a busy arterial bike lane vs. bicycling along a quiet local street?
Lessons Learned

• Support from the City of Portland and TriMet was essential
• Value of data integration and availability
• Challenges to integrate diverse data sources
  – Diverse temporal/spatial structures
  – Variety of devices/calibration
  – Data cleaning and validation...
• Detailed research questions required sophisticated statistical analysis (time series, autocorrelation, lagged variables, time series, ...)

Drinking from the data, analysis & modeling fire hose
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Related Papers I


Related Papers II


• Albright, E., Figliozzi, M., *Schedule recovery for late buses: What are the individual and joint contributions of Transit Signal Priority and bus operator behavior?* (submitted Public Transport Journal)
Questions?

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