Statistical Quantification of Speed and Reliability Advantages from Transit Signal Priority (TSP) Using High-Frequency Bus GPS Records

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Summary

• Metro Transit installed Transit Signal Priority (TSP) on Route 5
• One of the first (or maybe the first) implementations where TSP was the only change made to the route
• Measuring the before and after performance
• Modeling to find the effects of TSP
Route 5

- Highest ridership route with 9,000 to 12,000 rides per day
- Goes from Brooklyn Center to downtown Minneapolis to the Mall of America
- Improving travel time (speed) and reliability is our main goal
  - Transit Signal Priority is one tool that aims to improve both speed and reliability

How the TSP system is designed to work

1. A late bus enters a geo-fence
2. TSP request sent
3. Controller reviews request
4. Controller grants or denies request
   - Granted = early green or green extension
   - If stop cord is pulled or the door opens, the TSP request is withdrawn
**Measurement Approach**

- Corridor level approach
- Before and after periods
  - Oct 2018 and May 2019
- Using GPS data
  1. Record start and end timestamp
  2. Calculated the difference
  3. Remove door open time
  4. Repeat for
     - Each trip
     - Both corridors
     - Both directions
     - Both time periods

- One Problem!
  - We don’t know which bus requested and/or received priority…

**Data Quality**

- Lots of nuances in the data
- Discarded trips that:
  - Went off route
  - Did not have a timestamp in the start and end zone
  - Had poor GPS Quality
  - Made an unusual number of stops
  - Traveled an unusual distance
  - Other suspect data is removed
What are things looking like? North Corridor

What are things looking like? South Corridor
Modeling Approach

- Hierarchical Bayesian Approach
  - Using the BRMS R package that uses R Stan
  - BRMS offers functionality to specify hierarchical mean AND variance components

- Modeling Speed (Travel Time) accounting for:
  - Boardings
  - General traffic
  - TSP for corridor and direction *
  - Time of day for corridor and direction *
  - Differing variability for corridor and direction before and after TSP *

* Hierarchical term assuming that the actualizations of this factor are generated from a parent distribution

Time of Day Effect

- Accounting for dependence expected in different periods of the day
Less Boarding Associates with Faster Speeds

- Why boarding, not load?
  - Load may not capture passenger activity. E.g. 5 Boardings and 5 Alightings is no change in Load
- Modeled as a smoothed parameter
- interesting, since door open time has been removed
  - Acting as a proxy for something else?

More Traffic Means Slower Buses

- Downloaded estimated traffic volumes from StreetLight data vendor
- Matched average traffic volume for time of day by day to trip
- Modeled as a smoothed parameter
  - Surprisingly, linear effect!
  - Tipping point for when I could start trusting the model
TSP Effects, Mixed Results…

- North Corridor saw improvements
- South Corridor did not

Changes in Variability

- Northbound north corridor saw an increase in variability
- May have been a decrease in variability on southbound south corridor
Take home and next steps

• Bayesian hierarchical models are a good approach to transit data. They account for natural groupings in the data and have the added benefit of more straightforward interpretability
• Metro Transit it now putting into place an ongoing monitoring and adjustment process to enhance TSP performance
• Analyses like this will guide and enhance future deployments of TSP
• Adjust modeling approach
  • Skewed distribution
  • Boundary conditions

Thank you
Appendix

The Model

Speed = \text{Grand Mean} + \text{Boardings} + \text{General Traffic} + \text{TSP Effects} + \text{Time of Day Effects} + \text{Error}

\text{Normal(}
\text{speed} \sim s(\text{board\textunderscore scaled}) + s(\text{segVol\textunderscore scaled}) + (1|\text{year:corridor:direction}) + (1|\text{TOD:corridor:direction}),
\text{sigma} \sim (1|\text{year:corridor:direction})
\text{)}

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