The Effect of Transit Signal Priority on Bus Rapid Transit Headway Adherence

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Abstract

We report the results of an experiment to evaluate the impact of transit signal priority (TSP) on headway adherence for a bus rapid transit (BRT) system in Provo / Orem, Utah. The system grants TSP if the bus is running behind its unpublished schedule, but users perceive only a headway. In general, we find that more permissive TSP regimes modestly but significantly reduce the 85th percentile headway, controlling for directionality and time period. An inconsistent result gives that a strict TSP regime has a higher 85th percentile headway than not using TSP at all.

Keywords: Public transit, Transit signal priority, Traffic operations

1. Questions

Transit signal priority (TSP) allows traffic signals to flexibly accommodate transit vehicles. This may involve extending a green phase until the vehicle passes, triggering an early green if there is a vehicle waiting at the light, or even running specific transit-only phases. TSP helps transit vehicles maintain on-time performance (Liu et al., 2018), but often TSP will only engage at a signal if the vehicle is running behind its schedule, thus minimizing automobile delay when the bus is otherwise on schedule (Ni et al., 2020).

In 2018, the Utah Transit Authority (UTA) launched the Utah Valley Express (UVX) Bus Rapid Transit (BRT) system in Provo and Orem, Utah. The system connects two commuter rail stations, two major universities (Brigham Young and Utah Valley), and commercial districts in Orem and Provo. UVX has TSP on X of the X traffic signals along its route. The TSP is triggered when a vehicle is behind its schedule; however, the system does not publish a schedule and rather attempts to maintain a specific headway (6 minutes in the peak period and 10 minutes in the off-peak).

The research questions are therefore:

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- Does schedule-based TSP improve headway adherence for rapid transit systems?
- Is there an average improvement, or is there a reduction in extreme delay?
- Is there an improvement difference by time of day or for particular portions of a rapid transit route?

2. Methods

UTA provided timepoint data for all trips on the UVX system for the entirety of 2019. We calculated the headway between successive UVX trips at each stop, as well as the cumulative dwell time of all stations along the route. Because the UVX route loops around south Provo and stops at the Provo FrontRunner station twice, this created some minor difficulties in data processing, and we removed the timepoints on this portion of the route. We also limit our analysis to the period between 7 AM and 8 PM.

From January through June 6, the system operated with a 5-minute TSP threshold,. with TSP granted only if the vehicle was five or more minutes behind its scheduled timepoint. After August 12, the system switched to a 2-minute TSP threshold. During the summer, the TSP system was configured as follows for this experiment:

- May 2 through June 6, 2019: 5 minute threshold
- June 10 through July 12 and after August 12: 2 minute threshold
- July 15 through July 26: no TSP
- July 30 through August 9: TSP always activated

We discarded trips from January through April and September through December because the additional university passenger demand could interfere in the experiment and there were no tests of the "None" or "Always" TSP thresholds during the school year.

Standard statistical tests — such as the student's *t*-test or ordinary least squares regression models — are designed to ascertain the significance of a statistic at the *mean* of the distribution. In this application, we are less concerned with the mean deviation in headway, and are instead interested in whether TSP is able to reduce the lateness of buses that already have substantial deviation from their programmed headway. Consequently, we employ conditional quantile regression (Koenker and Hallock, 2001) to estimate the effect of TSP on headway deviation at the 85th percentile of the distribution. This is done with the `quantreg` package for R (Koenker, 2020; R Core Team, 2021)

3. Findings

Figure 1 shows the empirical cumulative density function for the headway deviation data, grouped by TSP threshold. Visually, the difference between the various threshold settings is not dramatic. The 5-minute threshold appears to have slightly more vehicles arrive ahead of the scheduled headway, and slightly fewer

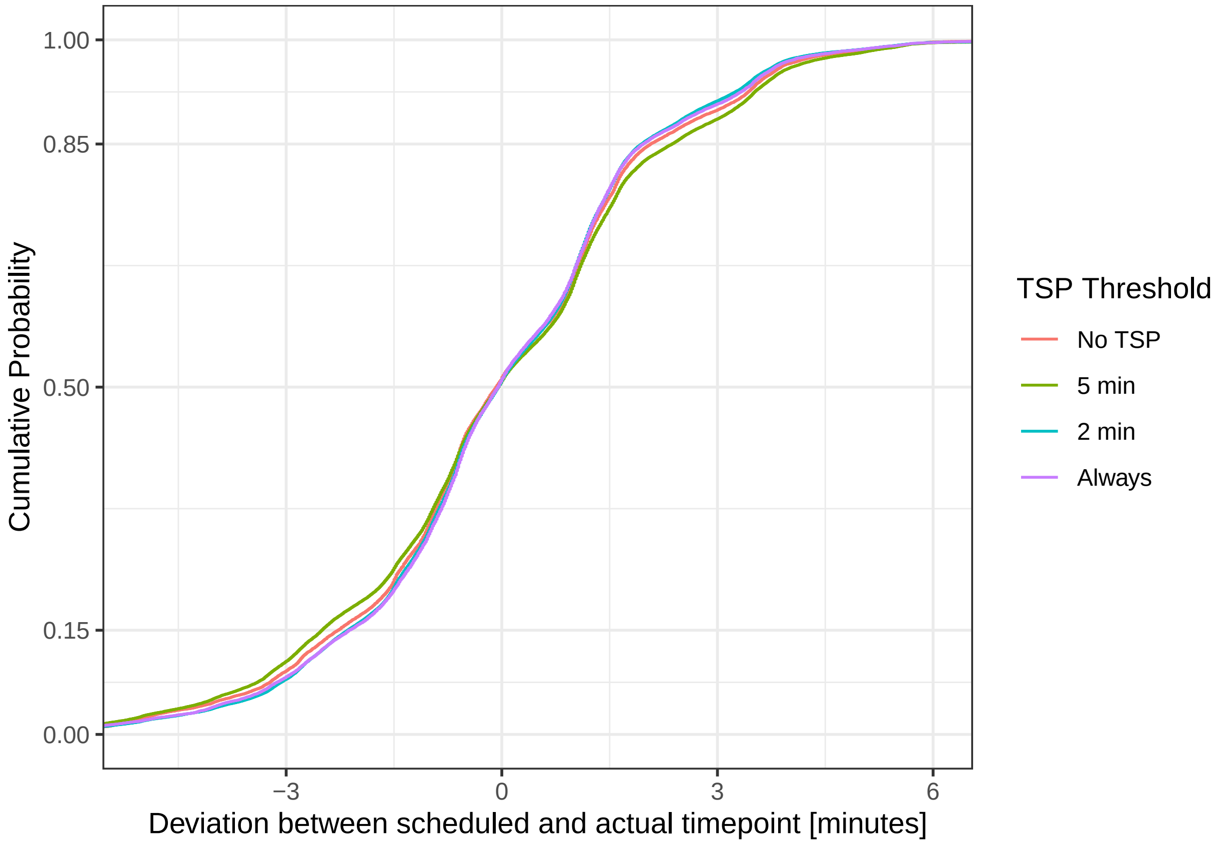

Figure 1: Cumulative probability distribution of headway deviation by threshold.

arrive behind it, than the other three threshold groups. The median and average of the distribution for all four thresholds is remarkably similar, and strengthens our determination to examine the edges of the distribution with a quantile regression model.

Table 1 presents the estimates of four models with an array of explanatory variables. In the model labeled "Threshold," each TSP threshold is controlled for with a dummy variable; the intercept term suggests that the 85th percentile bus arrives with a headway 2.0666667 minutes longer than it was supposed to have. The three threshold dummies are each significant, though the ordering of the coefficients is somewhat unintuitive. Relative to the situation with no TSP, making TSP always available reduces the headway of the 85th percentile bus by 0.1 minutes, and engaging TSP at a 2-minute threshold reduces the headway by 0.1166667. What is not intuitive is that engaging TSP with a 5-minute threshold actually makes the 85th percentile headway -0.3 minutes *longer* than not using it at all.

The other three models in Table 1 control for the direction of the service (southbound buses from Orem to Provo have a longer headway), the time period (operating in the PM peak lengthens the headway), and an interaction term between those two variables. With each additional control, the central findings related

Table 1: 85th Percentile Regression Estimates

	Threshold	Direction	Peak	All
(Intercept)	2.067 (46.600)***	1.683 (65.528)***	1.967 (57.740)***	1.650 (68.493)***
TSP: 5 minutes	0.300 (5.846)***	0.200 (6.113)***	0.233 (5.853)***	0.167 (5.579)***
TSP: 2 minutes	-0.117 (-2.467)**	-0.067 (-2.433)**	-0.117 (-3.569)***	-0.083 (-3.366)***
TSP: Always	-0.100 (-1.800)*	-0.083 (-2.430)**	-0.100 (-2.562)**	-0.100 (-2.849)***
Southbound		0.917 (42.553)***		0.883 (27.572)***
AM Peak			-0.050 (-2.284)**	0.000 (0.000)
PM Peak			0.617 (21.248)***	0.533 (11.790)***
Southbound $\times$ AM Peak				-0.067 (-1.282)
Southbound $\times$ PM Peak				-0.183 (-2.757)***
AIC	760,763.5	755,372.3	759,075.1	754,484.1
Log Likelihood	-380,377.8	-377,681.1	-379,531.6	-377,233

t-statistics in parentheses

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

to TSP are unchanged in either magnitude or significance.

The finding that a 5-minute TSP threshold appears to lengthen the headway relative to not using TSP at all is curious, and we cannot immediately account for it. The schedule of threshold changes was not randomized in any way, and it is possible that the results of this study are tied up in unaccounted seasonal variations. In spite of this curious finding, we find that — all else equal — TSP marginally improves the headway adherence of late-running BRT vehicles.

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