Evaluation of Traffic Signal Priority on Route 15L along E. Colfax Avenue in Denver: A Before-After TSP Study

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Introduction

The objective of the Transit Signal Priority (TSP) was to reduce travel time and improve reliability while increasing security and ridership along RTD's 15 Limited (15L) route on East Colfax Avenue from Broadway to Yosemite Street. The improvements originally identified to be studied as a part of the grant-funded project include transit signal priority, queue jumps, bypass lanes, bus bulbs, advanced fare collection, enhanced bus stop lighting, and heightened security.

Traffic Signal Priority (TSP) is an operational strategy that facilitates the movement of transit vehicles through traffic-signal controlled intersections. TSP is considered one of the popular transit management strategies that can help transit services become more reliable, faster, and more cost-effective. TSP has little impact on general traffic and is a relatively inexpensive way to make transit more competitive with the automobile. Transit signal priority modifies the normal signal operation process to better accommodate transit vehicles. RTD acknowledges TSP as one of the advanced tools to improve bus speed and reliability. Consequently, RTD developed a new TSP operating concept, and the designed TSP concept has been deployed at 18 intersections in the district to improve transit service and performance.

TSP Concept of Operations

Typically, TSP operation allows traffic signal controllers to skip conflicting signal phases, shorten conflicting phases, lengthen compatible phases, or modify phase sequence to serve the transit vehicle. Two primary TSP strategies are 1) Green Extension and 2) Early Green (Red Truncation). More specifically:

- A green extension strategy extends the green time for the TSP movement when a TSP-equipped transit vehicle is approaching. The green extension is one of the most effective forms of TSP since a green extension does not require additional clearance intervals.
- An early green strategy shortens the green time of the preceding phases to expedite the return to green (i.e., red truncation) for the movement where a TSP-equipped vehicle has been detected. This strategy only applies when the signal is red, and a TSP-equipped vehicle is approaching.
- Both green extension and early green strategies are available together within TSP enhanced control environment but are not applied to the same signal cycle.

RTD TSP Architecture

After assessing the state of the practice, recent experience, and modern communications technology available for the bus TSP design, RTD developed a unique TSP approach by utilizing RTD's cellular communications technology to implement TSP operation. The most significant advantage over other methods studied is that this approach fully utilizes the bus on-board equipment and system software that RTD has been applying to CAD/AVL and Automatic Passenger Counting (APC) systems. All that was required was some modification of the on-board programming module to enable TSP triggering and purchase of the relay device to bridge TSP communications between bus and traffic signal controller. This additional equipment is inexpensive and allows for simple maintenance of the system.

TSP Route 15L Implementation

As of Summer 2020, the TSP system has been installed at 14 intersections along E. Colfax Ave. and four (4) intersections along the US-36 corridor in Westminster. The table shows a summary of where and when TSP has been activated.

Table 1 – RTD TSP Locations and Activation Statuses

Corridor	Jurisdiction	Location	Direction	Status
E. Colfax Ave.	Denver	Lincoln	WB	Activated on 4/10/2018
		Grant	WB	Activated on 4/10/2018
		Logan	EB, WB	Activated on 4/10/2018
		Washington	EB, WB	Activated on 4/10/2018
		Clarkson	EB, WB	Activated on 4/10/2018
		Downing	WB	Activated on 4/10/2018
		Park	EB, WB	Activated on 4/10/2018
		York	EB	Activated on 4/10/2018
		Josephine	WB	Activated on 4/10/2018
		Steele	EB, WB	Activated in June 2018
		Garfield	EB, WB	Activated in June 2018
		Colorado	----------	Pending Intersection Geometry Upgrades
		Krameria	EB, WB	Activated on 4/10/2018
		Monaco Parkway	----------	Pending Intersection Control System Upgrades
		Quebec	EB, WB	Activated on 4/10/2018
		Yosemite	EB	Activated on 4/10/2018
US-36	Westminster	Church Ranch	EB	Activated on 1/9/2018
		Church Ranch	WB	Activated on 1/9/2018
		Sheridan	EB	Activated on 1/4/2018
		Sheridan	WB	Activated on 9/6/2017
	Broomfield	Interlocken	EB	Central System Upgrade Pending
		Interlocken	WB	Central System Upgrade Pending
	Superior	McCaslin	EB	Activation Pending
		McCaslin	WB	Activation Pending

Methods of Evaluation

RTD developed methods to explain the operational analysis of service improvements and evaluate their effectiveness by taking measurements to compare Before-After (B-A) TSP improvement. The data for measurement come from automated collection systems on buses for a four-month period, called a runboard, and result in large samples. Bus performance measures are calculated by direction and time-of-day and include: dwell at stops, delays between stops, punctuality, speed, and passing moments (including the distance between stops and passenger counts). A complete review of the methods is contained in Appendix A. It should be noted that although all the measurements were made and analyzed, not all were applicable to define the Route 15L TSP analysis.

Assessment

The Before-After (B-A) Performance Measurement Reports in Appendix B provide the comparative reports from the August 2017 and May 2018 runboards for both Eastbound and Westbound directions and five time periods of a day - a total of ten (10) reports. These runboards were selected to represent 'before' and 'after' conditions because the TSP intersections were activated in early 2018. The activation dates are documented in Table 1.

The following section presents the major takeaways of the assessments of the B-A performance measures.

- Delay is improved- it is examined that delays between stops where TSP has been implemented are decreased and that multiple TSP intersections are offer greater opportunity for reducing and sustaining scheduled running time.
- Punctuality is improved—Buses are found to leave stops at the scheduled time.
- Punctuality variation is reduced—Punctuality *median absolute deviation from the median* (MADM), which is the indicator used to statistically examine the effectiveness of the TSP system, significantly less, and schedulers can make changes with greater confidence.
- Dwell at stops downstream from TSP intersections can be expected to increase because bus operators are admonished not to leave stops early so that they will dwell longer.
- Running time is reduced – the reductions in running time result in improved schedules and perceived customer satisfaction. Historically, transit running times have gradually become more prolonged as traffic conditions have worsened. The following example compares Route 15L peak travel times in 2003 and 2018 between Colfax/Broadway and Colfax/Havana prior to the implementation of TSP:
    - January 2003, Westbound AM peak = 25 minutes
    - January 2018, Westbound AM peak = 32 minutes, an increase of 7 minutes or 28%
    - January 2003, Eastbound PM peak = 29 minutes
    - January 2018, Eastbound PM peak = 33 minutes, an increase of 4 minutes or 14%

  Based upon the TSP B-A data presented in this study, notable among these reductions was a peak period reduction in running time from Broadway to Downing from 5 minutes to 4 minutes. Other peak travel times remained unchanged through the corridor, but there was a measurable improvement in overall reliability and consistency. As a result, the scheduled running times were adjusted on Route 15L, effective with the May 2019 service change. Since these adjustments were made, the COVID-19 pandemic has dramatically changed traffic, travel time, and ridership characteristics. Running times on Route 15L were adjusted in May 2020 to match the lessened ridership and traffic better and adjusted again in September 2020 and January 2021. These adjustments cannot be attributed to the performance of the TSP system.

Following is a detailed summary of TSP effects by time-of-day and direction. The reports in Appendix B should be referenced while going through the following summaries. It primarily relies on looking down the columns that indicate whether the measure is significant or not, and the effects of that measure at the stop and succeeding stops. The cumulative effects determine what adjustments a scheduler can make.

Eastbound:

- Early AM: Improved punctuality with reduced variability, greater confidence in the schedule may result in recovery time (layover) savings
- AM Peak: No significant change
- Midday: No significant change
- PM Peak: The data show a little effect from Broadway to Downing, then a savings of 50 seconds from Downing to Josephine. This savings is maintained to Colorado Blvd. Approximately 30 seconds is saved from Colorado to Monaco, which is then maintained to Yosemite. This shows that between **1 and 2 minutes** could be saved and reinforced by the substantial improvements to punctuality and punctuality variation (MADM) at downstream stops and significant improvement for the route indicated in the summary statistics. The B-A results also indicate the desirability of further operational analysis, with possible time and vehicle savings.
- Evening: Improved punctuality with reduced variability, possible running time savings

Westbound:

- Early AM: Decline in punctuality but no increase in delays. Suspect other traffic delays from street construction in Aurora outside of the study area, causing the bus to depart late at all stops downstream, subject to further research.
- AM Peak: Same as Early AM
- Midday: Consistent running time with no delays, but no apparent impact from TSP. Suspect street construction in Aurora for late-running
- PM Peak: No change in variability, slightly faster travel time possibly due to TSP
- Evening: No change

Conclusion

There is pronounced improvement in Eastbound operation, with reduced travel time and variability and improved punctuality. Westbound operation shows less effect, although travel time and variability do show minor improvements. In addition to the TSP system discussed explicitly in this study, the implementation of the Route 15L Bus Stop Improvement program, with various bus priority measures to include queue jump, bypass lanes, and bus bulbs at selected stops, was substantially complete by the end of 2020. These improvements should further improve the speed and reliability of Route 15L. Running times will be further analyzed in the near future when the measurable performance measures are collected. Meanwhile, RTD is committed to continuously monitor the impact of TSP on transit operations and performances along TSP-equipped corridors.