Implementation of Transit Signal Priority (TSP) and Preemption at Grade Crossings

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ABSTRACT
The Regional Transportation District’s (RTD) I-225 Rail Line, a design build project currently under construction will bring light rail through Colorado’s Aurora City Center and provide a system which will balance automobile and Light Rail Transit (LRT) operations. This balanced approach has posed several challenges to the project team, given there are two gated crossings directly adjacent to signalized intersections within the City Center. Typically, traffic signals adjacent to gated crossings are preempted; however, the impacts to traffic from preemption at this location will be severe given the randomness of its activation and the high traffic volumes along the major arterial roadway being crossed. To overcome these challenges, a unique approach of collaborating TSP routines in conjunction with preemption is proposed to be implemented, which will allow a controlled release of the train from a station or a hold signal to ensure the train passes through the gated crossings with reduced impacts to traffic signal coordination. This paper will elaborate on the proposed approach of utilizing linked priority routines to maintain signal coordination while providing track clearance, holding the adjacent non-conflicting co-phases, and utilizing background preemption.

INTRODUCTION
The Denver Regional Transportation District (RTD) planned a five billion dollar capital program called “Fastracks” to build multiple light rail lines, commuter rail lines and bus rapid transit (BRT). Figure 1 provides an overview map of the RTD fixed guideway system, including lines that are already constructed and in revenue service, lines and extensions that are under construction, and future expansions.

Fastracks funding is provided by the revenue generated from a voter-approved sales tax increase, federal transit funds, and local contributions. Unanticipated inflation and recession in the recent years hindered the Fastracks program schedule. However, RTD was able to come up with unique approaches to keep the program on-track.

RTD had success with accepting and reviewing unsolicited proposals from various different contractors to design and build new Fastracks lines and extensions. In this type of design build contract, the contractor finds an investor and builds the lines through their funding. The new extension of the existing H LRT line and the addition of the R LRT line are being designed and built through this type of contract.
Figure 1 - RTD Fastracks Map
Figure 2 - I-225 Rail Line Extension Map
BACKGROUND

The I-225 Light Rail Line project (an extension of the H line and part of the new R line) is currently under construction. It is about 10.5 miles long with eight stations and is shown graphically in Figure 2. The project is divided into two segments.

Segment 2 is broken into several areas for ease of design completion and construction. Area B, nicknamed “The Horseshoe” due to the LRT’s “U” shape alignment around the Aurora City Center, is made up of Area B1 and Area B2, where Area B1 spans from the intersection of Abilene St & Exposition Ave to just west of the Sable Blvd & Exposition Ave intersection with the tracks running down the middle of Exposition Ave. Area B2 spans from the Sable Blvd & Exposition Ave intersection to the 2nd and Abilene St Station. The LRT alignment within Area B2 passes through the middle of the Exposition Ave & Sable Blvd intersection and then runs directly adjacent to the east side of Sable Blvd creating at-grade crossings with Centrepoint Drive, Alameda Ave, Commercial Access and Bayaud Ave before passing through the middle of the signalized intersection of Ellsworth Ave & Sable Blvd. The alignment then proceeds down the middle of Ellsworth Ave to the 2nd and Abilene Station. All crossings within Area B2 are gated except for Exposition Ave & Sable Blvd, Centrepoint Dr & Sable Blvd and Ellsworth Ave & Sable Blvd.

This paper will focus on the train and traffic interfaces through a portion of Area B2 spanning from the Aurora Metro Center Station to the Ellsworth Ave & Sable Blvd crossing, also nicknamed by the project team as “The Gauntlet”.

The crossings within The Gauntlet are at Alameda Ave, Commercial Access, Bayaud Ave and the intersection of Ellsworth Ave & Sable Blvd. Both the Alameda Ave and Bayaud Ave crossings are directly adjacent to signalized intersections with Sable Blvd. Refer to Figure 3 for an aerial map of The Gauntlet. Information for each street and crossing is provided below:

Sable Blvd is a four lane north/south minor arterial which provides connectivity for about 3.5 miles through downtown Aurora. The traffic signals along Sable Blvd are coordinated to maintain automobile traffic progression. The Average Daily Traffic (ADT) of Sable Blvd near Alameda Ave is projected to be approximately 19,200 vehicles per day (vpd) by the 2016 opening day.

Alameda Avenue is a six lane major east/west arterial which passes through the heart of the COA providing access to the Aurora City Center as well as Aurora’s City Hall. The Alameda Ave crossing is about 1900 feet from the I-225 / Alameda Single Point Urban Interchange (SPUI) with two closely spaced signalized intersections in between. The signalized intersections along Alameda Ave are coordinated to prevent queue spill back onto I-225. Alameda Ave’s ADT at the proposed crossing is projected to be approximately 42,400 vpd for opening day in 2016. Alameda Ave will be widened to accommodate additional left and right turn lanes resulting in a nine lane LRT crossing. Refer to Figure 4 for a traffic signal design plan of the intersection of Alameda Ave and Sable Blvd.
Commercial Access is a small two lane access from Sable Blvd to commercial property to the east. The Commercial Access crossing was proposed to be a ¾ movement access allowing right-in, right-out and left-in movements without a traffic signal. The projected ADT volumes for opening day will be approximately 770 vpd.

Bayaud Ave is a two lane local collector with left turn lanes providing access to a retail shopping center to the west and residential apartment access to the east. The projected ADT will be approximately 1,400 vpd for opening day. Refer to Figure 5 for a traffic signal design plan of the intersection of Bayaud Ave and Sable Blvd.
Figure 4: Alameda Ave and Sable Blvd Traffic Signal Plan

Figure 5: Bayaud Ave and Sable Blvd Intersection Traffic Signal Plan
Ellsworth Ave is a two lane east/west local collector providing connectivity from Abilene St to Sable Blvd. As part of the I-225 Rail Line project, the intersection of Ellsworth Ave and Sable Blvd will be controlled by a traffic signal in order to manage the passing of the train through the middle of the intersection. Opening day ADT volumes are projected to be approximately 2,900 vpd on Ellsworth Ave and 16,400 vpd on Sable Blvd at the Sable Blvd & Ellsworth Ave intersection.

Given the size of the Alameda crossing (traffic volume and number of lanes) and that Alameda Ave and Sable Blvd are both high volume coordinated arterials requiring traffic signal progression to avoid severe impacts to traffic operations and safety concerns, the Alameda Ave crossing became the focal point for train and traffic operations within the Horseshoe.

Based on the close proximity of the Alameda Ave and Bayaud Ave crossings with the adjacent signalized intersections, they were prime candidates for traffic signal preemption. This is based on guidance provided in the 2009 Manual on Uniform Traffic Control Devices (MUTCD), Section 8C.101, that states: “When a highway - LRT grade crossing equipped with a flashing-light signal system is located within 200 feet of an intersection or midblock location controlled by a traffic control signal, the traffic control signal should be provided with preemption in accordance with Section 4D.27.” Preemption of the adjacent traffic signals provides an opportunity for any automobiles potentially queued on the tracks to clear prior to the vehicle gates descending and the train entering the crossing as well as preventing conflicting traffic signal phases from activating while the train occupies the crossing. Traffic signal preemption became a major topic of discussion among the stakeholders. There were concerns regarding the randomness of traffic signal preemption relative to traffic operations and the potential for long traffic signal coordination recovery times (up to five cycle lengths). These random events could severely impact automobile traffic operations and traffic progression in such a traffic sensitive and congested area. Hence, a more balanced train and traffic operation was proposed as a result of coordination between the affected parties. This paper focuses on the preliminary concept of the traffic and train signal operations and design.

**CONCEPT OF OPERATIONS**

The overall concept of operations for the Gauntlet is to provide an appropriate balance of LRT and automobile traffic operations. The concept revolves around the intersection of Alameda Ave & Sable Blvd as mentioned in the previous section. In order to reduce impacts to traffic, it was agreed that the release of the train should be controlled such that it enters the Alameda Ave crossing when the intersection is at an optimal point in its traffic signal cycle. In addition, it was agreed that it was necessary for the train to make it through the three gated crossings in the Gauntlet (Alameda Ave, Commercial Access and Bayaud Ave) without stopping once the train was given the signal to proceed, to allow RTD to optimize LRT operations.

**Transit Signal Priority (TSP)**

Given preemption’s disruption to automobile traffic along Alameda Ave and Sable Blvd, the implementation of TSP was considered. TSP can be operated with passive priority or active priority. Passive priority is where the transit signal phase in a traffic signal is accounted for in the normal traffic signal cycle and operates continuously whether a transit vehicle is present or not. Active priority consists of being able to shorten conflicting phases, extending non-conflicting phases, modify phase sequences and skip phases to serve the transit vehicle when it is present. The latter approach relies heavily on traffic signal controller software that is customized for the specific TSP implementation at hand.

To mitigate delay concerns while maintaining safe operations, different levels of active priority were proposed to be implemented.

**TSP with Railroad Preemption**

In coordination with the stakeholders, the project concept of operations for TSP with railroad preemption was developed. This concept consists of utilizing TSP routines to mimic traditional traffic signal preemption. To achieve this, multiple TSP routines or “linked” priorities would be activated one after another. The first priority would serve as the traffic signal Right-of-

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Way (ROW) transfer and track clearance green phase upon train detection and the second priority would serve the non-conflicting traffic signal phases while the train crossing is occupied and the gates are down. The second priority routine will have a maximum time value based on the maximum green time defined for the priority routine. To provide a failsafe operation, a delayed background preemption routine can be activated to prevent the traffic signal from ever bringing up conflicting automobile phases while the gates are down and the train occupies the crossing’s island circuit. An example of where this would be used is if train stops on approach to a crossing due to an accident or the train breaks down. An advantage of using TSP with railroad preemption is how the TSP routines exit back into the background coordinated traffic signal cycle. For full priority within the Siemens controllers being used on the I-225 Rail Line project, two options are available. Option one is to jump directly to the current location of the coordination timer and option two is to go through offset transitions in the traffic signal cycle which could take up to three traffic signal cycles to get back into coordination. Option one can be used where traffic signal coordination is the number one priority and side street traffic can withstand being potentially skipped. Option two will not skip phases to get back into coordination providing better service for minor movements, but will take longer to get back into coordination. For the I-225 project, the priority recovery options will likely be determined for each crossing through the bench testing process and integrated testing.

**Northbound Train Progression**

A NB train arriving at Aurora Metro Center Station will dwell for a minimum 20 seconds to allow for loading and unloading. The train will be detected by a track circuit as the train enters the station and it will transmit a call to the Alameda railroad signal bungalow via a signal case at the station. The bungalow will send a call to the Alameda Ave & Sable Blvd traffic signal controller indicating that a train has arrived at the station. Once the traffic signal controller has reached a predefined reference point in its cycle, the following will occur:

- The first full “linked” TSP routine will activate at the Alameda Ave & Sable Blvd intersection to start the track clearance green phase (WB Alameda Ave through and left turn movements). This will be timed to occur when the WB through and left turn movements would normally occur if no train was present. This will minimize disruption to the coordination of the Alameda Ave & Sable Blvd intersection.
- The first full “linked” TSP routine will activate at the Bayaud Ave and Sable Blvd intersection to start its ROW transfer followed by a track clearance green phase (WB Bayaud Ave through and left turn movements).
- At the same time, as the TSP routines are activated, a call will be made to the Alameda Ave, Commercial Access and Bayaud Ave railroad signal bungalows to start a delay timer for the activation of their respective railroad warning devices. The activation of the Alameda and Bayaud railroad warning devices will coincide with each intersection’s track clearance green phase to allow the clearing of any potential vehicles on the track while preventing a preempt trap.
- Should the LRT operator need to cancel the call, this can be achieved via the train-to-wayside (TWC) loop. Cancelling the train call will bring the gates back up if they have already descended and release the TSP routines within the traffic signal controllers. Once the train operator is ready to go again, another call will be placed via the TWC loop to initiate the train activation sequence as mentioned above. The train operator will likely have to wait one additional traffic signal cycle at Alameda Ave and Sable Blvd.
- Given the distance from Metro Center Station to the Alameda Ave crossing, the wayside train signal will release the train into the Gauntlet just after the Alameda railroad warning devices activate. The timing of the train release will be optimized such that the train will enter the crossing at the optimal point the Alameda Ave & Sable Blvd traffic signal cycle and after the required total crossing warning time has transpired.
- Once the track clearance green phases have terminated, the second “linked” full TSP routines at Alameda Ave & Sable Blvd and Bayaud Ave & Sable Blvd will activate to serve the non-conflicting
traffic signal phases and prevent any conflicting traffic signal phases from being served while the crossings are active.

- As the train approaches the ungated Ellsworth Ave & Sable Blvd intersection/crossing, a full TSP routine is activated to ensure the train will not have to stop, therefore, completing the NB passage of the train through The Gauntlet.

**Southbound Train Progression**

A SB train approaching the ungated Ellsworth Ave & Sable Blvd intersection/crossing will activate a full TSP routine to ensure the train will be able to cross Sable Blvd without stopping. The train will be detected via a track circuit located west of the Ellsworth Ave and Sable Blvd intersection/crossing which will transmit a call to the Alameda Ave railroad signal bungalow and then to the Alameda Ave traffic signal controller indicating that a train is approaching the Gauntlet. While this communication is occurring, the train will be approaching and preparing to stop at a train wayside signal located just north of the Bayaud Ave crossing. Once the Alameda Ave & Sable Blvd traffic signal controller has reached the predefined reference point in its cycle, the following will occur:

- The first full “linked” TSP routine will activate at the Bayaud Ave and Sable Blvd intersection to start its ROW transfer followed by a track clearance green phase (WB Bayaud Ave through and left turn movements).

- The first full “linked” TSP routine will activate at the Alameda Ave & Sable Blvd intersection to start the track clearance green phase (WB Alameda Ave through and left turn movements). This will be timed to occur when the WB through and left turn movements would normally occur if no train was present. This will minimize disruption to the coordination of the Alameda Ave & Sable Blvd intersection.

- At the same time, as the TSP routines are activated, a call will be made to the Bayaud Ave, Commercial Access and Alameda Ave railroad signal bungalows to start a delay timer (each crossing will have a different delay) for the activation of their respective railroad warning devices. The activation of the Bayaud Ave and Alameda Ave railroad warning devices will coincide with each intersection’s track clearance green phase to allow the clearing of any potential vehicles on the track while preventing a preempt trap.

- Should the LRT operator need to cancel the call, this can be achieved via the TWC loop placed at the SB wayside train signal north of Bayaud Ave. Cancelling the train call will bring the gates back up if they have already descended and release the TSP routines within the traffic signal controllers. Once the train operator is ready to go again, another call will be placed via the TWC loop to initiate the train activation sequence as mentioned above. The train operator will likely have to wait a minimum of one additional traffic signal cycle at Alameda Ave and Sable Blvd.

- Once the track clearance green phases have terminated, the second “linked” full TSP routines at Bayaud Ave & Sable Blvd and Alameda Ave & Sable Blvd will activate to serve the non-conflicting traffic signal phases and prevent any conflicting traffic signal phases from being served while the crossings are active.

- Given the SB wayside signal is just north of the Bayaud Ave crossing, the wayside signal will release the train into the Gauntlet once the Bayaud Ave crossing gates are down and the total warning time has transpired. Again, the timing of the train release will be optimized such that the train will enter the crossing at the optimal point the Alameda Ave & Sable Blvd traffic signal cycle and after the required total crossing warning time has transpired.

- Once the train has been released from the SB wayside train signal, the train will be able to proceed without stopping until reaching the Aurora Metro Center Station.
Bench Testing

To verify the functionality of the concept presented above, bench testing will be required prior to implementation. The bench testing will mimic the final installation in the field using the actual equipment. Once the bench testing and field installation is complete, the train and traffic signal systems will go through an integrated testing in the field. It is anticipated that traffic signal and train signal timings will need to be adjusted during testing for optimized performance of the system.

CONCLUSION

The concept of operation to implement active TSP routines in conjunction with the traditional train signaling system was developed in coordination with the stakeholders, and equipment manufacturers. This unique approach is in final design. It is expected to function as designed with minor adjustments during and after installation to optimize the train and automobile traffic operations. Upon successful implementation of the concept into operation, it will provide an excellent proven reference for similar future projects encountered by various agencies.