Appendix D

TRANSIT TECHNOLOGY IMPLEMENTATION GUIDANCE

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ALAMEDA
County Transportation
Commission

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DRAFT MEMORANDUM

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CC:

From: Laurence Lewis

Project: E. 14th St./ Mission Blvd. and Fremont Blvd. Multimodal Corridor Project

Subject: Implementation Guidance for Transit Signal Technology Improvements

INTRODUCTION AND BACKGROUND

Project Overview

This memorandum describes implementation considerations for transit signal technology improvements recommended as part of the E. 14th St./Mission Blvd. and Fremont Blvd. Multimodal Corridor Project (Project). Transit signal improvements are included as part of the Bus-Only Lanes and Rapid Bus project recommendations. Transit signal improvements are also included in the package of mobility hub improvements to reduce bus travel times to and from BART stations.

The following discussion presents several transit signal-related improvements that were identified to address the Project's goals and needs. Near-term improvements are presented first, and longer-term improvement technologies are presented thereafter. For each improvement type, an overview is provided along with a discussion of implementation considerations and feasibility. For planning purposes, the improvement descriptions include planning level capital costs.

The remainder of this memorandum addresses the following:

- Transit signal progression
- Traditional transit signal priority
- Queue jumps
- NextGen transit signal priority technology

TRANSIT SIGNAL PROGRESSION

Typical signal progression is determined based upon the speed of general vehicular traffic (as opposed to transit vehicle speeds). This approach does not account for transit stop-related delays such as dwell time and time lost to acceleration and deceleration. Since average bus speeds are typically 5 to 10 mph slower than general traffic speeds, typical signal progressions can cause additional delay for transit vehicles. (For the Project Corridor, bus speeds are generally less than 25 mph, with speeds of less than 10 mph near BART stations and in the northern portion of the corridor between San Leandro and Hayward. In comparison, vehicular traffic speeds are generally between 18 and 35 mph.) Retiming signals based on transit speeds will mitigate delays related to buses traveling behind general traffic platoons.

A transit signal progression strategy works best for routes with the following:

- More than ten transit vehicles per hour;
- High pedestrian and bike activity levels; and
- Intersections with short signal cycles

These factors lower the average travel speeds for vehicular traffic, thereby limiting the differential in transit speeds versus vehicular speeds. (These factors also improve safety for pedestrians and bicyclists by discouraging high vehicle speeds.)

A successful transit signal progression should allow a high percentage of transit vehicles to arrive on the green signal phase at each signal along the corridor. This requires signals to be coordinated for a representative transit travel speed that considers stops, deceleration, dwelling time, acceleration time, and right-turn delay if applicable.

Considerations and Feasibility

As noted earlier, transit signal progression works best for routes with more than ten transit vehicles per hour, high pedestrian and bike activity levels, and intersections with short signal cycles. Transit signal progression is not recommended for areas with higher vehicle speeds (i.e., 85th-percentile speeds greater than 30 mph). This is because general vehicular traffic is likely to continue traveling at higher speeds but experience more stops and delays at signalized intersections, resulting in increased emissions and lower corridor efficiency.

Based on transit operating speeds and vehicular speed limits along the Project Corridor, the following areas should be considered for near-term transit signal progression improvements and should be confirmed as part of the project development phase:

- Mobility Hubs
    - Intersections and routes within ½ mile of all BART stations, Fremont ACE station, and Fremont Blvd./Decoto Rd. mobility hub
- Corridor Segments that have high transit activity and low-to-moderate vehicle speeds

- E. 14th St./Mission Blvd. from San Leandro Blvd. to Tennyson Rd.
- Decoto Rd. from Mission Blvd. to Fremont Blvd.
- Fremont Blvd. from Decoto Rd. to Washington Blvd.

Signal retiming for transit progression may be completed as part of larger corridor improvement projects (e.g., E. 14th/Mission Phase II, Fremont Blvd. Safe and Smart Corridor) or through standalone projects.

Implementation Costs

Costs for retiming traffic signals for transit progression range from $2,000 to $3,000 per intersection. Signal timing coordination should be reviewed and updated every 3 to 5 years based on transit travel times and traffic volumes.

TRADITIONAL TRANSIT SIGNAL PRIORITY (TSP)

The purpose of Transit Signal Priority (TSP) is to reduce bus travel times and improve on-time bus performance through minimizing delay at signalized intersections. A TSP system can provide transit travel time benefits without major roadway and infrastructure modifications.

Signal Phasing Strategies

TSP incorporates the following strategies to reduce transit vehicle delay at signals:

Early/Extended Green

This strategy allows buses to pass through the intersection during the current signal cycle by lengthening the green time when a bus is detected. Additional green time can be provided at either the beginning of the signal phase (i.e., early green) or at the end of the phase (i.e., extended green). Older traffic signal controllers extend the green time for a fixed time; however, newer controllers can adjust additional green times based on the estimated bus arrival time. Early/extended green can be limited to certain times of day (i.e. peak hours only) or to certain bus routes (i.e., express routes).

Phase Re-service/Insertion

This strategy inserts a second signal phase within the same cycle to reduce bus delay. This strategy is best applied for protected left-turn movements, where a left turn phase can be accommodated both before and after the adjacent through movement (i.e., leading and lagging).

TSP Technology Overview

The following section describes key attributes of TSP technology and the existing conditions for the Project Corridor:

Distributed Versus Centralized Systems

Traditional TSP deployments utilize distributed systems where signal decision-making occurs at each individual intersection. This contrasts with centralized TSP systems, where signal decisions are made from a central control location. (Centralized TSP systems are discussed in the later section on NextGen TSP).

AC Transit currently uses a distributed TSP architecture but desires to implement a central management system that would support a centralized TSP architecture.

TSP and Emergency Vehicle Priority

TSP equipment can work with or utilize the same equipment that allows emergency vehicles to communicate with traffic signals. Unlike the "high priority" requests by emergency vehicles, buses use "low priority" requests. Whereas high priority operations will truncate or stop signal phases, low priority operations do not skip phases and the timing changes are only granted if they fit within the existing cycle length and coordination settings. Additionally, TSP will be requested only if buses are behind schedule and are trying to catch up (i.e. conditional priority).

Transit Vehicle Detection

Traditional TSP systems use either optical or radio/GPS technologies for transit vehicle detection. Optical systems provide communication through a device on a vehicle which emits infrared light to a detector at the intersection. Optical systems are generally being phased out of TSP operations due to less reliable detection capabilities related to line-of-sight requirements. However, since many existing optical systems are utilized for emergency vehicle preemption, legacy optical systems are being modified to allow for dual optical and radio/GPS detection to maintain existing emergency vehicle preemption while upgrading TSP. (Long term, emergency preemption is also expected to transition to GPS-based systems.)

Radio/GPS systems use GPS to provide location and speed information for buses, then radio communication to transmit TSP requests between transit vehicles and intersections. GPS-based TSP systems can use pre-defined GPS mapped zones for each traffic signal to trigger a TSP signal call. Direct line of sight is not as critical for GPS-based TSP systems, however, obstructions like buildings may reduce the range and reliability of radio communication. When a bus enters the pre-defined zone, the TSP call is made via radio from the onboard bus equipment to a phase selector at the traffic signal controller. The call is terminated when the bus leaves the zone.

AC Transit has deployed GPS-based TSP systems at over 200 intersections within its service area, but none are currently present along the Project Corridor. Local projects that are currently under design will equip nearly 300 additional intersections with TSP, including Project Corridor intersections along Fremont Blvd.

Considerations and Feasibility

TSP improvements are recommended as part of the implementation of Rapid Bus along the Project Corridor. Additional, intersection-specific TSP treatments are recommended for intersections providing access to and from BART stations and other mobility hubs.

It is recommended that proposed near-term TSP improvements be implemented consistent with AC Transit's existing TSP deployments (i.e., a distributed intersection-level architecture that uses radio/GPS systems). This approach would allow for the use of existing onboard TSP equipment. Additionally, most jurisdictions in the Study Area use legacy optical emergency vehicle priority systems. This means that the existing emergency vehicle priority equipment can be easily integrated with the GPS-based TSP system.

Implementation Costs

Costs for installing a TSP system at a single intersection range from $10,000 to $20,000, with an additional operations/maintenance cost of $200 to $1,000 per intersection per year. Costs could increase significantly if the existing traffic signal infrastructure is old (e.g., full conduits that cannot receive new wiring), or if there is no existing vehicle and pedestrian detection.

QUEUE JUMPS

A transit queue jump is a bypass lane combined with a dedicated transit signal phase that permits transit vehicles to advance through an intersection before other waiting motorists. In advance of the green phase for general traffic, a transit phase (+/- 10 seconds) is provided to allow buses to "jump the queue" and navigate through the intersection.

Queue jump lanes are intended to reduce transit vehicle delay associated with traffic congestion and vehicle queuing at signals.

Considerations and Feasibility

A thorough feasibility evaluation is required for each potential location to ensure that queue jump lanes 1) can be designed in a way that provides a travel time benefit for transit operations; and 2) do not result in negative safety impacts to other modes. Installing a queue jump at suboptimal locations may result in increased delays to transit and/or non-utilization by bus operators.

Key operational and geometric characteristics that should be considered for queue jump lanes include:

- ***Type of queue jump lane*** - Queue jump lanes may be for exclusive transit use (preferred) or they may allow for right turns by general vehicular traffic in locations where bus-only lanes are infeasible.
- ***Queue jump length*** – Queue jump lanes should be long enough so that through traffic queues do not block bus access to the lane.

- ***General traffic queues*** - While very long general traffic queues may block access to a queue jump lane, through lane queues must also be significant enough to warrant the need for buses to bypass the queue. If queues are not substantial enough, bus operators are likely to stay in the general traffic lanes.
- ***Right-turn volumes*** – For queue jump lanes that are shared with right-turn movements, high right-turn volumes may prevent buses from utilizing the queue jump signal phase.
- ***Bus stop location*** - Queue jumps can be beneficial at locations with near-side bus stops, as the queue jump can help buses merge back into general traffic. (Note: AC Transit generally prefers far-side bus stops but will consider near-side bus stops where a far-side stop is impractical.)
- ***Impacts to intersection operations*** - A queue jump is facilitated through a dedicated signal phase, which means that the cycle length may be increased, or that signal time is reallocated from other movements. These timing changes may increase delay for other movements and degrade overall intersection operations.

Implementation Costs

The cost of installing a queue jump system at a single intersection ranges from $11,000 to $15,000, assuming that major signal modifications such as new conduits and signal pole upgrades/replacements are not needed. Signal modifications or upgrades may also trigger intersection-wide signal improvements for older traffic signals that are not compliant with current standards.

NEXT-GEN TRANSIT SIGNAL PRIORITY TECHNOLOGY

Distributed versus Centralized Architecture

As discussed in the earlier TSP technology section, a distributed TSP architecture has signal timing decision-making at the **local intersection level**. A transit vehicle communicates to the roadside traffic signal controller which then decides to extend green, truncate conflicting phases, or do nothing. The distributed approach is more common since it only requires reliable communications between the transit vehicle and the intersection traffic signal controller. AC Transit currently uses this configuration.

A centralized TSP architecture makes the transit signal priority requests at the **central system level**, not at the local intersection level. The centralized architecture requires a dependable communication network between the central control system and field devices such as transit vehicles and intersection equipment. Due to the complexities of additional communication links, a centralized TSP is less common than the distributed architecture approach. Additionally, centralized TSP becomes much more complex for corridors operating across several jurisdictions, as multiple signal systems are used. Center-to-Center communications between agencies would be required to achieve a cross-jurisdictional, centralized TSP system.

Centralized Architecture Types

Cloud-Based TSP

Traditional TSP systems require new hardware to be installed at every intersection. A cloud-based TSP system uses a commercial cellular network and can leverage existing equipment and communications infrastructure. A cloud-based TSP system offers the following benefits:

- Analytics can be completed for multiple transit vehicles and for intersections with varying signal system designs.
- Additional services can be provided without requiring significant hardware modifications or installations.
- Can be expanded quickly to new transit corridors and routes
- Allows for more automated signal optimization (i.e., without the need for manual data analysis)

Since the Project Corridor spans multiple jurisdictions, a cloud-based TSP system requires inter-agency agreements to be implemented. The City of Fremont plans to implement a cloud-based TSP pilot project as part of its Fremont Blvd. Safe and Smart Corridor Project.

Central Management Software (CMS)

A Central Management Software (CMS) is at the core of a centralized TSP system. A CMS is often coupled with the Advanced Traffic Management System that is controlled and monitored at a local jurisdiction's Traffic Management Center. In comparison to a cloud-based TSP system, a CMS still utilizes TSP devices installed at each intersection. However, the TSP devices can be operated remotely from the traffic management center, allowing for real-time responses. Additionally, data from both the transit vehicle and the signal equipment is synced via Wi-Fi and can be analyzed to improve system performance.

Considerations and Feasibility

As stated earlier, the City of Fremont is planning to implement a cloud-based TSP system along Fremont Blvd. as a pilot project. However, AC Transit's existing TSP system is based on a distributed network where decision-making occurs at the intersection level. A centralized cloud-based TSP system for the Project Corridor requires multijurisdictional coordination given the multiple types of signal equipment systems that exist.

AC Transit Central Management Software (CMS)

As a near-term strategy, AC Transit desires to utilize local jurisdictions' traffic management systems as part of a CMS. AC Transit anticipates establishing a CMS that would be used to manage TSP infrastructure across multiple jurisdictions. Through projects such as the East Bay BRT and the Line 97 Improvement Project (along Hesperian Blvd.), AC Transit is working with local agencies to establish communication links so that its CMS can access local traffic signal networks and communicate with intersection TSP equipment. These communications would be coordinated through local jurisdictions' Traffic Management Centers where they have been established; therefore, interagency coordination is critical.

Key implementation considerations include the following:

- While AC Transit's future CMS will allow for centralized operations and management for intersection TSP equipment, coordination with local agencies is required to obtain performance data. (In contrast, a cloud-based TSP would compile performance data across multiple jurisdictions.)
- While Advanced Traffic Management Systems allow for TSP functionality, each jurisdiction's system should be reviewed to ensure that appropriate TSP modules that are compatible with the adjacent jurisdictions are in place.
- Additional coordination is necessary regarding the status of centralized communications for Caltrans-maintained signals along the corridor. Specific coordination issues include 1) whether communications capabilities exist; and 2) whether communications systems are integrated with other non-Caltrans signals in the same local jurisdiction.

Implementation Costs

The cost of CMS is approximately $50,000. A TSP module for an existing Advanced Traffic Management System costs approximately $50,000, while a complete traffic management system upgrade would cost $150,000 to $300,000. These estimates do not include operating and maintenance costs.

RECOMMENDATIONS FOR PROJECT DEVELOPMENT

Recommended next steps for project development are as follows:

1. As part of the project development activities for Rapid Bus, evaluate the following signalized intersections for opportunities to retime for transit signal progression
   - Mobility Hubs
     - Intersections and routes within ½ mile of all BART stations, Fremont ACE station, and Fremont Blvd./Decoto Rd. mobility hub
   - Corridor Segments that have high transit activity and low-to-moderate vehicle speeds
     - E. 14th St./Mission Blvd. from San Leandro Blvd. to Tennyson Rd.
     - Decoto Rd. from Mission Blvd. to Fremont Blvd.
     - Fremont Blvd. from Decoto Rd. to Washington Blvd.
2. As part of the project development activities for Rapid Bus, analyze transit and vehicular traffic operations at the signalized intersections listed in Step 1 to identify locations that warrant transit signal priority treatments.
3. In conjunction with the traffic operations analysis described above, evaluate the feasibility of queue jump lanes for locations that warrant transit signal priority treatments.

4. For the recommended intersections identified through Step 2, identify traffic signal infrastructure needed to support near-term and long-term TSP. .

Key coordination needs during project development are as follows:

- Signal retiming for transit progression may be completed as part of larger corridor improvement projects (e.g., E. 14th/Mission Phase II, Fremont Blvd. Safe and Smart Corridor) or through standalone projects. Coordination with these ongoing projects should occur during the project development phase.
- The City of Fremont plans to implement a cloud-based TSP pilot project as part of its Fremont Blvd. Safe and Smart Corridor Project. Coordination should occur during the project development phase to allow the lessons learned from the pilot project to be applied to the remainder of the Project Corridor.
- AC Transit anticipates establishing a Central Management System (CMS) that would be used to manage TSP infrastructure across multiple jurisdictions. The CMS would be coordinated through local jurisdictions' Traffic Management Centers where they have been established; therefore, interagency coordination is critical.
- Additional coordination is necessary regarding the status of centralized communications for Caltrans-maintained signals along the corridor. Specific coordination issues include 1) whether communications capabilities exist; and 2) whether communications systems are integrated with other non-Caltrans signals in the same local jurisdiction