DIVISION OF TRAFFIC OPERATIONS
CALIFORNIA DEPARTMENT
OF TRANSPORTATION

Traffic Operations Manual

Chapter 210 Signal and Lighting Systems

Part 2 Transit Signal Priority

June 2025

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Section 1 Introduction

Transit Signal Priority (TSP) is a tool to improve bus speeds and reliability. TSP is a general term for a set of operational improvements that use technology to reduce dwell time at traffic signals for transit vehicles by holding longer green phases or shortening side street red times to serve an early green. TSP may be implemented at individual intersections, across corridors, or entire street systems. This document focuses on serving transit buses, not light rail transit (LRT).

TSP is not the same as traffic signal preemption, which typically originates from a train or an emergency vehicle. Trains cannot stop quickly and require preemption to ensure vehicles and pedestrians have sufficient time to safely clear the at-grade rail crossing ahead of the approaching train. Additionally, emergency vehicles require preemption to access the scene of an emergency quickly and safely, but also have the authority to move through an intersection regardless of the color phase indication of a signal. Priority is instead a request to be served immediately and ahead of all others. Without TSP, all vehicles are treated equally at the traffic signal intersection.

The benefit of serving TSP requests comes at the cost of taking cycle time from other vehicles. Vehicles traveling along the same path in conjunction with transit, called mixed-use, may benefit from longer green cycles while vehicles on the side street may have reduced green time. Servicing exclusive transit movements takes cycle green time from all vehicles. The cycle timing needs to be a careful balance between accommodating the demand of all road users and limiting congestion.

With mixed-use scenarios, transit is queued up along with vehicles, as transit and vehicles share the same lane. Under congestion, transit cannot move past queued vehicles. Serving frequent transit requests performs poorly under congestion with mixed-use.

Exclusive transit lanes better serve frequent transit but may cause lower vehicle throughput due to a reduction of vehicle lanes. To provide the lane for transit, a vehicle lane or parking lane may need to be reappropriated to the transit.

Caltrans actively promotes TSP to local agencies as a strategy to encourage the deployment of multimodal transportation solutions. Local transit agencies work with Caltrans to implement TSP and are responsible for initiating requests to add TSP to a signal. Per the *California Manual for Uniform Traffic Control Devices* (*CA MUTCD*), local transit agencies are required to pay for the installation and maintenance of TSP hardware with traffic signal access granted to them through an encroachment permit. Local transit agencies also incur costs associated with vehicle and transit agency hardware and software solutions that are used to manage and request TSP.

As of July 2024, there are nearly 500 signalized intersections with active TSP support statewide that are maintained and operated on the State Highway System. As a result of proactive local agencies and transit-supportive citizens, the majority (78%) of these 500 signals with TSP are concentrated within the Bay Area in District 4. The Los Angeles region of District 7 provides a significant contribution as well with 18% of the state's TSP traffic signals.

Deploying modern TSP systems requires three components:

- Detection system aboard the transit vehicle.
- Priority request server which can be aboard the transit vehicle or at a centralized transit center to help prioritize requests.
- TSP management system. TSP solutions require the traffic signal to provide the functionality, but the management system could collaborate with another system (such as a traffic management center [TMC], transit center, or cloud service).

Section 2 Guidance for Typical Intersections

Although recommended as being beneficial statewide, a decision on whether TSP should be utilized at an intersection must be guided by engineering judgment. This decision requires a mutual agreement between state and local agencies, with the state agency having the final approval and authorization on when to modify timing and shut-down TSP. Using TSP can help reduce transit travel times, improve schedule adherence, and improve transit and road network efficiency.

TSP may be beneficial where:

- Public transit utilization is significant.
- Buses travel along transit express routes with limited stops.
- Road geometrics can accommodate exclusive bus lanes.
- Side streets can accommodate impacts due to reduced phase service or potential disruptions to coordination.
- Local agencies are willing to invest in TSP.

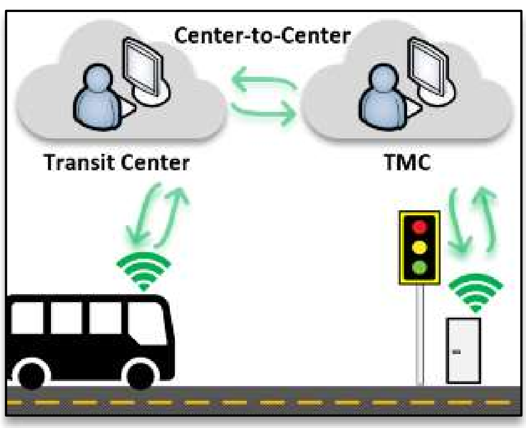
Section 3 Transit Signal Priority System Architectures

There are two TSP system architectures: centralized center-to-center and localized TSP. The selection of a TSP architecture depends on certain factors, including systems requirements, service expectations, scale of TSP traffic signal locations to be managed, and local agency investment. In some jurisdictions the transit center and TMC may be in the same facility, such as with a metropolitan transportation agency, when both transit and signal systems are managed by the same entity or local agency.

Topic 1 Centralized (Center-to-Center) Transit Signal Priority

Centralized TSP is the preferred architecture to accommodate transit system requirements for systems with complex fleet business rules and medium to large-scale TSP deployments. In this type of TSP system, as shown in Figure 210-1, a center-to-center system organizes and manages requests for priority from many vehicles at numerous locations within the transportation system.

Figure 210-1 Centralized (Center-to-Center) TSP



This architecture is best for jurisdictions that have some form of communication link between the traffic signal system and the transit system (or through a shared cloud service). For Caltrans, the TMC is typically a state facility, shared between Caltrans and the California Highway Patrol, with central systems that provide hardware and software solutions to manage field elements. The communication link requires access through a firewall to manage devices on another private network with restricted access, requiring a memorandum of understanding between all participating stakeholders.

The transit vehicle's onboard priority request system is equipped with a Global Positioning System (GPS) that communicates directly with its transit center, or fleet management center, where transit priority requests may be evaluated based on fleet business rules. Another scenario is possible where the priority request system is based at the TMC through the central system and operates in real-time servicing of vehicles as they approach intersections. In this type of system, the amount of communication between vehicles, signals, and the two types of management centers can become somewhat burdensome without high-speed communication, especially if a pre-determined ranking of priority is not established.

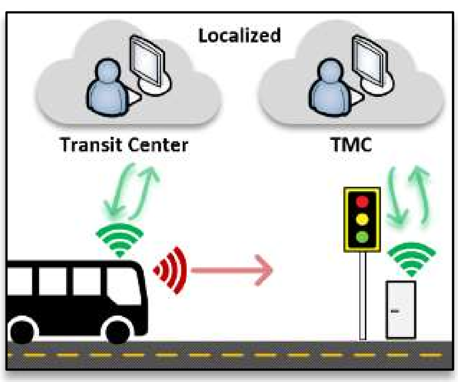
Numerous vendors provide transit solutions through the support of the National Transportation Communications for ITS Protocol 1211 (NTCIP 1211) Signal Control and Prioritization (SCP) standard. NTCIP 1211 requires support at both central systems to manage and traffic signals to implement TSP.

Topic 2 Localized Transit Signal Priority

If the expectation is for a TSP solution with a small fleet of transit vehicles utilizing TSP to traverse a few traffic signal locations, then localized TSP is a simple viable option. With localized TSP solutions, all priority decisions are made at the intersection level. Local systems require less management, and the decision to grant priority can be less nuanced than if a centralized location were managing.

In this type of system, as shown in Figure 210-2, the transit vehicle sends a priority request through a wireless or optical transmitter to the traffic signal each time it approaches an intersection.

Figure 210-2 Localized TSP



This method optionally communicates between transit centers and TMCs (or central systems) as opposed to centralized TSP, as shown in Figure 210-2 with the green-colored communication path. However, a transit center could assist the transit vehicle to manage and prioritize its TSP requests with transit schedule adherence. Localized TSP can be beneficial where TSP is limited to a few signals but may not scale well for fleet management or as a system-wide solution that is both cost-effective and manageable. At minimum, local agencies should install hardware on the bus to issue TSP requests and receivers near the signal cabinet to propagate TSP requests to the signal controller.

Section 4 Evaluation Approaches

With numerous TSP technologies to consider, transit practitioners need to evaluate options fairly.

Key qualitative measures for evaluating TSP functionality and performance include:

- Does the technology save motorists time?
- Is the technology reliable?
- Does the technology affect other users of the roadway?

Section 5 NTCIP 1211 Signal Control and Prioritization

The NTCIP 1211 SCP standard was jointly published by the American Association of State Highway and Transportation Officials, the Institution of Transportation Engineers, and the National Electrical Manufacturers Association, with the participation of numerous state and local agencies, vendors, and consultants. As of 2024, the latest NTCIP 1211 File Version 02.24 was published in 2014.

Vendors develop and market centralized management and field traffic signal solutions to the NTCIP 1211 SCP standard. SCP provides an ecosystem that serves priority requesters (such as buses, LRT, and freight), traffic signals, and management centers that monitor and configure traffic signal controllers. SCP focuses on serving the requested fleet vehicle priority while maintaining signal coordination with adjacent intersections. The goal of SCP is to have minimal negative impact on the general traffic while servicing priority requests where signal coordination quickly resynchronizes. In contrast, signal preemption, such as from a railroad train, directly impacts coordination between intersections and is covered in NTCIP 1202, Version 03A Object Definitions for Actuated Signal Controllers (ASC) Interface.

The core benefit of SCP is the servicing of priority requests from different vehicle classes of varying vehicle levels, with lower numbers representing higher importance, along with the vehicle’s requested time of service while limiting the impact on signal coordination. Vehicle classes might include train and bus classes, with trains having a class of one for critical and buses with a class of five for important. Vehicle levels address prioritization within a vehicle class, such as level one for express buses or level five for local buses.

The SCP ecosystem’s primary components consist of:

- **Priority Request Generator (PRG)** – Estimates times of service or departure and communicates with the Priority Request Server (PRS).
- **Priority Request Server** – Receives priority requests from different PRGs, prioritizes all priority requests based on each vehicle class type and level with its desired time of service, and exchanges service requests with the Coordinator (CO) in the traffic signal controller.
- **Coordinator** – Receives service requests from the PRS, sends status back to the PRS, and implements priority strategy received from the PRS. Using preconfigured settings, the CO utilizes phase and pedestrian omits while altering non-priority phase splits to extend the priority split time.

Secondary components of the SCP ecosystem include:

- **Fleet Management Center** – Receives fleet vehicle's location (and optionally priority requests) and relays the information to the TMC.

- **Fleet Vehicles** – Sends their location to a PRG or fleet management center.
- **Traffic Management Center** – Remotely configures the PRS and CO, receives priority requests from fleet management centers, and relays priority requests to the PRS.

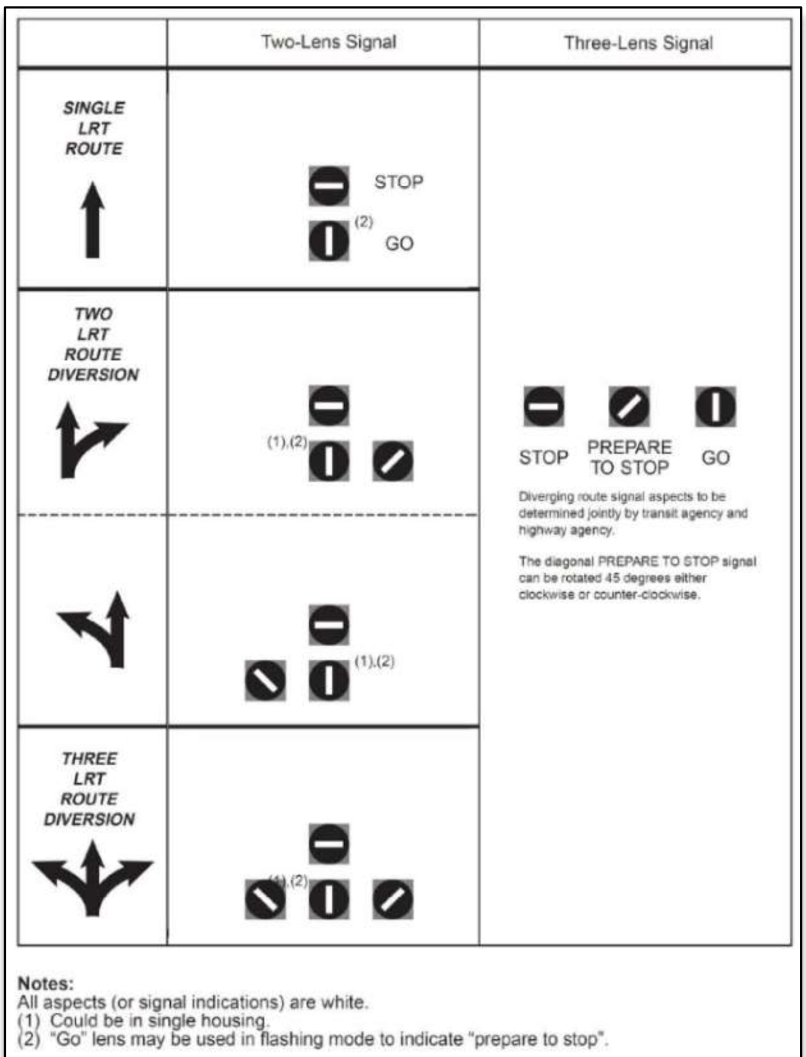
The process for transit vehicles to generate priority requests is defined in the American Public Transportation Association's Transit Communications Interface Profiles standard.

Section 6 Transit Signals

When transit shares the same lanes as vehicles, also called mixed-use, both types of vehicles share the same signal indications. If transit vehicles have an exclusive lane, then transit vehicles require the same signal indications used for LRT.

The signal indicators for exclusive LRT and transit vehicle movements are shown in Figure 210-3, taken from *CA MUTCD* Figure 8C-3(CA).

Figure 210-3 Signal Indicators for Exclusive LRT and Transit Vehicle Movements



Section 7 Transit Signal Priority Strategies

The most common TSP strategies either extend a phase to allow a transit vehicle to pass (for example, green extension) or terminate conflicting phases early to allow service and reduce red time (for example, red truncation). The green extension significantly reduces intersection delays compared to red truncation, and it should be given priority when competing calls exist. However, site-specific conditions should also be considered.

Transit signal priority comes at the expense of reducing side street green time which increases mainline vehicle throughput, affecting surrounding intersections by altering the behavior of traditional coordination plans. Additional vehicles may enter corridor segments that cannot be served within the cycle. These queued vehicles delay the designed timely progression of vehicles traveling through the corridor, as the approaching vehicles slow down for the queued vehicles that are accelerating to corridor-designed speed. Sustained vehicle delays can result in congestion of the corridor and surrounding streets.

To meet the preferred objectives, the transit stop location may affect how TSP is designed, timed, and implemented. The following sequences in Figures 210-4 and 210-5 show the effect of TSP when adjusting the signal timing using green extension or early green (red truncation).

Figure 210-4 Green Extension

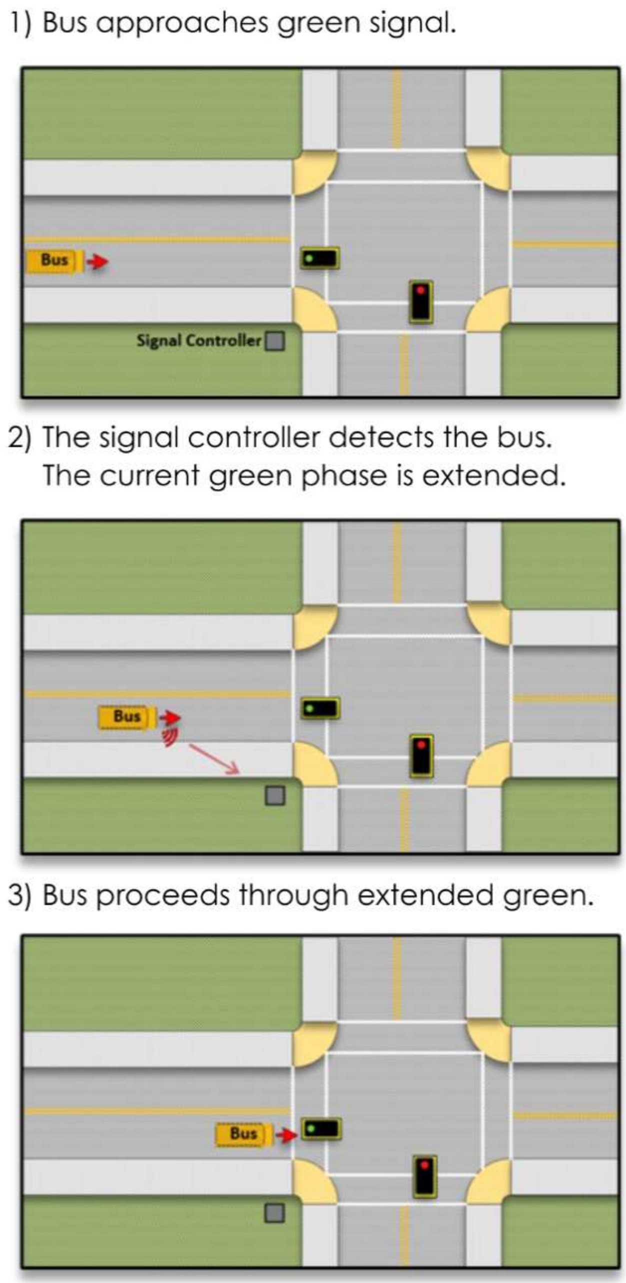
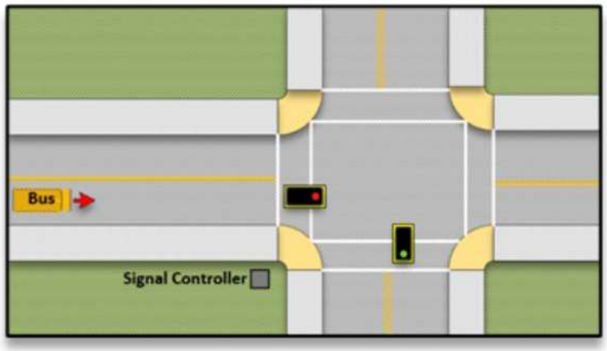
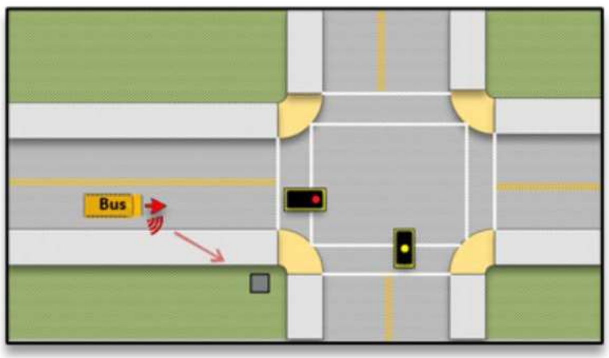


Figure 210-5 Early Green (Red Truncation)

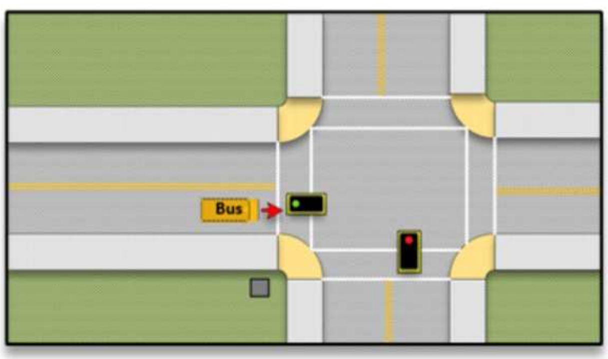
1) Bus approaches red signal.



2) The signal controller detects the bus.
The side street green phase ends early.

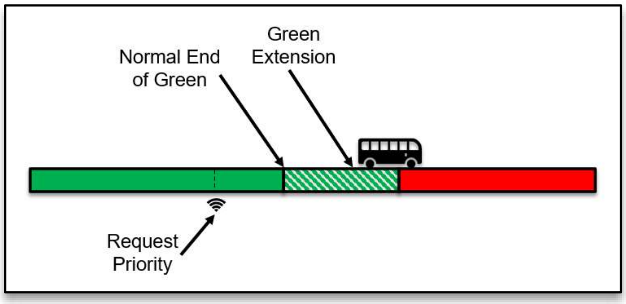


3) Bus proceeds through early green.



The green extension (also called phase extension) prolongs the green phase used by a bus as it approaches the intersection. An example of a green extension is in Figure 210-6, where the bus can save some delay.

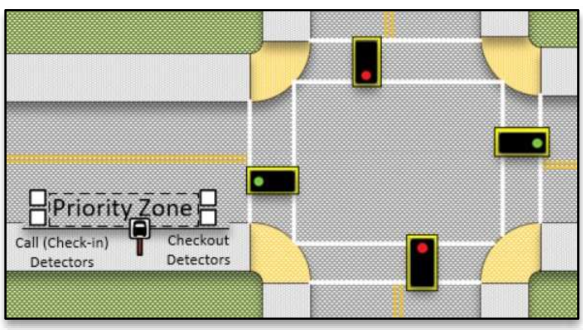
Figure 210-6 Example of a Green Extension



This action is practical when the bus priority is requested or detected near the normal end of a green phase, and the traffic signal determines that the bus will arrive after the normal green phase terminates without a priority. There are different ways of implementing green extensions: sometimes a fixed extension is added (for example, 10 seconds), and in other cases, a form of check-out detection is used so that the phase can end as soon as the bus has sufficient time to clear the intersection. Phase extension provides less intersection delay than early green.

Another form of green extension, shown in Figure 210-7, is available from a defined TSP priority zone with call detectors to check in and check out from the system.

Figure 210-7 TSP Priority Zone with Call Detectors

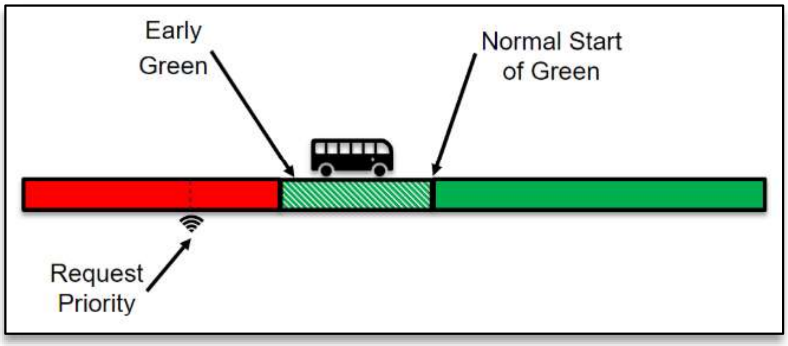


The check-out detectors are used to indicate the bus is moving into the intersection and no longer requires TSP. Check-out detectors can also be located past the stop bar. This type of system requires additional logic hardware that interfaces with the signal loops, controller, and central transit authority. Alternatively, the priority zone can be on the far side of the intersection, but the check-out detection indicates the bus is moving out of the priority zone and requesting TSP at the downstream intersection with an estimated time of service and departure.

Topic 1 Early Green

Early green (red truncation) is used when a bus is expected to arrive during a red phase. The traffic signal starts the next green phase earlier than the green phase would normally occur in the cycle, allowing the bus to progress sooner. Early greens are typically constrained by signal timing business rules and may only reduce signal delay for the bus instead of eliminating it. An example of an early green is shown in Figure 210-8.

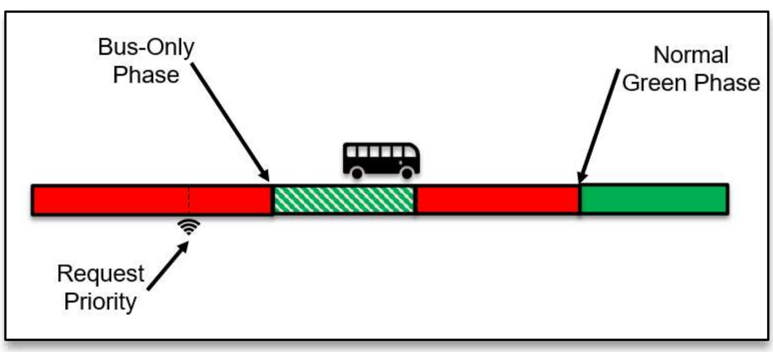
Figure 210-8 Example of Early Green



Topic 2 Bus-Only (Queue Jump)

A bus-only phase provides a protected or optionally exclusive phase for transit (for example, a queue jump). An example of a bus-only phase timing sequence is shown in Figure 210-9.

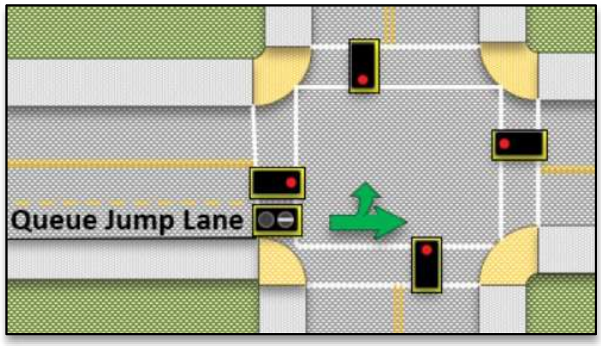
Figure 210-9 Example of a Bus-Only Phase



Some jurisdictions dedicate middle lanes for transit. As an example, the San Francisco Metropolitan Transportation Agency provides a corridor for exclusive bus movement with priority as needed along Van Ness Ave.

The intersection diagram in Figure 210-10 shows an example of an exclusive transit phase where transit vehicles are permitted to make through and turn movements while protected from all other vehicle movements. Drawbacks to this method include dedicating a lane for transit where it may be impractical to add another lane or unfavorable to allocate an existing vehicle lane to transit-only.

Figure 210-10 Intersection with Queue Jump Lane



Section 8 Competing Transit Service

Traffic signals may be required to manage requests from multiple competing subscribers, such as different vehicle classes including buses, bicycles, pedestrians, and other vehicles. Additionally, each vehicle class might have different vehicle levels defined to prioritize within the vehicle class. For example, LRT vehicles would have a higher priority vehicle class than buses. Some buses might have different vehicle levels to accommodate express or local bus routes. While an express bus might have a greater priority than a local bus, LRT priority would be served ahead of any bus priority request. TSP solutions should prioritize service based on considerations such as subscriber priority level, schedule adherence, passenger count, and route importance.

Topic 1 Considerations for Transit Signal Priority Requests

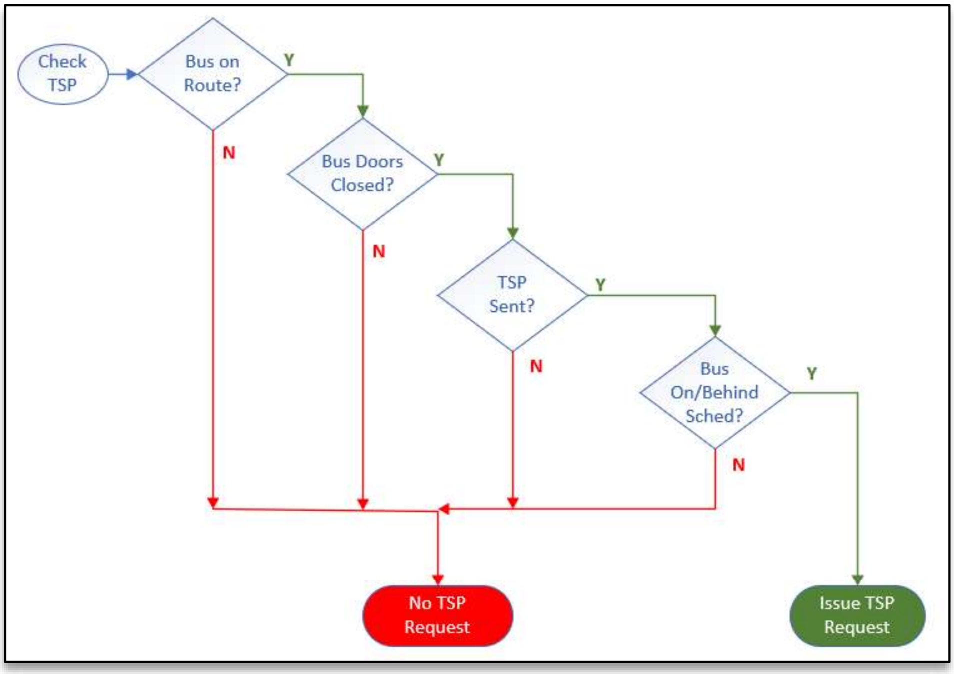
Priority requested from a transit vehicle should be based on predefined conditions warranting priority. Traffic signals honor the priority request if the bus movement is within the current phase being served or the phase is about to be served.

Criteria to consider before requesting priority may include:

- **Schedule Adherence (for example, lateness)** – Practitioners prefer to serve TSP only to transit vehicles running behind schedule. This consideration requires tracking the transit vehicle movement using automatic vehicle location (AVL) technology and comparing it against the expected scheduled location from a computer-aided dispatch (CAD) system.
- **Transit Vehicle Status** – TSP should only be an option when transit vehicles are operating in service, on the transit route, not loading passengers at a transit stop, and traveling within a specified zone near or approaching an intersection. This requires a high-precision GPS for location, direction, and speed.
- **Passenger Count** – Practitioners prefer to serve priority requests on routes with the greatest ridership or anticipated ridership, particularly if multiple requests for priority service occur. This consideration requires analyzing history and monitoring real-time ridership.
- **Sequential Limits** – The *CA MUTCD* states that TSP should not occur more than once every other signal cycle.
- **Level of Priority** – When priority routes intersect, it is required that vehicle classes and vehicle levels are assigned to each competing vehicle type and route, such as LRT, local transit vehicle, or express transit vehicle.

An operating agency may choose to create a decision tree that prioritizes transit vehicles based on several of the characteristics described above. Figure 210-11 illustrates a simple example of a decision tree used to evaluate conditional bus TSP business rules when integrated with CAD/AVL data.

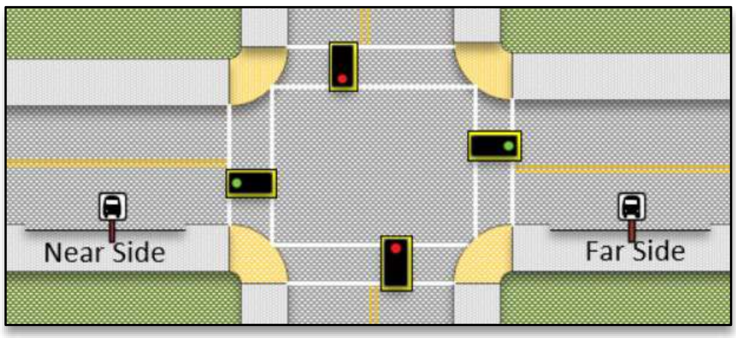
Figure 210-11 Example of a Decision Tree for Conditional Bus TSP Business Rules



Section 9 Transit Stop Locations

Transit stops are usually located on either the near or far side of an intersection as shown in Figure 210-12. There are various advantages and disadvantages dependent on several factors of the transit stop location, including roadway geometrics, local driving patterns, traffic volumes, nearness to other transit routes, and bus storage.

Figure 210-12 Transit Stops on Near Side and Far Side



Topic 1 Near-Side Bus Stops

Advantages of near-side bus stops include:

- A queue jump signal with an exclusive transit lane could move the bus ahead of stopped vehicles and allow for a protected left turn from the far-right lane.
- An early green could move transit vehicles through intersections with light traffic.
- An extended green could move transit vehicles through the intersection when waiting for a gap to merge into traffic.

Disadvantages of near-side bus stops include:

- Transit vehicles are always initially stopped before trying to get through an intersection and may take time to accelerate to match the flow of traffic.
- With heavy traffic, transit vehicles may need to wait for a gap to merge into traffic and potentially miss a requested TSP service window.
- Stopped vehicles or heavy traffic congestion can prevent transit vehicles from merging.
- The Queue jump lane would require additional signal indications and phasing to operate and road space to accommodate the exclusive bus movement.
- Busses may impede the vehicle’s corner sight distance for side street traffic, such as right-turn-on-red with pedestrians present.

Topic 2 Far-Side Bus Stops

Advantages of far-side bus stops include:

- Transit vehicles have more opportunities for gaps to merge into moving traffic flow and accelerate to match the flow of traffic.
- Being in the normal flow of traffic, transit vehicles could be moving when near the signal.
- Extended green can be used to move through intersections where transit might normally stop.
- Busses do not block corner sight distance to street traffic.

Disadvantages of far-side bus stops include:

- Transit vehicles are typically at the back of the vehicle platoon.
- In the event of heavy downstream traffic, it may be difficult to estimate the time of service for an early green TSP request.

Section 10 Best Practices

Several common TSP Best Practices include:

- TSP performs best at intersections with optimized timing. The use of adaptive signal technologies and the performance of signal timing reviews and subsequent manual timing adjustments will put TSP in a better position to serve requests.
- Have discussions with all interested TSP system subscribers and stakeholders early and often before attempting to design and deploy a system.
- If deploying transit vehicle detection systems at an intersection, be sure the choice of detector meets the needs of all subscribers who depend upon its use.
- TSP is noted to work best on transit far-side stops or stops located at the curb immediately beyond the intersection proper on the straight-through exit from the approach under consideration.

Section 11 Benefits

As supported in USDOT's *Transit Signal Priority: A Planning and Implementation Handbook*, the benefits of using TSP improvements include reduced transit travel times, improved schedule adherence, improved transit efficiency, and increased road network efficiency as measured by person mobility. The Federal Transit Administration also considers TSP to be important to the successful implementation of bus rapid transit systems.

In a demonstration project initiated by the Los Angeles County Metropolitan Transit Authority on busy Los Angeles County Metro bus lines, TSP improved travel time savings by 25 percent and, on one line, increased overall travel speeds by 29 percent.[1]

For case studies and the benefits of TSP see *Transit Signal Priority: Current State of the Practice (2020)* from the National Academies Press.

Footnote: [1]U.S. DOT Federal Transit Administration, *In Los Angeles, transit signal priority reduced total transit travel time by approximately 25 percent*, May 2008, <https://www.itskrs.its.dot.gov/2008-b00544?OpenDocument&Query=BOTM>.

Section 12 Costs

TSP system maintenance is a relatively insignificant cost that can be incorporated into regular maintenance of transit vehicles and systems. Additionally, costs to other users of roadways tend to be minimal, or even imperceptibly small because the adjustments to traffic signals are made in terms of seconds at a time, and signal timing readjusts quickly.[2] The costs associated with implementing TSP vary depending on geography and the level of complexity, often requiring funds for taxes and bond measures.

A large-scale TSP system was deployed in 2013 by the San Francisco Metropolitan Transportation Authority (SFMTA) with funding from sales tax revenues, bond measures, and developers paying transportation impact fees to serve TSP at 450 intersections with 900 buses.[3] Currently, SFMTA has expanded TSP commitment by devoting major corridors to favor transit over vehicles, notably along Market St. and Van Ness Blvd., by reducing vehicle lanes and street parking to provide exclusive bus lanes and transit boarding islands. Figure 210-13 shows an example of an exclusive San Francisco Municipal Railway transit lane and transit boarding island.

Figure 210-13 Exclusive Transit Lane with Boarding Island

Footnote: [2]Kang, H., Skehan, S., and Gephart, R., *The costs to implement a transit signal priority demonstration project in Los Angeles, California was $10 million*, September 2003, <https://www.itskrs.its.dot.gov/2003-sc00001?OpenDocument&Query=CApp>.

Footnote: [3]Anderson, P., Walk, M., Simek, C., *Transit Signal Priority: Current State of the Practice*, 2020, < Transit Signal Priority: Current State of the Practice | The National Academies Press>