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Memorandum

Date	**7/8/2010**
To	File
From	Adam Streit
Subject	Transit Intersection Signal Options

Introduction

Traffic Signal Priority (TSP) is an operational strategy that facilitates the movement of in-service transit vehicles (e.g., buses or streetcars) through signal controlled intersections. Two terms are often used to describe TSP, priority and preemption. These are two different processes and result in different intersection operations. Although they utilize similar equipment, traffic signal preemption interrupts the typical light cycle for special or authorized vehicles, whereas signal priority modifies the typical signal operation process to better accommodate transit vehicles. This memorandum provides a general description of the various signal priority options that are generally considered for Bus Rapid Transit (BRT) systems, the assumptions used for the operations plan for the San Juan – Carolina BRT, and a general description of the TSP equipment required, including capital and operating costs.

San Juan - Carolina BRT Route

The proposed San Juan - Carolina BRT Route is a 9 station stop system approximately 8 miles (12.8 km) long. It will pass through one non-signalized and 17 signalized intersections. Buses will primarily operate along an exclusive busway with some mixed traffic sections. The exclusive busway will generally be at-grade within the median of PR-3. This configuration requires the incorporation of the busway into many of the PR-3 intersections and signal operations between Carolina and Rio Piedras. A form of traffic signal priority and/or preemption will be advantageous for efficient BRT operations.

Traffic Signal Preemption

Preemption is traditionally used at railroad crossings and at signalized intersections where one mode, or user, requires a significant preference for safety or performance reasons. When a traffic signal is preempted, there is no consideration for maintaining the existing signal timing plan such that coordination can be maintained between adjacent traffic signals. Preemption uses a special timing plan, requiring the traffic signal controller to transition out of and back into the coordinated operation of the normal signal timing plan.

An operating option was developed for the San Juan-Carolina BRT that included Traffic Signal Preemption at each of the signalized intersections. This would eliminate delay to the BRT associated with stopping at each of the 17 intersections. It is assumed that although buses would not stop at the intersections, they would reduce speeds to ensure that the intersection was clear and that it was safe to proceed.

Traffic Signal Priority
Traffic Signal Priority (TSP) provides preference to a mode, or user, by integrating this preference into the overall intersection signal phasing, thereby providing preference without significantly impacting other traffic. Since bus service typically operates at high frequencies and can stop and start without significant delay, the use of signal priority for BRT systems is more common than signal preemption systems. Signal priority systems allow the transit service to maintain a high level of performance without significantly impacting operation of the intersection for other vehicles. For a transit service, TSP is typically used to improve overall trip speeds and maintain schedule adherence by reducing intersection delay.

TSP Strategies
There are multiple strategies that can be utilized for incorporating Traffic Signal Priority systems within a BRT corridor. These include:

- Passive Priority,
- Active Priority,
    - Early Green (red truncation),
    - Green Extension,
    - Actuated Transit Phase,
    - Transit Phase insertion,
    - Phase rotation, and
- Adaptive/Real-time control.

A Passive Priority strategy provides a priority to transit by developing signal phase timing that is most favorable to the operating characteristics of transit. Timing coordinated signals at the average bus speed instead of the average automobile speed can favor transit vehicles. A Passive Priority system operates continuously regardless whether a transit vehicle is present or not, and does not require a transit vehicle detection system. This type of system is the easiest and quickest form of TSP to implement. Passive Priority is typically used along single roadway segments where typical bus speed does not vary dramatically. Passive Priority was not considered in the development of the San Juan-Carolina BRT operating plan options.

Active Priority strategies involve detecting the presence of a transit vehicle and, depending on the system logic and the existing traffic situation, give the transit vehicle special treatment. An active system must be able to both detect the presence of a transit vehicle and predict its arrival time at the intersection.

> An Early Green strategy shortens the green time of the phase preceding the predicted arrival of the bus to expedite the return to green (i.e., red truncation) for the movement when a TSP-equipped vehicle (i.e. bus) has been detected. This strategy only applies when the signal is red for the approaching TSP-equipped vehicle.
>
> A Green Extension strategy extends the green time when a bus is approaching to allow for the bus to pass through the intersection. This strategy only applies when the signal is green

for the approaching bus. Green extension is one of the most effective forms of TSP since a green extension does not require additional clearance intervals, yet allows a transit vehicle to be served and significantly reduces the delay to that vehicle relative to waiting for an early green or special transit phase.

Early Green and Green Extension strategies may be applied together in a corridor to maximize the opportunity within the signal cycle for transit services to have priority. Although these two strategies can be implemented in the same corridor, they would not be implemented in the same traffic signal cycle so that timing coordination for the intersection could be maintained. These two strategies can be applied where buses are operating in mixed traffic or when a bus operating in a busway crosses an intersection. These two strategies were not employed in the development of the San Juan – Carolina BRT operating plan, although they may be considered at more advanced stages of design for particular intersections or groups of intersections.

<u>Actuated Transit Phases</u> are only executed when a transit vehicle is detected at the intersection (i.e. a vehicle approaching in an exclusive busway or in a mixed traffic left turn lane). When a special priority phase is inserted within the normal signal sequence, it is referred to as phase insertion. The transit phase can only be inserted when a transit vehicle is detected and requests priority for this phase, otherwise the signal will continue to operate as if the vehicle were not at the intersection. Two versions of this approach were included as options for the San Juan – Carolina BRT operating plan. One version required each bus to stop at the intersection upon arrival of the intersection before actuating the transit phase and proceeding. The other version allowed buses to proceed through the intersection when it arrived during the predominant phase (PR-3 through-movements), thereby negating the need for actuating the transit phase during those times.

<u>Phase Rotation</u> is a TSP strategy whereby the order of signal phases are "rotated". For example, a northbound left turn phase could normally be a lagging phase, meaning it follows the opposing through movement signal phase. A northbound left turning bus requesting priority that arrives before the start of the green phase for the through movement could request the left turn phase. With the phase rotation concept, the left turn phase could be served as a leading phase in order to expedite the passage of the transit vehicle. Phase rotation can be employed for transit in exclusive bus lanes or mixed-traffic. This approach was not included in the development of the San Juan – Carolina BRT operating plan.

<u>Adaptive/Real-time</u> control strategies consider not only the presence of a transit vehicle but can optimize the TSP based upon changing performance criteria (e.g., schedule adherence, running time). These types of strategies continuously optimize the effective timing plan based on real-time and observed data. They typically require early detection of a transit vehicle in order to provide more time to adjust the signals to provide priority while minimizing traffic impacts. Adaptive systems also often require the ability to update the transit vehicle's arrival time, which can vary due to the number of stops and traffic conditions. The updated arrival time can then be fed back

into the process of adjusting the signal timings. This approach was not included in the development of the San Juan – Carolina BRT operating plan.

TSP Equipment

There are three major components to any TSP system:

1) Transit Vehicle Detection / Priority Request System,
2) Communications Systems, and
3) Traffic Signal Control System.

Transit Vehicle Detection/Priority Request System

The Transit Vehicle Detection system is responsible for initiating requests for priority based on predefined criteria, which may be static, (e.g., priority automatically requested for all buses on certain routes), or dynamic (e.g., priority requested for buses behind schedule by more than 5 minutes). Depending on the approach selected, the detection system may be based at the local intersection level or at the management center level.

A transit vehicle may be detected at the local intersection level through a combination of an on-board transmitter and a receiver on the intersection approach. For detection at the network level, a transit vehicle may communicate with a transit or traffic management center, providing its location directly. When a priority request is generated, either at the intersection or network level, it may be forwarded directly to the local intersection controller or first pass through a central management center for approval and/or processing.

Communications System

The communications system for TSP includes the provision of detection information from transit vehicles to the local intersection or management center, and if a management center is used, from center-to-center and center-to-intersection, as necessary.

Traffic Signal Control System

The traffic signal control system is responsible for acting on the priority request and making any applicable changes to the signal indications via the local traffic signal controller. For a simpler system, the local traffic signal controller may be able to perform this function completely, while in other cases, a centralized traffic signal control system arbitrates the request prior to directing the local controller to take applicable action. Depending on predefined parameters, the traffic signal control system may or may not make actual changes to the signal indications. The traffic signal control system is also responsible for ensuring that higher priority requests (e.g. emergency vehicle preemption) override other requests in order of priority.

Capital Costs
A literature and industry review reveals that the capital costs for a basic TSP treatment per intersection costs approximately $62,000. All costs were derived from the Transit Signal Priority Handbook[1] and the Federal Transit Administration[2].

Capital Components of a TSP System[3]			
Component	**Unit Cost**	**Units**	**Source**
Loop Detectors (*Vehicle Detection*)	$ 10,890	No. Transit crossings per intersection	TSP Handbook
Signal Controllers (*Communications*)	$ 3,630	Each	TSP Handbook
Transponders (*Vehicle Detection / Comm.*)	$ 121	Bus	TSP Handbook
Intersection Treatment (*Signal Control*)	$ 36,450	Each	TSP Handbook
Software	$ 60,500	Lump Sum	TSP Handbook

Operating and Maintenance Costs
Depending on the maintenance agreement between the municipality and the transit agency, the operating and maintenance costs associated with a TSP intersection range from being negligible up to $1,090[4] per year per intersection[5].

[1] Harrlet R. Smith, Brendon Hemilty and Miomir Ivanovic, *Transit Signal Priority (TSP): A Planning and Implementation Handbook*. (Washington, D.C., Transportation Research Board, May 2005), pp. 114 – 120.
[2] U.S. Department of Transportation. *Intelligent Transportation Systems.* ONLINE 2001. Federal Transit Administration. Available: http://www.itscosts.its.dot.gov/its/benecost.nsf/ID/6105A5CEB6C12C9C85256DB100458915?OpenDocument&Query=Capp [Accessed: 6 July 2010].
[3] Costs adjusted from $2001 to $2009 at the US Bureau of Labor and Statistics rate of 21%.
[4] Costs adjusted from $2001 to $2009 at the US Bureau of Labor and Statistics rate of 9%.
[5] TSP Handbook, pp. 38.