# TSP in the urban environment: challenges, challenges and challenges

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Paper prepared for presentation

at the *Traffic Control Measures that Encourage a Shift in Travel Modes* Session

of the 2010 Annual Conference of the Transportation Association of Canada

Halifax, Nova Scotia

## Abstract

Transit Signal Priority (TSP) is getting attention these days as jurisdictions try to make transit more attractive to commuters. However, when practitioners add TSP to urban streets, they are faced with many challenges not found in ideal, suburban conditions. TSP transfers seconds from other phases in the timing plan to the transit phase. But how do you do that in an urban environment where there are only two phases and no margin available?

This is just one of many challenges. Urban TSP experiences are scarce, driving practitioners into uncharted territory. High pedestrian volumes, cyclists, pedestrian countdown timers, protected Walk phases and coordination, other projects interfering at street level, amongst others, are all part of the deal. More than once, practitioners have to think outside of the box to get results.

In a plug and play world, one expects technology to be a facilitator. But in the specialized world of traffic signals, practitioners should never underestimate the integration time of various components, and expect issues with firmwares that don't talk to each other, or suddenly become unstable when product B is connected to product A.

At the inception of a TSP project, jurisdictions and transit authorities should first establish clear goals and limits, taking into account the limitations and constraints brought by each other's operations, the urban environment and of course the available hardware. Once an operational protocol is set and agreed, the project team can then move forward and face the many challenges that pave the road to TSP.

## Introduction

Traffic engineering came of age in the middle of the 20th century when households became increasingly motorized. The prosperity that followed the Second World War lead to increased development, and with it urban sprawl in the form of growing cities and suburbs to serve the Baby Boom generation. Commuting within the urban centers took a sharp increase in the late sixties when women joined the workforce. Through the decades, the traffic engineer used his skill and toolbox to meet the growing transportation needs of the public. In the early days, meeting these needs meant building new roads, highways and bridges.

Transit has always been around, and was even there before the automobile became an affordable commodity for the working man. It too evolved during the boom years, with the bus becoming the vehicle of choice to cover the maze of surface streets that modern communities have become.

While transportation engineers developed major transit backbones in the form of rail-bound vehicles, both above and under the ground, the buses were more or less a forgotten element in the global commuting picture. On the supplier side, passenger capacity was increased through articulated or double-decker buses. However, all buses were left exposed to surface street traffic, and often stay stuck in it. Before "smart" traffic controllers were available, signals at intersections offered little in the way of helping buses through.

Policy-makers, urban planners and traffic engineers had limited, but radical, tools they could use: reserved bus lanes and pre-emption. On highways or in sprawling suburbs, reserved bus lanes can be created by paving shoulders or widening the roadways. In the urban core, space is at a premium and buildings often go right up to the sidewalks. The impact of a reserved bus lane is then severe as regular traffic must be condensed in the remaining lanes. Reserved lanes also impact curb side activities, like stores who depend on stop-by customers, by removal of parking or stopping privileges on the street.

Pre-emption for buses is a more sophisticated tool. A lighter version than emergency pre-emption, it can increase the green time at a signal when a bus needs it. By reducing the time a bus spends at a red light, pre-emption improves the efficiency of the bus route, but also that of motor vehicles in general since all benefit from increased green time. Thus, buses aren't getting any priority over other travel modes. Furthermore, pre-emption can't be applied in Central Business Districts (CBD) because of the proximity of signalized intersections. Pre-emption disrupts signal coordination, creating irregularities in traffic flows and increasing accident risks within a CBD.

As traffic signal controllers became "smarter", traffic engineers started working on algorithms that alter the phasing of an intersection to respond to transit operator's needs. It was the birth of Transit Signal Priority, or TSP. Today, in the 21st century, most signal controller manufacturers offer factory-made TSP programming in their products. When faced with bus-based transit issues, TSP is the sharpest tool in the traffic engineer's toolbox. However, the urban environment is full of constraints that the practitioner must balance. Applying TSP in the urban environment implies facing challenges that the traffic engineer will have to tackle to get success in his project. The following paper discusses these and ways to work around the challenges on the road to urban TSP.

## 1. The politics of transit priority

Transit priority fits the current approach to sustainable transportation, but such was not always the case. From the '50s to the '80s, the transportation community responded to the public's needs by building more roads or by widening those that existed. It was an easy solution to a recurring problem.

In today's world, preoccupation for the environment is becoming more and more prominent in the transportation equation. Communities can't accept more roads, either by choice or by design, or significantly don't actually want new roads. Commuting and transportation in general has to lessen its footprint on the environment. Vehicles are getting cleaner, and are burning less fuel, but they have to share the surface networks with active transportation modes (biking and walking) in addition to transit, whose ridership keeps increasing.

Improvements from road construction aren't the easy pill they used to be. Now, transportation engineers have to use their skills to optimize the road network for all users and to find unused capacity hidden within the existing roadway system.

However, who does what with the road network involves a great quantity of stakeholders, and it's not up to the traffic engineer to decide on how the public roadways are to be shared.

### *Challenge #1: Get a Clear Policy on Transit*

Managing all transportation demands in the urban street grid is a juggling act, but the traffic engineer is not the one throwing the balls in the mix. A jurisdiction has the mandate to establish policies that, amongst other things, will oversee all transportation aspects, including hierarchy.

Transportation policies can prioritize transit over the private automobile, but things aren't always that simple. Transportation priorities can be established for the jurisdiction at large, by area or even street by street. Jurisdictions being political creatures, they will aim to please all constituents, plus their stakeholders, such as transit authorities, port authorities, lobbyists and pressure groups. In the end, a transportation policy becomes an official guide line for practitioners, and some parts of it can even become by-laws.

And here lies the first challenge on the road to TSP: the traffic engineer often has to deal with conflicting priorities. When cars, buses, bikes, pedestrians and heavy trucks all vie for the same piece of asphalt, the guide line becomes blurry, official or not. All priorities are noble by themselves, but there is just that much roadway to share, and conflicts become inevitable.

Too often, the traffic engineer has to deal with a transit policy that is lost in a bowl of good intentions. The juggling act then begins. When transit priority does not have a clear road ahead, its performance will be limited by the constraints brought by active transportation facilities, by truck routes or taxi stands.

Policy is one aspect of a transit priority project that should be clear upstream of the traffic engineer's intervention. A clear policy simplifies constraints, streamlines the process and reduces delays and costs to the jurisdiction.

***Challenge #2: Traffic department and Transit Authority: understanding each other***

Transit authorities come in many shapes and sizes, but usually they are under the umbrella of a public jurisdiction. In ideal situations, they are quite near the traffic department in the structure, but more often they are on a remote arm and don't collaborate on a daily basis with groups who manage traffic signals.

Both groups have different missions at their core: the transit people must ensure a rigid adherence to their bus' schedules in order to meet the expectations of their customer. The signals people on other hand must offer safe and efficient travel to all citizens of the jurisdiction, be there on foot, bike, car, bus, taxi or heavy truck.

Transit and traffic groups must be understanding partners when working in a transit priority project. For example, transit people must understand that the traffic engineer has to ensure safe pedestrian crossings at a given intersection, even if that impedes or limits the performance of TSP devices to be added to the signals. Also, the traffic engineer has to accept that TSP and policy on transit will affect intersection capacity and that the level of service for automobiles won't be the same.

This level of understanding is a challenge on the road to TSP that is often underestimated. Collaboration of both groups early on a transit priority program ensures a better understanding of each other's constraints and will lessen frustration and setbacks as the project goes along.

***Challenge #3: Coordinating projects***

We have established that a TSP project needs to be based on a solid, clear transportation policy and that the parties involved need to have a good understanding of each other's mission within the jurisdiction. However, there are far more than two stakeholders in the equation. Policy makers need to coordinate projects and interventions on the roadway network where a transit priority program is to be realized. Public works, urban planners, residents and businesses must be part of the plan as early as possible.

Public money is a precious commodity, and it should not go to waste. You don't want to lay new concrete or pavement if the TSP project will cut into it to add conduits and devices. Also, if a bike program needs to share the same roadway, eventual bus lanes have to take that need into their design. Businesses may be affected by loss of curb side parking; a contingency plan is then needed.

Examples are infinite… the bigger the jurisdiction, the more coordination will be needed to ensure different groups aren't planning projects that can't integrate each other's. This challenge on the road to TSP, although more at the policy maker level, will benefit from the traffic engineer's involvement as his general knowledge of projects and long-term plans for his jurisdiction will help policy makers to make educated decisions.

***Challenge #4: The needs of the many…***

TSP, like any transit priority project, will have an effect on non-transit users, active or motorized. When selecting a public roadway for a TSP project, choosing a bus route with a high level of transit-riding commuters is of course the prime expression of need. TSP will help in stabilizing this route's schedule by minimizing delays at intersections. Customers that get to their destination on time are happy customers, and by word-of-mouth ridership may increase on this TSP-enabled route.

The needs of the many have of course more importance than the need of the few, who in this case are the motorists. As we have said, jurisdictions are political creatures and temptation may be high to create transit priority routes where visibility is high, even if the need is really elsewhere.

A jurisdiction's traffic professionals and their colleagues at the transit authority have the challenge of selecting the roadways where TSP will benefit the most users. Routes that are efficient and always on time are not the best starting point. Finding one that suffers from irregular schedules and slow service is a better bet. Improving a popular transit route's commercial speed is probably the best way to reap the rewards of a well-planned project and getting public recognition for the project.

Serving the needs of the many ensures that a TSP program will meet with success and expand to other roadways within the jurisdiction.

## 2. The technical foundations of TSP

### 2.1 Signals Controllers

TSP is the part of transit priority that relies on intersection control. To give priority to transit vehicles at an intersection, you must either rely on by-laws, rules of the road, or on technology. TSP develops on the later, and the advent of intelligent signal controllers made it possible.

Earlier signal controllers were electro-mechanical devices with limited possibilities. They could feature pushbutton-controlled pedestrian phases, or vehicular phases activated by regular, in-ground loop detectors. Although sturdy and durable (some are still in service at 40 years of age), these controllers can't manage pedestrian countdown signals and all the latest ITS (Intelligent Transportation Systems) devices.

Electronic controllers first made their apparition in the late '60s, but it wasn't until 1975 that operational standards first appeared on the market. Two families of signal controllers exist today: those that follow the Caltrans standard (California Transportation, better known as the 170 / 2070 series), and the NEMA standard (for National Electrical Manufacturers Association), first released as TS1 and later replaced by TS2.

At first limited to emulating the functions of electro-mechanical devices, electronic controllers evolved over the years to add increased options and flexibility in response to customers demands. Just like computers, signal controllers have an operating system referred to as a firmware. Typically, Caltrans controllers can run third-party operating software as they are by design a more open standard than the NEMA family. These use a proprietary firmware that is not open-sourced. Thus, any new functions have to be developed by the manufacturer in a customer – supplier relationship.

The latest trend in the signal controller industry is the move towards a hybrid platform that can support both the Caltrans and NEMA standards. While physical dimensions and wiring / connections must respect either of the two standards to fit in a jurisdiction's cabinets, the electronic side of the product has seen integration of both standards, resulting in a new common branding, the ATC-type controller (for Advanced Transportation Controller). These are also known in the transportation engineering world as "smart" controllers.

Thanks to the common ATC platform, technical advances can be shared between both families of signal controllers. The ATC standard is a product of joint collaboration between NEMA, the ITE (Institute of Transportation Engineers) and AASHTO (American Association of State Highway and Transportation Officials).

## 2.2 Controller firmwares

Although TSP algorithms made their appearance years ago, the advent of ATC controllers brought TSP into mainstream products and made the feature more readily available. With the older Caltrans controllers, jurisdictions or consultants developed their own operating software for the devices. On the NEMA side of things, such third-party development wasn't possible, and custom solutions appeared through procurement contracts. More often than not, TSP was handled by custom hardware being inserted between the bus detectors and the traffic controller. These proved troublesome in the long run, as mandatory controller firmware updates were complicated by the vast number of custom solutions present in the field. Controller manufacturers don't have to take in consideration the effects of firmware updates on third-party hardware, exposing jurisdictions to the probability of unstable TSP behaviour.

Some manufacturers, like Econolite, sold an optional TSP chipset for their ASC/2 line of products, making it distinctive from the standard chipset. But even that proved not ideal for the perennity of TSP through regular maintenance operations. The newer ATC line-up of NEMA products made access to TSP more simple and universal by making it a standard feature of the operating firmware. In some cases, an optional data key unlocks the TSP software, but the coding per se is built into the basic operating firmware package. In others, different firmware packages are offered, offering additional features, like TSP, with easier upgrades through well-branded products instead of custom solutions. This development has eliminated the weak link in TSP being created by easily outdated third-party hardware.

***Challenge #5: Taking inventory of Signal Controllers***

After this primer on signal controllers, we know that a certain type of product is needed to have access to TSP features. This challenge is about knowing what you have, and getting what you need.

In the urban environment, the street grid is usually tighter, and with that configuration comes more closely-spaced intersections, often equipped with signals. An urban jurisdiction will typically have more intersections than a suburban one, and a longer history of managing traffic signals. Therefore, it may have a fairly large inventory of signal controllers, comprising many types, brands and vintages, all with varying capacities. When dealing with hundreds of signal cabinets, keeping inventory is quite a challenge indeed.

When approaching a TSP project, a jurisdiction needs to have full knowledge of the hardware present on the path of the transit vehicles, in order to plan adding, or in the best cases, activating TSP. Most will have a readily available inventory on a database, but in order to reconfigure signal controllers around TSP, more in-depth knowledge is needed on firmware versions, detector racks, load switches, available communication protocols, and such.

Once the desired TSP route is agreed with the transit authority, the jurisdiction has to consider its controller inventory and see what changes are needed to grant TSP to the transit vehicles. It may involve a shuffling of signal controllers on multiple intersections, minor / major upgrades of some cabinets, procurement of new signal controllers / cabinets, or just about any combination of the above to achieve the desired results at the best possible cost for the public.

Procurement of new signal controllers is always a challenge. Besides the administrative issues with tendering (budgets, signatures, delays…), the jurisdiction has to review its tendering documents and / or standards and anticipate future needs...including TSP.

### 2.3 Cycles, Splits, Offsets, Phasings: getting the words out there

Before we get into the way TSP affects the workings of traffic signals, let's take a basic look at how traffic signals operate and at the terminology that is involved (terms in italics will be used throughout the text in the next sections and chapters).

When designing intersection controls, the *phasing* is the first element put to canvas, figuratively speaking. The phasing is the sequence of events that will take place at the intersection: through movements, turning movements, pedestrian signals, combined movements, priorities… Every movement is a phase, and the global sequence is referred to as the intersection's phasing. It is often drawn-up as a flowchart that follows electrical logic.

For every phase, we find a *recall mode* and *splits*. A phase can be put either on recall (it is always serviced, whether there are vehicles present or not), or on call, through detection devices that "sense" or "see" the presence of vehicles. Phases that are called by vehicle detectors are referred to as *actuated phases*. The splits are the number of seconds each phase is allowed during a given period of the day. Together, all splits form the intersection's *timing plan*. The *coordination phase* is the reference phase for the intersection, usually the one that services the main approaches and is coordinated with other intersections.

The sum of all phases within a sequence amounts to the intersection's *cycle length*, or the amount of time needed for the signal controller to cycle through all phases and start over again. Typically, a cycle lasts between 70 and 120 seconds, but just about any length is possible. Fully actuated intersections don't really have fixed cycles as they work from one phase to the next according to demand and timing parameters.

The *offset* is the amount of time in seconds that separate the intersection's coordination phase with those that are upstream and downstream along the main axis. Put on a space-time diagram, the offsets create a "staircase" of green lights that motorists see as a green wave as they progress from one traffic light to the other.

*Pedestrian signals* run either parallel to vehicular phases, or separately in what is called an exclusive pedestrian phase. These are displayed in three phases: Walk, Flash Don't Walk and Don't Walk. The Walk phase is analogous to the green light and is either protected, semi-protected or unprotected (the notion of protection here implies that no vehicular movement can cross the pedestrian's path). The Flash Don't Walk usually displays the time needed to cross or clear the intersection, as shown on a countdown timer, like a long version of the amber signal. The Don't Walk signal speaks for itself, serving as the pedestrian's red light.

***Challenge #6: Getting the stakeholders to understand the jargon***

Traffic engineers work within a very specialized field and their jargon is not as familiar as the usual public works vocabulary for stakeholders. To get all parties involved in a TSP project to fully understand the ramifications of the project, it is necessary for the practitioner to educate all involved. Teaching is always a challenge, but getting stakeholders to understand the foundations of TSP will help in creating realistic expectations for the project's outcome.

## 2.4 The basics of TSP

The TSP algorithm in the signal controller works within the existing phasing to give an advantage to the transit vehicle by way of reducing its idle time at red lights.

Transit Signal Priority has a similar effect to bus pre-emption on the timing plan. To facilitate a bus' passage through an intersection, it will induce one of two measures:

- red truncation;
- green extension.

In red truncation, the controller ends the secondary phase earlier than planned, thus giving the main traffic phase an early green. This reduces the idle time of the transit vehicle waiting at the red signal.

In green extension, it will extend the green signal of the main phase, enabling a bus to cross the intersection where it would otherwise need to stop.

The similarities between TSP and pre-emption end there, as although the results are similar, the behaviour of both signal algorithms is as different as night and day. Pre-emption, as the name implies, stops the signal's cycle to introduce a new phasing routine that's not part of the regular plan. Bus pre-emption is "soft", as it will not violate pedestrian Walk / Don't Walk times as a train or emergency pre-emption would. Still, it disrupts the cycle and breaks the coordination of the pre-empted signal with the others that surround it. Until more advanced traffic controllers were made available to practitioners, this was the only way to achieve bus priority at signals.

TSP introduced a "Robin Hood" approach to bus priority: it takes seconds from other phases and gives them to the one serving the bus route, but without altering the intersection's working cycle or its coordination. Instead of inserting a new routine in the existing phasing, it just selects an alternate timing plan. Furthermore, the practitioner can program a re-service time where the controller will "skip" a certain number of bus calls. This feature comes in handy when the secondary phases have important volume and can't be cut short one cycle after the other.

TSP is totally transparent to users of the road, as no "special" signal is displayed. Some might notice increased or reduced delays depending on what movement they are using across a TSP-enabled intersection.

***Challenge #7: Transparency is the new opaque***

While there seems to be at first an advantage to "invisible" TSP, the lack of the visible advantage given to / by transit vehicles may not be to the liking of the transit authority, or to the jurisdiction that foots the bill. As more policies favour public transit over single-occupancy vehicles, proof has to be given to the public that active measures actually improve transit's efficiency in the field…or that they are out there, period. While transit trips may benefit from reduced idle time and faster commercial speed, citizens may not perceive that the benefit comes from TSP. The fact that TSP gives more green time to all vehicles may also lessen its advantage over other travel modes.

Bus drivers could also benefit from some sort of feedback on whether or not a TSP measure was granted to their vehicle at the intersection.

Chapter 4 will explore a way to increase TSP's conspicuity to all users.

## 3.0 Integrating TSP in the urban intersection

### 3.1 Suburban intersection

We have seen that TSP uses "room" that is available within an existing intersection's timing plan. The more "room" it has to breathe, the more it thrives. This is why TSP is perfectly tailored to a standard NEMA intersection sequence known in the industry as the "full quad".

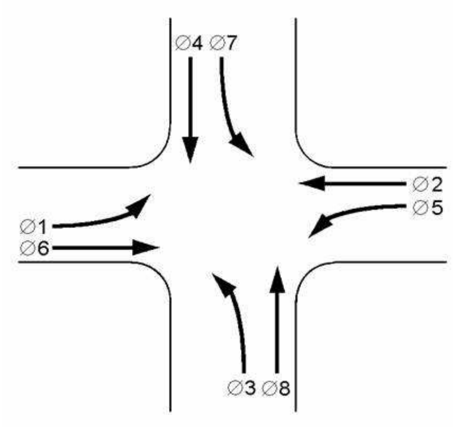


**Figure 3.1 – Phasing diagram of NEMA « full quad » intersection (source : FHWA)**

This sequence uses separate phases for each left-turn movement, along with separate phases for through movements combined with right turns. Often, these right turns will be serviced by turning islands that may or may not be controlled by the traffic signals.

Typically, such an intersection layout will also include actuation for many phases in order to, for example, extend the minimum time given to a left-turn phase.

The high number of available lanes has an impact on land use. The "full quad" intersection is fairly wide in all directions, and because of its dimensions it requires lengthy pedestrian crossing times. Combined with all the vehicle phases that need to be services, the end result is a long cycle. All of these factors combine to give multiple opportunities for transit priority. Transit vehicles can easily be given a 10-20 second window through TSP without much noticeable impact to other users.


**Figure 3.2 – Intersection of Hymus and Saint-Jean, Pointe-Claire QC (source : Ville de Montréal)**

However, this general intersection layout is mostly found in the suburbs, or on the periphery of the urban core of a city. It doesn't solve the dilemma faced by practitioners who must implement TSP in the urban environment.

### 3.2 Urban intersection

In the urban core, roadway geometry is constrained by limited rights-of-way, a denser land use and on-street parking. Practitioners must do without the room to sprawl that is offered by the suburbs.

Higher pedestrian density means that crossings are always being serviced at intersections, meaning that pushbuttons have little use in the daytime hours. Conflicts occur with vehicular turning movements, either with through movements or heavy pedestrian traffic. The higher density of businesses also generates kiss-and-ride movements, frequent stops by taxicabs and courier delivery services and parallel-parking drivers. Furthermore, the promotion of active transportation by big cities adds commuting cyclists to the mix. For the traffic engineer, the expression “urban jungle” fully applies.


**Figure 3.3: Intersection of Maisonneuve and Union, downtown Montreal (source : Ville de Montréal)**

Looking back at Figure 3.1, traffic signals at an urban intersection will often feature two simple phases for all movements: phase 2 for East-West and Phase 4 for North-South. Turning movements are either permissive (through gaps on a green ball signal) or prohibited by signage or one-way street layouts.

Why such a simple traffic plan? Simple: with no turning bays (due to lack of space), left-turn phases can't be safely offered. Also, the more phases are added, the longer the cycles get, creating more opportunity for gridlock in a CBD area where intersections typically are pretty close from one another. Urban traffic control benefits from short cycles for all users, especially pedestrians.

From an urban planning perspective, traffic control cabinets need to be more compact in the urban landscape, taking as little as possible of precious sidewalk real estate. Complex, multi-phased signal plans require more components and more space within a cabinet. While traffic cabinets in the suburbs are often installed on bulky concrete bases, in a CBD they are often strapped to traffic poles.

***Challenge #8: How does one include TSP in the urban intersection?***

With most urban intersections having only two phases, and with TSP taking advantage of available "spare" seconds on approaches other than that of the transit vehicle's, just how does one apply TSP here?

No need to look far to understand that the TSP will have to take time away from the lone secondary phase. This is where a solid, pro-transit policy will help the practitioner in making the necessary decisions.

With a two-phase intersection, TSP's impact will immediately be noticeable. In the case where the secondary street is little-traveled, careful calculation of pedestrian crossing time will have to be made in order to offer (at least) the minimal required time for a safe crossing. TSP will need bonus time on top of that to allow for its deployment at the intersection.

The policy comes more clearly into the picture when the secondary leg of the intersection is as well-traveled as that of the transit vehicle's. Impact on traffic will be clearly noticeable; the practitioner will want to carefully evaluate parameters such as TSP's re-service time to avoid gridlock.

No matter the importance of the secondary street, adding TSP to a two-phase intersection often means increasing the intersection's cycle length when no room is available on top of minimal pedestrian crossing times. While doing so might seem redundant, the transit vehicle will have an effective gain when a TSP measure is granted; elsewhere, the added seconds can be put to good use by increasing pedestrian's crossing times or improving the width of the green band on well-traveled secondary streets.

### 3.3 Location of bus stops

Transit vehicles in urban corridors are seldom of the "express", shuttle type. They must service multiple customers, in business, retail and residential areas in their jurisdictions. Bus or transit stops are used for boarding and alighting passengers; these stops will be numerous in urban transit routes as density requires more stops to service customers than in sprawling suburban neighbourhoods.

While placement of the transit stops is not under the control of the traffic engineer, the location of the stops has much importance in the performance of TSP and the design of the project. Stops can be either: far-side (downstream of the intersection), mid-block (between two intersections) or near-side (upstream of the intersection, right at the stop bar).

Far-side bus stops present the ideal situation for TSP. Both TSP measures, red truncation and green extension, speed-up movement of the transit vehicle across the intersection to the passenger stop.

A mid-block location has little impact on TSP. Depending on the distance between intersections, detector placement will be similar to a far-side installation and similar improvements can be expected on the way to the next stop.

The case of the near-side transit stop is different, and sure enough this configuration is more frequent in urban areas. Near-side stops are a preferred approach when a street features curb-side parking. The bus bay is formed by a no-parking or stopping zone along the curb up to the stop bar, creating a right-turn bay for general traffic when buses aren't present. At a TSP-enabled intersection, a near-side stop will benefit from green extension, giving the bus more seconds to go across the intersection and avoid being caught-up on the red signal.

Red truncation poses a problem, however: if the bus is boarding passengers while red truncation is active, the measure will be lost. The after-effects on the secondary street's level of service and coordination will still be there, though. Furthermore, since there usually is only one TSP window in a single intersection cycle, green extension won't be granted if the bus is still at the stop bar; adding to the wasted seconds is TSP's re-service time that will skip a given number of cycles even though no measure was put to good use by the transit vehicles.

### *Challenge #9: Optimizing TSP for near-side stops*

Relocating transit stops is an expensive proposition because of all the urban hardware that is involved: signs, posts and especially bus shelters. Also, the loss of right-turn bays is not desirable. Not helping either is the fact that far-side bus stops need a longer no-parking zone because the width of the intersection is not there anymore to help with the transit vehicle's insertion in traffic lanes. Thus, far-side bus stops aren't very popular with businesses that rely on curb-side parking and delivery zones.

Since the issue between TSP and far-side transit stops comes from boarding / alighting passengers, to avoid calling measures than can't be used the doors of the transit vehicle have to be interconnected with the TSP activation devices. The transit vehicle's on-board TSP systems need to "watch" for a complete cycling of the doors (opening and closing), or at least monitor if the doors are closed prior to making a TSP call to the traffic controller. Most if not all systems on the market are able to do that monitoring; if not, systems integrators can customize a solution.

### 3.4 Detecting the transit vehicles

For a transit vehicle to be granted a TSP measure at the intersection, it has of course to be "seen" by the signal controller. Regular traffic detection won't work here as there is a need to discriminate the signals received so that only transit vehicles actuate the measures. Different options exist, but selection and placement of the detectors are amongst the most critical elements of a TSP project.

TSP detectors are a research subject all by themselves. Without going in too deep in the details, there are two main families of detection devices:

1) intrusive (loop detectors, magnetic-field based devices)
2) non-intrusive (just about anything that doesn't have a component in the roadway structure).

Loop detectors are just about the most basic device available, and very reliable. They consist of buried electrical wiring, connected to a detector card within the traffic control cabinet. To get loops to actuate TSP, all transit vehicles must be equipped with an AVI (Automatic Vehicle Identification) transmitter. This, along with a special receiver in the cabinet enables the practitioner to customize a solution for transit vehicles. However, in the urban environment, loop detectors are a frail solution. Heavy traffic and roadway maintenance take a heavy toll on loops. Furthermore, large urban centers have multiple systems running under the street surface: water distribution, sewers, gas distribution, communications, cable and countless other services. The maintenance crews for these systems often need to cut into the roadway, leaving loops damaged and forgotten under the repaired pavement.

Non-intrusive solutions provide the answer to "pavement scars". Their components are mounted on masts and poles, protected from traffic and road maintenance work. Infrared detectors have been used for nearly thirty years for emergency vehicles; these have been adapted over the years for transit applications. Their reliability has been proven in the field, however from an ITS standpoint, they offer limited feedback.

Other technologies exist, using many kinds of wireless communication in their components (RFID – Radio Frequency IDentification, GPS – Global Positioning System, radar, micro-wave) or just about any possible blend of these technologies.

Detection solutions for TSP go from the very simple to the very complex. Objectives of the TSP project have to be clearly defined in order for one solution to stand out from another. No two jurisdictions are alike, and no two transit authorities either. Costs are always a factor, but operations have to be taken in the equation. For example, if a detection solution requires on-board equipment in the transit vehicles, cost per unit will be a major factor if the transit authority's fleet is important and shuffles from one transit route to another. When transit vehicles have to be singled-out for a given route, operations become less flexible.

From a purely technical approach, the choice of detection devices is perhaps the most critical aspect of a TSP project. All stakeholders need to be involved in the choice of a solution that meets the needs of the transit authority while being compatible with the traffic control cabinet.

### *Challenge #10: Getting Transit detection to work*

Just because a product is advertised on a glossy magazine page doesn't mean it will actually work on the first try. The electronics found in traffic products are complex devices that don't benefit of the mass exposure of consumer electronics. When mixing components from various suppliers in a traffic cabinet, a practitioner would like to get the same guaranteed, no-worries hook-ups as one gets when wiring-up a home theatre system. Not so. NEMA and Caltrans standards aren't a guarantee that a seamless integration will happen when Product A is connected to Product B.

In section 2.2, we discussed the topic of firmwares. Just like computer software, these evolve over time and create surprises down the road. As a TSP project goes along, time also passes between the project's inception, through the design phases, purchasing, bench-testing and finally installation in the field. This leaves a big window for signal maintenance technicians to upload updated firmwares in the signal controllers, an upgrade that may not have been forecasted by the detection device's supplier. A change of firmware may trigger unexpected actions, or error codes, resulting in either the TSP detection not working, or worse sending the traffic controller into safety mode (flashing all-red at all approaches).

Even if firmware versions are stable throughout the project, every jurisdiction is distinct and has specific components or firmwares within the traffic cabinet. Because of that, there is a strong chance that a generic, off-the-shelf detection solution for TSP won't work on the first try.

Systems integration is thus a critical component of the success of a TSP project. With safety of all users being the prime directive of the traffic engineer, it is strongly recommended to bench-test the complete TSP package for at least a month in controlled conditions. For most signal controllers, this delay allows for all error codes to surface and ensures a reasonable expectation for the system's reliability.

The traffic engineer has to convince the stakeholders to follow scheduling for the project that allows for delays, development, integration and bench-testing of the TSP components. Getting the detection solution to work while achieving TSP measures may take a year, and that has to be understood and accepted by all involved.

## 4.0 Use of the white bar transit priority signal in urban TSP

The transit priority signal (TPS) is better known as the "white bar" traffic lens that is used for signalling queue jumps for buses. Regulated by all transportation departments in North America, it is only to be used to facilitate a transit vehicle's insertion in regular traffic lanes. By definition, the white bar signal is not TSP, but more a stand-alone phase that is either recalled or actuated by detection.

However, it is the perfect partner in an urban TSP project. It addresses two of our challenges:

> Challenge #7: the lack of visible priority given to transit
> Challenge #9: near-side transit stops

The white bar is one of the most recognized forms of transit priority to users of the road. By using it in conjunction with TSP, it states to all that a clear priority movement has been given to a transit vehicle, and unlike regular TSP measures, other vehicles can't benefit from it. The white bar is for exclusive use by transit vehicles, and no other vehicles, nor cyclists and pedestrians, can move under it.

Furthermore, when on-street parking and near-side transit stops are present, the white bar allows the transit vehicle to proceed without any conflicts through the intersection, while changing lanes to avoid parked vehicles.

Since the white bar signal is controlled by a separate phase, it simply takes its time from the main coordinated vehicular phase. Actuation is done by the same detection system that covers the TSP. Red truncation may still occur, and if that happens the transit vehicle will get its visible priority while regular traffic gets its regular green time. It's a win-win situation. In instances where red truncation is not possible due to the timing of pedestrian signals or another operational constraint, the white bar signal gives the transit vehicles a measure it can put to good use at the beginning of its through phase.

The white bar can't be used though if a reserved bus lane is present according to most norms and rules of the road, as no insertion movement is made by the transit vehicle.

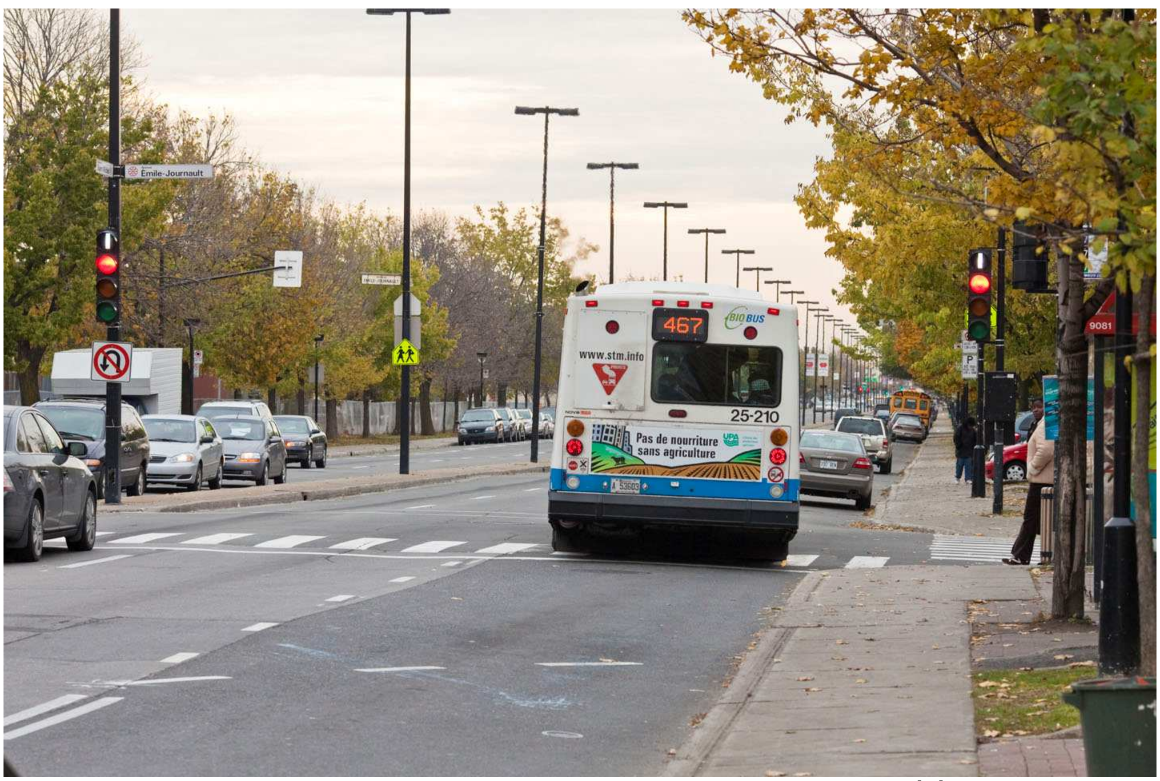


**Figure 4.1 – White bar signal from near-side bus stop in Montreal (source : Société de Transport de Montréal)**

### *Challenge #11: The boomerang effect of history*

Using the white bar signal outside of reserved bus lanes may have some after-effects. If a jurisdiction allowed in the past use of regulated bus lanes (and white bar signals) by other vehicles (such as taxicabs or high-occupancy vehicles), other drivers may think that this exception also applies to all white bar signals across the jurisdiction.

When other vehicles are allowed to use a white bar signal, usually a static sign needs to be posted at every intersection stating the exception. By association, drivers may illegally use other white bar signals, reducing the measure's effectiveness.

History can come back like a boomerang, and hit back with illegal movements at intersections that impede on TSP's performance. Public education is needed when implementing TSP, and a successful project will have a public relations program to educate citizens on the benefits of the project and the rules one must follow depending on how you are travelling through the TSP-enabled intersection.

## Conclusions

We have learned that in implementing a TSP project in the urban environment, traffic professionals will face challenges that don't surface when working with ideal, suburban conditions. Eleven challenges summarize the steps that must be taken:

- getting a clear policy on transit;
- finding common ground between traffic professionals on the jurisdiction and transit side of the equation;
- coordinating overlapping projects on a given roadway;
- serving the needs of the many;
- taking inventory of signal controllers in the field;
- teaching the traffic jargon to involved stakeholders;
- finding a way to give visibility to TSP;
- inserting TSP in simple, two-phase intersection timing plans;
- optimizing TSP for near-side stops;
- getting detection and TSP components to work with signal controllers;
- keeping a look-out for historical associations that may dilute TSP's effectiveness.

Dense, urban areas provide constraints that may not be well-understood by policy-makers and stakeholders. While traffic professionals will have to think out of the box to gain a TSP advantage within these limits, they must educate all parties involved with the limitations and side-effects brought by the alternate timing plans. Getting practitioners involved upstream of the technical phases of a TSP project will help in creating realistic expectations, but also in getting traffic professionals in tune with a pro-transit policy. Transit authorities have the responsibility to select routes that will benefit most from the regular schedules and higher commercial speeds brought forward by TSP.

Careful calculations have to be made when implementing TSP within a simple, urban intersection timing plan. Pedestrian crossing times have to be maintained at proper minimum levels, even if it means changing the intersection's cycle length. With even a few seconds being precious commodity at an urban intersection, wasted TSP measures created by boarding / alighting passengers in a bus should be avoided. To that effect, TSP actuation should monitor the vehicle's door operations and cancel calls to the signal controller when doors are opened.

For roadway configurations that offer near-side bus stops, practitioners will find advantages in combining TSP with the white bar transit priority signal. Not only will transit vehicles be getting a proper measure, but also the white bar brings unconditional priority to be seen by all other users of the road.

This is perhaps the best feature to add to urban TSP projects in order to compensate for the lack of flexibility brought by a denser land use, heavy traffic, high pedestrian counts, cycling facilities and simple timing plans often found within a city's CBD.