# Transit Signal Priority Fine-tuning – How to get more from your system


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ABSTRACT:

In recent years, transit signal priority (TSP) systems have been implemented in order to increase transit schedule reliability and decrease transit travel time, thereby improving the transit system operations, and making transit an attractive alternative mode of transportation.

A sophisticated TSP system includes three main components:

1. Transit Management System (TMS), which includes the Vehicle Logic Unit (VLU) on board the transit vehicle, and CAD/AVL and schedule and runcutting software;

2. Traffic Signal Control System, including central software and local controller; and

3. Transit vehicle detection system.

In some TMS applications, the schedule and runcutting software interfaces with the CAD/AVL. Typically, the schedule and runcutting software stores TSP data points (e.g. check-in and check-out), which are then past through the interface to the CAD/AVL software, and on to the VLU. Some of these data points include coordinates (e.g. GPS) of transit stops, and TSP trigger points. The VLU tracks the position of the transit vehicle and monitors it's progress along the route against the schedule. If the transit vehicle is off-schedule by a pre-determined limit, a request for TSP is initiated through the transit vehicle detection system.

In turn the traffic signal control system receives the request for priority, and implements a TSP strategy to progress the transit vehicle through the signalized intersection. Most often, green extension and early phase activation (red truncation) TSP strategies are used. The TSP parameters programmed in the traffic signal control system must work in co-operation with the TMS trigger points to advance the bus through the signalized intersection. This process becomes more complex when considering intersections with congestion by time of day, various bus stop scenarios (near side, far side, no stop), queue by-pass lanes, etc.

Although many TSP systems have been deployed, there is little published literature focusing on the methodology used in fine-tuning these TSP parameters after they've been installed on-street. This paper addresses this need by presenting the TSP fine tuning process, which was developed by IBI Group, and applied to recent TSP projects in the Region of York, and the City of Mississauga. The results presented in this paper are based on the York Region experience.

The objective of the fine tuning exercise is to verify that the TSP system is operating properly and that the TSP parameters, including VLU distances for

check in/check out and the controller maximum green extension and red truncation times, are suitable for the various intersections.  To accomplish this, a fine-tuning methodology was developed comprised of field observations, data analysis of transit and signal log data, as well as video recording of the actual transit operations.  Where required, TSP parameter changes were then proposed, making the TSP system more effective.

This paper will describe the development the TSP fine-tuning process, and the lessons learned from the application of the guidelines for the four transit systems.

# 1 INTRODUCTION

This paper describes the development of the Transit Signal Priority (TSP) Fine Tuning process, used to verify the TSP system and the TSP parameters at various intersections. The results of the fine tuning process are linked back to the traffic simulation analysis conducted to establish the initial suite of TSP parameters for implementation. The objective of the TSP fine tuning exercise is to verify that the TSP system is operating properly and that the TSP parameters, including Vehicle Logic Unit (VLU) distances for check in/check out distances, the controller maximum green extension and red truncation times, are suitable for the various intersections.

# 2 TSP SIMULATION

A VISSIM micro-simulation was conducted in York Region to estimate the impact and benefit of TSP, on the Highway 7 and Yonge Street corridor. Approximately 80 of the 140 signalized intersections scheduled for TSP deployment were included in the VISSIM analysis. The 80 signalized intersections were divided into logical control areas. For each traffic signal control area and time period (AM and PM peak periods), five simulation runs were completed to build up a statistical average of the operations. The simulation included a “warm up” or seeding period, which was used to populate the system network, before data on measures of effectiveness were collected.

The effects of TSP on both the mainline and cross street travel times were examined. Using the initial suite of TSP parameters established in consultation with the traffic and transit department, the travel time was reduced by 7.3 minutes in the AM peak, and 7.5 minutes during the PM peak at the 47 intersections analyzed. This represents a 5% reduction in transit vehicle travel time in the AM peak, and a 6% reduction in transit vehicle travel time in the PM peak.

Exhibit 1 provides and overall summary of TSP activities for all control areas modelled.

**Exhibit 1: Summary of TSP Activity**

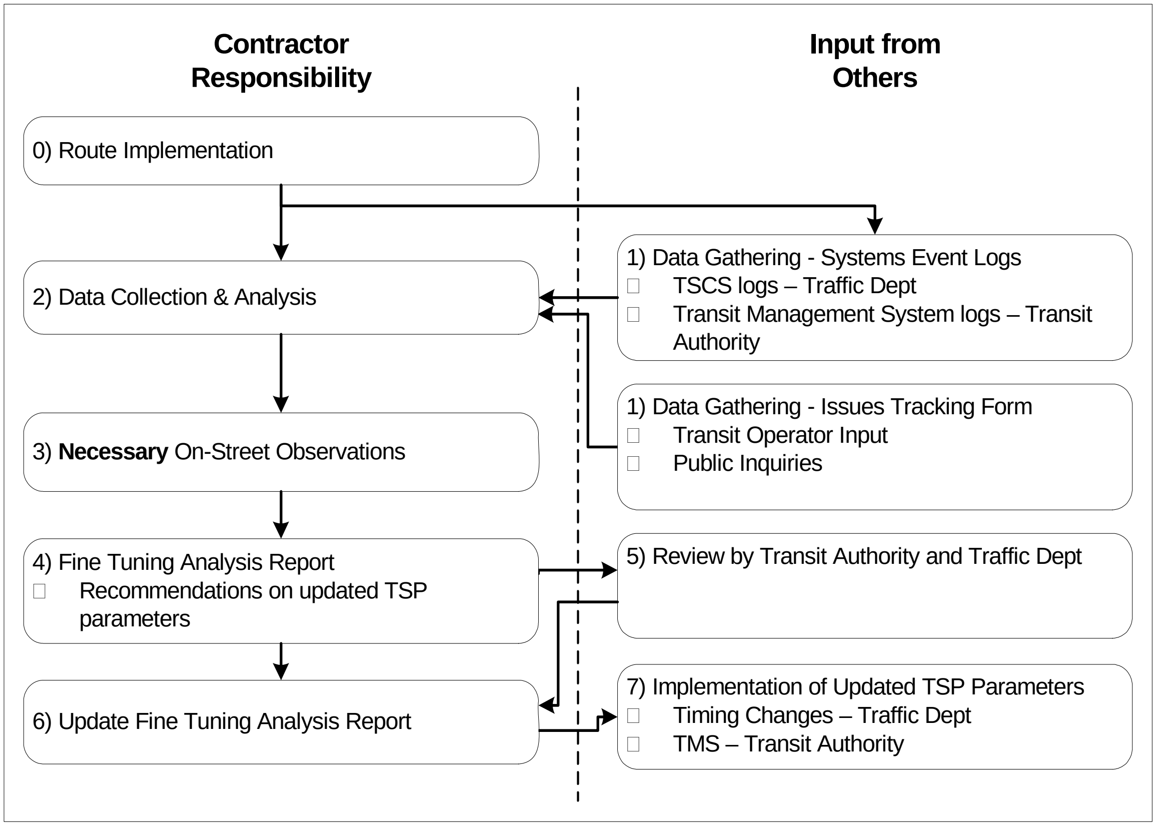
| TSP Activity | AM Peak | PM Peak |
|---|---|---|
| Number of TSP Requests | 812 | 809 |
| TSP Not Required | 464 | 397 |
| TSP Request Blocked Due to Reservice | 86 | 81 |
| Total Number of Successful TSP Calls | 262 | 331 |
| Number of Green Extensions Granted | 84 | 83 |
| Number of Red Truncations Granted | 178 | 248 |

Based on Exhibit 1, approximately 53% of the TSP calls were not required, because the transit vehicle cleared the intersection during the normal green phase. Of the remaining TSP requests (760), 22% were blocked due to the reservice feature, and TSP was not granted. Green extensions were granted 22% of the time, while red truncations were granted 56% of the time. This is an expected relationship, since there is a smaller window of opportunity for a green extension to be granted in comparison to a red truncation.

# 3 FINE TUNING PROCESS

Exhibit 2 presents the work-flow process for the fine tuning work.

**Exhibit 2: Fine Tuning Work Flow Process**




In total there are nine activities that require participation of different stakeholders. The three key activities in the TSP fine tuning process are described in the following.

## 3.1 System Event Logs

The TSP event logs from both the transit management system and traffic signal control system were assembled to quantitative assess the TSP performance. These logs were compared to assess the TSP operations, ensuring that when a TSP request is generated (transit management system event log), the TSP request was received and the priority routine was successful (traffic signal system).

## 3.2 On-Street Observations

On-street operations commenced at the conclusion of a 2-week waiting period. This time is a stabilization period where transit operators learn the route. These on-street operations were documented using the Fine Tuning On-Street Observation Form. Any noticeable issues with the traffic signal operations observed during on-street observations were recorded.

TSP on-street observations were conducted at intersections with unique operational characteristics such as queue jump lanes and TSP for left turn movements, and problematic intersections which are heavily congested during the peak periods, without TSP.

## 3.3 RouteMapper Lite™

The following equipment is required to conduct this activity:

- Transit vehicle;
- Traffic signal system TSP event logs;
- Transit Management System TSP event logs; and
- Route Mapper Lite™ video surveying system mounted on a transit vehicle.

**RouteMapper Lite™ Equipment**

A series of testing had been completed to verify that the hardware components of the traffic signal system and transit management system were functioning as designed. The fine tuning exercise is designed to verify that the transit management system and traffic signal control system TSP parameters are operating as programmed. The TSP parameters include the VLU check in and check out points, and the traffic signal controller maximum green extension time, red truncation time and delay time. These TSP parameters are verified through the transit management system and traffic signal system event logs, along with the Route Mapper Lite™ video data.

For each route, a transit vehicle with VLU that is in service and logged onto a route is used to conduct this test. The test is conducted during both peak periods (6:30 a.m. to 9:30a.m. and 3:30 p.m. to 6:30p.m.). The Route Mapper Lite™ software is used on a vehicle per peak period to log the test procedure for future playback and review.

This data is analyzed to confirm that the transit management system issued the correct request for priority at the correct point (check-in) and terminated the request for priority at the correct point (check-out), and that traffic signal controller received the correct request for priority (either high or low), and successfully implemented the TSP routine. This test is complete, once the intersection controller has successfully initiated the correct priority strategy for each priority input.

For those locations that did not receive the request for priority, or the controller initiated the incorrect priority strategy (e.g. high priority when low priority was requested), follow-up action is required to correct the problem. The operational data is reviewed once the change has been implemented to ensure that the problem has been corrected.

# 4 FINE TUNING RESULTS

## 4.1 System Event Logs

The objective of this exercise is to assemble the TSP event logs from the transit management system and traffic signal control system, and match the “requests for priority” (transit management system TSP event logs), with the “receipt of priority” (signal system TSP event logs). Transit management system and signal system TSP event logs were collected for January 10, 2006 (24 hour sample period). Exhibit 3 is a sample of the transit management system TSP event log.

**Exhibit 3: Transit Management System TSP Event Log**

| Date | Time | Action | Priority Point | State | Vehicle | Line | Stop |
|---|---|---|---|---|---|---|---|
| 10.Jan.06 | 8:43:08 | Pre-emption point log on | 0 log on [low] | Success | 102 | Purple | Martin Grove (728) |
| 10.Jan.06 | 8:43:18 | Pre-emption point log off | 0 log off [low] | Success | 102 | Purple | Martin Grove (728) |

As presented in Exhibit 3, the transit management system TSP event log provides information on:

- Date - date of TSP event log;
- Time - GPS time the TSP event occurred;
- Action - Identifies when the TSP emitter was turned on (pre-emption point log on), or off (pre-emption point log off);
- Priority Point - Identifies whether the request for priority was a low priority request (0 log on [low]), or a high priority request (0 log on [high]);
- State - Indicates whether the priority event was a success or failure, with respect to turning on an off the emitter;
- Vehicle - unique vehicle ID;
- Line - the Viva bus route;
- Stop - the Viva stop associated with the TSP priority point.

Exhibit 4 is a sample of the traffic signal system TSP event log.

**Exhibit 4: Signal System TSP Event Log**

| Date | Time | Action | Priority Point | State | Vehicle | Line | Stop |
|---|---|---|---|---|---|---|---|
| 10.Jan.06 | 8:43:08 | Pre-emption point log on | 0 log on [low] | Success | 102 | Purple | Martin Grove (728) |
| 10.Jan.06 | 8:43:18 | Pre-emption point log off | 0 log off [low] | Success | 102 | Purple | Martin Grove (728) |

As presented in Exhibit 4, the signal system TSP event logs provide information on:

- Date - The date and time of occurrence of the TSP event. Please note, the signal system uses an Internet website for a time source, and downloads this time to the local controller. As a result, the transit management system and the signal system time sources are not synchronized.
- Intersection Name - The name of the signalized intersection.

- Event Description - A description of the TSP event and TSP input (1 through 4). The TSP event includes:

- TR PRTY Cleared - Is logged when the transit vehicle requested priority, cleared prior to the start of the TSP phase. This message appears when the transit vehicle at the upstream intersection is detected at the downstream intersection.

- TR PRTY MX EXT TMOUT - Is logged when the transit vehicle requested priority, but did not clear the signalized intersection within the maximum allowable time set for the TSP algorithm. This message indicates that the TSP event has failed.

- TR PRTY OK - Is logged when a priority request has been successful (e.g. TSP algorithm successfully advanced the transit vehicle through the signalized intersection.

- TR PRTY RESVC INHIB - Is logged when the TSP request was blocked due to the reservice feature. The reservice feature inhibits successive TSP calls at a signalized intersection for a predetermined period of time. This time period is currently set at 2 minutes at major/minor intersections and 5 minutes at major/major intersections.

Exhibit 5 summarizes the TSP activity recorded for January 10, 2006 for the signalized intersections on the Blue and Purple Viva routes (both low and high priority per direction). This includes signalized intersections on Highway 7 (Purple) from York University in the west to Fairburn Drive in the east, and along Yonge Street (Blue) from Meadowview Avenue in the south to Elgin Mills Road in the north. In total 39 signalized intersection along the Highway 7 runningway were analyzed and 31 along the Yonge Street runningway.

**Exhibit 5: Traffic Signal System TSP Activity - January 10, 2006**

| **Route** | 4.1.1 DIRECTION | **TSP Activity** | | | | | **TSP Failure (%)** |
|---|---|---|---|---|---|---|---|
| | | **TR PRTY Cleared** | **TR PRTY OK** | **TR PRTY RESVC INHIB** | **TR PRTY MX EXT TMOUT** | **Total** | |
| Purple | Eastbound | 90 | 596 | 97 | 6 | 789 | 0.76 |
| Purple | Westbound | 29 | 191 | 41 | 11 | 272 | 0.04 |
| Blue | Northbound | 64 | 422 | 56 | 2 | 544 | 0.37 |
| Blue | Southbound | 63 | 410 | 67 | 20 | 560 | 3.57 |
| Total | | 246 | 1,619 | 261 | 39 | 2,165 | 1.80 |

As shown in Exhibit 5, through a comparison of the number of TSP failures (TR PRTY MX EXT TMOUT) with the total number of TSP events (Total), TSP is generally successful on both routes and in both directions of travel.

It is interesting to note that the percentage of TSP events blocked due to the reservice feature estimated in the VISSIM modelling exercise in Exhibit 1 (10%) is similar to the actual on-street performance presented in Exhibit 5 (12%).

## 4.2 On-Street Observations

TSP on-street observations were required to verify the specific intersection operations after the implementation of TSP. On-street observations were conducted at intersections with unique operational characteristics and problematic intersections. Intersections with unique operational characteristics include locations with queue jump lanes, left and right turns, or nearside stops. Problematic intersections that were deemed to experience cross street problems because of TSP were identified through the 90% TSP Parameters Design reports, concern expressed by stakeholder, and YR Issues Tracking form.

Prior to the start of on-street observations, a stabilization period where transit operators learn the route is required. A period of 2 weeks from the route implementation date of September 4th, 2005 was used as the stabilization period. On-street observations were conducted on the following days:

1. Wednesday September 28 to Friday September 30, 2005;
2. Monday October 3 to Thursday October 6, 2005;
3. Wednesday October 12 and Thursday October 13, 2005;
4. Monday October 17 and Tuesday October 18, 2005;
5. Tuesday November 8, 2005;
6. Monday November 14, 2005;
7. Thursday November 17, 2005;
8. Tuesday February 7 and Wednesday February 8, 2006;
9. Wednesday February 22 and Thursday February 23, 2006.

Observations on the impact of TSP to mixed traffic such as standing queues, or noticeable queue length and/or delay were recorded, and any noticeable issues with the traffic signal operations were either noted or reported to York Region dispatch.

Field observations were conducted at a total of 61 intersections. The following are some general comments based on the field observations conducted:

1. At queue jump locations, it is understood that the use of the queue jump lane is under the discretion of the driver. This process is quite effective since it was observed that queue jump lanes were used at the appropriate times to bypass long through movement queues. It was also observed that occasionally the drivers do not use the queue jump lane if stopping at the farside stop is not required. It should be reiterated to the drivers that queue jump lanes could be used in any situation even if they are not picking up or dropping off passengers.

2. It was observed at locations with competing turning movements that the right turn movements operate under good conditions and the left turn movements are generally congested. Hence, the implementation of TSP does benefit left turning vehicles.

3. At nearside stops, the check-in points are based on the location of the transit stop poles. It was observed that buses generally stop close to the bus shelters and not necessarily at the transit stop poles. After passenger pickup, right turning vehicles may be blocking the bus from pulling up past the transit stop pole. The drivers should be reminded to stop as close as possible to the transit stop pole so that TSP can be activated after passenger pickup.

4. No significant disruption to mixed traffic was observed at the study intersections.

5. Queuing problems where the queue lengths at Highway ramps exceed the available ramp lengths were not observed.

## 4.3 RouteMapper Lite™

The RouteMapper Lite™ exercise was used to verify that the transit management system and traffic signal control system TSP parameters are operating as programmed. The TSP parameters verified included the TSP trigger points (check in and check out points) stored in the VLU, and the correct TSP input activated in the traffic signal control system. These TSP parameters were verified through the transit management system and traffic signal system event logs, along with the RouteMapper Lite™ video surveillance system.

For VIVA subroute A and C (Blue and Purple) the following was performed:

- RouteMapper Lite™ data was collected for both the AM and PM peak periods on a transit vehicle with CoPilot VLU that is in service and logged onto a route. Data was collected on Tuesday October 4 and 5th 2005 for VIVA Purple and Wednesday October 5th and 6th 2005 for VIVA Blue.

- Transit management logs were requested for the specific in service buses where RouteMapper Lite™ data was collected.

- The traffic signal system logs were requested for the time period when RouteMapper Lite™ data was collected.

- Intersections were identified in the transit management logs by matching the corresponding GPS time to the RouteMapper Lite™ data.

- TSP requests made along the routes were match up with the corresponding signal system TSP log.

The process followed was:

- The transit management log from the VLU was used to identify the time at each TSP trigger point (both check-in and check-out);

- The time stamp from the VLU was matched with the time stamp on the RouteMapper Lite™ video data to identify the check-in and check-out point (both systems use GPS time);

- The RouteMapper Lite™ video data between each trigger point was reviewed to ensure that the check-in point was upstream of the intersection at the design distance, and the check-out trigger point was located at the stop bar.

- At locations where TSP requests were made, the signal system logs were used to confirm the successful implementation of TSP. This means that signal system received the request for priority, the correct input was activated (e.g. westbound high priority), and the routine was successful.

- Intersections were identified where follow-up action is required. For example, at locations that did not receive the request for priority, or the controller initiated the incorrect priority strategy (e.g. high priority when low priority was requested), or where the trigger points were missing or the location is accurate.

The survey uncovered a number of problems that can be categorized as follows:

- Missing trigger points - either check-in or check-out trigger points were not entered in the transit management system database.

- Trigger points incorrect - the TSP trigger points are entered, but are in the wrong location and need to be moved.

- Nearside stop locations - At many locations TSP is not working properly at nearside stops. This is mainly at locations where the nearside stop is located very close to the stop bar.

# 5 LESSONS LEARNED

The objective of the fine tuning exercise is to verify that the TSP system is operating properly, and that the TSP parameters, including the VLU distances for check in/check out, and the controller maximum green extension and red truncation times, are suitable for the various intersections. In general, based on the assessment completed in this report, the TSP parameters are operating properly, without a noticeable impact on mixed traffic.

Overall the fine tuning process worked well to identify TSP system deficiencies. Using only the signal system logs as a guide, would lead one to the incorrect conclusion that the system is fairly optimal (TSP failure rate of less than 2% in Exhibit 4-3). Using the process described above, adjustments at approximately 30% of the signalized intersections were recommended.

There were locations where adjustments were required to improve TSP operations. Some of the problematic intersections were identifiable from the traffic signal system TSP event logs, or through the meshing of the transit management system and the traffic signal control system. However, the use of the RouteMapper™ Lite GPS video surveillance software was an integral component of the fine tuning exercise, which "glued" the transit management and traffic signal system TSP event logs.

An important next step in the fine tuning process is to decompose the TSP activity by time of day, and schedule block in order to identify locations with high TSP activity and low TSP activity. The objective is to strategically adjust the schedule in order to effect TSP and improve the overall transit system performance.