Development and Application of Transit Signal Priority Implementation Guidelines - A Proven Process

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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.

Although many TSP systems have been deployed, there is little published literature focusing on the methodology used in selecting intersection specific TSP parameters. This paper addresses this need by presenting the TSP Implementation Guidelines, which were developed by IBI Group, and applied to recent TSP projects in the Region of York, City of Mississauga, Halifax Regional Municipality, and Region of Waterloo.

TSP Implementation Guidelines were developed based on TSP system capabilities and TSP strategies for different intersection characteristics. The guidelines take a two-level approach: overall governing guidelines, which include general rules that should be adhered to during TSP operations, and intersection specific guidelines, which deal with intersection specific TSP parameters. These guidelines are then used to establish parameters for groups of signalized intersections.

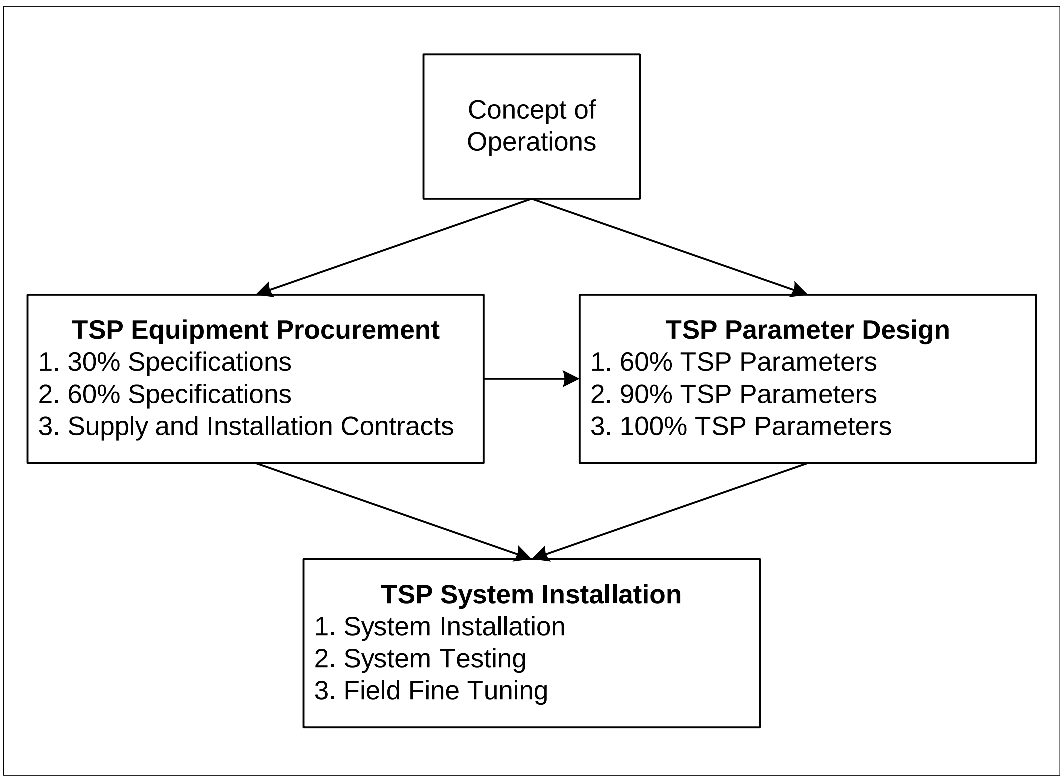
In each case, an analysis process was devised to effectively categorize and group the signalized intersections according to intersection characteristics and intersection operations. The information was compiled and organized logically using a database tool. Subsequently, the appropriate TSP parameters and strategies were identified to match the key intersection characteristics.
Overall, the TSP Implementation Guidelines were successful in developing the initial TSP parameters.

This paper will describe the development of the TSP Implementation Guidelines, and the lessons learned from the application of the guidelines for the four transit systems.

1 INTRODUCTION

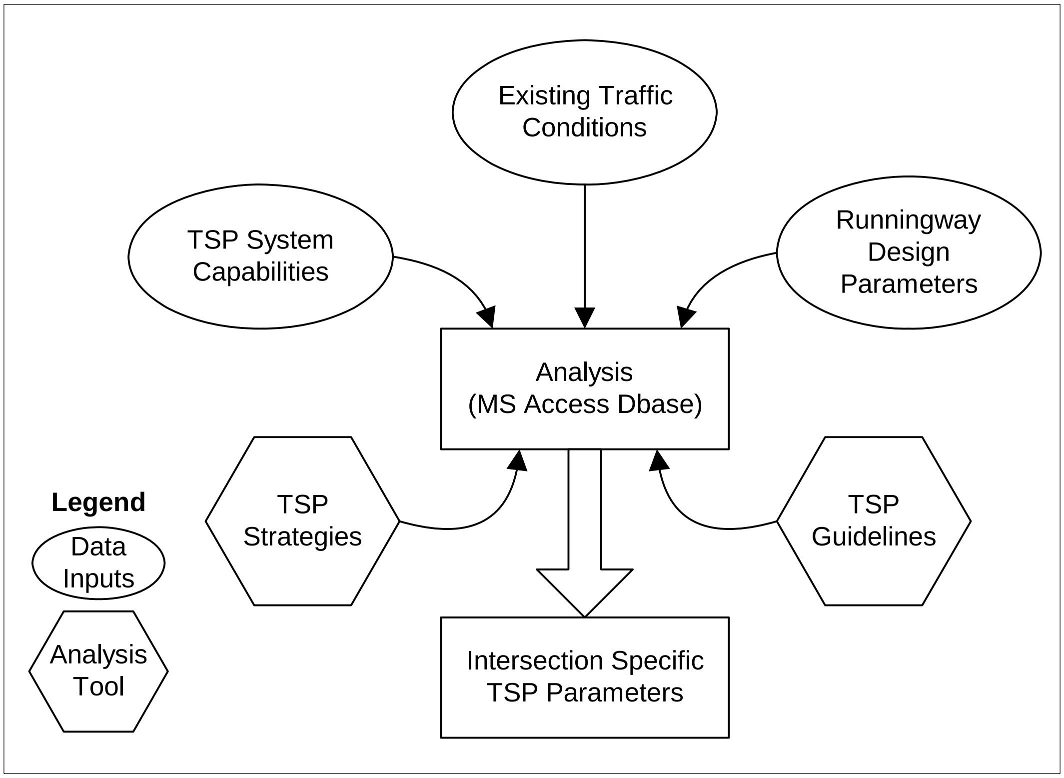
The purpose of this paper is to describe the development of the TSP Implementation Guidelines, and the lessons learned from the application of the guidelines for the four transit systems. The TSP Implementation Guidelines were developed as a method to quickly assess a large number of signalized intersections and apply a systematic process to arrive at an initial suite of TSP parameters for implementation. These TSP parameters can later be adjusted through system operation experience. The overall TSP design process has two streams of activities, specifically TSP equipment procurement and TSP parameter design, which will culminate in TSP system installation. Exhibit 1 depicts the stream of design activities.

Exhibit 1: TSP Parameter Design Overview



There are various influences to determining how TSP is to be achieved/implemented. An overall view of the decision-making process offering a glance at the different influences and considerations involved in the process is presented in Exhibit 2.

Exhibit 2: TSP Parameter Design Overview



2 ANALYSIS INPUTS

To facilitate the analysis depicted in Exhibit 2, a Microsoft Access database was developed. The following subsections describe the data collected for each of the data inputs identified in Exhibit 2, which include:

- Existing Traffic Conditions;
- Running Way Design Parameters;
- TSP System Capabilities;
- TSP Strategies.

2.1 Existing Traffic Conditions

The existing road traffic conditions for all signalized intersections along the routes are assembled. The data are stored in Synchro, which was used to generate intersection specific measures of effectiveness. The data extracted from Synchro includes: phase and cycle information; pedestrian volumes; Level-Of-Service (LOS); Minimum phase duration; Maximum phase duration. All of these are broken down by time of day (AM, PM and Off-peak period) and for each movement.

2.2 Running way Design Parameters

Two key running way parameters that are included in the TSP design are the stop locations (whether there is no stop, near side or far side stop), and the availability of queue jump lanes for the buses.

Generally, intersections with far side stops can have TSP designed similarly to intersections with no stops. Intersections with nearside stops pose the greatest difficulty in implementing TSP, because transit vehicles may or may not stop, and when they stop they have variable passenger loading/disembarking times.

The implementation of queue jump lanes is important because it allows the transit vehicle to by-pass standing queues during congested periods. However, the use of the queue jump lane is a transit operator decision that is made based on current traffic conditions. The TSP design assumes the use of queue jump lanes during certain time periods.

2.3 TSP System Capabilities

The following describes the TSP strategies that were shortlisted, along with the controller and vehicle logic unit functions available to support the TSP strategies.

2.3.1 TSP STRATEGIES

Based on design the TSP, and the functionality of the TSP system, the following TSP strategies will be implemented:

- Passive priority (queue jump lanes);
- Red truncation (early green)/green extension; and
- Actuated transit phase.

2.3.1.1 Passive Priority

The main passive priority treatment used is the implementation of queue jump lanes. Queue jump lanes were proposed for signalized intersections that experience a minimum of a one-cycle delay during either the AM or PM peak period. The length of the required queue jump lane to by-pass the queue was estimated based on field observations.

An overriding principle in civil design work is that the project must not “trigger” an Environmental Assessment process. This design constraint governed the queue jump design in terms of queue jump locations, and the overall length of the queue jump lane. A secondary consideration was the cost of the queue jump facility. If the queue jump lane would have excessive costs due to physical features (e.g. presence of utilities) then design adjustments were made. In some instances, queue jump lanes were shortened, or abandoned due to this constraint.

2.3.1.2 Red Truncation/ Green Extension

Based on previous experience and industry practice, red truncation and green extension are the most commonly applied TSP strategies. A red truncation (or early green) strategy decreases the green time of preceding phases to expedite the return to green for the transit vehicle. Conversely, a green extension strategy extends the current green (transit phase) to progress the transit vehicle through the signalized intersection without stopping. Green extension is considered the more beneficial form of TSP because it can achieve a more significant reduction in transit vehicle delay at a signalized intersection. For example, a 10 second green extension can save the transit vehicle a wait time equivalent to the competing phases, which dependent on phase splits may be equivalent to half the cycle length or more. In contrast a red truncation of 10 seconds will save the transit vehicle at most, 10 seconds.

2.3.1.3 Actuated Transit Phase

An actuated transit phase specific for transit vehicles may be required at terminal facilities to progress the transit vehicle into and out of the facility. The decision to use an actuated transit phase is a function of the access design (e.g. left turn in and out of the facility restricted to transit vehicles only).

In the York Region project two levels of priority are used, low and high. Both levels of priority are TSP, not emergency vehicle pre-emption. The determination for a low versus high priority request is based on schedule adherence. A transit vehicle moderately off schedule will request a low priority and receive up to a 10 second green extension, whereas a transit vehicle off schedule will request a high priority and receive up to a 20 second green extensions.

2.4 Application of TSP Strategies to Transit Stops

The following describes the specific TSP strategy that are used at signalized intersections without transit stops, with far side stops and with near side stops. Green extension and red truncation are the TSP strategies that are implemented. Typically the TSP green extension will occur in a green and don't walk display, which will follow the green and walk, and green and flashing don't walk display.

The TSP strategy description below also differentiates between the low and high TSP strategies that are used. The decision for implementing a low or high TSP strategy is based on the "lateness" of the transit vehicle. This decision making process occurs in the VLU.
Site-specific strategies are developed for signalized intersections where transit vehicles are turning. These are complex operations with transit movements competing with one another for green time.

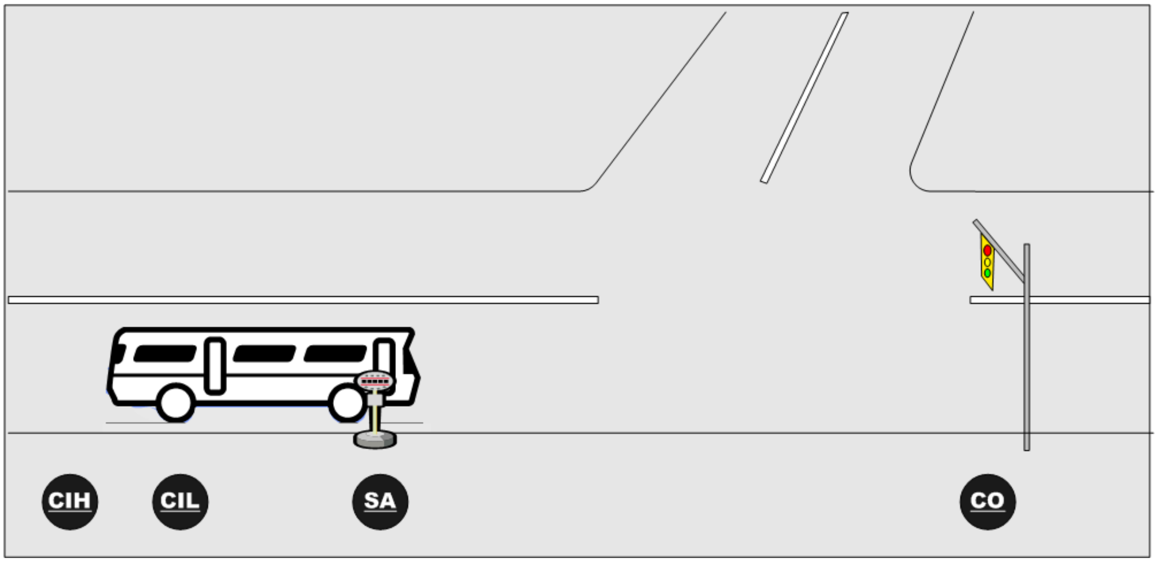
2.4.1 NO STOP

Green extension and red truncation strategies are applied to signalized intersections without transit stops. The transit vehicle priority request is determined by the VLU L based on a schedule adherence.

The objective of the green extension strategy is to progress the transit vehicle through the signalized intersection without stopping. The green extension duration is translated into a distance upstream from the signalized intersection, based on a peak period transit vehicle operating speed. For the high TSP request, point CIH in Exhibit 3 will be used for check-in, while a second point CIL, closer to the signalized intersection will be used to initiate the low priority request.

In general the red truncation matches the green extension duration for the low and high TSP request.

Exhibit 3: Check-In and Check Out



2.4.2 FAR SIDE STOP

The TSP strategy at far side stop locations mirrors the TSP strategy at no stop signalized intersections.

Without transit priority, near side stops are more efficient for transit operations since a portion of the transit vehicle stop time at the signalized intersection is combined with passenger boarding and alighting. The uncertainty of the transit vehicle stopping at near side bus stops complicates the TSP process. For this reason, the request for TSP at signalized intersections with far side stops should not be controlled by the schedule adherence calculation in the VLU, but rather be actively implemented for the approaching transit vehicle.

2.4.3 NEAR SIDE STOP

At signalized intersections with near side stops the underlying assumption is that the transit vehicle will stop. The stop assignment point will be used to initiate the priority request (refer to SA in Exhibit 3). Again the high and low TSP request will be implemented based on the VLU schedule adherence calculation. On the controller side the green extension time for both the high and low request will be the same (e.g. 5 seconds, which is enough time for the transit vehicle to accelerate and clear the signalized intersection). However the red truncation time can be varied under the high and low TSP request to expedite the return of green to the transit vehicle.

3 ANALYSIS PROCESS

The initial step in the development of TSP parameters is the characterization of signalized intersections along the transit routes. In order to effectively categorize the intersections and subsequently assign the appropriate TSP strategies, information related to the signalized intersection geometry, phasing and operations was compiled and logically organized in a Microsoft Access Database.

Once compiled, intersections can be grouped according to various key characteristics, and TSP strategies can be applied (e.g. max duration of green extension).

3.1 Database Tool

A relational database was selected as the most efficient format for data organization and manipulation for this initiative.

The data required of the characterization of signalized intersections are as follows:

- Intersection location information;
- Transit stop details;
- Signal timing information by time of day/timing period;
- Pedestrian volumes by time of day/timing period;
- Signal operations analysis results by time of day/timing period.

3.2 Characterizing Intersections

In order to characterize and group intersections, a decision tree was devised. Using the database, the decision tree was applied to generate groups of intersections with like characteristics that could be discussed as a group when applying TSP strategies. In order from highest order to lowest order the decisions are:

a. AM or PM

The traffic flow during the AM peak period can be quite different from during the PM peak period, particularly on routes traveling to/away from urban core.

b. Bus Through Movement or Turning Movement

If the bus is turning at an intersection then the TSP strategy must be developed specific for this movement.

c. Bus Route (Eastbound/Westbound or Northbound/Southbound)

It is important to identify the bus routes for the major corridors. The reason for this being each direction has different characteristics during different time periods, and at stop locations may have different stop treatments.

d. Intersection Classification

If the intersection cross street has two or more through lanes, then it is classified as a major cross street (i.e. major/major intersection). If the intersection cross street has only one through lane, then it is classified as a minor cross street (i.e. major/minor intersection). For the intersections that have transit turning movements, this decision is omitted.

e. Stop Locations (Near side, Far side, or No stop)

Stop locations vary at each intersections, by direction. It is necessary to determine whether it is a near side stop, far side stop, or simply no stop.

f. Intersection Level of Service

The intersection Level of Service (LOS) is divided into two categories: equal to or better than LOS C and equal to and worse than LOS D. Poorer levels of service indicate that these intersections are likely to be more difficult when applying TSP as there is less flexibility in extending/shifting signal times.

Exhibit 4 presents the decision tree starting at decision d) from above. A total of 12 outcomes are derived from the full decision tree. Exhibit 5 presents the actual TSP parameters applied to the decision tree.

Exhibit 4: Sample TSP Guidelines Decision Tree

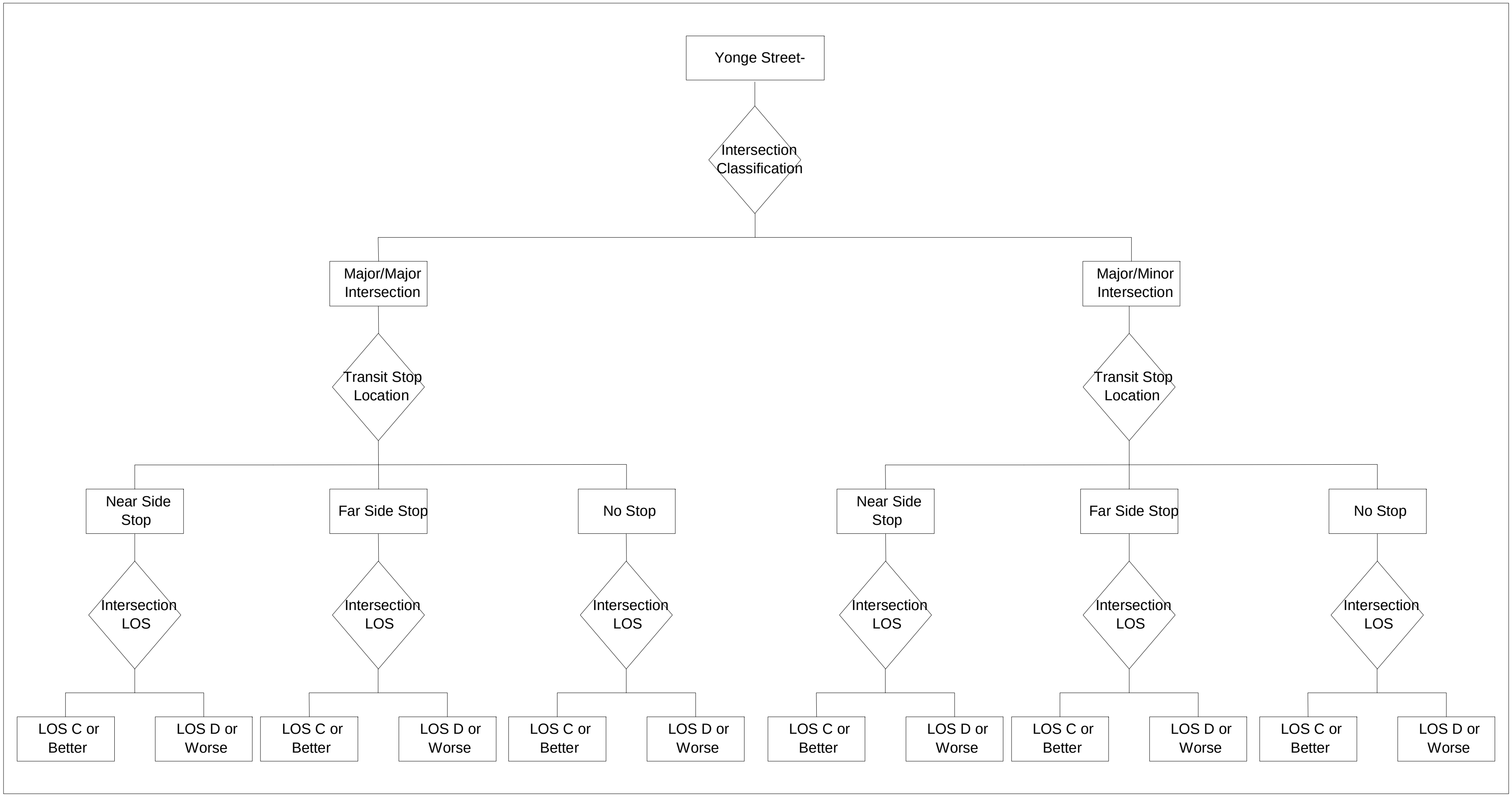


Exhibit 5: TSP Guidelines and Parameter Settings

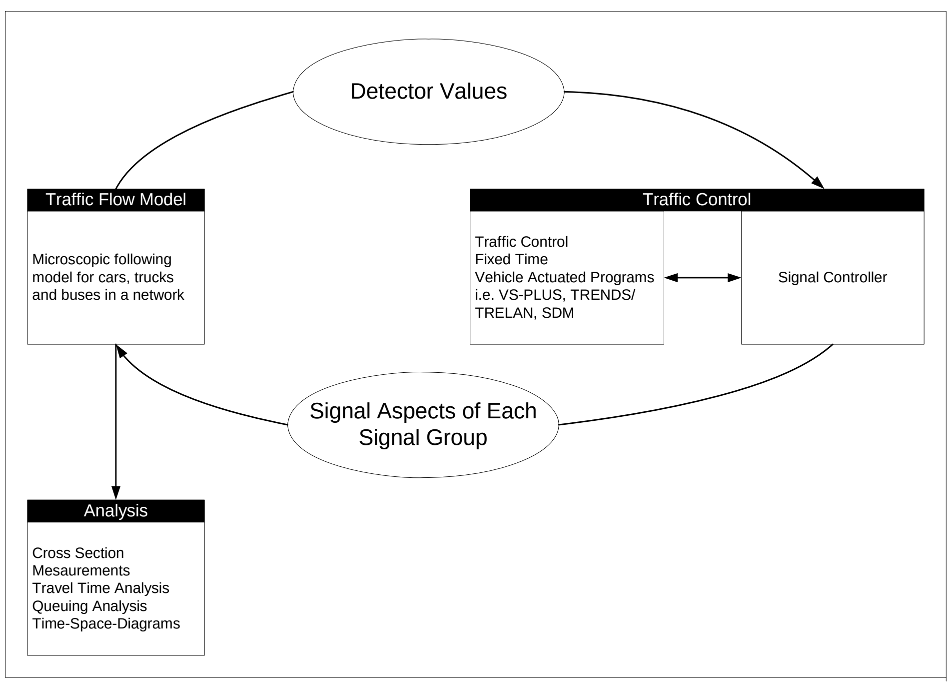
TSP Guideline	Decision	Green Extension		Red Truncation		TSP Re-service (minutes)
		Low	High	Low	High	
Intersection Classification	Major/Major	Max 10	Max 15	Max 10	Max 15	5
	Major/Minor	15	20	15	20	2
Intersection LOS	C or Better	-	-	-	-	2
	D or Worse	5	10	5	10	5
Transit Stop	Far Side	-	-	-	-	Unconditional
	Near Side	5	5	-	-	Conditional
	No Stop	-	-	-	-	Conditional

4 MODELING PACKAGE FUNCTIONALITY

The VISSIM traffic simulation model package is comprised of two separate programs, which trade information regarding detector call and signal status through an interface. The simulation generates an online animation of traffic operations, and offline it generates output files for gathering statistical data (e.g., travel times and queue lengths).

The traffic simulator (VISSIM) is a microscopic traffic flow simulation model complete with vehicle following and lane change logic. The signal state generator (VISVAP) is a signal control software that polls detector information from the traffic simulator on a discrete time step basis (with steps as small as 0.1 seconds). The signal state generator determines the signal status for the following interval and returns that information to the traffic simulator. Exhibit 6 illustrates the communication between the traffic simulator and the signal state generator.

Exhibit 6: Communication Between Traffic Simulator and Signal State Generator



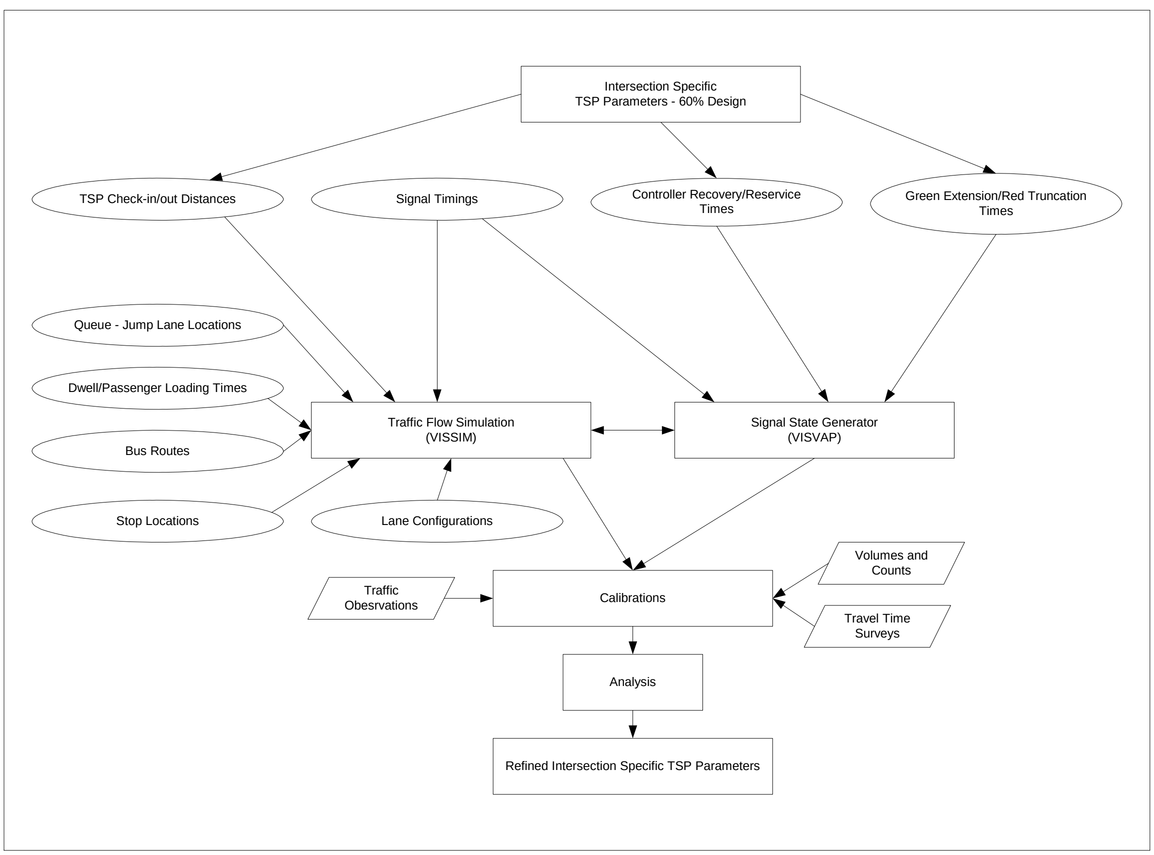
The VISVAP logic was developed to replicate the transit signal priority functionality available in the controller. While the TSP controller logic was not replicated in its entirety, the VISVAP logic developed is a reasonable approximation. Features of the VISVAP TSP logic include:

- Reservice time programmable by intersection;
- Green extension and red truncation TSP strategies;
- Two TSP treatments per approach are implemented, using both green extension and red truncation strategies;
- TSP assigned to both coordinated and non-coordinated phases;
- Variable check in points for high and low TSP treatments, as well as near side stop situations.

5 SIMULATION MODEL INPUTS

Each of the two component programs that form the traffic simulation model requires a specific set of inputs. Exhibit 7 is an overview of the TSP modeling process and the associated input data.

Exhibit 7: TSP Modeling and Parameter Refinement Overview



The data are presented in two groupings, one for inputs that contribute to base model construction and a second for inputs that apply to TSP modeling. The base model input components include the following:

Signal Timings (AM and PM):

- Bus Routes;
- Stop Locations;
- Passenger Loading/Dwell Time;
- Pedestrian Volumes;
- Bus Headways;
- Turning Movement Counts; and
- Lane Configurations.

The input parameters that apply to TSP modeling include:

- Locations of Queue-Jump Lanes;
- TSP Check-In/Out Points (for both high and low priority TSP);
- TSP Extension and Truncation Times; and
- Traffic Signal Controller Recovery/Reservice Times.

The following subsections detail how the individual analysis inputs apply to either the traffic simulator or the signal state generator and identify any assumptions that were made in determining their values.

5.1 Signal Timings

Signal timings are the only input data that need to be programmed into both the signal state generator and the traffic simulation program. Signal timings are the essential input for VISVAP and form the basis for its controller decision logic. In VISSIM, signal timing data are used to assign phasing logic when creating signal heads for the virtual intersections. Interaction between the two component programs deals primarily with signal timing issues.

5.2 Turning Movement Counts

Unlike some traffic simulation programs, VISSIM does not force turning movement count values. That is to say, the individual turning movement count volumes are input to the program and those values are then converted into a percentage of the total movement count at the intersection. The benefit of this approach is that the traffic volumes for the entire network, which are input as direction-specific entry and exit volumes at external nodes, can be increased or decreased without requiring that each movement volume be re-entered.

5.3 Lane Configurations

Lane configuration data (including link distances, storage bay lengths, number of lanes dedicated to each turning or though movement, lane widths, channelization, etc.) for the control area is input to the traffic simulation program to generate an accurate virtual road network. Aerial maps, along with field observations were used to confirm lane configurations.

For modeling purposes, four simulated routes are input to the traffic simulator for each actual bus route. More specifically, two routes for each direction, and within each direction one route designated high TSP and the other low designated TSP. The route start times are then staggered to create the required headway, and interlace the priority treatments.

5.4 Stop Locations

With respect to TSP, the primary concern with bus stops is whether they are located at the near side or the far side of the intersection. Differing TSP strategies have been developed to deal with near side and far side stops. In order to model the maximum delay due to stop frequency, and since we are modeling peak periods, the buses in the traffic simulator were hard coded to stop at every bus stop along their route.

5.5 Passenger Loading/Dwell Time

In the York Region VIVA Implementation, less time than usual is needed for passenger loading on buses due to prepaid fares and the use of both the front and back doors for loading and alighting of passengers. As a result a peak period mean dwell time of 25 seconds at each stop with a standard deviation of 5 second was assumed. Therefore, dwell time in the simulation can vary from 20 to 30 seconds. It should be noted that the purpose of this work is to estimate the effectiveness of TSP, rather than assess the impact of reduced passenger loading time.

5.6 Pedestrians Volumes

A review of the available pedestrian data available indicated that many arterial intersections have very low pedestrian volumes (i.e. less than 10 pedestrians per hour per intersection leg). Pedestrian volumes, where available were entered at intersections without transit stops. At intersections with transit stops the pedestrian volumes were assumed to be slightly greater than the estimated passenger loading (pedestrians may cross more than one intersection leg to reach a stop location).

5.7 Bus Headways

Some of the routes overlap creating smaller bus headways ranging between approximately 3 and 5 minutes. Route-specific headways are programmed on the bus route based on routing.

5.8 Queue Jump Lanes

Queue jump lanes are provided at intersections with a far side stop and an upstream right turn lane. The right turn lane is used as the queue jump lane. In the traffic simulation model queue jump lanes are coded as right turn lanes with the additional stipulation that Quick Start buses may use them for through movements. All other vehicles are not permitted to use the right turn lane for through movements.

5.9 Check-In/Out Detection

TSP check-in and checkout points vary by priority level. The relative lateness of a bus determines whether it receives high or low priority. For modeling purposes, we have compared two scenarios; namely 1) 'without TSP', and 2) 'with TSP'. The 'without TSP' scenario will estimate the transit vehicle travel time through the control areas without TSP. The 'with TSP' scenario will estimate the transit vehicle travel time through the network with TSP. The two scenarios will also be used to determine the relative disbenefit to mixed traffic resulting from TSP implementation. The 'with TSP' scenario assumes that 50% of the TSP requests will be high priority and the other 50% will be low priority. The priority level of each bus in the network is hard coded as described in the subsection on bus routing.

In the traffic simulator check-in/out points are modeled as detectors on the roadway. Detector distances were set using a vehicle travel speed of 50km/hr at major/minor roadways; a speed of 25km/hr was used for major/major intersections that are level one critical. These guidelines for TSP detector placement were developed based on a review of the travel time data collected for VISSIM model calibration. The actual detector placement will be refined based on model output. The high priority detectors (located furthest from the intersection) sense only high priority buses and the low priority detectors (located near the intersection) sense only low priority buses.

5.10 Extension and Truncation Times

TSP extension and truncation times are coded into the signal state generator. Green extension and red truncation times are defined for the type of intersection and its classification as shown in Exhibit 5. Nearside bus stops receive a maximum of 5 seconds of green extension or red truncation while extension and truncations at all other intersections range between 5 and 20 seconds.

5.11 Recovery/Reservice Times

A reservice time is used to limit the frequency of TSP requests at any particular intersection. A reservice times of either 2 or 5 minutes was used, depending on the intersection classification. A 5-minute reservice time was used at all major/minor intersections and major/minor intersections with a peak period intersection LOS D or worse. A 2-minute reservice time was used at non-critical major/major intersections (peal period LOS C or better). The reservice time is programmed into the signal state generator and when a TSP detection is received from VISSIM, VISVAP determines weather or not TSP is permitted and returns the appropriate command (either initiate TSP, or ignore TSP).

6 MODELING

At locations where critical intersections exist, control areas were established for VISSIM modeling. Nearby signalized intersections that require coordination with the critical intersections are included in each control area. Coordination does not exist between adjacent signals that are widely spaced, due to platoon dispersion. For this reason, any signalized intersections that are greater than 700 metres away from the critical intersection, are not included in the control area. Furthermore, control areas are typically limited to 3000 metres (3km)in length, and approximately 12 signalized intersections.

7 MODEL CALIBRATION

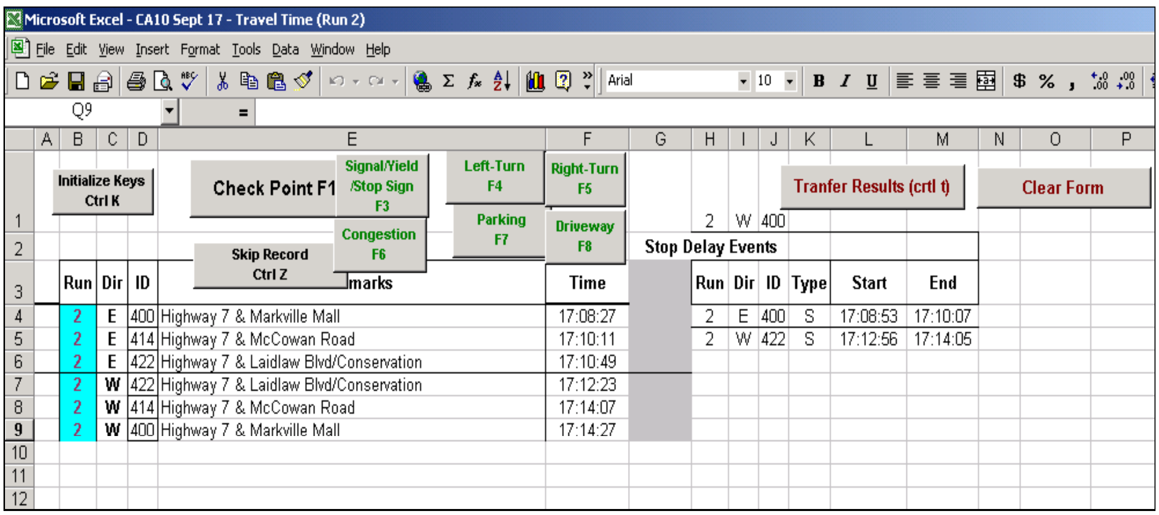
Inherently, calibrating a model requires that there exists some standard by which the model performance and outputs will be measured. The standards for calibration in this case were derived from various sources. Volume and movement counts, and traffic flow observations along with actual travel times were collected as part of a travel time survey. A description of that travel time survey and the extended calibration process are presented in this section.

7.1 Travel time Survey

Travel time surveys for model calibration were conducted across the network. Separate travel time surveys were conducted for each control area. Surveys of these control areas were carried out during both the AM and PM peak periods. Three runs across each control area were performed in the AM peak, and three in the PM peak.

Each run consisted of traveling along the desired road, and with the help of an excel spreadsheet designed specifically for travel time studies, noting key time intervals. A sample of the spreadsheet is shown in Exhibit 8.

Exhibit 8: Travel Time Spreadsheet



7.2 The Three-Stage Calibration Process

Calibration is perhaps the most challenging and labour intensive stage in the modeling process. It is an iterative process with complexities that vary directly with the level of accuracy required in the final product. With a refined intersection-specific set of TSP parameters in mind, a three-stage calibration process was used which include::

- Observational Calibration;
- Volumetric Calibration; and
- Travel Time Calibration.

Each stage of the calibration process provides an improved level of detail and may in fact be comprised of several smaller calibrations. The actual parameters within the model that are adjusted during each stage of the calibration process may feature some overlap however, the stage of calibration will be better indicated by the magnitude by which they change.

7.2.1 OBSERVATIONAL CALIBRATION

The observational calibration stage is the first step. It looks at how the simulation model operates as a whole and concentrates on issues like virtual driver behaviour, signal operations, and programming discrepancies.

Driver Behaviour

In contrast with less sophisticated models, which use constant speeds and deterministic car following logic, VISSIM employs a complex psychophysical driver behaviour model. This type of model attributes specific characteristics, such as aggressiveness, memory, and an ability to estimate, to each driver-vehicle unit resulting in a more realistic driver population. The attributes of driver-vehicle units can be adjusted to calibrate the model to actual conditions.

Signal timings

The calibration of signal timings is perhaps better described as a debugging process. Given that two separate programs (VISSIM and VISVAP) control elements of the traffic signal system, extreme care must be taken to ensure their continuity. The design of the simulator dictates that some timings cannot be coded conventionally. Therefore, the calibration, or debugging, process involves observing the operation of each signalized intersection in the model and then making the required adjustments to the timing plan in both the traffic simulation program and the signal state generator.

Some examples of signal timings calibration include observing a long amber time at an intersection or a signal where the EWG does not change to NSG when there is a north-south queue. In both of these cases, the VISSIM and VISVAP inputs need to be checked. In the first example, the amber time was inconsistent between the two programs. In the second example, the specified detector numbers for the north-south links were different between the two programs and hence the vehicles were not detected to trigger a phase change in the signal.

Another example of signal timings calibration is the inclusion of a ‘ghost’ phase at a T-intersection. This was used to trick the logic in operating similar to a four-legged intersection. Without the ‘ghost’ phase the signal does not operate properly and may display for example a northbound green and eastbound green simultaneously. In another instance, the program required that both concurrent pedestrian phases be hard coded to operate simultaneously with the permissive left turns. In a NEMA controller, this operation would proceed logically without requiring specific coding.

7.2.2 VOLUMETRIC CALIBRATION

The second stage of the calibration process begins to look at the measure of effectiveness such as vehicle throughput and queues. It focuses on the routing decisions and movement volumes within the traffic simulation network.

Routing Decisions

As mentioned earlier, VISSIM assigns turning movement volumes based on percentages derived from hard coded count volumes. Sometimes, the assigned volumes do not reflect the actual conditions as accurately as necessary. In such instances, the inflow and outflow volumes require adjusting (balancing) in order to correct the discrepancy. This scenario presented itself rather frequently during the calibration process due to the nature of the program.

7.2.3 TRAVEL TIME CALIBRATION

The travel time calibration stage is the most detailed and it involves trying to match the travel times generated by the traffic simulation model with actual travel times. The actual travel times were collected via the previously described travel time survey of the control area.

Model Time vs. Survey Time

The ultimate goal of calibration is to have the simulator model travel times that mirror those measured in the travel time surveys as accurately as possible. A software application (a cooperative series of linked spreadsheets and relational databases) was developed to aid in the travel time calibration process. The average segment travel times (travel time between signalized intersections) were determined from the travel time surveys and are input to the application. Simulation runs in VISSIM are then conducted. Five runs for each control area are simulated and the application collects the output data. A trimmed average of the segment travel times are then calculated. The trimmed average simulated travel times are then compared to those measured in the surveys. When significant deviations from the survey times occur model parameters are changed to influence the travel time.

Some examples of travel time calibration adjustments are:

- Increase/decrease left turn speeds;
- Increase/decrease lane change aggressiveness; and
- Increase driver knowledge of the area.

For example, driver knowledge of the area was increased, in the simulation, at a particular intersection where one through lane was dropped a short distance beyond the intersection. The initial model travel time was significantly slower than the times measured in the field on that section, and many vehicles were queuing up trying to change lanes downstream of the intersection. Observations of actual traffic activity showed that the majority of drivers were aware of the lane drop and changed lanes prior to entering the intersection. This behaviour was coded into the simulator and the model travel time changed to a level much closer to the surveyed value.

8 LESSONS LEARNED

The traffic and transit agencies must work cooperatively in developing the TSP parameters.

The equipment procurement process iterated through a 30% design, 60% design and ultimately system procurement process. The TSP parameter design process started with a 60% design and advanced through a 90% design and ultimately to a 100% design for implementation. Completing the two activity streams in parallel, allowed feedback between the design and procurement, which ultimately improved both by confirming that the intended design could be constructed.

The decision tree process simplified the process of selecting TSP parameters, by categorizing similar intersections for analysis purposes. By organizing the intersections into categories, it made it easier to discuss the potential impact of TSP with the various stakeholders.

It is difficult to anticipate the impact of conditional TSP on the mixed traffic, and the benefit to transit. A modelling exercise provides an initial estimate of the potential benefits and disbenefits of TSP. However, when a new system is to be deployed, or new transit schedules are to be designed, historical data may not exist that can provide an estimate of potential TSP activity.

Without a performance objective established for TSP (i.e. reduce travel time by 5 minutes), it is difficult to reach a consensus on how much TSP is warranted, and hence establish parameter values.

By modelling an unconditional operation, a worst-case scenario for mixed traffic can be estimated, and a best case for transit. This approach eliminates any concern with respect to schedule adherence.

An important benefit of the modelling exercise is the visualization of the TSP operation, rather than the quantification of the potential benefits and disbenefits.

At the start of the process the emphasis was on conducting an extensive modelling exercise. Through the design process, participants became more comfortable with the TSP concepts, and the intersection categorization technique. In the end the stakeholder group relaxed the modelling exercise as they began to understand the TSP operation.