TRAFFIC MANAGEMENT CENTRE

INTELLIGENT TRANSPORTATION SYSTEMS (OPERATIONS)

GUIDELINES FOR USING SYNCHRO 9 (INCLUDING SIMTRAFFIC 9)

March 18, 2016

Toronto Transportation Services Division

ITS Operations
Traffic Management Centre

DOCUMENT CONTROL

Contact Information

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Amendment History

No.	Details	Version	Revision Date (YYYY/MM/DD)
1	Existing "Guidelines for using Synchro 7 (including SimTraffic 7" updated for Synchro Version 9.0.	Draft 1.0	2015/08/17
2	Original draft reviewed by Darryl Spencer (Engineer, ITSO), Pierre Vandall (Project Lead, ITSO), and Rajnath Bissessar (Manager, ITSO).	Draft 1.1	2015/09/28
3	Draft 1.1 reviewed by workshop participants and email respondents: *District Traffic Planning* - Godly Abraham, Geoffrey Lau, Luigi Nicolucci *District Traffic Operations (DTO)* – Farhad Awabin, Christopher Chahil, Jim Edwards, Muhammad Qamar I*nfrastructure Planning* – Grace Nzainga *Cycling Infrastructure* – Darryl Olsen *Public Realm* – Sheyda Saneinejad *City Planning* – Diane Ho, Matthew Davis, Nasim Norouzi, Satbinder Pabla, Garvin Tom *ITS Operations (ITSO)* – Rajnath Bissessar, Irem Khan, Pierre Vandall	Final (Version 1)	2016/03/18

APPROVAL

The version of this document dated March 18, 2016 was approved by the following:

- Safety and Mobility Committee (SMC) of Transportation Services on April 21, 2016.
- Transportation Planning of City Planning on April 26, 2016.
- TPROW Managers of Transportation Services on April 28, 2016.

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Abbreviations

APS	Accessible Pedestrian Signal
ATCS	Adaptive Traffic Control System
AWSC	All-way-Stop Control
CBD	Central Business District
CCG	Canadian Capacity Guide (for Signalized Intersections)
DTO	District Traffic Operations
FDW	Flashing Don't Walk
HCM 2000	Highway Capacity Manual 2000 (US)
HCM 2010	Highway Capacity Manual 2010 (US)
HOV	High Occupancy Vehicles
f_{LU}	Lane Utilization Factor
LOS	Level of Service
MOC	Mode of Control
MOE	Measure of Effectiveness
OD	Origin-Destination
OTC	Ontario Traffic Council
pcphgpl	passenger car per hour of green per lane
Ped	Pedestrian
PHF	Peak Hour Factor
Prot	Protected Phase
Perm	Permissive Phase
RTOR	Right turn on red

SA	Semi-actuated
SAP	Semi-actuated Pedestrian
SAV	Semi-actuated Vehicle
SCOOT	Split, Cycle and Offset Optimization Technique
sqrt	Square Root
TMC	Turning Movement Count
TSU	City's Traffic Safety Unit
TWLTL	Two-way Left Turn Lane
TSOG	Traffic Signal Operations Group of ITS Operations
TSP	Transit Signal Priority
TWSC	Two-way-Stop Control
v/c	Volume to capacity ratio
vph	Vehicles per hour
vphpl	Vehicles per hour per lane
v50	50th Percentile Volume
v95	95th Percentile Volume
V15	Peak 15 minute volume
V60	Peak hour volume
Veh	Vehicles

Glossary

Accessible Pedestrian Signals (APS) Signal devices designed to assist pedestrians who are visually and/or hearing impaired by providing information that they can interpret to understand when they may cross at a signalized intersection.

Adaptive Traffic Control System (ATCS) A traffic control system that automatically adjusts signal timing parameters in real-time to allow for signal operations that respond to actual, real-time traffic conditions.

Capacity The maximum rate at which vehicles can pass through a given point in an hour under prevailing conditions, known as the saturation flow rate, applied in conjunction with the ratio of time during which vehicles may enter the intersection.

Controller (Timer) A device that controls traffic at an intersection by alternating the right-of-way between conflicting streams of vehicular traffic, or vehicular traffic and pedestrians crossing a roadway.

Coordinated Actuated Signal operation in coordination with other signalized intersections, and using vehicle, bicycle, and/or pedestrian detection to define signal timing.

Coordination The ability to coordinate multiple signalized intersections to enhance the operation of one or more directional movements in a system.

Cycle Length The time required to complete a full sequence of signal indications at a signalized intersection.

Delay The additional travel time experienced by a driver, passenger, or pedestrian.

Detector A device used to count and/or determine the presence of a vehicle, bicycle, or pedestrian.

Double Cycle A cycle length that is half the duration of the cycle length of other signals in a coordinated system

Effective Green Time The time during which vehicles in a given traffic movement proceed through the signalized intersection. It is equal to the total phase time minus the lost time (where the total phase time equals the sum of the green, amber, and all red interval times).

Feathering A congestion mitigation strategy that spreads out the traffic queue along a corridor with excessive congestion.

Flashing Don't Walk (FDW) The time provided for a pedestrian to clear the crosswalk, equivalent to the time required to cross the entire width of the intersection. It is also known as the "pedestrian clearance interval".

Free Flow A flow of traffic unaffected by upstream or downstream conditions.

Fully Actuated Mode of Control (FA) A signal operation in which vehicle detectors and/or pedestrian pushbuttons at each approach to the intersection control the occurrence and length of every phase.

Fully Signalized Offset Intersections A type of operation at offset intersections that incorporate both of the closely located minor street legs into the traffic signal installation.

Fixed Time Mode of Control (FXT) A signal operation in which the vehicle signal indication changes automatically from the main street to the side street, and back, even if there are no vehicles/pedestrians wishing to cross the main street.

Gating A congestion mitigation strategy that controls the inflow of traffic into sensitive areas (i.e. where queue routinely builds up).

Growth Factor This can be used to adjust traffic volumes. Within Synchro, volume data is multiplied by the Growth Factor when calculating Adjusted Volumes and Lane Group Volumes.

Hardwire Interconnect Interconnection using physical cable between two controllers that allows closely spaced signals to maintain a fixed offset relationship at all times.

Ideal Saturated Flow This is a macroscopic model term used by Synchro which will affect the Headway Factor and therefore influence headways and Saturated Flow Rates.

Intersection Pedestrian Signal (IPS) A control device dedicated primarily to providing traffic gaps for pedestrian right-of-way at an intersection. Main road traffic is fully signalized while the side road must be controlled with stop signs. They are also known as "Half Signals".

Lane Utilization This determines how the traffic volumes assigned to a lane group are distributed across each lane. A value of 1 indicates equal distribution across all lanes.

Lost Time The time in a signal phase (where the total phase time equals the green plus amber plus all red interval times) when no vehicles are able to pass through the signalized intersection. Lost time is comprised of two parts: start-up lost time and clearance lost time.

Measures of Effectiveness (MOEs) Measurable parameters that demonstrate the benefits, impacts, and cost-effectiveness of signal timing plan alternatives on road users for the individual intersection, associated corridor and entire network.

Offset The time relationship between the coordinated phase's defined reference point and a defined master reference (i.e. master clock) point.

Offset Intersections A location where two minor streets intersect a major street at "nearly" the same location, operating like two T-intersections located very close to each other on the arterial road.

Offset Transition A state of a controller to resynchronize traffic signals to its coordinated operations every time a signal timing plan is changed, or after pre-emption is served.

Partially Signalized Offset Intersections A type of operation at offset intersections that incorporate only one of the minor street legs into the traffic signal installation and effectively operate like a signalized T-intersection.

Passage Time A feature that extends the green interval based on the detector status once the phase is green.

Peak Hour Factor The ratio of the flow rate for the entire hour, to the flow rate for the peak 15 minutes. It quantifies the uniformity of flow across the peak hour.

Permissive Movement A movement where vehicles are allowed to proceed if there are available gaps in the conflicting flow.

Pre-emption Upon actuation of a pre-defined pre-emption, the traffic signal controller terminates the current phase and serves a pre-defined pre-emption phase. The most common use of this operation in Toronto is to manipulate the normal operation of traffic signals to provide preferential treatment to rail, emergency and transit vehicles.

Protected / Permissive Movement A compound movement protection at a signalized intersection that displays the protected phase before the permitted phase.

Saturated Flow Rate The actual maximum flow rate for this lane group after adjusting for all of the interference factors. The Saturated Flow Rates represent the number of lanes multiplied by the Ideal Saturated Flow Rate and interference factors due to heavy vehicles, buses, parking manoeuvres, lane widths, area type, grade, and turning movements.

Semi-actuated Mode of Control (SA) A signal operation in which signals will not change to the side street unless a vehicle or pedestrian has been detected, and in which the side street display and display time varies depending on whether a pedestrian call has been received or not.

Semi-actuated Pedestrian Mode of Control (SAP) A signal operation in which signals will not change to the side street unless a vehicle or pedestrian has been detected, and in which the side street will serve the pedestrian "walk" phase regardless of whether or not a pedestrian call has been received.

Semi-actuated Vehicle Mode of Control (SAV) A signal operation in which there is no pedestrian crossing across the main street and side street display and display time varies depending on vehicle call.

Separate Traffic Signal Phasing A signal phasing sequence which would have the traffic signals cycle from the major street to permit traffic on only one of the minor street legs to proceed, followed by traffic on the second minor street leg, then back to the major street.

Split Cycle Offset Optimisation Technique (SCOOT) An adaptive traffic control system that determines its traffic timing plans based on real-time information received from vehicle detectors located on the approaches to signalized intersections.

Split Phase A signal phasing sequence where one approach is given exclusive right-of-way into the intersection followed by the opposing approach being provided exclusive right-of-way into the intersection.

Streetcars Transit vehicles used along streetcar routes. Typical streetcar routes can either operate separated from other modes of traffic, or share the right-of-way with other users.

Traffic Management Centre (TMC) A section within the Transportation Services Division that is comprised of six units: Traffic Safety Unit, ITS Operations, ITS Capital Projects Planning & Delivery, Traffic Plant Installation & Maintenance, Transportation Business Systems, and Signs & Markings.

Traffic Signals Electronic devices that are designed to assign the right of way to the various traffic and pedestrian movements at a signalized intersection.

Transit Signal Priority (TSP) In Toronto, TSP is provided as transit pre-emption. Upon detection of an approaching transit vehicle at a traffic signal, the controller may invoke timing changes (e.g. early green or green extension), or it may invoke phasing changes (e.g. servicing an actuated priority phase, inserting a phase into the cycle, or rotating the phase within the cycle), in order to reduce delay for an approaching transit vehicle.

Transportation Services Division (TSD) A division within the City that maintains transportation infrastructure including roads, bridges, sidewalks, and boulevards within the four city districts. TSD is responsible for all aspects of traffic operations, roadway regulation, street maintenance, asset management, right of way occupation and snow removal.

TransSuite Traffic Control System (TransSuite TCS) A hybrid traffic control system that relies on second-by-second communication to monitor signal operations, but relies on field equipment to maintain coordination (i.e. the field equipment can maintain signal coordination for about 24 hours if there is a loss of communication).

Urban Traffic Control (UTC) A traffic control system that operates in tandem with SCOOT. UTC provides pre-determined signal timing plans and is used as a stopgap measure if SCOOT is not available.

Walk Rest Modifier (WRM) A type of operation installed at semi-actuated signalized intersections to increase operational efficiency by allowing the signals to return to the main street "walk" display if the side street right-turn vehicle demand clears prior to the start of the main street amber.

Executive Summary

Toronto is the largest city in Canada and the fourth largest city in North America. It is a global centre for business, finance, arts and culture, and home to a diverse population of 2.8 million people. The city is served by a road network consisting of 40 km of expressways and over 5,600 km of roads. There are approximately 2,300 traffic signals on the road network.

The City of Toronto uses capacity analysis software to conduct operational and planning analyses of its transportation network. The health of the network can be assessed at both the intersection and network level. Measures of effectiveness (MOEs) are outputted from the software to provide study-specific quantitative indications at the local and network levels. From these MOEs, operational and planning strategies can be developed to promote smooth and efficient traffic movement through the intersection and along the network.

Synchro is the macroscopic analysis and optimization software that the City uses to conduct these operational and planning analyses. The "Guidelines for Using Synchro 9 (including SimTraffic 9)" was developed to provide guidance for City staff and consultants working for the City when developing transportation models and conducting traffic analysis using Synchro Version 9.0 (or later).

All traffic analyses performed by the analyst using Synchro Version 9.0 (or later), shall conform to the Guidelines outlined in this document. All assumptions contained within this Report are consistent with the City of Toronto's *Traffic Signal Operations Policies and Strategies (May 7, 2015)*.

Chapter 1 of this Report provides an overview of the application of Synchro analysis within the City; Chapters 2 through 9 of this Report provides detail of all relevant input and output parameters presented within the Synchro interface, and provides details on the following methodologies:

- Highway Capacity Manual 2000 (HCM 2000);
- Highway Capacity Manual 2010 (HCM 2010):
  - Automobile mode;
  - Pedestrian mode;
  - Bicycle mode; and
- Synchro/ICU methodology.

Chapter 10 of this Report provides additional details on particular conditions which require in-depth analysis; Chapter 11 provides additional details regarding SimTraffic methodology; and Chapter 12 discusses the MOEs to be reported to the City.

Working Synchro files must be submitted to the City so that staff can review the network that was created and all the intersection input parameters. It is the responsibility of the analyst undertaking the analysis to discuss the scope of work, analysis methodologies to be used, and the measures of effectiveness to report with City staff on a case-by-case basis, prior to proceeding, in order to properly assess the analysis requirements.

1. INTRODUCTION

1.1. Background

All traffic analyses performed by analyst using Synchro Version 9.0 (or higher), shall conform to the Guidelines outlined in this document. The modelling of existing conditions may require variances to some of the following Guidelines to provide an actual representation of existing conditions. These variances must be discussed with City staff prior to proceeding.

All assumptions contained within this Report are consistent with the City of Toronto's *Traffic Signal Operations Policies and Strategies (May 7, 2015)*. If discrepancies between these two documents exist, the assumptions presented within the *Toronto Official Policy* hold precedent. It is the responsibility of the analyst undertaking the analysis to discuss any discrepancies of assumptions with City staff prior to proceeding.

The working Synchro files must be submitted to the City so that staff can review the network that was created and all the intersection input parameters. Any analysis not conforming to these Guidelines (unless agreed otherwise with the City) will be rejected and a complete re-submission may be required.

1.2. Planning vs. Operational Analysis

Planning techniques are used for longer-range projects and for assisting in the determination of the type of facility and its basic dimensions. Therefore, planning analysis is limited to existing and proposed signals analyzed in a transportation impact or environmental assessment study. For planning purposes, it is possible to obtain an approximate level of service through the judicious use of assumed values for most of the model inputs. The only site specific data required are the traffic volumes and number of lanes for each movement together with a minimal description of the signal design and other operating parameters. In some circumstances, where the intersection is approaching or is at capacity, the use of more site-specific parameters may be appropriate. Under such cases, the use of assumed values must be discussed with City staff. Site-specific data regarding pedestrians, bicycle use and transit use may also be critical in planning analysis, particularly when dealing with multi-use developments, higher development densities, and proximity to higher-order infrastructure.

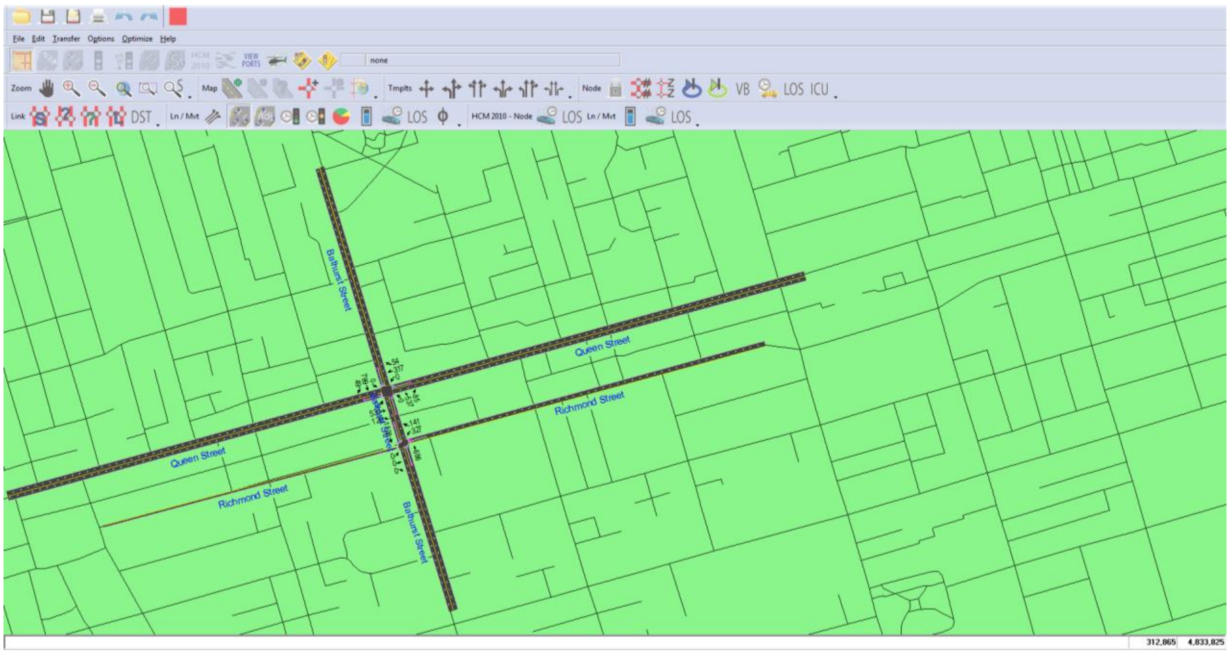
Operational procedures deal with a detailed assessment of operating conditions within a relatively short time frame when all factors are known or can be reasonably estimated. Therefore, operational analysis should be performed for existing signals. When Synchro is used for operational purposes, more site-specific data and other operational parameters must be considered.

A transportation impact or environmental assessment study could include both types of analysis – an operational analysis for existing conditions and a planning analysis for proposed conditions.

1.3. General Information on Data Requirements and Synchro Calculated Values

Generally, the fields that require input (the numeric portions) will be black in colour and will be discussed further in these Guidelines. Numeric fields that are blue have been calculated by the software and do not normally require adjustment. For many of the Synchro calculated values, this document refers the reader to the Synchro Manual for detailed information (by pressing the "F1", the user can access a "PDF" copy of the manual). This document discusses the cases in which the City may accept values that override the software calculated values. Any numeric fields that are red in colour would have been overwritten by the Synchro user, or indicate a violation generated by the software, for example, a split that does not protect the minimum pedestrian clearance times. To cancel overwritten values and restore the Synchro calculated values to a field, the user should press the "F12" key while in the appropriate field.

2. MAP SETTINGS



Any City network must be created using metric units. Link distances must be verified by some independent means such as field measurement, recent aerial photographs (including Google Earth) or recent scaled maps. Link distances must reflect the distance from the middle of one intersection to the middle of another, and not from stop bar to stop bar. The map must reflect the existing geometric layout as accurately as possible, especially features such as road narrowing, mid-block driveways, two-way left turn lanes (TWTL) and bus bays.

3. LANE SETTINGS

LANE SETTINGS	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lanes and Sharing (#RL)												
Traffic Volume (vph)	54	151	174	40	176	20	86	169	25	26	778	141
Street Name	Front Street			Front Street			Church Street			Church Street		
Link Distance (m)	—	427.6	—	—	528.5	—	—	175.5	—	—	517.6	—
Links Speed (km/h)	—	48	—	—	48	—	—	48	—	—	48	—
Set Arterial Name and Speed	—	EB	—	—	WB	—	—	NB	—	—	SB	—
Travel Time (s)	—	32.1	—	—	39.6	—	—	13.2	—	—	38.8	—
Ideal Satd. Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Lane Width (m)	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7
Grade (%)	—	0	—	—	0	—	—	0	—	—	0	—
Area Type CBD	—	☐	—	—	☐	—	—	☐	—	—	☐	—
Storage Length (m)	40.0	—	40.0	40.0	—	40.0	0.0	—	0.0	0.0	—	0.0
Storage Lanes (#)	1	—	1	1	—	1	—	—	—	—	—	—
Right Turn Channelized	—	—	None	—	—	None	—	—	None	—	—	None
Curb Radius (m)	—	—	—	—	—	—	—	—	—	—	—	—
Add Lanes (#)	—	—	—	—	—	—	—	—	—	—	—	—
Lane Utilization Factor	1.00	0.95	1.00	1.00	0.95	1.00	0.95	0.95	0.95	0.95	0.95	0.95
Right Turn Factor	1.000	1.000	0.850	1.000	1.000	0.850	—	0.987	—	—	0.978	—
Left Turn Factor (prot)	0.950	1.000	1.000	0.950	1.000	1.000	—	0.985	—	—	0.999	—
Saturated Flow Rate (prot)	1789	3579	1601	1789	3579	1601	—	3479	—	—	3496	—
Left Turn Factor (perm)	0.950	1.000	1.000	0.950	1.000	1.000	—	0.579	—	—	0.933	—
Right Ped Bike Factor	1.000	1.000	1.000	1.000	1.000	1.000	—	1.000	—	—	1.000	—
Left Ped Factor	1.000	1.000	1.000	1.000	1.000	1.000	—	1.000	—	—	1.000	—
Saturated Flow Rate (perm)	1789	3579	1601	1789	3579	1601	—	2045	—	—	3265	—
Right Turn on Red?	—	—	☑	—	—	☑	—	—	☑	—	—	☑
Saturated Flow Rate (RTOR)	0	0	189	0	0	145	—	11	—	—	21	—
Link Is Hidden	—	☐	—	—	☐	—	—	☐	—	—	☐	—
Hide Name in Node Title	—	☐	—	—	☐	—	—	☐	—	—	☐	—

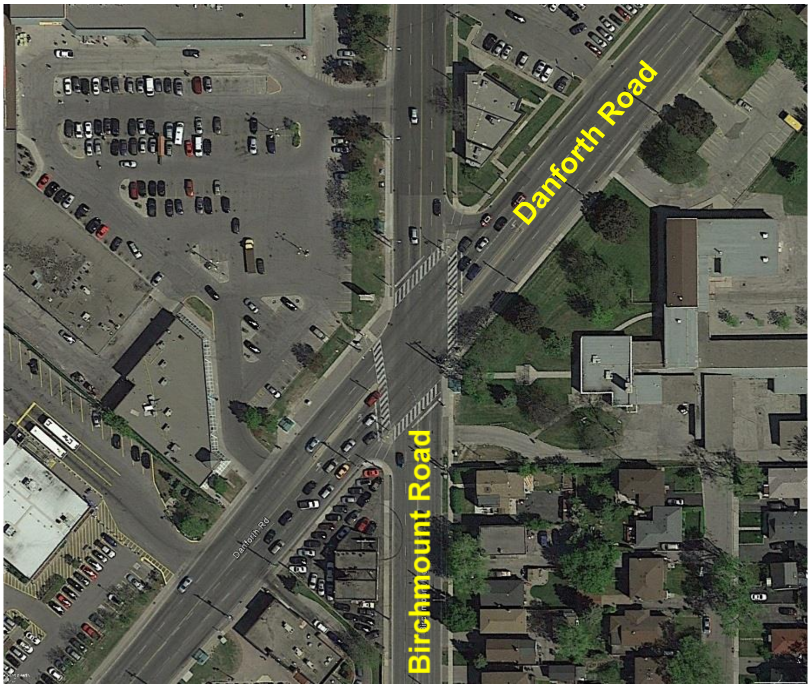
3.1. User Inputs

3.1.1. Changing the Name of the Approach Direction

The naming convention for each movement and approach is automatically generated by Synchro based on the network geometry provided, where North is located at the top of Map View. Where the road network is drawn diagonally along the x and y axes, the automatically generated directions may not meet the appropriate naming conventions, and Synchro may mislabel a movement (e.g. labeling a through movement as a left turn) which may impact the analysis of that movement (e.g. incorporating Left Turn Factor in the calculation). The name of an approach can be manually inputted, in order to reclassify a diagonal approach into an orthogonal approach, by right-clicking on the movement images for that approach, and selecting a new direction. Selecting a direction already in use by another approach will cause the other approach to automatically select a new direction. The analyst should assign N/S and E/W based on what the City prescribes on the relevant timing card(s).

Changing the Name of an Approach Direction is not appropriate if the intersection is skewed such that the approach legs are irregularly spaced. See the example below of the intersection of Danforth Road and Birchmount Road, where Danforth Road intersects Birchmount Road at an angle much less than 90 degrees, and therefore should not be renamed, as it will impact the analysis.

Figure 3-1. Irregular Intersection - Danforth Road and Birchmount Road



3.1.2. Lanes and Sharing

To enter a movement that the lane diagram does not allow, such as at unconventional intersections, volume data can still be entered and the lane diagram will automatically be updated in the “Map Window”. For example, for an intersection with an EB approach, a one-way NB approach and a lane turning SB, the EB right turn volumes can be entered and the software will generate a new lane.

3.1.3. Traffic Volume (vph)

3.1.3.1. “Supply” Volumes

Existing traffic volumes must be current volumes (not older than two years) obtained from the City’s Traffic Safety Unit (TSU). If TSU current volumes are not available, then the analyst can undertake its own traffic counts. Unless otherwise specified, the volumes supplied by the TSU are intersection volumes that have been counted at the stop lines. These “supply” volumes cannot exceed the capacity “supplied” by geometric and signal timing considerations. The volume/capacity (v/c) ratio of movements, based on “supply” volumes, should not be greater than 1.0. Section 3.1.3.2 provides the City's approach to adjusting traffic volumes to allow the analysis of truer intersection demand, which can result in v/c's greater than 1.0. Section 5.3.1 discusses the situations in which Synchro may generate v/c ratios greater than 1.0.

If the analyst undertakes its own counts, then such counts must be done under the same conditions under which the proposed signal is to operate. For example, an analyst should not undertake counts during the summer vacation for a proposed signal at the entrance to a college or university campus, because such counts would not be reflective of normal operation.

For illegal movements that may be encountered in the field, for example, right turns on a right turn on red (RTOR) prohibition, the approach would be to conduct the analysis in three ways:

- Existing conditions, including non-compliance;
- Existing conditions, assuming full compliance; and
- Proposed conditions, assuming full compliance.

For the non-compliance situation, saturation flow must be measured in the field and the value manually entered into Synchro.

3.1.3.2. "Demand" Volumes

In the event of oversaturation, the number of vehicles arriving at an approach can be substantially greater than the number of vehicles that can be discharged. Similarly, projected traffic volumes can exceed approach capacity. The capability of the intersection to discharge such traffic demand can be evaluated only if approaching volumes are used. In such situations the v/c ratio may exceed 1.0.

To ensure that major intersections are properly analyzed, regardless of whether for operational or planning studies, the City has developed an approach to adjust the intersection volumes using upstream data to reflect approach demand. The approach requires the volumes from a minimum of one upstream signal to be included in the analysis of any major intersection.

The methodology of "volume balancing", which is conducted to through movements (but not to turning movements) involves the following steps:

1) Identify locations that have a volume imbalance greater than 10%
2) Determine land uses and presence of accesses within the areas where imbalances are greater than 10%
3) Based on the land use, accesses and local knowledge, determine if the imbalance is justified
4) If the imbalance is not justified, then volumes will be balanced using the major/major intersection as reference for balancing the smaller intersections within 10%, using the following assumptions:
    a) If Major/Major volume is greater than adjacent Major/Minor intersection volume, then increase the Major/Minor through volume
    b) If Major/Major volume is less than consecutive adjacent Major/Minor intersection volumes, then increase the Major/Major volume
    c) If Major/Minor is imbalanced with consecutive adjacent Major/Minors, increase or decrease accordingly
    d) In general, Major/Major volumes should not be lowered to accommodate volume balancing

Since this approach can lead to the volumes exceeding the available capacity at an intersection, then it is possible for the v/c ratio to exceed 1.0, and Synchro parameters (such as Saturation Flow Rate, Lost Time, Peak Hour Factor) should not be adjusted to artificially lower the v/c to hide any capacity problems.

An acceptable alternative approach involves using the volumes supplied by the TSU, and supplementing the data by monitoring residual queues. Data on residual queues should be counted on a cycle by cycle basis and then averaged over the analysis period. Data collection should be treated similarly to a left-turn study, where the number of vehicles, waiting at the start of a phase but unable to clear during each cycle, is counted. The number of cycles taken for back of queue vehicles to clear the intersection should also be recorded. Alternatively, additional traffic counts should be conducted at upstream locations away from any queuing, provided that there is no significant sink or source in between.

3.1.4. Link Distance (m)

Link distances must be to scale and must not be overwritten as Synchro uses this data to calculate travel time. Link distance is measured from centre of intersection to centre of intersection.

3.1.5. Link Speed (km/h)

The speeds assigned to a link must match on-street regulatory speed limits.

3.1.6. Travel Time (s)

This value represents the free flow travel time from node to node and is calculated by the software. It must not be overwritten.

3.1.7. Ideal Saturated Flow (vphpl)

The report “Saturation Flow Rates in the City of Toronto” specifies a default ideal saturation flow of 1900 passenger car per hour of green per lane (pcphgpl). This default saturation flow must be used for Synchro analysis.

In the absence of field measured saturation flows, a number of adjustment factors must be considered and, if applicable, applied to adjust the Ideal Saturated Flow values on each approach lane of the intersection. User judgement must be applied; the goal is to ensure that saturated flow replicate field conditions as much as possible. These adjustment factors are shown in the “Lane” and “Volume” Windows.

Saturation flow adjustment factors need not be applied if the saturation flows have been measured for the particular movement.

The following conditions are applicable for field measured saturation flows:

- A proposed Saturation Flow based on a one day saturation flow study would not be accepted unless it is factored down by 5 %;
- The “factoring down” would be waived if at least three studies were undertaken for the same movement on different days of the same week or over three consecutive weekends for weekend studies; and
- In case of doubt of the veracity of the study, the City could request details of the saturation flow study.

Although rates above the City’s stipulated values are possible, they are not recommended for use in planning or operational design. Traffic patterns and characteristics may change over time so typical or conservative values should be used to account for this possible variability. Regardless of any field studies, the City will not accept values in excess of the following:

- Through movement: 2005 pcphgpl;
- Left Turn Green Arrow: 2050 pcphgpl;
- Double Left Turn Green Arrow: 2000 pcphgpl; and
- High Occupancy Vehicle (HOV) lane: 1680 pcphgpl.

3.1.8. Lane Width (m)

Actual lane widths should be entered. If lane widths are not available, the following default values can be applied:

- 3.5 metres for through lanes;
- 3.0 metres for left-turn lanes; and
- 3.0 metres for right-turn lanes.

Any lane width greater than 4.8 metres is entered as two lanes. The City’s “Vehicle Travel Lane Width Guidelines” is available is on the City’s website.

3.1.9. Grade (%)

A default value of 0 is used if the grade is relatively flat. Where there is a noticeable grade, the analyst should determine the grade or use a value that is acceptable to the City.

3.1.10. Area Type

There are four operational districts in Toronto – Etobicoke/York, North York, Toronto/East York and Scarborough. Virtually all signalized intersections in the downtown area of the Toronto/East York District, and some intersections in outlying high activity areas, are generally classified as belonging to a Central Business District (CBD) environment. Signalized intersections in areas other than those noted above are generally classified as belonging to a non-CBD environment. In uncertain situations, City staff must be consulted, since in these circumstances, the use of the CBD/non-CBD environment will be assessed on a case by case basis. Synchro conforms to the Highway Capacity Manual 2000 (HCM 2000) and applies an internal adjustment of 0.9 to the Ideal Saturated Flow for CBD environments.

CBD characteristics are:

- Narrow street rights-of-way;
- Frequent parking manoeuvres;
- Frequent traffic congestion;
- Vehicle blockages;
- Abundant taxi or bus/streetcar activity or both;
- Small radius turns;
- Shared through/left lanes;
- High pedestrian activity;
- Dense population (high rise apartments, condominiums or offices);
- Mid-block curb cuts;
- Closely spaced intersections (<150 metres); and
- One way streets.

All these characteristics may not necessarily be present for an intersection to be deemed CBD. City staff must be consulted in uncertain situations.

3.1.11. Storage Length (m)

Actual storage lengths must be entered. The storage length excludes the taper. If the left or right turn lane goes all the way back to another intersection, enter "0". If two or more storage lanes are present, enter the average length of the lanes, not the sum. Storage length is used for analyzing potential blocking problems in SimTraffic such as through traffic blocking left turn traffic, and left turn traffic blocking through traffic. If "0" is entered, no blocking analysis is performed.

3.1.12. Storage Lanes (#)

This value only appears when the storage length is greater than 0. By default, the number of storage lanes is equal to the number of turning lanes. This field can be overwritten so that some of the turning lanes are full travel lanes, or some of the through lanes can be storage lanes.

3.1.13. Right Turn Channelized

This field is active for the rightmost movement. If there is no right turn channel, the default of “None” should be used. This field is not used by Synchro for calculating measures of effectiveness (MOEs); however, it is used by SimTraffic for simulation. If there is a channelized right turn, the available options are “Yield”, “Free”, “Stop”, and “Signal”.

3.1.14. Curb Radius

This field is only active if a right turn channel is defined. This field controls the graphics and layout in SimTraffic. It is measured from the back of curb to the center point of the radius. The software accepts values between the minimum of 4.5 metres and the maximum of 75.0 metres. The City’s “Curb Radii Guidelines” is available is on the City’s website.

3.1.15. Add Lanes (#)

This field is only active if a right turn channel is defined. This field allows the user to add receiving lanes (where traffic can move freely) for the right turn channel. If a value of 0 is used, no receiving lanes are added and traffic in the right turn channel must yield or merge into the receiving lanes.

3.1.16. Right Turn on Red (RTOR)

A check mark in this field is applied except in a situation where right turns on red are prohibited by regulation.

3.2. Synchro Calculated Values

3.2.1. Lane Utilization Factor

Traffic lanes are not equally utilized because of vehicles stopping in the curb lane, the absence of right turn and/or left-turn lanes, the presence of a HOV lane, vehicles wishing to turn right or left, presence of street cars, road conditions and the presence of unused streetcar tracks. The lane utilization factor (f_{LU}) adjusts the saturated flow rate to account for the uneven distribution of traffic between lanes. The default f_{LU} values, calculated by Synchro, correspond with those specified in Chapter 10 of the HCM 2000 (page 10-26, Exhibit 10-23) and are accepted unless field studies show otherwise. If field observations confirm traffic is evenly distributed across all lanes in a lane group, then a f_{LU} of 1.0 can be used. Refer to Section 10.4 for a procedure for HOV lane analysis or for analysis of situations where vehicles do not use lanes equally (in lane groups with multi-lanes).

3.2.2. Right Turn Factor

The values calculated by Synchro are accepted unless field studies show otherwise. The right turn factor represents how much interference from right turn traffic reduces the saturated flow rate. If there is an exclusive right turn lane and the approach to the right has an exclusive left turn phase, then right turn traffic can turn right on this phase using the protected right turn factors.

3.2.3. Left Turn Factor (Prot)

Left Turn Factors for protected phases in Synchro can be overridden; however, these values must not be changed.

3.2.4. Left Turn Factor (Perm)

Left Turn Factors for permissive phases in Synchro can be overridden; however, these values must not be changed. Synchro uses a “Permitted Left Turn Factors Report” to calculate the permissive left turn adjustment factor, and obtain information about the lanes and saturation flow rates. It is roughly equivalent to the HCM 2000 “Supplemental Permitted Left Turn Worksheet”.

3.2.5. Right Ped Bike Factor

The Right Ped Bike Ped Factor must not be overwritten unless supported by field studies.

3.2.6. Left Ped Factor

The Left Ped Factor must not be overwritten unless supported by field studies.

3.2.7. Saturated Flow Rate (Prot)

These values must not be overwritten unless supported by field studies. If field measured saturation flow rate values are available, the sum of the flow rate for each lane in a lane group should be input in the Saturated Flow Rate (ck). The protected and permissive values are measured separately.

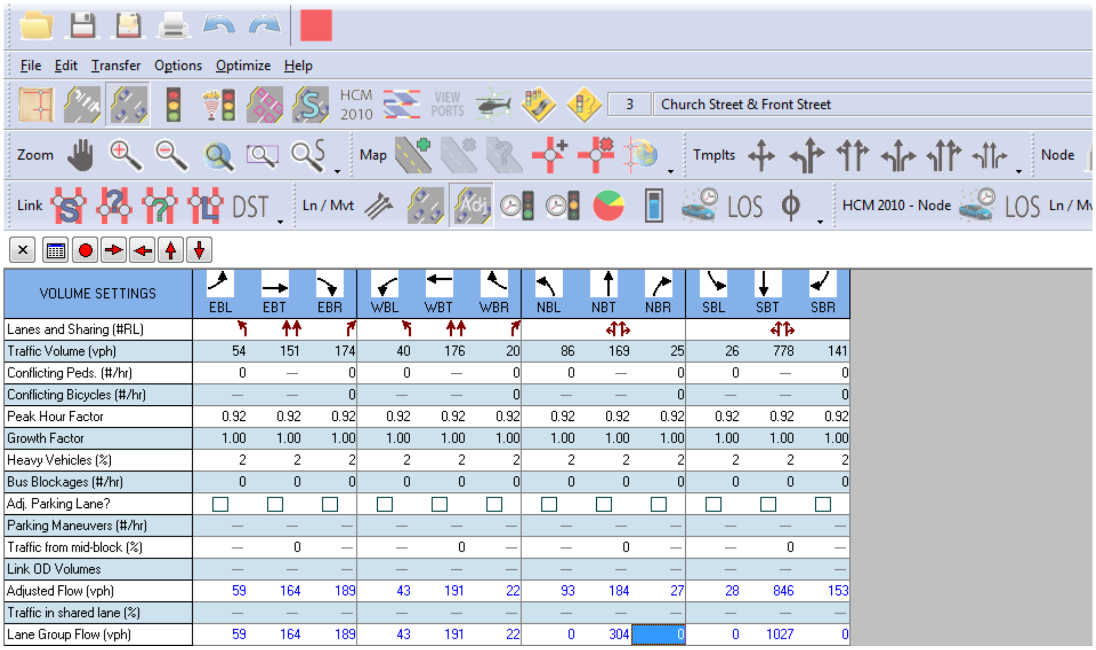
3.2.8. Saturated Flow Rate (Perm)

These values must not be overwritten unless supported by field studies. If field measured saturation flow rate values are available, the sum of the flow rate for each lane in a lane group should be input in the Saturated Flow Rate (perm). The protected and permissive values are measured separately.

3.2.9. Saturated Flow Rate (RTOR)

Synchro automatically calculates saturation flow rate for RTOR. This flow rate is applied to a movement whenever it has a red signal. The RTOR should not be manually overwritten unless substantiated by field studies since overwritten values will not be updated when the volumes or signal timings change.

4. VOLUME SETTINGS



VOLUME SETTINGS	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lanes and Sharing (#RL)												
Traffic Volume (vph)	54	151	174	40	176	20	86	169	25	26	778	141
Conflicting Peds. (#/hr)	0	—	0	0	—	0	0	—	0	0	—	0
Conflicting Bicycles (#/hr)	—	—	0	—	—	0	—	—	0	—	—	0
Peak Hour Factor	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
Growth Factor	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Heavy Vehicles (%)	2	2	2	2	2	2	2	2	2	2	2	2
Bus Blockages (#/hr)	0	0	0	0	0	0	0	0	0	0	0	0
Adj. Parking Lane?	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Parking Maneuvers (#/hr)	—	—	—	—	—	—	—	—	—	—	—	—
Traffic from mid-block (%)	—	0	—	—	0	—	—	0	—	—	0	—
Link OD Volumes	—	—	—	—	—	—	—	—	—	—	—	—
Adjusted Flow (vph)	59	164	189	43	191	22	93	184	27	28	846	153
Traffic in shared lane (%)	—	—	—	—	—	—	—	—	—	—	—	—
Lane Group Flow (vph)	59	164	189	43	191	22	0	304	0	0	1027	0

4.1. User Inputs

4.1.1. Peak Hour Factor (PHF)

For both operational and planning analysis, to ensure the “worst case” conditions are analyzed over a peak hour period, one of the following options is used when entering PHF values:

1) The “Peak Hour Factor Calculations Report” can be obtained from the TSU and applied;
2) The average PHF is applied to the whole intersection. If an individual movement or approach has sharp peaking characteristics, then a PHF should be calculated and applied for each movement or approach;
3) If a turning movement count was conducted in 15 minute intervals (independent from the TSU), the highest 15 minute count can be multiplied by four and entered in the “Traffic Volume” field. A value of 1.00 is entered in the PHF field;

    - This is equivalent to calculating the PHF for the highest 15 minute count and using the peak hour volume, since all variables are part of the PHF formula:
    - PHF = V60 / (4 * V15).

4) If hourly volumes are entered and PHF data is unknown, as a default use PHF = 0.90 for the morning and off-peak periods and 0.95 for the afternoon peak period for through movements. Use a PHF of 0.90 for all periods for left turn phases; and
5) At signalized intersections near stadiums, arenas, transit facilities and major tourist attractions, where there may be a heavy surge in traffic volume, the PHF must be reduced to reflect the traffic flow rate during the peak demand period or use peak 15-minute flow rates

(using the method identified in item 3 above). The same would apply to signalized intersections near industrial establishments where a shift change can cause a surge in traffic.

4.1.2. Growth Factor

For operational analysis, no adjustment is necessary and a Growth Factor of 1.00 must be used. For planning analysis, current volumes can be adjusted to show future volumes with the Growth Factor. The Growth Factor, if any, is supplied by the City.

4.1.3. Heavy Vehicles (%)

Heavy vehicles are defined as those with more than four tires touching the pavement. The number of heavy vehicles for each movement is shown on the counts provided the TSU. Synchro applies a default of 2%, which can be edited to reflect actual field conditions.

4.1.4. Bus Blockages (#/hr)

In cases where there is a shared through/right turn lane, the number of buses that stop and block traffic at a near-side bus stop must be entered.

In cases where there is an exclusive right turn lane or bus bay, if field observations show that buses are queued up in the bus bay and the queue is hindering the flow of through traffic, then the through lane saturation is adjusted accordingly. If buses merging from a right turn lane hinders the flow of through traffic, then a similar adjustment is made to the through saturation flow. An alternative technique is to enter the Bus Blockages in the right turn lane and then apply 30% of that value to the adjacent through lane. The Bus Blockage assumes an average blockage of 14.4 seconds. If 30% of the bus blockages is applied to the through lane, then an average delay of 4.32 seconds would be applied to the through lane for each occurrence.

4.1.5. Adjacent Parking Lane?

If there is on-street parking, apply a checkmark to the box for that approach. Selecting “No” parking lane is different from “Yes” parking lane with zero manoeuvres per hour.

4.1.6. Parking Maneuvers

If a check mark was added to the “Adjacent Parking Lane” box, the number of parking manoeuvres per hour for the affected lane group can be entered. The maximum number of parking manoeuvres per hour is 100.

4.1.7. Traffic from Mid-block (%)

The default value for this field is zero. A value of zero indicates that 0% of the traffic is from driveways and unsignalized intersections and all of the traffic came from the upstream signal. A value of 50 indicates that 50% of the traffic is from driveways and unsignalized intersections. The optimizer uses this information when calculating delays. If a link has a lot of traffic from mid-block sources, then coordinating this link will not reduce delays as much as it will for other links.

4.1.8. Link OD Volumes

Link OD volumes are not normally used - no value is typically required for analysis – however, link OD volumes can be useful in animating weaving lane changes within SimTraffic. This field can be useful for closely spaced signals and for adjacent signals that are at on/off ramps to a highway (diamond interchanges). This field allows the user to have control over the origins and destinations of vehicles at adjacent signals i.e. the user can ensure the software does not assign traffic exiting a highway at one signal and return to the highway at an adjacent signal.

4.2. Synchro Calculated Values

4.2.1. Adjusted Flow (vph)

This value is equal to the entered volume divided by the Peak Hour Factor and multiplied by the Growth Factor. The value must not be overwritten.

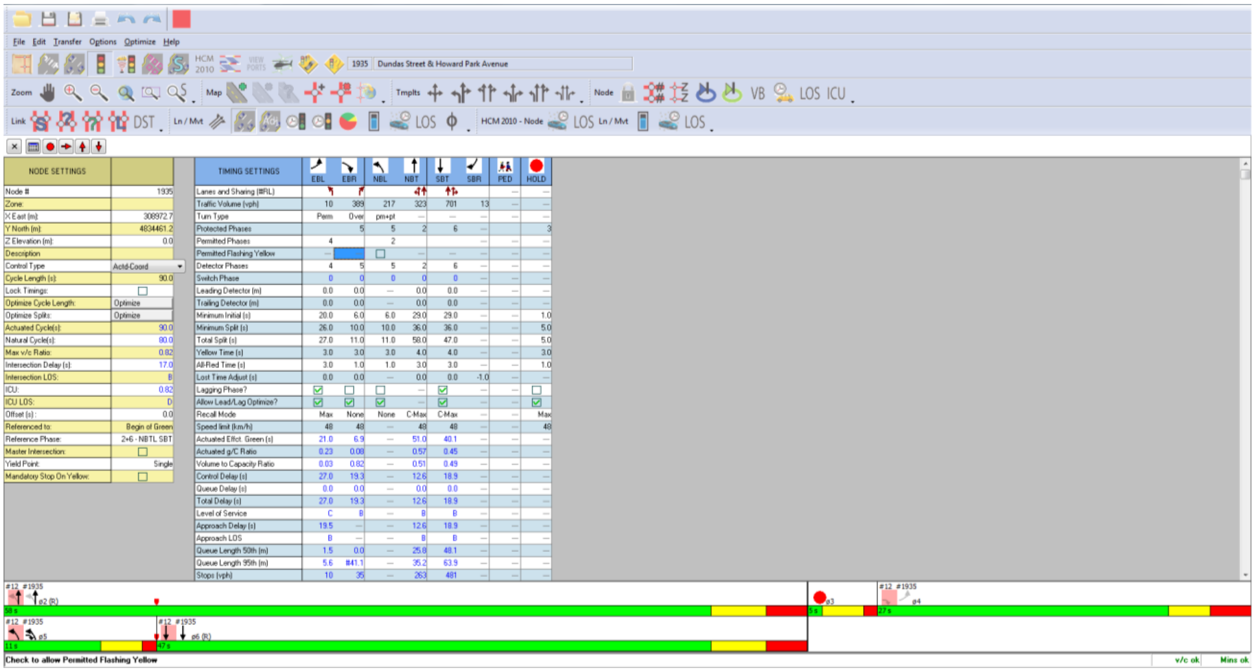
4.2.2. Traffic in Shared Lane (%)

Synchro will only assign data to this field if there is a combination of a shared through/turning lane plus an exclusive turning lane. Synchro uses this field to assign a percentage of the turning traffic to the shared/turning lane since not all turning traffic will use the exclusive turning lane. The assignment of traffic to the shared lane is between 10% and 90% of the turning traffic. If field observations show a greater percentage of traffic using the shared lane than is assigned by the software, it is possible to override the value applied by the software. Changes to this field will impact Synchro calculated MOEs; changes to this setting will not impact the simulation in SimTraffic.

4.2.3. Lane Group Flow (vph)

The Lane Group Flow shows how volumes are assigned to lane groups. The value must not be overwritten.

5. TIMING SETTINGS



5.1. Node Settings - User Inputs

5.1.1. Node#

A signal's identification number, known as a PX number, is provided in the signal timing report issued by the City – it should be entered. Otherwise, the software automatically assigns a node number.

5.1.2. Control Type

The mode of control (MOC), which is included with the signal timings information provided by the City's Traffic Signal Operations Group (TSOG) unit, is used in selecting the appropriate controller type. The MOC for existing signals in the City must remain the same during intersection analysis. The "Actuated-Coordinated" option is normally selected from the following control types:

- "Pre-timed" for fixed timed intersections with no callable movements;
- "Actuated-Uncoordinated" for fully actuated intersections (where all movements are callable) and no signal coordination is provided;
- "Semi-Actuated Uncoordinated" for signals where the side street is actuated, but no coordination is provided; and
- "Actuated-Coordinated" for semi-actuated intersections or for pre- timed intersections with callable left turn phases.

The City does not have fully actuated signals (FA) so the “Actuated-Uncoordinated” is not be used. The City uses the following modes of control:

1. **Fixed Time (FXT)** – A signal operation in which the vehicle and pedestrian signal displays automatically alternate between the main street and the side street, regardless of vehicle and pedestrian demands.
2. **Semi-actuated Pedestrian (SAP)** – A signal operation in which signals will not change to the side street unless a vehicle or pedestrian has been detected, and in which the side street will serve the pedestrian "walk" phase regardless of whether or not a pedestrian call has been received.
3. **Semi-actuated Type 2(SA2)** – A signal operation in which the signal displays will not change to the side street unless a vehicle or pedestrian has been detected. At SA2 locations, the pedestrian "walk" phase will only be served for the callable side streets if a pedestrian call has been received.
4. **Semi-actuated Vehicle (SAV)** – A signal operation in which there are no main street pedestrian crossings and there are no pushbuttons.
5. **Pedestrian Actuated (PED)** – A signal operation at Mid-block Pedestrian Signals (MPS) only, where the mid-block pedestrian crossing is actuated by a pedestrian pushing a button.

5.1.3. Cycle Length

The cycle length may be entered in the “Cycle Length” field; however, Synchro adds the total splits to calculate the cycle length automatically. If new traffic signals are being included in the network, existing control area issues must be considered in determining cycle lengths for the proposed signals (i.e. what cycle lengths are being used by existing adjacent signals? Are adjacent signals coordinated? Are adjacent signals closely spaced?). If signals are spaced within 150 metres, providing coordination becomes critical for motorist safety and traffic flow. If signals are spaced over 800 metres apart, vehicle platoons become more dispersed between the signals and providing coordination is less important.

In the downtown area, where most intersections have three or four phases, the City maintains consistent cycle lengths between major and minor intersections with a maximum of 80 seconds in the morning and afternoon peak periods, and 70 seconds in the off-peak period, except on arterials where long pedestrian crossing distances dictate the need for longer cycle lengths, such as University Avenue and Spadina Avenue.

In suburban areas, where intersections with more than four phases are more common, the City restricts the maximum cycle length at major intersections to the 125 – 135 seconds range, based on 1.0 m/s walk speed.

Refer to the City's *Traffic Signal Operations Policies and Strategies, Section 5.5 (May 7, 2015)* for more detail.

5.1.4. Lock Timings

The “Lock Timings” box should only be checked if the user does not want to allow that specific intersection’s timings to be changed i.e. if a Synchro network is created and the user intends to optimize the entire network’s timings.

5.1.5. Offset

The offset should be entered in this field; the offset is included with the signal timings provided by TSOG. When signals are spaced less than 150 m, then the main street ambers should be programmed to maintain a fixed offset relationship. City staff often develop offsets to ensure the adjacent main street signals display their ambers simultaneously to ensure motorists do not misinterpret the signal displays at adjacent signalized intersections.

Main street through traffic volumes are typically used to determine which direction to favour when selecting offsets. There are cases where it may be desirable to coordinate one signal's turning movement with another signal's through movement - particularly if signals are closely spaced. As a general rule, if one direction has greater than 55% of the total through traffic volume (for through volumes in opposing directions), the direction with the greater volume is favoured when developing the offset.

Refer to the City's *Traffic Signal Operations Policies and Strategies, Section 5.7 (May 7, 2015)* for additional information on signal coordination.

5.1.6. Referenced to

The values below should be used for the following timer types:

- TS2-1st Green: for Epac and Peek ATC1000 timers
- Begin of Green: for Econolite and Peek 3000 timers

5.1.7. Reference Phase

This field refers to the coordinated phases. The main street coordinated phases should typically correspond with phases "2+6".

5.1.8. Master Intersection

For most analyses, it is not necessary to designate a Master Intersection. The Master Intersection is used in Synchro to reference offsets to the cycle counter at that intersection – its offset will always be zero.

5.1.9. Yield Point

The user can select "Single", "Flexible" or "By Phase". The "Single" option is the default in Synchro and must not be changed.

5.1.10. Mandatory Stop On Yellow

By default, SimTraffic allows at least two vehicles to proceed during a signal phase. By checking the box, no sneaker vehicles will be allowed during the yellow interval. This parameter does not impact results within Synchro.

5.2. Timing Settings - User Inputs

Existing signal timings and MOC must be current data obtained from TSOG. The timing information must not be more than six months old when used in the analysis.

5.2.1. Turn Type

The Left turn types available in Synchro and applicable to the City include:

- Split (left and through traffic share a protected phase);
- Permitted (vehicles must yield to pedestrians and oncoming traffic);
- Protected (movement is made on left turn signal and there are no conflicts with oncoming traffic and pedestrians) ;
- Protected and Permitted (left turns move on a left turn signal and then on a permitted phase);
- NA (used where left turns are prohibited); and
- Custom (non-standard phase combination).

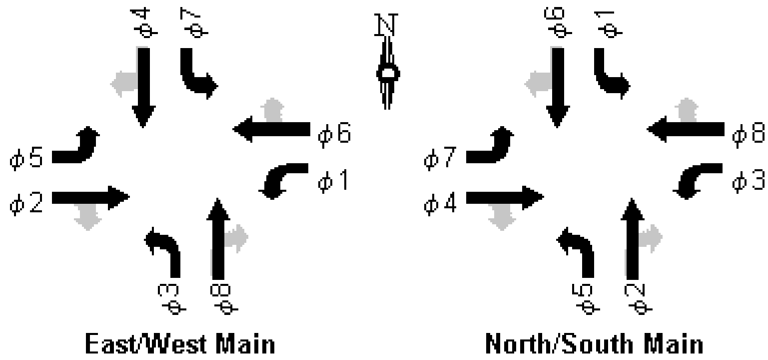
Other Left turn types available in Synchro include Dallas Permitted and Dallas Permitted plus Protected. These are used to represent signals with special left turn signal heads, which display the same phase information to oncoming traffic. These configurations are used to eliminate the lagging left turn trap problem. The City does not use these configurations.

The Right turn types available include:

- Permitted (right turns yield to pedestrians during green ball);
- Protected (right turns are unimpeded by vehicles or pedestrians);
- Overlap (right turns go on a compatible left turn phase);
- Permitted plus Overlap;
- Protected plus Overlap;
- Free (used if a right turn channelization and acceleration lane exist; “F” should be coded in the permitted phase; this should not be used as a substitute for Right Turns on Red – refer to Section 3.1.15);
- NA (used where right turns are prohibited); and
- Custom (non-standard right turn phases).

5.2.2. Protected & Permitted Phases

The diagram below shows the phase numbers normally assigned to different movements, depending on the direction of the main street.



5.2.3. Detector Phases

The default values must be retained. If a movement is served by more than one phase, the "Detector Phases" can be overridden to specify that only one of the phases is connected to the detector. The Synchro split optimizer assigns green time based on the first listed detector phase.

5.2.4. Switch Phase

The default value for this field is 0. This "Switch Phase" is a secondary phase that extends the entered phase when it is green. This setting does not place a call and does not call the primary Detector Phase when the entered switch phase is green. This setting can be used for the permitted phase of a permitted plus protected left turn.

5.2.5. Leading Detector and Trailing Detector

Leading and trailing detector data should be entered in the "Detector Settings" screen, as a correct sequence must be followed for the City's default values to be accepted in Synchro. Refer to Sections 7.1.3 and 7.1.4.

5.2.6. Minimum Initial

The Minimum Initial time is the minimum green time for the phase. Absolute minima are:

a) Protected Turn Phases – Minimum of 6.0 seconds
b) Side Street Through Phases – Minimum of 7.0 seconds
c) Main Street Through Phases – Minimum of 12.0 seconds

In addition, when determining minimum vehicular green times, the percentage of heavy vehicles should also be reviewed on an intersection-by-intersection basis. A high percentage of trucks may necessitate increasing the minimum green time by time of day.

At Semi-actuated (SA2) or Semi-actuated Vehicle (SAV) intersections with a very wide main street and high bicycle traffic on the side street, increasing the minimum green time, as per OTC Bicycle Traffic Signals Guide (2015), should be considered.

5.2.7. Minimum Split

Adequate green times must be provided to satisfy the minimum pedestrian crossing time (Walk + Flashing Don't Walk). Intersection specific Walk and Flashing Don't Walk durations are provided by TSOG when signal timing information is requested.

Due the communication lag between field equipment and the controller, an extra second must be added above the minimum pedestrian crossing time when calculating the minimum split. The default minimum splits should be calculated as follows:

a) Protected Turn Phases = Minimum Split (6.0 seconds) + Yellow + All-Red + 1
b) Through Phase with Pedestrian Timings = Walk + FDW + Yellow + All-Red + 1
c) Through Phase without Pedestrian Timings = Minimum Split + Yellow + All-Red + 1

Refer to Section 6.1.6 and 6.1.7 for additional information on Walk and Flashing Don't Walk times.

5.2.8. Total Split

The total split time is the total phase time including the green, yellow, and all-red time.

5.2.9. Yellow Time

Clearance values for through phases must comply with the Ontario Traffic Manual, Book 12. In the absence of current speed data, the posted speed shall be used as the design criteria. The minimum amber interval for a through phase is 3.0 seconds.

The standard amber clearances for left turn phases are:

- Fully Protected Left-Turns – 3.0 seconds;
- Protected/Permissive Left-Turns – 3.0 seconds; and
- T-intersection – 3.0 seconds.

5.2.10. All-Red Time

Clearance values for through phases must comply with the Ontario Traffic Manual, Book 12. In the absence of current speed data, the posted speed shall be used as the design criteria. The minimum all-red clearance for a through phase is 2.0 seconds.

For mixed traffic phases with a high proportion of bicycles, the vehicular all-red interval may be increased by up to 1.0 second to accommodate bicycle traffic.

The standard all-red clearances for left turn phases are:

- Fully Protected Left-Turns – 2.0 seconds (less than 3 lanes), 3.0 seconds (3 or more lanes);
- Protected/Permissive Left-Turns – 1.0 second; and
- T-intersection – 2.0 seconds.

Refer to the City's *Traffic Signal Operations Policies and Strategies, Section 5.3.3 (May 7, 2015)* for additional information on all-red time for bicycle traffic. For exclusive bike phase, refer to OTC Bicycle Traffic Signals Guide (2015) Chapter 3.

5.2.11. Lost Time Adjust

The following Lost Time Adjustment default values are used:

- For off peak analysis, use 0; and
- For peak period analysis, use -1.

The above is based on the formula:

Lost Time Adj. = Start Up Lost Time - Extension of Effective Green, where:

- Start Up Lost Time is two seconds; and
- Extension of Effective Green is two seconds for off peak and three seconds for peak conditions.

5.2.12. Lagging Phase

In protected/permissive combinations, the protected phase should typically be a “Lead” phase. For safety reasons, the City of Toronto does not normally use lagging left turn phases. Lagging phases are only used in the City of Toronto if they are fully protected.

5.2.13. Allow Lead/Lag Optimize?

As a default, no check mark is applied. If a check mark is applied, then the splits are optimized in Synchro and Synchro will be allowed to designate left turn phases as either leading or lagging.

5.2.14. Recall Mode

If a signal is operating as fixed/pre-timed, the default for all the phases is “Max”. If a fixed/pre-timed signal has a callable advance left turn phase, the callable movement is coded as “None”; this causes the controller type to change automatically to “actuated/coordinated”.

If an intersection is actuated-coordinated, the default for the coordinated phase is “Coord”. The options for the side-street include: “None”, “Min”, “Ped”, and “Max”. Typically, “None” is selected for the side streets at semi-actuated intersections. The other options should only be used if an intersection cycles (and the side-street is served regardless of vehicle and/or pedestrian demand).

5.3. Synchro Calculated Values

The results shown within the Timing Settings window represent analysis results using Synchro methodology, and do not necessarily equal to the results using HCM 2000 methodology. It is the responsibility of the analyst undertaking the analysis to discuss the analysis methodologies to be used. Please refer to Section 12 for more detail.

5.3.1. Volume to Capacity Ratio

An approach value of v/c greater than 1.0 indicates that the approach is oversaturated. A value of v/c between 0.90 and 1.00 represent near capacity conditions. When an analysis of actual volumes at an existing signalized intersection results in v/c values greater than 1.00, it implies that input parameters may need adjusting. The model must be calibrated to reflect the existing situation.

Some of the reasons Synchro software may generate a v/c over 1.00 include the following:

- The City's approach for adjusting volumes discussed in Section 3.1.3.2 is applied;
- The turning movement count volumes (TMC) contain errors;
- The TMC is correct, but timing changes were made since the count was done (for example, the previous phase duration may have permitted 1000 vehicles to clear, but the existing phase duration may only allow 800 to clear);
- The default values (Ideal sat flow of 1900, start-up lost time, extension of effective green, etc.) may not be suitable at this location. To find out for certain, it is possible to conduct field studies and use field measured data to replace the default values in the analysis;
- The Synchro methodology may not be applicable for certain applications, for example, analysis of SCOOT (traffic adaptive) signals; and
- If demand volume is greater than supply volume i.e. the intersection is operating above capacity.

If field observations indicate aggressive driving and vehicles encroaching on the subsequent phases, then the effective green times for the subsequent phases must be reduced accordingly (by adjusting the Lost Time Adjust field). Adjusting the saturation flow would not be acceptable under such circumstances since it would imply that conflicting movements could travel through the intersection simultaneously. Any modifications to the saturation flow must be supported by surveys of the intersection to confirm that individual movements do not use up green time from following conflicting phases.

5.3.2. Queue Length 50th & 95th (m)

The “Queue Length 50th (m)” field represents the maximum back of queue with 50th percentile traffic volume (i.e. during a typical cycle), in metres. The “Queue Length 95th (m)” field represents the maximum back of queue with 95th percentile traffic volume, in metres. The calculations for both 50th and 95th percentile queue are the same, where the only difference is the volume assumed for the analysis. The 50th percentile volume is equal to the Adjusted Flow for that lane group, and the 95th percentile volume is calculated based on the following calculation shown within the Synchro 9 Manual, page 17-22:

$v95 = v * PHFx * [1 + 1.64 * (\mathrm{sqrt}(vc) / vc)]$, where

- $v95 = 95^{th}$ Percentile Volume
- v = Arrival Flow Rate = 50^{th} Percentile Volume
- PHFx = peak hour factor (assumed min of 0.9)
- vc = vehicles per cycle = v * C / 3600
- C = cycle length

The '~' and '#' footnotes indicate that the volume modeled exceeds capacity. The ~ footnote indicates that the approach is above capacity and the queue length could be much longer. The queue length is theoretically infinite and blocking problems may occur. The value shown for the 50^{th} percentile queue is sufficient to hold one cycle of traffic. This will prevent capacity problems from being compounded by insufficient storage space.

The # footnote indicates that the volume for the 95^{th} percentile cycle exceeds capacity. This traffic was simulated for two complete cycles of 95^{th} percentile traffic to account for the effects of spillover between cycles. If the reported v/c <1 for this movement, the methods used represent a valid method for estimating the 95^{th} percentile queue. In practice, 95^{th} percentile queue shown will rarely be exceeded and the queues shown with the # footnote are acceptable for the design of storage bays.

The presence of both the '~' and '#' footnotes suggests that vehicle queuing may extend into upstream and/or downstream intersections or block access to auxiliary turn lanes, resulting in gross overestimation of intersection and network capacity. This situation can be prevalent on streets with closely-spaced signals. Macroscopic intersection capacity analysis methods such as Synchro do not account for the potential impact of downstream congestion on intersection operations, nor do they detect and adjust for the impact of turn pocket overflows on through traffic and intersection operations.

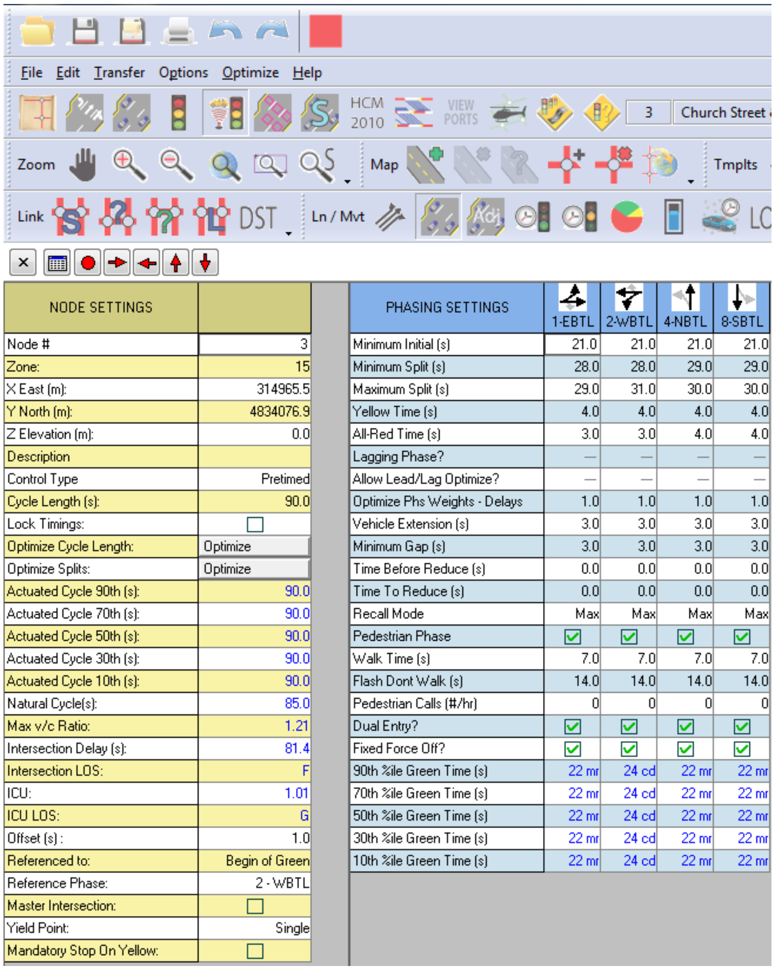
The 'm' footnote indicates that volume for the 95^{th} percentile queue is metered by an upstream signal.

In many cases, the 95^{th} percentile queue will not be experienced due to upstream metering. If the upstream intersection is at or near capacity, the 50th percentile queue represents the maximum queue experienced. Similarly, if the upstream intersection has a v/c ratio over 0.8; the maximum queue is approximately equal to the 50^{th} percentile queue divided by the upstream v/c ratio. For example, if the 50^{th} percentile queue is 45 metres, and the v/c ratio upstream is 0.90; the maximum possible queue would therefore be 45 / 0.90 = 50 metres.

If these 95th percentile volumes at an upstream intersection (A) result in that intersection to operate with a v/c ratio > 1.0 (i.e. if the queue results at intersection A show the # symbol), it is theoretically impossible for these 95th percentile volumes to proceed to the following intersection (B).

Therefore, since the 95th percentile volumes at the intersection of interest (B) would not occur, neither would the 95th percentile queues.

6. PHASING SETTINGS



NODE SETTINGS	
Node #	3
Zone:	15
X East (m):	314965.5
Y North (m):	4834076.9
Z Elevation (m):	0.0
Description	
Control Type	Pretimed
Cycle Length (s):	90.0
Lock Timings:	☐
Optimize Cycle Length:	Optimize
Optimize Splits:	Optimize
Actuated Cycle 90th (s):	90.0
Actuated Cycle 70th (s):	90.0
Actuated Cycle 50th (s):	90.0
Actuated Cycle 30th (s):	90.0
Actuated Cycle 10th (s):	90.0
Natural Cycle(s):	85.0
Max v/c Ratio:	1.21
Intersection Delay (s):	81.4
Intersection LOS:	F
ICU:	1.01
ICU LOS:	G
Offset (s):	1.0
Referenced to:	Begin of Green
Reference Phase:	2 - WBTL
Master Intersection:	☐
Yield Point:	Single
Mandatory Stop On Yellow:	☐

PHASING SETTINGS	1-EBTL	2-WBTL	4-NBTL	8-SBTL
Minimum Initial (s)	21.0	21.0	21.0	21.0
Minimum Split (s)	28.0	28.0	29.0	29.0
Maximum Split (s)	29.0	31.0	30.0	30.0
Yellow Time (s)	4.0	4.0	4.0	4.0
All-Red Time (s)	3.0	3.0	4.0	4.0
Lagging Phase?	—	—	—	—
Allow Lead/Lag Optimize?	—	—	—	—
Optimize Phs Weights - Delays	1.0	1.0	1.0	1.0
Vehicle Extension (s)	3.0	3.0	3.0	3.0
Minimum Gap (s)	3.0	3.0	3.0	3.0
Time Before Reduce (s)	0.0	0.0	0.0	0.0
Time To Reduce (s)	0.0	0.0	0.0	0.0
Recall Mode	Max	Max	Max	Max
Pedestrian Phase	☑	☑	☑	☑
Walk Time (s)	7.0	7.0	7.0	7.0
Flash Dont Walk (s)	14.0	14.0	14.0	14.0
Pedestrian Calls (#/hr)	0	0	0	0
Dual Entry?	☑	☑	☑	☑
Fixed Force Off?	☑	☑	☑	☑
90th %ile Green Time (s)	22 mr	24 cd	22 mr	22 mr
70th %ile Green Time (s)	22 mr	24 cd	22 mr	22 mr
50th %ile Green Time (s)	22 mr	24 cd	22 mr	22 mr
30th %ile Green Time (s)	22 mr	24 cd	22 mr	22 mr
10th %ile Green Time (s)	22 mr	24 cd	22 mr	22 mr

6.1. User Inputs

6.1.1. Vehicle Extensions (Maximum Gap)

The minimum vehicle passage time shall be as follows:

(a) Left-turn movements with setback loops – 2.0 seconds;
(b) Left-turn movements with stop bar loops – 2.5 seconds;
(c) Through/left-turn/right-turn movements on side street at semi-actuated intersections – 3.0 seconds; and
(d) Transit signal priority – 1.0 second.

6.1.2. Minimum Gap

The default value of three seconds should be retained if volume-density operation is not used.

6.1.3. Time Before Reduce

The default value of 0 should be retained. When using volume-density operation, this field represents the amount of time before gap reduction begins.

6.1.4. Time to Reduce

The default value of 0 should be retained. When using volume-density operation, this is the amount of time to reduce the gap from Vehicle Extension (or maximum gap) to Minimum Gap.

6.1.5. Pedestrian Phase

Set this field to “Yes” if there is a pedestrian phase for this movement. Setting Pedestrian Phase to “No” will disable the pedestrian phase and the input fields for “Walk Time”, “Flash Don't Walk”, and “Pedestrian Calls”.

6.1.6. Walk Time

The pedestrian minimum "walk" and clearance intervals shall be determined in accordance to the modified form of the CCG method. The method is based on the provision of a minimum "walk" duration of seven seconds.

Refer to the City's *Traffic Signal Operations Policies and Strategies, Section 5.3.6 (May 7, 2015)* for additional information on Walk Time.

6.1.7. Flashing Don’t Walk

The pedestrian minimum clearance intervals shall be determined in accordance to the modified form of the CCG method. The method is based on the provision of a minimum pedestrian clearance (i.e. Flashing Don't Walk – FDW) duration equal to a 1.2 m/s walk speed across the entire pedestrian crossing. The total "walk" plus FDW interval should equal to a 1.0 m/s walk speed across the entire crossing. The FDW does not extend into the amber or all-red interval.

Refer to the City's *Traffic Signal Operations Policies and Strategies, Section 5.3.6 (May 7, 2015)* for additional information on Flashing Don’t Walk Time.

6.1.8. Pedestrian Calls

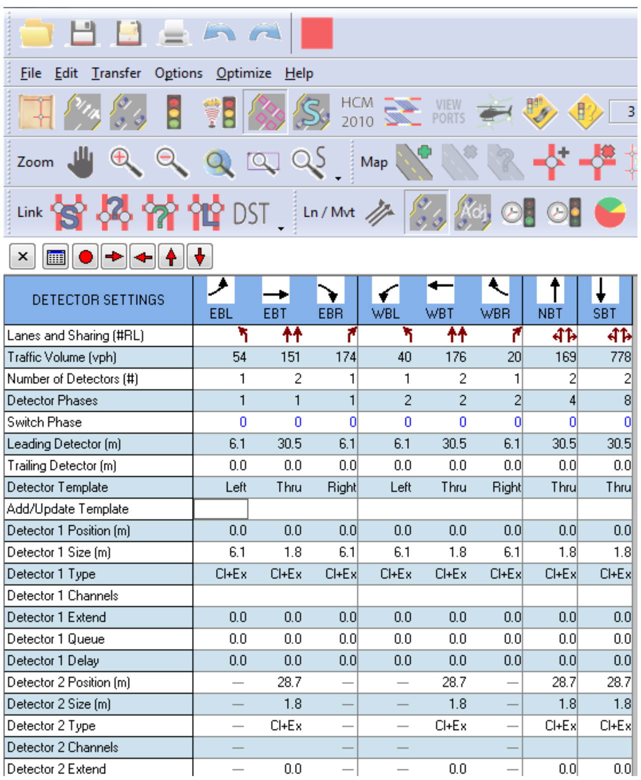
The value entered in this field is the number of pedestrian push button calls per hour for the phase. Data is required only if the intersection is equipped with pedestrian push buttons and the phase is actuated/callable, therefore, fixed/pre-timed signals do not require data in this field. The number of pedestrian calls per hour may not match the pedestrian crossing volumes entered in the “Conflicting Pedestrians” field in the “Volume” window. In the absence of field observations, the number of pedestrian calls can be estimated using the procedure on page 11-7 of the Synchro Manual.

6.1.9. Fixed Force Off

The following default settings are used for the Fixed Force Off:

- For SCOOT signals equipped with interval-based controllers, all phases at fixed and semi-actuated (SA2-VMG, SAP or SAV) intersections should have a check mark;
- For SCOOT signals equipped with phase-based controllers and for TransSuite signals, all phases at fixed intersections and main street phases at semi-actuated (SA2-VMG, SAPLO or SAV) intersections should have a check mark; and
- For SCOOT signals equipped with phase-based controllers and TransSuite signals, the side street phases at semi-actuated (SA2-VMG, SAP or SAV) intersections should not have a check mark.

7. DETECTOR SETTINGS



DETECTOR SETTINGS	EBL	EBT	EBR	WBL	WBT	WBR	NBT	SBT
Lanes and Sharing (#RL)								
Traffic Volume (vph)	54	151	174	40	176	20	169	778
Number of Detectors (#)	1	2	1	1	2	1	2	2
Detector Phases	1	1	1	2	2	2	4	8
Switch Phase	0	0	0	0	0	0	0	0
Leading Detector (m)	6.1	30.5	6.1	6.1	30.5	6.1	30.5	30.5
Trailing Detector (m)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Detector Template	Left	Thru	Right	Left	Thru	Right	Thru	Thru
Add/Update Template								
Detector 1 Position (m)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Detector 1 Size (m)	6.1	1.8	6.1	6.1	1.8	6.1	1.8	1.8
Detector 1 Type	Cl+Ex	Cl+Ex	Cl+Ex	Cl+Ex	Cl+Ex	Cl+Ex	Cl+Ex	Cl+Ex
Detector 1 Channels								
Detector 1 Extend	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Detector 1 Queue	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Detector 1 Delay	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Detector 2 Position (m)	—	28.7	—	—	28.7	—	28.7	28.7
Detector 2 Size (m)	—	1.8	—	—	1.8	—	1.8	1.8
Detector 2 Type	—	Cl+Ex	—	—	Cl+Ex	—	Cl+Ex	Cl+Ex
Detector 2 Channels	—		—	—		—		
Detector 2 Extend	—	0.0	—	—	0.0	—	0.0	0.0

7.1. User Inputs

7.1.1. Number of Detectors

Detectors are numbered from the stop bar back per approach, with detector one starting at the stop bar. If there is a fixed movement (i.e. the movements associated with phases 2 & 6), there will be 0 detectors shown.

7.1.2. Switch Phase

The “Switch Phase” field is discussed in Section 5.2.4.

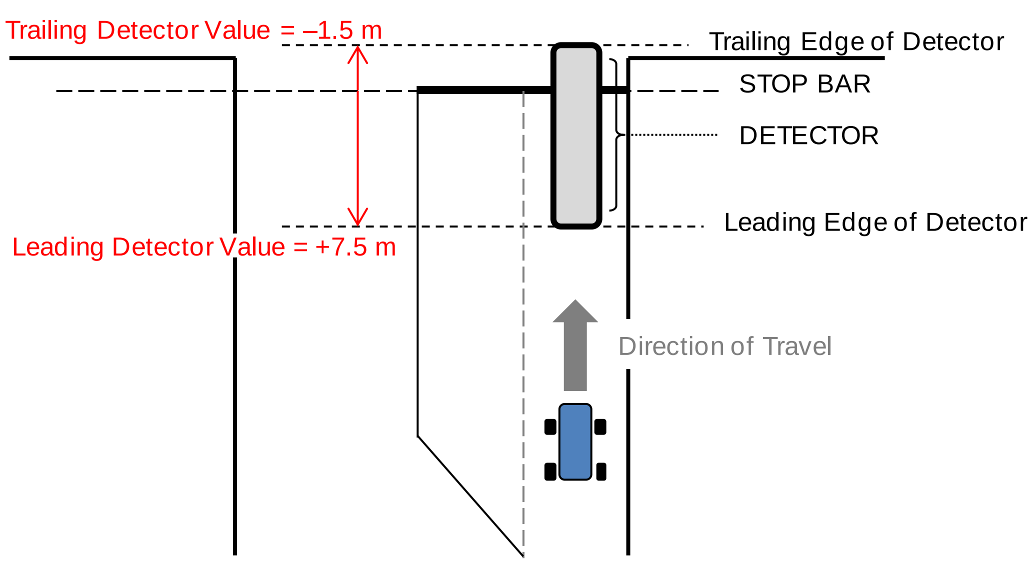
7.1.3. Leading Detector

The leading detector value is the distance from the leading edge of the most advanced detector to the stop bar in metres. This allows the user to define where a detection zone begins in a lane or lane group.

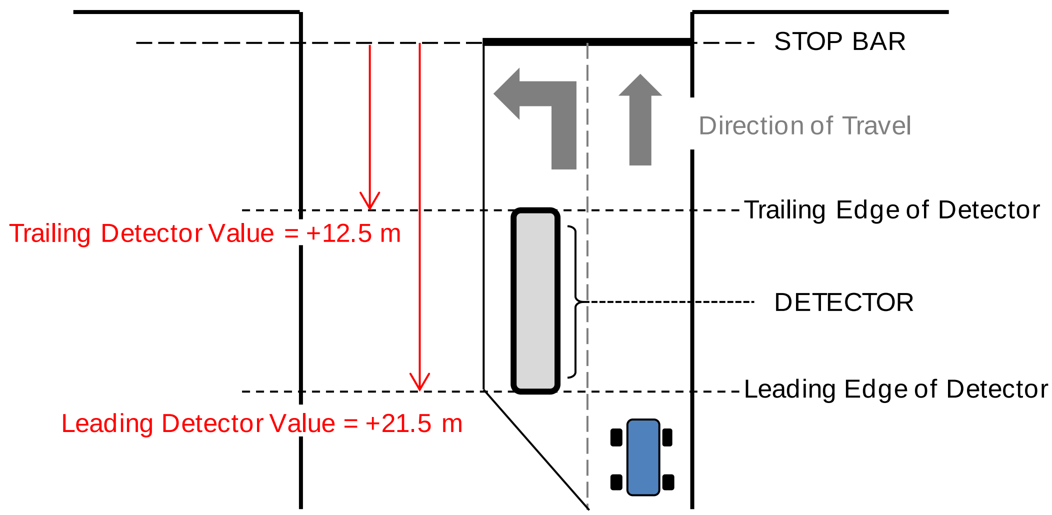
To ensure the City’s default values are accepted in Synchro, a correct sequence must be followed when entering detector data in the software. Prior to entering the Leading Detector data, the user should enter data in the Detector 1 Position (refer to Section 7.1.4). After data is entered in the Detector 1 Position, the following default values should be entered in the Leading Detector field (to replicate where the City typically installs detectors):

- For side street detection at actuated signals, stop bar loops are used where the leading detector is normally located 7.5 metres from the stop bar;
- For fully protected left-turns, stop bar loops are used where the leading detector is normally located 7.5 metres from the stop bar; and
- For protected/permissive left-turns, setback loops are used where the leading detector is normally located 21.5 metres from the stop bar.

The above is based on the normal 9.0 metres long stop bar and setback loops. For situations where there are legacy left-turn loops that are 3.0 metres or 5.0 metres long, adjustments need to be made to the leading detector value.



Side Street Detection at Actuated Signals
and Fully Protected Left-Turn Detection (Stop Bar Loop)



Protected/Permissive Left-Turn Detection (Setback Loop)

If there is more than one detector, for example, one setback loop has a leading edge 100 metres from the stop bar and the second loop has a leading edge 7.5 metres from the stop bar, then the 100 metres value is entered. As discussed in Section 7.1.4, the detector field can be edited.

Editing the Leading Detector value has no impact on Synchro's MOEs but does affect the dimensions of the detector loop that is animated in SimTraffic.

7.1.4. Trailing Detector and Detector 1 Position

This trailing detector value is the distance from the trailing edge of the trailing detector to the stop bar in metres. This allows the user to define where a detection zone ends at or near the stop bar in a lane or lane group. A negative value can be entered if the trailing detector extends past the stop bar.

To ensure the City's default values are accepted in Synchro, a correct sequence must be followed when entering detector data in the software. Prior to entering the Leading Detector data (Section 7.1.3), the user should enter data in the Detector 1 Position (but not in the Trailing Detector field). After the user enters data in the Detector 1 Position field, the Trailing Detector field will automatically reflect the correct value. The following default values should be entered in the Detector 1 Position field:

- For side street detection at actuated signals, stop bar loops are used where the trailing detector is normally located -1.5 metres from the stop bar;
- For fully protected left-turns, stop bar loops are used where the trailing detector is normally located -1.5 metres from the stop bar; and
- For protected/permissive left-turns, setback loops are used where the trailing detector is normally located 12.5 metres from the stop bar in left turn lanes.

If there is more than one detector for example, one setback loop has a trailing edge 95 metres from the stop bar and the second loop has a leading edge -1.5 metres from the stop bar, then the -1.5 metres value is entered.

Note that upon entering the Detector 1 Position, if the analyst clicks on the cell for Trailing Detector the value will return to the Synchro default; by default, the maximum distance that the trailing edge of the detector can extend past the stop bar is -0.2 metres. To achieve the required detector size in Synchro with -0.2 metres for the Trailing Detector value, enter 8.8 metres in the leading edge field.

7.1.5. Detector Size

When the City default detector data is entered (refer to Sections 7.1.3 and 7.1.4), the Detector 1 Size field will automatically be adjusted to replicate typical City detector sizes. Detectors are generally 9.0 metres long for side street detection at actuated signals and for left turn lanes. However, the City has legacy left-turn loops that are 3.0 metres or 5.0 metres long. If there is more than one detector size, only then will the user be required to enter data in the Detector Size field. Up to five detectors can be entered in the software.

7.1.6. Detector Type

The options for this field are Calling, Extend and Call+Extend. The default value is Call+Extend.

7.1.7. Detector Extend

This field represents how long a call on a detector will be held/extended for. Unless a detector has an unconventional operation, the default value is three seconds.

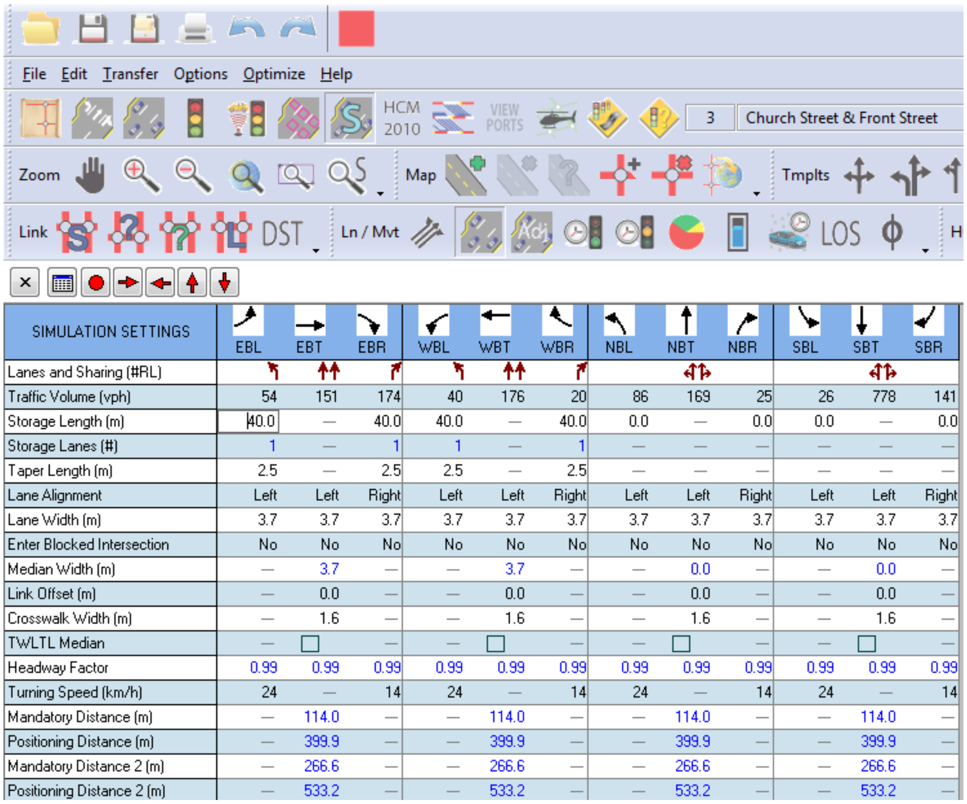
7.1.8. Detector Queue

The default value for this field is 0. A value entered in this field will provide an initial extension value on a phase (when it begins) for the time entered.

7.1.9. Detector Delay

The default value for this field is 0. A value entered in this field will delay placing a call on a phase (after a vehicle arrives on the detector) until after the time entered has passed.

8. SIMULATION SETTINGS



SIMULATION SETTINGS	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lanes and Sharing (#RL)												
Traffic Volume (vph)	54	151	174	40	176	20	86	169	25	26	778	141
Storage Length (m)	40.0	—	40.0	40.0	—	40.0	0.0	—	0.0	0.0	—	0.0
Storage Lanes (#)	1	—	1	1	—	1	—	—	—	—	—	—
Taper Length (m)	2.5	—	2.5	2.5	—	2.5	—	—	—	—	—	—
Lane Alignment	Left	Left	Right	Left	Left	Right	Left	Left	Right	Left	Left	Right
Lane Width (m)	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7
Enter Blocked Intersection	No	No	No	No	No	No	No	No	No	No	No	No
Median Width (m)	—	3.7	—	—	3.7	—	—	0.0	—	—	0.0	—
Link Offset (m)	—	0.0	—	—	0.0	—	—	0.0	—	—	0.0	—
Crosswalk Width (m)	—	1.6	—	—	1.6	—	—	1.6	—	—	1.6	—
TWLTL Median	—	☐	—	—	☐	—	—	☐	—	—	☐	—
Headway Factor	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99
Turning Speed (km/h)	24	—	14	24	—	14	24	—	14	24	—	14
Mandatory Distance (m)	—	114.0	—	—	114.0	—	—	114.0	—	—	114.0	—
Positioning Distance (m)	—	399.9	—	—	399.9	—	—	399.9	—	—	399.9	—
Mandatory Distance 2 (m)	—	266.6	—	—	266.6	—	—	266.6	—	—	266.6	—
Positioning Distance 2 (m)	—	533.2	—	—	533.2	—	—	533.2	—	—	533.2	—

8.1. User Inputs

"Lanes and Sharing", "Traffic Volume", "Storage Length" and "Storage Lane" data are already entered in the "Lane Settings" window and do not need to be re-entered. Other values in this Window do not impact the Synchro calculated MOEs but will be used for SimTraffic.

8.1.1. Taper Length

The value entered in this field affects the taper length displayed on the map in the "Map Window". In SimTraffic, the taper length determines when vehicles can enter the storage lane. Default taper length in Synchro is 2.5 metres, but field measured values should be used.

8.1.2. Lane Alignment

This setting allows the user to specify whether lanes should align to the right or left through an intersection. The options include; Left, Right, L-NA (left, no add), R-NA (right, no add). The default is Right for right turns, Left for left turns and through, and Right-NA for U-turns. Refer to the Synchro Manual for other lane alignment scenarios.

8.1.3. Enter Blocked Intersection

This field controls simulation modeling gridlock avoidance. The four options for modeling blocked intersections are; “Yes”, “No”, “1 vehicle” and “2 vehicles”. The default value is “No” for intersections and “Yes” for bends and ramp junctions. Change to “No” for high speed approaches and movements.

8.1.4. Link Offset

If two legs of an existing intersection are offset by 10 metres or less, the Link Offset setting must be used. If the two legs are further apart than 10.0 metres, the legs can be coded as separate links. See Section 10.9 for additional information regarding offset intersections.

8.1.5. Crosswalk Width

Actual crosswalk widths should be entered. This distance is measured from the stop bar to the far side of the crosswalk. If crosswalk widths are not available, the following default values can be applied:

- 4.6 meters for conventional intersections; and
- 9.0 meters for mid-block/pedestrian signals.

8.1.6. Two-Way Left Turn Lane (TWLTL) Median

Adding a check mark to this field draws a TWLTL in the median. The TWLTL is visual only and will not be used by vehicles in the Synchro model. Storage taper lengths still apply. Checking off the TWLTL also sets the TWLTL for the reverse link. At the discretion of City staff, part of the TWLTL can be used for left turn storage at an intersection.

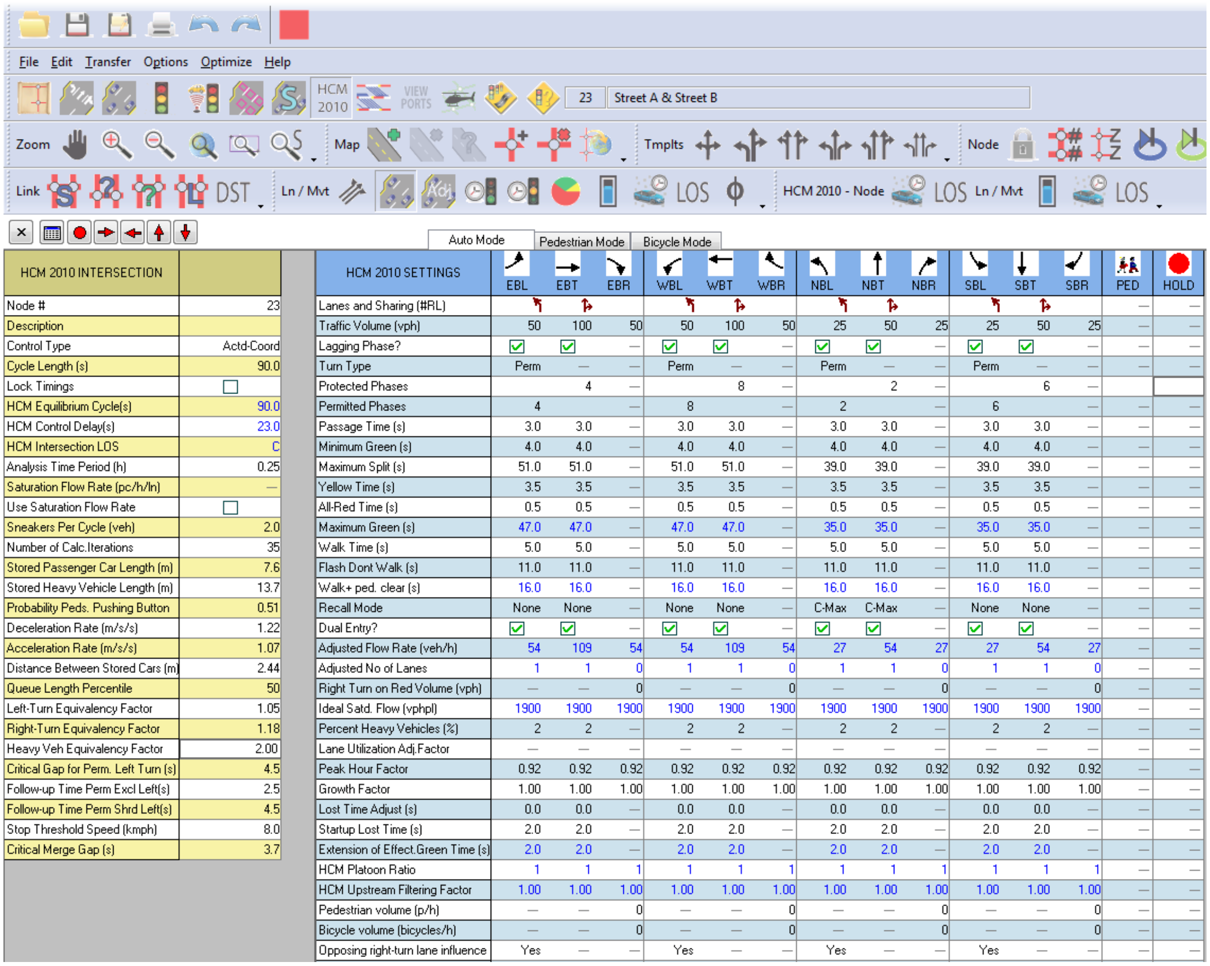
8.1.7. Turning Speed (km/h)

Turning speed are 15 km/h for right turns and 25 km/h for left turns. Synchro does not use this information. It is only used for SimTraffic.

9. HCM 2010 SETTINGS

Although some values from the previous settings windows translate over into HCM 2010 settings, it is recommended that data input for HCM 2010 analysis be input directly into the HCM 2010 settings window and tabs. It is the responsibility of the analyst to ensure proper input within the HCM 2010 settings window and tabs.

9.1. Signalized Intersections – Auto Mode



HCM 2010 INTERSECTION	
Node #	23
Description	
Control Type	Actd-Coord
Cycle Length (s)	90.0
Lock Timings	☐
HCM Equilibrium Cycle(s)	90.0
HCM Control Delay(s)	23.0
HCM Intersection LOS	C
Analysis Time Period (h)	0.25
Saturation Flow Rate (pc/h/ln)	—
Use Saturation Flow Rate	☐
Sneakers Per Cycle (veh)	2.0
Number of Calc.Iterations	35
Stored Passenger Car Length (m)	7.6
Stored Heavy Vehicle Length (m)	13.7
Probability Peds. Pushing Button	0.51
Deceleration Rate (m/s/s)	1.22
Acceleration Rate (m/s/s)	1.07
Distance Between Stored Cars (m)	2.44
Queue Length Percentile	50
Left-Turn Equivalency Factor	1.05
Right-Turn Equivalency Factor	1.18
Heavy Veh Equivalency Factor	2.00
Critical Gap for Perm. Left Turn (s)	4.5
Follow-up Time Perm Excl Left(s)	2.5
Follow-up Time Perm Shrd Left(s)	4.5
Stop Threshold Speed (kmph)	8.0
Critical Merge Gap (s)	3.7

HCM 2010 SETTINGS	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR	PED	HOLD
Lanes and Sharing (#RL)													—	—
Traffic Volume (vph)	50	100	50	50	100	50	25	50	25	25	50	25	—	—
Lagging Phase?	☑	☑	—	☑	☑	—	☑	☑	—	☑	☑	—	—	—
Turn Type	Perm	—	—	Perm	—	—	Perm	—	—	Perm	—	—	—	—
Protected Phases		4	—		8	—		2	—		6	—		
Permitted Phases	4		—	8		—	2		—	6		—	—	—
Passage Time (s)	3.0	3.0	—	3.0	3.0	—	3.0	3.0	—	3.0	3.0	—	—	—
Minimum Green (s)	4.0	4.0	—	4.0	4.0	—	4.0	4.0	—	4.0	4.0	—	—	—
Maximum Split (s)	51.0	51.0	—	51.0	51.0	—	39.0	39.0	—	39.0	39.0	—	—	—
Yellow Time (s)	3.5	3.5	—	3.5	3.5	—	3.5	3.5	—	3.5	3.5	—	—	—
All-Red Time (s)	0.5	0.5	—	0.5	0.5	—	0.5	0.5	—	0.5	0.5	—	—	—
Maximum Green (s)	47.0	47.0	—	47.0	47.0	—	35.0	35.0	—	35.0	35.0	—	—	—
Walk Time (s)	5.0	5.0	—	5.0	5.0	—	5.0	5.0	—	5.0	5.0	—	—	—
Flash Dont Walk (s)	11.0	11.0	—	11.0	11.0	—	11.0	11.0	—	11.0	11.0	—	—	—
Walk+ ped. clear (s)	16.0	16.0	—	16.0	16.0	—	16.0	16.0	—	16.0	16.0	—	—	—
Recall Mode	None	None	—	None	None	—	C-Max	C-Max	—	None	None	—	—	—
Dual Entry?	☑	☑	—	☑	☑	—	☑	☑	—	☑	☑	—	—	—
Adjusted Flow Rate (veh/h)	54	109	54	54	109	54	27	54	27	27	54	27	—	—
Adjusted No of Lanes	1	1	0	1	1	0	1	1	0	1	1	0	—	—
Right Turn on Red Volume (vph)	—	—	0	—	—	0	—	—	0	—	—	0	—	—
Ideal Satd. Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	—	—
Percent Heavy Vehicles (%)	2	2	—	2	2	—	2	2	—	2	2	—	—	—
Lane Utilization Adj.Factor	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Peak Hour Factor	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	—	—
Growth Factor	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	—	—
Lost Time Adjust (s)	0.0	0.0	—	0.0	0.0	—	0.0	0.0	—	0.0	0.0	—	—	—
Startup Lost Time (s)	2.0	2.0	—	2.0	2.0	—	2.0	2.0	—	2.0	2.0	—	—	—
Extension of Effect.Green Time (s)	2.0	2.0	—	2.0	2.0	—	2.0	2.0	—	2.0	2.0	—	—	—
HCM Platoon Ratio	1	1	1	1	1	1	1	1	1	1	1	1	—	—
HCM Upstream Filtering Factor	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	—	—
Pedestrian volume (p/h)	—	—	0	—	—	0	—	—	0	—	—	0	—	—
Bicycle volume (bicycles/h)	—	—	0	—	—	0	—	—	0	—	—	0	—	—
Opposing right-turn lane influence	Yes	—	—	Yes	—	—	Yes	—	—	Yes	—	—	—	—

9.1.1. HCM 2010 Intersection Settings

9.1.1.1. Equilibrium Cycle (s)

This is the calculated Cycle Length based on the methods described within the HCM 2010. For coordinated and pre-timed signals, this will be equal to the cycle length.

Synchro calculates this value.

9.1.1.2. HCM Control Delay (s)

This is the calculated control delay (s) for the entire intersection based on the methods described within the HCM 2010.

Synchro calculates this value.

9.1.1.3. HCM Intersection LOS

This is the calculated LOS for the entire intersection based on the methods described within the HCM 2010. Control delay alone is used to characterize LOS for an entire intersection.

Synchro calculates this value.

9.1.1.4. Saturation Flow Rate (pc/h/ln)

By default, this item will be displayed as an uneditable dash. If the Use Saturation Flow Rate box is checked (see Section 9.1.1.5) then this value can be used to override the Saturation Flow Rate for every moment at this intersection. Otherwise, each movement's "Ideal Satd. Flow" can be defined separately within the HCM 2010 Settings (Section 9.1.2).

Analyst should use saturation flow rate as defined in Section 3.1.7.

9.1.1.5. Use Saturation Flow Rate

Checking this box will allow the user to override the Saturation Flow Rate for every moment at this intersection (see Section 9.1.1.4).

Analyst should use saturation flow rate as defined in Section 3.1.7.

9.1.1.6. Sneakers Per Cycle (veh)

This represents the number of vehicles that are served during the clearance intervals (ambers + all reds) of a cycle. This could be field measured by the analyst preparing the study. The acceptable range is from 2 to 10 vehicles, where values larger than 2 should be justified with field studies.

9.1.1.7. Number of Calc. Iterations

The HCM 2010 methodology analyzes actuated signals based on a series of iterative calculations. The "solution" is based on the difference between two successive iterations. Max value is 100.

The Synchro default value is 35.

9.1.1.8. Stored Passenger Car Length (m)

The average length of a passenger vehicle, measured from front bumper of first vehicle to front bumper of second vehicle.

The Synchro default value is 7.6 metres.

9.1.1.9. Stored Heavy Vehicle Length (m)

The average length of a heavy vehicle, measured from front bumper of first vehicle to front bumper of second vehicle.

The Synchro default value is 13.7 metres.

9.1.1.10. Probability Peds. Pushing Button

This value represents the Probability of a Pedestrian Pushing the Button during the Don’t Walk interval. See HCM 2010 page 31-26 for more information.

The Synchro default value is 0.51.

9.1.1.11. Deceleration Rate (m/s^2)

This represents the average deceleration rate based on a red and green signal indication, respectively.

The Synchro default value is 1.22 m/s^2.

9.1.1.12. Acceleration Rate (m/s^2)

This represents the average acceleration rate based on a red and green signal indication, respectively.

The Synchro default value is 1.07 m/s^2.

9.1.1.13. Distance Between Stored Cars (m)

Average distance to the nearest point of detection for two queued vehicles.

The Synchro default value is 2.44 metres and is referenced in HCM 2010, page 31-16.

9.1.1.14. Queue Length Percentile

The length of queue that will not be exceeded should be entered in the Queue Length Percentile cell. See HCM 2010, page 31-18 for more information.

The Synchro default value is 50.

9.1.1.15. Left-Turn Equivalency Factor

Equivalent number of through vehicles for each left turn vehicle, given an exclusive lane and no conflicting movement. See HCM 2010, page 31-17 for more information.

The Synchro default value is 1.05.

9.1.1.16. Right-Turn Equivalency Factor

Equivalent number of through vehicles for each right-turn vehicle, given an exclusive lane and no conflicting movement. See HCM 2010, page 31-18 for more information.

The Synchro default value is 1.18.

9.1.1.17. Heavy Vehicle Equivalency Factor

Equivalent number of passenger vehicles for each heavy vehicle, given an exclusive lane and no conflicting movement.

The Synchro default value is 2.00.

9.1.1.18. Critical Gap for Perm. Left Turn (s)

Critical gap for permitted left turn at signalized intersection.

The Synchro default value is 4.5 s and is referenced in HCM 2010, page 31-55.

9.1.1.19. Follow-up Time for Perm. Excl Left Turn (s)

Follow-up time for permitted left turn from an exclusive lane at signalized intersection.

The Synchro default value is 2.5 s and is referenced in HCM 2010, page 31-18.

9.1.1.20. Follow-up Time for Shrd Left Turn (s)

Follow-up time for permitted left turn from a shared lane at signalized intersection.

The Synchro default value is 4.5 s and is referenced in HCM 2010, page 31-18.

9.1.1.21. Stop Threshold Speed (km/hr)

The speed (when a vehicle first drops below) at which a vehicle will stop.

The Synchro default value is 8.0 km/hr.

9.1.1.22. Critical Merge Gap (s)

The Critical Gap required for a through driver desiring to merge into an adjacent lane.

The Synchro default value is 3.7 s and is referenced in HCM 2010, page 31-31.

9.1.2. HCM 2010 Settings

9.1.2.1. Lost Time Adjust (s)

The Lost Time Adjustment is the start-up lost time minus extension of effective green.

The default Lost Time Adjustment is 0s. Maximum Lost Time Adjust is 3s.

9.1.2.2. Start-up Lost Time (s)

Start-up Lost Time is time lost at the start of green as queued drivers react to the green indication, and increase their speed, such that constant saturation headway is achieved by the higher queue positions.

The default for start-up lost time is 2.5 seconds. Maximum Start-up Lost Time is 10s.

9.1.2.3. Extension of Effect. Green Time (s)

The Extension of the Effective Green Time is the amount of time vehicles continue to enter after yellow interval begins.

Within Synchro, Extension of Effect Green Time is auto-calculated to be equal to Start-up Lost Time minus Lost Time Adjust. The default Extension of Effective Green Time is 2.5 s.

9.1.2.4. HCM Platoon Ratio

The HCM Platoon Ratio describes the quality of progression associated with arrivals to a phase. For left-turn movements with permitted phasing, the platoon ratio describes arrivals during the Protected Phase. For right turn movements with a protected operation concurrent with the complementary left, the platoon ratio describes arrivals during the permitted right-turn operation.

Platoon Ratio is designated using a number from 0 to 2.0 where Synchro auto-calculates this parameter.

9.1.2.5. HCM Upstream Filtering Factors

The upstream filtering adjustment factor I accounts for the effect of an upstream signal on vehicle arrivals to the subject movement group. Specifically, this factor reflects the way an upstream signal changes the variance in the number of arrivals per cycle. The variance decreases with increasing volume-to-capacity ratio, which can reduce cycle failure frequency and resulting delay.

The filtering adjustment factor varies from 0.09 to 1.0. A value of 1.0 is appropriate for an isolated intersection (i.e., one that is 1 km or more from the nearest upstream signalized intersection). A value of less than 1.0 is appropriate for non-isolated intersections.

The Synchro default value is 1.0.

9.1.2.6. Opposing Right-Turn Lane Influence

This factor is used to adjust the capacity of left turning vehicles due to right turning vehicles from the opposing approach. Select Yes or No from the pull down menu based on field observations. The Synchro default value is “Yes”.

9.1.2.7. Initial Queue (veh)

The initial queue represents the queue present at the start of the subject analysis period for the subject movement group. This queue is created when oversaturation is sustained for an extended time. The initial queue can be estimated by monitoring queue count continuously during each of the three consecutive cycles that occur just before the start of the analysis period. The smallest count observed during each cycle is recorded. The initial queue estimate equals the average of the three counts. The initial queue estimate should not include vehicles in the queue due to random, cycle-by-cycle fluctuations. The Synchro default value is 0 veh.

9.1.2.8. Receiving Lanes

The number of receiving lanes represents the count of lanes departing the intersection. This number should be separately determined for each left-turn and right-turn movement. Experience indicates that proper turning cannot be executed at some intersections because a receiving lane is frequently blocked by double-parked vehicles. For this reason, the number of receiving lanes should be determined from field observation when possible. Synchro generates the initial value based on the downstream lanes programmed into the network. This parameter is determined based on the coded network geometry and should reflect site conditions.

9.1.2.9. Turn Bay or Segment Length (m)

These are roughly equal to the storage length set within the Lane Settings (see Section 3.1.11) for all exclusive turn lanes, and the link distance (as drawn within the Map Settings) for all travel lanes. Synchro makes small adjustments (<5 metres) to take into account tapering.

9.1.2.10. Parking Present?

State whether there are on-street parking manoeuvres located within 75 metres of the stop line on an intersection leg. Click in order to take parking manoeuvres into account for the analysis. The Synchro default value is “No”.

9.1.2.11. Parking Maneuvers (#/hr)

This rate represents the count of influential parking manoeuvres that occur on an intersection leg, as observed during the analysis period. An influential maneuver occurs directly adjacent to a movement group, within a zone that extends from the stop line to a point 75 metres upstream of it. A manoeuvre occurs when a vehicles enters or exits a parking stall. If more than 180 manoeuvres/h exist, then a practical limit of 180 should be used. On a two-way leg, manoeuvres are counted only for the right side of the leg (i.e. approaching the intersection); one a one-way leg, manoeuvres are separately counted for each side of the leg.

The Synchro default value is 0.

9.1.2.12. Bus Stopping Rate (#/hr)

The bus stopping rates represents the number of local buses that stop and block traffic flow in a movement group within 75 metres of the stop line (upstream or downstream), as measured during the analysis period. The stop can be on the near side or far side of the intersection. If more than 250 buses/h exist, then a practical limit of 250 should be used.

The Synchro default value is 0.

9.1.2.13. Stop line Detector Length (m)

The stop-line detector length represents the length of the detection zone used to extend the green indication. This detection zone is typically located near the stop line, and may have a length of 12.2 metres or more. However, it can be located some distance upstream of the stop line and may be as short as 1.8 metres. The latter configuration typically requires a long minimum green, or use of the controller's variable initial setting.

The Synchro default value is 20 metres and 100 metres for turn lanes and thru lanes, respectively.

9.1.2.14. HCM 2010 Capacity (veh/h)

This is the calculated capacity of a lane group based on the methods described within the HCM 2010. See page 18-41 and Chapter 31 within HCM 2010 for details regarding the calculation of capacity for a lane group.

Synchro calculates this value.

9.1.2.15. HCM Volume/Capacity

The volume-to-capacity ratio quantifies the degree to which a phase's capacity is used by a lane group. In general, a volume-to-capacity ratio greater than 1.0 is an indication of actual or potential breakdown.

Synchro calculates this value.

9.1.2.16. HCM Lane Group Delays (s/veh)

This is the calculated control delay (s) for a lane group based on the methods described within the HCM 2010. The delay calculated represents the average control delay experienced by all vehicles which arrive during the analysis period. The control delay for a given lane group is computed as the sum of uniform delay, incremental delay and initial queue delay. The methodology is described in detail starting on page 18-46 of HCM 2010, with additional details in Chapter 31.

Synchro calculates this value.

9.1.2.17. HCM Lane Group LOS

This is the calculated LOS for the lane group based on the methods described within the HCM 2010. In general, LOS is an indication of the general acceptability of delay to drivers. Control delay and volume-to-capacity ratios are used to characterize LOS for a lane group. See Exhibit 18-4 within the HCM 2010 for detailed Automobile LOS criteria.

Synchro calculates this value.

9.1.2.18. HCM Approach Delay (s/veh)

This is the calculated control delay (s) for an approach based on the methods described within the HCM 2010 starting on page 18-46.

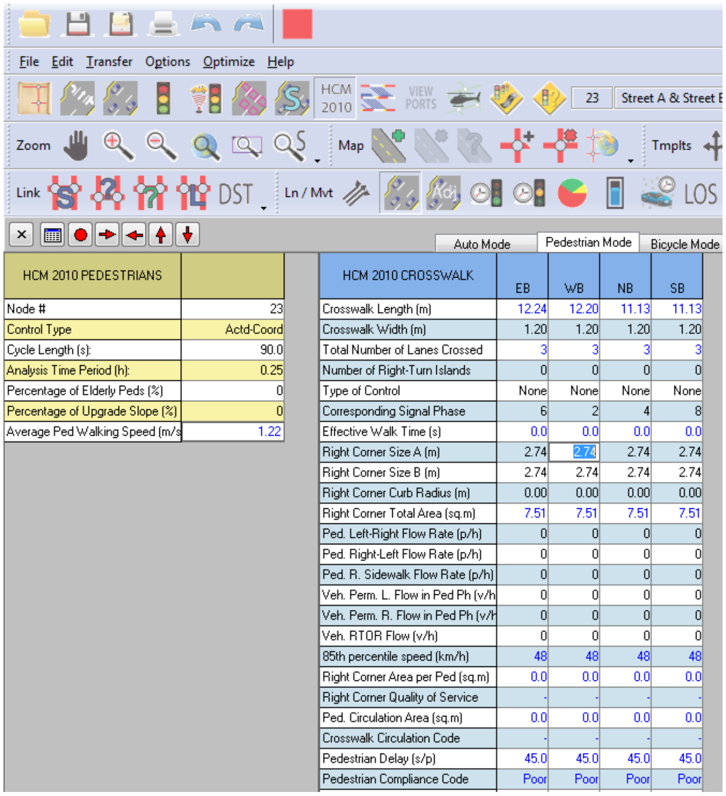
Synchro calculates this value.

9.1.2.19. HCM Approach LOS

This is the calculated LOS for the approach based on the methods described within the HCM 2010. In general, LOS is an indication of the general acceptability of delay to drivers. Control delay alone is used to characterize LOS for an approach. See Exhibit 18-4 within the HCM 2010 for detailed Automobile LOS criteria.

Synchro calculates this value.

9.2. Signalized Intersections – Pedestrian Mode



9.2.1. HCM 2010 Pedestrians Settings

9.2.1.1. Percentage of Elderly Peds (%)

Enter the average percentage of elderly pedestrians at the study intersection. Unless demographic information is available for an intersection, a default value of 7 should be used. The value is derived from 2011 Census data, which shows approximately 13% of the City's population is over 65 years of age.

9.2.1.2. Percentage of Upgrade Slope (%)

Enter the average percentage of upgrade slope along the study intersection crosswalks.

The Synchro default value is 0.

9.2.1.3. Average Ped Walking Speed (m/s)

An average Walk speed of 1.0 m/s should be used. If demographic data is available, then use the following values:

- 0.9 m/s in cases where at least 20% of pedestrians crossing the signalized intersection are older pedestrians (65 years of age or older); and
- 0.8 m/s in cases where at least 20% of pedestrians crossing the signalized intersection use assistive devices for mobility.

9.2.2. HCM 2010 Crosswalk Settings

9.2.2.1. Crosswalk Length (m)

Crosswalk length is measured from the outside edge to outside edge of the road pavement, or curb where present, along the marked pedestrian travel path. The centre of the crosswalk should be used for the measurement.

This value auto-calculates based on lane width inputs (see Section 3.1.8 or the HCM 2010 Settings within Auto Mode) , but should be overridden where field data available.

9.2.2.2. Crosswalk Width (m)

The cross width represents an effective width, and should reflect the narrowest walking space along the crosswalk path. If there are no observed constraints which regularly encroach into the crosswalk area, or obstructions within the median, then the effective width should be equal to the physical width of the crosswalk.

A default value of 3.0 meters should be used.

9.2.2.3. Numbers of Lanes Crossed (#)

This represents the total number of traffic lanes a pedestrian would have to cross, calculated for each approach.

Synchro calculates this value and should not be overridden.

9.2.2.4. Number of Right-Turn Islands (#)

This is the number of right-turn islands present on the approach. A value between 0 and 2 can be entered. The Synchro default value is 0.

9.2.2.5. Type of Control

This is the type of pedestrian signal control for that approach. The options are “none”, “actuated”, “pre-timed”, “actuated plus rest in walk” or “no signal”. The Synchro default value is “none”.

9.2.2.6. Corresponding Signal Phase

This is the signal phase associated with the pedestrian movement, correlating to the intersection signal timing plan. Synchro automatically selects the corresponding movements based on traditional timing conventions.

9.2.2.7. Effective Walk Time (s)

Research indicates that, at intersections with pedestrian signal heads, pedestrians typically continue to enter the intersection during the first few seconds of the pedestrian clearance interval. This behavior effectively increases the effective walk time available to pedestrians. A conservative estimate of this additional walk time is 4.0 s. A nonzero value for this additional time implies that some pedestrians are initiating their crossing during the Flashing Don’t Walk indication. Refer to the HCM 2010 Chapter 18 for details.

The Synchro default value is 0.

9.2.2.8. Right Corner Size A & B (m)

These parameters are the width of the available pedestrian waiting area at the corner of the intersection. Side A is measured in the direction of the crosswalk crossing the major street. Side B is measured in the direction of the crosswalk crossing the minor street. Refer to the Synchro 9 manual page 14-10 or HCM 2010 page 18-61 for additional details.

The Synchro default value is 2.74 metres.

9.2.2.9. Right Corner Curb Radius (m)

This represents the corner radius of the curb of the available pedestrian waiting area. This parameter could be field measured or taken from design drawings. The City’s “Curb Radii Guidelines” is available is on the City’s website.

The Synchro default value is 0 metres.

9.2.2.10. Right Corner Total Area (sq.m)

This is the total area of the available pedestrian waiting area. Synchro auto-calculates this value based on previous user input (Sections 9.2.2.8, 9.2.2.9). HCM 2010 methodology can be used to verify this area if additional field data is available. Refer to the Synchro 9 manual page 14-10 or HCM 2010 page 18-61 for additional details.

9.2.2.11. Ped Left-Right Flow Rate (p/h)

This is the flow rate of pedestrians from left to right at this approach. Direction is based on the perspective of vehicles approaching the intersection.

This value needs to be measured in the field.

9.2.2.12. Ped Right-Left Flow Rate (p/h)

This is the flow rate of pedestrians from right to left at this approach. Direction is based on the perspective of vehicles approaching the intersection.

This value needs to be measured in the field.

9.2.2.13. Ped R Sidewalk Flow Rate (p/h)

This is the flow rate of pedestrians on the right sidewalk corner which does not cross a crosswalk at the intersection being analyzed.

This value needs to be measured in the field.

9.2.2.14. Veh Perm L Flow in Ped Ph (v/h)

This is the permitted left-turn demand flow rate, in units of vehicles per hour. This number is not the total hourly left-turn flow rate, it is only the flow rate of the permitted turns.

This value needs to be measured in the field.

9.2.2.15. Veh Perm R Flow in Ped Ph (v/h)

This is the permitted right-turn demand flow rate, in units of vehicles per hour. This number is assumed to be the total permitted right-turn flow rate, including RTOR's.

This value needs to be measured in the field.

9.2.2.16. Veh RTOR Flow (v/h)

This is the right-turn on red flow rate, in units of vehicles per hour. This would be the RTOR within the right-turning flow rate that could otherwise turn permissively into the crosswalk while the crosswalk is being used by pedestrians.

This value needs to be measured in the field.

9.2.2.17. 85th Percentile Speed (km/h)

This is the 85th percentile speed at a mid-segment location on the major/minor street, in units of kilometres per hour. Synchro assumes this is equal to the link speed as defined in Section 3.1.5.

9.2.2.18. Right Corner Area per Ped (sq.m)

This is the right corner area per pedestrian in square metres per pedestrian. Synchro automatically calculates this based on the previous inputs, and must not be overridden.

9.2.2.19. Right Corner Quality of Service

The pedestrian level of service for the subject crosswalk based on the score in HCM 2010 Exhibit 18-5 (page 18-7 from the HCM 2010).

Synchro calculates this value.

9.2.2.20. Ped Circulation Area (sq.m)

This represents the subject crosswalk circulation area per pedestrian, in units of square-metres per pedestrian. This is auto calculated by Synchro based on the previous input and should not be overridden.

9.2.2.21. Crosswalk Circulation Code

Based on the calculated Pedestrian Circulation Area (pedestrian space), Synchro will provide a number which refers to the qualitative descriptions provided within HCM 2010 Exhibit 18-24 located on HCM 2010, page 18-60.

Synchro calculates this value.

9.2.2.22. Pedestrian Delay (s/p)

The Pedestrian Delay is calculated by Synchro and is based on the HCM 2010 methods; see HCM 2010 page 18-68.

Synchro calculates this value.

9.2.2.23. Pedestrian Compliance Code

The pedestrian compliance code is calculated by Synchro and is based on the HCM 2010 methods. See the dialogue provided within the first three paragraphs shown on HCM 2010 page 18-69.

Synchro calculates this value.

9.2.2.24. Pedestrian Crosswalk Score

The pedestrian LOS score for the intersection is calculated using the methodology shown within HCM 2010 page 18-69.

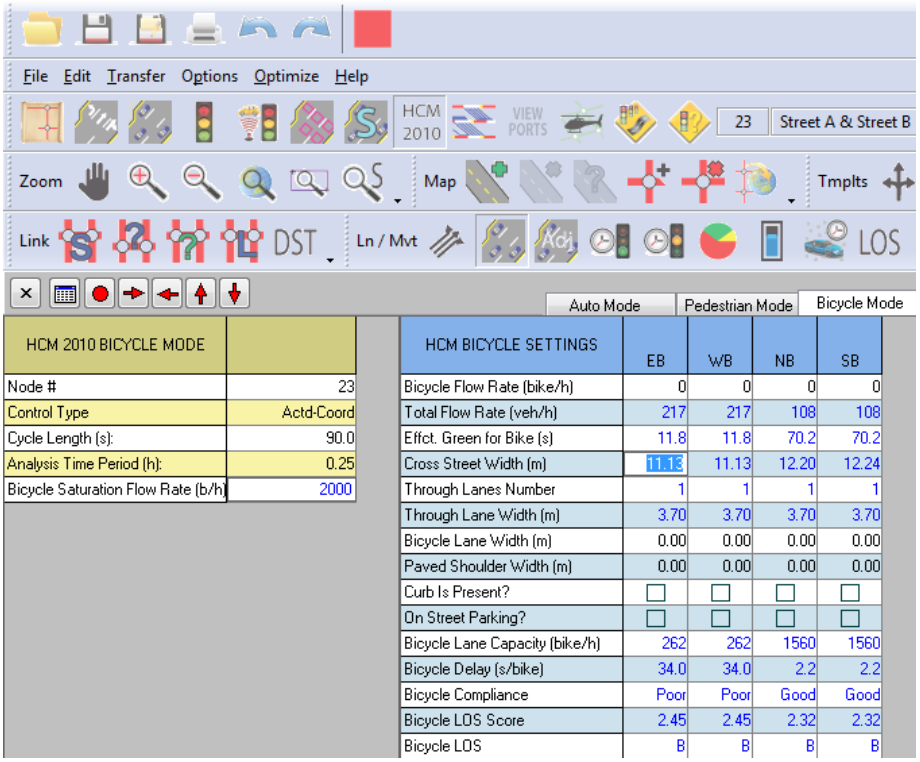
Synchro calculates this value.

9.2.2.25. Pedestrian Crosswalk LOS

Pedestrian delay represents the average time a pedestrian waits for a legal opportunity to cross an intersection leg. The LOS score is an indication of the typical pedestrian's perception of the overall crossing experience. Pedestrian LOS Score is based on HCM 2010 methodology shown within HCM 2010 page 18-70, of which pedestrian delay is only one component.

Synchro calculates this value.

9.3. Signalized Intersections – Bicycle Mode



9.3.1. HCM 2010 Bicycle Mode Settings

9.3.1.1. Bicycle Saturation Flow Rate (bike/h)

The maximum bicycle rate of flow as measured at the stop line during the green indication. HCM 2010 recommends a saturation flow rate of 2,000 bicycles/h as an average value achievable at most intersections, and recommends site observations to determine saturation flow rates otherwise.

The Synchro default value is 2000 bike/hr.

9.3.2. HCM Bicycle Settings

9.3.2.1. Bicycle Flow rate (bike/h)

The bicycle flow rate is based on the count of bicycles whose travel path is crossed by vehicles turning right from the subject approach during the analysis period. This value needs to be measured in the field.

9.3.2.2. Cross Street Width (m)

The street width represents the width of the cross street as measured along the outside through vehicle lane on the subject approach between the extended curb line limits of the cross street.

Synchro auto-calculates based on previous inputs, but this can be updated based on real-world data.

9.3.2.3. Bicycle Lane Width (m)

This is the bicycle lane adjacent to the outside lane. Synchro accepts values between 0 metres (i.e. no bicycle lane) and 2.55 metres.

This value needs to be measured in the field.

9.3.2.4. Paved Shoulder Width (m)

This is the paved outside shoulder width adjacent to the bicycle lane. Synchro accepts values between 0 metres (i.e. no bicycle lane) and 2.55 metres.
This value needs to be measured in the field.

9.3.2.5. Curb is Present?

Check box if curb is present, leave unchecked if no curb is present. The Synchro default value is “no”.

9.3.2.6. On Street Parking?

Check box if parking is present, leave unchecked if no parking is present. The Synchro default value is “no”.

9.3.2.7. Bicycle Lane Capacity (bike/h)

Based on the previous fields, this value is calculated by Synchro based on the HCM 2010 methods. See HCM 2010, page 18-71. This result should not be overridden.

Synchro calculates this value.

9.3.2.8. Bicycle Delay (s/bike)

Based on the previous fields, this value is calculated by Synchro based on the HCM 2010 methods and represents the delay experienced by each bicycle. See HCM 2010, page 18-72. This result should not be overridden.

Synchro calculates this value.

9.3.2.9. Bicycle Compliance

The bicyclist compliance code based on the HCM 2010 methods. See dialogue on HCM 2010, page 18-72.

Synchro calculates this value.

9.3.2.10. Bicycle LOS Score

The bicycle LOS score for the intersection is calculated by the methodology described within HCM 2010, pages 18-72 and 18-73.

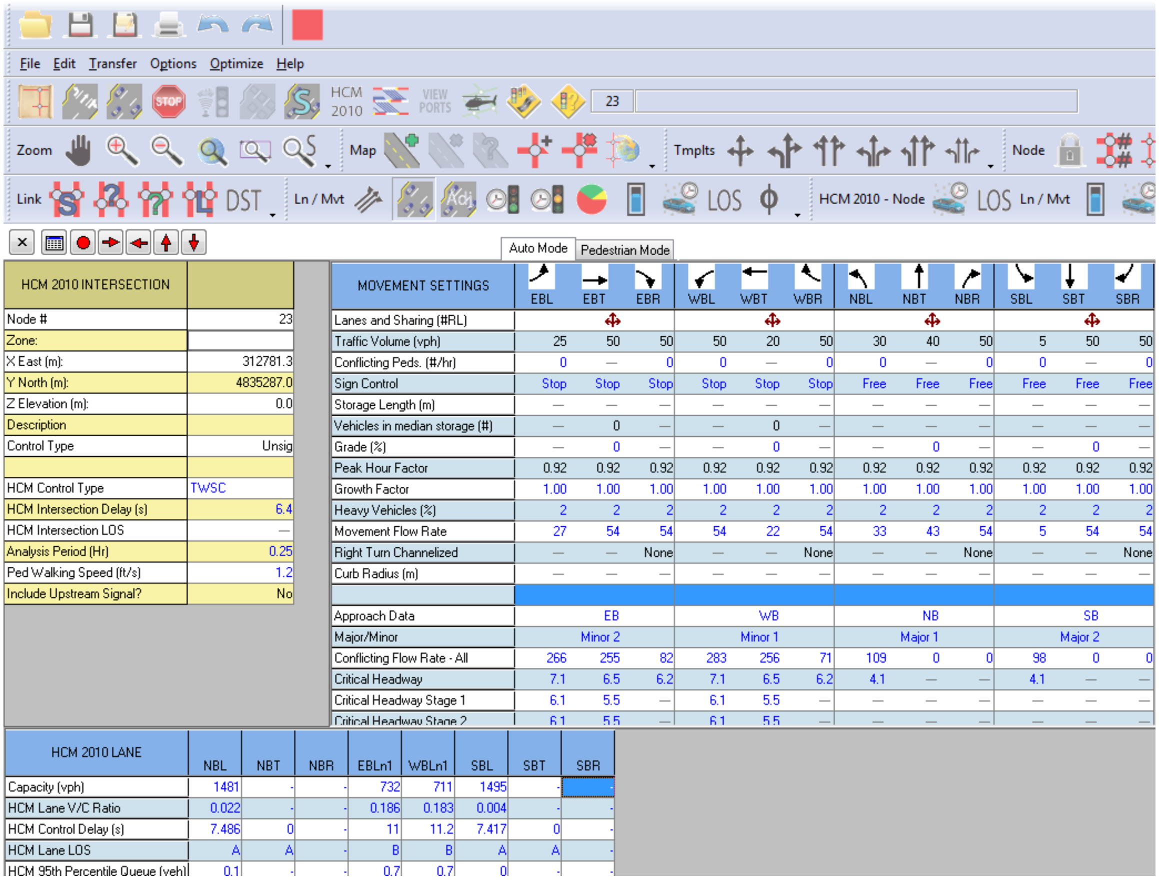
Synchro calculates this value.

9.3.2.11. Bicycle LOS

Bicycle delay represents the average time a bicyclist waits for a legal opportunity to cross an intersection leg. The LOS score is an indication of the typical bicyclist’s perception of the overall crossing experience. Bicycle LOS Score is based on HCM 2010 methodology, of which bicycle delay is only one component. See HCM 2010 page 18-72 for more details.

Synchro calculates this value.

9.4. Two-way Stop Control Intersections – Auto Mode



9.4.1. HCM 2010 Intersection

9.4.1.1. HCM Control Type

This should be TWSC, indicating that Two-Way-Stop Control methodologies are being applied.

9.4.1.2. HCM Intersection Delay (s)

This is the overall intersection control delay per vehicle. It should be noted that the major street through traffic is not accounted for in this calculation, since its delay is assumed to be zero.

Synchro calculates this value.

9.4.1.3. HCM Intersection LOS

The LOS for the intersection is not calculated, since traffic along the major street is considered free-flowing and thus experiences zero delay.

Synchro calculates this value.

9.4.1.4. Ped Walking Speed (m/s)

This is the walking speed of pedestrians used in the two-way stop calculations. Pedestrian walking speed should be the criteria outlined in Section 6.1.7.

The Synchro default value is1.05 m/s.

9.4.1.5. Include Upstream Signal?

Select “No” if you do not wish to have the calculations adjusted due to the presence of an upstream signal. Select “Yes” if you wish to have the calculations adjusted due to the presence of an upstream signal. The calculations are adjusted based on the platooning of traffic from the signalized intersection. Typically “Yes” should be selected.

The Synchro default value is “No”.

9.4.2. Movement Settings

9.4.2.1. Vehicle in Median Storage (#)

If a wide median exists on the main street, and left turns from the side street use the median as storage to perform the left turn in two stages, enter the number of left turning vehicles (1) or (2) that can be stored within the median.

The Synchro default value is 0.

9.4.2.2. Major/Minor

Each approach is assigned a label based on whether it is considered the major roadway or minor roadway. These are assigned automatically by Synchro based on the placement of the stop signs.

9.4.2.3. Conflicting Flow Rate - All

The total conflicting flow rate based on crossing the major street in either one or two manoeuvres.

Synchro calculates this value.

9.4.2.4. Critical Headway (s)

Critical headway is the critical headway of a crossing vehicle completing the designated movement using only one manoeuvreSynchro default values should be maintained unless headway parameters have been collected by field observations.

Synchro defaults vary depending on turn type.

9.4.2.5. Critical Headway Stage 1 (s)

Critical Headway Stage 1 is the first of two critical headways associated to a crossing vehicle completing each of the two designated manoeuvres; also see Section 9.4.2.5. Synchro default values should be maintained unless headway parameters have been collected by field observations.

Synchro defaults vary depending on turn type.

9.4.2.6. Critical Headway Stage 2 (s)

Critical Headway Stage 2 is the second of two critical headways associated to a crossing vehicle completing each of the two designated manoeuvres; also see Section 9.4.2.4. Synchro default values should be maintained unless headway parameters have been collected by field observations.

Synchro defaults vary depending on turn type.

9.4.2.7. Follow-up Headway

This value is the time between the departure of one vehicle from the minor street, and the departure of the next vehicle using the same major-street headway, under a condition of continuous queuing on the minor street.

Synchro defaults vary depending on turn type.

9.4.2.8. Potential Capacity-1 Maneuver

The Potential Capacity is calculated based on the methodology described within HCM 2010 page 19-16.

Synchro calculates this value.

9.4.2.9. Time Blocked by Platoon (%)

The Time Blocked by platoon (%) is calculated if there is an upstream or downstream signalized intersection within 1 km of the study TWSC intersection. This value is determined based the reference phase and offset of the signalized intersection(s).

Synchro calculates this value.

9.4.2.10. Movement Capacity – 1 & 2 Maneuvers

These values are the capacity of a crossing vehicle completing the designated movement, using one and two manoeuvres, respectively. Several capacity adjustment factors that account for the impeding effects of higher-ranked movements are considered in these calculations.

Synchro calculates these values.

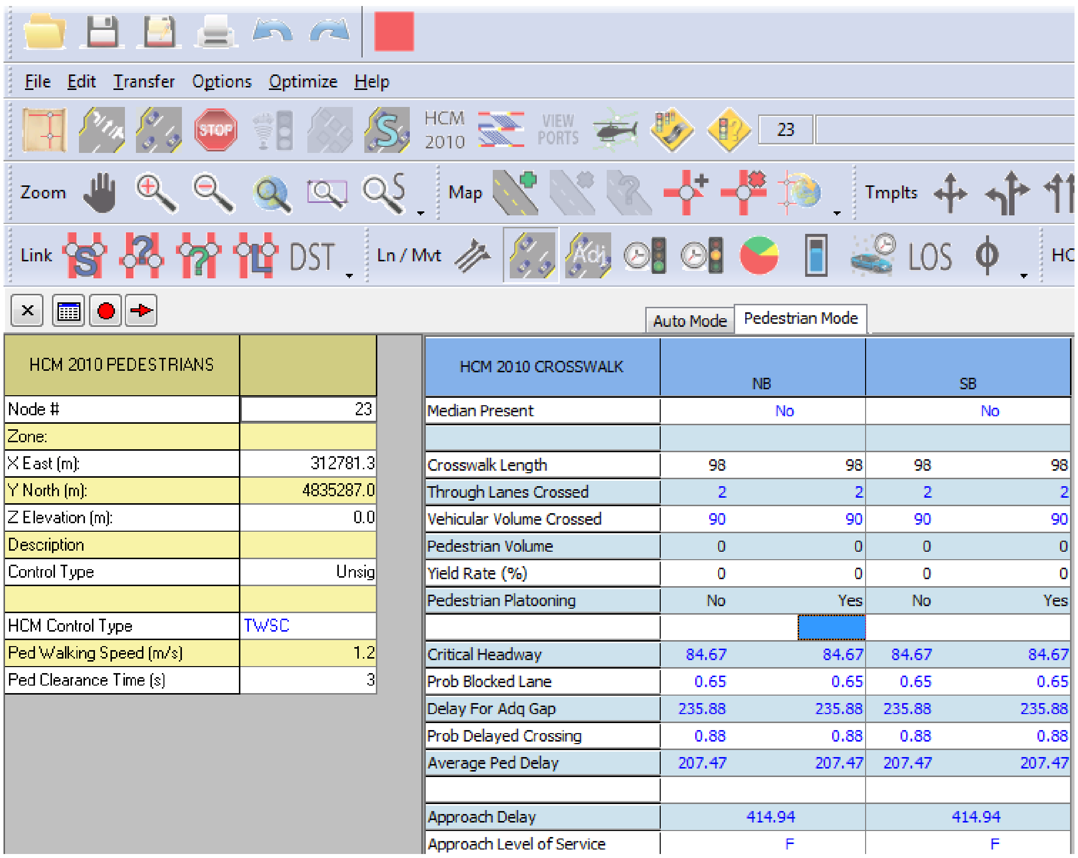
9.4.3. HCM 2010 Lane

9.4.3.1. HCM 95th Percentile Queue

The 95th Percentile Queue is based on the methodology described within HCM 2010 page 19-30.

Synchro calculates this value.

9.5. Two-way Stop Control Intersections – Pedestrian Mode



9.5.1. HCM 2010 Pedestrians

9.5.1.1. Ped Walking Speed (m/s)

This is the average pedestrian walking speed at the study intersection.

The Synchro default value is 1.05 m/s, however the City specifies a walking speed of 1.0 m/s.

9.5.1.2. Ped Clearance Time (s)

This value represents the pedestrian start-up time and end clearance time.

The Synchro default value is 3.

9.5.2. HCM 2010 Crosswalk

9.5.2.1. Median Present?

"Yes" or "No" will automatically be selected based on the Median Width coded within the Simulation Settings screen. "No" indicates that pedestrians cross the entire length of the roadway at once. "Yes" indicates that pedestrians cross a portion of the roadway, wait in the median, and then cross the remaindering portion of the roadway. If "Yes" is displayed, a second crosswalk dialogue box will be displayed.

For the City of Toronto the default should be marked as 'No', as regardless of the width of the crossing, pedestrians will cross the entire length of the roadway.

9.5.2.2. Through Lanes and Vehicular Volume Crossed

The total number of through lanes crossed by the pedestrian, and the total number of through vehicles that the pedestrian is in conflict will be displayed.

Synchro calculates this value.

9.5.2.3. Yield Rate (%)

This value represents the average rate that motorist will yield to pedestrians waiting to cross the roadway. The use of local data should be used if available. Refer to the Synchro 9 manual Table 14-4 for average yield rates. For additional information see Chapter 19 of the HCM 2010.

The Synchro default value is 0.

9.5.2.4. Pedestrian Platooning

Users should select "Yes" or "No" from the pull down menu to indicate whether Pedestrian Platooning exists at the intersection. Pedestrian platooning is defined as groups of pedestrians crossing the roadway as a group.

The Synchro default value is "no".

9.5.2.5. Critical Headway

The Critical Headway is defined as the time in seconds below which a pedestrian will not attempt to begin crossing the roadway. The calculated value depends on whether pedestrian platooning exists at the intersection.

Synchro calculates this value.

9.5.2.6. Prob Blocked Lane

The probability that a lane is blocked by a vehicle is calculated based on user input.

Synchro calculates this value.

9.5.2.7. Prob Delays XCrossing

The probability that a pedestrian or group of pedestrians will be delayed is calculated based on user input. Synchro calculates this value.

9.5.2.8. Delay for Adq Gap

The average delay that a pedestrian or group of pedestrians will experience waiting for an adequate gap is calculated based on user input.

Synchro calculates this value.

9.5.2.9. Average Ped Delay

This is the calculated average pedestrian delay based on the HCM 2010 methods for each individual crosswalk.

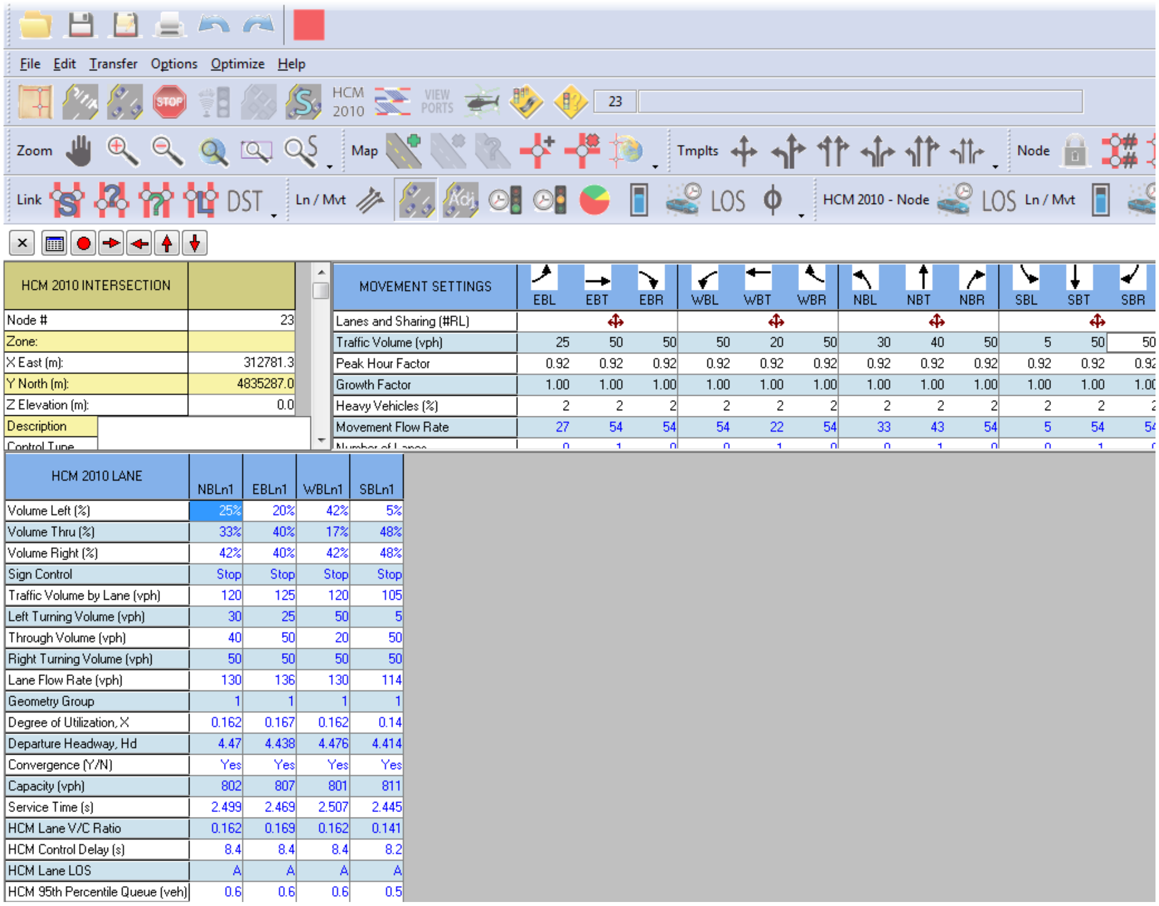
Synchro calculates this value.

9.5.2.10. Approach Delay & Level of Service

The sum of all delays at the analyzed approach is used to determine the Level of Service based on the HCM 2010 methods for each crosswalk segment.

Synchro calculates this value.

9.6. All-way Stop Control Intersections



9.6.1. HCM 2010 Intersection

9.6.1.1. HCM Control Type

This should be AWSC, thus indicating All-Way Stop Control methodologies are being applied.

9.6.2. Movement Settings

9.6.2.1. Opposing Approach, & Conflicting Approach Left & Right

The opposing approach, conflicting approach left, and conflicting approach right, are defined by the HCM 2010 with respect to the subject approach being analyzed.

Synchro calculates these values.

9.6.2.2. Opposing and Conflicting Lanes

This value is the number of lanes associated with the approaches defined above.

Synchro calculates these values.

9.6.3. HCM 2010 Lane Settings

9.6.3.1. Volume Left, Thru & Right (%)

These values represent the corresponding volume movement being analyzed within each lane.

Synchro calculates this value.

9.6.3.2. Geometry Group

Based on the intersection configuration, and the number of lanes along each approach, each approach is assigned a value based on Exhibit 20-10 of the HCM 2010. This value is then used to determine the base saturation headways, and headway adjustment factors. See Table 14-2 within the Synchro 9 Manual for the conversion of the geometry group listed within the HCM 2010. See the HCM 2010 for additional details.

Synchro calculates this value.

9.6.3.3. Degree of Utilization, X

This value represents the probability of finding at least one vehicle on that approach.

Synchro calculates this value.

9.6.3.4. Departure Headway, Hd

This value represents the average time between departures of successive vehicles on a given approach.

Synchro calculates this value.

9.6.3.5. Convergence (Y/N)

A value of Y indicates that the calculated value of departure headway is within 0.1 second of the initial assumed value of departure headway.

Synchro calculates this value.

9.6.3.6. Service Time (s)

These values represent the average time spent by a vehicle in the first position (at the stop bar) waiting to depart.

Synchro calculates this value.

10. SPECIAL CONSIDERATIONS

10.1. Signal Coordination

Refer to the City's *Traffic Signal Operations Policies and Strategies, Section 5.7 (May 7, 2015)*.

10.2. Model Calibration

When an operational analysis of a network of signals is undertaken, the model should be calibrated to ensure that the model reflects the field conditions. Field observations are substantially more complicated than the estimation of benefits from the Synchro software, but it is more significant because it is physical "proof" of what's happening in the field. Such field observations are necessary to calibrate and evaluate the reality of the computer models. Typical field observations include travel time or delay, number of stops, saturation flow rates, vehicle queue lengths and general field notes. Field data collection effort can be supplemented by a photographic log of the project area, videotaping the corridor and conducting conflict studies at several locations. A sufficient amount of data should be collected to be representative of the conditions in the study area.

To properly calibrate the simulation model, the conditions simulated should be as identical as possible to the observed existing conditions. Unrelated design changes such as adding a lane or a left-turn bay, or traffic management schemes should be avoided for the existing conditions model. Construction timings and construction activities should also be avoided. These changes could affect the results obtained in the field, possibly leading to inconclusive statements about the analysis results.

Field data should be collected at the same periods that were modeled in Synchro. For example, if models were developed for the weekday morning peak, weekday off-peak and weekday afternoon peak, then the periods for field data collection should be identical so that the implemented timing plans correspond to the traffic patterns for those periods. The time required for data collection varies with the number of signals in the system, the number of timing plans, available personnel and equipment, and other considerations particular to the specific system. Ideally, all variables will remain constant during the data collection activities. However, traffic measurements will generally vary by time of day, day of week, car type, driver, etc. Effort should be made to minimize this variation by using the same car and driver in each case and collecting data under similar conditions.

10.3. Volume Balancing

Field-collected traffic volumes almost always contain mathematical inconsistencies and the data must be adjusted or "balanced" to obtain a mathematically consistent data set. For example, if we start with the observed volume at a signalized intersection and proceed in the direction of travel, adding volumes entering the network and subtracting volumes leaving the network, the running total almost never matches the observed volume at the next signalized intersection.

These inconsistencies arise from the following:

- counting errors
- counting on different days (counts typically vary by 10 percent or more on a daily basis) primarily from the fact that currently it is not possible to count the entire network simultaneously
- major traffic sources (or sinks) between locations
- queuing between intersections
- counting with different technologies.

Discrepancies in the counts must be reconciled before proceeding to the model development task. The analyst must review the counts and determine (based on local knowledge and field observations) the probable causes of the discrepancies. Counting errors and counts made on different days are treated differently from counting differences caused by mid-block sources/sinks or mid-block queuing. The process for balancing counts is to review the data as a whole and identify directional traffic counts that are not consistent with the surrounding data. Traffic counts will have to be checked by starting at the beginning or perimeter of the system and add or subtract entering and exiting traffic. Along the way, count information should match from one station to the next. If it does not balance, a decision needs to be made on how to best reconcile the counts.

10.4. HOV Lanes

In general, Synchro is not the ideal option for doing analysis of HOV Lanes. Other microsimulation software, such as Aimsun should be used.

If it is necessary for the analyst to model an HOV Lane in Synchro, then special attention will be required when creating the model to ensure the on-street conditions are replicated as closely as possible. A field study is required to justify using Synchro analysis.

A field study may be required to determine an appropriate lane utilization factor (refer to Section 3.2.1) for HOV lane analysis. Traffic volumes must be counted for each lane of a lane group and the following formula should be used to calculate the lane utilization factor $f_{LU.}$

> f_{LU} = unadjusted volume for the lane group (in veh per hour) / (number of lanes * unadjusted volume from the single lane with the highest volume (in veh per hour))

If a field saturation flow study is conducted at an intersection, then the lane utilization factor used for the specific intersection analysis (along with the other adjustment factors) can be set to 1.0 so that the influence of the adjustment factors are not double counted. In the absence of individual lane counts, a conservative approach would be to exclude the HOV lane (and its volume) from the analysis, since, during peak periods, adjacent lanes handle most of the volume and operate at or near capacity.

In the case where there is non-compliance, the approach would be to conduct the analysis in three ways:

- Existing conditions, including non-compliance;
- Existing conditions, assuming full compliance; and
- Proposed conditions, assuming full compliance.

10.5. Streetcars

In general, Synchro is not the ideal option for doing analysis of streetcar routes. Other microsimulation software, such as Aimsun should be used.

If it is necessary for City staff to model a streetcar intersection in Synchro, then special attention will be required when creating the model, to ensure the on-street conditions are replicated as closely as possible.

If streetcars occupy a mixed traffic lane and the streetcar frequency is more than one every five minutes in each direction, then the streetcar lane should be excluded from the analysis along with any left turn movements. The reason for excluding the lane from the analysis is that streetcars impede the flow of traffic in the streetcar lane and hinder the flow in the curb lane when passengers board and alight the streetcars. If a left /through shared lane has an advanced phase, then the streetcar lane should be coded as a left turn lane only (and not as a shared through/left lane).

10.6. Transit Priority

In general, Synchro is not the ideal option for doing analysis of Transit Priority routes. Other microsimulation software, such as Aimsun should be used.

If it is necessary for City staff to model a Transit Priority intersection in Synchro, then special attention will be required when creating the model, to ensure the on-street conditions are replicated as closely as possible.

If an intersection is equipped with transit priority pre-emption, historical traffic signal log data should be obtained from TSOG to assist in the analysis. The log data can be used to calculate the average green times and split times for the study period since the timings include for the adjustments made to the splits whenever a signal goes into “resynch” to recover its offset after a transit priority pre-emption event. In the absence of available log data, an analysis of the worst case conditions can be conducted by adding maximum extension values to the splits (if a movement is to be equipped with extensions or using lowest truncated values (if a movement is to allow truncations).

If an analysis is conducted for a proposed signal on an existing transit priority route, the average transit priority extensions from existing adjacent signals can be used if the adjacent signals have the same mode of control and transit priority parameters.

10.7. Traffic Adaptive

Traffic adaptive systems such as SCOOT (Split Cycle Offset Optimization Technique) automatically derives and implements the appropriate signal timings in response to unanticipated variations in traffic conditions consistent with overall signal system objectives. The volumes of traffic approaching a traffic signal from different directions are continuously detected and the system automatically adjusts the duration of the green displays to best match the requirements of the oncoming traffic.

Synchro is not the best software for modelling adaptive control. A micro-simulation software, such as Aimsun, VISSIM or Paramics, is preferable. If City staff do not have ready access to micro-simulation software, then Synchro modelling is acceptable. There are two approaches that can be used.

In the first approach, Synchro analyses must be done for eight 15 minute slices during the morning and afternoon peak periods. Average cycle length, splits and offsets must be derived from SCOOT for each 15-minute slice and then matched with 15 minute traffic volumes. While this approach is theoretically possible, it involves a great deal of data collection and analyses - the volume data and timings data must be collected on the same day.

The easier alternative would be to use the typical (average) timings for the peak period but also do field observations for the study period to see if the model matches field conditions, bearing in mind that timings can vary from cycle to cycle under SCOOT control. The information provided by TSOG for SCOOT signals is in two parts:

- The range in values allowed by SCOOT by time of day (cycle length and split ranges from minimum to maximum); and
- The “typical” timings for different critical time periods (i.e. the morning peak, midday off peak, afternoon peak, night and weekend plans).

A SCOOT intersection analysis should use typical timings for the analysis of existing conditions. If proposed timings are developed, the minimum and maximum cycle length and split values must not be violated. If an analysis is conducted for a proposed signal on an existing SCOOT route, the minimum, maximum and typical cycle length values of the adjacent signals should be enforced to ensure signal coordination is considered.

10.8. Bicycle Lanes

Signalized intersections which meet HCM 2010 criteria can take into account Bicycle Lane Width (m) when calculating Bicycle LOS Score and Bicycle LOS. See Section 9.3 for more details.

If the intersection is not signalized, and does not meet HCM 2010 criteria for analysis, Synchro does not have special considerations for bicycle lanes. Bicycle lanes should be ignored - only vehicle lanes should be coded.

10.9. Offset Intersections

Refer to the City's *Traffic Signal Operations Policies and Strategies, Section 5.4.5 (May 7, 2015)*.

10.10. Roundabouts

Synchro is not the best software for modelling Roundabouts. Depending on the scope of the project, a micro-simulation software, such as Aimsun, VISSIM or Paramics, may be preferable. Alternatively, software suites such as RODEL, or SIDRA INTERSECTION provides more accurate results. It is the responsibility of the analyst undertaking the analysis to discuss the analysis of roundabouts with City staff on a case-by-case basis, prior to proceeding, in order to properly assess the analysis requirements.

11. SIMTRAFFIC

SimTraffic is the animation portion of Synchro that simulates the data inputted into Synchro. Generally, the simulations provide a good representation of existing and future impacts but could yield results that are contradictory to reports created in Synchro. Network animation attempts to provide realistic macroscopic scenarios for the entire network by modeling the performance of individual vehicles using a range of vehicle types and vehicle behaviours. Individual intersection simulation results may be different from that shown in Synchro due to network constraints such as gating. Gating involves making signal timing adjustments (offsets, splits, cycle lengths) to restrict traffic from entering or leaving a critical area.

The following complex situations must be analysed with SimTraffic:

- Closely spaced signals;
- Intersections operating under congested conditions; and
- Ramp signals.

SimTraffic could also be a tool for public consultation / presentation.

Since one simulation may not be representative of typical conditions, data must be collected for a minimum of five separate simulations and the average values of MOEs then reported. The following parameters under “Options”, “Intervals and Volumes” and “Intervals” are required:

- The “Recording” start time should be the start of the period being simulated (i.e. 8:00 a.m. if the am peak/study period starts at 8:00 a.m.);
- The “Seeding” duration must provide enough time for a vehicle to traverse the entire network between the two most distant points, including all stops. If the travel time is typically ten minutes during the study period, the “Seeding” duration should be at least ten minutes;
- The “Seeding” start time should be the “Recording” start time less the “Seeding” duration (i.e. the “Seeding” start time should be 7:50 a.m. if a “Recording” start time is 8:00 a.m., and the “Seeding” duration is ten minutes.);
- The “Recording” duration should be a minimum of 60 minutes; this duration should allow sufficient time for any queuing problems to build up and so appear in the simulation;
- The default values for “Record Statistics” (for “Seeding”), the “PHF Adjust”, the “AntiPHF Adjust”, and the “Percentile Adjust” should be retained (and should be set to “No”);
- The default values for “Record Statistics” (for “Recording”), and the “Growth Factor Adjust” should be retained (and should be set to “Yes”); and
- At least five separate files must be generated, either using a “Random Number Seed” of “0” for each file, or using a different Random Number Seed for each run (i.e.: 1 for first run/file, 2 for second, 3 for third, etc.).

The default values for vehicle and driver types under the “Drivers” and “Vehicles” tabs should be retained.

12. REPORTS

It is the responsibility of the analyst undertaking the analysis to discuss the analysis methodologies to be used (e.g. HCM 2000, HCM 2010, Synchro/ICU, etc.) and the measures of effectiveness to report back to City staff. This should be completed on a case-by-case basis, prior to proceeding, in order to properly assess the analysis requirements.

In general, the Synchro/ICU methodology is preferred for reporting measures of effectiveness as the results are typically referenced during the model calibration process (e.g. v/c and travel times). As there are specific limitations to HCM 2010 analysis, Synchro/ICU or HCM 2000 analysis can still be used in situations where:

1. Intersection configuration is not supported by HCM 2010 methodology;
2. Multi-modal analysis is not necessary for the exercise/decision makers; and
3. Data required for accurate HCM 2010 analysis is not readily available.

When performing analysis within or near areas of significant multi-modal use, HCM 2010 analysis shall be considered through discussion with the City.

Typically, the Synchro/ICU calculated MOEs required by the City include volume/capacity ratio, approach delay/LOS, intersection delay, queue length, stops, and fuel consumption. The working Synchro files must be submitted to the City so that staff can review the network (i.e. link distances, speeds etc.) that was created and all the intersection input parameters (i.e. geometry, volumes, saturation flows etc.). Prior to submission, the analyst must undertake a quality control check of the before and after models.

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