GUIDELINES FOR USING SYNCHRO 11 (INCLUDING SIMTRAFFIC 11)

January 15, 2021

Transportation
Services Division

Traffic Systems Operations
Traffic Management Section

DOCUMENT CONTROL

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CHRONOLOGY

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1	Existing "Guidelines for using Synchro 9 (including SimTraffic 9" updated for Synchro Version 11.0.	1.0	2020/10/30
2	Original draft reviewed by Ihtesham Ahmad (Engineer, TSO), Katerina Bisbicis (Engineer in Training, TSO), and Rajnath Bissessar (Manager, TSO).	1.1	2020/11/16
3	Version 1.1 was presented at a virtual workshop held on November 17, 2020 which was attended by staff from the following City units: - Active Traffic Management - Area 2 Traffic Planning - Cycling and Pedestrian Projects - Development Planning and Review (Area 1 and 2) - Traffic Systems Operations - TS Planning Design and Construction Coordination - Vision Zero Projects	1.1	2020/11/16
4	Addressed comments from workshop and follow up e-mails.	1.2 (Final)	2021/01/15

APPROVAL

The version of this document dated January 15, 2021 was approved by the following:

- Safety and Mobility Committee (SMC) of Transportation Services on January 21, 2021.
- Transportation Services Directors Team on January 22, 2021.

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Abbreviations

APS	Accessible Pedestrian Signal
ATCS	Adaptive Traffic Control System
ATO	Area Traffic Operations
AWSC	All-way-Stop Control
CBD	Central Business District
D&AU	Data and Analytics Unit
FDW	Flashing Don't Walk
FT	Fixed Time
HCM 2000	Highway Capacity Manual 2000 (US)
HCM 2010	Highway Capacity Manual 2010 (US)
HCM 6	Highway Capacity Manual 2016 (US)
HOV	High Occupancy Vehicles
IPS	Intersection Pedestrian Signal
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

Sq. m Square Metre
sqrt Square Root

TMC Turning Movement Count
TWLTL Two-way Left Turn Lane

TSO Traffic Systems 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 50^{th} Percentile Volume

v95 95^{th} 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.

Adjusted Flow The adjusted flow (vph) is the Future Volume, calculated by adjusting the base volume by the Peak Hour Factor and the Growth Factor.

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.

Closely Spaced Signal Signals that are located close enough to one another that they require mitigating measures to prevent drivers from perceiving the wrong signal indications.

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.

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).

Flashing Don't Walk (FDW) The time provided for a pedestrian to clear the crosswalk. 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 on 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 (FT) 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.

Half Cycle A cycle length that is half the duration of the cycle length of other signals in a coordinated system. Also referred to Double Cycle.

Interconnect Wired or wireless interconnection between two or more controllers that facilitates the operation of closely spaced signals.

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 pedestrian right-of-way at an intersection. Main road traffic is fully signalized while the side road(s) are 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 1.0 indicates equal distribution across all lanes.

Leading Pedestrian Intervals (LPI) A Leading Pedestrian Interval (LPI) provides an advanced walk signal so that pedestrians begin to cross the street before vehicles get a green signal. The purpose of LPI is to provide pedestrians an advantage over turning vehicles at signalised intersections.

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.

Midblock Pedestrian Signal (MPS) A control device dedicated primarily to providing pedestrian right-of-way at midblock locations. Main road traffic is fully signalised. The pedestrian phase is called by pedestrian pushbuttons.

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.

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 when 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.

Pedestrian Actuated (PA) Mode of Control A signal operation at a mid-block pedestrian crossing that is actuated by a pedestrian pushbutton. It provides pedestrians with a protected crossing opportunity by requiring motorists to stop at the signal.

Pedestrian Recycle (PR) An operational feature, installed at semi-actuated signalised intersections, to increase operational efficiency, which causes the main street pedestrian signals to display the FDW every cycle. In the absence of side street demand at the end of the main street FDW, the signal will revert to main street walk. The City uses the PR feature under coordinated operation.

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 Left Turn Movement Phasing sequence which provides a separate phase for left-turning traffic only. It allows left turns to be made only on a green left arrow signal indication, with no pedestrian movement or no opposing vehicular traffic conflicting with the left turn.

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 applying all of the adjustment factors. The Saturated Flow Rates represent the number of lanes multiplied by the Ideal Saturated Flow Rate and adjustment factors due to heavy vehicles, buses, parking maneuvers, lane widths, area type, grade, and turning movements.

Semi-actuated with Fixed Time Pedestrian Mode of Control (SA1) A signal operation in which one or more phases are actuated, however the main street, side street and associated pedestrian phases are on recall. Vehicle detection is provided for actuated phases (typically a turning movement).

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 phase is actuated and extendible by vehicle call only.

Semi-actuated Mode of Control (SA2) A signal operation in which the signal display will not change to the side street unless a vehicle or pedestrian has been detected.

Sydney Coordinated Adaptive Traffic System (SCATS) An adaptive traffic control system that manages timing of signal phases at traffic signals for individual intersections as well as for a segment of the network equipped with SCATS. The system is based on the automatic plan selection from a library in response to the data derived from loop detectors or other road traffic sensors.

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 A type of LRV used along streetcar routes typically in an urban setting. Typical streetcar routes can either operate separated from other modes of traffic, or share the right-of-way with other users. There are three types of Streetcars used in Toronto, all with varying characteristics: Canadian Light Rail Vehicle (CLRV), Articulated Light Rail Vehicle (ALRV) and Flexity Outlook.

Streetcar CLRV A streetcar used by the TTC since the 1970's. Generally speaking, a "streetcar" is a type of LRV which runs on tracks in mixed traffic. Specifications: Length: 15.3m, Max speed: 80km/h, Seating: 42, Capacity: 102, Braking rate: 1.6 m/s/s.

Streetcar ALRV A longer articulated double model of the CLRV. Specifications: Length: 23.2m, Max speed: 80km/h, Seating: 61, Capacity: 155, Braking rate: 1.6 m/s/s.

Streetcar Flexity Outlook The Flexity Outlook is the first modern low-floor and wheelchair accessible streetcar used in the City of Toronto by TTC. Specifications: Length: 30.2m, Max speed: 70km/h, Seating: 70, Service Load: 132, Crush Load: 251.

Traffic Management (TM) Section A section within the Transportation Services Division that is comprised of seven units: Active Traffic Management; Traffic Systems Planning, Design and Capital Coordination; Traffic Systems Construction and Maintenance; Traffic Systems Operations; and Traffic Operations, Traffic Operations (Area 1 and Area 2); and Work Zone (Construction Coordination).

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. 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) An operational feature, installed at semi-actuated signalised intersections where the signal operates in free mode. WRM causes the signal to rest in main street green and walk, forces the main street FDW when a side street vehicle or pedestrian call is received, and reverts back to main street green and walk if the side street call is cancelled before the end of the main street FDW.

Executive Summary

INTRODUCTION

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 2.9 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 over 2,400 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 and to provide an equitable level of service to all road users.

Synchro is the deterministic analysis and optimization software that the City uses to conduct these operational and planning analyses. The "Guidelines for Using Synchro 11 (including SimTraffic 11)" was developed to provide guidance to the following:

- City staff conducting operational analysis relating to signal optimisation, bicycle lane implementation, HOV implementation, development of construction timings etc.;
- Consultants (working for the City) conducting operational analysis relating to signal optimisation, bicycle lane implementation, HOV implementation etc.;
- City staff reviewing transportation impact studies submitted by developers and their consultants; and
- Consultants working on behalf of third parties.

All traffic analyses performed by the analyst using Synchro Version 11 (or later), shall conform to the Guidelines outlined in this document. All assumptions contained within these Guidelines are consistent with the following City documents:

- *Traffic Signal Operations Policies and Strategies* (December 2020);
- *Pedestrian Timing at Signalised Intersections* (May 2019);
- *Vehicle Change and Clearance Intervals* (May 2020); and
- *Spacing of Traffic Signals* (July 2020).

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

- Highway Capacity Manual 6th Edition (HCM 6);
- 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 measures of effectiveness (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. On a case-by-case basis, it is the responsibility of the analyst to discuss the scope of work, analysis methodologies to be used, and the measures of effectiveness with City staff, prior to proceeding, in order to properly assess the analysis requirements.

1. INTRODUCTION

1.1. Background

All traffic analyses using Synchro Version 11 (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 following policy documents:

- *Traffic Signal Operations Policies and Strategies* (December 2020);
- *Pedestrian Timing at Signalised Intersections* (May 2019);
- *Vehicle Change and Clearance Intervals* (May 2020); and
- *Spacing of Traffic Signals* (July 2020).

If there are discrepancies between the Synchro Guidelines and the above four documents, the assumptions presented within the most recent document hold precedent. It is the responsibility of the analyst to discuss any discrepancies and/or assumptions with City staff prior to proceeding.

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

1.2. Planning vs. Operational Analysis

Planning techniques are used for longer-range projects and for helping to determine 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 the 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 Cubic/Trafficware *Synchro Studio 11 User Guide* for detailed information (by pressing the “F1” while using the Synchro software, the user can access a “PDF” copy of the User Guide). 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

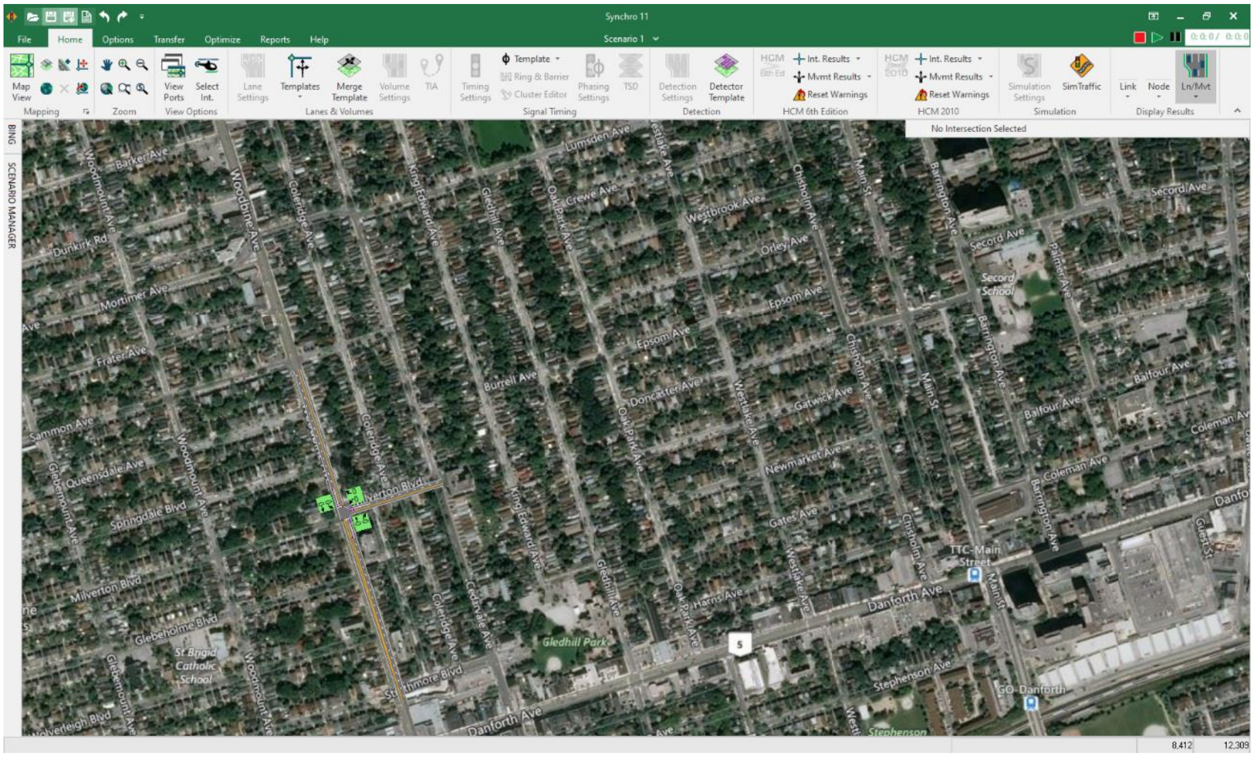


Figure 2-1 Map View with Base Map

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 Bing Maps or 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. Refer to the *Synchro Studio 11 User Guide* for guidance on using the default Bing Maps background and for importing background images and drawings.

3. LANE SETTINGS

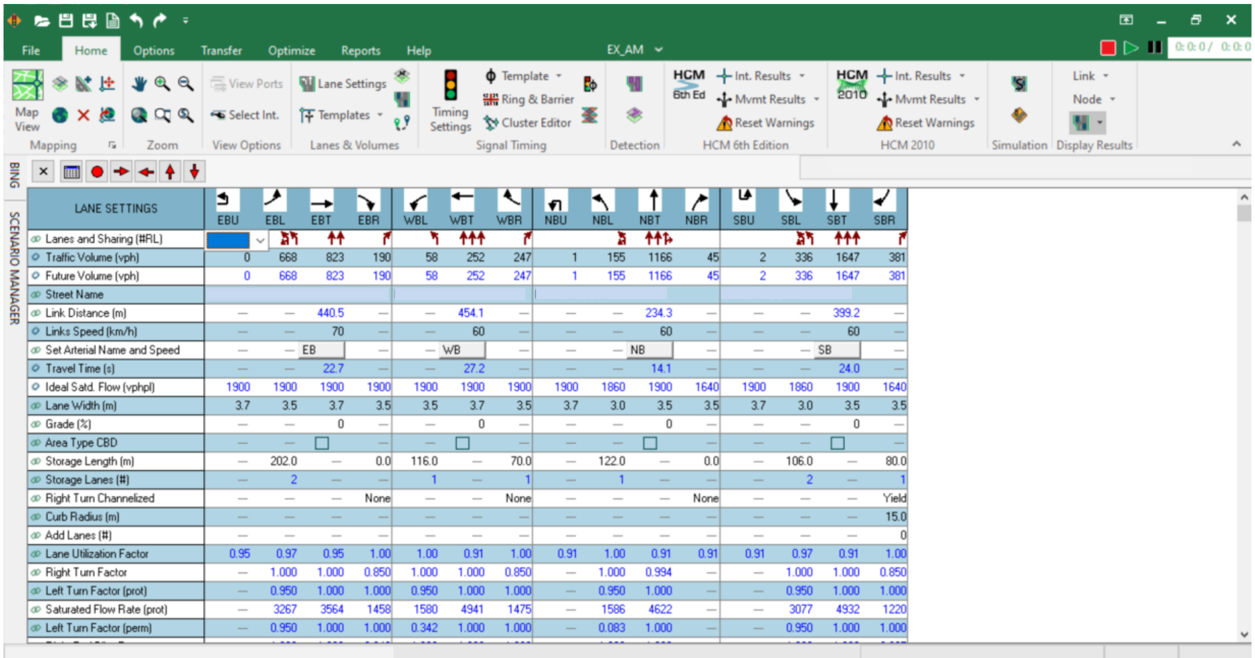


Figure 3-1 Lane Settings Window

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 North/South and East/West 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.

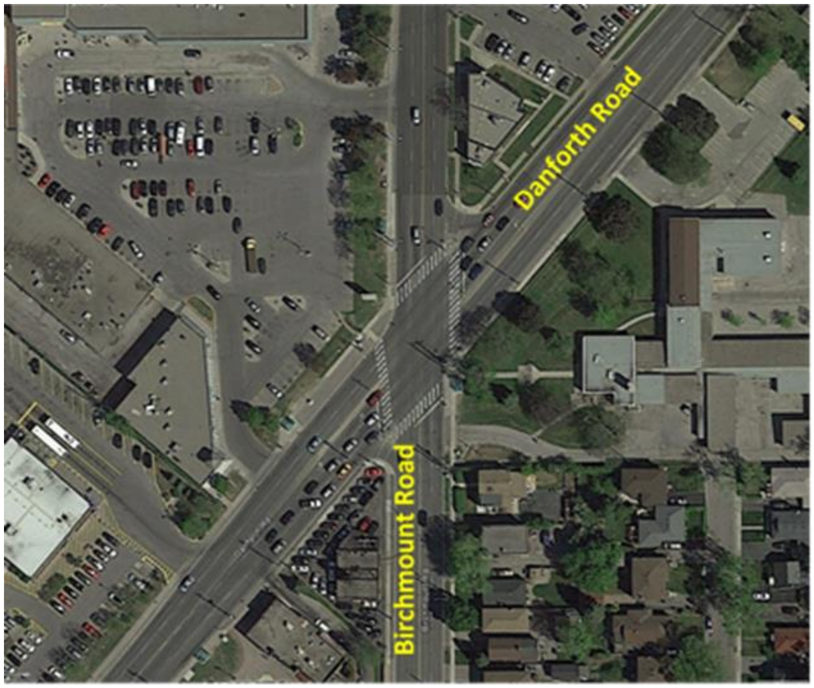


Figure 3-2 Irregular Intersection - Danforth Road and Birchmount Road

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 Data and Analytics Unit (D&AU). The email address for requesting volumes is VolumeCollision_Requests@toronto.ca. If D&AU's current volumes are not available, then the analyst can undertake his/her own traffic counts. Unless otherwise specified, the volumes supplied by the D&AU 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. Therefore, 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 his/her 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 Adjust, 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 D&AU, 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 and is the default value generated by Synchro. This value is modified by the Synchro software using a variety of adjustment factors, and then there are two separate saturated flow rates that are calculated for the permitted movement and for the protected movement (when applicable). The calculated values should match the field collected saturated flow rates. User judgement must be applied; the goal is to ensure that the calculated saturated flow rate replicates field conditions as much as possible. These adjustment factors are shown in the “Lane” and “Volume” Windows.

Saturation flow adjustment factors as well as the ideal saturated flow rates may be superseded if field measured saturation flows have been measured for the particular movement and are entered directly into the Saturated Flow Rate (perm) or Saturated Flow Rate (prot) fields on the “Lane” window.

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 ideal saturated flow rate adjustments that result in calculated (protected) saturated flow rate 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. The grade is entered in Synchro as a percentage. A positive value is used for an uphill grade, and a negative value is used for a downhill grade.

Refer to the City's *Standard Operating Procedure for Vehicle Change and Clearance Intervals (May 2020)* for guidance on how to calculate the approach grade.

3.1.10. **Area Type**

There are two areas in Toronto – Area 1 (Toronto/East York and Scarborough) and Area 2 (Etobicoke/York, North York). The downtown area of Toronto is generally considered to be the area bounded by Queens Quay, Spadina Ave, College St/Carlton St, and Jarvis St. Most of the 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; 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 HCM 6th Edition 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 10.5 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 “complete implementation of the HCM 2000 permitted left turn model”, to calculate the permissive left turn adjustment factor.

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 (prot). 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

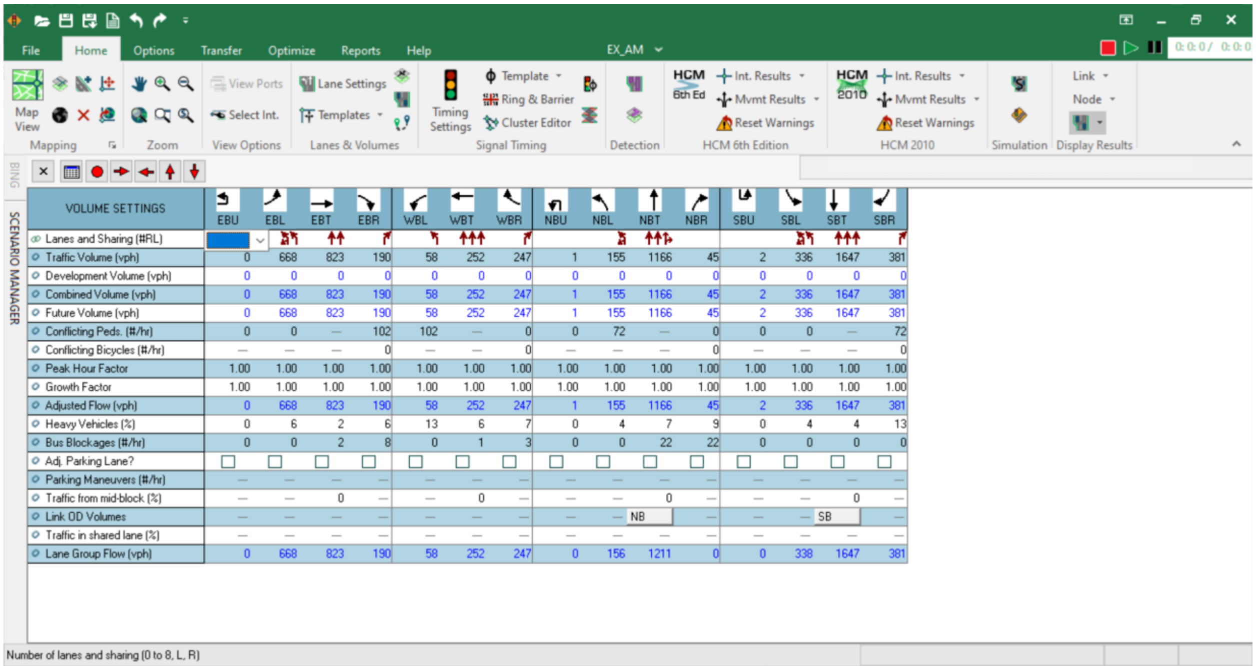


Figure 4-1 Volume Settings Window

4.1. User Inputs

4.1.1. Conflicting Pedestrians (#/hr)

At locations where there are pedestrians crossing the roadway, the hourly number of pedestrians that conflict with right- or left-turning traffic must be entered.

4.1.2. Conflicting Bicycles (#/hr)

This value represents the number of bicycles per hour that conflict with right-turning traffic.

4.1.3. 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 D&AU TMC 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 D&AU), 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;

   a. 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:
   b. 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.

4.1.4. 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.

4.1.5. Heavy Vehicles (%)

Heavy vehicles are defined as vehicles larger than typical passenger vehicles such as single-unit trucks, tractor-trailers and buses. The number of heavy vehicles for each movement is shown on the counts provided by the D&AU. Synchro applies a default of 2%, which can be edited to reflect actual field conditions.

4.1.6. 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.

4.1.7. 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.

4.1.8. 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.

4.1.9. 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.

4.1.10. 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.

4.1.11. TIA Module

Synchro 11 features a TIA Module which can distribute and assign development generated traffic volumes throughout the road network. It is the responsibility of the analyst to discuss with City Staff whether to use this module for the analysis. Refer to the Synchro Studio 11 User Guide for further information on the TIA Module.

4.1.12. Scenario Manager

Synchro 11 features the Scenario Manager that combines similar models into a single-file format, to improve file management and reduce model development and maintenance efforts. The functionality of scenario manager includes:

- Saving multiple scenarios such as AM peak, PM peak, existing and future traffic, to a single Synchro file versus the challenge of managing multiple files for each analysis scenario;
- Modifying the timing plans for each scenario separately;
- Modifying the volumes for each scenario separately;
- Updating geometry in one scenario while automatically applying to all scenarios; and
- Switching between scenarios to easily compare analysis results with different volumes and/or timings.

Refer to the *Synchro Studio 11 User Guide* for further information on the Scenario Manager.

4.2. Synchro Calculated Values

4.2.1. Development Volume (vph)

This value represents the total volume of traffic generated by developments created in the TIA module. The value can only be changed in the TIA module.

4.2.2. Combined Volume (vph)

This value is equal to the entered volume plus the “Development Volume”. This value cannot be overwritten.

4.2.3. Future Volume (vph)

The “Future Volume” is calculated by applying a growth factor to the “Combined Volume”. This growth factor is defined in the TIA module.

4.2.4. Adjusted Flow (vph)

This value is equal to the “Future Volume” divided by the Peak Hour Factor and multiplied by the Growth Factor. The value must not be overwritten.

4.2.5. 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.

4.2.6. 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

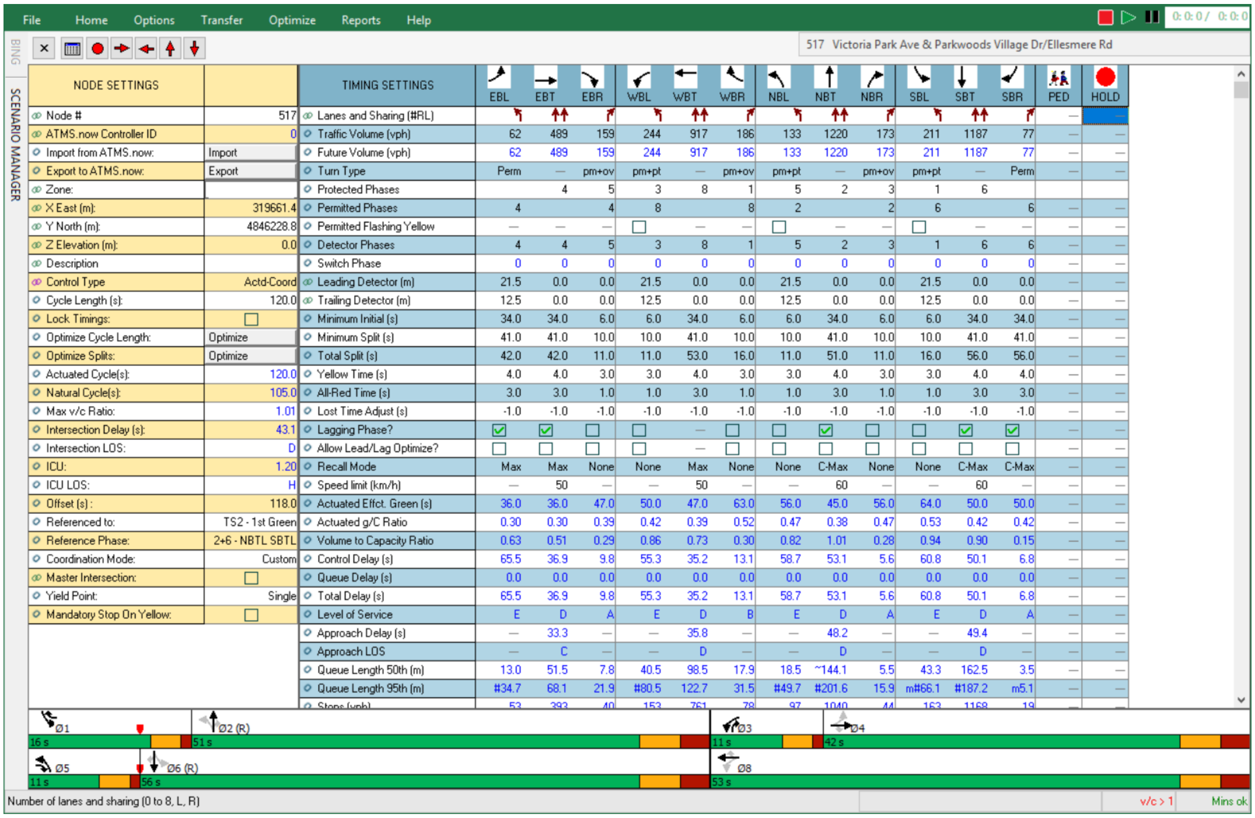


Figure 5-1 Timing Settings Window

5.1. Node Settings - User Inputs

5.1.1. Node

A signal's identification number, known as a TCS 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 Systems Operations unit, is used in selecting the appropriate controller type. The email address for requesting signal timings is signaltimings@toronto.ca. The MOC for existing signals in the City must remain the same during the intersection analysis. The Control Type 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.

If the signal operates under free operation, or operates on an Adaptive Traffic Control System (ATCS), then the mode of control should be set to “Actuated-Uncoordinated”. For all other signals, the City uses the following modes of control:

1) **Fixed Time (FT) –** FT is a signal operation in which the vehicle and pedestrian signal displays automatically alternate between the main street and the side street, even if there are no vehicles on the side street and/or no pedestrians wishing to cross the main street. FT Signals do not have any vehicle detection and except for the purpose of providing Audible Pedestrian Signals (APS), there is no pedestrian actuation.

2) **Semi-actuated Pedestrian (SAP)** – SAP is a signal operation in which signals will not change to the side street unless a vehicle or pedestrian has been detected. Demand on either a vehicle presence loop detector or a pedestrian pushbutton will actuate both the vehicle green and pedestrian "walk" display. Vehicles and pedestrians receive the same amount of time regardless of the actuation source. There are no vehicle extensions.

3) **Semi-actuated with Fixed Time Pedestrian (SA1)** – SA1 is a signal operation in which one or more phases are actuated, however the main street, side street and associated pedestrian phases are on recall. Vehicle detection is provided for actuated phases (typically a turning movement) and except at Accessible Pedestrian Signal locations, there are no pedestrian pushbuttons.

4) **Semi-actuated (SA2) –** SA2 is a signal operation in which the signal display will not change to the side street unless a vehicle or pedestrian has been detected. The side street signal display and vehicle green time varies depending on whether a pedestrian call has been received or not. Pushbutton activation is required for the “walk” indication to be displayed. Demand on only a vehicle detector actuates the vehicle green display the "don't walk" display will continue to be displayed for pedestrians. If there is no continued vehicle presence, vehicles receive a minimum green time. If there is continued vehicle presence on the detector, the side street green time can be extended to a predetermined maximum value. Demand on a pedestrian pushbutton actuates both the vehicle green display and the "walk" display for the pedestrian minimum green time, followed by a "flashing don't walk" display, while the vehicle green continues to be displayed.

5) **Semi-actuated Vehicle (SAV)** – SAV is a signal operation in which there is no pedestrian crossing across the main street and side street phase is actuated and extendible by vehicle call only. If there is no continued vehicle presence, vehicles receive a minimum green time. Continued vehicle demand extends the vehicle green display up to a predetermined maximum value.

6) **Pedestrian Actuated (PED)** – PED is a signal operation at Midblock Pedestrian Signals (MPS) and Intersection Pedestrian Signals (IPS), where the pedestrian crossing is actuated by a pedestrian pushbutton. It provides pedestrians with a protected crossing opportunity by requiring motorists to stop at the signal.

7) **Fully Actuated (FA)** – FA is a signal operation in which all phases are actuated.

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 closely spaced, providing coordination becomes critical for motorist safety and traffic flow.

For the purpose of determining if the closely spaced signal criteria applies, signal spacing shall be measured as the distance from the downstream curb of the crossing street at the first intersection to the stop line of the second intersection, as denoted by D_{Link} in Figure 5-2 below. Where the road is bidirectional, signal spacing must be measured in both directions and the shorter distance used.

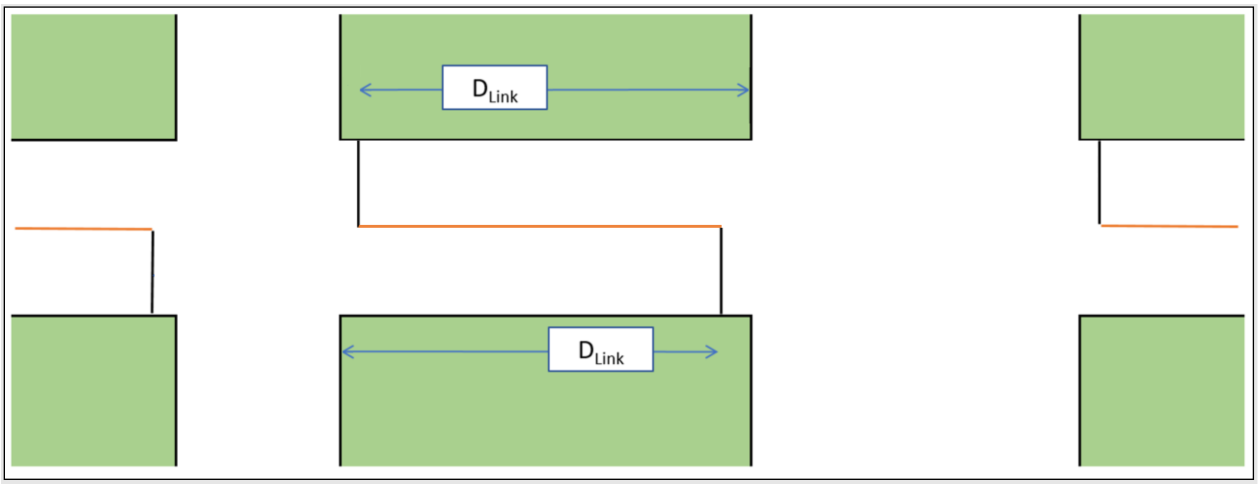


Figure 5-2 Signal spacing distance measurement

Signals are considered closely spaced when the signal spacing (D_{Link}) is less than the minimum distances in Table 5-1:

Table 5-1 Minimum signal spacing for closely spaced signals

Posted Speed (km/h)	Minimum Distance, D_{Link} (m)
30	65
40	85
50	110

60	135
70	165

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 90 seconds in the morning and afternoon peak periods and 80 seconds in the off-peak period, except on arterials with long pedestrian crossing distances such as University Ave and Spadina Ave. In suburban areas, where intersections with more than four phases are more common, the City restricts the maximum cycle length at major intersections on major arterials to the 130 – 140 seconds range, based on 1.0 m/s walk speed.

During the peak periods, minor intersections on an arterial route may operate at longer cycle lengths to maintain signal coordination. Where the percentage of traffic flow is greater than 55% in one direction, one way progression in that direction is to be provided; otherwise two way progression is to be provided. The City may consider half cycling for MPS and IPS during all coordination plans, if conditions permit. For half cycling, the higher cycle length must be an even number.

Refer to the City's *Traffic Signal Operations Policies and Strategies* (2021), the City's *Standard Operating Procedure for Vehicle Change and Clearance Intervals* (May 2020), and the City's Standard *Operating Procedure for Pedestrian Timing at Signalised Intersection* (May 2019) for more details.

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 TSO.

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 at ramp signals or 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.

When signals meet the City's closely spaced criteria, mitigating measures can impact the signals' offsets. Refer to the City's *Traffic Signal Operations Policies and Strategies*, Section 5.8 (2021) for additional information on signal coordination and signal spacing mitigation strategies.

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 ASC-2, Econolite ASC-3, Econolite Cobalt and Peek 3101 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. Coordination Mode

This field is a shortcut that will toggle the "Fixed Force Off" checkmark for all semi-actuated phases. Refer to Section 6.1.9 for more on Fixed Force Off.

5.1.9. 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.

5.1.10. Yield Point

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

5.1.11. 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 TSO. 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 3.1.16);
- NA (used where right turns are prohibited); and
- Custom (non-standard right turn phases).

5.2.2. Protected & Permitted Phases

Figure 5-3 below shows the phase numbers normally assigned to different movements, depending on the direction of the main street.

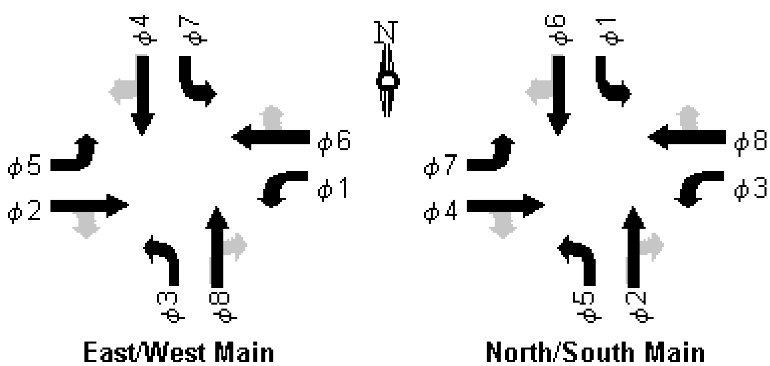


Figure 5-3 Typical Phases Associated with Movements

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. 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 7.1.37.1.2 and 7.1.4.

5.2.5. **Minimum Initial (s)**

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

At Semi-actuated (SA) 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 Ontario Traffic Manual, Book 12A (Bicycle Traffic Signals), should be considered.

5.2.6. **Minimum Split (s)**

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 TSO when signal timing information is requested. Refer to Section 6.1.6 and 6.1.7 for additional information on Walk and Flashing Don't Walk times. The total split time is the total phase time including the green, yellow, and all-red time.

5.2.7. **Yellow Time (s)**

The yellow time (or change intervals) for all phases must comply with the Ontario Traffic Manual, Book 12. The posted speed shall be used as the design criteria. The minimum amber interval is 3.0 seconds.

The amber change interval for through traffic is calculated using the following equation:

$$Y = t + v / (2a + 70.6g)$$

where:

Y = amber/yellow interval
t = driver perception and reaction time (1.0s)
v = vehicle approach speed (km/h)
a = vehicle deceleration (11km/h/s)
70.6 = represents twice the acceleration of gravity (km/h/s)
g = percent road grade (as a decimal); positive for uphill, negative for downhill

In addition, adjustments for buses, heavy vehicles, bicycles, dedicated transit phases, and other vehicles should also be reviewed on an intersection-by-intersection basis when determining amber intervals.

Refer to the City's *Standard Operating Procedure for Vehicle Change and Clearance Intervals (May 2020)* for more details.

5.2.8. All-Red Time (s)

The all-red time (or clearance intervals) for all phases must comply with the Ontario Traffic Manual, Book 12. The posted speed shall be used. The minimum all-red clearance is 1.0 second.

The standard all-red clearance for through traffic is:

$$R = \{ 3.6 (w + l) / v \}$$

where:

R = all-red interval
3.6 = represents the factor to convert km/h to m/s
w = vehicle crossing distance (m)
l = average vehicle length (6.0 m for vehicles)
v = vehicle approach speed (km/h)

Given that bicycles travel at slower speeds than vehicles, cyclists require less time to perceive an amber indication and stop safely prior to the onset of the red, and they require more time to cross the intersection after crossing the stop bar. For an exclusive bicycle phase, the methodology below is implemented:

$$R = \{ 3.6 (w + l) / v \}$$

where:

R = all-red interval
3.6 = represents the factor to convert km/h to m/s
w = vehicle crossing distance (m)
l = average vehicle length (1.8 m for bicycles)
v = vehicle approach speed (17 km/h for bicycles)

In addition, adjustments for buses, heavy vehicles, bicycles, dedicated transit phases, and other vehicles should also be reviewed on an intersection-by-intersection basis when determining all-red clearance intervals.

Refer to the City's *Standard Operating Procedure for Vehicle Change and Clearance Intervals (May 2020)* for more details.

5.2.9. 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.

5.2.10. 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.

5.2.11. 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.

5.2.12. 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).

If a signal is operating under FREE operation, the main phases are set to "Max" and "None" is selected for the side streets. Main streets are typically assigned phases 2 and 6.

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 the HCM 6 methodology. It is the responsibility of the analyst to discuss with the City the analysis methodologies to be used. Please refer to Section 912 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 ATCS signals such as SCOOT and SCATS.
- 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 amber (change) and all-red (clearance times), then the effective green times for the phase may be increased accordingly (by adjusting the Lost Time Adjust field). The Lost Time Adjustment should never be greater than the available amber change time because that would imply vehicles are travelling through the intersection during an all-red clearance time.

Saturated Flow Rates may be adjusted to fine tune the Synchro model so that a movement is not operating over capacity (with a v/c ratio greater than 1.00). However, any modifications to the saturation flow rate beyond the limits provided in Section 3.1.7 must be supported by surveys of the saturated flow rates for each lane group.

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 volumes, 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 11 User Guide*, page 20-25:

v95 = v * PHFx * [1 + 1.64 * (sqrt (vc) / vc)]

where:

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

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 50th 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 95th percentile cycle exceeds capacity. This traffic was simulated for two complete cycles of 95th percentile traffic to account for the effects of spillover between cycles. If the reported v/c < 1.0 for this movement, the methods used represent a valid method for estimating the 95th percentile queue. In practice, 95th 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 does 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 95th percentile queue is metered by an upstream signal. This means that the presence of the upstream signal is controlling the arrival of vehicles at the downstream intersection, thus limiting the queue length. In many cases, the 95th 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 50th percentile queue divided by the upstream v/c ratio. For example, if the 50th 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 intersection (B) would not occur, neither would the 95th percentile queues.

6. PHASING SETTINGS

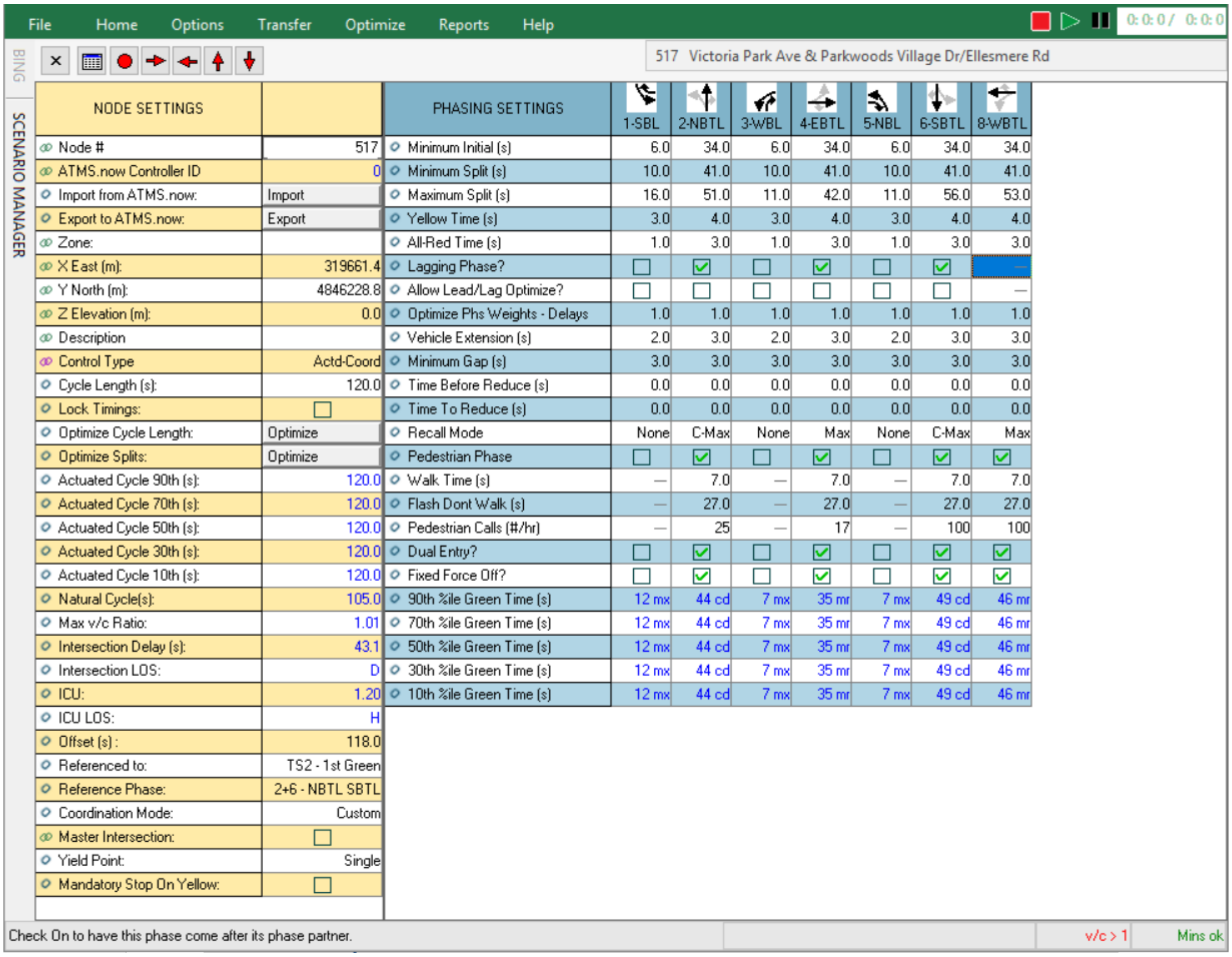


Figure 6-1 Phasing Settings Window

6.1. User Inputs

6.1.1. Vehicle Extensions (Maximum Gap) (s)

Vehicle Extension is also known as the maximum gap. When a vehicle crosses a detector, it will extend the green time by the Vehicle Extension time. The minimum vehicle passage time shall be as follows:

a) Protected/permissive left-turns with setback detection – 2.0 seconds;
b) Fully protected left-turns with stop bar detection – 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 (s)

This is the Minimum Gap time that the controller will use with volume-density operation. If volume-density operation is not used, set this value to the same as the Vehicle Extension.

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

6.1.3. **Time Before Reduce (s)**

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 (s)**

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 (also known as maximum gap) to Minimum Gap.

6.1.5. **Pedestrian Phase**

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

6.1.6. **Walk Time (s)**

Walk time is the amount of time for the pedestrian “Walk” signal is displayed. Pedestrian Walk phases are only provided when the phase has pedestrian calls (i.e. pushbutton), or if the pedestrian phase has a recall. This value can be ignored if the phase is in maximum recall and the split is long enough to accommodate pedestrians.

The pedestrian minimum "walk" and clearance intervals shall be determined in accordance with 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 *Pedestrian Timing at Signalised Intersections* guidelines (May 2019).

6.1.7. **Flashing Don’t Walk (s)**

This is the pedestrian clearance time. This value can be ignored if the phase is in maximum recall and the split is long enough to accommodate pedestrians.

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 walk speed should be equal to or less than 1.0 m/s for the total of Walk plus FDW intervals. Refer to the City's *Pedestrian Timing at Signalised Intersections* (May 2019) guidelines for walk speeds less than 1.0 m/s.

When checking and optimizing splits, Synchro requires that the green time be greater or equal to the walk plus flashing don’t walk time. The vehicle change and clearance intervals are not part of the flashing don’t walk interval.

6.1.8. Pedestrian Calls (#/h)

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. Conflicting Pedestrians is the number of pedestrians that right turning traffic must yield to. Pedestrian Calls are the number of pedestrians activating this phase. Normally the two values will be the same.

When counting pedestrians, people traveling in groups can be counted as a single pedestrian call. This value is used to determine how many cycles per hour will need to have a pedestrian phase.

In the absence of field observations, the number of pedestrian calls can be estimated using the procedure on page 12-9 to page 12-10 of the *Synchro 11 User Guide*.

6.1.9. Fixed Force Off?

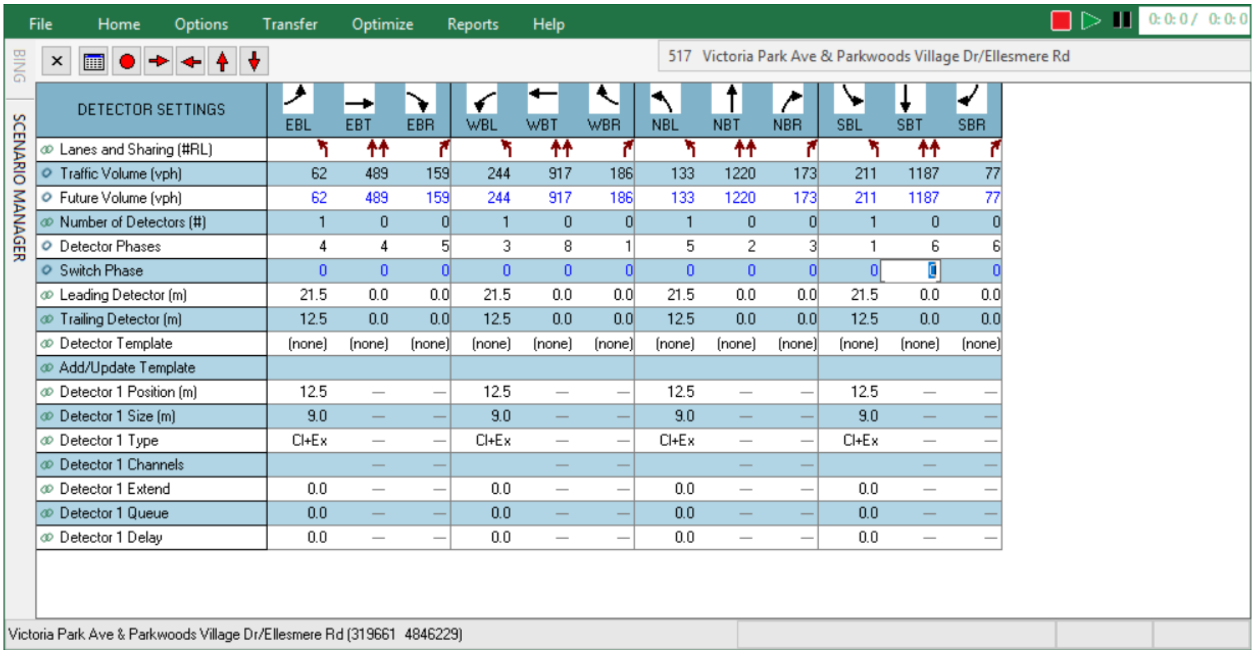
Set Fixed Force Off to “On” to give more time to side streets. Set Fixed Force Off to “Off” to give all extra time back to the main street.

The amount of time available for side street phases and their starts can also be manipulated by the Yield Point and using Actuation for the Coordinated phases.

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

- For signals equipped with interval-based controllers, all phases at fixed and semi-actuated intersections should have a checkmark;
- For signals equipped with phase-based controllers, all phases at fixed intersections and main street phases at semi-actuated intersections should have a checkmark;
- For signals equipped with phase-based controllers, the side street phases at semi-actuated intersections should not have a checkmark; and
- Fixed force off should be disabled for left-turn phases.

7. DETECTOR SETTINGS



DETECTOR SETTINGS	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lanes and Sharing (#RL)												
Traffic Volume (vph)	62	489	159	244	917	186	133	1220	173	211	1187	77
Future Volume (vph)	62	489	159	244	917	186	133	1220	173	211	1187	77
Number of Detectors (#)	1	0	0	1	0	0	1	0	0	1	0	0
Detector Phases	4	4	5	3	8	1	5	2	3	1	6	6
Switch Phase	0	0	0	0	0	0	0	0	0	0	0	0
Leading Detector (m)	21.5	0.0	0.0	21.5	0.0	0.0	21.5	0.0	0.0	21.5	0.0	0.0
Trailing Detector (m)	12.5	0.0	0.0	12.5	0.0	0.0	12.5	0.0	0.0	12.5	0.0	0.0
Detector Template	(none)	(none)	(none)	(none)	(none)	(none)	(none)	(none)	(none)	(none)	(none)	(none)
Add/Update Template												
Detector 1 Position (m)	12.5	—	—	12.5	—	—	12.5	—	—	12.5	—	—
Detector 1 Size (m)	9.0	—	—	9.0	—	—	9.0	—	—	9.0	—	—
Detector 1 Type	Cl+Ex	—	—	Cl+Ex	—	—	Cl+Ex	—	—	Cl+Ex	—	—
Detector 1 Channels		—	—		—	—		—	—		—	—
Detector 1 Extend	0.0	—	—	0.0	—	—	0.0	—	—	0.0	—	—
Detector 1 Queue	0.0	—	—	0.0	—	—	0.0	—	—	0.0	—	—
Detector 1 Delay	0.0	—	—	0.0	—	—	0.0	—	—	0.0	—	—

Figure 7-1 Detector Settings Window

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 **Error! Reference source not found.**.

7.1.3. Leading Detector (m)

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 phases at actuated signals, stop bar detectors are used where the leading detector is normally located 7.5 metres from the stop bar;

- For fully protected left-turns, stop bar detectors are used where the leading detector is normally located 7.5 metres from the stop bar; and
- For protected/permissive left-turns, setback detectors are used where the leading detector is normally located 12.5 metres from the stop bar for third vehicle detection and 6.25 m for second vehicle detection.

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

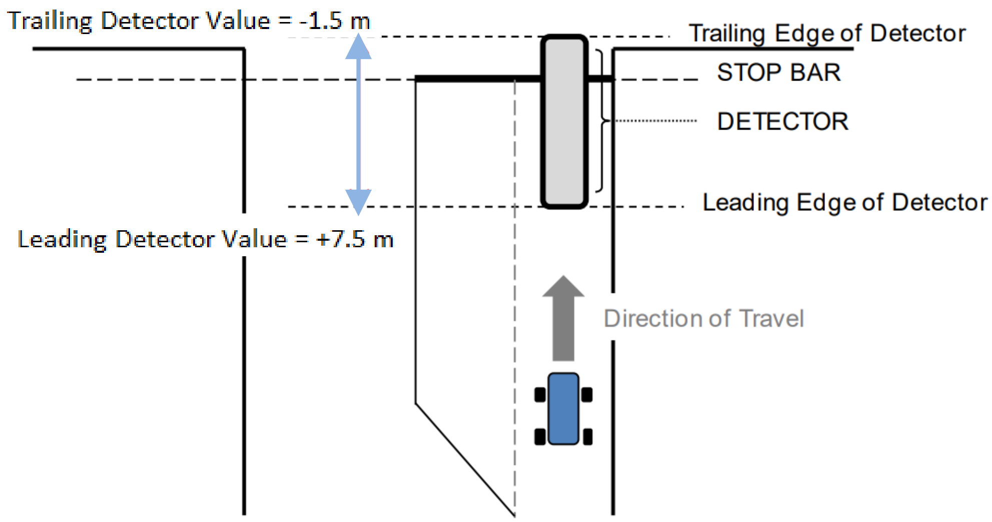


Figure 7-2 Side Street or Protected Left-Turn Detection - First Vehicle Stop Bar Detection

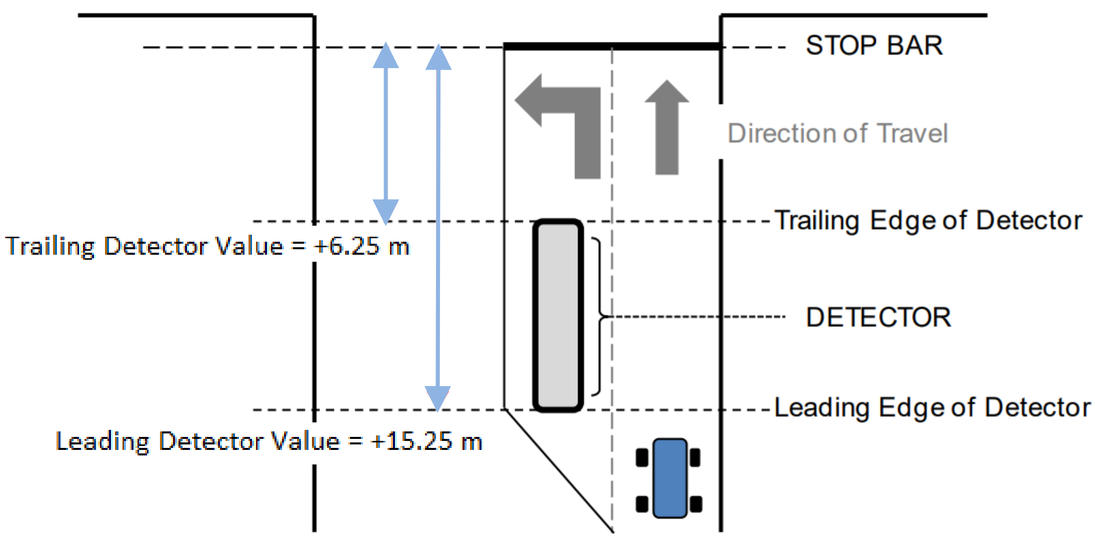


Figure 7-3 Protected/Permissive Left-Turn Detection - Second Vehicle Setback Detection

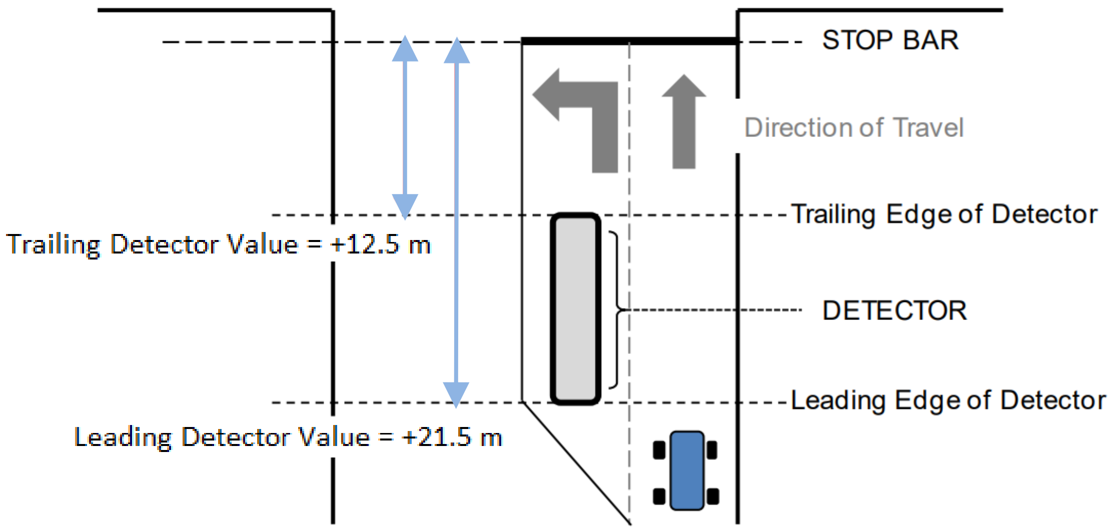


Figure 7-4 Protected/Permissive Left-Turn Detection - Third Vehicle Setback Detection

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 (m) and Detector 1 Position (m)

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 detectors are used where the trailing detector is normally located -1.5 metres from the stop bar;
- For fully protected left-turns, stop bar detectors are used where the trailing detector is normally located -1.5 metres from the stop bar; and
- For protected/permissive left-turns, setback detectors are used where the trailing detector is normally located 12.5 metres from the stop bar in left turn lanes for third vehicle detection and 6.25 m for second vehicle detection.

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.

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 (m)

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 some legacy left-turn detection 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 Channel

The Detector Channel is not currently used by Synchro or SimTraffic. Refer to the *Synchro Studio 11 User Guide* for more information.

7.1.9. 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.

7.1.10. 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

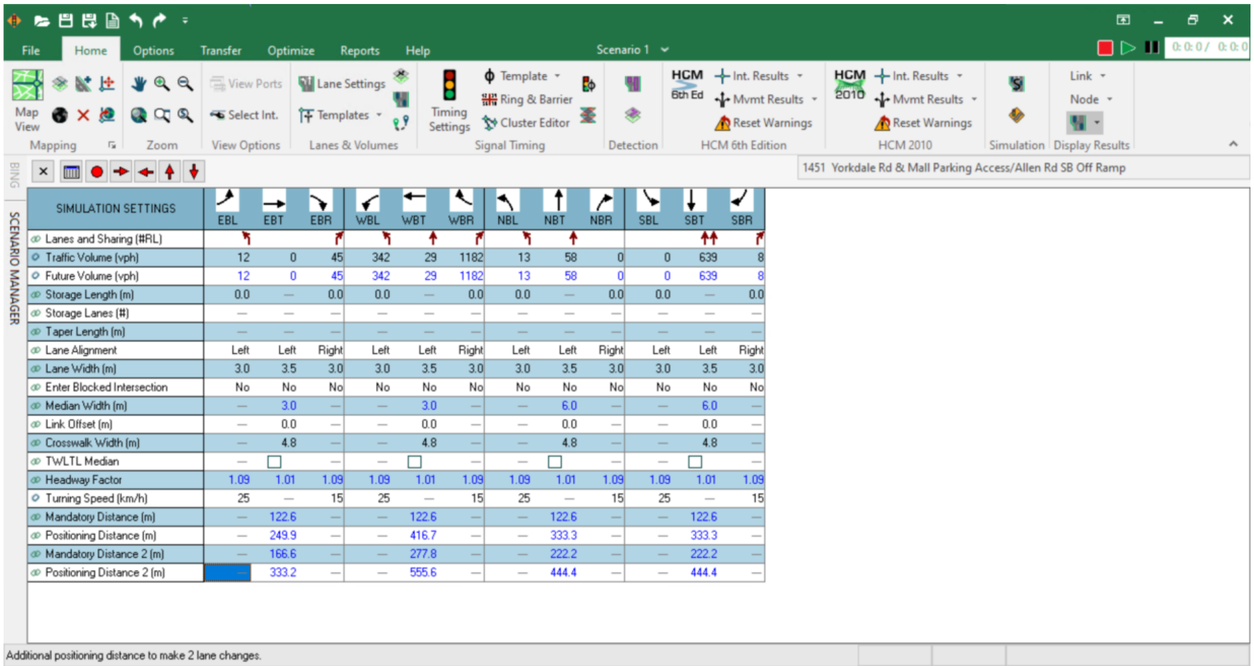


Figure 8-1 Simulation Settings Window

8.1. User Inputs

"Lanes and Sharing", "Traffic Volume", "Storage Length", "Storage Lane" and "Lane Width" 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 (m)

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 Studio 11 User Guide* 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 (m)

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 10.10 for additional information regarding offset intersections.

8.1.5. Crosswalk Width (m)

This distance is measured from the stop bar to the far side of the crosswalk. The following default values are used by SimTraffic:

- 4.8 meters for conventional intersections; and
- 9.0 meters for midblock/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)

The default turning speed is 14 km/h for right turns and 24 km/h for left turns. Consideration should be given to update these values by interpolating the cornering speed using Table 3-1 of the City's *Standard Operating Procedure for Vehicle Change and Clearance Intervals (May 2020)* which summarizes the relationship between vehicle cornering speed and curve radii. Synchro does not use this information; it is only used for SimTraffic.

9. HCM 6TH EDITION SETTINGS

Although some values from the previous settings windows translate over into HCM 6th Edition settings, it is recommended that data input for HCM 6th Edition analysis be input directly into the HCM 6th Edition settings window and tabs. It is the responsibility of the analyst to ensure proper input within the HCM 6th Edition settings window and tabs.

9.1. Signalized Intersections – Auto Mode

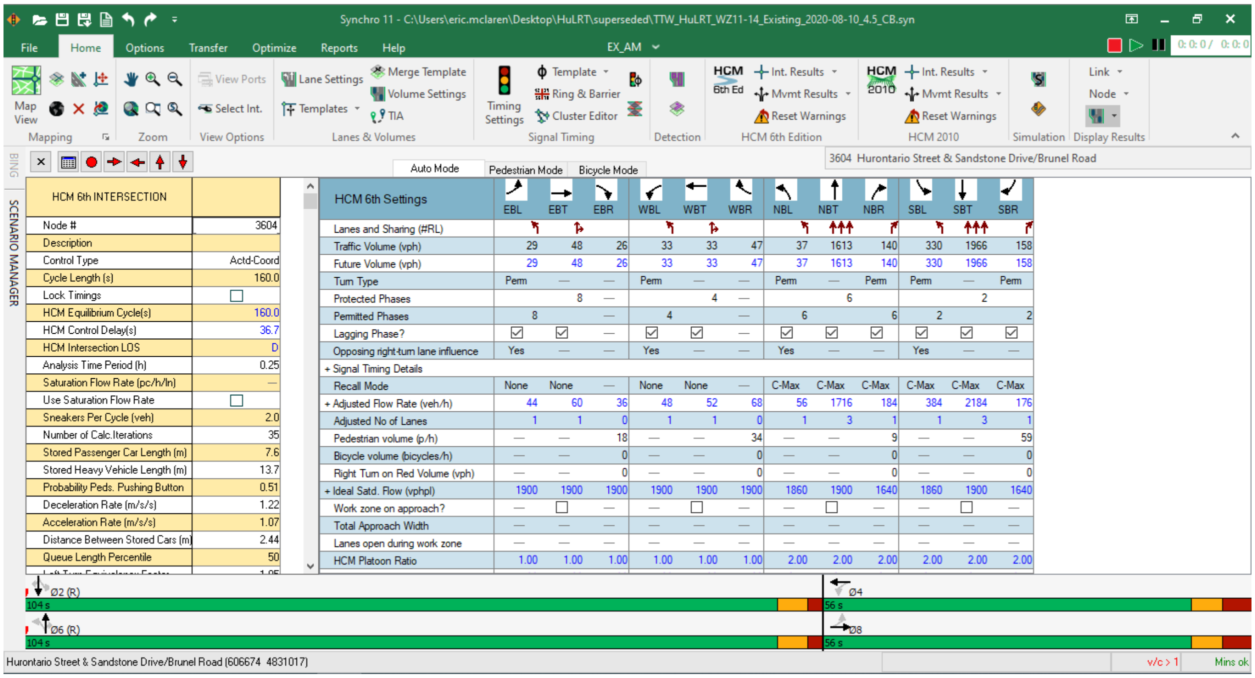


Figure 9-1 Auto Mode Window

9.1.1. HCM 6th Edition Intersection Settings

9.1.1.1 Equilibrium Cycle (s)

This is the calculated Cycle Length based on the methods described in the HCM 6th Edition. 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 in the HCM 6th Edition. 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 6th Edition. 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 movement at this intersection. Otherwise, each movement's "Ideal Satd. Flow" can be defined separately within the HCM 6th Edition Settings (Section 9.1.2). The 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). The 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 6th Edition 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)

This value is 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)

This value is 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 6th Edition for more information. The Synchro default value is 0.51.

9.1.1.11 Deceleration Rate (m/s^2)

This value 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 value 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)

This value is the average distance to the nearest point of detection for two queued vehicles. The Synchro default value is 2.44 m and is referenced in HCM 6th Edition.

9.1.1.14 Queue Length Percentile

This is the length of queue that will be included in the HCM 6th Edition reports. The Synchro default value is 50. Other accepted percentiles are 85th, 90th and 95th.

9.1.1.15 Left-Turn Equivalency Factor

This factor represents the equivalent number of through vehicles for each left turn vehicle, given an exclusive lane and no conflicting movement. See HCM 6th Edition for more information. The Synchro default value is 1.05.

9.1.1.16 Right-Turn Equivalency Factor

This factor represents the equivalent number of through vehicles for each right-turn vehicle, given an exclusive lane and no conflicting movement. See HCM 6th Edition for more information. The Synchro default value is 1.18.

9.1.1.17 Heavy Vehicle Equivalency Factor

This factor represents the 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)

This represents the critical gap for permitted left turns at a signalized intersection. The Synchro default value is 4.5 s and is referenced in HCM 6th Edition.

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

This represents the follow-up time for permitted left turns from an exclusive lane at a signalized intersection. The Synchro default value is 2.5 s and is referenced in HCM 6th Edition.

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

This represents the follow-up time for permitted left turns from a shared lane at a signalized intersection. The Synchro default value is 4.5 s and is referenced in HCM 6th Edition.

9.1.1.21 Stop Threshold Speed (km/hr)

This represents 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)

This represents 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 6th Edition.

9.1.2. HCM 6th Edition Settings

9.1.2.1 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”.

9.1.2.2 Lost Time Adjust (s)

The Lost Time Adjust(ment) is the start-up lost time minus extension of effective green. The default Lost Time Adjust is 0s. Maximum Lost Time Adjust is 3s.

9.1.2.3 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 2.0 seconds. Maximum Start-up Lost Time is 10s.

9.1.2.4 Extension of Effect. Green Time (s)

The Extension of the Effective Green Time is the amount of time vehicles continue to enter after the 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 Effect Green Time is 2.0 s.

9.1.2.5 Right Turn on Red Volume (vph)

The Right Turn on Red Volumes is the volume of vehicles that turn right during the red interval. This value must be entered by the user based on volumes measured in the field, however, TrafficWare provides the following formula for estimating the right turn on red volume:

$$vRTOR = minimum(sRTOR, v) * r/C$$

Where:

vRTOR = right turn on red volume
sRTOR = RTOR saturation flow as calculated by Synchro
r = effective red time
v = adjusted lane group flow before RTOR reduction
C = cycle length

9.1.2.6 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”.

9.1.2.7 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.

9.1.2.8 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.

9.1.2.9 Work Zone on Approach?

Check this box if there is a work zone present in or adjacent to the travel lanes on the approach up to 76 metres in advance of the stop bar. This was included as part of HCM 6th Edition to adjust the saturation flow rate for work zones.

9.1.2.10 Total Approach Width

If there is a work zone on the approach, input the total width of all through, left-turn and right-turn lanes.

9.1.2.11 Lanes Open during Work Zone

If there is a work zone on the approach, input the number of through and left-turn lanes that are open during the work zone. Note that the number of right-turn lanes does not need to be inputted.

9.1.2.12 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.

9.1.2.13 HCM Upstream Filtering Factors

The Upstream Filtering adjustment Factor 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.

9.1.2.14 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.

9.1.2.15 Include Unsignalized Delay?

If this box is checked, the volume for any channelized right-turn movement with free, yield or stop control will be included in the calculation of approach delay and intersection delay.

9.1.2.16 Unsignalized Movement Delay

Input the delay for the unsignalized movement approaching a signalized intersection. Note, Synchro does not calculate this delay, therefore, it must be estimated through other means such as field measurements or SimTraffic.

9.1.2.17 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 tapering into account.

9.1.2.18 HCM 6th Edition Capacity (veh/h)

This is the calculated capacity of a lane group based on the methods described within the HCM 6th Edition . See HCM 6th Edition for details regarding the calculation of capacity for a lane group. Synchro calculates this value.

9.1.2.19 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.

9.1.2.20 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 6th Edition. 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 in the HCM 6th Edition. Synchro calculates this value.

9.1.2.21 HCM Lane Group LOS

This is the calculated LOS for the lane group based on the methods described within the HCM 6th Edition. 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 the HCM 6th Edition for detailed Automobile LOS criteria. Synchro calculates this value.

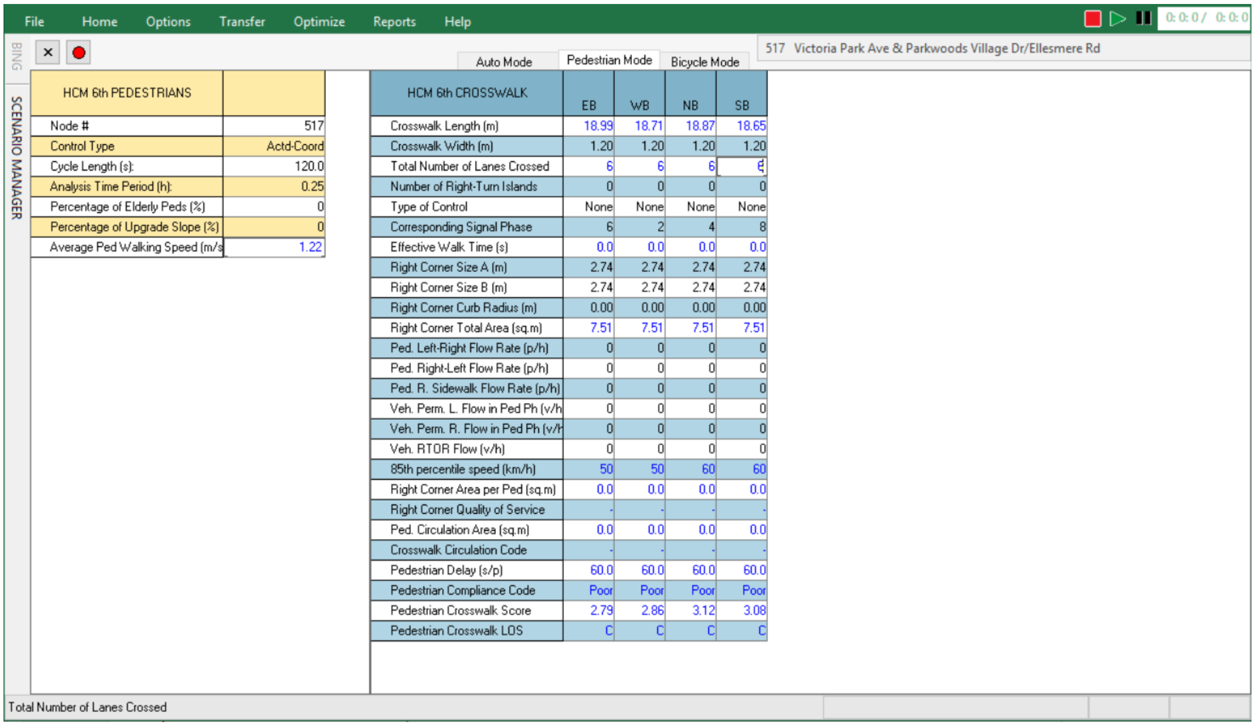
9.1.2.22 HCM Approach Delay (s/veh)

This is the calculated control delay (s) for an approach based on the methods described within the HCM 6th Edition. Synchro calculates this value.

9.1.2.23 HCM Approach LOS

This is the calculated LOS for the approach based on the methods described within the HCM 6th Edition. 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 the HCM 6th Edition for detailed Automobile LOS criteria. Synchro calculates this value.

9.2. Signalized Intersections – Pedestrian Mode



HCM 6th PEDESTRIANS	
Node #	517
Control Type	Actd-Coord
Cycle Length (s):	120.0
Analysis Time Period (h):	0.25
Percentage of Elderly Peds (%)	0
Percentage of Upgrade Slope (%)	0
Average Ped Walking Speed (m/s	1.22

HCM 6th CROSSWALK	EB	WB	NB	SB
Crosswalk Length (m)	18.99	18.71	18.87	18.65
Crosswalk Width (m)	1.20	1.20	1.20	1.20
Total Number of Lanes Crossed	6	6	6	6
Number of Right-Turn Islands	0	0	0	0
Type of Control	None	None	None	None
Corresponding Signal Phase	6	2	4	8
Effective Walk Time (s)	0.0	0.0	0.0	0.0
Right Corner Size A (m)	2.74	2.74	2.74	2.74
Right Corner Size B (m)	2.74	2.74	2.74	2.74
Right Corner Curb Radius (m)	0.00	0.00	0.00	0.00
Right Corner Total Area (sq.m)	7.51	7.51	7.51	7.51
Ped. Left-Right Flow Rate (p/h)	0	0	0	0
Ped. Right-Left Flow Rate (p/h)	0	0	0	0
Ped. R. Sidewalk Flow Rate (p/h)	0	0	0	0
Veh. Perm. L. Flow in Ped Ph (v/h	0	0	0	0
Veh. Perm. R. Flow in Ped Ph (v/h	0	0	0	0
Veh. RTOR Flow (v/h)	0	0	0	0
85th percentile speed (km/h)	50	50	60	60
Right Corner Area per Ped (sq.m)	0.0	0.0	0.0	0.0
Right Corner Quality of Service	-	-	-	-
Ped. Circulation Area (sq.m)	0.0	0.0	0.0	0.0
Crosswalk Circulation Code	-	-	-	-
Pedestrian Delay (s/p)	60.0	60.0	60.0	60.0
Pedestrian Compliance Code	Poor	Poor	Poor	Poor
Pedestrian Crosswalk Score	2.79	2.86	3.12	3.08
Pedestrian Crosswalk LOS	C	C	C	C

Figure 9-2 Pedestrian Mode Window

9.2.1. HCM 6th Edition 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 8 should be used. The value is derived from 2016 Census data, which shows approximately 15.6% 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 6th Edition 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 of the HCM 6 Settings within Auto Mode), but should be overridden where field data is available.

9.2.2.2 Crosswalk Width (m)

The crosswalk width represents an effective width. Unless there is a known width constraint, the crosswalk's effective width should be the same as its physical width. A width constraint may be found when vehicles are observed to encroach regularly into the crosswalk area or when an obstruction in the median (e.g. a signal pole or reduced-width cut in the median curb) narrows the walking space. A default value of 3.0 meters should be used.

9.2.2.3 Numbers of Lanes Crossed (#)

This is the total number of vehicular lanes crossed by a pedestrian on the subject approach. The value is automatically populated by Synchro based on the intersection geometry and should not be overwritten.

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 6th Edition 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 11 User Guide* page 16-15 or HCM 6th Edition page 19-70 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 6th Edition methodology can be used to verify this area if additional field data is available. Refer to the *Synchro 11 User Guide,* page 16-15 or HCM 6th page 19-70 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 when viewing the crosswalk from the subject approach. The direction is based on the perspective of vehicles approaching the intersection.

Typically, this value needs to be measured in the field. Without field measured data or field observations, the directional split should be assumed to be equivalent for each direction of flow (i.e. the left-to-right flow and the right-to-left flow would be equal to half of the total crosswalk volume).

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. The direction is based on the perspective of vehicles approaching the intersection. Typically, this value needs to be measured in the field. Without field measured data or field observations, the directional split should be assumed to be equivalent for each direction of flow (i.e. the left-to-right flow and the right-to-left flow would be equal to half of the total crosswalk volume).

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 pedestrian circulation area for the right corner of the subject crosswalk. 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 from HCM 6 Exhibit 19-9 (page 19-16 from HCM 6). Synchro calculates this value.

9.2.2.20 Crosswalk Circulation Area (sq. m)

The Crosswalk Circulation area is the subject crosswalk circulation area per pedestrian. This is auto calculated by Synchro based on the previous input and should not be overridden.

9.2.2.22 Pedestrian Delay (s/p)

The Pedestrian Delay is calculated by Synchro based on the HCM 6th Edition methodology. Refer to HCM 6 equation 19-70 on page 19-83 for additional information. Synchro calculates this value.

9.2.2.23 Pedestrian Compliance Code

The pedestrian compliance code is based on the HCM 6th Edition methodology. Please refer to Page 16-18 of the *Synchro 11 User Guide*. Synchro calculates this value.

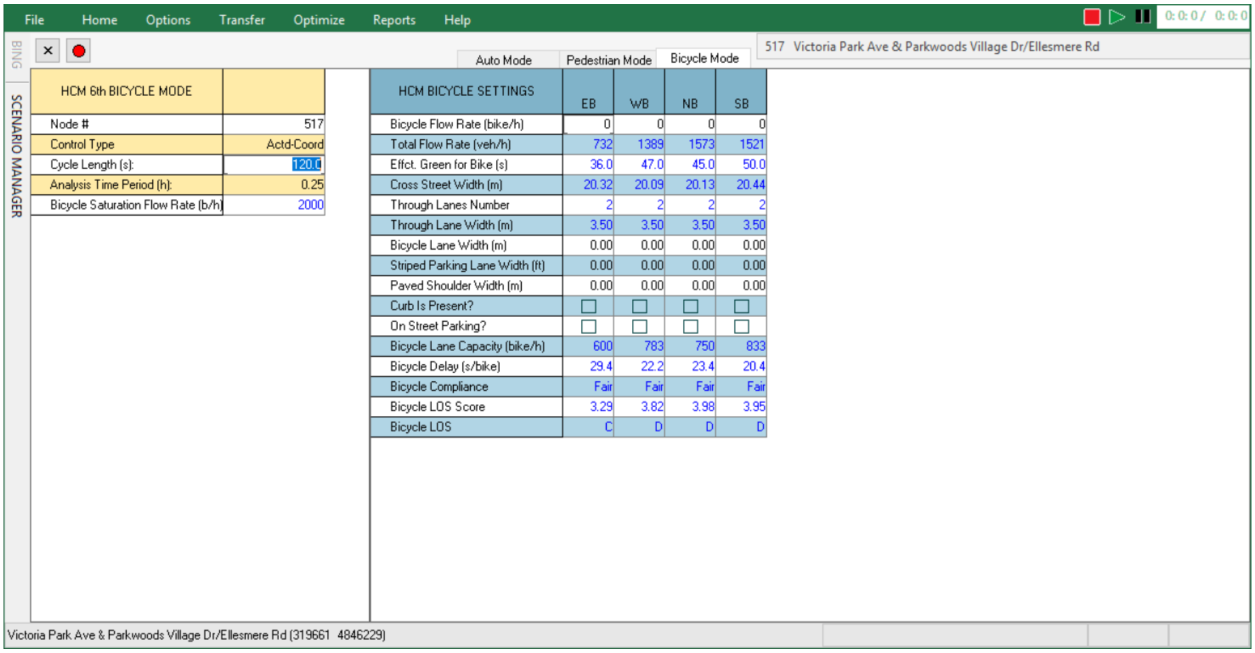
9.2.2.24 Pedestrian Crosswalk Score

The pedestrian LOS score for the intersection is calculated by using Equation 19-71 through Equation 19-76 of the HCM 6th Edition. Refer to the HCM 6 page 19-84 for additional information. 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. Synchro calculates this value.

9.3. Signalized Intersections – Bicycle Mode



HCM 6th BICYCLE MODE	
Node #	517
Control Type	Actd-Coord
Cycle Length (s):	120.0
Analysis Time Period (h):	0.25
Bicycle Saturation Flow Rate (b/h)	2000

HCM BICYCLE SETTINGS	EB	WB	NB	SB
Bicycle Flow Rate (bike/h)	0	0	0	0
Total Flow Rate (veh/h)	732	1389	1573	1521
Effct. Green for Bike (s)	36.0	47.0	45.0	50.0
Cross Street Width (m)	20.32	20.09	20.13	20.44
Through Lanes Number	2	2	2	2
Through Lane Width (m)	3.50	3.50	3.50	3.50
Bicycle Lane Width (m)	0.00	0.00	0.00	0.00
Striped Parking Lane Width (ft)	0.00	0.00	0.00	0.00
Paved Shoulder Width (m)	0.00	0.00	0.00	0.00
Curb Is Present?	☐	☐	☐	☐
On Street Parking?	☐	☐	☐	☐
Bicycle Lane Capacity (bike/h)	600	783	750	833
Bicycle Delay (s/bike)	29.4	22.2	23.4	20.4
Bicycle Compliance	Fair	Fair	Fair	Fair
Bicycle LOS Score	3.29	3.82	3.98	3.95
Bicycle LOS	C	D	D	D

Figure 9-3 Bicycle Mode Window

9.3.1. HCM 6th Edition 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 6th Edition recommends a default 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.

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.

9.3.2.3 Striped Parking Lane Width (m)

This is the width of the on-street striped parking lane, if used. Synchro accepts values of 0 metres (i.e. no parking lane) and 10 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 or outer vehicle lane. Shoulder width is measured to the curb face when a curb is present. 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 6th Edition methodology. See HCM 6, page 19-89. 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 6th Edition methodology and represents the delay experienced by each bicycle. See HCM 6, page 19-90. This result should not be overridden. Synchro calculates this value.

9.3.2.9 Bicycle Compliance

The bicyclist compliance code is based on the HCM 6th Edition methodology. See details in the *Synchro 11 User Guide* page 16-21. Also, refer to HCM 6th Edition for further details. Synchro calculates this value.

9.3.2.10 Bicycle LOS Score

The bicycle LOS score for the intersection is calculated by using Equation 19-79 through Equation 19-82 of the HCM 6th Edition. Refer to HCM 6th Edition for details. Synchro calculates this value.

9.3.2.11 Bicycle LOS

The LOS score is an indication of the typical bicyclist's perception of the overall crossing experience. Refer to HCM 6th Edition, page 19-16 and Exhibit 19-9 for details. Synchro calculates this value.

9.4. Two-way Stop Control Intersections – Auto Mode

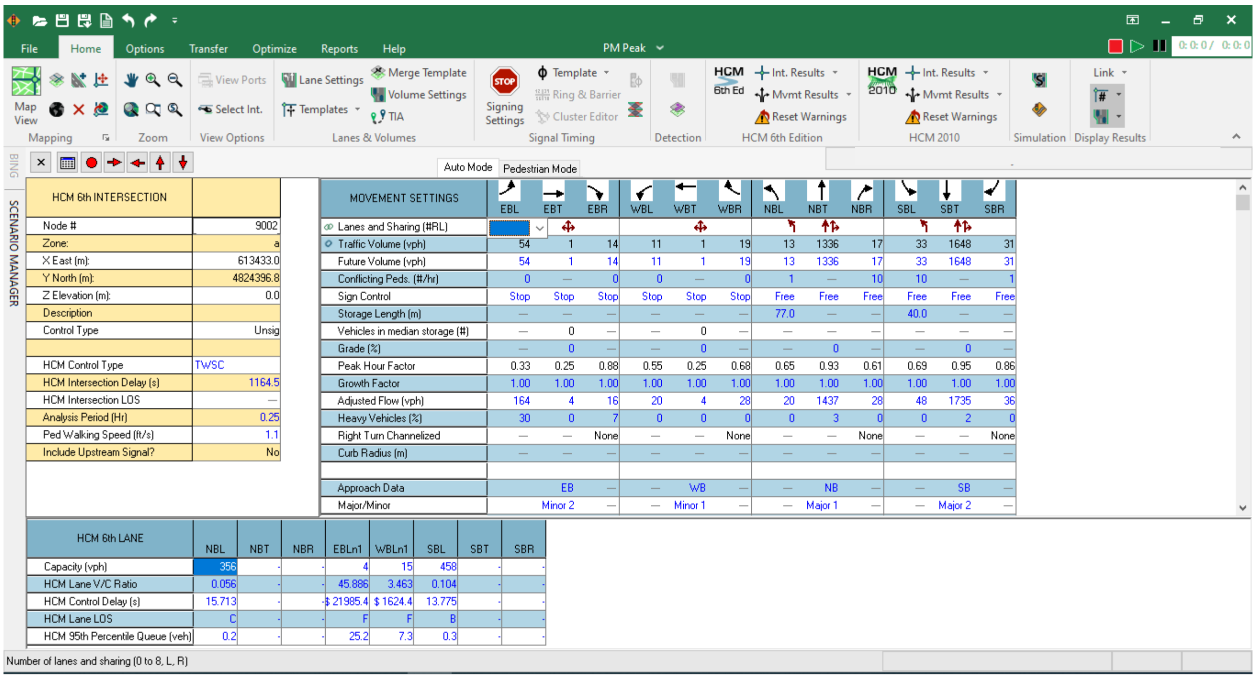


Figure 9-4 Two-Way Stop Control Settings Window – Auto Mode

9.4.1. HCM 6th Edition 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 is 1.05 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 manoeuvre. Synchro default values should be maintained unless headway parameters have been collected by field observations. Synchro defaults vary depending on turn type.

9.4.2.4 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.

9.4.2.5 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.

9.4.2.6 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.

9.4.2.7 Potential Capacity-1 Maneuver

The Potential Capacity is calculated based on the methodology described within HCM 6th Edition. Synchro calculates this value.

9.4.2.8 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.

9.4.2.9 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.

9.4.2.10 HCM Approach Control Delay (s)

This is the average control delay per vehicle for the approach. See HCM 6th Edition for additional details.

9.4.2.11 HCM Approach LOS

The LOS is determined using the HCM LOS table and the average control delay for the approach.

9.4.3. HCM 6th Edition Lane

9.4.3.1 Capacity (vph)

This value represents the maximum flow rate calculated for each lane. See HCM 6th Edition for additional details.

9.4.3.2 HCM Lane V/C Ratio

This is the volume to capacity ratio for the subject lane.

9.4.3.3 HCM Control Delay

The control delay is the delay per vehicle for each minor street lane and major street left-turns.

9.4.3.4 HCM Lane LOS

The LOS is determined using the HCM LOS table and the average control delay for each lane.

9.4.3.5 HCM 95th Percentile Queue

The 95th Percentile Queue is based on the methodology described within HCM 6th Edition. Synchro calculates this value.

9.5. Two-way Stop Control Intersections – Pedestrian Mode

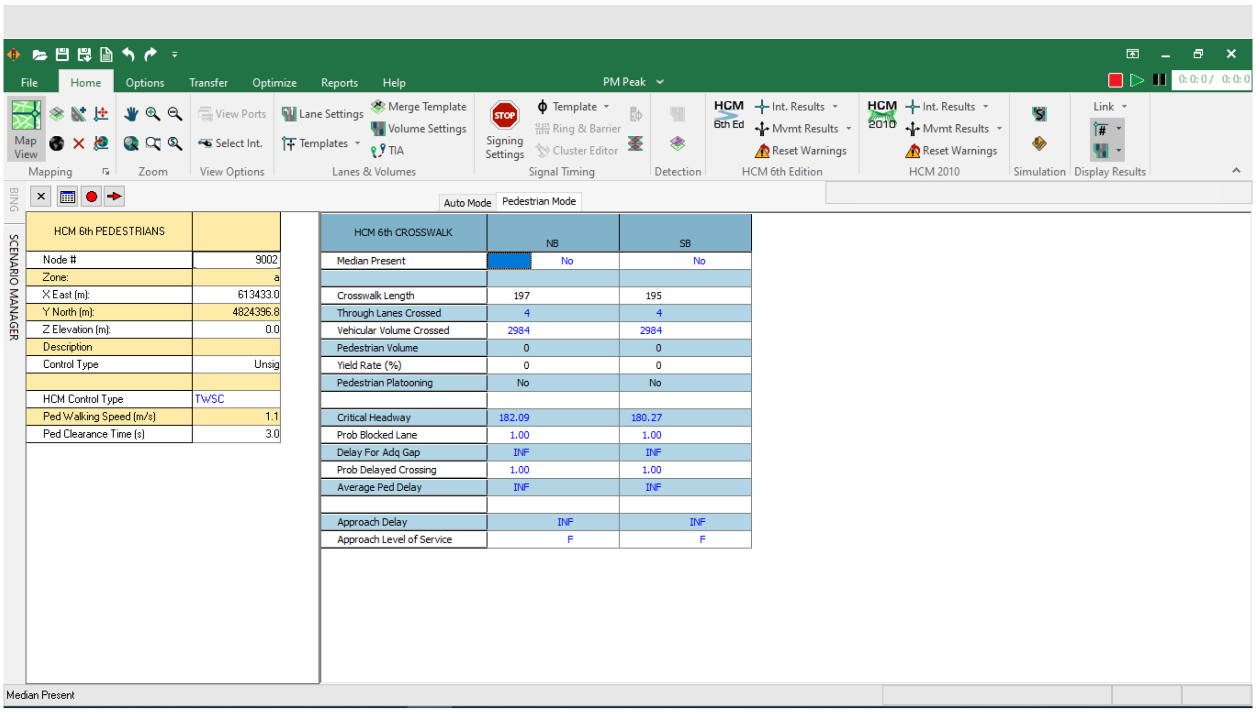


Figure 9-5 Two-Way Stop Control Settings Window – Pedestrian Mode

9.5.1. HCM 6th Edition 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. The analyst should use the walking speed shown on the City's timing card.

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 s.

9.5.2. HCM 6th Edition 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.

Refer to the City's timing card to determine whether "Yes" or "No" should be coded.

9.5.2.2 Crosswalk Length

The length of the crosswalk is measured from outside edge to outside edge of road pavement along the marked crosswalk. This value is automatically calculated but can be overwritten.

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 11 User Guide* Table 16-2 for average yield rates. For additional information see the HCM 6th Edition. 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.

9.5.2.8 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 6th Edition 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 6th Edition methods for each crosswalk segment. Synchro calculates this value.

9.6. All-way Stop Control Intersections

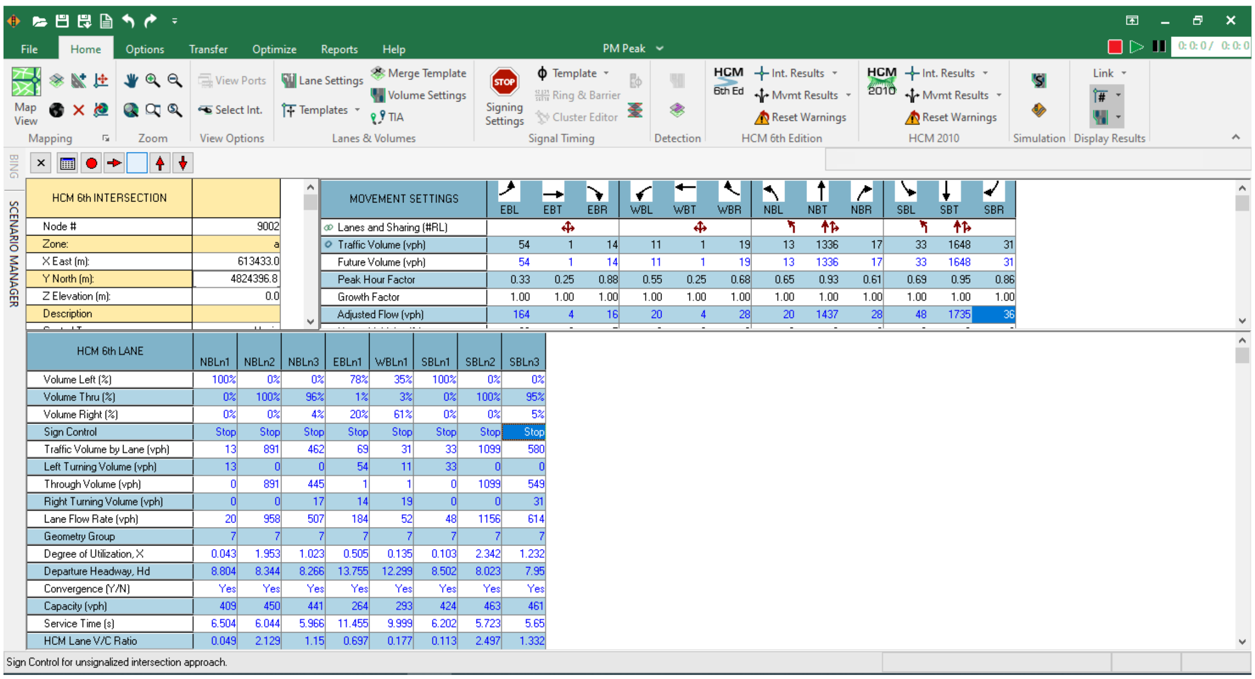


Figure 9-6 All Way Stop Control Settings Window

9.6.1. HCM 6th Edition 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 6th Edition 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 6th Edition Lane Settings

9.6.3.1 Volume Left, Thru & Right (%)

These values represent the corresponding movement volume being analyzed within each lane as a percentage of the total volume on the subject approach. 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 the HCM 6th Edition. This value is then used to determine the base saturation headways, and headway adjustment factors. See Table 16-13 within the *Synchro Studio 11 User Guide* for the conversion of the geometry group listed within the HCM 6th Edition. See the HCM 6th Edition 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* document, Section 5.7.

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, "sneaker studies", 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 calibrate the Synchro model, the geometric configuration should be as identical as possible to the observed existing conditions. Geometric changes or traffic management measures should be avoided in the existing conditions model (exception for single-lane roads with widths more than 4.8m, as discussed in Section 3.1.8). Construction timings and construction activities should also be avoided, unless they represent a long term impact that will influence both existing and future conditions. These changes could affect the results obtained in the field, possibly leading to inconclusive statements about the analysis results.

The calibration of Synchro models for City of Toronto projects generally include (but not limited to) the following types of adjustments:

- *Calibration of volume-capacity ratios* – where volume/capacity ratio exceeds 1.0 under default parameters using *observed* turning movement volumes, calibration of ideal saturation flow or lost time adjustments may be required to replicate field observe throughput.
- *Calibration of arterial travel time* – where the Arterial Level-of-Service report travel time in Synchro exceeds observed travel time, calibration may be required to adjust the signal delays to reflect field conditions. The calibration targets for travel times are met when travel times represent ±15% difference for 85% of the segments.
- *Calibration of queues* – where field observed queuing conditions differ from Synchro modelling conditions, calibration may be required to better reflect the field observed queues

Field data should be collected for 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
- other considerations particular to the specific system.

Ideally, all variables will remain constant during the data collection activities. However, traffic volume measurements will generally vary by time of day, day of week, car type, driver, etc. Effort should be made to minimize this variation by collecting data under similar conditions, or using big data to smooth out the effect of outliers. For travel time study data collection, using the same car and driver, if possible, should also be considered.

To meet the calibration for volume capacity ratios, travel time, and queues, the City typically accepts changes to the following parameters:

- Lost Time Adjustment (LTA),
- Saturation Flow Rates (ISF, SF),
- Peak Hour Factors (PHF),
- Lane Utilization Factors (LUF).

The calibration targets and parameters should be approved by the City at the onset of any analysis project. These parameters are discussed further in the subsections below and summarized in Table 10-1.

Table 10-1: Parameters Used in Model Calibration

Parameter	Synchro Default	Uncalibrated Base Model	Range of Values for Calibration
Lost Time Adjustment (s)	0	Off Peak = 0 Peak Period = -1	Values to be adjusted on a case-by-case basis for left-turn movements only. Allowable range = 0 to -3.
Ideal Saturated Flow Rate (vphpl)	1900	1900	Adjustments to the saturated flow rate will not exceed these values as outlined in the City of Toronto Synchro Guidelines: • *Through Movement = 2005* • *Flashing Advance d Green = 2100* • *Left-turn Green Arrow = 2050* • *Double Left-turn Green Arrow = 2000* • *High Occupancy Vehicle Lane = 1680*
Peak Hour Factor (PHF)	0.92	The average intersection PHF applied to all movements of an intersection	Adjusted on a case-by-case basis where a specific movement PHF differs significantly from the average intersection PHF. The approach level or movement level PHF can be adopted based on turning movement counts.
Lane Utilization Factor	Calculated by software	Use Synchro calculated values	Adjusted on a case-by-case basis where a specific movement is operating at or close to capacity. In a congested area, drivers may choose to drive on a lane that is relatively open. Therefore, volumes in multiple lanes will tend to be balanced.

10.2.1. Lost Time Adjustment (LTA)

The maximum range for this parameter shall be the clearance time for each movement.

Since the City does not typically accept values greater than -3 seconds, the analyst shall use higher values only if they are justified based on field investigation; higher values require City approval. This effectively provides additional capacity to the movement by allowing ‘sneakers’ to perform the left-turn during the inter-green period (amber and all-red) by artificially extending green time. This is often observed during congested conditions where more aggressive driving results in more sneakers. The City guidelines require a default value of -1 for AM and PM peak periods and 0 for OFF, Night, and Weekend periods.
If values lower than -3 are proposed, then the lost time for the following phase is expected to increase.

10.2.2. Saturation Flow Rate (ISF, SF)

Synchro uses an Ideal Saturation Flow Rate as a base value, and this base value is adjusted according to input parameters until a final value is arrived at and used in the capacity calculations. This final value is the Saturation Flow Rate (protected), and there is another Saturation Flow Rate (permitted) that is also calculated for non-protected movements. Both the Saturation Flow Rates ‘(protected)’ and ‘(permitted)’ are based on the Ideal Saturation flow Rate and modified by the various input parameters associated with lane settings, volume settings, and some timing settings (i.e. to determine permitted capacity of a movement).

The City of Toronto study entitled *Saturation Flow Rates for The City of Toronto* provides upset limits for saturated flow rates which were based on field studies throughout the City and informed by further background research. The study concluded that single lane left-turn green arrows may have saturated flow rates of up to 2,050 vehicles per hour of green time, a maximum of 2,000 vehicles per hour of green time per lane for double left-turn green arrow movements, and a maximum of 2,005 vehicles per hour of green time per lane, for through-right movements. These values are interpreted as the upper limits for the adjusted Saturation Flow Rates (protected) in Synchro.

For this reason, the Ideal Saturated Flow Rate may be adjusted to higher values while the adjusted Saturated Flow Rate (protected), which is used to calculate the volume-capacity ratio, shall be constrained to above mentioned upper limits.

The saturated flow rate used to calculate capacity is the 9th row from the bottom of the screenshot shown in Figure 10-1 and these are the values that shall be constrained during calibration. If field saturation flow studies were performed, this is where the values would be entered directly.

SimTraffic simulations shall also be used as a tool to support adjusting the saturation flow rate if field observed queue lengths match the SimTraffic queue lengths and if further adjustment to the saturation flow rate better replicates the number of cycles to clear queues in SimTraffic according to the field observations.

LANE SETTINGS	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lanes and Sharing (#RL)												
Traffic Volume (vph)	155	1060	85	60	1450	60	175	565	80	100	440	275
Future Volume (vph)	155	1060	85	60	1450	60	175	565	80	100	440	275
Street Name	Eglinton Ave			Eglinton Ave			Pharmacy Ave			Pharmacy Ave		
Link Distance (m)	—	263.7	—	—	507.7	—	—	184.7	—	—	184.4	—
Links Speed (km/h)	—	60	—	—	60	—	—	50	—	—	50	—
Set Arterial Name and Speed	—	EB	—	—	WB	—	—	NB	—	—	SB	—
Travel Time (s)	—	15.8	—	—	30.5	—	—	13.3	—	—	13.3	—
Ideal Satd. Flow (vphpl)	1900	1900	1900	1900	1900	1900	2100	1900	1900	1900	1900	1900
Lane Width (m)	3.0	3.5	3.0	3.0	3.5	3.0	3.0	3.5	3.0	3.0	3.5	3.0
Grade (%)	—	0	—	—	0	—	—	0	—	—	0	—
Area Type CBD	—	☐	—	—	☐	—	—	☐	—	—	☐	—
Storage Length (m)	90.0	—	0.0	60.0	—	35.0	25.0	—	0.0	20.0	—	0.0
Storage Lanes (#)	1	—	—	1	—	1	1	—	—	1	—	—
Right Turn Channelized	—	—	None	—	—	None	—	—	None	—	—	None
Curb Radius (m)	—	—	—	—	—	—	—	—	—	—	—	—
Add Lanes (#)	—	—	—	—	—	—	—	—	—	—	—	—
Lane Utilization Factor	1.00	0.77	0.91	1.00	0.77	1.00	1.00	0.95	0.95	1.00	0.95	0.95
Right Turn Factor	1.000	0.989	—	1.000	1.000	0.850	1.000	0.981	—	1.000	0.942	—
Left Turn Factor (prot)	0.950	1.000	—	0.950	1.000	1.000	0.950	1.000	—	0.950	1.000	—
Saturated Flow Rate (prot)	1604	3999	—	1560	4095	1383	1773	3333	—	1652	3190	—
Left Turn Factor (perm)	0.086	1.000	—	0.116	1.000	1.000	0.156	1.000	—	0.399	1.000	—
Right Ped Bike Factor	1.000	0.998	—	1.000	1.000	0.933	1.000	0.993	—	1.000	0.992	—
Left Ped Factor	1.000	1.000	—	0.997	1.000	1.000	0.996	1.000	—	0.983	1.000	—
Saturated Flow Rate (perm)	145	3999	—	190	4095	1290	290	3333	—	682	3190	—
Right Turn on Red?	—	—	☑	—	—	☑	—	—	☑	—	—	☑
Saturated Flow Rate (RTOR)	0	10	—	0	0	109	0	16	—	0	124	—
Link Is Hidden	—	☐	—	—	☐	—	—	☐	—	—	☐	—
Hide Name in Node Title	—	☐	—	—	☐	—	—	☐	—	—	☐	—

Ideal Saturated Flow Rate
(not directly used to calculate capacity)

Saturated Flow Rate
(used to calculate capacity)

Upper Limits:

- Through: 2005 vphgpl
- FAG: 2100 vphgpl
- LTA: 2050 vphgpl
- DLTA: 2000 vphgpl
- HOV: 1680 vphgpl

Figure 10-1 Saturated Flow Rate Calibration

10.2.3. Peak Hour Factor (PHF)

Unlike the lost time adjustment and the ideal saturated flow rate, changes to the PHF affect the modelled traffic volume rather than the movement's capacity. The PHF can be adjusted to individual movement PHF rather than the intersection or approaching level PHF. A higher PHF value reflects a steady traffic flow throughput during the entire period under analysis, which is normally observed during oversaturated conditions. Lower PHFs suggest surges in the traffic flow and will increase the Lane Group Flows that are used to calculate v/c ratios.

10.2.4. Lane Utilization Factor (LUF)

The LUF can be adjusted to match the existing conditions when appropriate. LUF value tends to be approaching 1.0 during oversaturated conditions since drivers typically weave into the least congested lane. Over time, all lanes in the same movement will become saturated. On the other hand, the LUF value shall be lower if more drivers choose to stay on a particular lane to avoid weaving in an area such as approaching a highway on-ramp or at a streetcar stop. This only applies to 'lane groups' with multiple lanes.

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 midblock sources/sinks or midblock 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.

Section 3.1.3.2 summarizes the City of Toronto methodology for volume balancing, however, it is at the analyst's discretion to determine whether this method is appropriate for the study.

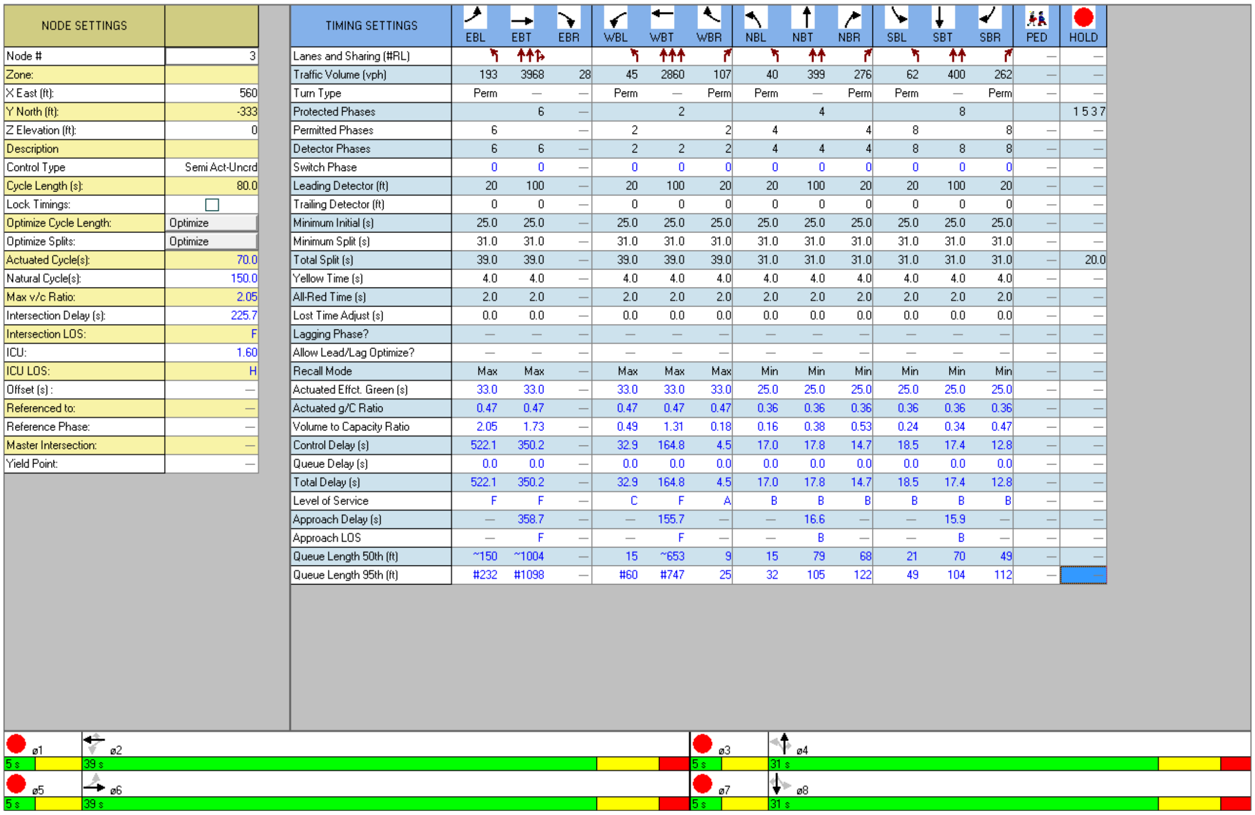
10.4. Leading Pedestrian Intervals (LPI)

Synchro software can be used to analyze the capacity impacts of implementing LPIs. On the "Timing Settings" page, the user can place a "Hold" interval for each LPI per direction before the start of the corresponding through movement (i.e. phase 2, 4, 6 and 8). The "Max" recall mode is used to activate the "Hold" phase under Synchro and SimTraffic. Phase 1, 3, 5 and 7 are the recommended phase numbers for LPIs because Synchro only allows a limited number of characters under the "Hold" phase. Phase 9, 10, 11 and 12 would exceed the limit when there are four LPIs at the same intersection.

When using a "Hold" interval to model LPIs, the offset reference point in Synchro is at the start of the main street through movement (i.e. phase 2, 4, 6, 8). However, when inputting the offset into the controller, the offset reference point is the at start of the LPI. Therefore, when transferring the offset value from the Synchro model to the timing card and/or controller, the analyst must subtract the LPI duration from the Synchro offset value. The relationship between the Synchro offset and the timing card offset is:

Timing Card Offset = Synchro Offset – LPI duration

Figure 10-2 shows the ring structure with LPI in all directions and no left-turn phase. As stated in the *LPI Assessment and Implementation Guidelines (2014)*, LPI is not feasible at crossings where there is a protected left turn phase.



NODE SETTINGS	
Node #	3
Zone:	
X East (ft):	560
Y North (ft):	-333
Z Elevation (ft):	0
Description	
Control Type	Semi Act-Uncrd
Cycle Length (s):	80.0
Lock Timings:	
Optimize Cycle Length:	Optimize
Optimize Splits:	Optimize
Actuated Cycle(s):	70.0
Natural Cycle(s):	150.0
Max v/c Ratio:	2.05
Intersection Delay (s):	225.7
Intersection LOS:	F
ICU:	1.60
ICU LOS:	H
Offset (s) :	—
Referenced to:	—
Reference Phase:	—
Master Intersection:	—
Yield Point:	—

TIMING SETTINGS	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR	PED	HOLD
Lanes and Sharing (#RL)													—	—
Traffic Volume (vph)	193	3968	28	45	2860	107	40	399	276	62	400	262	—	—
Turn Type	Perm	—	—	Perm	—	Perm	Perm	—	Perm	Perm	—	Perm	—	—
Protected Phases		6	—		2			4			8			1 5 3 7
Permitted Phases	6		—	2		2	4		4	8		8	—	—
Detector Phases	6	6	—	2	2	2	4	4	4	8	8	8	—	—
Switch Phase	0	0	—	0	0	0	0	0	0	0	0	0	—	—
Leading Detector (ft)	20	100	—	20	100	20	20	100	20	20	100	20	—	—
Trailing Detector (ft)	0	0	—	0	0	0	0	0	0	0	0	0	—	—
Minimum Initial (s)	25.0	25.0	—	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0	—	—
Minimum Split (s)	31.0	31.0	—	31.0	31.0	31.0	31.0	31.0	31.0	31.0	31.0	31.0	—	—
Total Split (s)	39.0	39.0	—	39.0	39.0	39.0	31.0	31.0	31.0	31.0	31.0	31.0	—	20.0
Yellow Time (s)	4.0	4.0	—	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	—	—
All-Red Time (s)	2.0	2.0	—	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	—	—
Lost Time Adjust (s)	0.0	0.0	—	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	—	—
Lagging Phase?	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Allow Lead/Lag Optimize?	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Recall Mode	Max	Max	—	Max	Max	Max	Min	Min	Min	Min	Min	Min	—	—
Actuated Effct. Green (s)	33.0	33.0	—	33.0	33.0	33.0	25.0	25.0	25.0	25.0	25.0	25.0	—	—
Actuated g/C Ratio	0.47	0.47	—	0.47	0.47	0.47	0.36	0.36	0.36	0.36	0.36	0.36	—	—
Volume to Capacity Ratio	2.05	1.73	—	0.49	1.31	0.18	0.16	0.38	0.53	0.24	0.34	0.47	—	—
Control Delay (s)	522.1	350.2	—	32.9	164.8	4.5	17.0	17.8	14.7	18.5	17.4	12.8	—	—
Queue Delay (s)	0.0	0.0	—	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	—	—
Total Delay (s)	522.1	350.2	—	32.9	164.8	4.5	17.0	17.8	14.7	18.5	17.4	12.8	—	—
Level of Service	F	F	—	C	F	A	B	B	B	B	B	B	—	—
Approach Delay (s)	—	358.7	—	—	155.7	—	—	16.6	—	—	15.9	—	—	—
Approach LOS	—	F	—	—	F	—	—	B	—	—	B	—	—	—
Queue Length 50th (ft)	~150	~1004	—	15	~653	9	15	79	68	21	70	49	—	—
Queue Length 95th (ft)	#232	#1098	—	#60	#747	25	32	105	122	49	104	112	—	—

Figure 10-2 Ring structure for LPIs in Synchro

10.5. 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 a 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.

10.6. 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).

10.7. 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 TSO 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 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.

10.8. Adaptive Traffic Control (Smart Signals)

Traffic adaptive systems such as SCOOT (Split Cycle Offset Optimization Technique) and SCATS (Sydney Coordinated Adaptive Traffic System) 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 suited for modelling adaptive control. A micro-simulation software, such as AIMSUN and VISSIM, is preferable. If City staff do not have ready access to micro-simulation software, and wants to use Synchro, then 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 ATC signal timing logs 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 adaptive control. The information provided by TransSuite signal phasing logs for adaptive signals is in two parts:

- The range in values allowed by the adaptive traffic control 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).

An adaptive traffic control 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 adaptive traffic control route, the minimum, maximum and typical cycle length values of the adjacent signals should be enforced to ensure signal coordination is considered.

10.9. Bicycle Lanes

Signalized intersections which meet HCM 6 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 6 criteria for analysis, Synchro does not have special considerations for bicycle lanes. Bicycle lanes should be ignored - only vehicle lanes should be coded.

At Semi-actuated intersections with bike lanes on the side street, bike volumes should be treated as vehicle volume for actuation purposes.

10.10. Offset Intersections

Refer to the City's *Traffic Signal Operations Policies and Strategies* document, Section 5.4.5.

10.11. Roundabouts

Synchro is not the best software for modelling Roundabouts. Depending on the scope of the project, micro-simulation software, such as AIMSUN and VISSIM, is preferable. Alternatively, software suites such as ARCADY or SIDRA INTERSECTION provides more accurate results. It is the responsibility of the analyst 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 by 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 to discuss the analysis methodologies to be used (e.g. HCM 2000, HCM 2010, HCM 6th Edition, 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 the HCM 6th Edition analysis and HCM 2010 analysis; Synchro/ICU or HCM 2000 analysis can still be used in situations where:

a) Intersection configuration is not supported by HCM 6th Edition methodology (e.g. intersections with non-NEMA phasing, more than four approaches, exclusive pedestrian or hold phases and certain lane configurations such as left-turn movements shared between an exclusive and shared lane);
b) Multi-modal analysis is not necessary for the exercise/decision makers; and
c) Data required for accurate HCM 6th Edition analysis is not readily available.

When performing analysis within or near areas of significant multi-modal use, HCM 6th Edition analysis shall be considered. This should be discussed with City staff.

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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