Working White Paper on the Implementation of the Highway Capacity Manual 6th Edition in Synchro®

1st Edition – January 18, 2017

2nd Edition – March 9, 2018

Copyright © 1993 - 2018 Trafficware, LLC. All rights reserved.

No part of this publication may be reproduced, stored in a retrieval system, or transmitted, in any form or by any means, electronic, mechanical, recording, or otherwise, without the prior written permission of the publisher. The information is designed to provide authoritative information and guidance in regard to the subject matter covered.

Updates

March 9, 2018: *Added FAQ for Signalized Intersections*

Quick Reference Guide

If you're interested in simply knowing how Synchro incorporates the HCM 6th Edition methodologies without all the extra information, this section is for you. One word of caution, though. ***Take the time to read this document at least once.*** The limitations of the HCM 6th Edition methodologies are critical elements to understand as you compare it to other analysis methodologies. It is Trafficware's goal to match the methods as they are described in the manual.

Signalized Intersections

- Auto, Pedestrian, and Bike modes available
- NEMA Phasing adherence required
- Right turns on red (RTOR) volumes required
- Unsignalized right-turn delay may be included
- Calibration parameters can be adjusted by user
- Coordination effects are taken into account for intersections within 0.60 miles
- Platoon ratio is calculated by Synchro, but can be adjusted by the user

Two-Way Stop Control Intersections

- Auto and Pedestrian modes available
- One and two-stage maneuvers are coded using a pull-down menu
- U-turn analysis included
- Coordination effects are taken into account for signalized intersections within 0.60 miles
- Follow-up and Critical Headways are user adjustable

All-Way Stop Control Intersections

- Overall intersection delay and LOS is displayed

Roundabouts

- One, two-lane, and combination of one/two lane circulatory roadways
- Yielding and free-flowing slip ramps
- Follow-up and Critical Headways are user adjustable

Contents

Updates ii

Quick Reference Guide iii

Executive Summary 3
- Overview of the HCM 6th Edition 3
- Implementation of the HCM 6th Edition 4

Section 1 – Signalized Intersections (Auto Mode) 5
- Introduction 5
- Unsignalized Movements 5
- Heavy Vehicles and Grade 6
- Known Issues and Limitations 7
- Synchro's Signalized Intersection Screen (Auto Mode) 7
- Work Zones 8
- Additional Discussion of Known Issues and Limitations 8
- Frequently Asked Questions 10

Section 2 Signalized Intersections (Pedestrian Mode) 11
- Introduction 11
- Delay & Level of Service Thresholds 11
- Known Issues and Limitations 11
- Synchro's Signalized Intersection Screen (Pedestrian Mode) 12

Section 3 Signalized Intersections (Bicycle Mode) 14
- Introduction 14
- Parking Lane Width 14
- Delay & Level of Service Thresholds 14
- Known Issues and Limitations 15

Section 4 Two-Way Stop Control Intersections (Auto Mode) 16
- Introduction 16
- Delay & Level of Service Thresholds 16
- Known Issues and Limitations 16
- Additional Discussion of Known Issues and Limitations 16

Section 5 Two-Way Stop Control Intersections (Pedestrian Mode) 17
- Introduction 17
- Motorist Yield Rate 17
- Known Issues and Limitations 17

Section 6 All-Way Stop Control Intersections 19
- Introduction 19
- Delay & Level of Service Thresholds 19

Known Issues and Limitations....19

Section 7 – Roundabouts.... 20

Introduction....20

New Capacity Model....20

Known Issues and Limitations....21

Additional Discussion of Known Issues and Limitations....21

Calibration....21

Section 8 – Appendix.... 22

Executive Summary

Welcome to Trafficware's *White Paper* summarizing the Synchro implementation of the methodologies included within the Transportation Research Board's Highway Capacity Manual (HCM) 6th Edition. This document is intended to be a 'living document' or working paper that is maintained and disseminated online at www.trafficware.com. If you are also a user of Synchro 9, be sure to review the Working White Paper for HCM 2010 in Synchro 9.

As updates to Synchro become available, or when changes and/or clarifications are made to the HCM 6th Edition, this document will be revised and an updated version posted online. The intent of this document is to highlight key issues related to the HCM 6th Edition rather than an exhaustive account of the various methodologies. It is highly recommended that you review the HCM 6th Edition manual in addition to this white paper. It is Trafficware's goal to match the methods as they are described in the manual.

Overview of the HCM 6th Edition

The HCM 6th Edition is a publication of the National Academy's Transportation Research Board (TRB). The 6th Edition is based on over 50 years of transportation-related research into the concepts and procedures for evaluating the multimodal performance of highway and street facilities. Previous versions of the HCM have had a year attached, rather than an edition number. In the future, it is likely that chapters may be updated individually, allowing each chapter to have its own version number.

The organization of the HCM 6th Edition is similar to that of the HCM 2010. However, it should be noted that a couple new chapters were added, and as a result several of the other chapter numbers have changed. The manual is organized into four major volumes, including an electronic-only Volume 4 that houses the supplemental chapters, example problems, a technical reference library, and various computational engines developed for several of the more complex procedures. It should be noted that the computational engines were developed by TRB to evaluate some, but not necessarily all, of the procedures described within the various chapters of the HCM 6th Edition.

In addition to the traditional focus on vehicular movement, the HCM 6th Edition builds on the multimodalism introduced in the HCM 2010. The integration of pedestrians and bicyclists within several chapters of the HCM provides transportation professionals the ability to assess the overall transportation experience from the user's perspective.

As with any operational analysis methods, there will always be a set of limitations that surround the use of the various methodologies. Most of the limitations set forth by TRB for the HCM 6th Edition are similar to those of the HCM 2010. As you begin to use Synchro to conduct a HCM 6th Edition analysis, one should review the HCM 6th Edition to confirm that use of HCM 6th Edition is applicable. Each section of this white paper includes a list of the primary limitations, as noted by TRB.

Several of the supplemental chapters in the HCM 6th Edition, volume 4 include Planning-Level Analysis Applications. It should be noted that the analysis in Synchro is based on the complete analysis from the respective chapters, and the planning level analysis is not included.

Implementation of the HCM 6th Edition

Synchro 10 currently supports the signalized intersection, all-way stop control (AWSC), two-way stop control (TWSC), and the roundabout methods. Table 1 depicts a summary of the various HCM 6th Edition analysis methods and which methods have been incorporated within Synchro 10.

Table 1 - HCM 6th Edition Operational Methods

HCM 6th Edition	Description	Modes in HCM 6th Edition	Modes Within Synchro 10			
			Auto (A)	Pedestrian (P)	Bicycle (B)	Transit (T)
Chapter 19	Signalized Intersections	A, P, B	✓	✓	✓	na
Chapter 20	Two-Way Stop-Controlled Intersections	A, P	✓	✓	na	na
Chapter 21	All-Way Stop-Controlled Intersections	A	✓	na	na	na
Chapter 22	Roundabouts	A	✓	na	na	na

Notes:
1. A = Auto, P = Pedestrian, B = Bicycle, T = Transit
2. na = not applicable. HCM 6th Edition does not support a method at this time.
3. ✓= HCM 6th Edition Method included in Synchro.
4. Coordination between intersections is based on the methods described in Chapter 19.

Upon opening the HCM 6th Edition window, a screen that ***mimics*** the various HCM 6th Edition methodologies will appear. Trafficware has implemented the operational methods as they are presented in the HCM 6th Edition Manual. It should be noted that each of the methods have various limitations and applicability set forth by TRB. It is strongly recommended that you review these limitations as outlined by TRB. The limitations for each method are also summarized in the following sections of this white paper.

A report can be generated for all of the HCM 6th Edition analysis methods. Select the desired node and either press [CTRL] + [R] or go select HCM 6th in the Reports tab.

Section 1 – Signalized Intersections (Auto Mode)

This section summarizes what's new in the HCM 6th Edition for the automobile mode at ***isolated*** signalized intersections and how Synchro has implemented the applicable sections of Chapter 19 (Signalized Intersections) and Chapter 31 (Supplemental Signalized Intersections). It should be noted that additional calculations, as described in Chapter 18 (Urban Street Segments), are required for actuated-coordinated intersections. The Appendix provides a brief summary of the method for shared-lane analysis, which is the same methodology used for HCM 2010 analysis since the release of Synchro 8.0.804.

Introduction

There are a few changes and additions to the automobile methodologies for signalized intersections, but the overall analysis methodologies remain similar to those in HCM 2010. Some of the major changes as compared with the 2010 HCM include:

- Delay of unsignalized movements can be considered
- Combined saturation flow rate adjustment factor for heavy vehicles and grade
- New saturation flow adjustment factors for intersection work zone presence

Unsignalized Movements

If unsignalized right-turn movements exist, the delay for these movements may be included as an ***input*** to the methodology. If provided, the unsignalized movement delay is used in the calculation of approach delay and intersection delay.

HCM 6th Edition does not provide a method to compute the unsignalized delay. It should be estimated externally, and input as shown below. The following methods may be used to estimate unsignalized delay:

- Direct field measurement
- Observation of similar conditions
- Simulation
- Special application of the HCM TWSC methodology

Unsignalized movements with a high volume or high delay should be estimated carefully, as they will have a more significant impact on the overall intersection results than that of lower volume movements. Free-flow right turns may be assumed to have zero delay.

Figure 1 Unsignalized Movement Delay

HCM 6th Settings	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lanes and Sharing (#RL)												
Traffic Volume (vph)	71	318	106	118	600	24	133	1644	111	194	933	111
Future Volume (vph)	71	318	106	118	600	24	133	1644	111	194	933	111
Turn Type	Perm	—	—	Perm	—	—	pm+pt	—	—	pm+pt	—	—
Protected Phases		2	—		6	—	3	8	—	7	4	—
Permitted Phases	2		—	6		—	8		—	4		—
Lagging Phase?	☑	☑	—	☑	☑	—	☐	☑	—	☐	☑	—
Opposing right-turn lane influence	Yes	—	—	Yes	—	—	Yes	—	—	Yes	—	—
+ Signal Timing Details												
Recall Mode	None	None	—	None	None	—	None	None	—	None	None	—
+ Adjusted Flow Rate (veh/h)	71	318	0	118	600	24	133	1644	111	194	933	111
Adjusted No of Lanes	1	2	0	1	2	0	1	2	0	1	2	0
Pedestrian volume (p/h)	—	—	120	—	—	120	—	—	40	—	—	40
Bicycle volume (bicycles/h)	—	—	0	—	—	0	—	—	0	—	—	0
Right Turn on Red Volume (vph)	—	—	0	—	—	0	—	—	0	—	—	0
+ Ideal Satd. Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Work zone on approach?	—	☐	—	—	☐	—	—	☐	—	—	☐	—
Total Approach Width	—	—	—	—	—	—	—	—	—	—	—	—
Lanes open during work zone	—	—	—	—	—	—	—	—	—	—	—	—
HCM Platoon Ratio	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
HCM Upstream Filtering Factor	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Initial Queue (veh)	0	0	—	0	0	—	0	0	—	0	0	—
Include Unsignalized Delay?	—	—	☑	—	—	—	—	—	—	—	—	—
Unsig. Movement Delay (s/veh)	—	—	10.00	—	—	—	—	—	—	—	—	—
Right Turn Channelized	—	—	Yield	—	—	None	—	—	None	—	—	None
HCM 6th Capacity (veh/h)	149	908	—	260	862	34	317	1530	102	225	1551	184
HCM Volume/Capacity	0.477	0.350	—	0.453	0.696	0.698	0.419	1.075	1.085	0.861	0.602	0.602
HCM Lane Group Delay(s/veh)	45.6	28.3	10.0	36.8	35.5	36.2	13.8	76.5	83.1	32.6	17.5	17.5
HCM Lane Group LOS	D	C	A	D	D	D	B	F	F	C	B	B
HCM Approach Delay (s/veh)	—	26.9	—	—	36.0	—	—	75.1	—	—	19.9	—
HCM Approach LOS	—	C	—	—	D	—	—	E	—	—	B	—

As seen in the above figure, you have the option whether or not to include the delay for any unsignalized movements. If unsignalized movement(s) are present at the intersection, but their delay is not included, the unsignalized right-turn volume will not be factored into the calculation of Approach Delay or Intersection Delay. This is consistent to the methodology presented in HCM 2010. Synchro's HCM 6th Edition reports include a footnote stating whether the delay is included for each unsignalized movement at the intersection.

Heavy Vehicles and Grade

HCM 2010 and previous editions of the Highway Capacity Manual included separate saturation flow rate adjustment factors for heavy vehicles and grade. In the HCM 6th Edition, these have been combed into a single saturation flow rate adjustment factor as seen in the equations below:

Negative Grade: $f_{HVg} = \frac{100-0.79P_{HV}-1.07P_g}{100}$

Non-Negative Grade: $f_{HVg} = \frac{100-0.78P_{HV}-0.31P_g^2}{100}$

The percent grade can be entered in Synchro's Lane Settings window. The percent heavy vehicles can be entered in Synchro's Volume Settings window. Both the grade and heavy vehicles are used for the HCM 6th Edition analysis, HCM 2010 analysis, Synchro's Percentile Delay analysis, and simulation in SimTraffic.

Known Issues and Limitations

As with any operational analysis methods, there will always be a set of limitations that surround the use of the various methodologies. Most of the limitations set forth by TRB for the HCM 6th Edition are similar to those of the HCM 2010. As you begin to use Synchro to conduct a HCM 6th Edition analysis, one should review the HCM 6th Edition to confirm that use of HCM 6th Edition is applicable. The following bullets highlight the key limitations as identified by TRB:

Overall Intersection

- Intersections with three (3) or four (4) approaches.
- Isolated from nearby intersections. Adjustments for actuated-coordinated networks only.
- Phasing must adhere strictly to standard NEMA phasing.

Auto Mode

- Turn bay overflow
- Multiple advance detectors per travel lane
- Demand starvation due to closely spaced intersections
- Queue spillback between intersections
- Phase overlaps (i.e. typical diamond interchange phasing)
- Right-turn on red (RTOR) delays are considered negligible and are not calculated
- Turn movements served by more than two exclusive lanes
- Drop or add lanes along intersection approaches
- Rest-in-walk mode for actuated and non-coordinated phases
- Premature phase termination due to short detection length, passage time, or both

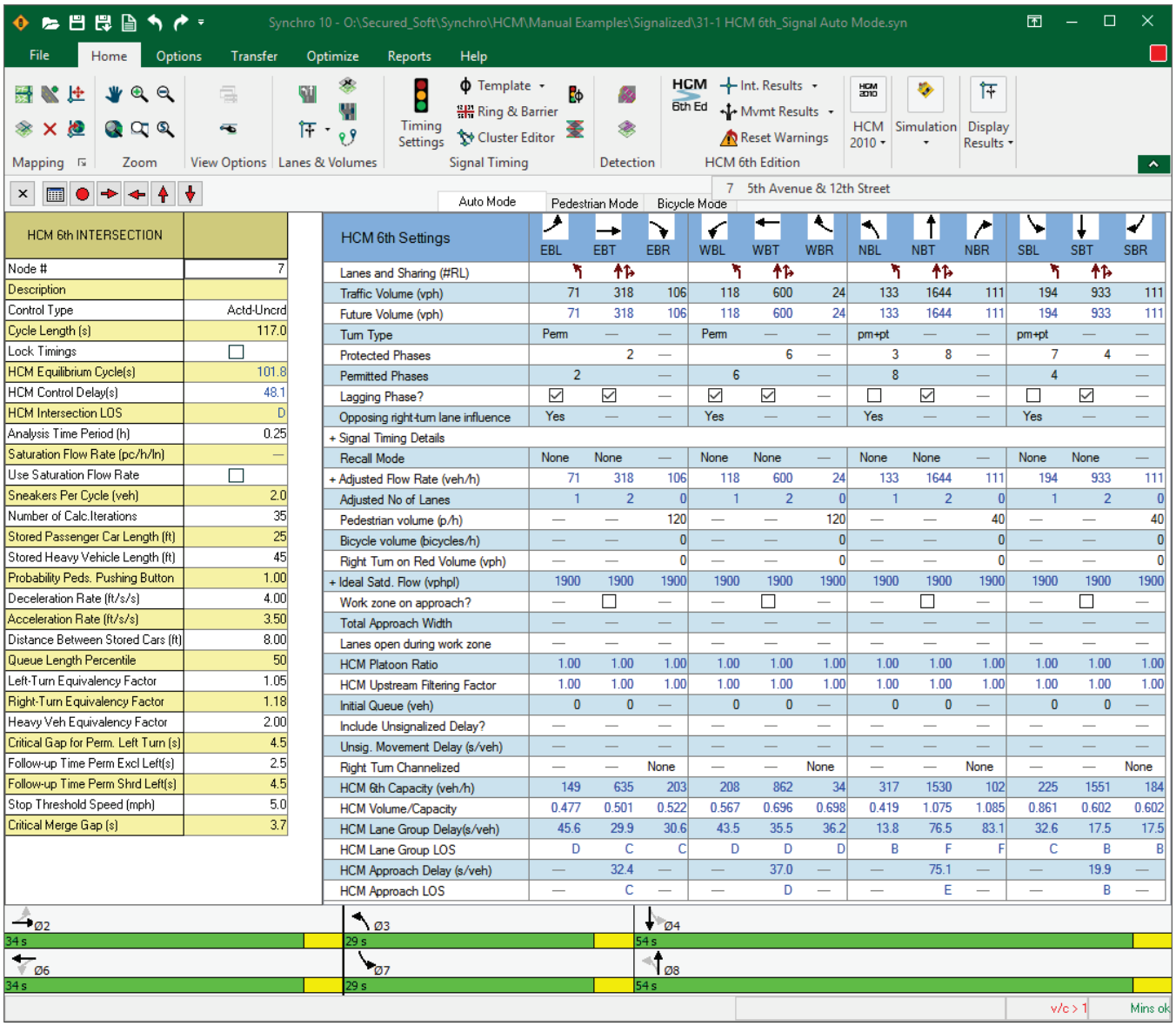
Synchro's Signalized Intersection Screen (Auto Mode)

Once you have created a signalized intersection, press the HCM 6th Edition icon on the HOME tab to interactively view the results based on the HCM 6th Edition methods. Several of the displayed values are carried over from the Synchro Lane, Volume, Timing, Phasing, and/or Detector Setting windows. There are, however, several input parameters specific to the HCM 6th Edition procedures, including:

- Right Turn on Red Volume
- Unsignalized movement delay
- Work zone on approach?
- Opposing right-turn influence
- Platoon Ratio
- Initial Queue

The figure below depicts the HCM 6th Edition screen in Synchro. It should be noted that the "*calibration parameters*" as defined by the HCM 6th Edition Manual, are located along the left window pane (*HCM Intersection)* portion of the screen.

Figure 2 - Signalized Intersection Auto Mode in Synchro



Work Zones

A new saturation flow rate adjustment factor is included in the HCM 6th Edition to account for the presence of work zones on the intersection approach. For purposes of applying this calculation, the "intersection approach" considers work zones located between the stop line and 250 feet upstream. This factor takes into account any reduction in width or number of lanes on the intersection approach.

Additional Discussion of Known Issues and Limitations

With the initial implementation of the HCM 6th Edition signalized intersection procedures in Synchro, a few issues are apparent and there are implicit and explicit limitations that the user should bear in mind. With pending clarifications and/or changes to the supporting text and computation code, some of these conditions may be addressed in the near future. These items are not exhaustive and may not address all possible issues the user

might encounter. Updates are expected to address some of these issues; however, they currently include the following:

- There are a number of limitations of the HCM 6th Edition methodologies as stated in Chapter 19 that are handled by capabilities already offered in Synchro, including but not necessarily limited to: impacts on delay as the result of queue spillback, starvation, and storage blocking; multiple detectors in the same lane; turn movements served by more than two exclusive lanes; through movements served by more than 4 lanes; the inhibition of maximum settings or the allocation of unused time to non-coordinated phases; gap reduction of variable initial settings associated with actuated volume-density control.

- The HCM 6th Edition procedures rely on a strict adherence to a standard 2-ring NEMA 8-phase configuration and design, such that phases 1 and 5 are intended for use as the primary roadway left-turn phases, phases 2 and 6 are intended for use as the primary roadway through phases, phases 3 and 7 are intended for use as the secondary roadway left-turn phases, and phases 4 and 8 are intended for use as the secondary roadway through phases. If the given signalized intersection deviates from this convention, Synchro currently issues a warning message and the HCM 6th Edition results are not displayed.

  The methods do in fact support several combinations of left-turn phase operation and sequence, split phasing, right-turn overlaps during supporting left-turn phases, and leading or lagging left-turn operations; however, several common phasing situations are not supported and results would not be generated with the following:
  - Exclusive pedestrian or hold phases;
  - More than one intersection on the same controller (group or cluster control);
  - Phasing Overlap (other than right-turn overlap phasing);
  - A-typical phase numbering; and
  - More than 8 phases, or more than 2 phases in either ring on either side of the barrier.

- Synchro does not currently support the HCM 6th Edition option to enable simultaneous gap-out under actuated control.

- Certain lane geometries are not currently support by the HCM 6th Edition computational engine. For example, a left turn movement that operates from both an exclusive and a shared lane. A future clarification and/or change to the HCM 6th Edition is expected to address this issue and provide improved computational code and/or supporting text; however, in the meantime, this limitation exists in the HCM 6th Edition module as implemented by Synchro. Appendix A includes information related to the new method.

- The HCM 6th Edition manual describes a procedure to compute the Intersection v/c ratio. However, this calculation is not included in the computational engine as provided by TRB. At this time, the HCM 6th Edition Intersection v/c ratio is not reported in Synchro.

- Chapter 30 of the HCM 6th Edition, Urban Street Segments: Supplemental, provides a methodology to compute an adjustment factor for downstream lane blockages. The Urban Street Segment analysis, including this adjustment factor, is not included in Synchro 10.

- Chapter 29 of the HCM 6th Edition, Urban Street Facilities: Supplemental, provides a methodology to compute an adjustment factor for sustained spillback. The Urban Street Segment analysis, including this adjustment factor, is not included in Synchro 10.

- Chapter 31 of the HCM 6th Edition: Signalized Intersections (Supplemental), describes both floating force mode and fixed force mode for noncoordinated phases at a coordinated intersection. These options control the force-off points for noncoordinated phases. For purposes of HCM 6th Edition analysis, Synchro assumes all noncoordinated phases use fixed force mode.

Frequently Asked Questions

Why is the delay for a right-turn much higher using HCM 6th Edition methodology than using Synchro's Percentile Delay methodology?

HCM 6th Edition does not provide an equation or suggested methodology for computing the right-turn-on-red (RTOR) volume or associated delay. Instead, it is suggested that RTOR Volume be counted in the field whenever possible (refer to page 19-25 of HCM 6th Edition). This value should then be entered into the 'Right Turn on Red Volume (vph)' field in Synchro's HCM 6th Edition grid.

If you do not enter a RTOR Volume, a value of 0 will be assumed. This is overly conservative in most cases and may lead to much higher calculated delay using HCM 6th Edition methodology than those calculated by Synchro's Percentile Delay methodology.

As many Synchro users know, Synchro also includes a 'Right Turn on Red?' option in the Lane Settings window. If checked, this option will calculate the expected Right Turn on Red Saturation Flow Rate, which is then used in Synchro's Percentile Delay methodology. If desired, users can estimate the RTOR Volume based on the RTOR Saturation Flow Rate using the following equation:

*vRTOR = minimum (sRTOR,v) * r/C = RTOR reduction to volume*

sRTOR = RTOR saturation flow as calculated by Synchro

r = effective red time

v = adjusted lane group volume (before RTOR reduction)

C = cycle length

Section 2 Signalized Intersections (Pedestrian Mode)

This section identifies what's new in the HCM 6th Edition for the pedestrian mode at signalized intersections and how Synchro has implemented the applicable sections of Chapter 19 (Signalized Intersections) and Chapter 32 (Supplemental Signalized Intersections).

Introduction

There are a few changes and additions to the pedestrian methodologies for signalized intersections, but the overall analysis methodologies remain similar to those in HCM 2010. Some of the major changes include:

- Updated Level of Service (LOS) thresholds

If you are interested in this analysis method, one should review the HCM 6th Edition Manual along with this section to determine how to conduct your analysis.

Delay & Level of Service Thresholds

Similar to the methodology provided in HCM 2010, the HCM 6th computes a Pedestrian LOS Score for each crosswalk. Unlike LOS for the Auto mode, the Pedestrian LOS is based on many factors including geometry and circulation areas, rather than delay alone. Corrections have been made to the Pedestrian LOS thresholds in the HCM 6th Edition. The table compares the LOS thresholds for HCM 6th Edition and HCM 2010.

Table 2 - Pedestrian Mode LOS Thresholds for Signalized Intersections

Level of Service	LOS Score	
	HCM 2010	HCM 6th Edition
A	≤ 2.00	≤ 1.50
B	> 2.00 – 2.75	> 1.50 – 2.50
C	> 2.75 – 3.50	> 2.50 – 3.50
D	> 3.50 – 4.25	> 3.50 – 4.50
E	> 4.25 – 5.00	> 4.50 – 5.50
F	> 5.00	> 5.50

Known Issues and Limitations

As you begin to use Synchro to conduct a HCM 6th Edition analysis, please review this section (as well as the HCM 6th Edition itself) to familiarize yourself with the various methods and their limitations. The following bullets highlight the key limitations:

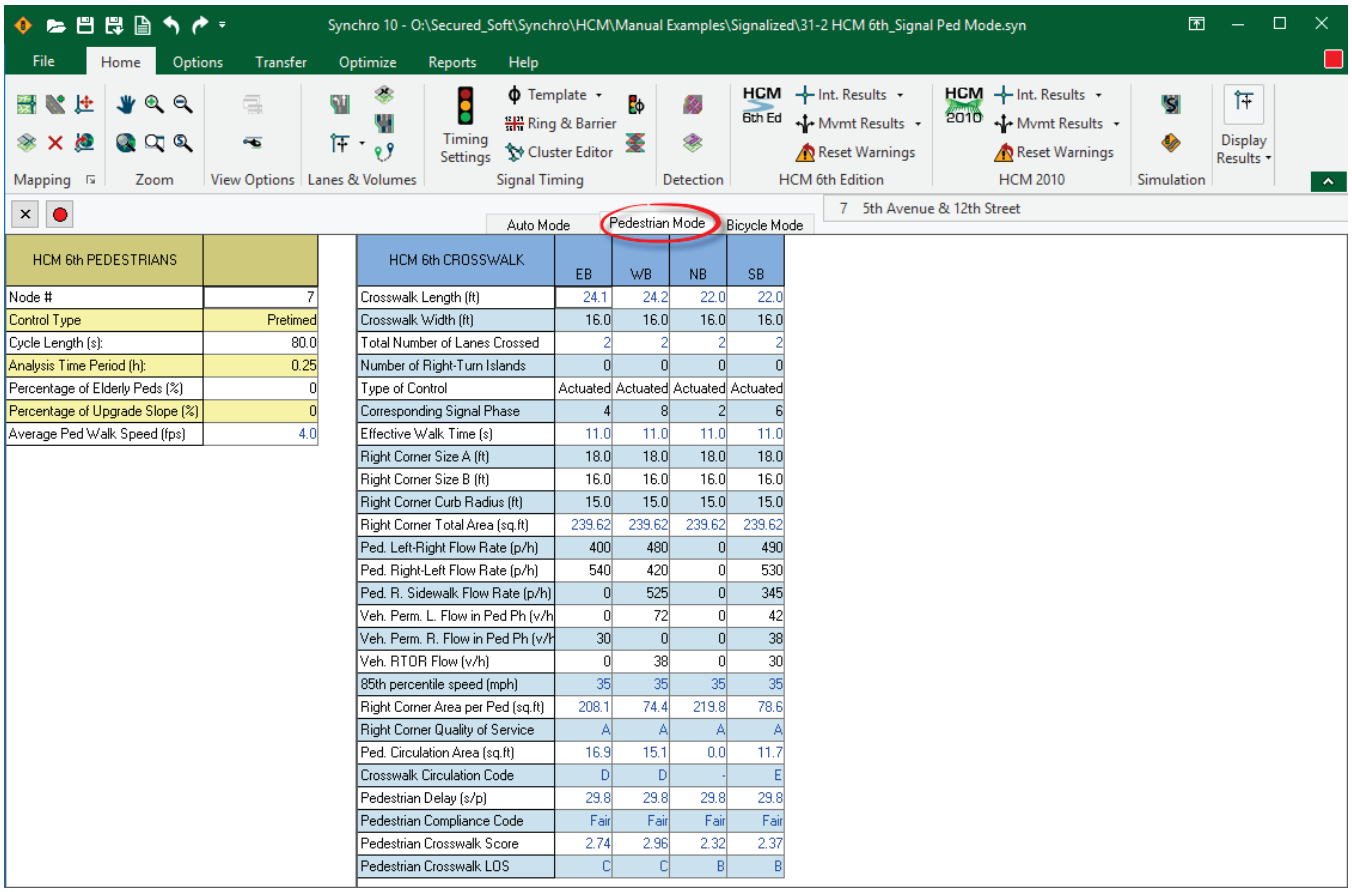
- Maximum of four (4) approaches
- Isolated from nearby intersections. Adjustments for actuated-coordinated networks only.
- Phasing must adhere strictly to standard NEMA phasing.
- Crosswalk grades maximum 2%
- Presence of railroad crossings
- Unpaved sidewalks
- Free channelized right turn lanes with multiple lanes or high travel speeds
- Does not account for other means of travel such as Segway or roller skates

- Does not account for pedestrian subgroups (such as elderly, disabled, etc) that may have differing walking speeds or behaviors from the "typical pedestrian"

Synchro's Signalized Intersection Screen (Pedestrian Mode)

Once a user has created a signalized intersection, pressing the HCM 6th Edition icon allows the user to interactively view the results based on the HCM 6th Edition methodology. Several of the displayed values are carried over from the Synchro Lane, Volume, and Timing Setting windows. There are, however, many new input parameters based on the HCM 6th Edition procedures. The figure below depicts the HCM 6th Edition screen in Synchro. Figure 3 includes a sketch of the pedestrian data that should be entered to complete a pedestrian analysis.

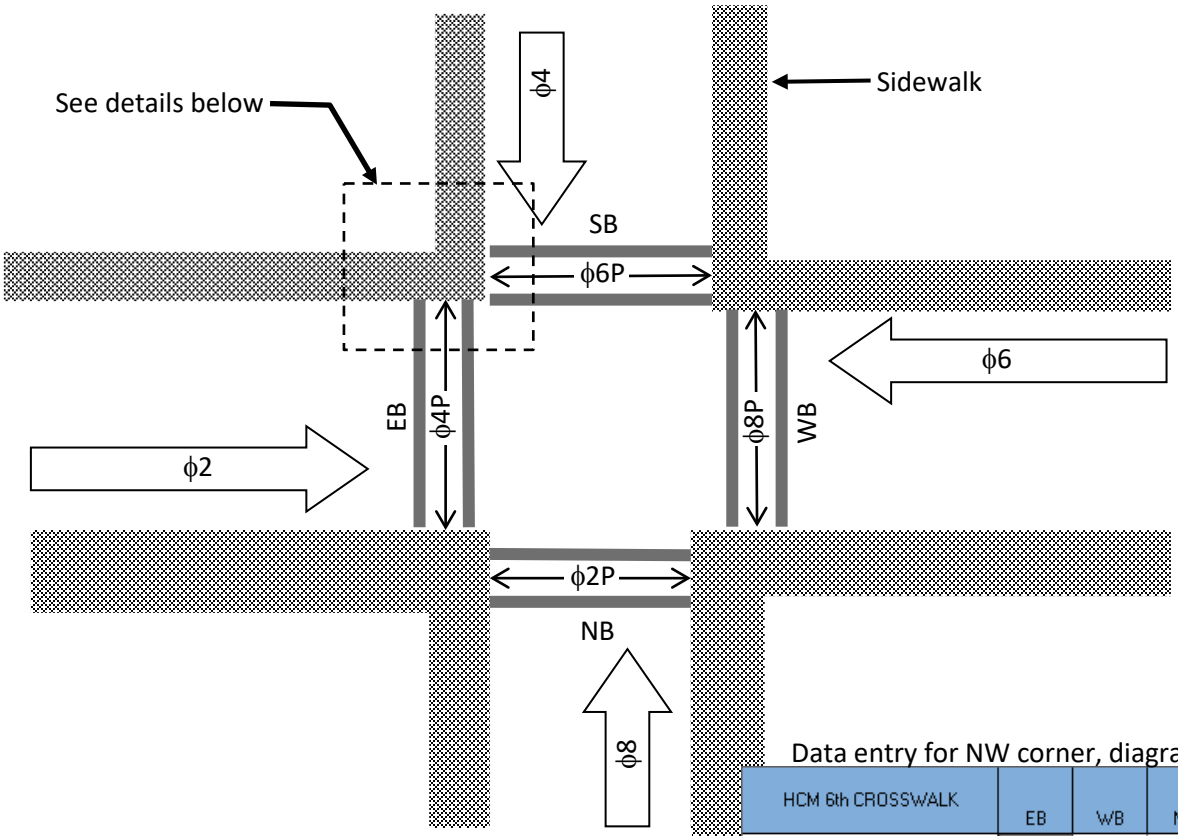
Figure 3 - Signalized Intersection Ped Mode in Synchro

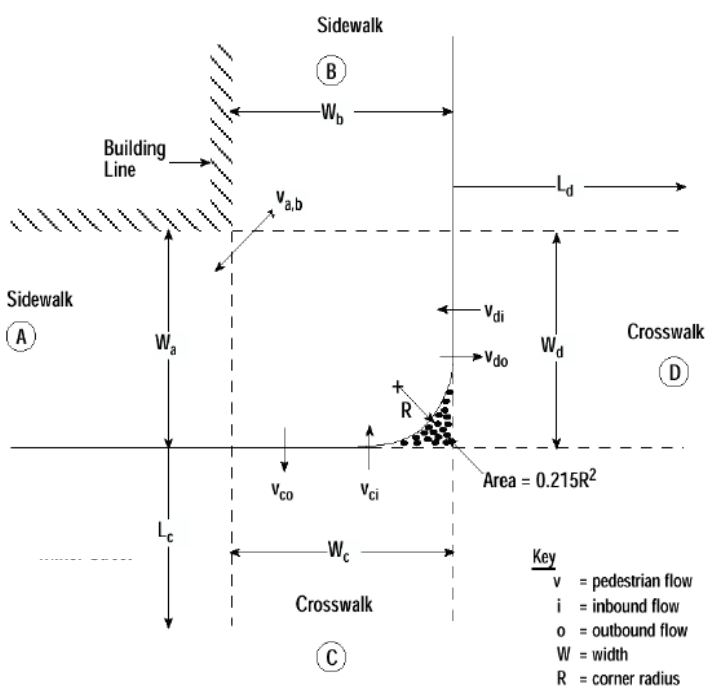


HCM 6th PEDESTRIANS	
Node #	7
Control Type	Pretimed
Cycle Length (s):	80.0
Analysis Time Period (h):	0.25
Percentage of Elderly Peds (%)	0
Percentage of Upgrade Slope (%)	0
Average Ped Walk Speed (fps)	4.0

HCM 6th CROSSWALK	EB	WB	NB	SB
Crosswalk Length (ft)	24.1	24.2	22.0	22.0
Crosswalk Width (ft)	16.0	16.0	16.0	16.0
Total Number of Lanes Crossed	2	2	2	2
Number of Right-Turn Islands	0	0	0	0
Type of Control	Actuated	Actuated	Actuated	Actuated
Corresponding Signal Phase	4	8	2	6
Effective Walk Time (s)	11.0	11.0	11.0	11.0
Right Corner Size A (ft)	18.0	18.0	18.0	18.0
Right Corner Size B (ft)	16.0	16.0	16.0	16.0
Right Corner Curb Radius (ft)	15.0	15.0	15.0	15.0
Right Corner Total Area (sq.ft)	239.62	239.62	239.62	239.62
Ped. Left-Right Flow Rate (p/h)	400	480	0	490
Ped. Right-Left Flow Rate (p/h)	540	420	0	530
Ped. R. Sidewalk Flow Rate (p/h)	0	525	0	345
Veh. Perm. L. Flow in Ped Ph (v/h	0	72	0	42
Veh. Perm. R. Flow in Ped Ph (v/h	30	0	0	38
Veh. RTOR Flow (v/h)	0	38	0	30
85th percentile speed (mph)	35	35	35	35
Right Corner Area per Ped (sq.ft)	208.1	74.4	219.8	78.6
Right Corner Quality of Service	A	A	A	A
Ped. Circulation Area (sq.ft)	16.9	15.1	0.0	11.7
Crosswalk Circulation Code	D	D	-	E
Pedestrian Delay (s/p)	29.8	29.8	29.8	29.8
Pedestrian Compliance Code	Fair	Fair	Fair	Fair
Pedestrian Crosswalk Score	2.74	2.96	2.32	2.37
Pedestrian Crosswalk LOS	C	C	B	B

Figure 4 - Signalized Intersection Ped Mode Data





Data entry for NW corner, diagram at left.

HCM 6th CROSSWALK	EB	WB	NB	SB
Crosswalk Length (ft)	L_c	24.2	22.0	L_d
Crosswalk Width (ft)	W_c	16.0	16.0	W_d
Total Number of Lanes Crossed	2	2	2	2
Number of Right-Turn Islands	0	0	0	0
Type of Control	Actuated	Actuated	Actuated	Actuated
Corresponding Signal Phase	4	8	2	6
Effective Walk Time (s)	11.0	11.0	11.0	11.0
Right Corner Size A (ft)	18.0	18.0	18.0	W_a
Right Corner Size B (ft)	16.0	16.0	16.0	W_b
Right Corner Curb Radius (ft)	15.0	15.0	15.0	R
Right Corner Total Area (sq.ft)	239.62	239.62	239.62	239.62
Ped. Left-Right Flow Rate (p/h)	v_{co}	480	0	v_{di}
Ped. Right-Left Flow Rate (p/h)	v_{ci}	420	0	v_{do}
Ped. R. Sidewalk Flow Rate (p/h)	0	525	0	$v_{a,b}$
Veh. Perm. L. Flow in Ped Ph (v/h	0	72	0	42
Veh. Perm. R. Flow in Ped Ph (v/h	30	0	0	38
Veh. RTOR Flow (v/h)	0	38	0	30
85th percentile speed (mph)	35	35	35	35
Right Corner Area per Ped (sq.ft)	208.1	74.4	219.8	78.6
Right Corner Quality of Service	A	A	A	A
Ped. Circulation Area (sq.ft)	16.9	15.1	0.0	11.7
Crosswalk Circulation Code	D	D	-	E
Pedestrian Delay (s/p)	29.8	29.8	29.8	29.8
Pedestrian Compliance Code	Fair	Fair	Fair	Fair
Pedestrian Crosswalk Score	2.74	2.96	2.32	2.37
Pedestrian Crosswalk LOS	C	C	B	B

Section 3 Signalized Intersections (Bicycle Mode)

This section identifies what's new in the HCM 6th Edition for the bicycle mode at signalized intersections and how Synchro has implemented the applicable sections of Chapter 19 (Signalized Intersections) and Chapter 32 (Supplemental Signalized Intersections).

Introduction

There are a few changes and additions to the bicycle methodologies for signalized intersections, but the overall analysis methodologies remain similar to those in HCM 2010. Some of the major changes as compared with the 2010 HCM include:

- Striped parking lane width
- Updated Level of Service (LOS) thresholds

If you are interested in this analysis method, one should review the HCM 6th Edition Manual along with this section to determine how to conduct your analysis.

Parking Lane Width

If a striped parking lane is present, the parking lane width is now considered when calculating the bicycle LOS.

Delay & Level of Service Thresholds

Similar to the methodology provided in HCM 2010, the HCM 6th computes a Bicycle LOS Score for each approach. Corrections have been made to the Bicycle LOS thresholds in the HCM 6th Edition. The table compares the LOS thresholds for HCM 6th Edition and HCM 2010.

Table 3 - Bicycle Mode LOS Thresholds for Signalized Intersections

Level of Service	LOS Score	
	HCM 2010	HCM 6th Edition
A	≤ 2.00	≤ 1.50
B	> 2.00 – 2.75	> 1.50 – 2.50
C	> 2.75 – 3.50	> 2.50 – 3.50
D	> 3.50 – 4.25	> 3.50 – 4.50
E	> 4.25 – 5.00	> 4.50 – 5.50
F	> 5.00	> 5.50

Known Issues and Limitations

As you begin to use Synchro to conduct an HCM 6th Edition analysis, please review this section (as well as the HCM 2010 itself) to familiarize yourself with the various methods and their limitations. The following bullets highlight the key limitations as identified by TRB:

- Intersections with three (3) or four (4) approaches.
- Isolated from nearby intersections. Adjustments for actuated-coordinated networks only.
- Phasing must adhere strictly to standard NEMA phasing.

Section 4 Two-Way Stop Control Intersections (Auto Mode)

This section identifies what's new in the HCM 6th Edition for two-way stop control (TWSC) intersections and how Synchro has implemented the applicable sections of Chapter 20 (TWSC Intersections) and Chapter 32 (Supplemental Stop-Controlled Intersections).

Introduction

The HCM 6th Edition method for TWSC intersections is very similar to the HCM 2010 method.

Delay & Level of Service Thresholds

The LOS thresholds for lane groups takes into account the volume-to-capacity (v/c) ratio, in addition to control delay, such that a v/c ratio above 1.0 would result in an LOS 'F' regardless of the corresponding value of control delay. Values for approach and overall intersection LOS are still based only on control delay.

Known Issues and Limitations

As with any operational analysis methods, there will always be a set of limitations that surround the use of the various methodologies. As you begin to use Synchro to conduct a HCM 6th Edition analysis, one should review the HCM 6th Edition to confirm that use of HCM 6th Edition is applicable. The following bullets highlight the key limitations as identified by TRB:

- Intersections with three (3) or four (4) approaches.
- Major Roadway – Maximum of three through lanes (shared or exclusive).
- Minor Roadway – Maximum of three through lanes with no more than one exclusive lane per movement.
- Upstream signal methodology only accounts for the effects of coordinated intersections.
- Rank 1 movements (major-street throughs and right-turns) are assumed to be unimpeded by pedestrians.

Additional Discussion of Known Issues and Limitations

- Under certain scenarios with upstream or downstream signals, HMC 2010 Equation 20-35 yields undesirable values when zero is selected as $v_{c,u,x}$ based on Equation 20-33. This assumes all conflicting flow happens during the platoon block time. In these situations, Synchro assigns a value of one (1) for use in Equation 20-35. It is represented with "*" superscript preceding the value within the Synchro HCM 6th Edition window as well as in the report. This prevents zeroing of the Capacity in Equation 20-35, and the results are observed to be more realistic.

- HCM references various tables with parameters used in the calculations based on the total number of through lanes along the study roadway (2, 4, and 6 lanes). Trafficware uses these values but divides them up to number of lanes by approach (1, 2, and 3 lane approach). This allows the user to analyze an intersection with an unequal number of through approach lanes in the calculations as it relates to conflicting volumes for various movements.

Section 5 Two-Way Stop Control Intersections (Pedestrian Mode)

This section identifies what's new in the HCM 6th Edition for the pedestrian mode at two-way stop control intersections and how Synchro has implemented the applicable sections of Chapter 20 (TWSC Intersections) and Chapter 32 (Supplemental Stop-Controlled Intersections).

Introduction

The HCM 6th Edition method to analyze pedestrians at TWSC intersections is very similar to the HCM 2010 method.

Motorist Yield Rate

In some situations, drivers will yield to a pedestrian waiting to cross. The HCM 6th Edition includes the parameter *Yield Rate (%)* to account for the percentage of drivers that yield to a pedestrian. Driver yielding behavior is influenced by many factors, including roadway geometry, speeds, pedestrian crossing treatment, local culture, and law enforcement practices. The table below provides information on typical motorist responses to various pedestrian crossing treatments. These values can be used in combination with local knowledge and engineering judgement to estimate the Yield Rate.

Table 4 - Effect of Pedestrian Crossing Treatment on Motorist Yield Rates

Crossing Treatment	Staged Pedestrians*		Unstaged Pedestrians**	
	Number of Sites	Mean Yield Rate (%)	Number of Sites	Mean Yield Rate (%)
Overhead flashing beacon (push button activated)	3	47	4	49
Overhead flashing beacon (passive activation)	3	31	3	67
Pedestrian crossing flags	6	65	4	74
In-street crossing signs (20-30 mph)	3	87	3	90
High-visibility signs and markings (35 mph)	2	17	2	20
High-visibility signs and markings (25 mph)	1	61	1	91
Rectangular rapid-flash beacon	N/A	N/A	17	81

**Staged data was collected with pedestrians trained by the research team to maintain consistent positioning, stance, and aggressiveness in crossing attempts.*

***Unstaged data was collected through video recordings of the general population.*

Known Issues and Limitations

As with any operational analysis methods, there will always be a set of limitations that surround the use of the various methodologies. As you begin to use Synchro to conduct an HCM 6th Edition analysis, one should review the HCM 6th Edition to confirm that use of HCM 6th Edition is applicable. The following bullets highlight the key limitations as identified by TRB:

- Midblock crossings.
- Crossing of up to four through lanes.
- Random arrivals, equal directional and lane distribution on the major street.
- Upstream signals not accounted for.
- Pedestrians walking parallel to roadway do not impact crossing pedestrians.

Section 6 All-Way Stop Control Intersections

This section identifies what's new in the HCM 6th Edition for all-way stop control (AWSC) intersections and how Synchro has implemented the applicable sections of Chapter 21 (AWSC Intersections) and Chapter 32 (Supplemental Stop-Controlled Intersections).

Introduction

The HCM 6th Edition method for AWSC intersections is very similar to the HCM 2010 method.

Delay & Level of Service Thresholds

The LOS thresholds for lane groups takes into account the volume-to-capacity (v/c) ratio, in addition to control delay, such that a v/c ratio above 1.0 would result in an LOS 'F' regardless of the corresponding value of control delay. Values for approach and overall intersection LOS are still based only on control delay.

Known Issues and Limitations

As with any operational analysis methods, there will always be a set of limitations that surround the use of the various methodologies. Most of the limitations set forth by TRB for the HCM 6th Edition are similar to those of the HCM 2010 and HCM 2000. As you begin to use Synchro to conduct a HCM 6th Edition analysis, one should review the HCM 6th Edition to confirm that use of HCM 6th Edition is applicable. The following bullets highlight the key limitations as identified by TRB:

- Intersections with three (3) or four (4) approaches.
- Isolated from nearby intersections.
- Up to three lanes per approach.
- Pedestrian effects not considered.

Section 7 – Roundabouts

This section identifies what's new in the HCM 6th Edition for roundabouts and how Synchro has implemented the applicable sections of Chapter 22 (Roundabouts) and Chapter 33 (Supplemental Roundabouts).

The HCM 6th Edition includes an updated capacity model as a result of new research. FHWA-sponsored research studied roundabout operations for 24 approaches at single-lane roundabouts and 37 approaches at multilane roundabouts, updating NCHRP Project 03-65. The research and resulting capacity model is summarized in NCHRP Report 572: Roundabouts in the United States.

Introduction

The new capacity model in the HCM 6th Edition results in higher capacities than those calculated using HCM 2010 methodologies. This address concerns throughout the user community that capacities are lower than observed.

Research found significant variation in roundabout capacities throughout the U.S., contributing to a considerable spread to the data. Local driving culture and density of roundabouts in an area likely influence this variation in capacity. Current research indicates that U.S. drivers seem to display more hesitation and caution in using roundabouts than drivers in other countries, which results in lower observed capacities. Research has not found significant increases in capacity over time, but some geographic areas showed significantly higher capacities than the national average.

New Capacity Model

The new capacity model included in the HCM 6th Edition includes new coefficients for existing equations 22-1, 22-2, 22-3, 22-4, 22-5, 22-6, and 22-7. As seen in the table below, the predicted capacity calculated using HCM 6th Edition tends to be higher than that computed using HCM 2010.

Table 5 - Roundabout Capacity

Entry Lanes	Opposing Lanes	HCM 2010		HCM 6th Edition	
		$V_c = 0$	$V_c = 1000$	$V_c = 0$	$V_c = 1000$
1	2	1130	561	1420	607
Right	2	1130	561	1420	607
Left	2	1130	534	1350	538
1	1	1130	416	1380	498
R or L	1	1130	416	1420	572

Note: V_c = conflicting flow rate (pc/h)

Known Issues and Limitations

As with any operational analysis methods, there will always be a set of limitations that surround the use of the various methodologies. As you begin to use Synchro to conduct a HCM 6th Edition analysis, one should review the HCM 6th Edition to confirm that use of HCM 6th Edition is applicable. The following bullets highlight the key limitations as identified by TRB:

- Intersections with three (3) or four (4) approaches.
- Isolated from nearby intersections, including nearby roundabouts or signalized intersections.
- Not intended for rotaries, neighborhood traffic circles, or signalized approaches.
- Up to two entry lanes and up to one bypass lane per approach.
- Maximum of two circulating lanes.
- Flared entry lanes.
- Priority reversal under extremely high traffic volumes.
- A moderate level of pedestrian or bicycle activity.
- Pedestrian signals at roundabout crosswalks

Additional Discussion of Known Issues and Limitations

The HCM 6th Edition does not account for geometric features such as the inscribed circle diameter, entry lane width, entry angle, and the presence of a splitter island. Current research indicates that these characteristics may impact capacity, but the trends are not strong enough to include in the capacity model at this time.

Calibration

The roundabout model can be calibrated to local conditions using field measurements of the following parameters:

- *Follow-Up Headway* – The amount of time between vehicles entering roundabout. The maximum entry flow is given by 3,600 s/h divided by the follow-up headway, which is analogous to the saturation flow rate for a movement receiving a green indication at a signalized intersection.
- *Critical Headway* – This parameter is based on the amount of time required for a vehicle to safely enter the conflicting stream.

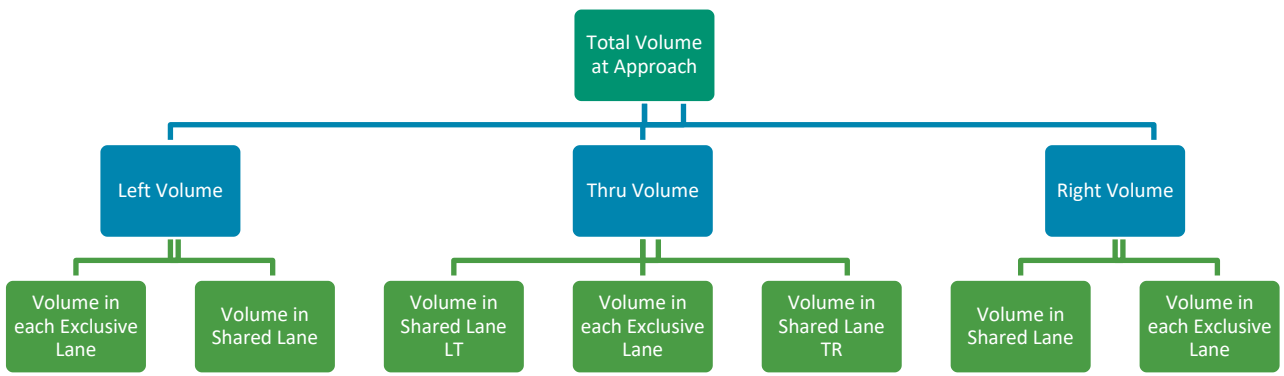
Section 8 – Appendix

Intersections that include approach geometrics with an exclusive left/right turn lane and a shared left/right turn /through lane are not fully supported by the HCM 6th Edition. To overcome this limitation, Trafficware has developed a method to estimate volumes (using equivalency factors) by lane group categories that are HCM 6th Edition compliant. The same methodology is included in Synchro's implementation of HCM 2010.

The method is relatively straight-forward and focuses the analysis of the shared lane(s) functioning as a de facto lane. The shared volume components are used to determine if the shared lane functions as a de facto lane, i.e. if the shared left-thru lane has a much higher presence of lefts, than through movements, then the shared lane can be analyzed as a de facto left, and vice versa.

The method consists of the following three key steps;

- **Step 1**: Distribution of volumes based on a lane-by-lane assignment – An average volume is computed using the exclusive left/right turn volume plus volume attributed to an exclusive through lane. The average is determined based on the number of left/right and through lanes per approach.

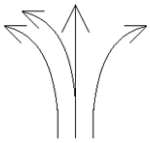


- **Step 2:** Comparing the left/right volume in shared lanes – Once the volumes have been distributed, a preference factor (0.90) is used to bias the preference towards the through movement. Depending on the greater volume of the two shared components, the shared Lane is identified either as a de facto left, through, or right.

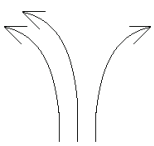
- **Step 3:** Adjustment of volumes – The volumes are multiplied by an equivalency factor to account for lane assignment. The table below highlights the current default values.

	Left Lane	Through Lane	Right Lane
Left-turn	1.00	1.40	0.90
Through	0.70	1.00	0.67
Right-turn	1.07	1.50	1.00

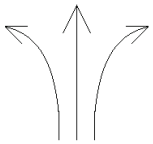
Let's consider an example to highlight the steps described above. Consider the illustrated approach geometry (shown below) with one exclusive left and right turning lanes, and one thru lane share with lefts. Let the original volumes be represented as VL, VT and VR respectively.



Based on the methodology listed above, the following two approach lane geometrics are possible;



OR



De facto Left De facto Thru

The table below includes a summary of eight possible *volume* scenarios and the corresponding shared lane that is determined based on the methodology above.

#	Approach Type	Original Volumes					Adjusted Volumes			Shared Lane acting as:
		L		T	R		L	T	R	
1	Single Left, Shared Left/Thru Single Right	600		50	50		636	0	50	de facto Left
		325	275							
2	Single Left, Shared Left/Thru Single Right	600		100	50		671	0	50	de facto Left
		350	250							
3	Single Left, Shared Left/Thru Single Right	600		150	50		375	465	50	de facto Thru
		375	225							
4	Single Left, Shared Left/Thru Single Right	600		200	50		400	480	50	de facto Thru
		400	200							
5	Single Left, Shared Left/Thru Single Right	500		50	50		536	0	50	de facto Left
		275	225							
6	Single Left, Shared Left/Thru Single Right	500		100	50		571	0	50	de facto Left
		300	200							
7	Single Left, Shared Left/Thru Single Right	500		150	50		325	395	50	de facto Thru
		325	175							
8	Single Left, Shared Left/Thru Single Right	500		200	50		350	410	50	de facto Thru
		350	150							