QEM User's Guide

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Quick Estimation Method (QEM) for Traffic Signal Timing

Introduction

One of the biggest challenges in meso and macrosimulation is the estimation of signalized intersection capacities. These simulation tools lack a good signal control emulator that would provide realistic signal timing and phasing data, and simplify the exporting process of signalized intersections. Almost all signal timing adjustments had to be set manually once they are exported from meso/macrosimulation to microsimulation, or Synchro-like software. For existing networks, this process can somewhat be simplified by importing field traffic control data, but it becomes more complex for predicted and estimated traffic conditions, when the field data are not available. Therefore, the development of a tool for quick estimation of signal timings is an important step in simplifying the cross resolution modeling efforts. The QEM_SIG Excel spreadsheet that accompanies the NeXTA software represents a computational engine for estimating signalized intersections operation. It is relying on the HCM 2010 methodology for signalized intersection analysis and the HCM QEM method, but it is also using other methodologies for computing parameters of signalized intersections (as described in the Signal Timing Manual (STM), 2008 edition). It can be used as a stand-alone application, or integrated with NeXTA. The latest edition of the stand-alone application is a macro-enabled workbook, so the use needs to **enable macros** after starting the application. The macros are used to export Synchro CSV files and create signalized intersection analysis reports in the PDF format for a more convenient representation of results.

Figure 1 shows the input/output configuration, while Figure 2 shows the data flow of the QEM application.

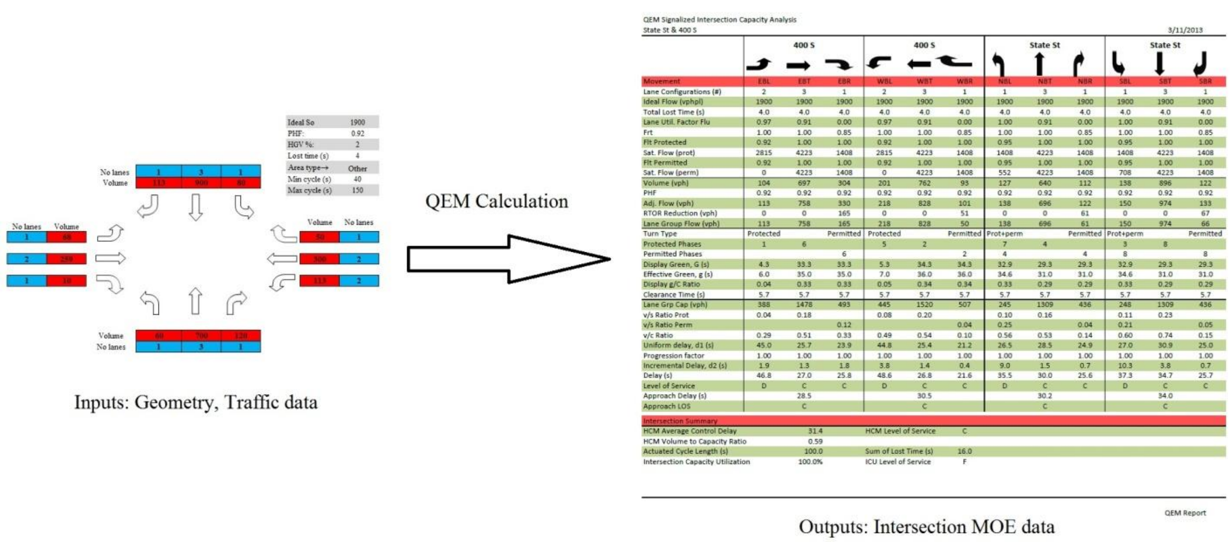


Figure 1. *QEM input/output configuration.*

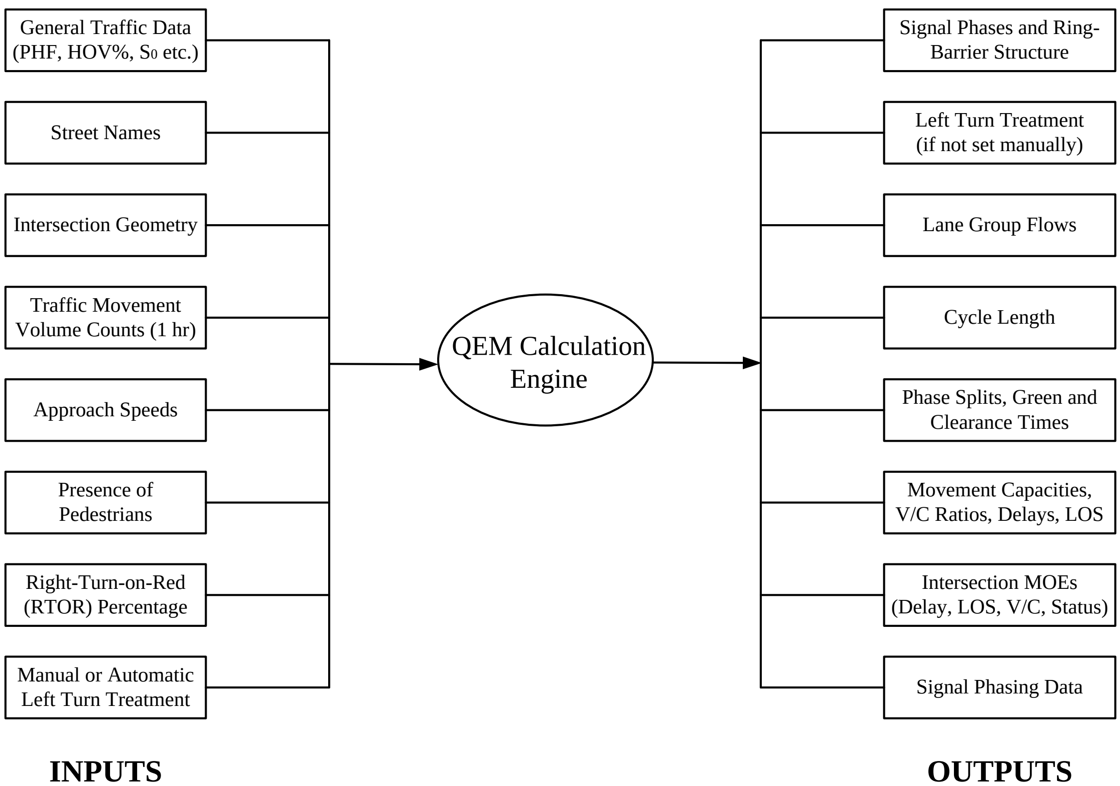


Figure 2. *QEM data flow.*

Methodology

The methodology of the QEM application is given by sections, and they are defined as follows (different tabs in the spreadsheet):

- Sheet 1 – input/output sheet for communication with NeXTA
- Input sheet – data input section; this is the only section where the user needs to input intersection data if the spreadsheet is used as a stand-alone application
- Phase designation – assigning phases to intersection movements, determining left turn treatment and defining ring-barrier structure
- Lane volumes – calculation of lane volumes (HCM 2010 Chapter 31)
- Phase calculation – calculation of the cycle length, green time (splits) allocations, movement capacities, V/C ratios, and Levels of Service (LOS)
- Phasing – calculate phasing data for correct export to Synchro
- Summary sheet – output sheet with calculation results
- LAYOUT, LANES, VOLUME, PHASING and TIMING sheets – output sheets for automatic Synchro export
- Report – sheet that summarizes QEM results in a format similar to the Synchro report, used for the PDF export of the intersection capacity analysis results

Sheet 1 communicates with NeXTA during mesosimulation, and it reads and writes signal control data. For each intersection in the simulation, Sheet 1 reads lane configurations, turning volumes, and main movement speeds, and uses them in the calculation procedure. Then it returns data for phase designation (that includes protected/permitted phases for left turns), detector phases, effective green, capacity, V/C ratio, delay, LOS, and the complete array of phasing data. NeXTA can further use these outputs to export traffic data in the UTDF format for use with Synchro or VISSIM. When the QEM spreadsheet is used as a stand-alone application, Sheet 1 must not be deleted nor amended, since it actively communicates with other sections. It does not provide outputs in a user-friendly format, but these outputs can be used to manually export lanes/volumes/phasing/timing data to Synchro. The look of Sheet 1 is shown in Figure 3.

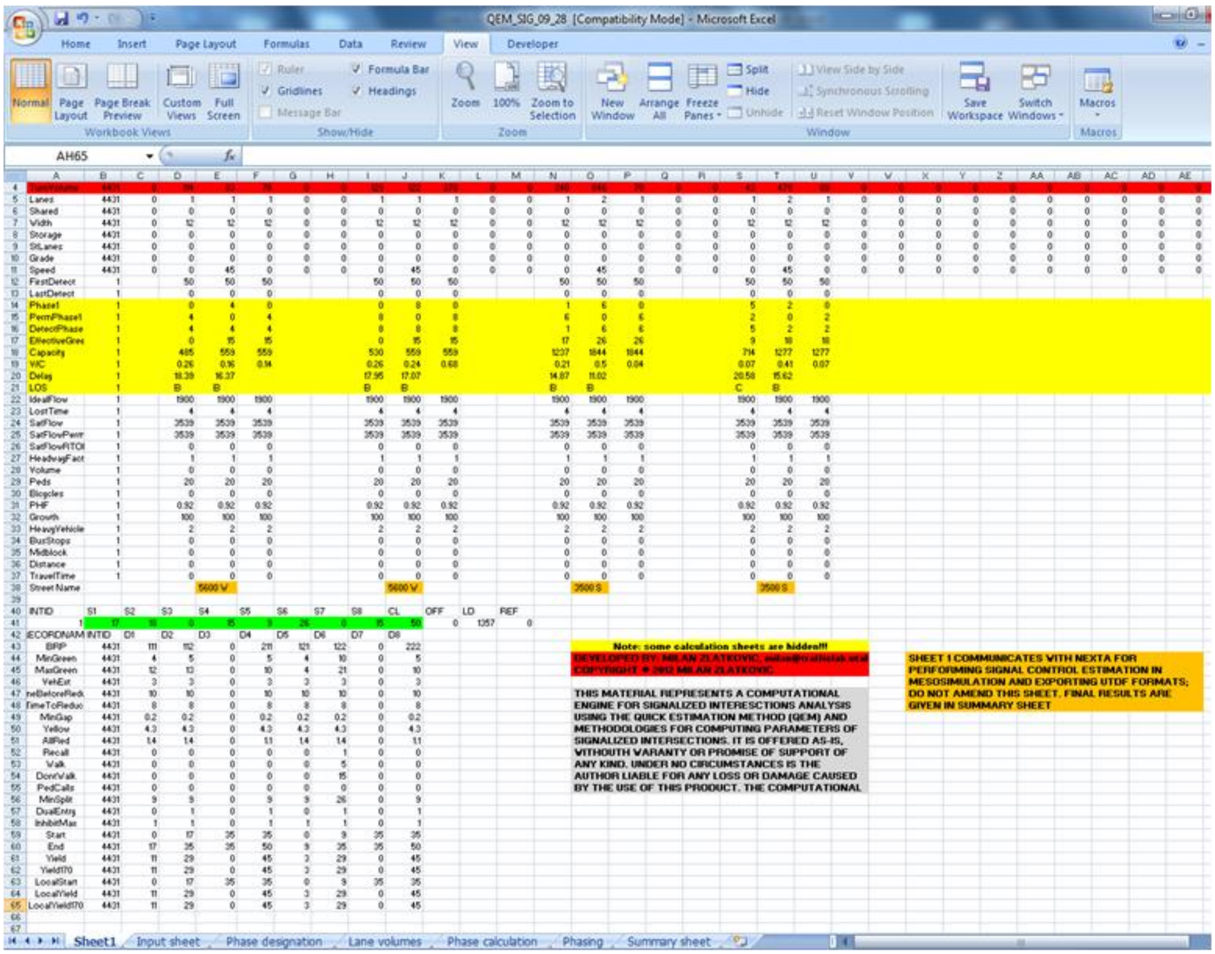


Figure 3. *The look of Sheet 1.*

The **Input sheet** is the only section where the user is asked to enter intersection data. This sheet is important if the QEM is used as a stand-alone application, although some inputs are required for NeXTA integration. The following inputs are needed:

- Street names – optional.

- Intersection lane configuration – required (number of lanes for each approach and each movement).
- Turning volumes for each movement – required.
- Right Turn on Red (RTOR %) – required. The estimated values for this entry are 50-75% for exclusive right turn lanes, and less than 10% for shared
- Approach through speeds – important if these speeds are greater than 45 mph, since this is one of the requirements for protected only left turn treatments. Also needed for correct calculation of phasing data.
- Presence of pedestrians – select option (Yes/No) from the drop-down menu. If pedestrians are present, pedestrian timing will be included in minimum splits and cycle calculation. For urban intersection, this option should generally be enabled. If QEM is used with the NeXTA software, this option can be set only once, and it will be the same for all intersection that NeXTA is estimating.
- Manual selection of left turn treatment – if used as a stand-alone version and field data regarding left turn treatment are known, this entry allows for a manual selection of left turn treatment. If activated, this option will allow left turn treatment for each approach to be selected from the drop-down menu. The options are: Protected, Permitted, Protected + permitted, or blank. This entry will override the automatic designation of left turn treatments.

Note: if used with NeXTA, this option should be disabled. Also, if for some approaches the selection is not defined ("blank"), left turns for that approach will be assigned automatically.

- Ideal saturation flow rate – by default, this value is 1900 vphpl. Can be changed to reflect calibrated saturation flow rate for local conditions.
- Peak Hour Factor (PHF) – if known, it can be entered in this field. Otherwise, it can be set to the value of 0.9.
- Percentage of heavy vehicles (HGV %) – if known, it can be entered in this field. Otherwise, the default value can be set to 3%.
- Lost time per phase (s) – by default, this value is 4 seconds. Can be changed to reflect calibrated lost time for local conditions.
- Area Type – the drop down menu in this field offers a selection between "CBD" (Central business district) and "Other". Area Type should be selected for the analyzed network.
- Minimum and maximum cycle length inputs – allows the user to define these values for local conditions. By default, the minimum cycle length is 40 seconds, and maximum is 150 seconds.

The Input Sheet also contains two action buttons, Synchro CSV Export, and Generate QEM Report. The Synchro CSV Export creates the five CSV files for direct import into Synchro (LAYOUT, LANES, VOLUME, PHASING and TIMING). These files are written into the same folder where the QEM spreadsheet is located. The Generate QEM Report creates a signalized intersection analysis report in the PDF format for a more convenient reporting of results. The PDF report is directly saved into the same folder where the QEM spreadsheet is located with a filename "Intersection NAME OF INTERSECTION QEM Report". The name of the intersection is automatically taken from the street names defined in the Input Sheet. The QEM report has a similar format as the corresponding report obtained from Synchro.

After the input values are defined, the user should not change any other values in other sheets. Figure 4 shows the layout of the Input sheet.

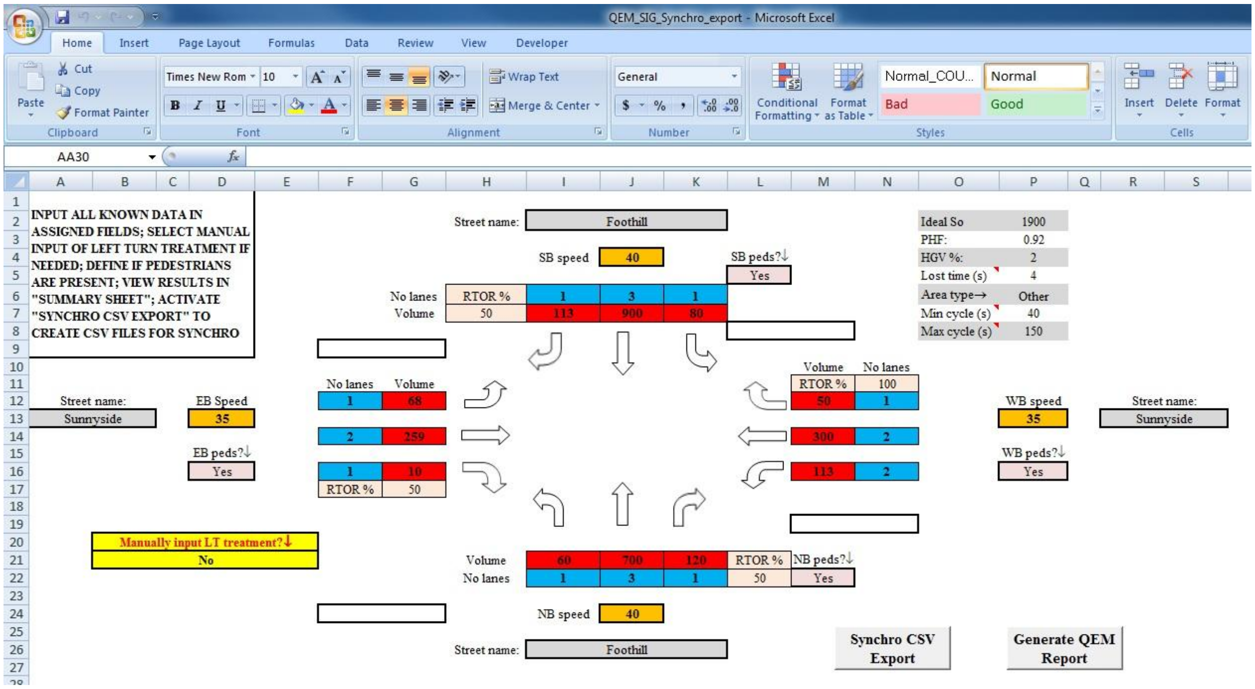
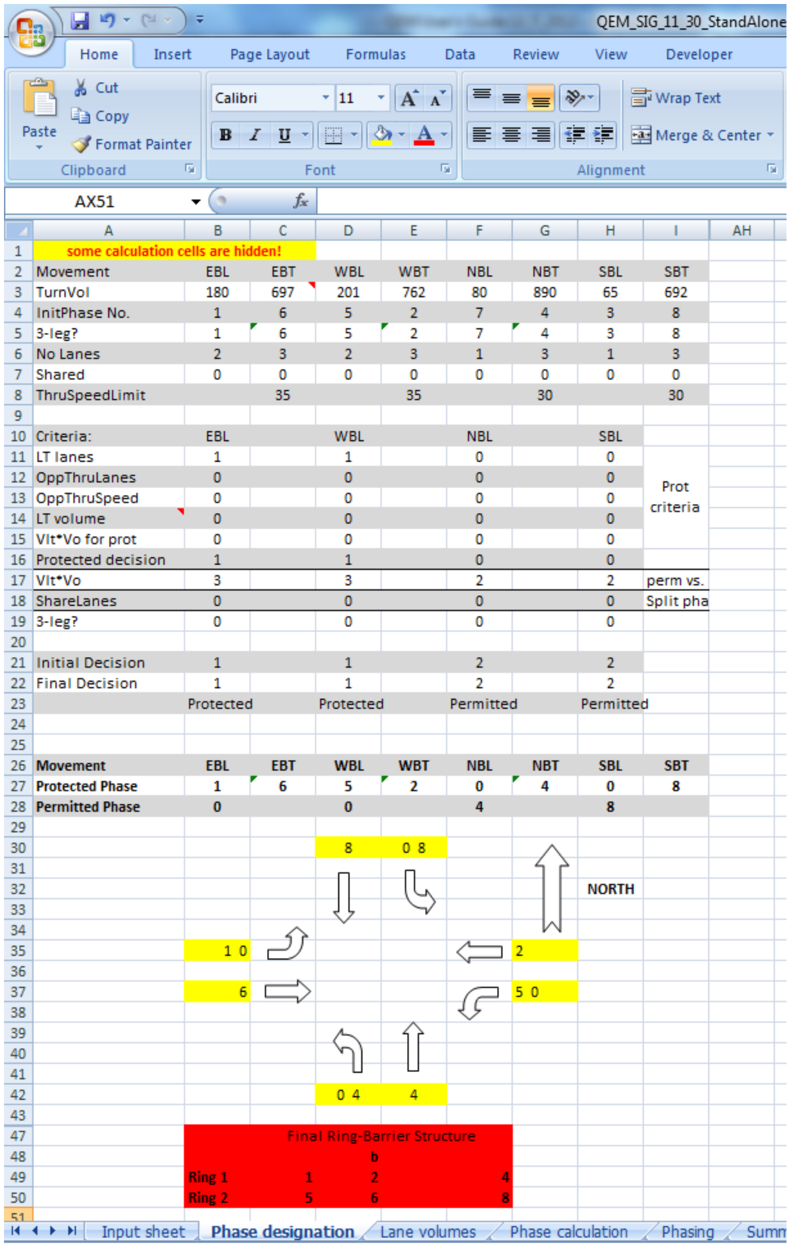


Figure 4. *The layout of the Input sheet.*

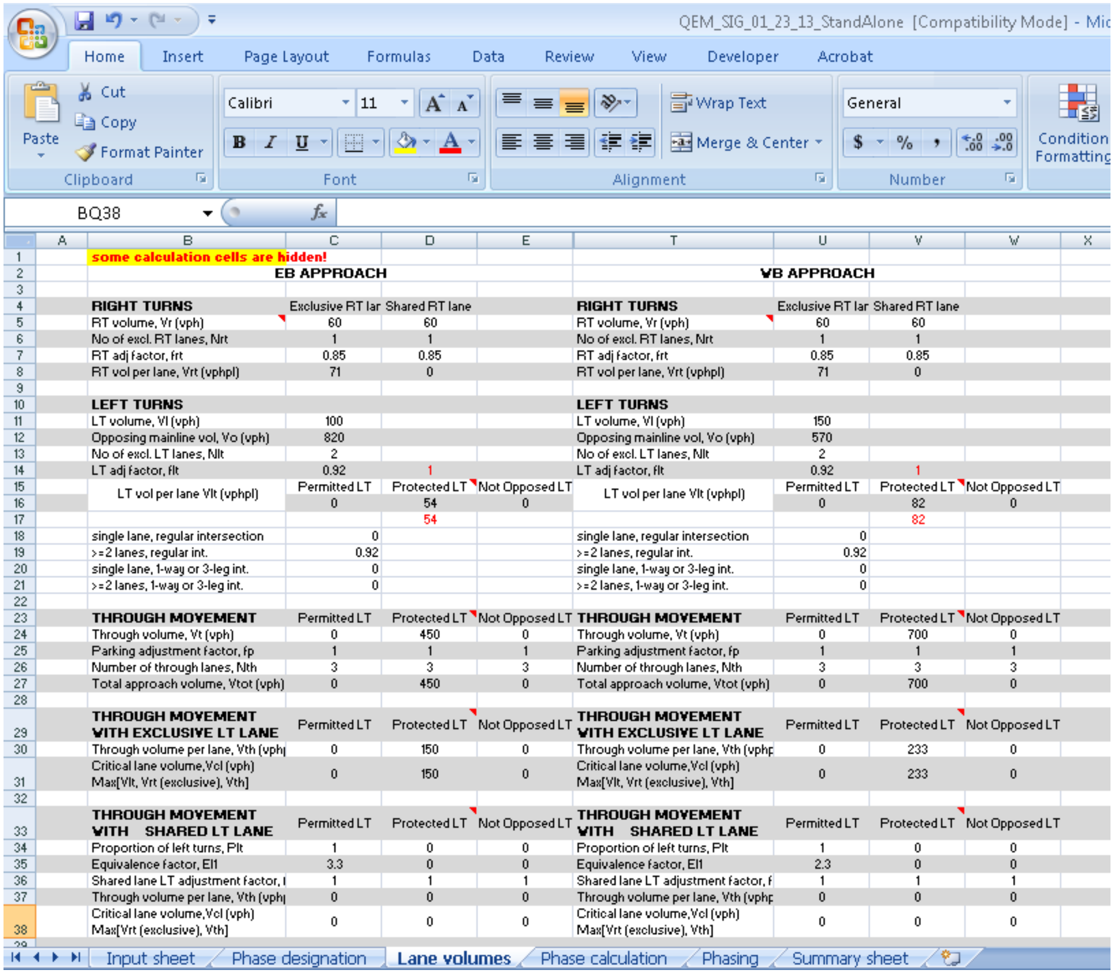
The **Phase designation** sheet determines the major street (NS or EW), defines phases for each movement, and determines the left turn treatment based on the criteria defined in the HCM and STM (Protected only, Permitted only, or Protected + permitted). If the left turn treatment is manually selected in the Input sheet, this selection will be implemented, and the automatic designation overridden. In the case of a 3-leg intersection, the left turn is treated as permitted (the through phase is shown). For phase numbering, the Utah Department of Transportation (UDOT) standard is used: if NS is the major movement, the NB through movement is phase 2; if EW is the major movement, the WB through movement is phase 2. Once the phases and left turn treatments are known, the program defines the standard dual ring-barrier structure for the given case, which is used in follow-up calculations. The Phase designation sheet is shown in Figure 5.



	A	B	C	D	E	F	G	H	I
1	some calculation cells are hidden!								
2	Movement	EBL	EBT	WBL	WBT	NBL	NBT	SBL	SBT
3	TurnVol	180	697	201	762	80	890	65	692
4	InitPhase No.	1	6	5	2	7	4	3	8
5	3-leg?	1	6	5	2	7	4	3	8
6	No Lanes	2	3	2	3	1	3	1	3
7	Shared	0	0	0	0	0	0	0	0
8	ThruSpeedLimit		35		35		30		30
9									
10	Criteria:	EBL		WBL		NBL		SBL	
11	LT lanes	1		1		0		0	
12	OppThruLanes	0		0		0		0	Prot
13	OppThruSpeed	0		0		0		0	criteria
14	LT volume	0		0		0		0	
15	Vlt*Vo for prot	0		0		0		0	
16	Protected decision	1		1		0		0	
17	Vlt*Vo	3		3		2		2	perm vs.
18	ShareLanes	0		0		0		0	Split pha
19	3-leg?	0		0		0		0	
20									
21	Initial Decision	1		1		2		2	
22	Final Decision	1		1		2		2	
23		Protected		Protected		Permitted		Permitted	
24									
25									
26	**Movement**	**EBL**	**EBT**	**WBL**	**WBT**	**NBL**	**NBT**	**SBL**	**SBT**
27	**Protected Phase**	**1**	**6**	**5**	**2**	**0**	**4**	**0**	**8**
28	**Permitted Phase**	**0**		**0**		**4**		**8**	
30				8	0 8				
32								NORTH	
35		1 0					2		
37		6					5 0		
42				0 4	4				
47		Final Ring-Barrier Structure							
48				b					
49		Ring 1	1	2		4			
50		Ring 2	5	6		8			

Figure 5. *Phase designation sheet.*

The **Lane volumes** sheet calculates critical lane volumes for each intersection approach. It follows the methodology defined in the HCM 2010, Chapter 31. The computed lane volumes are later used in cycle length calculation. This sheet is shown in Figure 6.



	A	B	C	D	E	T	U	V	W	X
1		some calculation cells are hidden!								
2			EB APPROACH				VB APPROACH			
3										
4		RIGHT TURNS	Exclusive RT lar	Shared RT lane		RIGHT TURNS	Exclusive RT lar	Shared RT lane		
5		RT volume, Vr (vph)	60	60		RT volume, Vr (vph)	60	60		
6		No of excl. RT lanes, Nrt	1	1		No of excl. RT lanes, Nrt	1	1		
7		RT adj factor, frt	0.85	0.85		RT adj factor, frt	0.85	0.85		
8		RT vol per lane, Vrt (vphpl)	71	0		RT vol per lane, Vrt (vphpl)	71	0		
9										
10		LEFT TURNS				LEFT TURNS				
11		LT volume, Vl (vph)	100			LT volume, Vl (vph)	150			
12		Opposing mainline vol, Vo (vph)	820			Opposing mainline vol, Vo (vph)	570			
13		No of excl. LT lanes, Nlt	2			No of excl. LT lanes, Nlt	2			
14		LT adj factor, flt	0.92	1		LT adj factor, flt	0.92	1		
15		LT vol per lane Vlt (vphpl)	Permitted LT	Protected LT	Not Opposed LT	LT vol per lane Vlt (vphpl)	Permitted LT	Protected LT	Not Opposed LT	
16			0	54	0		0	82	0	
17				54				82		
18		single lane, regular intersection	0			single lane, regular intersection	0			
19		>=2 lanes, regular int.	0.92			>=2 lanes, regular int.	0.92			
20		single lane, 1-way or 3-leg int.	0			single lane, 1-way or 3-leg int.	0			
21		>=2 lanes, 1-way or 3-leg int.	0			>=2 lanes, 1-way or 3-leg int.	0			
22										
23		THROUGH MOVEMENT	Permitted LT	Protected LT	Not Opposed LT	THROUGH MOVEMENT	Permitted LT	Protected LT	Not Opposed LT	
24		Through volume, Vt (vph)	0	450	0	Through volume, Vt (vph)	0	700	0	
25		Parking adjustment factor, fp	1	1	1	Parking adjustment factor, fp	1	1	1	
26		Number of through lanes, Nth	3	3	3	Number of through lanes, Nth	3	3	3	
27		Total approach volume, Vtot (vph)	0	450	0	Total approach volume, Vtot (vph)	0	700	0	
28										
29		THROUGH MOVEMENT VITH EXCLUSIVE LT LANE	Permitted LT	Protected LT	Not Opposed LT	THROUGH MOVEMENT VITH EXCLUSIVE LT LANE	Permitted LT	Protected LT	Not Opposed LT	
30		Through volume per lane, Vth (vph	0	150	0	Through volume per lane, Vth (vphp	0	233	0	
31		Critical lane volume,Vcl (vph) Max[Vlt, Vrt (exclusive), Vth]	0	150	0	Critical lane volume,Vcl (vph) Max[Vlt, Vrt (exclusive), Vth]	0	233	0	
32										
33		THROUGH MOVEMENT VITH SHARED LT LANE	Permitted LT	Protected LT	Not Opposed LT	THROUGH MOVEMENT VITH SHARED LT LANE	Permitted LT	Protected LT	Not Opposed LT	
34		Proportion of left turns, Plt	1	0	0	Proportion of left turns, Plt	1	0	0	
35		Equivalence factor, El1	3.3	0	0	Equivalence factor, El1	2.3	0	0	
36		Shared lane LT adjustment factor, f	1	1	1	Shared lane LT adjustment factor, f	1	1	1	
37		Through volume per lane, Vth (vph	0	0	0	Through volume per lane, Vth (vphp	0	0	0	
38		Critical lane volume,Vcl (vph) Max[Vrt (exclusive), Vth]	0	0	0	Critical lane volume,Vcl (vph) Max[Vrt (exclusive), Vth]	0	0	0	

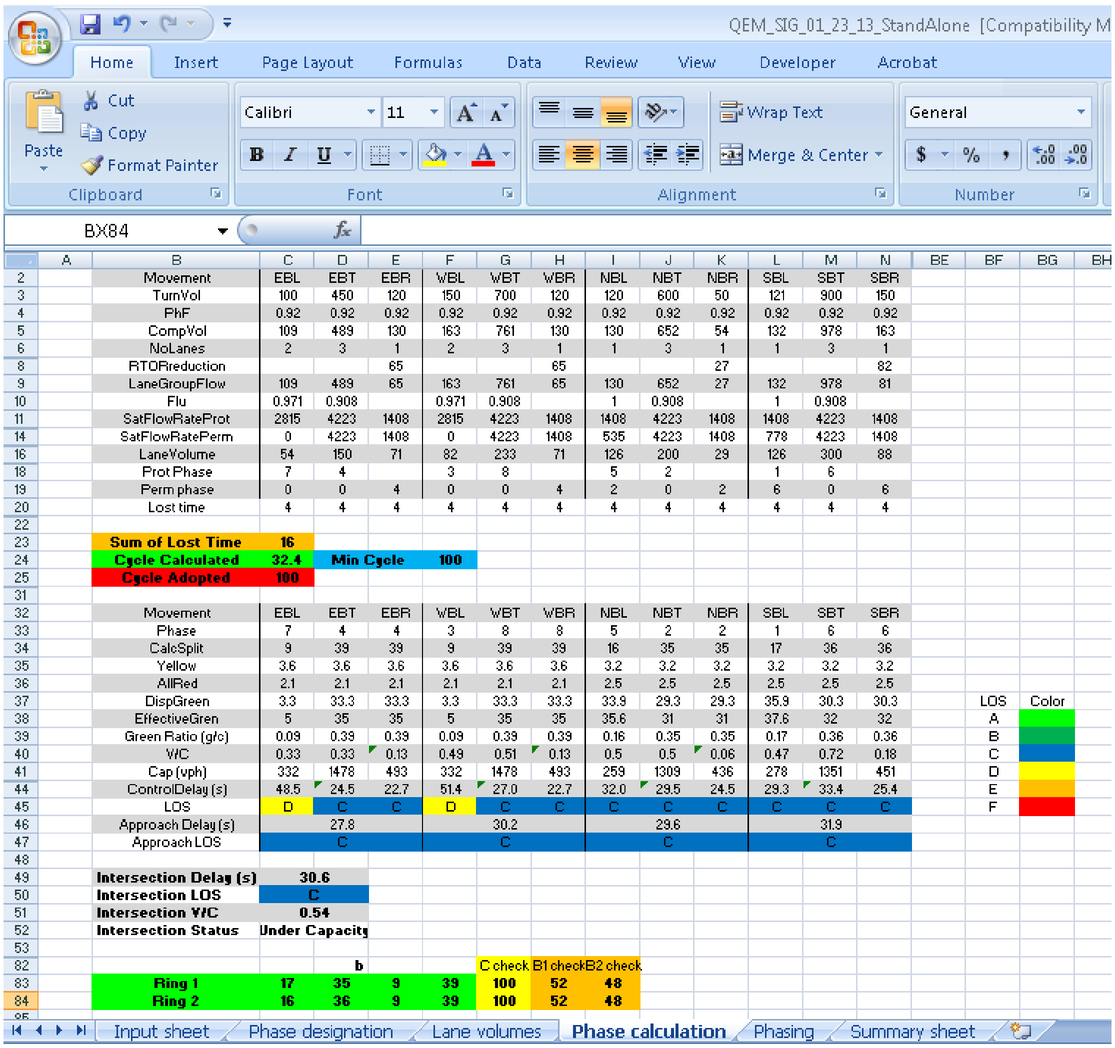
Figure 6. *Lane volumes sheet.*

The **Phase calculation** sheet, shown in Figure 7, performs calculations of all signal control parameters. It is using inputs defined by the user/NeXTA, and outputs from the previous steps. The critical movement methodology is used in cycle length calculations. The cycle length calculation is limited to 10 second increments, in the default range between 40 seconds (Cmin) and 150 seconds (Cmax), or in the range defined by the user.The following steps is implemented in parameters calculation:

1. Calculate cycle length and initial phase splits based on the HCM methodology.
2. The corresponding splits (green time + exchange interval) are assigned to each phase in the ring-barrier structure.
3. The splits are recalculated for each phase based on the cycle length and the critical ring split summation.
4. The splits are recalculated again for each barrier, following the critical barrier split summation. This step ensures the simultaneous barrier crossing and prevents phase conflicts.
5. The calculated splits are compared to the minimum splits (see Phasing), and are reassigned if necessary.

6. When the phase splits are know, the HCM procedure is followed to calculate movement capacities, V/C ratios, control delays and LOS.

This section goes beyond the typical QE methodology, since it gives realistic signal timing parameters common in all North American ring-barrier controllers. This is especially significant for a fast conversion process used in cross-resolution modeling (when the application is used in conjunction with NeXTA).



	B	C	D	E	F	G	H	I	J	K	L	M	N
2	Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
3	TurnVol	100	450	120	150	700	120	120	600	50	121	900	150
4	PhF	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
5	CompVol	109	489	130	163	761	130	130	652	54	132	978	163
6	NoLanes	2	3	1	2	3	1	1	3	1	1	3	1
8	RTORreduction			65			65			27			82
9	LaneGroupFlow	109	489	65	163	761	65	130	652	27	132	978	81
10	Flu	0.971	0.908		0.971	0.908		1	0.908		1	0.908	
11	SatFlowRateProt	2815	4223	1408	2815	4223	1408	1408	4223	1408	1408	4223	1408
14	SatFlowRatePerm	0	4223	1408	0	4223	1408	535	4223	1408	778	4223	1408
16	LaneVolume	54	150	71	82	233	71	126	200	29	126	300	88
18	Prot Phase	7	4		3	8		5	2		1	6	
19	Perm phase	0	0	4	0	0	4	2	0	2	6	0	6
20	Lost time	4	4	4	4	4	4	4	4	4	4	4	4
22													
23	Sum of Lost Time	16											
24	Cycle Calculated	32.4	Min Cycle		100								
25	Cycle Adopted	100											
31													
32	Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
33	Phase	7	4	4	3	8	8	5	2	2	1	6	6
34	CalcSplit	9	39	39	9	39	39	16	35	35	17	36	36
35	Yellow	3.6	3.6	3.6	3.6	3.6	3.6	3.2	3.2	3.2	3.2	3.2	3.2
36	AllRed	2.1	2.1	2.1	2.1	2.1	2.1	2.5	2.5	2.5	2.5	2.5	2.5
37	DispGreen	3.3	33.3	33.3	3.3	33.3	33.3	33.9	29.3	29.3	35.9	30.3	30.3
38	EffectiveGren	5	35	35	5	35	35	35.6	31	31	37.6	32	32
39	Green Ratio (g/c)	0.09	0.39	0.39	0.09	0.39	0.39	0.16	0.35	0.35	0.17	0.36	0.36
40	V/C	0.33	0.33	0.13	0.49	0.51	0.13	0.5	0.5	0.06	0.47	0.72	0.18
41	Cap (vph)	332	1478	493	332	1478	493	259	1309	436	278	1351	451
44	ControlDelay (s)	48.5	24.5	22.7	51.4	27.0	22.7	32.0	29.5	24.5	29.3	33.4	25.4
45	LOS	D	C	C	D	C	C	C	C	C	C	C	C
46	Approach Delay (s)		27.8			30.2			29.6			31.9	
47	Approach LOS		C			C			C			C	
48													
49	Intersection Delay (s)	30.6											
50	Intersection LOS	C											
51	Intersection V/C	0.54											
52	Intersection Status	Under Capacity											
53													
82			b			C check	B1 check	B2 check					
83	Ring 1	17	35	9	39	100	52	48					
84	Ring 2	16	36	9	39	100	52	48					

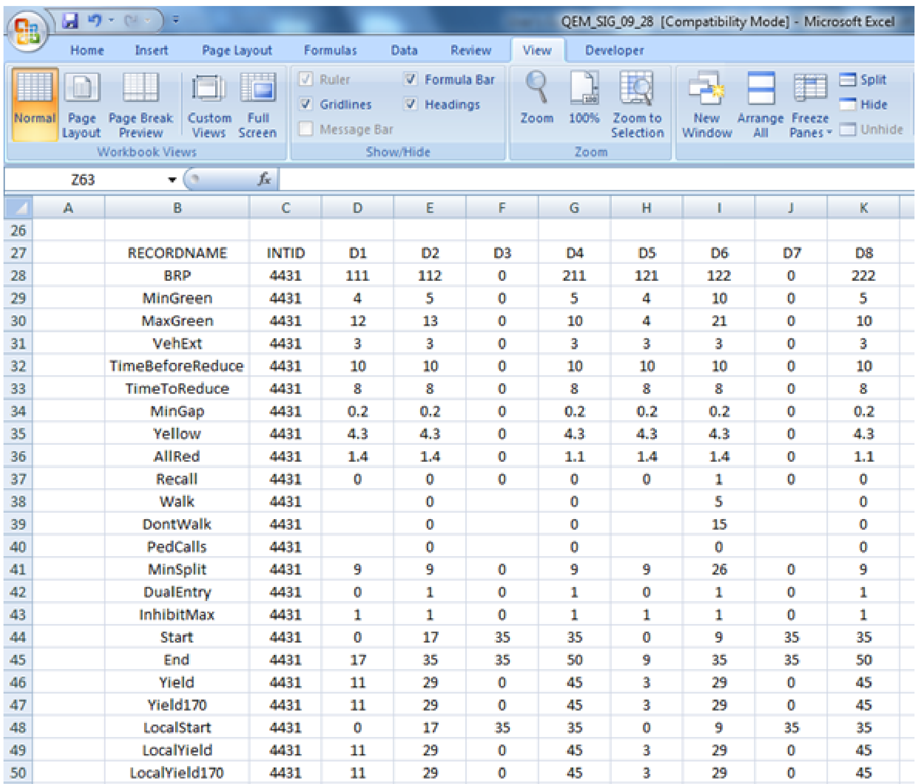
LOS	Color
A	
B	
C	
D	
E	
F	

Figure 7. *Phase calculation sheet.*

The **Phasing sheet**, given in Figure 8, calculates all the phasing data required by Synchro for an error-free analysis. It is using default tables from the STM for different parameters. The parameters calculated in this sheet are:

Minimum green	Minimum phase recall	Phase end time
Maximum green	Walk time	Phase yield time

Vehicle extension	Don’t walk time	Phase yield for type 170 controllers
Time before reduce	Pedestrian recalls	Local start time
Time to reduce	Minimum split	Local yield time
Minimum gap	Dual entry	Local yield time for type 170 controllers
Yellow time	Max time call inhibition	
All red time	Phase start time	



	A	B	C	D	E	F	G	H	I	J	K
26											
27		RECORDNAME	INTID	D1	D2	D3	D4	D5	D6	D7	D8
28		BRP	4431	111	112	0	211	121	122	0	222
29		MinGreen	4431	4	5	0	5	4	10	0	5
30		MaxGreen	4431	12	13	0	10	4	21	0	10
31		VehExt	4431	3	3	0	3	3	3	0	3
32		TimeBeforeReduce	4431	10	10	0	10	10	10	0	10
33		TimeToReduce	4431	8	8	0	8	8	8	0	8
34		MinGap	4431	0.2	0.2	0	0.2	0.2	0.2	0	0.2
35		Yellow	4431	4.3	4.3	0	4.3	4.3	4.3	0	4.3
36		AllRed	4431	1.4	1.4	0	1.1	1.4	1.4	0	1.1
37		Recall	4431	0	0	0	0	0	1	0	0
38		Walk	4431		0		0		5		0
39		DontWalk	4431		0		0		15		0
40		PedCalls	4431		0		0		0		0
41		MinSplit	4431	9	9	0	9	9	26	0	9
42		DualEntry	4431	0	1	0	1	0	1	0	1
43		InhibitMax	4431	1	1	0	1	1	1	0	1
44		Start	4431	0	17	35	35	0	9	35	35
45		End	4431	17	35	35	50	9	35	35	50
46		Yield	4431	11	29	0	45	3	29	0	45
47		Yield170	4431	11	29	0	45	3	29	0	45
48		LocalStart	4431	0	17	35	35	0	9	35	35
49		LocalYield	4431	11	29	0	45	3	29	0	45
50		LocalYield170	4431	11	29	0	45	3	29	0	45

Figure 8. *Phasing sheet.*

The **Summary sheet** (see Figure 9) gives all the main outputs from previous steps in is a user-friendly graphical representation. The following parameters are shown:

- Turning volumes (vph)
- Phase designations
- Number of lanes for each movement
- Split durations (s)
- Movement capacities (vph)
- V/C ratios
- Control delays (s)
- Intersection LOS

- Summary table

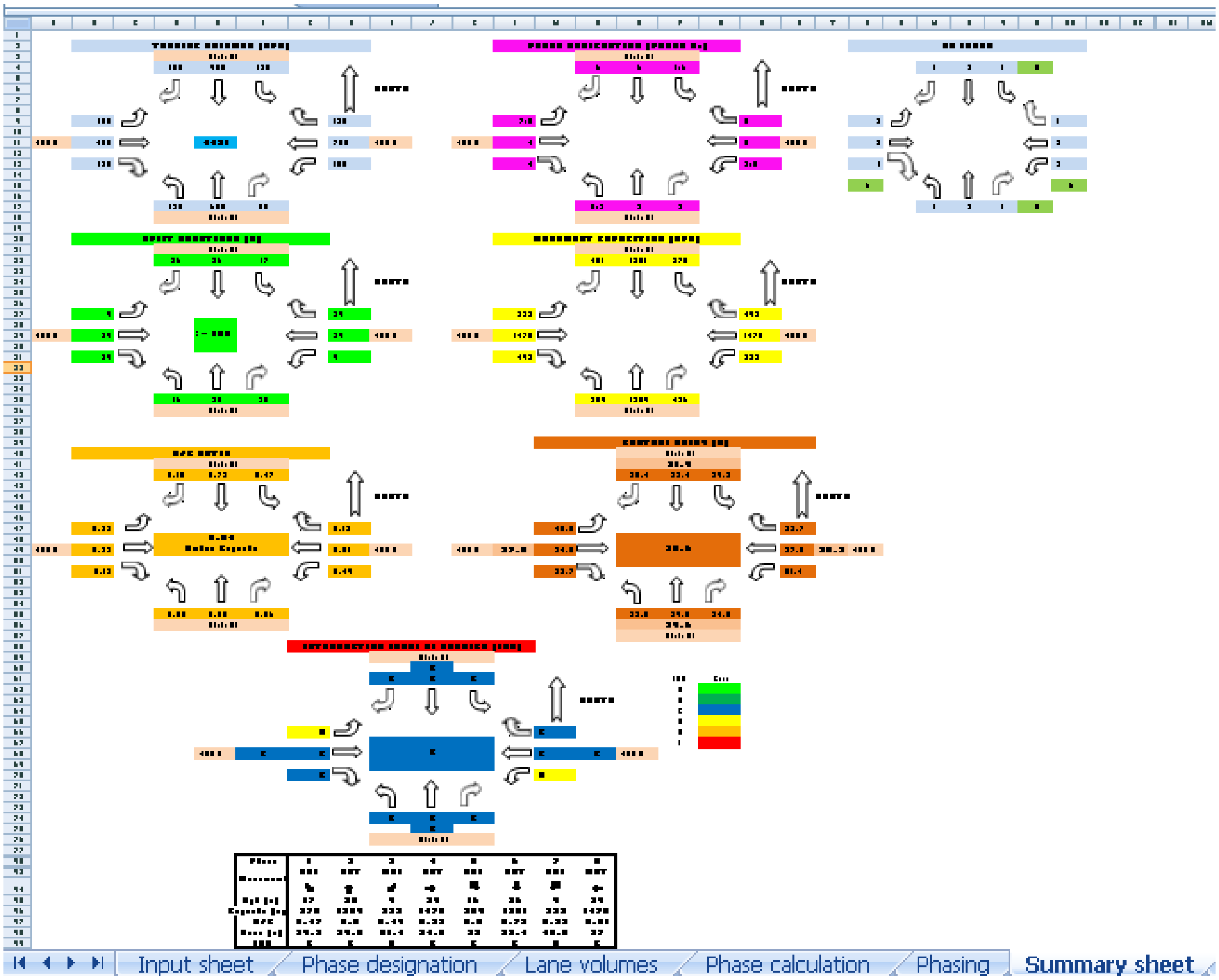


Figure 9. *Summary sheet.*

The LAYOUT, LANES, VOLUME, PHASING and TIMING sheets contain data formatted for a Synchro 6 export. When the Synchro CSV Export in the Input Sheet is activated, these five sheets will be written as separate CSV files used for importing the given intersection into Synchro. These files are automatically written into the same folder where the QEM application is located.

The Report sheet summarizes intersection analysis results in a format similar to Synchro reports, which is convenient for a quick assessment of the results. When the Generate QEM Report in the Input Sheet is activated, the Report sheet will automatically be exported as a PDF file convenient for results reporting. This PDF file is written into the same folder where the QEM application is located, and is automatically given the name containing the analyzed intersection. The layout of this sheet is given in Figure 10.

QEM Signalized Intersection Capacity Analysis
Foothill & Sunnyside

3/11/2013

	Sunnyside			Sunnyside			Foothill			Foothill		
Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations (#)	1	2	1	2	2	1	1	3	1	1	3	1
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Total Lost Time (s)	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
Lane Util. Factor Flu	1.00	0.95	0.00	0.97	0.95	0.00	1.00	0.91	0.00	1.00	0.91	0.00
Frt	1.00	1.00	0.85	1.00	1.00	0.85	1.00	1.00	0.85	1.00	1.00	0.85
Flt Protected	0.95	1.00	1.00	0.92	1.00	1.00	0.95	1.00	1.00	0.95	1.00	1.00
Sat. Flow (prot)	0	2815	1408	2815	2815	1408	0	4223	1408	0	4223	1408
Flt Permitted	0.95	1.00	1.00	0.92	1.00	1.00	0.95	1.00	1.00	0.95	1.00	1.00
Sat. Flow (perm)	1027	2815	1408	0	2815	1408	554	4223	1408	664	4223	1408
Volume (vph)	68	259	10	113	300	50	60	700	120	80	900	113
PHF	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
Adj. Flow (vph)	74	282	11	123	326	54	65	761	130	87	978	123
RTOR Reduction (vph)	0	0	6	0	0	54	0	0	65	0	0	62
Lane Group Flow (vph)	74	282	5	123	326	0	65	761	65	87	978	61
Turn Type	Permitted		Permitted	Protected		Permitted	Permitted		Permitted	Permitted		Permitted
Protected Phases		4		3	8			2			6	
Permitted Phases	4		4			8	2		2	6		6
Display Green, G (s)	25.6	25.6	25.6	3.3	34.3	34.3	34.2	34.2	34.2	34.2	34.2	34.2
Effective Green, g (s)	27.0	27.0	27.0	5.0	36.0	36.0	36.0	36.0	36.0	36.0	36.0	36.0
Display g/C Ratio	0.32	0.32	0.32	0.04	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.43
Clearance Time (s)	5.4	5.4	5.4	5.7	5.7	5.7	5.8	5.8	5.8	5.8	5.8	5.8
Lane Grp Cap (vph)	123	950	475	415	1267	634	106	1900	634	109	1900	634
v/s Ratio Prot	0.00	0.10		0.04	0.12		0.00	0.18		0.00	0.23	
v/s Ratio Perm	0.07		0.00			0.00	0.12		0.05	0.13		0.04
v/c Ratio	0.60	0.30	0.01	0.30	0.26	0.00	0.61	0.40	0.10	0.80	0.51	0.10
Uniform delay, d1 (s)	22.0	19.5	17.6	35.8	13.7	0.0	16.7	14.8	12.7	18.9	15.7	12.7
Progression 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
Incremental Delay, d2 (s)	19.8	0.8	0.0	1.9	0.5	0.0	23.4	0.6	0.3	44.3	1.0	0.3
Delay (s)	41.8	20.3	17.7	37.7	14.2	0.0	40.1	15.4	13.0	63.2	16.7	13.0
Level of Service	D	C	B	D	B	N/A	D	B	B	E	B	B
Approach Delay (s)		24.6			18.4			16.8			19.7	
Approach LOS		C			B			B			B	

Intersection Summary			
HCM Average Control Delay	19.8	HCM Level of Serv	B
HCM Volume to Capacity Ratio	0.37		
Actuated Cycle Length (s)	80.0	Sum of Lost Time (	12.0
Intersection Capacity Utilization	69.0%	ICU Level of Servic	C

QEM Report

Figure 10. *Report sheet.*

Using QEM as a Stand-Alone Application

The QEM Excel application was initially designed and developed to work with NeXTA during cross-resolution modeling integration. However, the current version can work as a stand-alone application and it allows for manual user inputs. For this purpose, the user communicates with the Input sheet to input the data that are needed for quick signal timing estimation. The following inputs are needed:

- Street names – optional.
- Intersection lane configuration – required (number of lanes for each approach and each movement).
- Turning volumes for each movement – required.
- Approach through speeds – important if these speeds are greater than 45 mph, since this is one of the requirements for protected only left turn treatments.
- Presence of pedestrians – select option (Yes/No) from the drop-down menu for each approach separately. If pedestrians are present, pedestrian timing will be included in the minimum splits and cycle calculations. For urban intersection, this option should generally be enabled.
- Manual selection of left turn treatment – if the field data regarding left turn treatment are known, this entry allows for a manual selection of left turn treatment. If activated, this option will allow left turn treatment for each approach to be selected from the drop-down menu. The options are: Protected, Permitted, Protected + permitted, or blank. This entry will override the automatic designation of left turn treatments.
- Right Turn on Red (RTOR %) – Enter the estimated (or calculated) percentage of right turning vehicles that make a turn during the red signal interval. An estimated RTOR percentage is 50-75% for exclusive right turn lanes, and less than 10% for shared lanes. The default used value is 50%.
- Ideal saturation flow rate – by default, this value is 1900 vphpl; can be changed if the user has calibrated saturation flow rate for local conditions.
- Peak Hour Factor (PHF) – if known, it can be entered in this field. Otherwise, it can be set to the value of 0.9.
- Percentage of heavy vehicles (HGV %) – if known, it can be entered in this field. Otherwise, the default value can be set to 3%.
- Lost Time (s) per phase – this value is 4 seconds by default. It can be changed to reflect local conditions.
- Area Type selection – select an option from the drop-down menu. The options are "CBD" (Central business district) and "Other". The correct option should be selected for the analyzed network.
- Minimum and maximum desired cycle lengths – These values can be imputed to reflect local conditions. By default, the cycle length is between 40 s (minimum) and 150 s (maximum).

Example 1: Typical 4-leg Intersection

The first example is provided for the intersection of State Street and 400 S in Salt Lake City, UT. Both approaches on State Street have three lanes for through, one lane for left turns, and separate right turn lanes. The speed limit along State Street is 30 mph. Both approaches on 400 S have three lanes for through movements, two left turn lanes, and a separate right turn lane. The speed limit on 400 S is 35 mph. Traffic data for this intersection date from 2009, and the counts used are for the PM peak hour, 5:00 – 6:00 pm. The peak hour factor is 0.92, and the percentage of heavy vehicles is 2%. Pedestrian crossings are present at all approaches. The intersection layout is given in Figure 11.

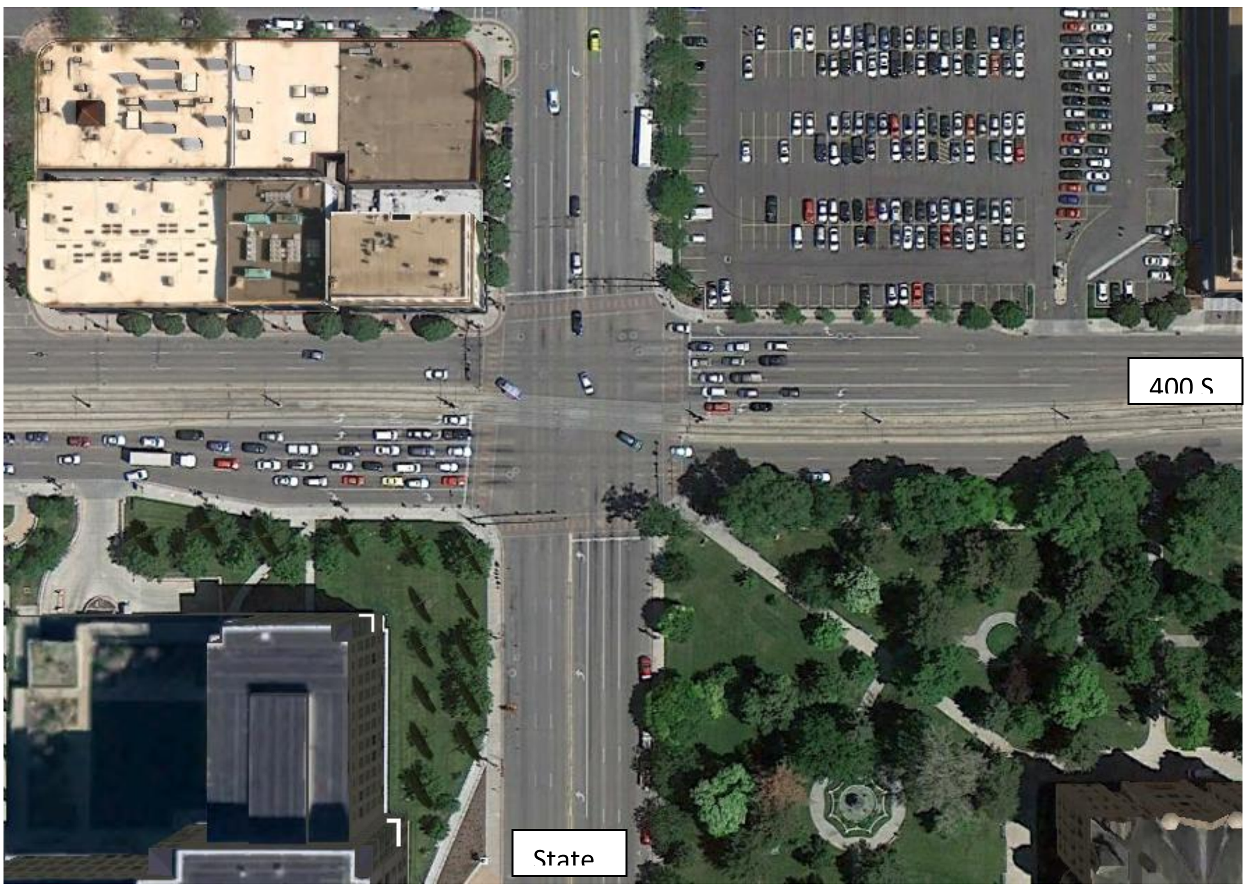


Figure 11. *State Street 400 S intersection layout.*

These data are used as inputs for QEM. Figure 12 shows the QEM input data configuration. Manual selection for left turn treatment is disabled in this case.

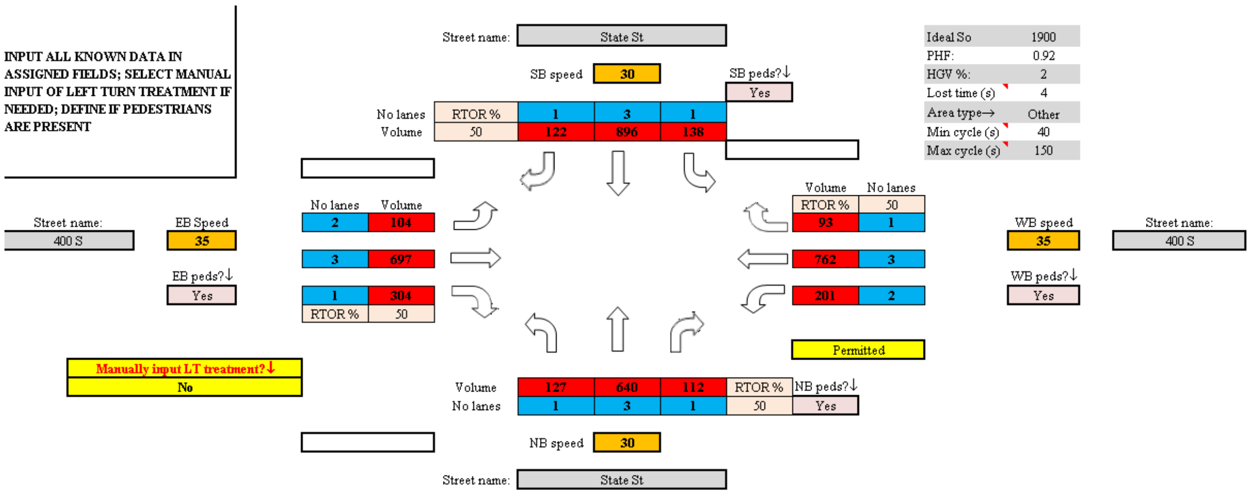
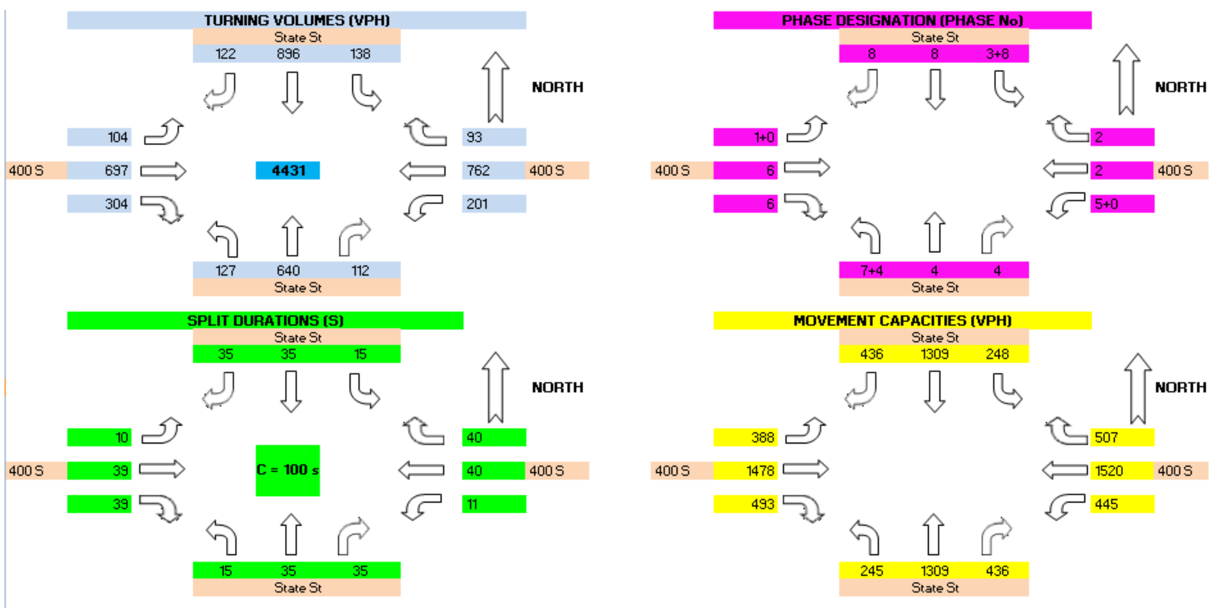


Figure 12. QEM inputs for State Street 400 S intersection.

Based on the given inputs, the QEM spreadsheet yields the results as shown in Figure 13:



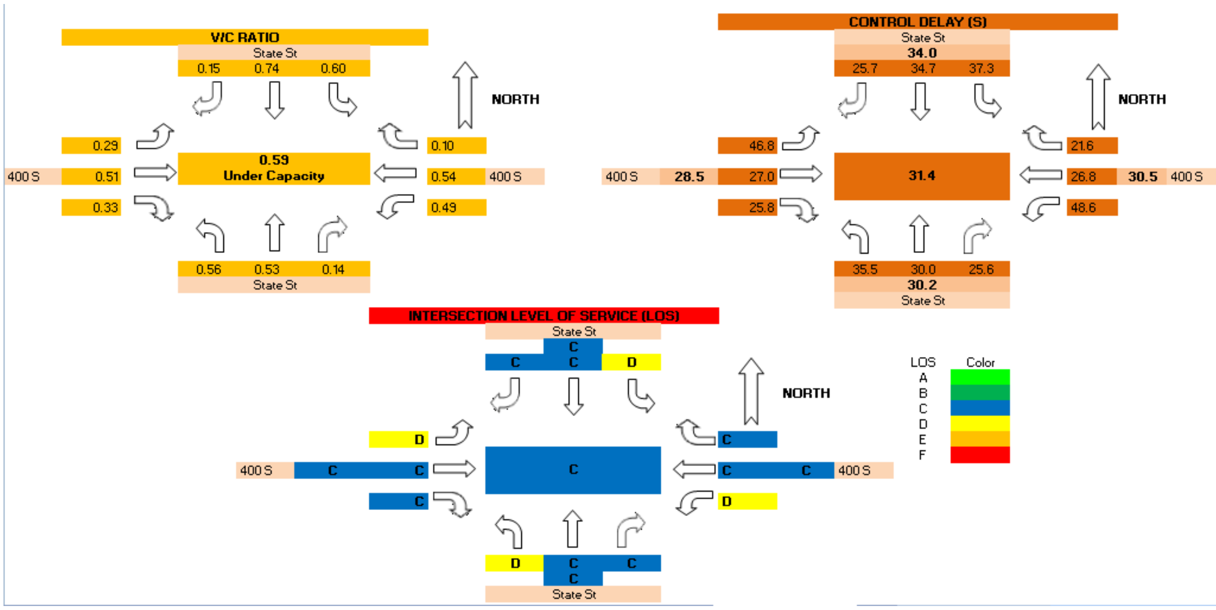


Figure 13. *QEM results for State Street 400 S intersection.*

QEM assigns protected + permitted left turns to NB and SB movements along State Street, and protected only left turns for EB and WB movements along 400 S. This is the same as the intersection operates in the field. The cycle length is estimated to 100 s, intersection delay is 31.4 s, and LOS is C.

When the same inputs, phasing and timing data are transferred to Synchro, the following results are obtained (Figure 14):

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Total Lost time (s)	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
Lane Util. Factor	0.97	0.91	1.00	0.97	0.91	1.00	1.00	0.91	1.00	1.00	0.91	1.00
Frt	1.00	1.00	0.85	1.00	1.00	0.85	1.00	1.00	0.85	1.00	1.00	0.85
Flt Protected	0.95	1.00	1.00	0.95	1.00	1.00	0.95	1.00	1.00	0.95	1.00	1.00
Satd. Flow (prot)	3433	5085	1583	3433	5085	1583	1770	5085	1583	1770	5085	1583
Flt Permitted	0.95	1.00	1.00	0.95	1.00	1.00	0.16	1.00	1.00	0.29	1.00	1.00
Satd. Flow (perm)	3433	5085	1583	3433	5085	1583	304	5085	1583	533	5085	1583
Volume (vph)	104	697	304	201	762	93	127	640	112	138	896	122
Peak-hour factor, PHF	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
Adj. Flow (vph)	113	758	330	218	828	101	138	696	122	150	974	133
RTOR Reduction (vph)	0	0	161	0	0	65	0	0	84	0	0	92
Lane Group Flow (vph)	113	758	169	218	828	36	138	696	38	150	974	41
Turn Type	Prot		Perm	Prot		Perm	pm+pt		Perm	pm+pt		Perm
Protected Phases	1	6		5	2		7	4		3	8	
Permitted Phases			6			2	4		4	8		8
Actuated Green, G (s)	4.3	33.3	33.3	5.3	34.3	34.3	38.6	29.3	29.3	38.6	29.3	29.3
Effective Green, g (s)	6.0	35.0	35.0	7.0	36.0	36.0	42.0	31.0	31.0	42.0	31.0	31.0
Actuated g/C Ratio	0.06	0.35	0.35	0.07	0.36	0.36	0.42	0.31	0.31	0.42	0.31	0.31
Clearance Time (s)	5.7	5.7	5.7	5.7	5.7	5.7	5.7	5.7	5.7	5.7	5.7	5.7
Lane Grp Cap (vph)	206	1780	554	240	1831	570	289	1576	491	360	1576	491
v/s Ratio Prot	0.03	0.15		c0.06	c0.16		c0.05	0.14		0.05	c0.19	
v/s Ratio Perm			0.11			0.02	0.15		0.02	0.13		0.03
v/c Ratio	0.55	0.43	0.30	0.91	0.45	0.06	0.48	0.44	0.08	0.42	0.62	0.08
Uniform Delay, d1	45.7	24.8	23.6	46.2	24.5	21.0	19.4	27.6	24.4	18.7	29.4	24.4
Progression 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
Incremental Delay, d2	10.1	0.7	1.4	38.5	0.8	0.2	5.6	0.9	0.3	3.5	1.8	0.3
Delay (s)	55.8	25.6	25.1	84.6	25.3	21.2	25.0	28.5	24.7	22.2	31.3	24.8
Level of Service	E	C	C	F	C	C	C	C	C	C	C	C
Approach Delay (s)		28.3			36.2			27.5			29.5	
Approach LOS		C			D			C			C	

Intersection Summary			
HCM Average Control Delay	30.4	HCM Level of Service	C
HCM Volume to Capacity ratio	0.53		
Actuated Cycle Length (s)	100.0	Sum of lost time (s)	12.0
Intersection Capacity Utilization	56.9%	ICU Level of Service	B
Analysis Period (min)	15		

c Critical Lane Group

Figure 14. *Synchro results for 5600 W 3500 S intersection.*

Generate QEM Report in the QEM application creates a similar report shown in Figure 15, automatically named “Intersection State St & 400 S QEM Report”:

QEM Signalized Intersection Capacity Analysis
State St & 400 S 3/11/2013

	400 S			400 S			State St			State St		
Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations (#)	2	3	1	2	3	1	1	3	1	1	3	1
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Total Lost Time (s)	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
Lane Util. Factor Flu	0.97	0.91	0.00	0.97	0.91	0.00	1.00	0.91	0.00	1.00	0.91	0.00
Frt	1.00	1.00	0.85	1.00	1.00	0.85	1.00	1.00	0.85	1.00	1.00	0.85
Flt Protected	0.92	1.00	1.00	0.92	1.00	1.00	0.95	1.00	1.00	0.95	1.00	1.00
Sat. Flow (prot)	2815	4223	1408	2815	4223	1408	1408	4223	1408	1408	4223	1408
Flt Permitted	0.92	1.00	1.00	0.92	1.00	1.00	0.95	1.00	1.00	0.95	1.00	1.00
Sat. Flow (perm)	0	4223	1408	0	4223	1408	552	4223	1408	708	4223	1408
Volume (vph)	104	697	304	201	762	93	127	640	112	138	896	122
PHF	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
Adj. Flow (vph)	113	758	330	218	828	101	138	696	122	150	974	133
RTOR Reduction (vph)	0	0	165	0	0	51	0	0	61	0	0	67
Lane Group Flow (vph)	113	758	165	218	828	50	138	696	61	150	974	66
Turn Type	Protected		Permitted	Protected		Permitted	Prot+perm		Permitted	Prot+perm		Permitted
Protected Phases	1	6		5	2		7	4		3	8	
Permitted Phases			6			2	4		4	8		8
Display Green, G (s)	4.3	33.3	33.3	5.3	34.3	34.3	32.9	29.3	29.3	32.9	29.3	29.3
Effective Green, g (s)	6.0	35.0	35.0	7.0	36.0	36.0	34.6	31.0	31.0	34.6	31.0	31.0
Display g/C Ratio	0.04	0.33	0.33	0.05	0.34	0.34	0.33	0.29	0.29	0.33	0.29	0.29
Clearance Time (s)	5.7	5.7	5.7	5.7	5.7	5.7	5.7	5.7	5.7	5.7	5.7	5.7
Lane Grp Cap (vph)	388	1478	493	445	1520	507	245	1309	436	248	1309	436
v/s Ratio Prot	0.04	0.18		0.08	0.20		0.10	0.16		0.11	0.23	
v/s Ratio Perm			0.12			0.04	0.25		0.04	0.21		0.05
v/c Ratio	0.29	0.51	0.33	0.49	0.54	0.10	0.56	0.53	0.14	0.60	0.74	0.15
Uniform delay, d1 (s)	45.0	25.7	23.9	44.8	25.4	21.2	26.5	28.5	24.9	27.0	30.9	25.0
Progression 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
Incremental Delay, d2 (s)	1.9	1.3	1.8	3.8	1.4	0.4	9.0	1.5	0.7	10.3	3.8	0.7
Delay (s)	46.8	27.0	25.8	48.6	26.8	21.6	35.5	30.0	25.6	37.3	34.7	25.7
Level of Service	D	C	C	D	C	C	D	C	C	D	C	C
Approach Delay (s)		28.5			30.5			30.2			34.0	
Approach LOS		C			C			C			C	

Intersection Summary			
HCM Average Control Delay	31.4	HCM Level of Service	C
HCM Volume to Capacity Ratio	0.59		
Actuated Cycle Length (s)	100.0	Sum of Lost Time (s)	16.0
Intersection Capacity Utilization	74.6%	ICU Level of Service	D

QEM Report

Figure 15. *QEM report results for 5600 W 3500 S intersection.*

It can be seen that the QEM application and Synchro yield very similar results for this intersection:

	QEM	Synchro
Intersection delay (s)	31.4	30.4
Intersection LOS	C	C
Intersection V/C	0.59	0.53

Optimization in Synchro yields a cycle length of 95 s, intersection delay of 28 s, and intersection LOS C. In the field, this intersection operates in an actuated-coordinated mode on a 120 s cycle during the PM peak period for which the input data are used.

Example 2: 3-leg Intersection

The second example is provided for the neighboring intersection of 5200 W and 3500 S in West Valley City, UT, which is a 3-leg intersection with no SB approach. Both approaches on 3500 W have two lanes for through movements. The WB approach on 3500 S has a separate left turn lane, while the EB approach shares the rightmost through lane with right turns. 5200 W NB approach has separate lanes for left and right turn movements. The speed limit along 3500 W is 40 mph, while the speed limit on 5200 W is 35 mph. Traffic data for this intersection date from 2007, and the counts used are for the PM peak hour, 5:00 – 6:00 pm. The peak hour factor is 0.92, and the percentage of heavy vehicles is 2%. There is no WB pedestrian crossing. The intersection layout is given in Figure 16.

Figure 16. *5200 W 3500 S intersection layout.*

These data are used as inputs for QEM. Figure 17 shows the QEM input data configuration.

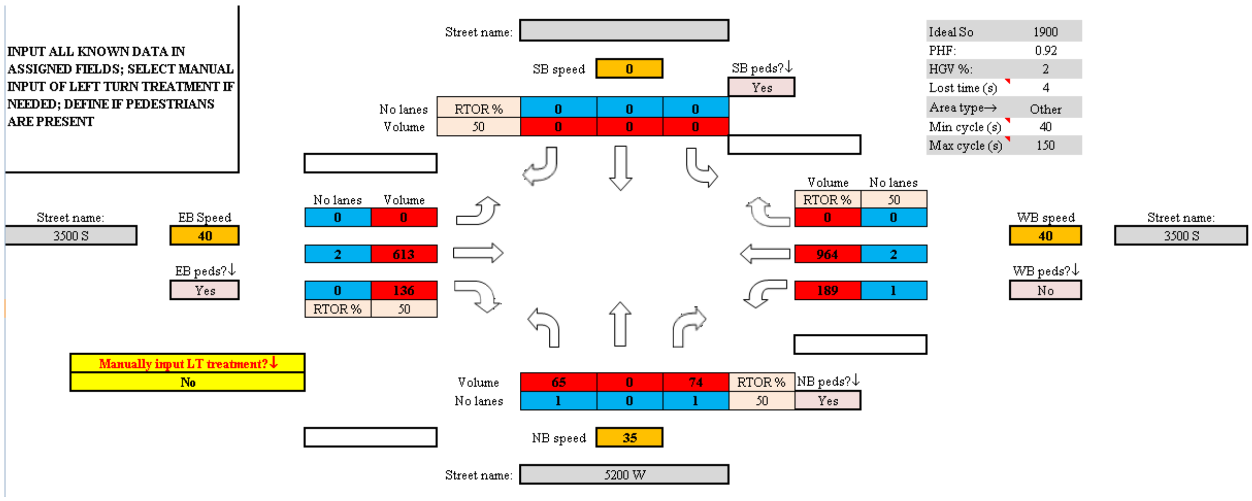
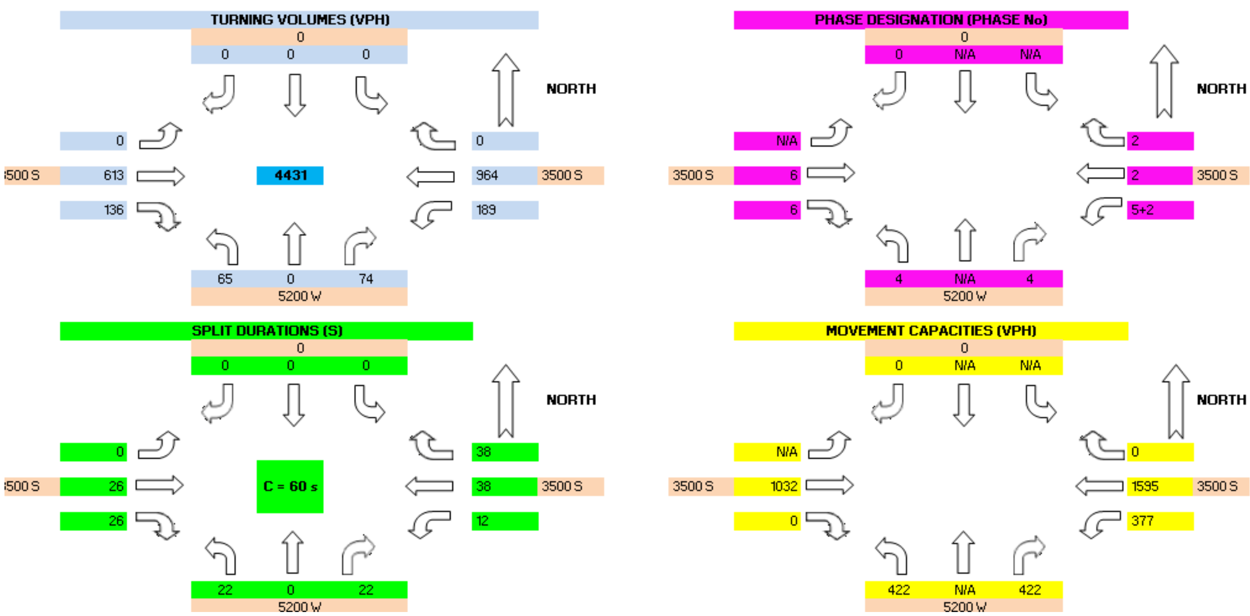


Figure 17. *QEM inputs for 5200 W 3500 S intersection.*

Based on the given inputs, the QEM yields the results given in Figure 16:



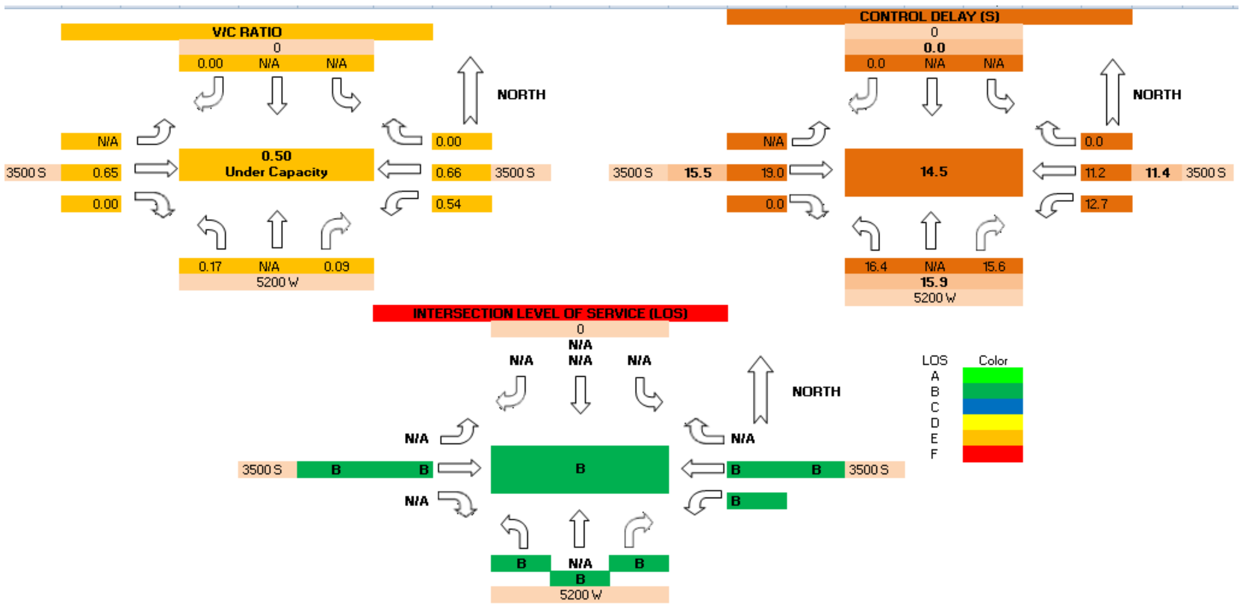


Figure 18. *QEM results for 5200 W 3500 S intersection.*

QEM calculates the cycle length to 60 s, and assigns WB left turns as protected + permitted, and NB left turns as permitted only. When the same inputs, phasing and timing data are transferred to Synchro, the following results are obtained:

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Total Lost time (s)		4.0		4.0	4.0		4.0		4.0			
Lane Util. Factor		0.95		1.00	0.95		1.00		1.00			
Frt		0.97		1.00	1.00		1.00		0.85			
Flt Protected		1.00		0.95	1.00		0.95		1.00			
Satd. Flow (prot)		3443		1770	3539		1770		1583			
Flt Permitted		1.00		0.19	1.00		0.95		1.00			
Satd. Flow (perm)		3443		349	3539		1770		1583			
Volume (vph)	0	613	136	189	964	0	65	0	74	0	0	0
Peak-hour factor, PHF	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
Adj. Flow (vph)	0	666	148	205	1048	0	71	0	80	0	0	0
RTOR Reduction (vph)	0	32	0	0	0	0	0	0	56	0	0	0
Lane Group Flow (vph)	0	782	0	205	1048	0	71	0	24	0	0	0
Turn Type				pm+pt			custom		custom			
Protected Phases		6		5	2							
Permitted Phases				2			4		4			
Actuated Green, G (s)		20.9		32.9	32.9		17.0		17.0			
Effective Green, g (s)		22.0		34.0	34.0		18.0		18.0			
Actuated g/C Ratio		0.37		0.57	0.57		0.30		0.30			
Clearance Time (s)		5.1		5.1	5.1		5.0		5.0			
Lane Grp Cap (vph)		1262		387	2005		531		475			
v/s Ratio Prot		c0.23		0.07	c0.30							
v/s Ratio Perm				0.23			c0.04		0.02			
v/c Ratio		0.62		0.53	0.52		0.13		0.05			
Uniform Delay, d1		15.6		8.1	8.0		15.3		14.9			
Progression Factor		1.00		1.00	1.00		1.00		1.00			
Incremental Delay, d2		2.3		5.1	1.0		0.5		0.2			
Delay (s)		17.9		13.2	9.0		15.8		15.1			
Level of Service		B		B	A		B		B			
Approach Delay (s)		17.9			9.7			15.5			0.0	
Approach LOS		B			A			B			A	

Intersection Summary			
HCM Average Control Delay	13.1	HCM Level of Service	B
HCM Volume to Capacity ratio	0.44		
Actuated Cycle Length (s)	60.0	Sum of lost time (s)	12.0
Intersection Capacity Utilization	45.4%	ICU Level of Service	A
Analysis Period (min)	15		

c Critical Lane Group

Figure 19. *Synchro results for 5200 W 3500 S intersection.*

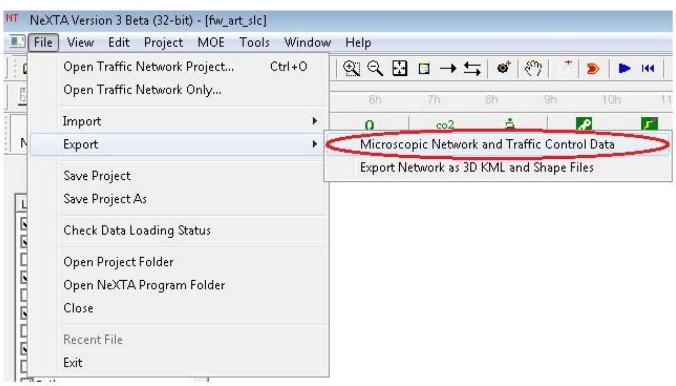
The comparison of the results is as follows:

	QEM	Synchro
Intersection delay (s)	14.5	13.1
Intersection LOS	B	B
Intersection V/C	0.44	0.50

Using QEM in NeXTA

The QEM application is fully integrated with NeXTA. It performs on-the-fly signal parameters estimation using turning volumes obtained through NeXTA/DTALite simulation. The current running speed is about one signalized intersection per second, and it can handle any number of signalized intersections in the given network. The estimated signal timing parameters are placed into a separate QEM_Log file, and they are used for exporting to Synchro or other software. All the signal timing and phasing data are provided in the UTDF format, which enables exchange among different traffic software applications.

The accompanying QEM_SIG.xls file needs to be copied to the NeXTA's home folder. This is a separate version of the QEM application that does not contain macros. In the Input Sheet, the user should disable manual selection of left turn treatment, and select whether the pedestrian timing will be included. The user also needs to define (or use the default values) for the ideal saturation flow rate, peak hour factor (PHF), percentage of heavy vehicles (HGV%), lost time per phase, area type, and values for minimum and maximum cycle lengths before performing signal parameter estimation in NeXTA. The QEM is called through NeXTA's menu by going to File>Export>Microscopic Network and Traffic Control Data, and then selecting the Perform Quick Estimation Method (QEM) for Signals option in the dialog box, as shown in Figure 20. This operation will call the Excel QEM spreadsheet and perform the estimation of signal timing parameters for each defined signalized intersection in the network. The user also receives information about the demand loading period, and the volume conversion factor to be used with QEM, since QEM works with one-hour volumes only.



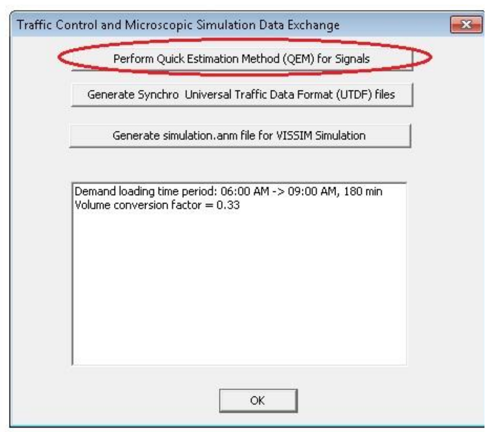


Figure 20. *Starting QEM through NeXTA interface.*

<u>Example: Arterial Network from Salt Lake County</u>

The example given here is for a part of the 3500 S corridor from Salt Lake County, UT, spanning between 2700 W and 5600 W. Before calling the QEM application, the user needs to open the desired network in NeXTA and perform DTA simulation. When the simulation is completed, the user calls the QEM application following the described procedure.

Before starting QEM, the user will be informed to make sure that all Excel files are closed before starting this process.

When the QEM is started, it will automatically call Excel, which will appear in the toolbar, as given in Figure 21. If the user opens the Excel file, they can see how the procedure of signal timing estimation is being performed intersection by intersection.

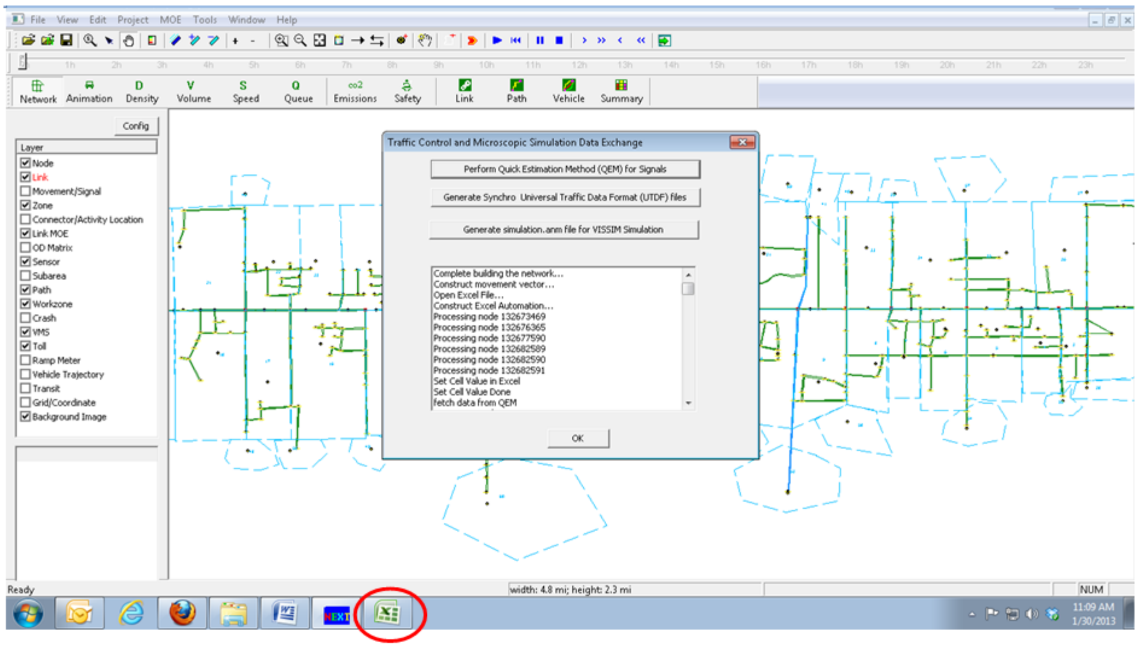


Figure 21. *Automatic signalized intersection estimation through NeXTA/QEM interface.*

The duration of this process depends on the number of signalized intersections in the network. Roughly, it takes about a second per intersection (this time will depend on the PCU speed). When the QEM procedure is completed, the user will be notified about the number of intersections that have estimated capacities and signal timing plans, as shown in Figure 22.

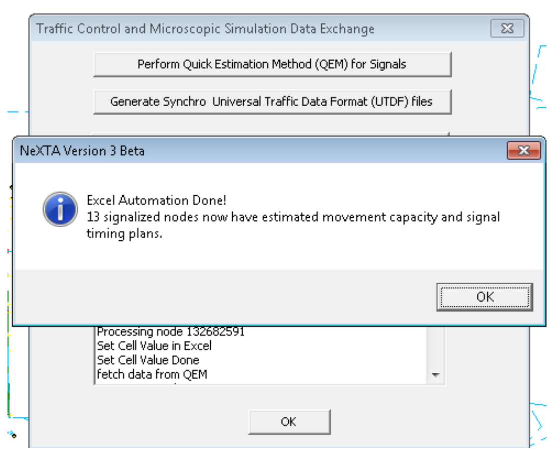


Figure 22. *QEM automation completion message.*

The QEM output data will be written to the accompanying QEM_log.csv file, which is also located in NeXTA's home folder. These data are used to write lanes/volume/phasing/timing data for Synchro export.

Now the Synchro export can be completed by pressing the "Generate Synchro Universal Traffic Data Format (UTDF) files" button (see Fig. 20). This operation will create a new folder in the project folder, named "Exporting_Syncro_UTDF", which consists of five .csv files: Lanes, Layout, Phasing, Timing and Volume. These are the files used to create the same network in Synchro.

To import the network to Synchro, complete with signal timing/phasing data, follow these steps (**Note**: these procedure is for Synchro Version 6):

1. Open a new project in Synchro, select Transfer tab from the menu, and go to Data Access…

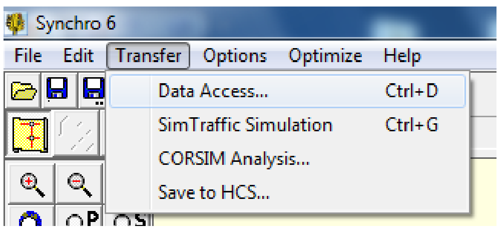


Figure 23. *Data Access in Synchro.*

2. In the opened dialog box, Go to the Layout tab, press Select, and go to the Exporting_Synchro_UTDF folder in the project folder.

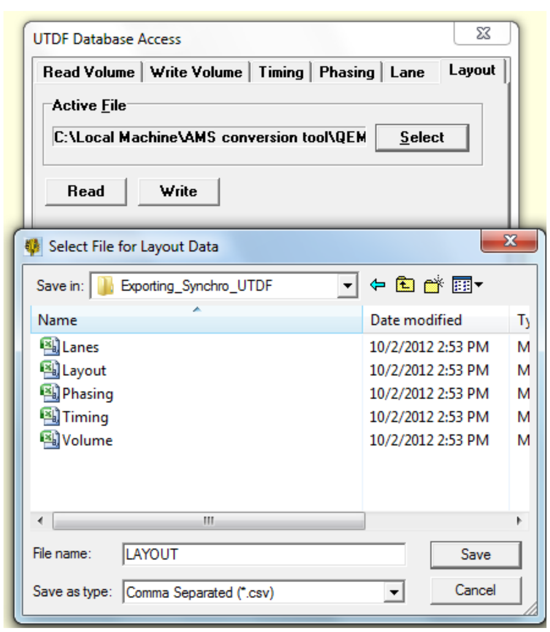


Figure 24. *Reading Layout.csv file.*

3. Click on the Layout file, press Save, and then Read. Synchro will report a warning in the Layout file reading. This is OK, since Synchro needs to reconfigure the intersection numbering. Press Resume, and the Layout file will be read.
4. While still in the Layout tab, press Select again, and rename the layout file to Synchro_Layout. Press Save, and then Write. Synchro will replace the layout file with the new that has a consistent intersection node numbering.

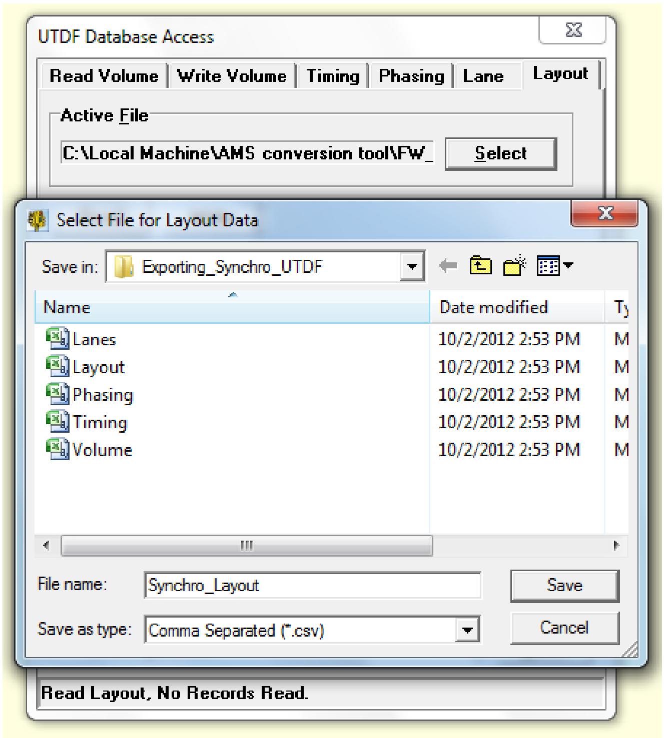


Figure 25. *Writing Synchro_Layout.csv file.*

5. Go to the Lane tab, make sure that the “Include Volume Related Data” box is checked, press Select, and select the Lanes file from the Exporting_Synchro_UTDF folder. Press Read. Syncro will read the lanes data and return a message on the number of records written.
6. Repeat step 5 for phasing data in the Phasing tab.
7. Repeat step 6 for timing data in the Timing tab. Make sure to change the “Timing Plan Name” from “Default” to “1” to read the correct timing plan.
8. Go to the Read Volume tab and read volumes from the Exporting_Synchro_UTDF folder following the same procedure as in the previous steps.

After all the steps are completed, the network from NeXTA will be imported to Synchro. The user can access any signalized intersection and read Synchro signal parameters. If needed, a network-wide signal timing optimization can be performed in Synchro. The converted network is shown in Figure 26.

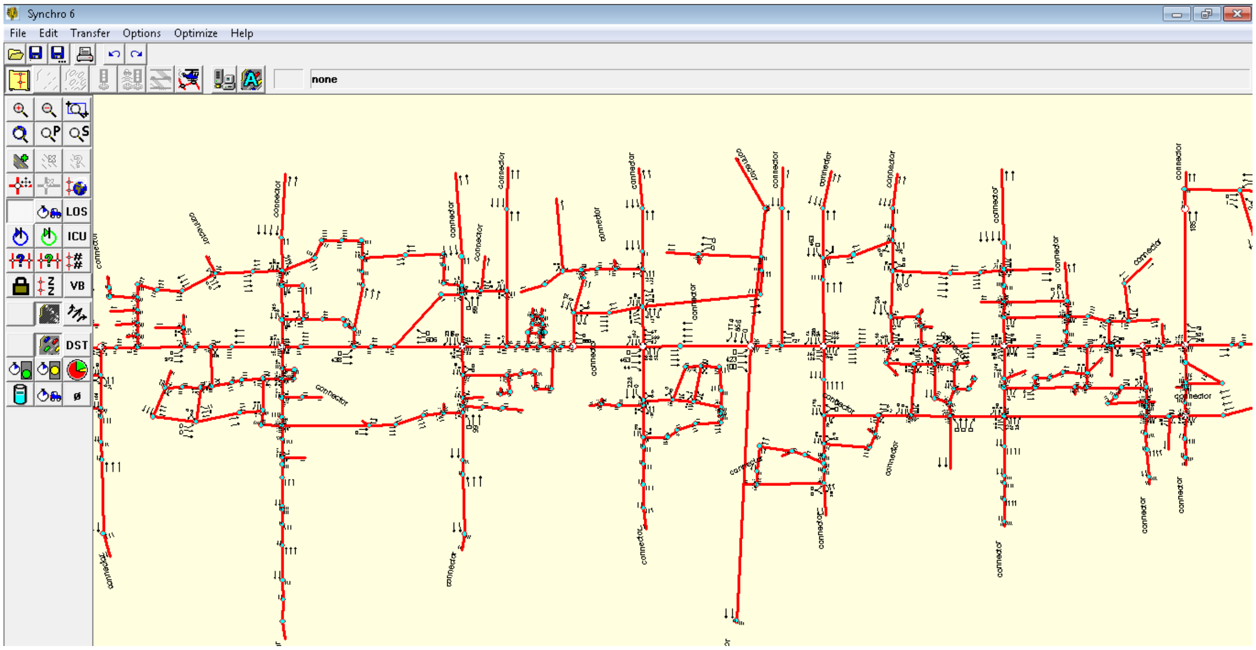


Figure 26. *NeXTA network exported to Synchro, with QEM signal timing data.*

If the Synchro CSV files are exported from the macro-enabled stand-alone application, the same Synchro importing process is used to transfer the data. However, in this case, there is no need for Step 4, writing the Synchro_Layout.csv file, since only one intersection is written at a time.

Signalized Intersection Capacity Analysis Study: Foothill Corridor Example

The stand-alone QEM application can be used to perform signalized intersection capacity analysis studies. For that purpose, it is necessary to perform a data collection to obtain the needed inputs. The minimum data needed for the analysis are intersection geometry (number of lanes for each movement), traffic volume counts for each movement, and posted speed limits.

Intersection geometry can be obtained in the field, with the observer making a sketch of the intersection. The sketch should include number of lanes for each intersection approach, as well as a designation of separate right and left turn lanes, and the number of those lanes. Alternatively, the intersection geometry can be obtained through aerial imagery. The observer should also note the speed limits along the streets before the intersection approach.

Traffic movement counts should be performed for a typical mid-week work day (Tuesday, Wednesday or Thursday), when there are no holidays and the schools are in session, and under good weather conditions. In the Foothill corridor example, the counts should be performed for the PM peak hour, which is 5:00 – 6:00 PM. The counts are collected by two observers for each intersection, using manual method with data collection sheets. The traffic movement counts are collected in 15-minute intervals, to capture fluctuations in traffic demand within the peak hour (calculate Peak Hour Factor – PHF). In general, traffic counts should include cars and trucks separately, to determine the percentage of heavy vehicles in the traffic flow.

For the best organization of traffic counts, it is recommended that the observers place themselves as shown in Figure 27. That way each observer will count the nearest approach, and after the counts are collected, the results will be merged for the entire intersection.

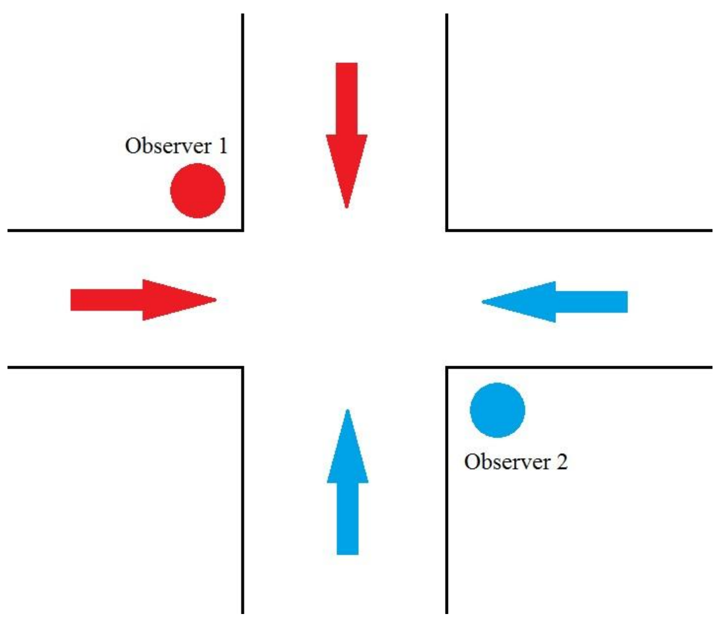


Figure 27. *Observer placement for intersection movement counts.*

The observers will use traffic count sheets as shown in Figure 28. Each observer will collect data for 15-minute intervals, which means there will be four sheets per observer for the PM peak hour counts. The observers will count cars and truck separately for each movement. In this example, there will be no separate counts for pedestrians or bicyclists. Motorcycles, pick-up trucks, SUVs, vans and station wagons will be counted under cars, while other large trucks and buses will be counted under trucks.

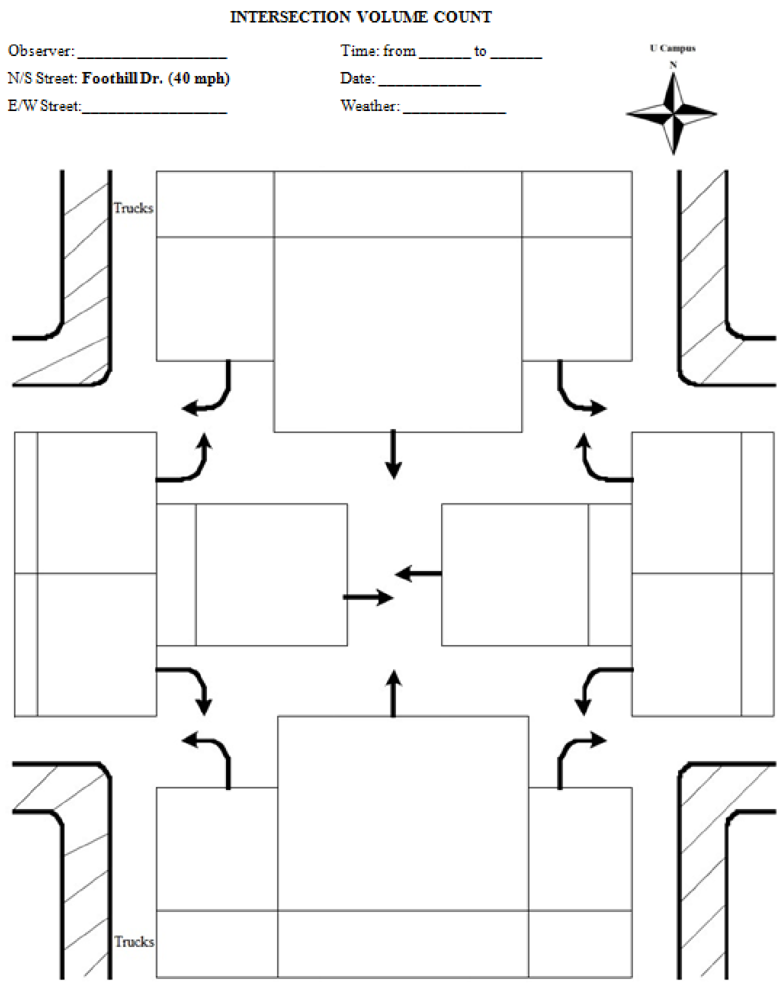


Figure 28. *Intersection movement count sheet.*

When all the data are collected, it can be used to populate the QEM application input and perform intersection capacity analysis. The observers are also encouraged to separately record residual queues (unserviced vehicles) for through and left movements at the end of each green period, for visual verification of the results obtained from the application.