10.6.2 Progression Analysis

Traffic Signal Progression Analysis
This section pertains to progression analysis for planning and project development. OAR 734-020-0480 requires an analysis to demonstrate that the additional or revised signal still provides a progression bandwidth as large as that required or as presently exists for through state highway traffic at the critical intersection. The **critical intersection** carries the highest highway volume per lane in the arterial signal system. The highway or arterial signal system includes, but is not limited to, signals within a half of a mile of an existing or future signal. Progression analysis ensures a new or revised signal operates as a coordinated system upon completion and for 15 to 20 years into the future.

At the start of the study, the analyst should work with Region Traffic to determine whether the progression analysis uses existing signal timings or optimized coordinated system timings. Existing signal timing is always required for microsimulation of existing conditions. If existing timings are chosen, the Region Traffic Signal Manager will provide timing files, timing sheets, or Synchro files of the existing settings. Optimized timings are subject to approval by ODOT and become the baseline for comparisons. The following settings should be optimized for each scenario:

- Cycle Length, splits and offsets
- Phase Sequence (Lead/Lag Lefts)
- Phase Lengths (Splits) optimizing highway through movement

Optimizing these settings should help to meet the minimum progression bandwidth criteria established in OAR 734-020-0480. Phase split times should also accommodate the traffic demand within a reasonable level of service. The mobility standards of intersection v/c ratios must be met. Queue lengths shall be reported. Examples of signal modifications covered by the rule are changes in cycle length, additional phases or approaches, longer crosswalks, and intersection relocation.

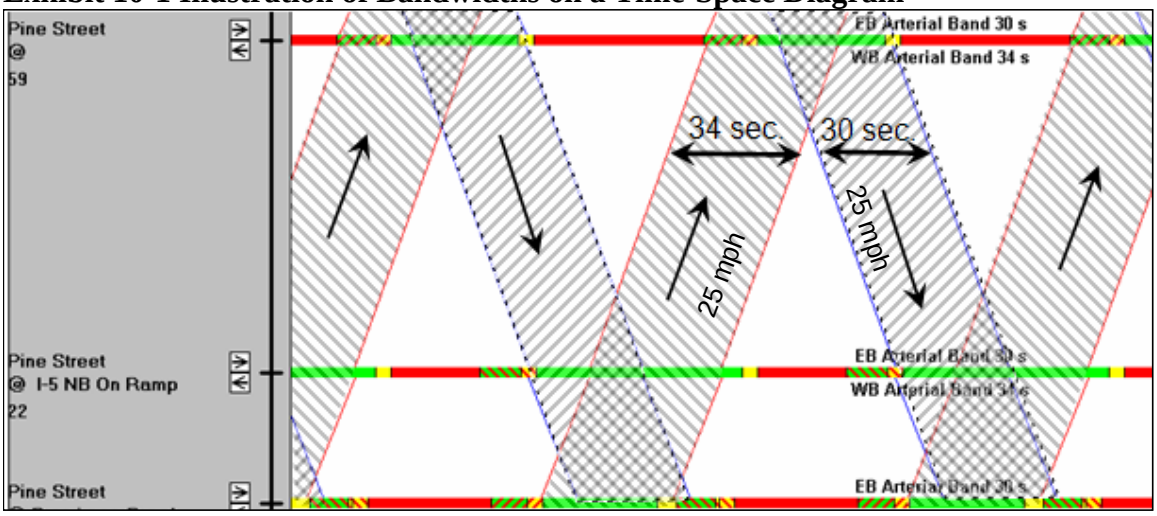
Requirements for Signal Progression Analysis
Analysis required under OAR 734-020-0480 must meet the following requirements:

- Adequate existing and future traffic signal system operation during peak hours
- Progression speed, in both directions, no more than 10 mph below posted speed during peak periods and no more than 5 mph below during off-peak periods. Lower speeds require approval by the State Traffic Engineer.
- Sufficient vehicle storage, within the traffic system, without encroaching on functional boundaries of adjacent lanes and intersections. See the Access Management Unit procedures and the APM for functional boundaries of intersections.
- Common cycle length with optimized highway green time and adequate pedestrian times

Complete time-space diagrams (see Exhibit 10-1) are required for each analysis scenario, including the existing coordinated system. The time-space diagram indicates the distance between signalized intersections on the vertical axis and time on the horizontal axis. The

thickness of the bandwidth represents the time in the signal system for progression. The slope of the band the progression speed the time space diagram. Be sure to show the arterial, not link, bandwidth. Include a report of the offsets, phasing and split times for each signal in the system. When using Synchro, report bandwidths of the two highway directions (select under options), with 90th percentile arrival rates. Synchro's progression bandwidth includes yellow and green time.

Exhibit 10-1 Illustration of Bandwidths on a Time-Space Diagram



Progression Bandwidth Calculator

Exhibit 10-2 shows the progression bandwidth calculator, available on the TPAU website.

Exhibit 10-2 Progression Bandwidth Calculator

Project Information	
Analyst:	
Agency/Company:	
Date:	
Project Name:	
Section:	
Analysis Time Period:	
Jurisdiction:	
Year/Alternative:	

Parameter	Value[2]	
Inputs		
Cycle Length (sec)		
Posted Speed of Arterial (mph)		
Progression Speed (mph)		
Direction of Flow		
Lane Group Flow (vph)		
Saturation Flow Rate (veh per hour of green)		
Analyst's Initial Optimized Highway Progression Bandwidth		
Calculations[3]		
1. No. of Cycles per hour		
2. G/C, hours of green required per hour		
3. Minimum seconds of green per hour		
4. Minimum seconds of green per cycle		
Generic Yellow Time	3.5	3.5
Results		
Minimum Progression Bandwidth = Minimum Green + Yellow Time		
Is the analysts initial progression bandwidth equal to or larger than the minimum progression bandwidth?		

[1] This calculator is to be applied at the most critical intersection in a progressed signal system. At the critical intersection, the arterial approach volume and saturation flow rate are used to set the minimum required progression bandwidth in each direction.

[2] See Notes tab for instructions.

[3] See Manual Calculation tab for description of steps.

The Progression Bandwidth Calculator is an Excel spreadsheet intended for use in project development as a preliminary estimate of bandwidth adequacy. The tool estimates the minimum required progression bandwidth for a signalized system based on volumes at the critical intersection. One can calculate required inputs or gather them from Synchro. The minimum progression bandwidth is determined for the critical intersection using the following four steps:

1. Calculate the number of cycles per hour:

   $$\text{Number of cycles per hour} = \frac{3600}{\text{Cycle length}}$$

2. Calculate minimum percent green time required for critical lane group:

   $$\text{Minimum percent green time required} = \frac{\text{Volume in critical lane group}}{\text{Adjusted Saturated Flow Rate}}$$

3. Convert minimum green time to seconds:

   Minimum green time required (seconds) = Minimum percent green x 3600

4. Calculate minimum progression bandwidth required to accommodate the critical volume:

   $$\text{Green time required per cycle} = \frac{\text{Minimum green time required}}{\text{Number of cycles per hour}}$$

   Minimum Progression Band = Minimum green time per cycle + Yellow time

The Progression Bandwidth Calculator focuses on section (1)(e) of OAR 734-020-0480 while addressing other sections. Section (1)(a) suggests morning, midday, and evening peak analysis; each period can be analyzed (one at a time). Section (1)(b) requires a progression speed (both directions) of no more than 10 mph below the posted speed for peak periods and no more than 5 mph below for non-peak hours. The main product is an initial minimum progression bandwidth as required in Section (1)(e). Section (2) covers analyzing existing and future conditions.

This spreadsheet calculator is to aid in preliminary analysis, but is not intended as a final analysis for a new signal or modification. Consult Region Traffic or Traffic-Roadway Section (TRS) regarding the required final analysis and report.

Before a signal is planned or designed, an Intersection Traffic Control Study should be conducted and/or reviewed by Region Traffic. An Intersection Traffic Control Study should analyze corridors (including medians and other modifications) and intersection control types for potential solutions to a location's specific problems. A signal may be inappropriate to the site or location being studied in the Traffic Control Study. There might not be any urban indicators, such as street lighting or curb and sidewalk to create driver expectation. Meeting a Manual on

Uniform Traffic Control Devices (MUTCD) signal warrant does not validate a signal installation. For guidance on new or revised traffic signals, see Chapter 7 of the APM, the 2005 Development Review Guidelines, the Traffic Signal Policy and Guidelines, and OAR 734-020-0480.

Inputs

Inputs from the optimized critical intersection are required and may be obtained from the Synchro Lanes, Volumes, Timings Report. Required inputs are entered under the Inputs section in the Value column and used to calculate the minimum progression bandwidth.

Input Location

Under the Inputs section of the calculator, the needed inputs are: cycle length, posted speed, progression speed, direction of flow, volume, and saturation flow rate. These values may be obtained from the Synchro Lanes, Volumes, Timings Report, as shown in Exhibits 10-3 and 10-4.

- **Cycle Length (sec)**
- **Posted Speed** - Posted or 85th percentile speed.
- **Progression Speed (mph)** - The Synchro link speed may be used. The progression speed should be no more than 10 mph lower than the posted speed during peak periods, or no more than 5 mph lower during off-peak periods.
- **Direction of Flow**
- **Lane Group Flow (vph)** - Demand volume per lane (adjusted by PHF) after signals are optimized for highway progression.
- **Saturation Flow Rate (veh per hour of green)** - The adjusted Saturation flow rate in vehicles per hour of green.

Exhibit 10-3 Synchro Lanes, Volumes, Timings Report

Lanes, Volumes, Timings
3: Maple Ave & Highway 3/8/2010

Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Volume (vph)	134	67	194	160	80	27	321	596	214	67	529	154
Ideal Flow (vphpl)	1750	1750	1750	1750	1750	1750	1750	1750	1750	1750	1750	1750
Storage Length (ft)	250		250	250		0	250		0	250		0
Storage Lanes	1		1	1		0	1		0	1		0
Taper Length (ft)	25		25	25		25	25		25	25		25
Lane Util. Factor	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.95	0.95	1.00	0.95	0.95
Frt			0.850		0.962			0.960			0.966	
Flt Protected	0.950			0.950			0.950			0.950		
Satd. Flow (prot)	1630	1716	1458	1630	1650	0	1630	3129	0	1630	3149	0
Flt Permitted	0.598			0.705			0.950			0.950		
Satd. Flow (perm)	1026	1716	1458	1210	1650	0	1630	3129	0	1630	3149	0
Right Turn on Red			Yes			Yes			Yes			Yes
Satd. Flow (RTOR)			98		13						33	
Link Speed (mph)		30			30			35			35	
Link Distance (ft)		434			550						1287	
Travel Time (s)		9.9			12.5			15.2			25.1	
Peak Hour Factor	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
Adj. Flow (vph)	146	73	211	174	87	29	349	648	233	73	575	167
Shared Lane Traffic (%)												
Lane Group Flow (vph)	146	73	211	174	116	0	349	881	0	73	742	0
Enter Blocked Intersection	No	No	No	No	No	No	No	No	No	No	No	No
Lane Alignment	Left	Left	Right	Left	Left	Right	Left	Left	Right	Left	Left	Right
Median Width(ft)		12			12			12			12	
Link Offset(ft)		0			0			0			0	
Crosswalk Width(ft)		12			12			12			12	

Exhibit 10-4 Synchro Lanes, Volumes, Timings Report (cont)

Lanes, Volumes, Timings
3: Maple Ave & Highway 3/8/2010

Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Switch Phase												
Minimum Initial (s)	4.0	4.0	4.0	4.0	4.0		4.0	4.0		4.0	4.0	
Minimum Split (s)	27.5	27.5	8.5	27.5	27.5		8.5	22.5		8.5	24.5	
Total Split (s)	34.0	34.0	44.0	34.0	34.0	0.0	44.0	70.6	0.0	15.4	42.0	0.0
Total Split (%)	28.3%	28.3%	36.7%	28.3%	28.3%	0.0%	36.7%	58.8%	0.0%	12.8%	35.0%	0.0%
Maximum Green (s)	29.5	29.5	39.5	29.5	29.5		39.5	66.1		10.9	37.5	
Yellow Time (s)	4.0	4.0	4.0	4.0	4.0		4.0	4.0		4.0	4.0	
All-Red Time (s)	0.5	0.5	0.5	0.5	0.5		0.5	0.5		0.5	0.5	
Lost Time Adjust (s)	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5
Total Lost Time (s)	4.0	4.0	4.0	4.0	4.0	3.5	4.0	4.0	3.5	4.0	4.0	3.5
Lead/Lag			Lag				Lag	Lead		Lag	Lead	
Lead-Lag Optimize?			Yes				Yes	Yes		Yes	Yes	
Vehicle Extension (s)	2.5	2.5	2.5	2.5	2.5		2.5	2.5		2.5	2.5	
Minimum Gap (s)	2.0	2.0	2.0	2.0	2.0		2.0	2.0		2.0	2.0	
Time Before Reduce (s)	8.0	8.0	8.0	8.0	8.0		8.0	8.0		8.0	8.0	
Time To Reduce (s)	4.0	4.0	4.0	4.0	4.0		4.0	4.0		4.0	4.0	
Recall Mode	None	None	None	None	None		None	C-Min		None	C-Min	
Walk Time (s)	7.0	7.0		7.0	7.0			7.0			7.0	
Flash Dont Walk (s)	16.0	16.0		16.0	16.0			10.0			13.0	
Pedestrian Calls (#/hr)	0	0		0	0			0			0	
Act Effct Green (s)	22.2	22.2	57.2	22.2	22.2		31.1	66.3		21.6	54.8	
Actuated g/C Ratio	0.18	0.18	0.48	0.18	0.18		0.26	0.55		0.18	0.46	
v/c Ratio	0.77	0.23	0.28	0.78	0.37		0.83	0.50		0.25	0.51	
Control Delay	71.0	41.2	8.8	68.6	39.5		57.9	19.6		51.1	17.7	
Queue Delay	0.0	0.0	0.0	0.0	0.0		0.0	0.0		0.0	0.0	
Total Delay	71.0	41.2	8.8	68.6	39.5		57.9	19.6		51.1	17.7	
LOS	E	D	A	E	D		E	B		D	B	
Approach Delay		35.4			56.9			30.5			20.7	
Approach LOS		D			E			C			C	

Intersection Summary

Area Type: Other
Cycle Length: 120
Actuated Cycle Length: 120
Offset: 0 (0%), Referenced to phase 2:NBT and 6:SBT, Start of Yellow, Master Intersection
Natural Cycle: 75
Control Type: Actuated-Coordinated

Progression bandwidth provided - The progression bandwidth attained by the analyst after optimization is used to compare to the minimum required bandwidth result from the calculator. The Synchro 90th percentile bandwidth may be used. See Exhibit 10-1.

Example 10-1 Progression Bandwidth Example

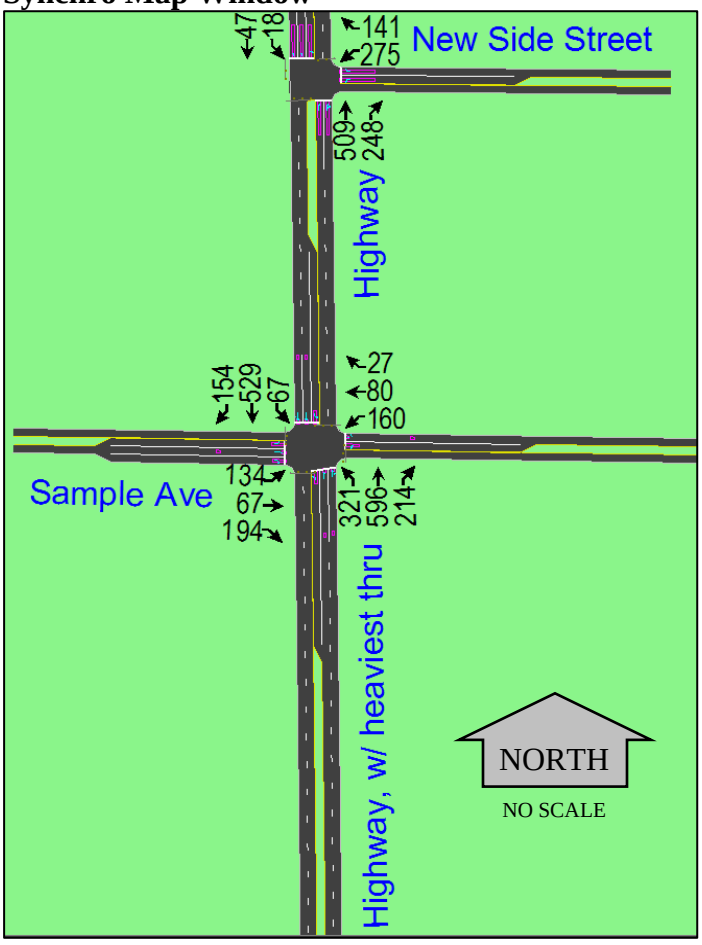
Application of the Progression Bandwidth Calculator is illustrated in this Example.

The build analysis example intersection is a signalized intersection that will be the critical intersection in a coordinated system. The Region Traffic Signal Manager had been contacted earlier in the process and provided information for the no-build analysis. The build analysis of this intersection timing was optimized for highway movement, including cycle length (splits and offsets), phase sequence (Lead/Lag Lefts), and phase lengths (splits).

The peak hour volumes and lane configurations are shown in the figure. The highway posted speed is 35 mph. The progression speed on the highway is 35 mph.

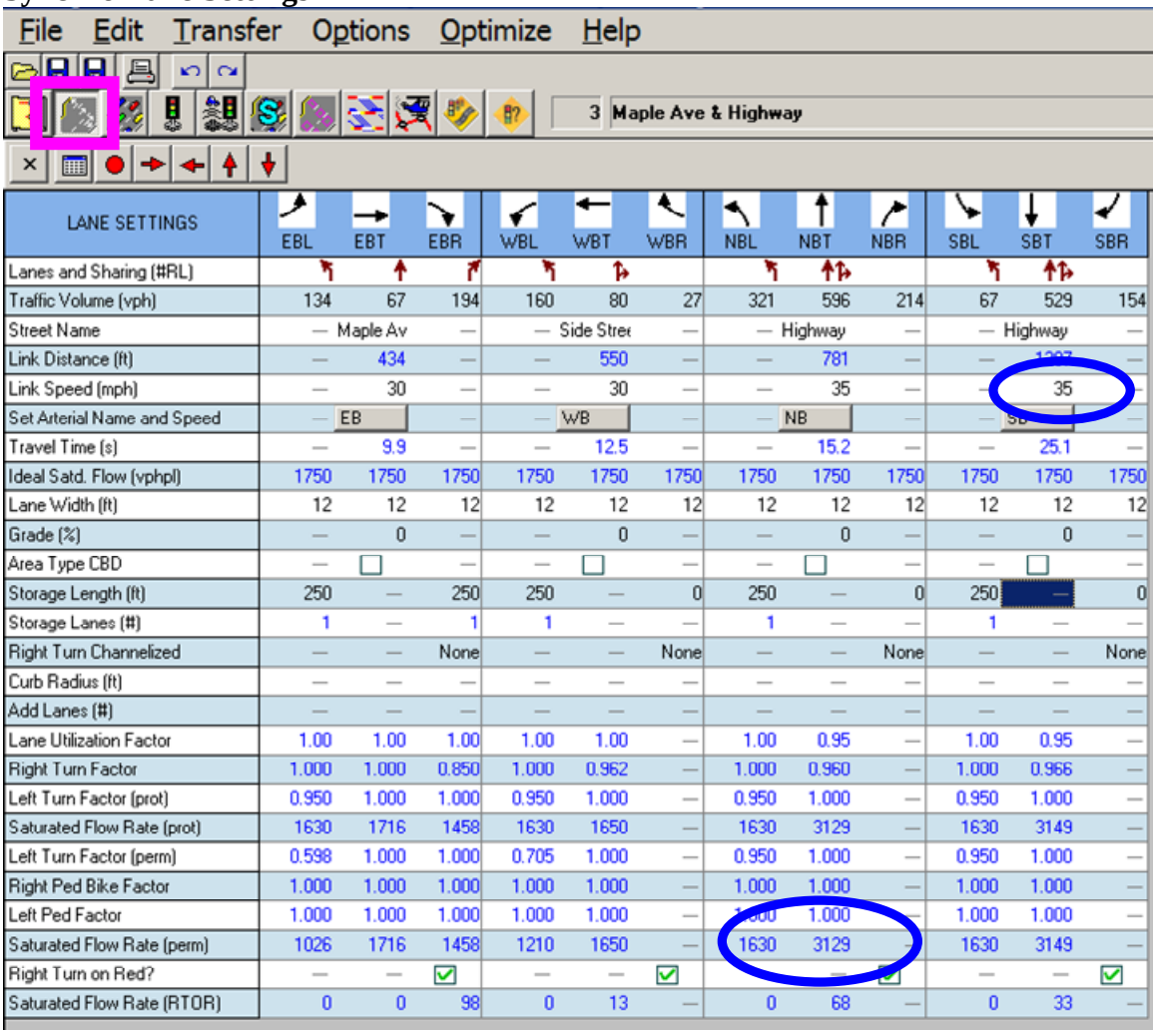
The following Synchro screenshots illustrate where to find input values for the calculator.

Synchro Map Window



The progression speed and saturated flow rate can be found on the Lane Settings window.

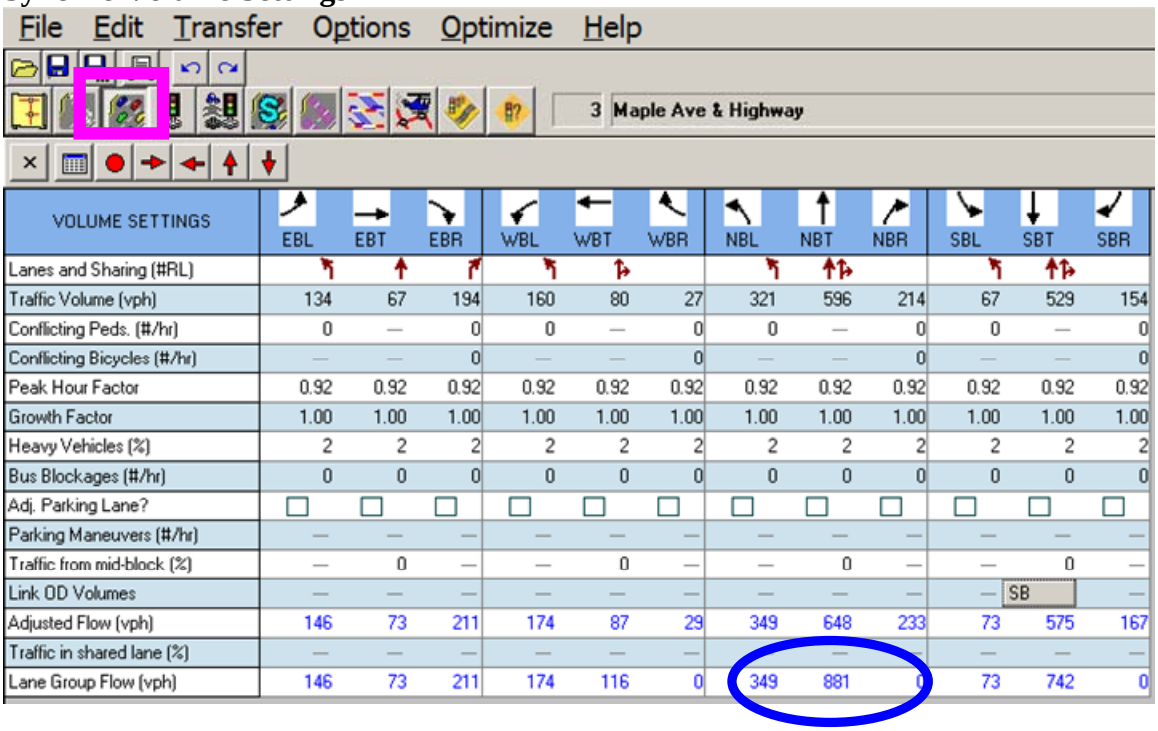
Synchro Lane Settings



LANE SETTINGS	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lanes and Sharing (#RL)												
Traffic Volume (vph)	134	67	194	160	80	27	321	596	214	67	529	154
Street Name	—	Maple Av	—	—	Side Stree	—	—	Highway	—	—	Highway	—
Link Distance (ft)	—	434	—	—	550	—	—	781	—	—	[illegible]	—
Link Speed (mph)	—	30	—	—	30	—	—	35	—	—	35	—
Set Arterial Name and Speed	—	EB	—	—	WB	—	—	NB	—	—	SB	—
Travel Time (s)	—	9.9	—	—	12.5	—	—	15.2	—	—	25.1	—
Ideal Satd. Flow (vphpl)	1750	1750	1750	1750	1750	1750	1750	1750	1750	1750	1750	1750
Lane Width (ft)	12	12	12	12	12	12	12	12	12	12	12	12
Grade (%)	—	0	—	—	0	—	—	0	—	—	0	—
Area Type CBD	—	☐	—	—	☐	—	—	☐	—	—	☐	—
Storage Length (ft)	250	—	250	250	—	0	250	—	0	250	—	0
Storage Lanes (#)	1	—	1	1	—	—	1	—	—	1	—	—
Right Turn Channelized	—	—	None	—	—	None	—	—	None	—	—	None
Curb Radius (ft)	—	—	—	—	—	—	—	—	—	—	—	—
Add Lanes (#)	—	—	—	—	—	—	—	—	—	—	—	—
Lane Utilization Factor	1.00	1.00	1.00	1.00	1.00	—	1.00	0.95	—	1.00	0.95	—
Right Turn Factor	1.000	1.000	0.850	1.000	0.962	—	1.000	0.960	—	1.000	0.966	—
Left Turn Factor (prot)	0.950	1.000	1.000	0.950	1.000	—	0.950	1.000	—	0.950	1.000	—
Saturated Flow Rate (prot)	1630	1716	1458	1630	1650	—	1630	3129	—	1630	3149	—
Left Turn Factor (perm)	0.598	1.000	1.000	0.705	1.000	—	0.950	1.000	—	0.950	1.000	—
Right Ped Bike Factor	1.000	1.000	1.000	1.000	1.000	—	1.000	1.000	—	1.000	1.000	—
Left Ped Factor	1.000	1.000	1.000	1.000	1.000	—	[illegible]	1.000	—	1.000	1.000	—
Saturated Flow Rate (perm)	1026	1716	1458	1210	1650	—	1630	3129	—	1630	3149	—
Right Turn on Red?	—	—	☑	—	—	☑		—	☑	—	—	☑
Saturated Flow Rate (RTOR)	0	0	98	0	13	—	0	68	—	0	33	—

Lane group volumes are found on the Synchro Volume Settings window.

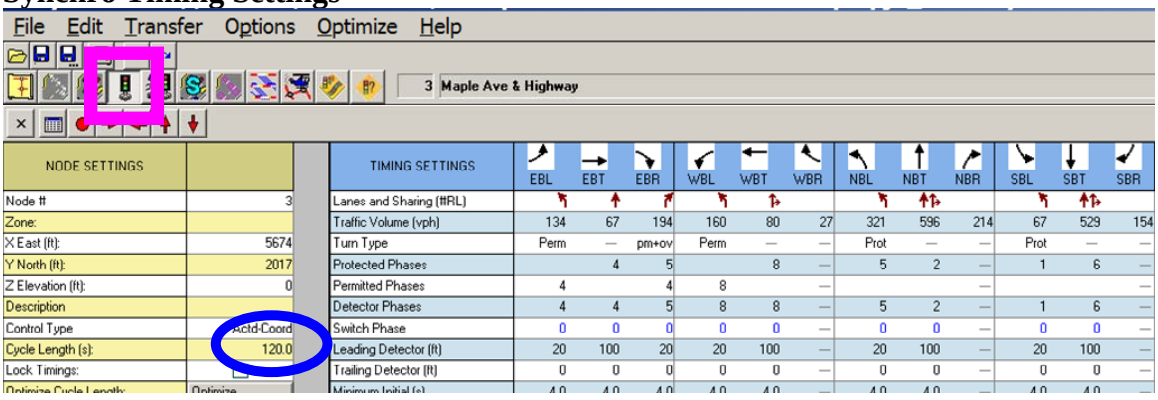
Synchro Volume Settings



VOLUME SETTINGS	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lanes and Sharing (#RL)												
Traffic Volume (vph)	134	67	194	160	80	27	321	596	214	67	529	154
Conflicting Peds. (#/hr)	0	—	0	0	—	0	0	—	0	0	—	0
Conflicting Bicycles (#/hr)	—	—	0	—	—	0	—	—	0	—	—	0
Peak Hour Factor	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
Growth Factor	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Heavy Vehicles (%)	2	2	2	2	2	2	2	2	2	2	2	2
Bus Blockages (#/hr)	0	0	0	0	0	0	0	0	0	0	0	0
Adj. Parking Lane?	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Parking Maneuvers (#/hr)	—	—	—	—	—	—	—	—	—	—	—	—
Traffic from mid-block (%)	—	0	—	—	0	—	—	0	—	—	0	—
Link OD Volumes	—	—	—	—	—	—	—	—	—	—	SB	—
Adjusted Flow (vph)	146	73	211	174	87	29	349	648	233	73	575	167
Traffic in shared lane (%)	—	—	—	—	—	—	—	—	—	—	—	—
Lane Group Flow (vph)	146	73	211	174	116	0	349	881	0	73	742	0

The cycle length is located on the Timing Settings window.

Synchro Timing Settings

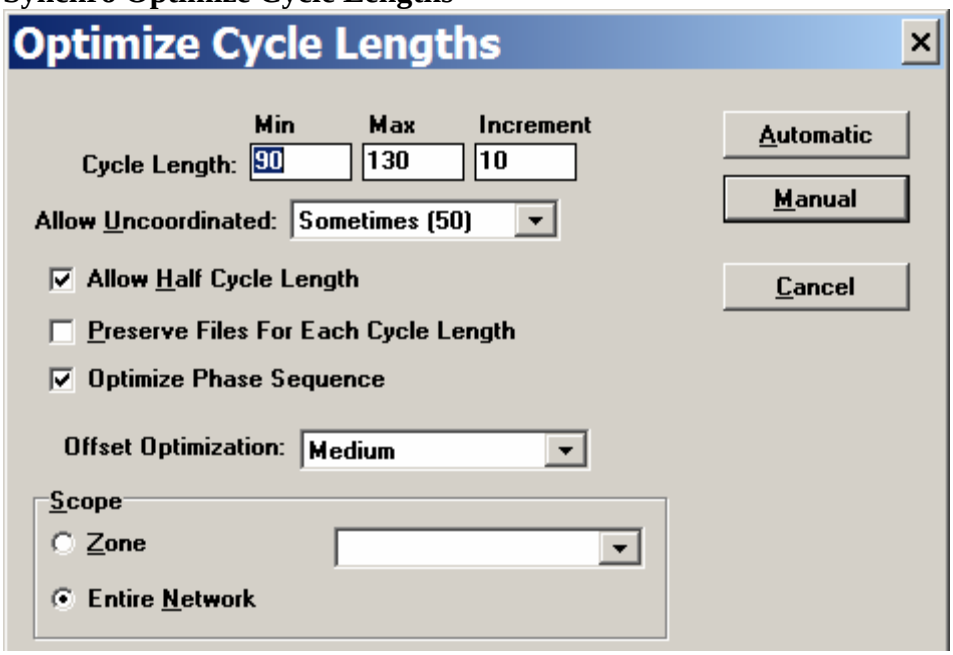


NODE SETTINGS	
Node #	3
Zone:	
X East (ft):	5674
Y North (ft):	2017
Z Elevation (ft):	0
Description	
Control Type	Actd-Coord
Cycle Length (s):	120.0
Lock Timings:	

TIMING SETTINGS	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lanes and Sharing (#RL)												
Traffic Volume (vph)	134	67	194	160	80	27	321	596	214	67	529	154
Turn Type	Perm	—	pm+ov	Perm	—	—	Prot	—	—	Prot	—	—
Protected Phases		4	5		8	—	5	2	—	1	6	—
Permitted Phases	4		4	8		—			—			—
Detector Phases	4	4	5	8	8	—	5	2	—	1	6	—
Switch Phase	0	0	0	0	0	—	0	0	—	0	0	—
Leading Detector (ft)	20	100	20	20	100	—	20	100	—	20	100	—
Trailing Detector (ft)	0	0	0	0	0	—	0	0	—	0	0	—
Minimum Initial (s)	4.0	4.0	4.0	4.0	4.0	—	4.0	4.0	—	4.0	4.0	—

The Cycle Length is also determined from the Network Cycle Lengths window.

Synchro Optimize Cycle Lengths



Progression Bandwidth Calculator

Project Information		
Analyst:		
Agency/Company:		
Date:		
Project Name:		
Section:		
Analysis Time Period:		
Jurisdiction:		
Year/Alternative:		
Parameter	**Value[2]**	
Inputs		
Cycle Length (sec)	120	
Posted Speed of Arterial (mph)	35	35
Progression Speed (mph)	35	35
Direction of Flow	Northbound	Southbound
Lane Group Flow (vph)	881	742
Saturation Flow Rate (veh per hour of green)	3129	3149
Progression bandwidth provided		
Calculations[3]		
1. No. of Cycles per hour	30	
2. G/C, hours of green required per hour	0.282	0.236
3. Minimum seconds of green per hour	1014	848
4. Minimum seconds of green per cycle	33.8	28.3
Generic Yellow Time	4	4
Results		
Minimum Progression Bandwidth = Minimum Green + Yellow Time	**37.8**	**32.3**

[1] This calculator is to be applied at the most critical intersection in a progressed signal system. At the critical intersection, the arterial approach volume and saturation flow rate are used to set the minimum required progression bandwidth

[2] See Notes tab for instructions.

[3] See Manual Calculation tab for description of steps.

Notice that the calculations show up as all the inputs are entered. The results can then be compared to the analyst's progression bandwidth.

Bandwidth Capacity

When analyzing the critical intersection (both directions), estimate carrying capacity of a progression bandwidth with the following equation:

$$\text{Bandwidth Capacity (veh/cycle)} = \frac{(\text{Bandwidth(sec)} - \text{Lost Time}) \times (\text{Adj. Sat. Flow Rate})}{3600}$$

where:

Bandwidth (sec)= useable green time per cycle
Adjusted Sat. Flow = maximum flow rate of through lane group after adjustments

The bandwidth capacity can be compared to the average platoon size at the critical intersection, which may be calculated with the simplified equation:

$$\text{Average Platoon Size} = \frac{C * V}{3600}$$

where:

C = cycle length
V = volume (adjusted for PHF)

The comparison of bandwidth capacity to critical intersection platoon size is a way to check the spreadsheet analysis. The two methods should provide compatible results.

Output Not Meeting OAR 734-020-480
If a proposed signal will not meet the rule, evaluate other alternatives, such as:

- New/revise intersection relocation
- Additional lanes to reduce green time
- Reduce phases on one or more signals
- Alternate side street route
- Take out of coordination for pedestrians

If a proposed signal still does not meet the rule, consult with Region Traffic or TRS. Design exceptions must be coordinated with TRS.

Available Analysis Tools
To meet the requirements of the rule, analysts may use any coordinated system software or hand calculations and time-space diagrams. A few of the computer software programs recognized as capable of performing this analysis include:

- **Synchro:** The ODOT preferred software from Trafficware optimizes traffic signal timing, splits, offsets and cycle lengths for individual intersections, an arterial, or a complete network. Synchro performs ICU and HCM analysis. Synchro provides time space diagrams in bandwidths. Synchro creates files for SimTraffic or other simulation software.
- **Passer II**: The software developed by Texas Transportation Institute (TTI) determines saturation flow, offsets, and optimizes bandwidths and efficiency of signalized arterials.

Micro simulation programs (such as SimTraffic, CORSIM and VISSIM) do not produce signal progression timing. They can model signal progression timing as an input. SimTraffic

automatically models progression timing developed in Synchro.