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TecNote 7001 - Modeling 4-Phase Diamond Interchange Operation With Synchro / SimTraffic

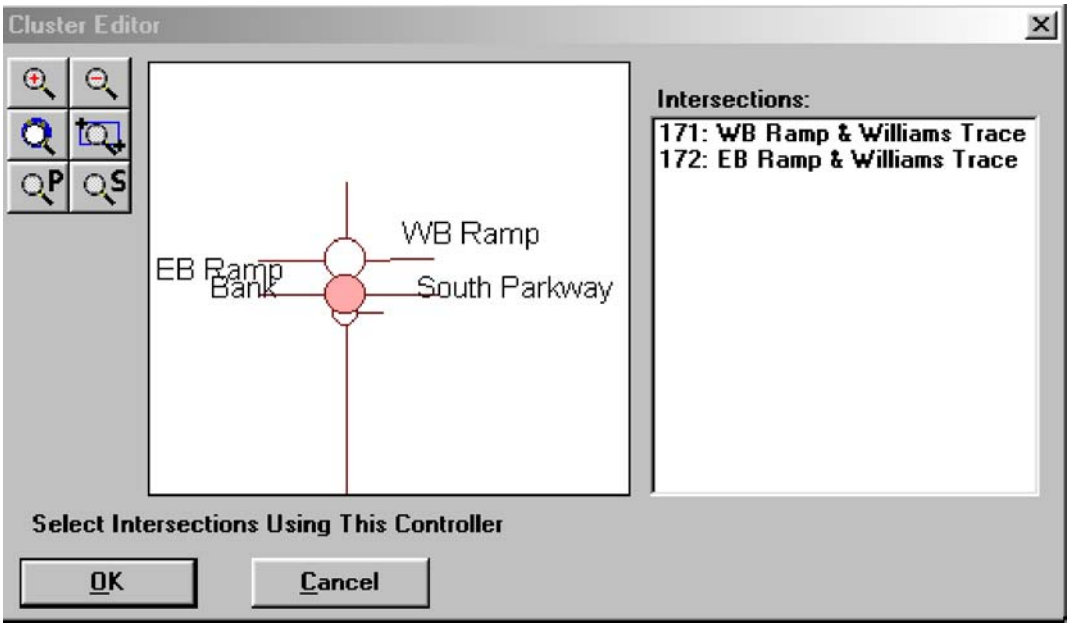
Various phasing schemes can be used to optimize signal operations at a diamond interchange and closely spaced intersections. PASSER III can be used to study the benefit of 3-phase, 4-phase, and separate ring operation. Texas Transportation Institute Publication TX-00/4913-1, "COORDINATION OF DIAMOND INTERCHANGES WITH ADJACENT TRAFFIC SIGNALS", October 2000 is an excellent guide to selecting a phasing scheme for highly congested diamond interchanges.

As a general rule:

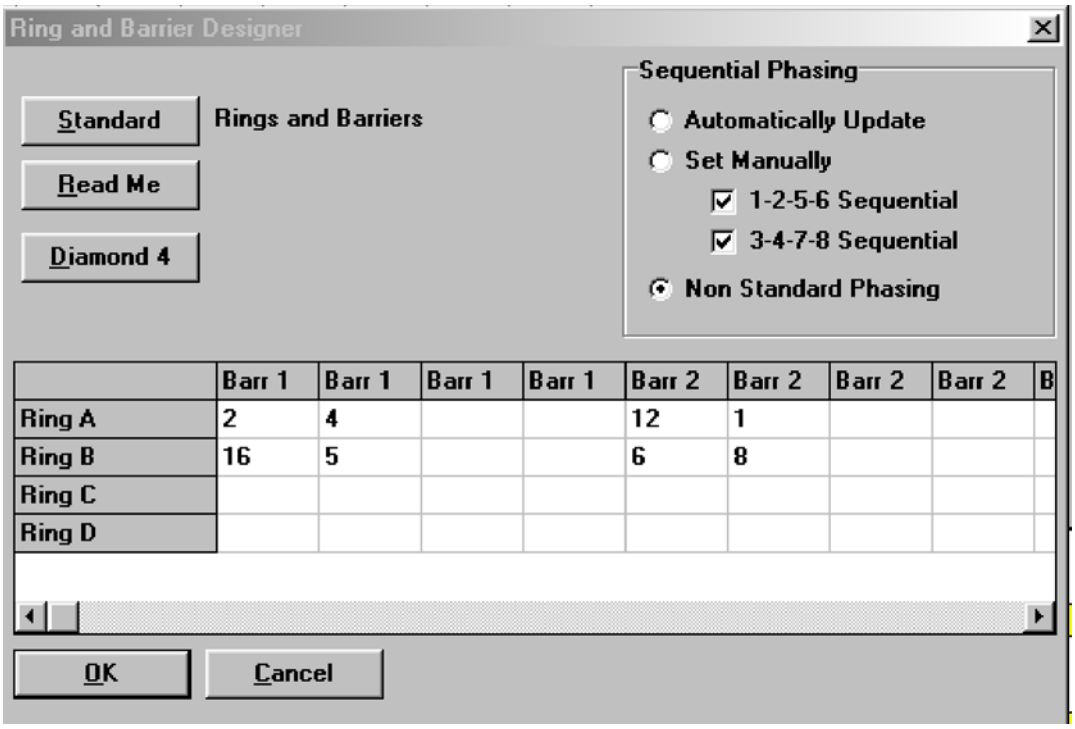
- 3-phase operation works best when the frontage road spacing is greater than 350-400 ft.
- 4-phase operation works best when the frontage road spacing is less that 250-300 ft. especially when the interior turning movements are significant.
- Frontage road spacing between 250- 400 ft. can go either way depending on a number of factors that can be modeled and studied with PASSER III.

The phasing scheme selected for the interchange can be "locked" in Synchro and modeled as part of a network of coordinated signals using Synchro / SimTraffic from Trafficware. Synchro is a very popular model and is gaining wide acceptance across the country because it is so easy to use and because the documentation and help files are excellent.

Trafficware distinguishes between *Group Control* (tightly coupled and closely spaced signals) and *Local Control* (independent signal phasing). The *Cluster Editor* was added in Synchro 4.0 and 5.0 to define *Group Control* for closely spaced signals to simulate diamond operation and complex phasing schemes using a single controller .

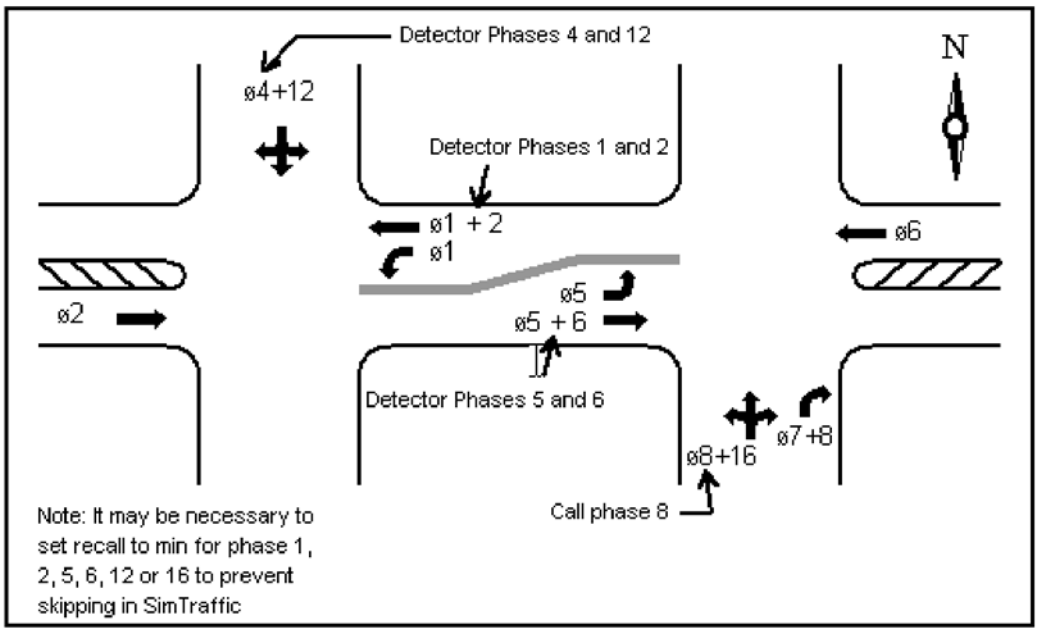


The *Ring and Barrier Designer* allows you to define up to 16 phases in 4 rings just like the Naztec version 50 software provided in the TS2 / 2070 controllers:



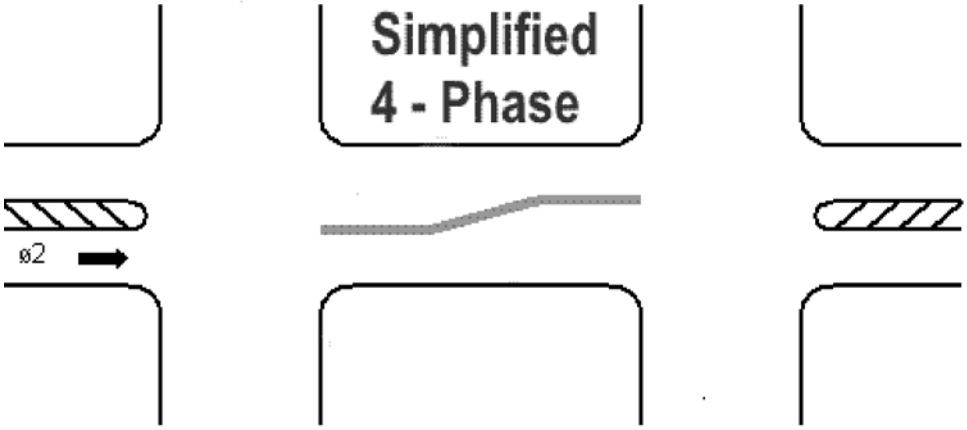
The "Diamond 4" button in the *Ring and Barrier Designer* was used to select the phase sequence shown above for a 4-phase diamond intersection. Search on the "diamond" in Synchro's help file to read more about *Group Control*. Synchro's phasing schemes for a diamond interchange are based on

read more about *Group Control*. Synchro's phasing schemes for a diamond interchange are based on the following:

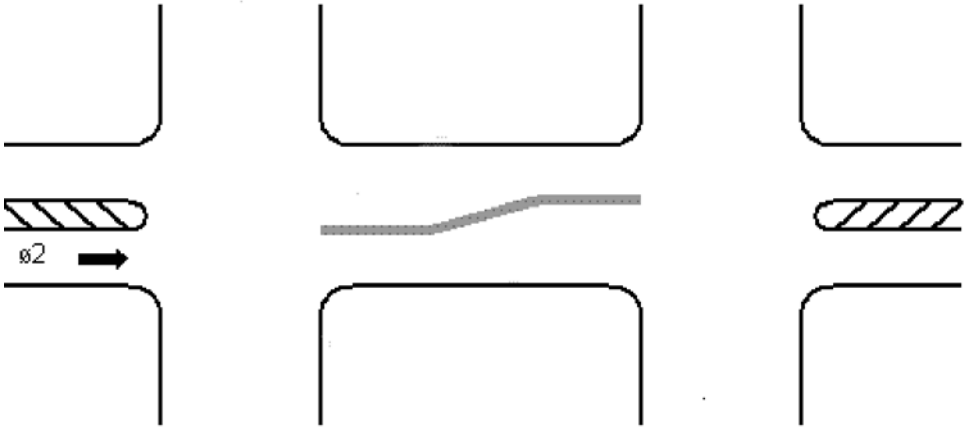


Work through "SETTING UP A TIMING PLAN" in Synchro's help file which is a step-by-step tutorial on how to set up *Group Control* and phase the intersections for your interchange model. If you don't set the controller type as "Pretimed", you will need to be sure to code the detectors necessary to drive all of the phases in your model, or else you will create a lot of "slack time" from the actuated phases when you view your model in SimTraffic.

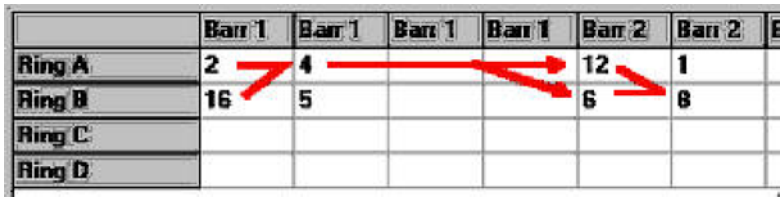
4-phase diamond operation appears quite complex at first glance. However, if you only look at the phases entering the interchange, you will see that each approach is serviced in a clockwise sequential order as shown below. Don't let the interior turn phases confuse you - just think of the interior phases as "slaves" to the phases allowing traffic to enter the interchange. The purpose of the interior phases is to insure that the through traffic is always progressed through the downstream signal.



You can add capacity to a 4-phase diamond interchange by allowing the arterial movements to time with the end of the downstream frontage road signal. Phase 12 and 16 extend the frontage roads with an overlap that times with the through movements as shown below: The min and max times for phase 12 and 16 are set to the travel times for vehicles entering the interchange on phase 2 and 6 and traveling to the downstream frontage road while that frontage road is being extended. Again, the interior phases are just "helper phases" to insure that the through movement downstream is progressed through the interchange.

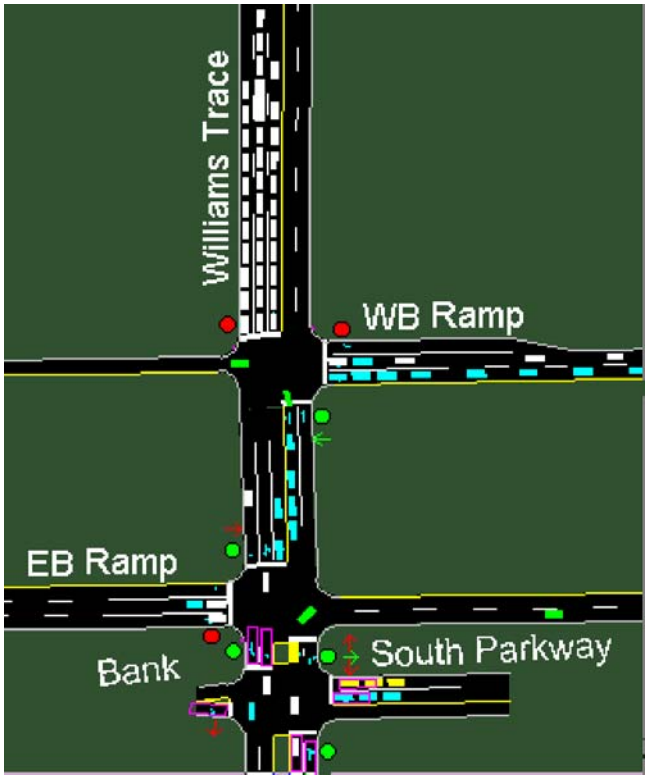


Now, does the *Ring and Barrier Designer* above make more sense? Can you follow the sequence from 2+16 to 4 to 6+12 to 8? Again, the interior phases 1 and 5 are just "helper phases" to insure that the through movement downstream is progressed through the interchange.



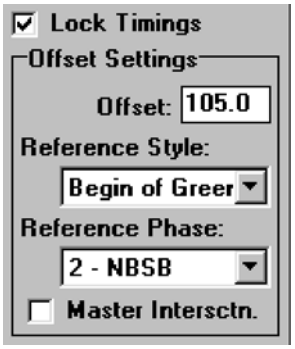
4-Phase Diamond - North / South Arterial Example

Below is a coding example of a north/south arterial at a 4-phase diamond interchange. The two ramp signals are modeled with "Group Control" and the nearby signal at South Parkway is modeled separately using "Local Control". However, a single 16 phase / 4 ring Naztec Version 50 controller could be used to drive all three intersections by running South Parkway in a separate ring. Synchro could then be used to model all three intersections under "Group Control" using the *Ring and Barrier Designer* to model the controller operation.



Synchro is used to adjust the split times for the WB and EB Ramps (with "Lock Timings" turned off). Then the timings are locked as shown below and Synchro is used to adjust the offsets with the rest of the network (30 intersections in this case).

In this example, the calculated offset is referenced to the beginning of phase 2 which is the SBT (southbound through movement) entering the interchange from the north. When you code the offset in the controller, don't forget to reference it to the "begin-of-green" of the coord phase (phase 2 in this case). Otherwise, the controller and Synchro will not reference offsets to the same point in the cycle and you won't get the true results calculated by the model.



The additional coding needed to correctly model the frontage road signals in Synchro is provided below. You must "Lock" these Group Control intersection as part of a larger network.

WB Frontage Road

Phase 12 extends the WB frontage road after phase 4 ends. The southbound movement (SBT), phase 2 is allowed to time with phase 16 (the frontage road extension for the EB frontage road).

TIMING WINDOW	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT
Lanes and Sharing (#RL)											
Traffic Volume (vph)	0	0	0	1266	270	187	338	538	0	0	1170
Turn Type				Split		Prot	Prot				
Protected Phases				4 12	4 12	4 12	1	1 2			2 16
Permitted Phases								1 2			
Detector Phases				4 12	4 12	4 12	1	1 2			2 16

EB Frontage Road

Phase 16 extends the EB frontage road after phase 8 ends. The northbound movement (NBT), phase 6 is allowed to time with phase 12 (the frontage road extension for the WB frontage road).

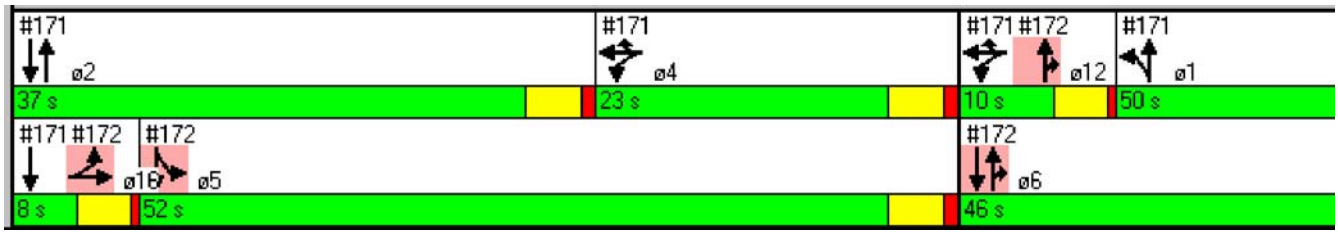
TIMING WINDOW	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lanes and Sharing (#RL)												
Traffic Volume (vph)	206	328	63	0	0	0	0	671	705	845	1590	0
Turn Type	Split								Prot	Prot		
Protected Phases	8 16	8 16						6 12	6 12	5	5 6	
Permitted Phases											5 6	
Detector Phases	8 16	8 16						6 12	6 12	5	5 6	

Phase Timings for Both Frontage Roads

Note that the frontage road extensions (phase 12 and 16) are set to 10" and 8". These are the travel times for traffic entering the interchange during phase 2 and 6 traveling to the downstream frontage roads as shown in the above illustration.

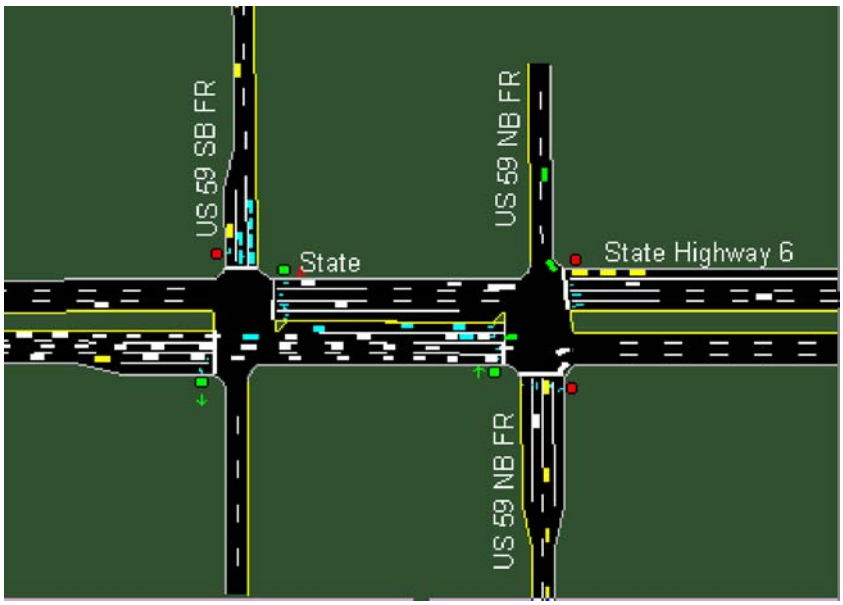
PHASING WINDOW	1-NBTL	2-NBSB	4-WBTL	5-SBTL	6-NBSB	8-EBTL	12-WBTL	16-SBT
Minimum Initial (s)	1.0	5.0	5.0	5.0	5.0	2.0	1.0	1.0
Minimum Split (s)	5.5	16.0	16.0	9.5	50.0	15.0	5.0	5.0
Maximum Split (s)	50.0	37.0	23.0	52.0	46.0	14.0	10.0	8.0
Yellow Time (s)	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5
All-Red Time (s)	1.0	1.0	1.0	1.0	1.0	1.0	0.5	0.5
Lead/Lag	Lag	Lead	Lag	Lag	Lead	Lag	Lead	Lead
Allow Lead/Lag Optimize?	Fixed	Fixed	Fixed	Fixed	Fixed	Fixed	Fixed	Fixed

This coding will produce the following *Group Control* sequence in Synchro for 2 separate intersections (#171 and #172) modeling both sides of the interchange.

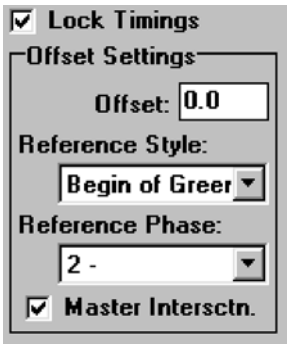


4-Phase Diamond - East / West Arterial Example

Below is a coding example of a east/west arterial at a 4-phase diamond interchange. The orientation is different from the example above, but the process of using the *Cluster Editor*, *Ring and Barrier Designer* and assigning phases 12 and 16 as frontage road extensions is the same. The coding is provided below as an additional example of how to model 4-phase diamond operation using Synchro and SimTraffic.



In this example, our offset is referenced to the beginning of phase 2 which is the WBT (westbound through movement) entering the interchange from the east traveling west. The phasing orientation is based on how the controller is actually phased on the street - Synchro can model whatever is there. Also notice that the interchange is the "Master Intersection" for the network. This setting insures that the offset is synced to 0.0" and the rest of the network is referenced to this intersection.



SB Frontage Road

Phase 16 extends the SB frontage road after phase 8 ends. The eastbound movement (EBT), phase 6 is allowed to time with phase 12 (the frontage road extension for the NB frontage road).

TIMING WINDOW	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lanes and Sharing (#RL)												
Traffic Volume (vph)	0	1397	169	236	983	0	0	0	0	689	8	470
Turn Type			Custon	Prot						Split		Custon
Protected Phases		6 12	6 12	5	5 6					8 16	8 16	8 16
Permitted Phases			6 12		5 6							8 16
Detector Phases		6 12	6 12	5	5 6					8 16	8 16	8 16

NB Frontage Road

Phase 12 extends the NB frontage road after phase 4 ends. The westbound movement (WBT), phase 2 is allowed to time with phase 16 (the frontage road extension for the SB frontage road).

TIMING WINDOW	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR
Lanes and Sharing (#RL)									
Traffic Volume (vph)	507	1578	0	0	1067	336	153	368	473
Turn Type	Prot					Custon	Split		Custon
Protected Phases	1	1 2			2 16	2 16	4 12	4 12	4 12
Permitted Phases						2 16			4 12
Detector Phases	1	1 2			2 16	2 16	4 12	4 12	4 12

Phase Timings for Both Frontage Roads

The frontage road extension times are 9" and 11" in this case (phases 12 and 16). The through movements serviced by phases 2 and 6 are allowed to time with the end of the downstream frontage road.

PHASING WINDOW	1-EBTL	2-EBWB	4-NBTL	5-WBTL	6-EBWB	8-SBTL	12-NBTL	16-WBT
Minimum Initial (s)	2.0	0.0	0.0	0.0	0.0	0.0	1.0	1.0
Minimum Split (s)	50.0	34.0	22.0	41.0	24.0	36.0	5.0	5.0
Maximum Split (s)	48.0	42.0	21.0	52.0	27.0	30.0	9.0	11.0
Yellow Time (s)	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5
All-Red Time (s)	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Lead/Lag	Lag	Lead	Lag	Lag	Lead	Lag	Lead	Lead
Allow Lead/Lag Optimize?	Fixed	Fixed	Fixed	Fixed	Fixed	Fixed	Fixed	Fixed

The phase orientation may vary in your application; however the examples above will help you correctly model a 4-phase diamond controller with Synchro and SimTraffic.