Modeling Signalized Traffic Intersections Using SAS Simulation Studio

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Contents

Introduction

- **Traffic congestion is a never-ending problem for road users in cities & urban areas.**

- **Increasing volume of road vehicles vs decreasing size of roads.**

- **These have posed many challenges to the Traffic Management and City Authorities to provide satisfactory solutions.**

Introduction

- **Problem.**
  - **Road junctions often create the worst traffic congestions.**

- **Solution.**
  - **Traffic Lights.**
    - **Installing traffic lights are not sufficient.**
      - **Solution – Simulation : VISSIM, CORSIM, SUMO, SIMTraffic, etc.**

Introduction

- In this paper, we describe how we can use SAS Simulation Studio to build a simulation model to study some of these factors in order to plan and design better timing of the signals to provide smooth and safe flow of traffic.
- We use Sunway's entrance road junction as a real study case.

Entrance road to Sunway University

- **As an example we present the signal timing plan that is currently implemented in the 3-way intersection of the entrance road into Sunway University.**
- **TABLE I shows the signal timing plan. The traffic streams that are allowed to proceed during the phases of the signal timing plan are depicted in Fig. 4.**

TABLE I
Signal Timing Plan of 3-Way Intersection

	Traffic Streams				
Phases	*SL*	*SR*	*WR*	*EL*	*ES*
1	*R*	*R*	*G/*	*R*	*R*
2	*R*	*R*	*R*	*G*	*G*
3	*G*	*G*	*R*	*R*	*R*

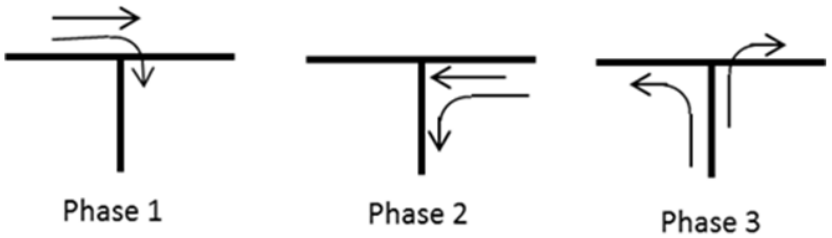


Fig. 4. Traffic streams in each phase of the signal timing plan of the 3-way intersection

Case Study - Sunway University 3-way intersection

- **The simulations were carried out for 2 peak periods (7.30 – 9.30 am and 5.00 – 7.00 pm) during a whole day.**
- **TABLE III shows the timing plan used from for the morning and evening peak periods**

TABLE III
Signal Timing Plan of 3-Way Intersection (Sunway)

	Time(sec)	*SL*	*SR*	*WR*	*ES*	*EL*
Morning Peak	70	*R*	*R*	*G*	*R*	*R*
	35	*R*	*R*	*R*	*G*	*G*
	35	*G*	*G*	*R*	*R*	*R*
Evening Peak	35	*R*	*R*	*G*	*R*	*R*
	35	*R*	*R*	*R*	*G*	*G*
	70	*G*	*G*	*R*	*R*	*R*

TABLE IV gives the mean inter-arrival times (in sec.) of vehicles arriving at the junctions used in the simulations for both peak periods

TABLE IV.
Mean interarrival times used in simulation

	Mean interarrival time (exponential)	
	Morning Peak	Evening Peak
South Road	21	7.7
West Road	22	33
East Road (straight thru)	7.2	3.9
East Road (left turn)	21	20

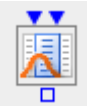
SAS Simulation Studio

- **Simulation Studio is a SAS software package that uses object-oriented discrete-event simulation to model and analyze systems.**

- **It has a user friendly graphical interface and uses base blocks to build the simulation model.**

- **Each block has well-defined and specialized functionalities and communicates with each other via ports.**

Some Base Blocks in SAS Simulation Studio

- Entity block  -- generates entities, e.g. arrivals
- Number holder block  -- to store values
- Queue block  -- storage of entities
- Server block  -- to provide resource - server
- Formula block  -- define expressions/formulae
- Numeric block  -- to generate random variates
- Delay block  -- to delay entity in system
- Valve block  -- controls the flow of entities in system

Modeling the traffic signal in Simulation Studio

- **The traffic signal is modeled using a server block together with a flow control block and formula block.**
- **For simplicity, we model a traffic signal with only two phases, (red and green).**
- **Fig. 1 shows a traffic signal with a cycle time of 60 sec. consisting of a 40 sec. red phase and a 20 sec. green phase.**

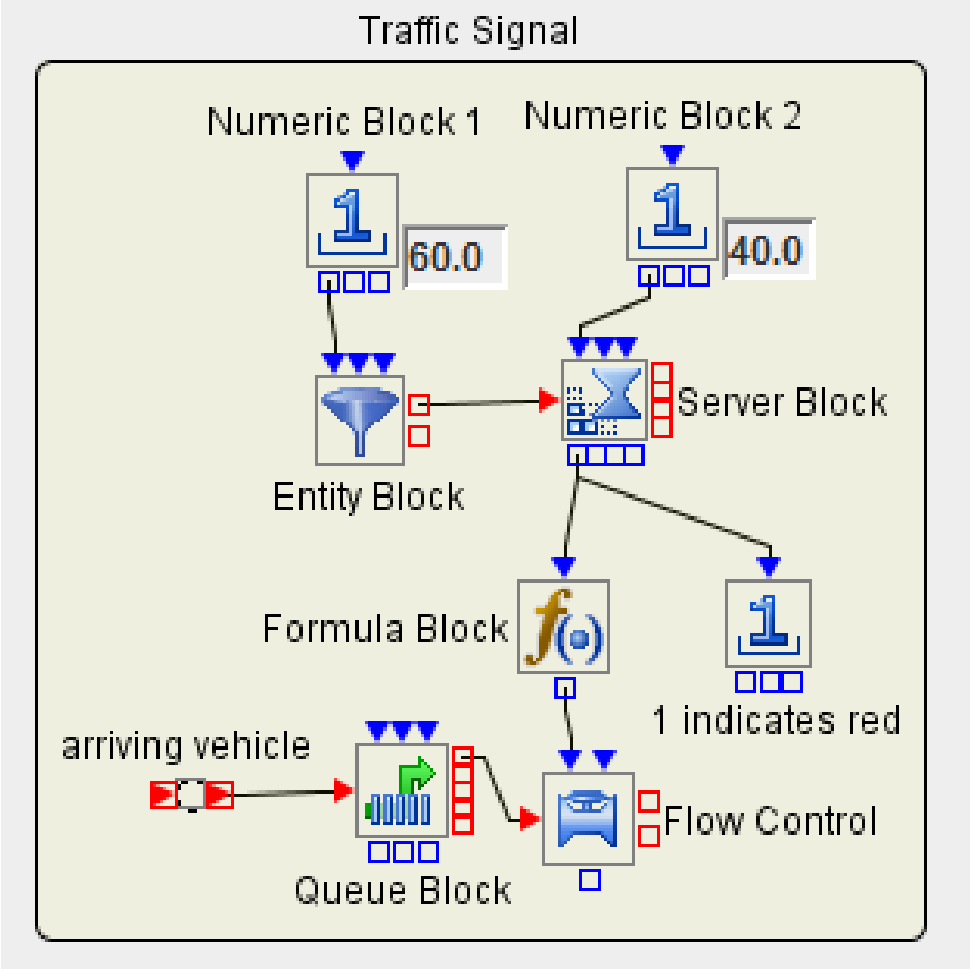
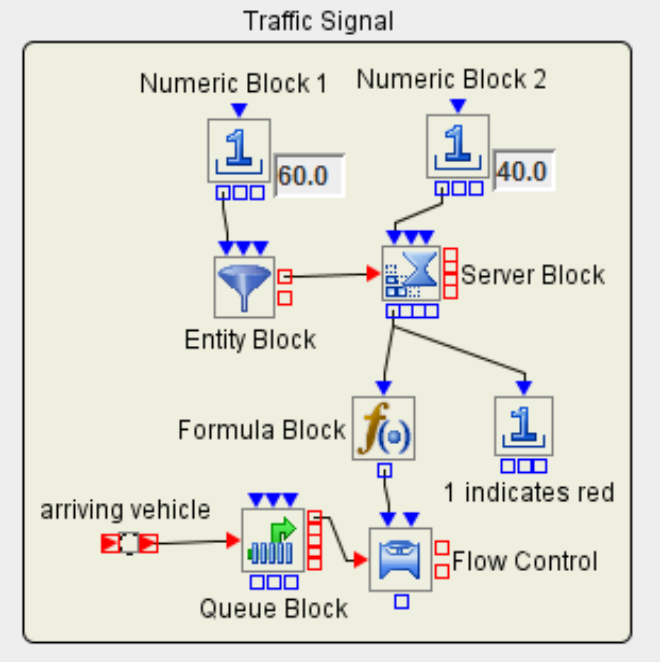


Fig. 1

Modeling the traffic signal in Simulation Studio

- **Numeric block 1 and the Entity Block generate the cycle length of the traffic signal**
- **Flow Control Block and Formula Block regulate the red and green phases.**
- **The Entity Block generates a 60 sec. traffic signal cycle by generating an entity to enter the Server Block once every 60 sec.**
- **The Server Block serves the entity for a constant 40 sec. service time representing the duration of the red phase. The busy or idle state of the server represents the red or green phase of the signal.**
- **The Formula Block then passes the busy/idle state value of the server to the Flow Control Block which blocks (red phase) or allows (green phase) vehicles to pass through.**

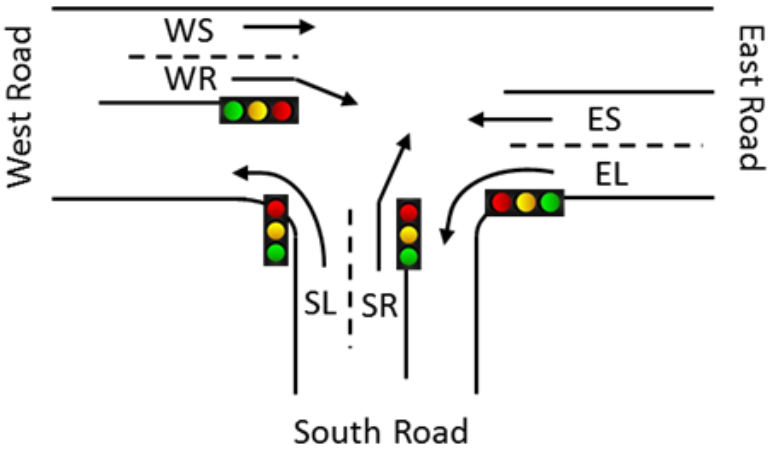


Modeling the traffic signal in Simulation Studio

- **Basically two types of road intersections.**
  - **3-way intersection.**
  - **4-way intersection.**
- **In order for traffic to flow in an orderly fashion at these intersections, a well-coordinated traffic signal is a necessary condition but is not sufficient to optimize waiting time.**
- **How these traffic signals are coordinated will depend on the type of intersection, terrain, traffic volume and many other factors.**

Basic 3-way intersection

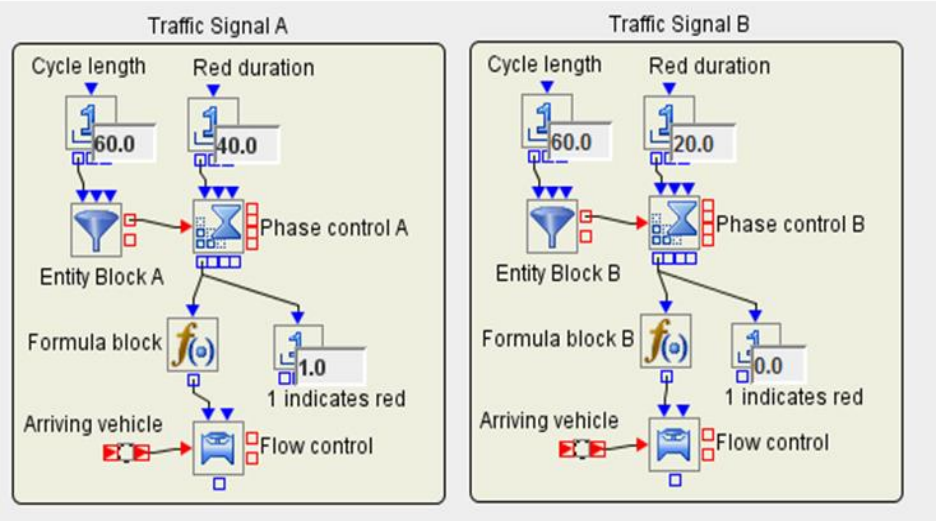
- **Typically, the 3-way intersection has 4 sets of signal lights as shown in figure below.**
- **Six traffic streams are identified in the figure**
  - **SL coming from South Road turning left into West Road**
  - **SR, turning right into East Road**
  - **ES is traffic stream from East Road proceeding straight through to West Road**
  - **EL, turning left into South Road**
  - **WS is traffic stream from West Road proceeding straight through to East Road without signal control**
  - **WR is traffic turning right into South Road.**



Timing plan

- **Coordination of the traffic signals in the timing plan in Simulation Studio is achieved by setting the appropriate start time in the Entity Block of the traffic signal.**
- **For example, Fig. 3 shows a timing plan for Traffic Signal A and B together with the simulation models of the traffic signals.**
- **In Signal A, the start time of Entity Block A is set at 0 while the start time of Entity Block B in Signal B is set at 40. With this setting, the timing of the red/green phases of the signals will be coordinated**

Cycle length	*Phase duration*	*Signal A*	*Signal B*
60 sec.	*40 sec.*	*R*	*G*
	20 sec.	*G*	*R*



South Road junction

- **The next figure shows the simulation model of the South Road junction in Simulation Studio. Arrivals are generated in the compound block labeled South Junction and a Formula Block and a Switch Block are used to divert vehicles to turn left to the *SL* signal light or to turn right to the *SR* signal light based on the probabilities p_{SL} *or* p_{SR}**
- **The compound blocks labeled *SL* Signal and *SR* Signal simulate the *SL* and *SR* traffic lights respectively. Vehicles leaving the *SL* and *SR* Signal blocks exit to the WestRd and EastRd blocks respectively.**

Modeling 3-way intersection in Simulation Studio

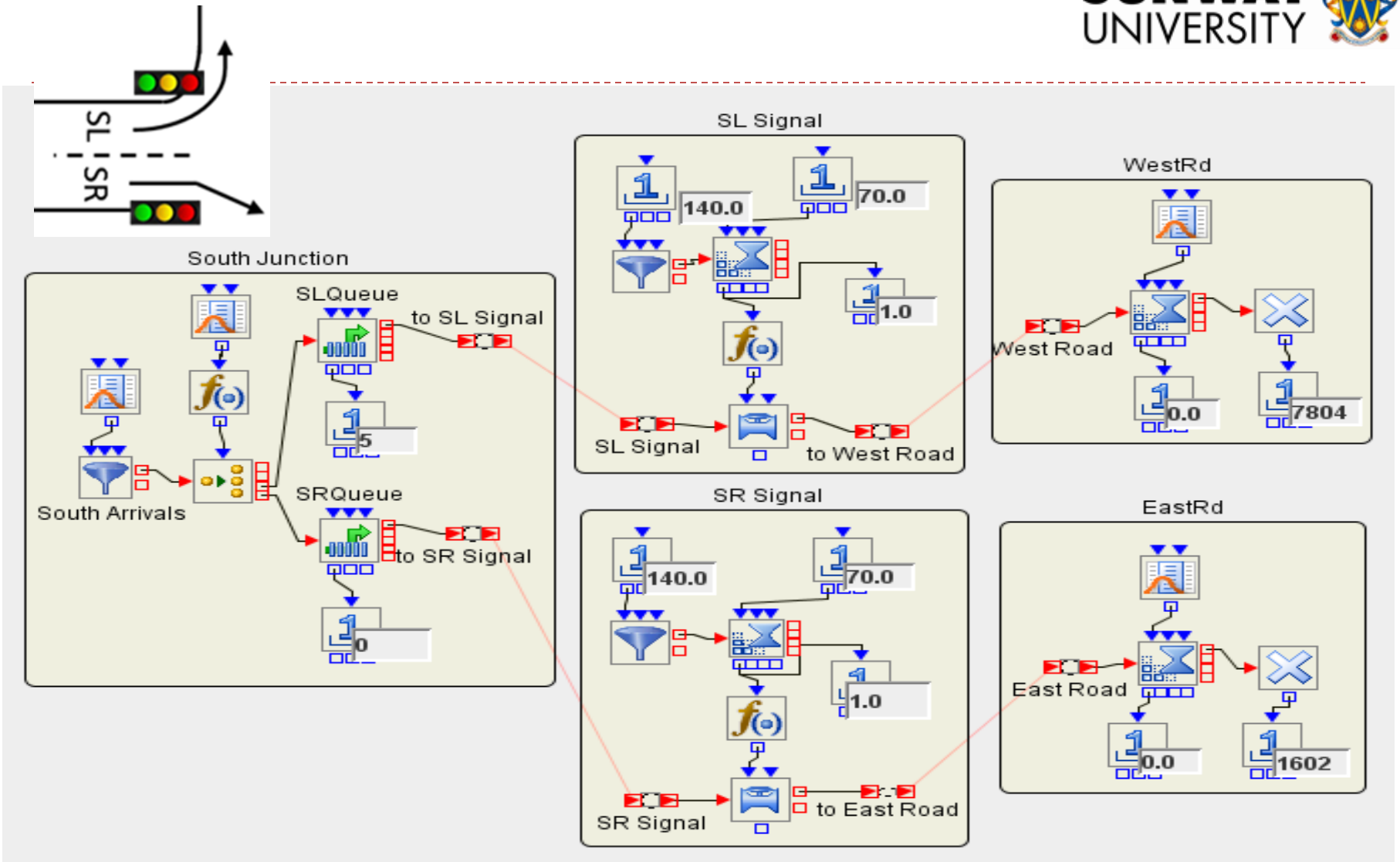
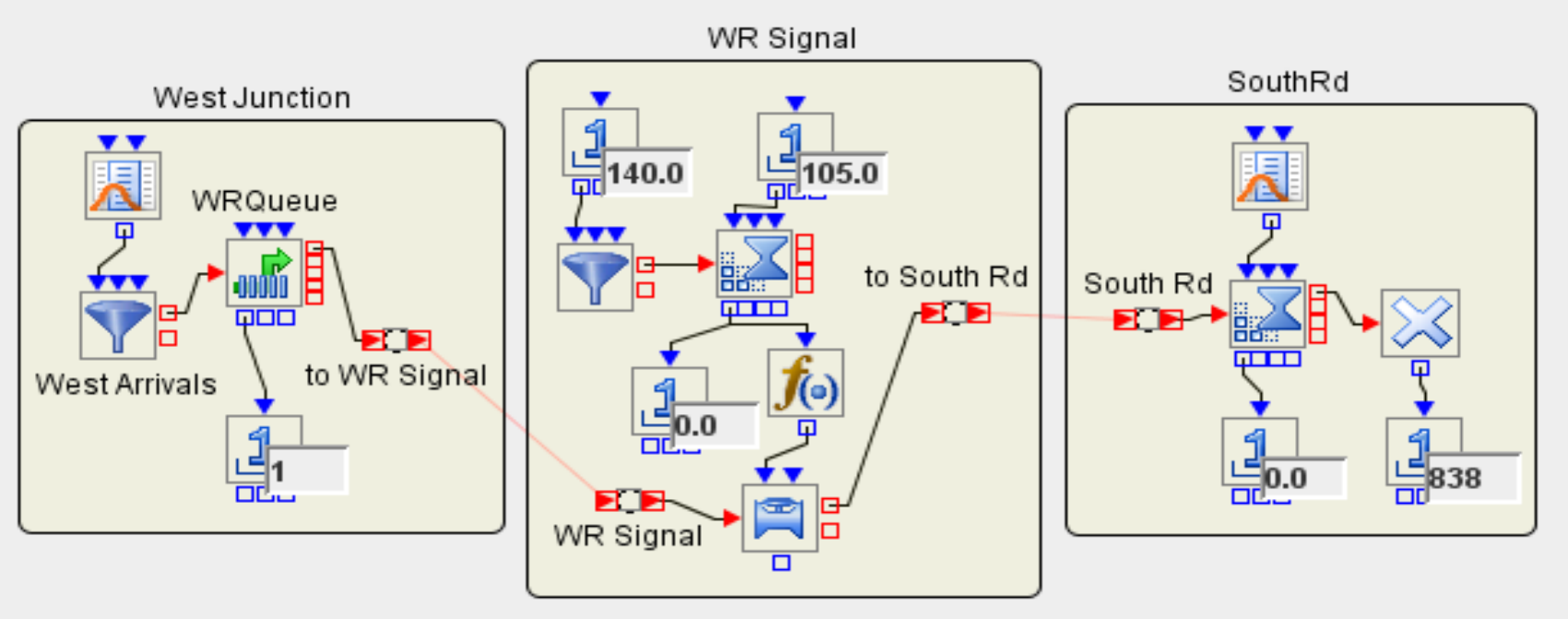


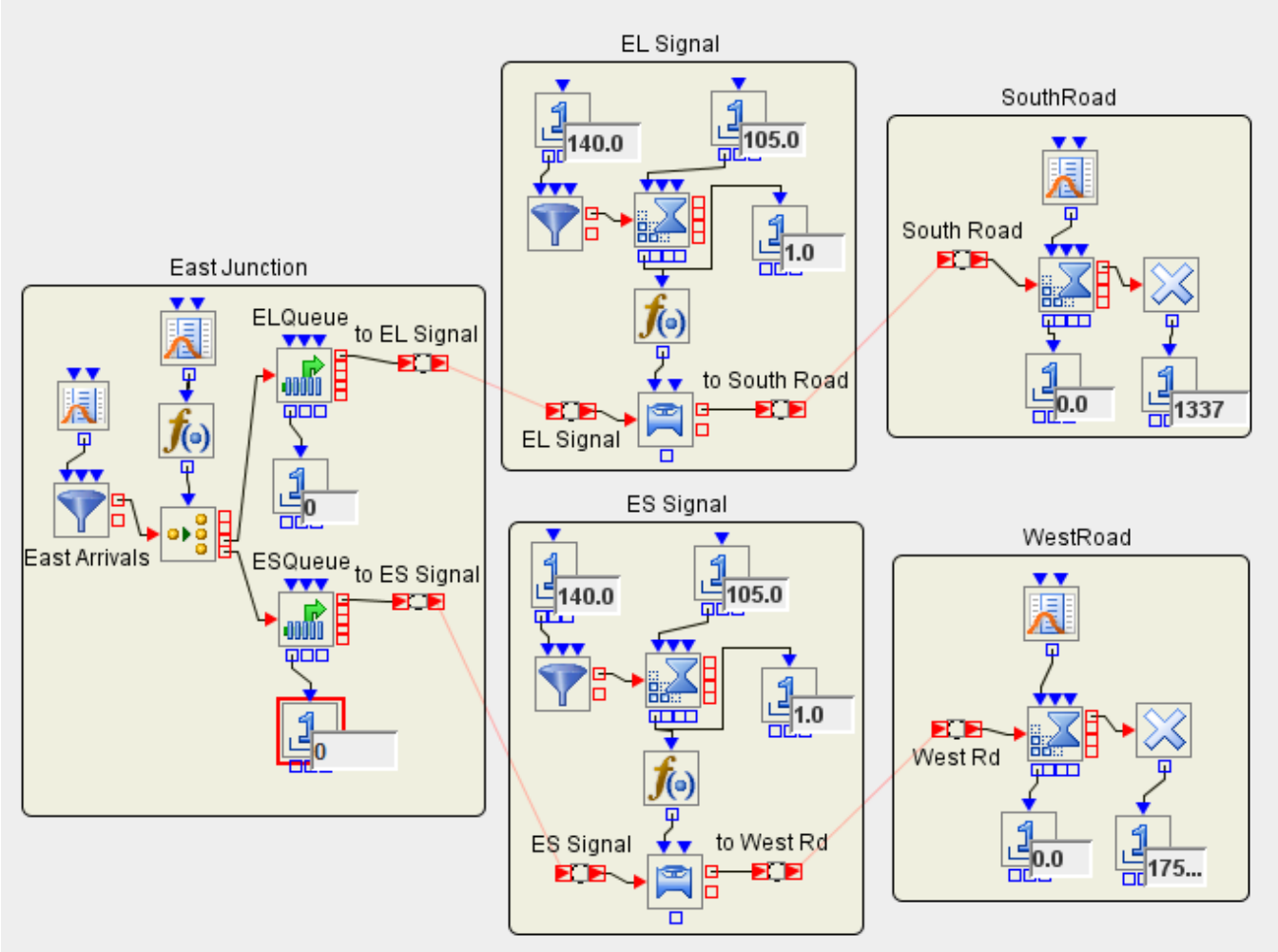
Fig. 5: Simulation Model of South Road junction of a 3-way intersection in Simulation Studio

West Road junction



Simulation Model of West Road junction of a 3-way intersection in Simulation Studio

East Road junction



Simulation Model of East Road junction of a 3-way intersection in Simulation Studio

Simulation results

- **Simulation of the Sunway University 3-way intersection for both peak periods with the current signal timing plan was carried out with 10 replications.**
- **TABLE V shows average queue length and average waiting time for each of the traffic streams. These results are consistent with observed data.**

TABLE V.
Average Queue Length and Waiting Time for current timing plan.

Traffic stream	Morning Queue Length	Evening Queue Length	Morning Waiting Time	Evening Waiting Time
EL	1.58	6.69	33.25	134.37
ES	3.41	19.05	24.56	74.28
SL	5.34	3.04	158.00	29.34
SR	4.41	1.20	324.28	57.24
WR	6.11	5.35	134.39	176.91

Simulation results

- **We also simulated the intersection with a different signal timing plan which allows a longer green phase to the *SL* and *EL* traffic streams.**
- **The timing plan is shown in TABLE VI.**
- **The simulation was also carried out for 10 replications and the results are shown in TABLE VII.**

TABLE VI.
New Signal Timing Plan of 3-Way Intersection (Sunway)

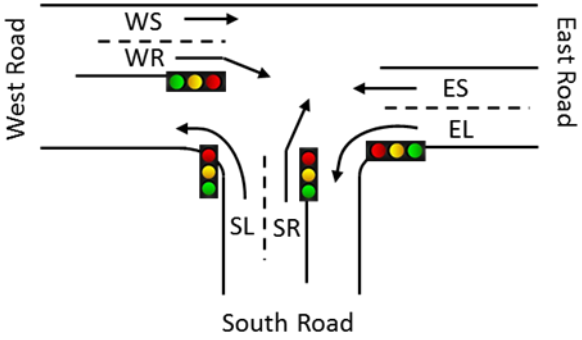
	Time(sec)	*SL*	*SR*	*WR*	*ES*	*EL*
Morning Peak	35	*G*	*R*	*G*	*R*	*R*
	35	*R*	*R*	*R*	*G*	*G*
	35	*G*	*R*	*R*	*G*	*G*
	35	*G*	*G*	*R*	*R*	*G*
Evening Peak	35	*G*	*R*	*G*	*R*	*R*
	35	*R*	*R*	*R*	*G*	*G*
	70	*G*	*G*	*R*	*R*	*G*

Simulation results

TABLE VII.
Average Queue Length and Waiting Time for new timing plan

Traffic stream	Morning Queue Length	Evening Queue Length	Morning Waiting Time	Evening Waiting Time	% improvement in waiting times Morning	% improvement in waiting times Evening
EL	0.50	0.51	10.45	10.25	68.57	92.37
ES	3.40	18.03	24.54	70.67	0.08	4.86
SL	0.44	0.96	13.10	9.30	91.71	68.30
SR	4.74	1.18	346.36	55.36	-6.81	3.39
WR	6.38	5.00	141.37	166.96	-5.19	5.62

Average Queue Length and Waiting Time for new timing plan



Summary

From the results in TABLE V and VII we can see that the average queue length and waiting times for *EL* and *SL* traffic streams are considerably reduced for the new timing plan while the values for the other 3 streams remain the same.

Conclusion

- In this paper, we have used SAS Simulation Studio, a non specialized simulation software to model and simulate signalized traffic intersections.
- A case study is also presented and the results obtained are consistent with observed data.
- This showed that the model can be used as basic units to build more complex models of signalized traffic systems.
- In the near future, a wider case study consisting of a complex road and signalized traffic system around the university will be investigated.