CE 572 – Spring 2015

Intersection Traffic Operations

Class 09

6 February 2015

Model Categories	Attributes and Contrasts
Computational Simulation	Directly computes results from equations or tables Tracks events and processes
Empirical Analytical	Based on field data Based on theory
Deterministic Stochastic	Produces same results for given set of inputs Results can vary based on statistical distributions
Microscopic Macroscopic	Individual driver decisions Aggregated flow characteristics
Event scan Time scan	Based on status of events of interest Updates made every time step
Evaluation Optimization	Performance data produced Objective function optimized based on performance data

Model Categories

Computational
Simulation

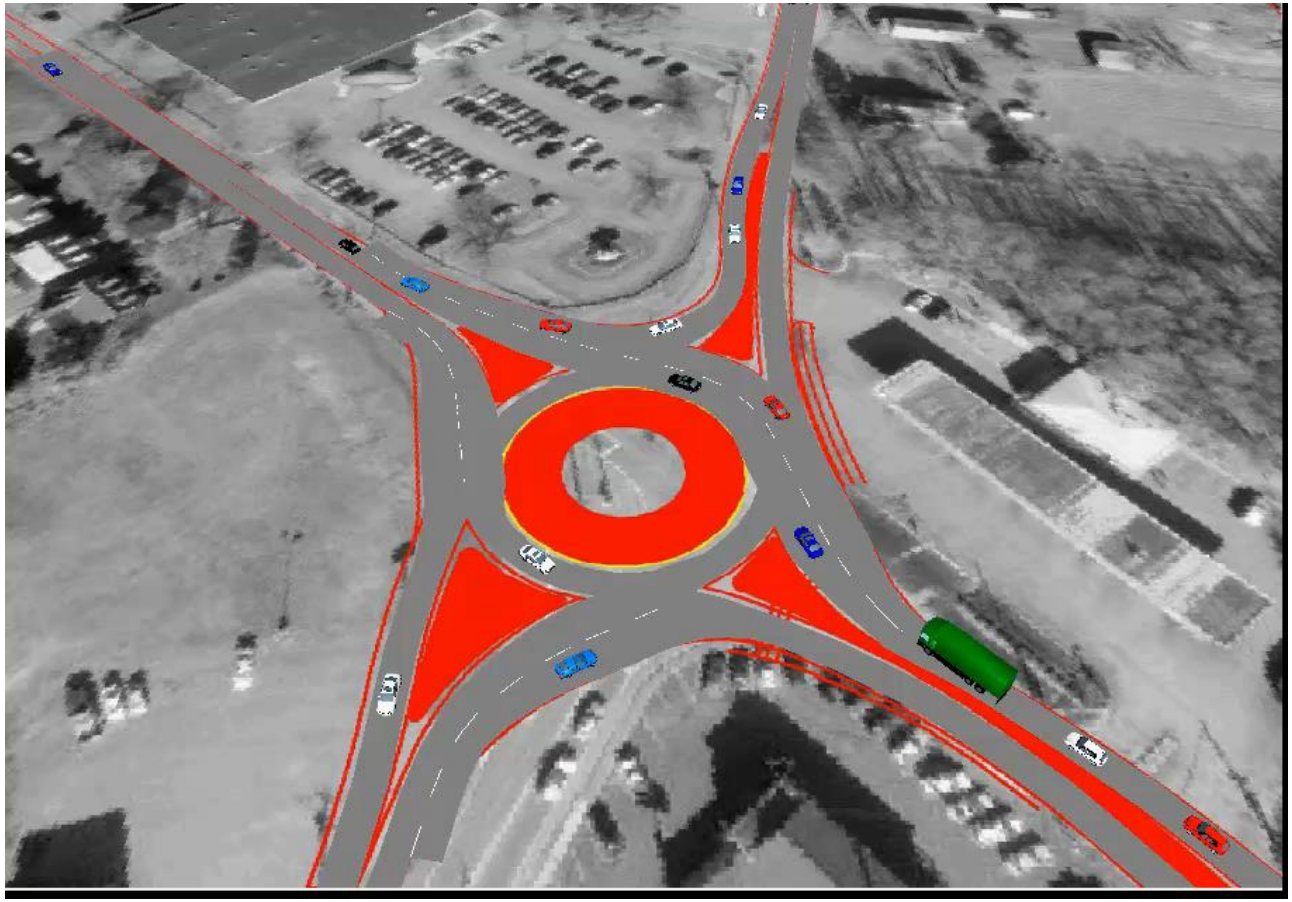
Empirical
Analytical

Deterministic
Stochastic

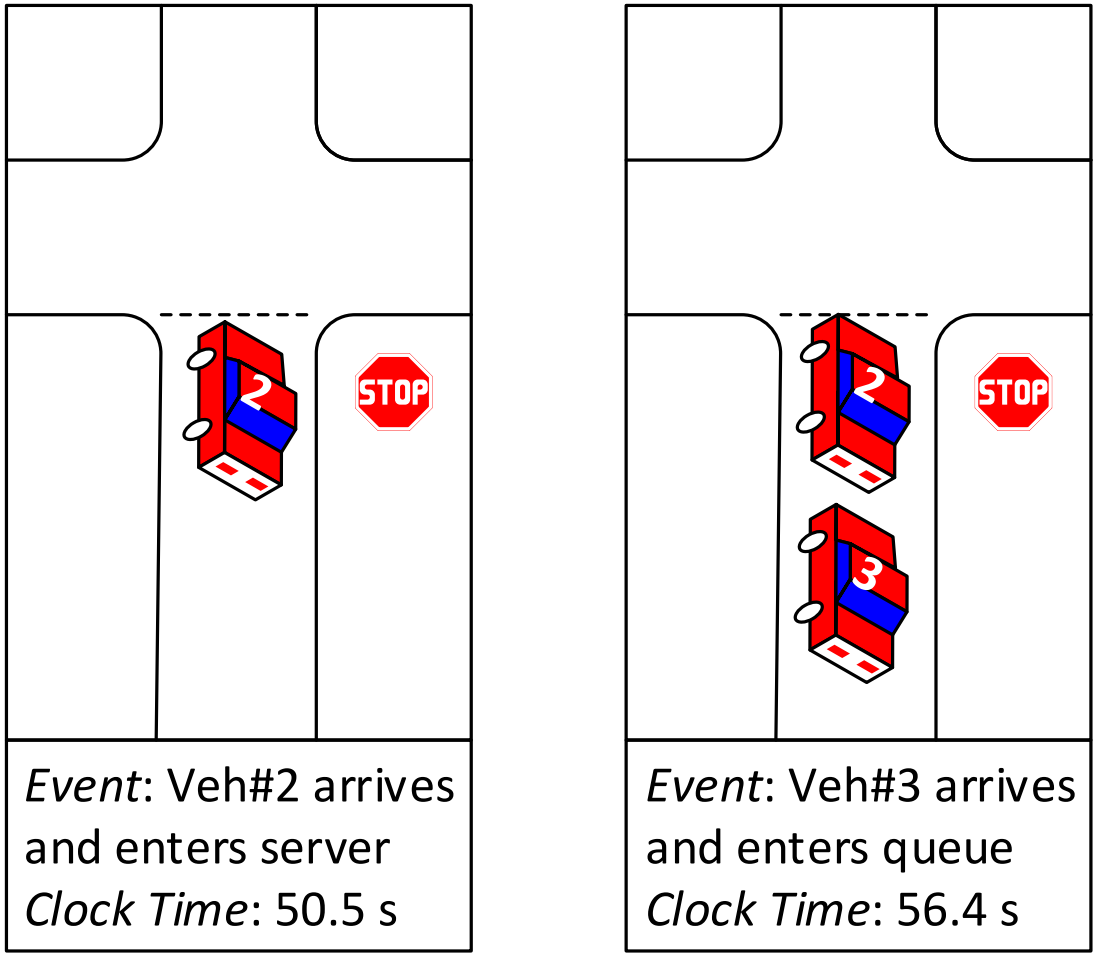
Microscopic
Macroscopic

Event scan
Time scan

Evaluation
Optimization



Model Categories
Computational **Simulation**
Empirical **Analytical**
Deterministic **Stochastic**
Microscopic Macroscopic
Event scan Time scan
Evaluation Optimization



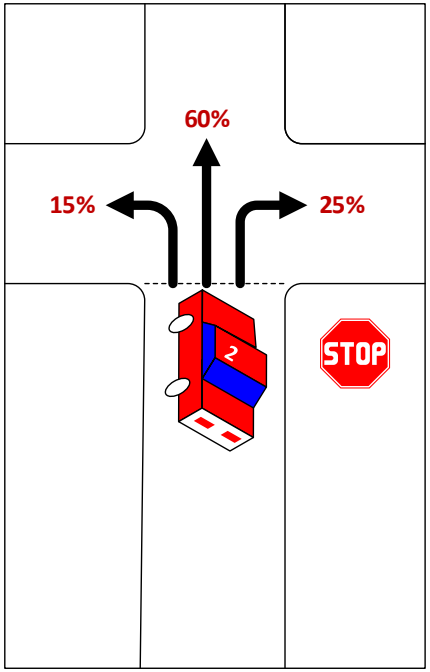
Event: Veh#2 arrives and enters server
Clock Time: 50.5 s

Event: Veh#3 arrives and enters queue
Clock Time: 56.4 s

Generator of event:

Interval: Arrival headway
Duration: 5.9 s

Discrete Events/Inputs



Event	Probability	Range of Random Numbers
Left turn	0.15	0.00 - 0.15
Through	0.60	0.16 – 0.75
Right turn	0.25	0.76 – 1.00

Model task	Example
Pick random number between 0 and 1	*0.81*
Generate event	*Right turn*

Continuous Events/Inputs

Let's assume that we can generate a random number R_n between zero and one that represents the probability P[h≥H].

$$R_n = P[h \geq H] = e^{-\lambda H}$$

Solving for the headway H:

$$R_n = e^{-\lambda H}$$

$$\ln(R_n) = -\lambda H$$

$$H = -\frac{1}{\lambda}\ln(R_n)$$

Model task	Example
Pick random number between 0 and 1	*0.49*
Generate interval between events (headway)	*12.8 sec*

Veh#	Random number	H (interval)	AT (clock time)	Random number	SST (clock time)	ST (interval)	SET (clock time)
1	0.47233	13.5	0.0	0.03930	0.0	15.4	15.4
2	0.06045	50.5	50.5	0.21612	50.5	7.3	57.8
3	0.72227	5.9	56.4	0.96334	57.8	0.2	58.0
4	0.46346	13.8	70.2	0.05013	70.2	14.2	84.4
5	0.55474	10.6	80.8	0.27233	84.4	6.2	90.6

Clock Times

- Arrival Time (AT)
- Service Start Time (SST)
- Service End Time (SET)

Times Between Events

- Headway
- Service Time

Veh#	Random number	H (interval)	AT (clock time)	Random number	SST (clock time)	ST (interval)	SET (clock time)
1	0.47233	13.5	0.0	0.03930	0.0	15.4	15.4
2	0.06045	50.5	50.5	0.21612	50.5	7.3	57.8
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5	0.55474	10.6	80.8	0.27233	84.4	6.2	90.6

Model Process

1. **Generate headway between vehicles 1 and 2**
2. Compute arrival time for vehicle 2
3. Compute service start time for vehicle 2
4. Generate service time for vehicle 2
5. Compute service end time for vehicle 2

Veh#	Random number	H (interval)	AT (clock time)	Random number	SST (clock time)	ST (interval)	SET (clock time)
1	0.47233	13.5	0.0	0.03930	0.0	15.4	15.4
2	0.06045	50.5	50.5	0.21612	50.5	7.3	57.8
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Model Process

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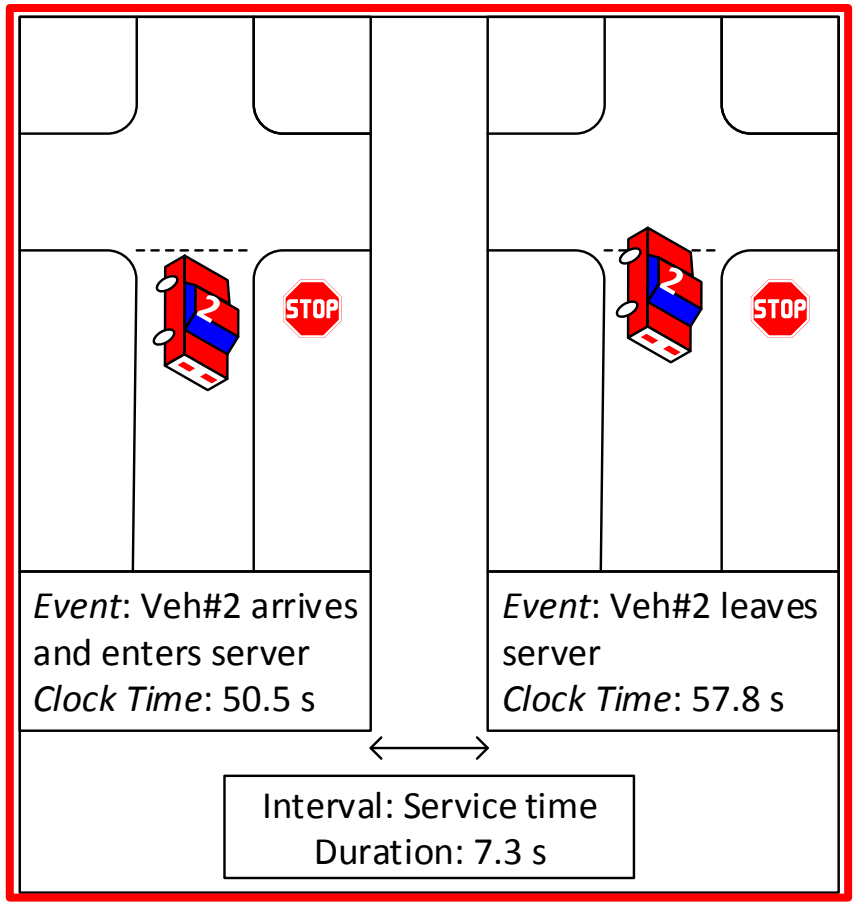

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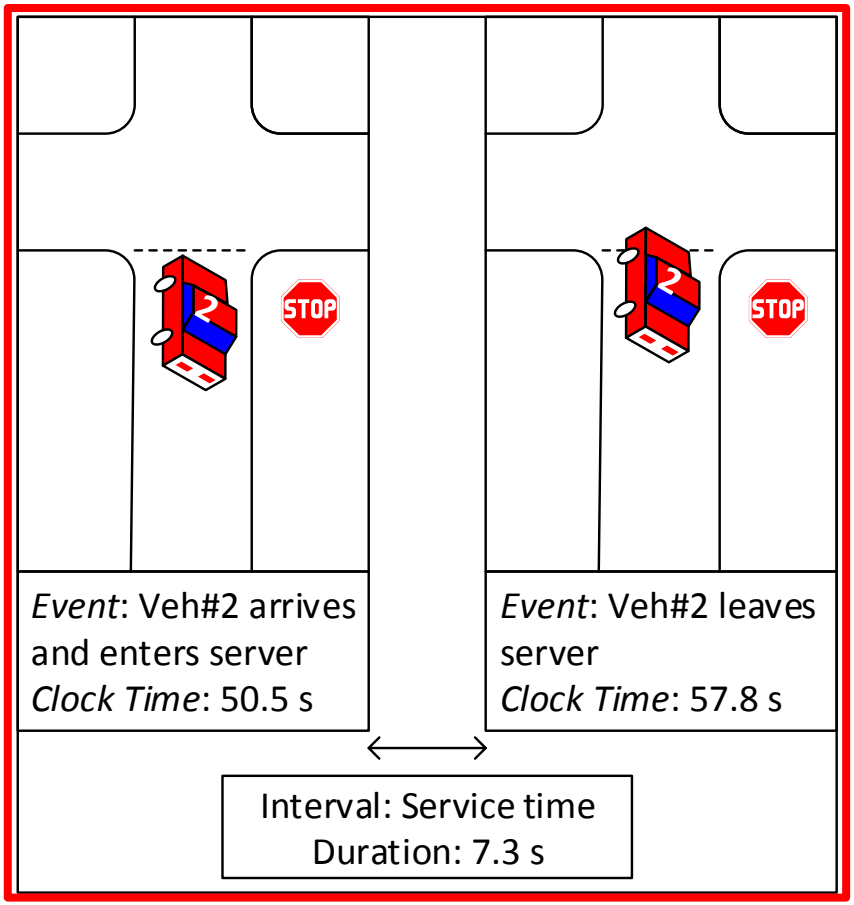

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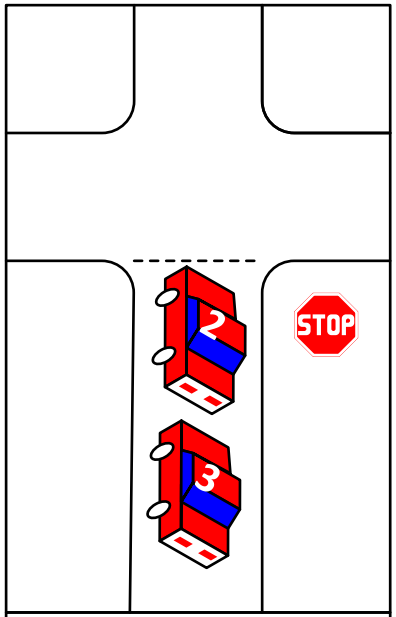
Model Process

1. **Generate headway between vehicles 2 and 3**
2. **Compute arrival time for vehicle 3**
3. Compute service start time for vehicle 3
4. Generate service time for vehicle 3
5. Compute service end time for vehicle 3



Event: Veh#3 arrives and enters queue
Clock Time: 56.4 s

Veh#	Random number	H (interval)	AT (clock time)	Random number	SST (clock time)	ST (interval)	SET (clock time)
1	0.47233	13.5	0.0	0.03930	0.0	15.4	15.4
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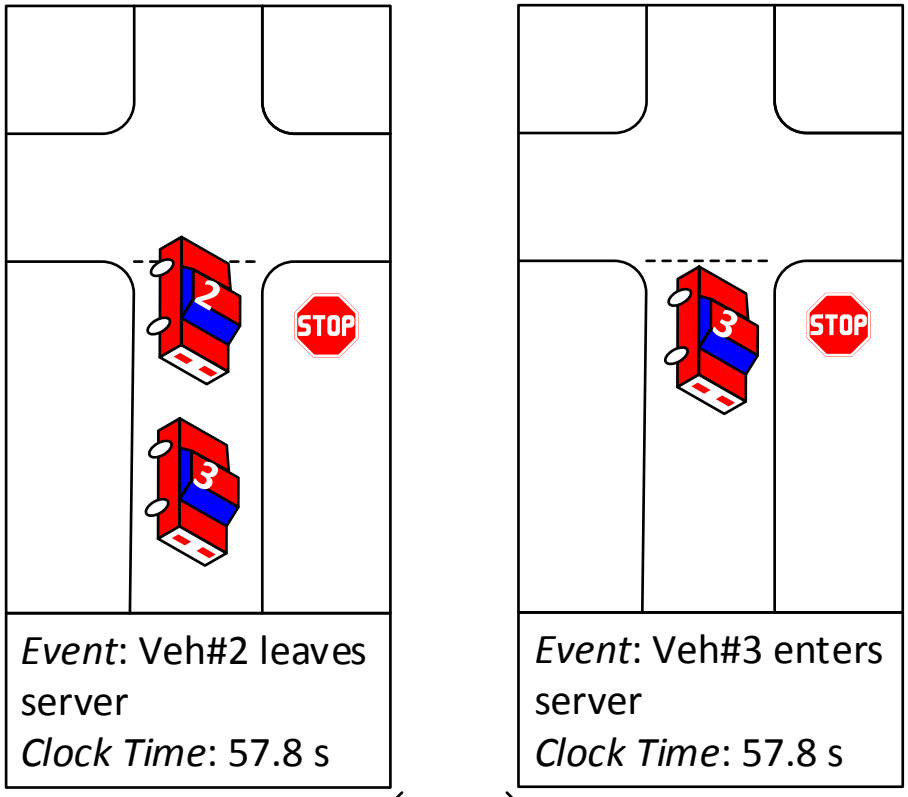
Model Process

1. Generate headway between vehicles 2 and 3
2. Compute arrival time for vehicle 3
3. **Compute service start time for vehicle 3**
4. Generate service time for vehicle 3
5. Compute service end time for vehicle 3



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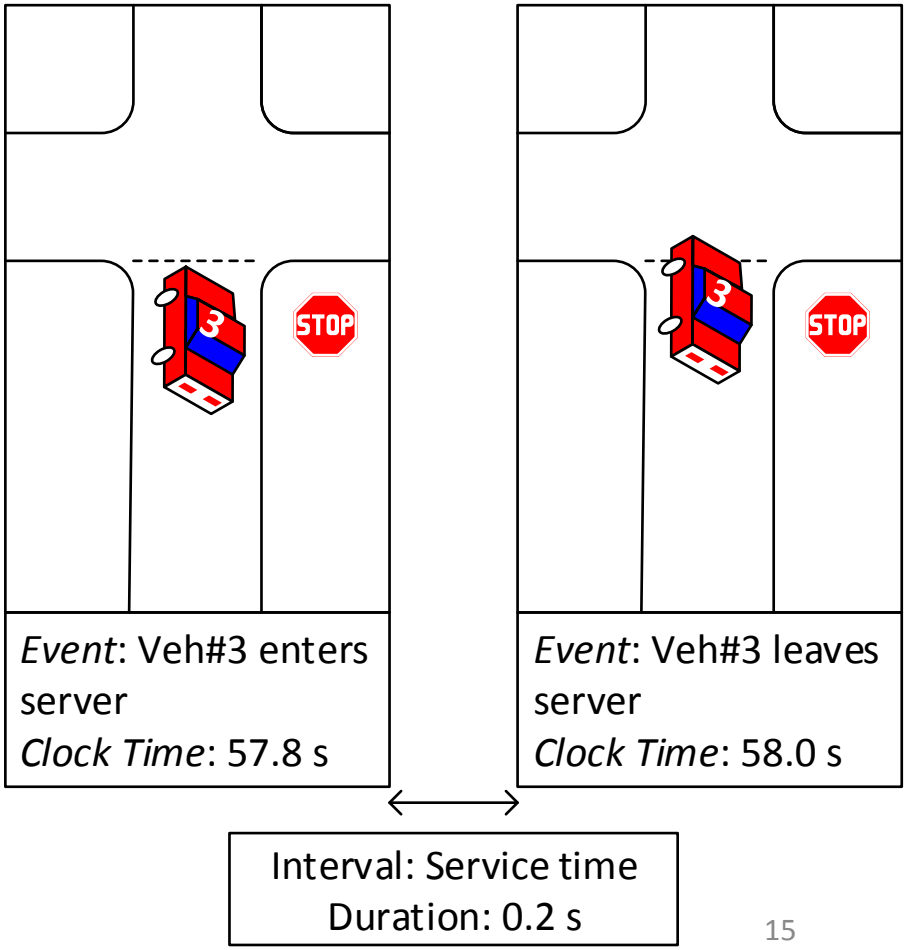
4. **Generate service time for vehicle 3**
5. **Compute service end time for vehicle 3**



Performance Measures

- ***Time in queue***
- Time in server
- Time in system

Veh#	Random number	H (interval)	AT (clock time)	Random number	SST (clock time)	ST (interval)	SET (clock time)
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$$\text{Time in queue} = \text{Mean}(SST_i - AT_i)$$

Performance Measures

- Time in queue
- ***Time in server***
- Time in system

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Time in server= Mean(ST_i)

Performance Measures

- Time in queue
- Time in server
- ***Time in system***

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$$\text{Time in system} = \text{Mean}(ST_i) + \text{Mean}(SST_i - AT_i)$$

Time in server Time in queue

Assignment 14

Objective:

Develop a stochastic, event-oriented simulation model for a two-way stop-controlled intersection that can be used to evaluate the performance of this intersection.

Assumptions:

- Each approach to the intersection has one lane.
- The east-west direction is the major street, while the north-south direction is the minor street.
- Vehicle headways on both streets are assumed to be randomly distributed.

Assignment 14

Requirements:

- Your simulation model should be flexible enough to handle varying flow rates on either the minor street or the major street, as well as different values of the critical headway and the follow-up headway.
- The spreadsheet should include three sections: an input section, a model computation section, and output sections for the queuing theory results and the simulation results.
- The Input Section should include the minor street flow rate (veh/hr), the major street flow rate (veh/hr), the critical headway (sec), the follow-up headway (sec), the minor street capacity (veh/hr), the mean service rate (veh/sec) for the minor street vehicles, and the mean arrival rate (veh/sec) for the minor street vehicles.
- The Model Computational Section should include the following data for each vehicle: vehicle number, randomly-generated arrival headway, the arrival time of the vehicle into the system, the service start time (time vehicle arrives into the server), a randomly-generated service time, and the service end time (time vehicle departs from the server and the system).
- The Output-Simulation Results Section should include the mean service time, the mean queue time, the mean time in the system (average delay per vehicle), the simulation time, and the minor street flow rate.

Assignment 14

Task:

Set up your simulation model for a simulation run that will process 200 minor street vehicles and produce the output data described above. Assume the following data:

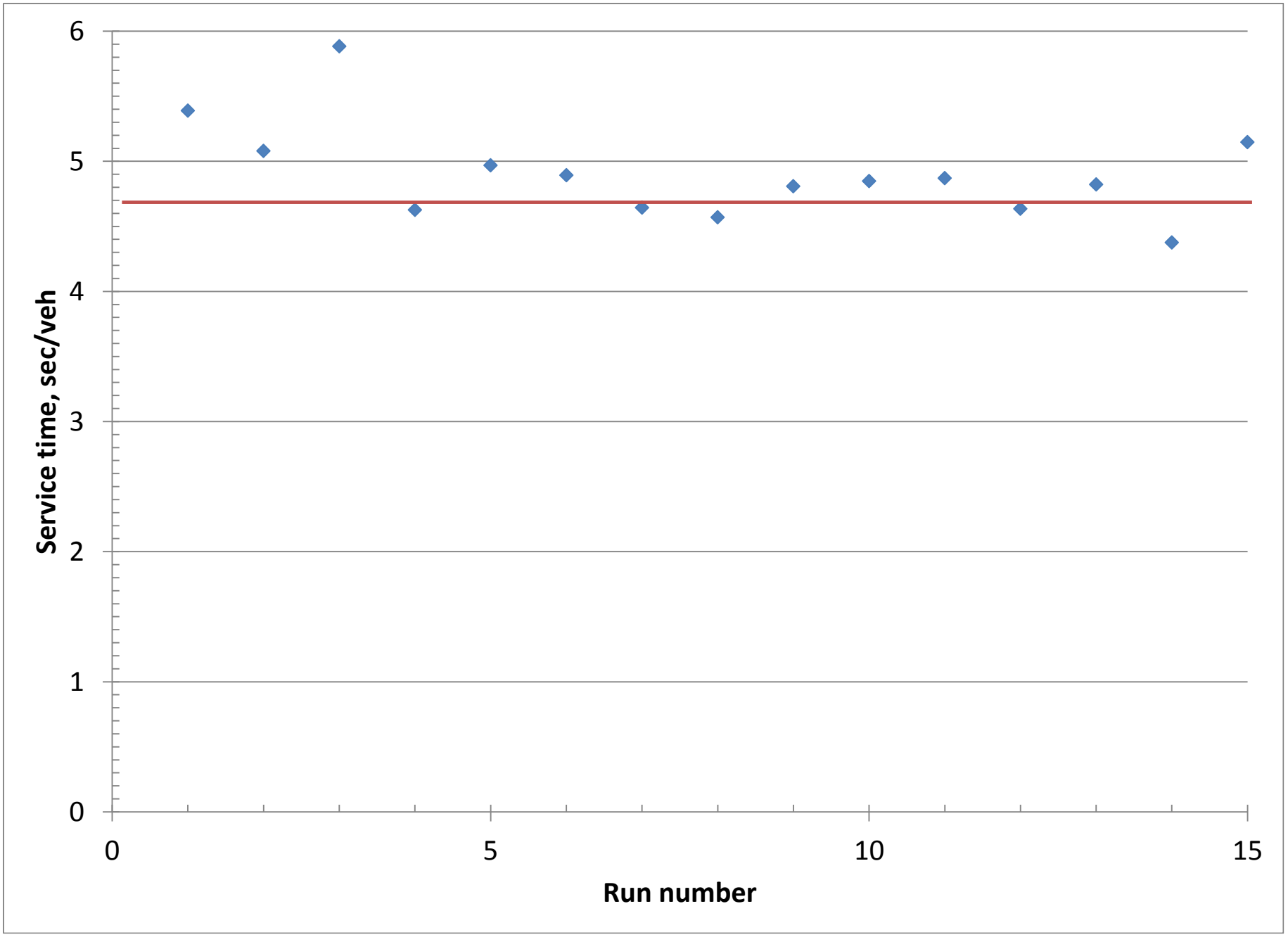
- Mean minor street flow rate is 200 veh/hr, mean major street flow rate is 300 veh/hr
- Critical headway for minor street drivers is 6.5 sec, follow-up headway for minor street drivers is 4.0 sec

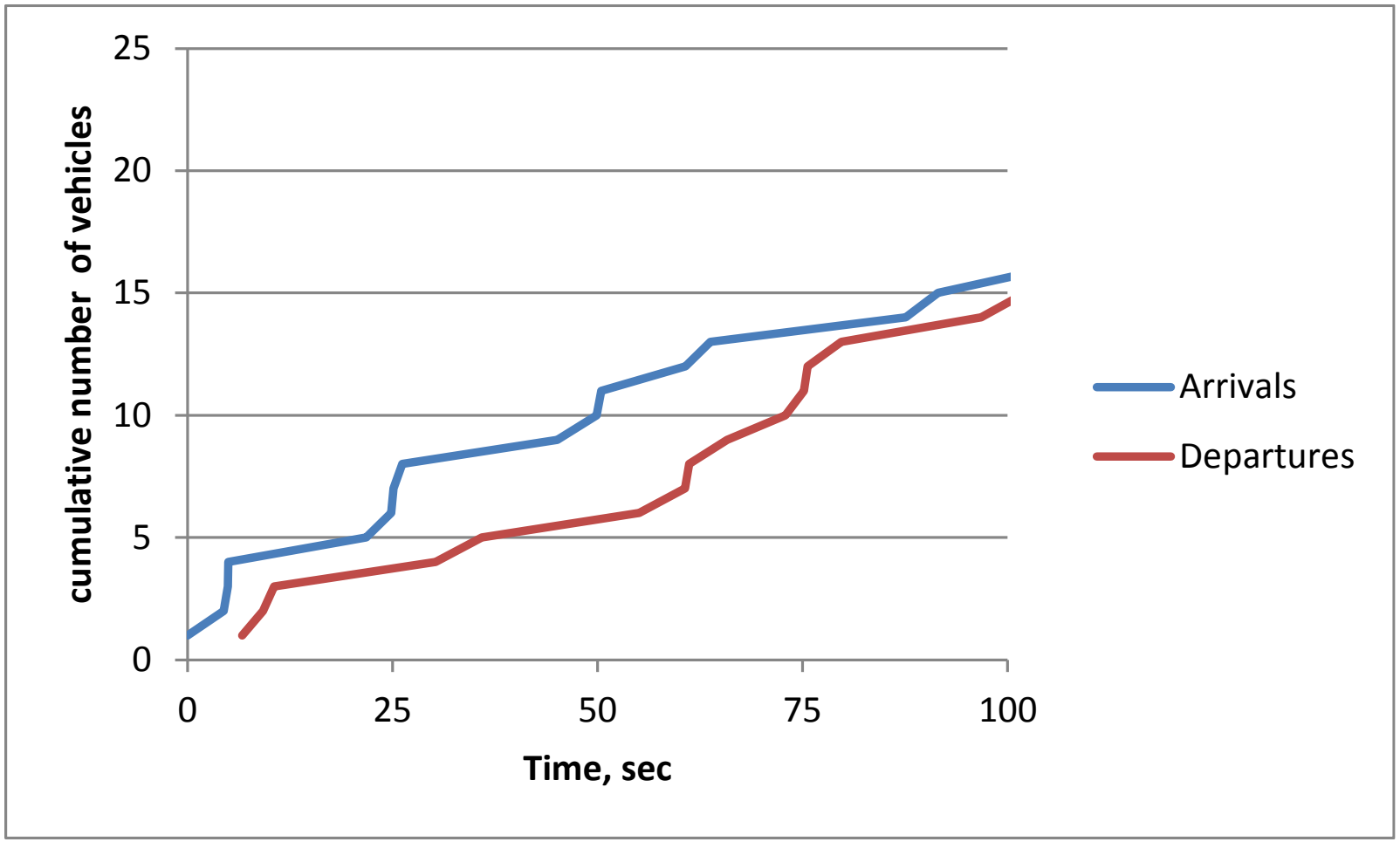
Run the simulation model 20 times, each time recording the required output:

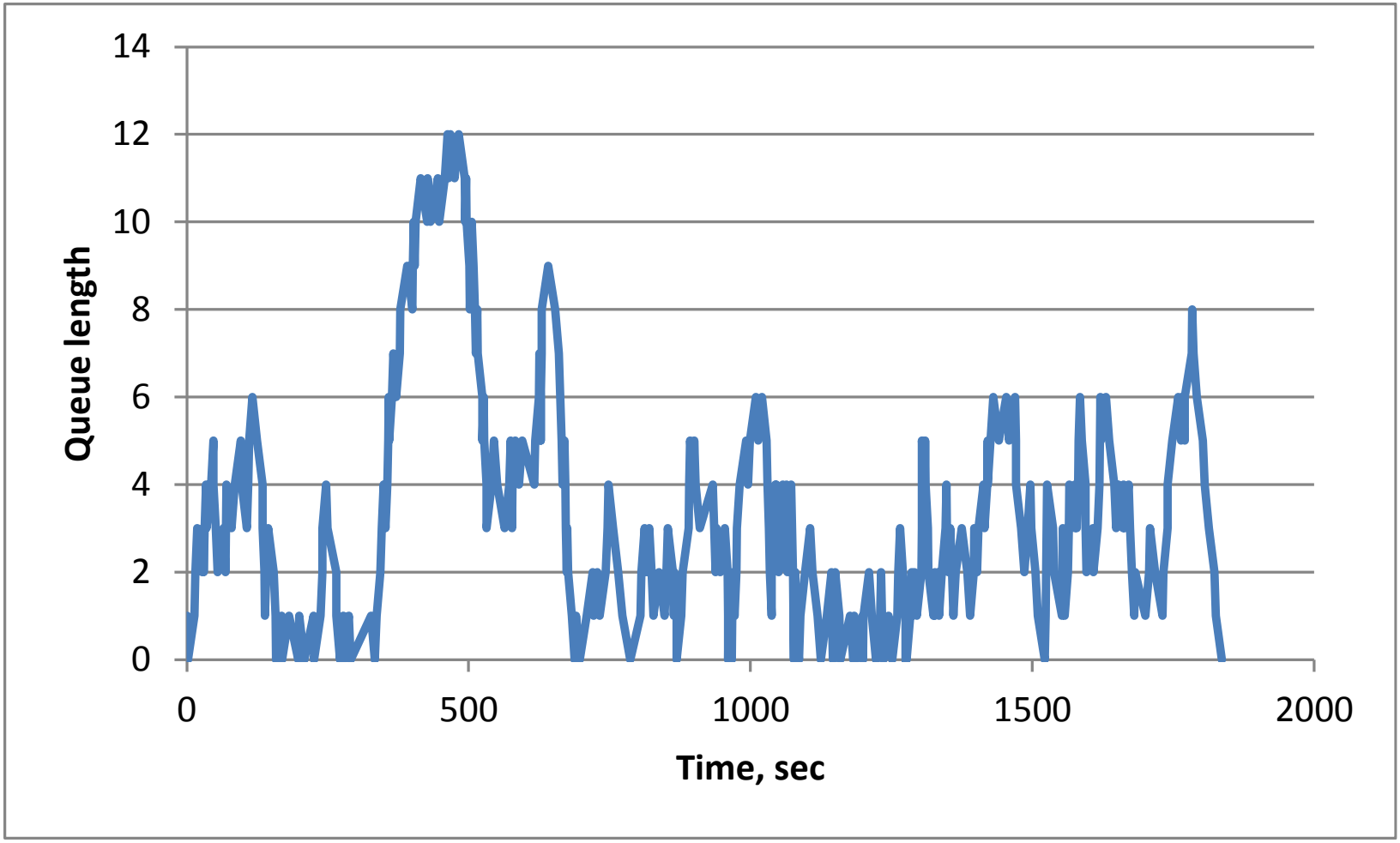
- Mean service time
- Mean queue time
- Mean time in the system (average delay per vehicle)
- Simulation time
- Minor street flow rate.

Deliverable:

Your deliverable is an Excel spreadsheet with your basic model and the results of the simulation.


6
5
4
3
2
1
0
Service time, sec/veh
0
5
10
15
Run number


cumulative number of vehicles
25
20
15
10
5
0
0
25
50
75
100
Time, sec
Arrivals
Departures


14
12
10
8
6
4
2
0
Queue length
0
500
1000
1500
2000
Time, sec

Input									
Minor street flow rate	200	veh/hr							
Major street flow rate	300	veh/hr							
Critical gap	6.0	sec/veh							
Follow up time	3.3	sec/veh							
Minor street capacity	757	veh/hr							
Minor street service rate	0.210	veh/sec							
Minor street arrival rate	0.056	veh/sec							
Model Computation									
	Veh#	**Ran#**	**Hdwy**	**ArrTime**	**Ran#**	**ST**	**SST**	**SET**	**Qtime**
	1	0.26890	23.6	0	0.20201	7.6	0	7.6	0.0
	2	0.00324	103.2	103.2	0.32949	5.3	103.2	108.5	0.0
	3	0.15158	34.0	137.1	0.37364	4.7	137.1	141.8	0.0
	4	0.74472	5.3	142.5	0.77031	1.2	142.5	143.7	0.0
	5	0.57943	9.8	152.3					
	6	0.04791	54.7	207.0					
	7	0.33591	19.6	226.6					
	8	0.75799	5.0	231.6					
	9	0.47892	13.3	244.8					
	10	0.12575	37.3	282.2					
	11	0.35570	18.6	300.8					

Output-Queuing Theory				**Output-Simulation Results**		
E[ST]	4.8	sec/veh		Mean ST	4.5	sec/veh
E(QT]	1.7	sec/veh		Mean QT	0.8	sec/veh
E[ST]+E[QT]	6.5	sec/veh		Mean delay	5.3	sec/veh
Intensity	0.264			SimTime	4079.6	sec
				MinorFlow	176.7	veh/hr

Experiment #1

Run	MeanST	MeanQT	Delay	SimTime	MinorFlow
1	5.4	1.5	6.9	3500.5	207.3
2	5.1	2.5	7.6	2925.7	246.2
3	5.9	2.6	8.5	3725.7	193.3
4	4.6	1.7	6.3	3238.6	222.6
5	5.0	4.3	9.3	3571.9	201.7
6	4.9	1.7	6.6	3357.2	214.7
7	4.6	1.7	6.4	3764.2	191.3
8	4.6	2.3	6.8	3451.0	209.0
9	4.8	1.6	6.5	3836.5	188.2
10	4.8	1.8	6.6	3190.3	226.1

Veh#	Ran#	Hdwy	ArrTime	Ran#	ST	SST	SET	Qtime
1	0.26890	23.6	0	0.20201	7.6	0	7.6	0.0
2	0.00324	103.2	103.2	0.32949	5.3	103.2	108.5	0.0
3	0.15158	34.0	137.1	0.37364	4.7	137.1	141.8	0.0
4	0.74472	5.3	142.5	0.77031	1.2	142.5	143.7	0.0
5	0.57943	9.8	152.3	0.39448	4.4	152.3	156.7	0.0
6	0.04791	54.7	207.0	0.81550	1.0	207.0	207.9	0.0
7	0.33591	19.6	226.6	0.23918	6.8	226.6	233.4	0.0
8	0.75799	5.0	231.6	0.83952	0.8	233.4	234.2	1.8
9	0.47892	13.3	244.8	0.56315	2.7	244.8	247.6	0.0
10	0.12575	37.3	282.2	0.05791	13.6	282.2	295.7	0.0
11	0.35570	18.6	300.8	0.17568	8.3	300.8	309.0	0.0
12	0.84880	3.0	303.7	0.61347	2.3	309.0	311.4	5.3
13	0.71497	6.0	309.8	0.44722	3.8	311.4	315.2	1.6
14	0.08886	43.6	353.3	0.71210	1.6	353.3	355.0	0.0
15	0.00161	115.8	469.1	0.55267	2.8	469.1	471.9	0.0