Traffic Operations at Intersections: Learning and Applying the Models and Methods of the Highway Capacity Manual Using Simplified Scenarios and Computational Engines
Chapter 2. Capacity of All-Way Stop-Controlled Intersections
Online Problems

Expand your understanding of the AWSC intersection model by considering the following problems. The problems are organized according to the sections of Chapter 2 of the textbook. In some cases, you can use your computational engine for Scenario 2-2 to help you develop answers to these problems. The last section of problems deals with "complex scenarios" where you will be introduced to some of the adjustment factors that are included in the HCM to address such factors as turning movements and heavy vehicles.

Section 2. What Do We Observe in the Field?

Problem 2.1

One of the best methods of studying the operation of an AWSC intersection is through field observation. Locate a suitable AWSC intersection and observe it for a period of 30 minutes during a peak flow period. Answer the following questions based on your observations:

- Are there continuous queues on any of the approaches?
- During these periods of continuous queuing, do you observe a particular order of vehicle departures from each stop line into the intersection?
- What is the mean headway between the consecutive departures of vehicles on one approach? Base your answer on a sample of ten headways that you record.
- What factors do you think affect the value of this headway?
- What other observations of interest did you make?

Section 3. Formulating the Model

Problem 2.2

What does the term "degree of conflict" mean?

Problem 2.3

Describe the probability of occurrence for Case 2 and Case 5.

Problem 2.4

Define the term "departure headway".

Section 5. Scenario 3-2. Calculating the Capacity of Each Lane for a Standard 4-Leg Single Lane Intersection

Problem 2.5

The worksheet shown below shows the results of an analysis of an AWSC intersection using Scenario 2-2. After you have studied this worksheet, are the following statements are true or false? For the statements that you believe to be true, provide a brief justification to support your choice(s).

	A	B	C	D	E
1	**AWSC Intersection Model - 4 Legs (Scenario 2-2)**				
2					
3	**Given Conditions**	**NB**	**SB**	**EB**	**WB**
4	Volume, v (veh/hr)	440	425	250	350
5					
6	**Calculations**	**NB**	**SB**	**EB**	**WB**
7	Lambda, λ (veh/sec)	0.122	0.118	0.069	0.097
8					
9	Degree of utilization	**NB**	**SB**	**EB**	**WB**
10	X_S	1.00	0.97	0.63	0.83
11	X_O	0.97	1.00	0.83	0.63
12	X_{CL}	0.63	0.83	1.00	0.97
13	X_{CR}	0.83	0.63	0.97	1.00
14					
15	Probability of DOC cases	**NB**	**SB**	**EB**	**WB**
16	$P[C_1]$	0.002	0.000	0.000	0.000
17	$P[C_2]$	0.059	0.061	0.000	0.000
18	$P[C_3]$	0.012	0.000	0.005	0.011
19	$P[C_4]$	0.415	0.412	0.185	0.376
20	$P[C_5]$	0.512	0.527	0.810	0.614
21	$\Sigma P[C_i]$	1.000	1.000	1.000	1.000
22					
23	**Results**	**NB**	**SB**	**EB**	**WB**
24	Departure headway, h_d (sec/veh)	8.2	8.2	9.1	8.6
25	Degree of utilization, X	1.00	0.97	0.63	0.83
26	Iterations	26			

a. The capacity of the NB approach is 440 vehicles per hour.
b. The probability of a SB vehicle encountering a vehicle on the NB approach, and not on the EB and WB approaches, 0.061.

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Problem 2.6

The worksheet shows the results of an analysis of an AWSC intersection using the method of Scenario 2. After you have studied this worksheet, answer the following questions based on the traffic conditions shown for this intersection; provide brief justifications to support your answers.

	A	B	C	D	E
1	**AWSC Intersection Model - 4 Legs (Scenario 2-2)**				
2					
3	**Given Conditions**	**NB**	**SB**	**EB**	**WB**
4	Volume, v (veh/hr)	284	192	336	545
5					
6	**Calculations**	**NB**	**SB**	**EB**	**WB**
7	Lambda, λ (veh/sec)	0.079	0.053	0.093	0.151
8					
9	Degree of utilization	**NB**	**SB**	**EB**	**WB**
10	X_S	0.59	0.42	0.66	1.00
11	X_O	0.42	0.59	1.00	0.66
12	X_{CL}	0.66	1.00	0.59	0.42
13	X_{CR}	1.00	0.66	0.42	0.59
14					
15	Probability of DOC cases	**NB**	**SB**	**EB**	**WB**
16	$P[C_1]$	0.000	0.000	0.000	0.080
17	$P[C_2]$	0.000	0.000	0.238	0.158
18	$P[C_3]$	0.196	0.138	0.000	0.174
19	$P[C_4]$	0.526	0.471	0.515	0.424
20	$P[C_5]$	0.277	0.391	0.247	0.164
21	$\Sigma P[C_i]$	1.000	1.000	1.000	1.000
22					
23	**Results**	**NB**	**SB**	**EB**	**WB**
24	Departure headway, h_d (sec/veh)	7.5	7.9	7.1	6.6
25	Degree of utilization, X	0.59	0.42	0.66	1.00
26	Iterations	17			

a. Why does the $\Sigma P(C_i) = 1$ for each approach?

b. If an approach is operating at capacity, what should be the product of the flow rate and the departure headway?

c. If a vehicle is on the SB approach, what is the probability of a vehicle being on the NB approach, with no vehicles present on the EB or WB approaches?

d. Would you agree that the capacity of the WB approach is 545 veh/hr?

e. Is the capacity of the eastbound approach is greater than or less than 336 veh/hr?

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Problem 2.7
What is the maximum flow that can be observed on one approach of an AWSC intersection? Under what conditions will this maximum flow occur?

Problem 2.8
What is the maximum flow that can be observed at a single-lane four-leg AWSC intersection? Under what conditions will this maximum flow occur?

Problem 2.9
Given a flow rate of 300 veh/hr on the NB approach for a two-leg AWSC intersection. How does X for the NB and WB approaches vary with increasing volume on the WB approach?

Problem 2.10
Consider an AWSC intersection with volumes as shown below. What additional volume can be accommodated on the WB approach of the intersection?

- NB volume = 284 veh/hr
- SB volume = 192 veh/hr
- EB volume = 336 veh/hr
- WB volume = 543 veh/hr

Problem 2.11
Consider an AWSC intersection with volumes as shown below. What is the volume departing from the EB approach?

- NB volume = 425 veh/hr
- SB volume = 250 veh/hr
- EB volume = 475 veh/hr
- WB volume = 325 veh/hr

Problem 2.12
Given the following volumes measured for two 15-minute periods as shown below. What is your estimate for the degree of saturation X for each approach for each of these two time periods?

Time Period #1

- NB volume = 425 veh/hr
- SB volume = 250 veh/hr
- EB volume = 475 veh/hr
- WB volume = 325 veh/hr

Time Period #2

- NB volume = 300 veh/hr
- SB volume = 100 veh/hr
- EB volume = 250 veh/hr
- WB volume = 300 veh/hr

Problem 2.13
Describe how you would compute the capacity of one approach of an AWSC intersection with four legs using the spreadsheet computational engine. Construct an example using your computational engine to illustrate this calculation.

Problem 2.14
Consider an AWSC intersection with four approaches. What results are predicted when the volumes on each approach are set to 500 veh/hr? Describe what you would observe in the field for these conditions?

Problem 2.15
Consider an AWSC intersection with four approaches. Suppose the NB volume is 500 veh/hr and the volumes on the other approaches are zero. What is the capacity of the NB approach?

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Problem 2.16

An intersection currently has the following volumes. It is expected that traffic on all legs would increase at 4 per cent per year. How long would it take for the intersection to be become congested. Describe the operation of the intersection at this stage.

	A	B	C	D	E
1	**AWSC Intersection Model - 4 Legs (Scenario 2-2)**				
2					
3	**Given Conditions**	**NB**	**SB**	**EB**	**WB**
4	Volume, v (veh/hr)	280	330	195	212
5					
6	**Calculations**	**NB**	**SB**	**EB**	**WB**
7	Lambda, λ (veh/sec)	0.078	0.054	0.092	0.060
8					
9	Degree of utilization	**NB**	**SB**	**EB**	**WB**
10	X_S	0.46	0.33	0.53	0.36
11	X_O	0.33	0.46	0.36	0.53
12	X_{CL}	0.53	0.36	0.46	0.33
13	X_{CR}	0.36	0.53	0.33	0.46
14					
15	Probability of DOC cases	**NB**	**SB**	**EB**	**WB**
16	$P[C_1]$	0.205	0.166	0.235	0.173
17	$P[C_2]$	0.100	0.140	0.130	0.192
18	$P[C_3]$	0.341	0.275	0.313	0.230
19	$P[C_4]$	0.292	0.334	0.269	0.326
20	$P[C_5]$	0.061	0.086	0.053	0.079
21	$\Sigma P[C_i]$	1.000	1.000	1.000	1.000
22					
23	**Results**	**NB**	**SB**	**EB**	**WB**
24	Departure headway, h_d (sec/veh)	5.9	6.1	5.7	6.0
25	Degree of utilization, X	0.46	0.33	0.53	0.36
26	Iterations	11			

Complex Scenarios

Let's now transition from our simplified scenario perspective to more complex scenarios. For AWSC intersections, this complexity includes consideration of turning movements and heavy vehicles. As you may recall, our simplified scenarios are based on TH vehicles and passenger cars only. So, what happens when we consider turning movements and heavy vehicles? The HCM includes adjustment factors to the saturation headways to account for these factors. The table below, from the HCM, shows adjustments for left turns, right turns, and heavy vehicles

Factor	Saturation headway adjustment, sec
Left turns	0.2
Right turns	-0.6
Heavy vehicles	1.7

$$h_{adj} = h_{LT,adj}P_{LT} + h_{RT,adj}P_{RT} + h_{HV,adj}P_{HV}$$

Use this equation and the adjustment factors to solve the following problems. You will have to modify the computational engine to do so.

Problem 2.17

If instead of TH movements only, what do you think would happen to the values of X for each approach if 20 percent of the volume were LT movements? Were RT movements? Don't use any calculation aids, just use your understanding of the operation of AWSC intersections to come to an answer.

Problem 2.18

Given the following volumes:

- NB volume: 440 veh/hr
- SB volume: 425 veh/hr
- EB volume: 250 veh/hr
- WB volume: 350 veh/hr

Suppose that the following was also true:

- LT proportion: 10%
- RT proportion: 15%
- HV proportion: 10%

How does the result here with this complex scenario compare with the result from a simplified scenario?

Problem 2.19

Given the following volumes (same as in the previous problem):

- NB volume: 440 veh/hr
- SB volume: 425 veh/hr
- EB volume: 250 veh/hr
- WB volume: 350 veh/hr

Using the same volumes for the SB, EB, and WB approaches, conduct a sensitivity analysis to assess the effect of using the complex scenario for a range of NB volumes considering variation in:

- LT proportion from 0% to 25%
- HV proportion from 0% to 25%