CHAPTER 7

Timing Processes for the Intersection

Purpose

In Chapter 6, you studied the operation of one intersection approach and determined the value of the vehicle extension time that would extend the green for as long as a queue existed, but not longer. The focus was on the traffic flow and signal timing on one approach only, with no consideration of the effect of this value on the other intersection approaches. In this chapter, now that you have established a basic understanding of the timing processes for one approach of an intersection, we will consider how the timing parameters on one approach affect the operation on the other approaches and the intersection overall.

Learning Objectives

When you have completed the activities in this chapter, you will be able to

- Describe the function of the maximum green time
- Describe the effect of the maximum green time on the cycle length and delay
- Describe the maximum green time setting and timer process
- Determine the optimal maximum green time (based on the optimal cycle length) at a signalized intersection
- Determining the effect of the minor street vehicle extension setting on the efficiency of major street and intersection operations
- Describe the advantages and disadvantages of increasing maximum green time on intersection operations
- Set the maximum green time for both approaches of an intersection, balancing the performance of both the minor street and the major street
- Compare the maximum green times that you developed in your design with those used in practice

Chapter Overview

This chapter begins with a *Reading* (Activity #39) on the relationship between the maximum green time, the cycle length, and delay. The chapter also includes four activities including an assessment of your understanding of the effect of the maximum green time on intersection operations (Activity #40), the effect of long vehicle extension times on one approach on the operation of the other approaches (Activity #41), and the pros and cons of increasing the maximum green time in order to solve the problem of phase failure (Activity #42). You will complete a design activity (Activity #43) in which you will select the maximum green time for the design project with which you have been working. The chapter concludes with an *In Practice* activity (Activity #44) with background on the maximum green time, both recommended values for its setting and how this timing process works.

Activity List

Number and Title		Type
39	Maximum Green Time, Cycle Length, and Delay	*Reading*
40	What Do You Know About Maximum Green Time, Cycle Length, and Delay?	*Assessment*
41	Determining the Effect of the Minor Street Vehicle Extension Time on Intersection Operations	*Discovery*
42	Determining the Effect of the Maximum Green Time on Intersection Operations	*Discovery*
43	Setting the Maximum Green Timing Parameter for All Approaches of an Intersection	*Design*
44	Maximum Green Time	*In Practice*

ACTIVITY

39 Maximum Green Time, Cycle Length, and Delay

READING

Purpose

The purpose of this activity is to give you the opportunity to learn how the setting of the maximum green time limits the delay experienced by vehicles traveling through the intersection.

Learning Objectives

- Describe the function of the maximum green time
- Describe the effect of the maximum green time on the cycle length and delay

Deliverables

- Define the terms and variables in the Glossary
- Prepare a document that includes answers to the Critical Thinking Questions

Glossary

Provide a definition for each of the following terms or variables. Paraphrasing a formal definition (as provided by your text, instructor, or another resource) demonstrates that you understand the meaning of the term or phrase.

cycle length	
maximum green time	
uniform delay	
C	
d_1	
g	

G	
g/C	
r	
s	
v	

CRITICAL THINKING QUESTIONS

When you have completed the reading, prepare answers to the following questions.

1. Why does delay increase as cycle length increases?

2. What is the function of the maximum green time?

3. What is the process followed by the maximum green timer?

INFORMATION

Overview

In Chapter 6 you learned how to set the passage time in conjunction with the length of the detection zone so that the phase continues to time as long as the queue is being served, and no longer. But what if the volumes are so high that the phase extends long enough to unfairly delay vehicles on the other intersection approaches? How long should a phase be allowed to time? In this chapter we will consider the effect of the maximum green time (and, as a result, the cycle length) on the delay experienced by all users of the intersection.

Uniform Delay Equation

The Highway Capacity Manual provides an equation for computing control delay (the delay attributed to the control device) for an approach at a signalized intersection. The equation includes three terms, one each for the following components of delay: uniform delay, incremental delay, and initial queue delay. For low or moderate traffic volumes, the first term of this equation (the uniform delay term) provides a reasonable estimate of delay, as a function of cycle length (C), green time (g), volume (v), and saturation flow rate (s). You considered this equation in Chapter 2 (Activity #8).

$$d_1 = \frac{0.5C(1-g/C)^2}{1-(v/s)}$$

Another view of the uniform delay term, substituting r/C for $(1–g/C)$, is given at right:

$$d_1 = \frac{0.5C(r/C)^2}{1-(v/s)}$$

In both formulations, we can see the effect of green time (g), red time (r), and cycle length (C) on delay. Delay increases as the red time increases, and thus as the cycle length increases.

Delay and Cycle Length

Consider an example intersection for which there are two intersecting one-lane one-way streets. Figure 138 shows the delay for one approach, assuming a green ratio (g/C) of 0.5, volume of 500 veh/hr, and a saturation flow rate of 1800 veh/hr/green based on the uniform delay equation shown above. As the cycle length increases, the delay increases in a linear manner.

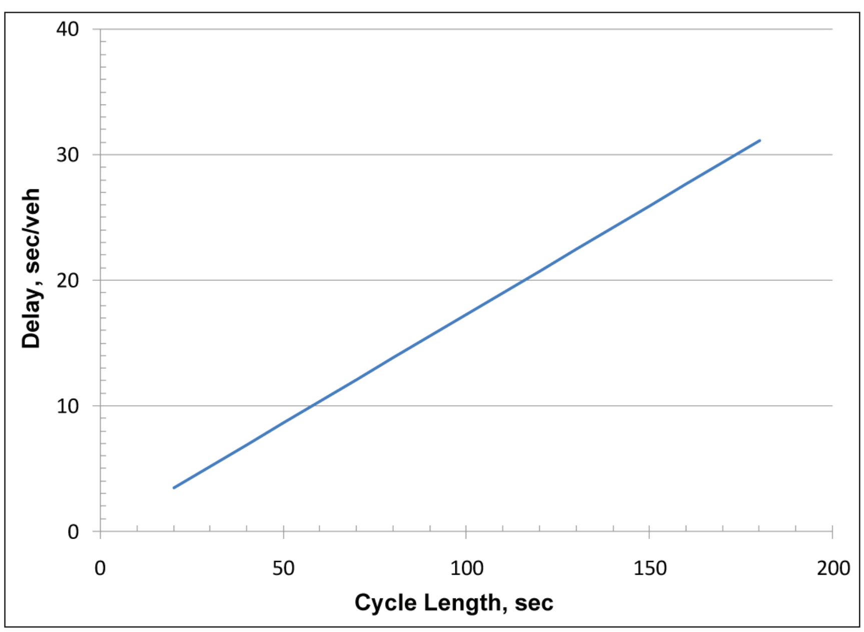

Figure 138. Delay vs. cycle length for one approach

How does this relate to efficient phase termination, particularly limiting the length of the cycle by setting a maximum green time for each approach? To understand this relationship, let's consider two cases, each case with different green interval durations. In case 1, the green time is half the length of the green time for case 2. In case 1, the red and green intervals are equal and their sum is the cycle length: $C_1 = r_1 + g_1$

For case 2, the red and green intervals are also the same, and the cycle length C_2 is twice the duration of C_1:

$$C_2 = 2C_1 = 2(r_1 + g_1) = r_2 + g_2$$

The timing for these two cases is illustrated in Figure 139.

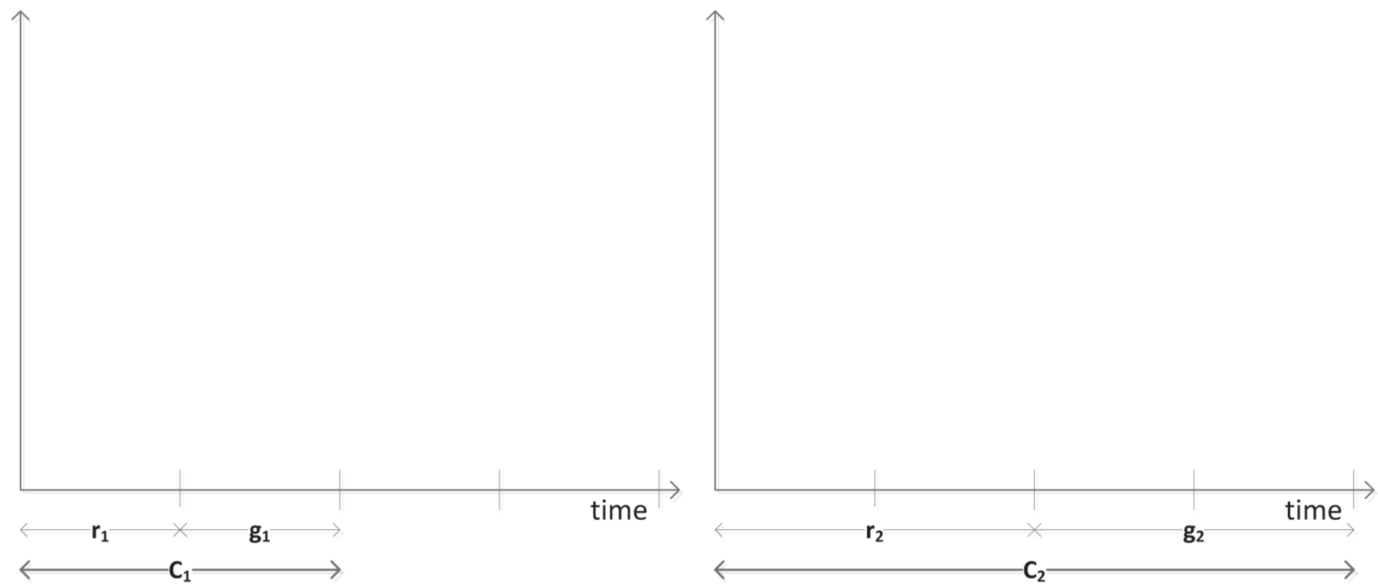

Figure 139. Two cases, with different green time durations

We will further assume that the arrival flow rates in both cases are the same and equal to *v*. We can illustrate this notion in the pair of cumulative vehicle diagrams shown in Figure 140, where the number of vehicles that have arrived at the intersection at the end of the second cycle in case 1 is equal to the number of vehicles that have arrived at the end of the first cycle in case 2. The slope of both lines is the arrival rate or volume, *v*.

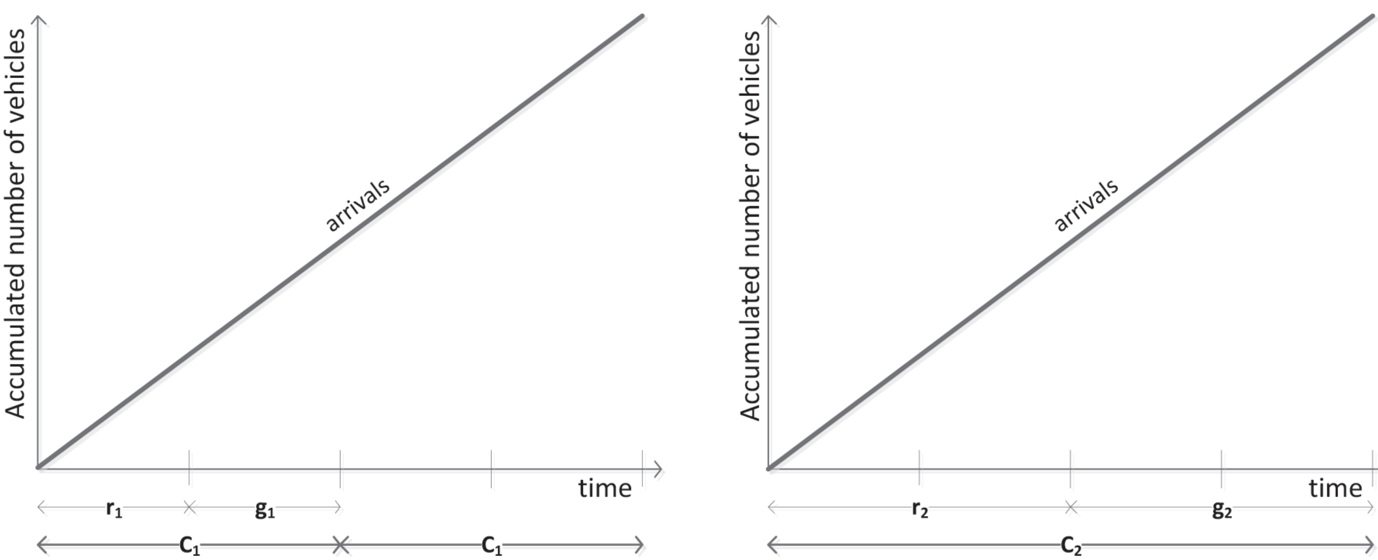

Figure 140. Cumulative vehicle diagrams for two cases

We will further assume that the green durations (g_1 and g_2) shown in each case are equal to the maximum green times for the cases and that the queues clear at the end of green. We can then show the departure curves for both cases, in Figure 141.

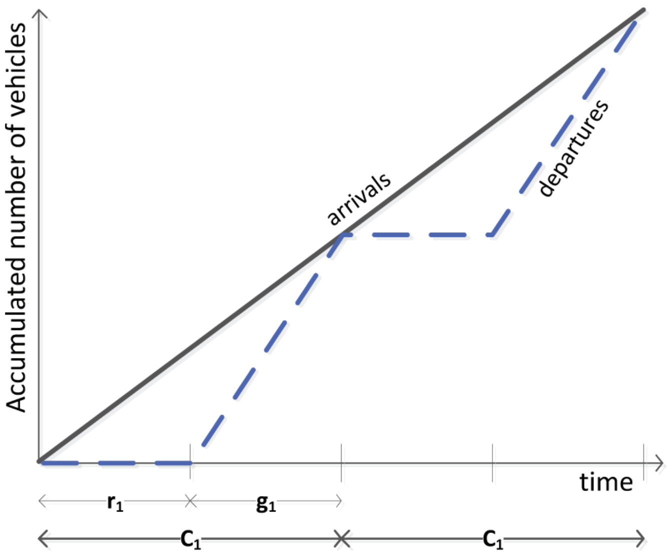

Figure 141. Cumulated Vehicle Diagrams, cases 1 and 2

As we saw in Chapter 2, another way of representing these flows is with a queue accumulation polygon. The vertical distance between the arrival and departure curves at any point in time is the queue length at that point in time. This vertical distance over time is shown in the queue accumulation polygons in Figure 142. In addition, the areas of the polygons (in this case, triangles) are equal to the total delay experienced by all users during that time interval.

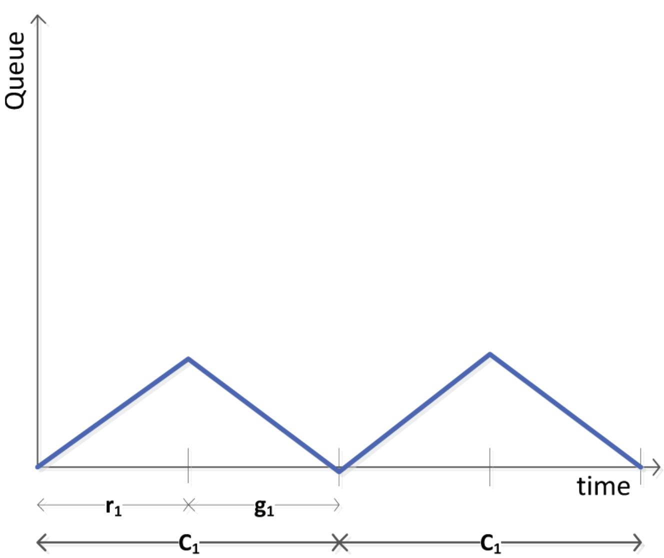

Figure 142. Queue accumulation polygons, cases 1 and 2

Figure 143 shows that the total delay for case 2, in which the maximum green time is twice as long as for case 1, is twice the delay for case 1.

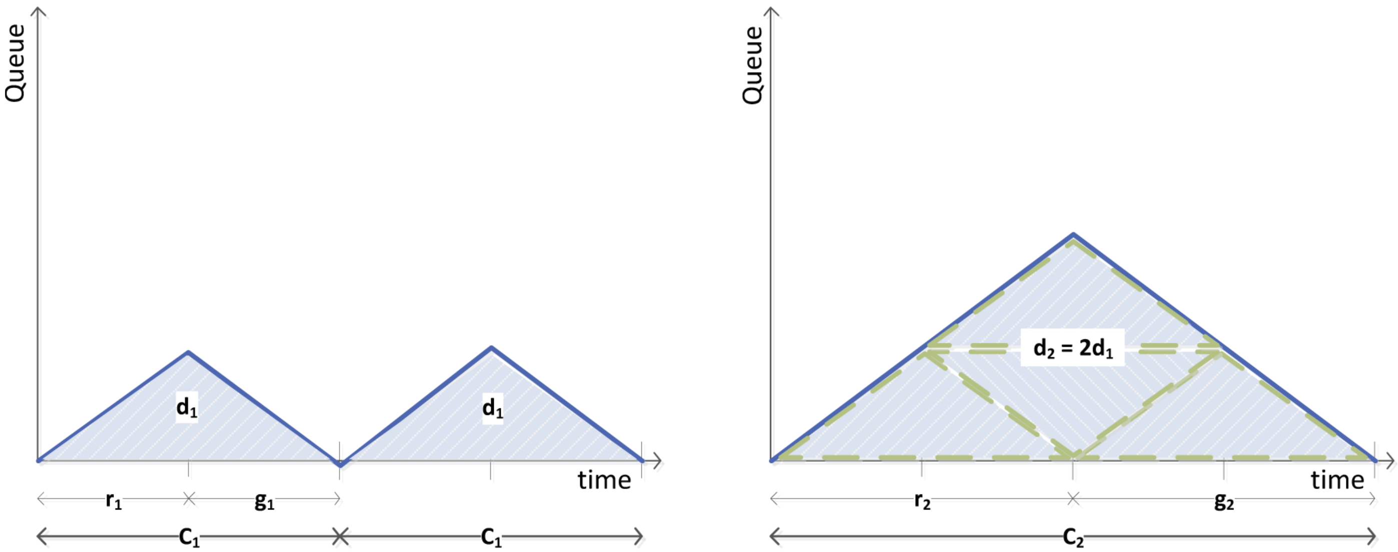

Figure 143. Total delay, cases 1 and 2

Example Calculation

Let's now look at a numerical example to validate what we just observed graphically. In this example, we'll show two cases, the first with a cycle length of 60 seconds, and then second with a cycle length of 120 seconds. In both cases the $g/C = 0.50$ and the arrival flow rate is 500 vehicles per hour.

For case 1, the area of the triangle, dt_1, is:

$$d_{t1} = 0.5(\text{base})(\text{height}) = 0.5C_1\ (vr_1) = 0.5(60)(4.2) = 125 \text{ veh} - \text{sec}$$

The average delay is equal to the total delay dt_1 divided by the number of vehicles that arrive during the cycle ($vC_1 = 8.3$ vehicles):

$$d_{a1} = \frac{d_{t1}}{vC_1} = \frac{125}{8.3} = 15 \text{ sec/veh}$$

For case 2, the total delay and the average delay are:

$$d_{t2} = 0.5(\text{base})(\text{height}) = 0.5C_1\ (vr_1) = 0.5(120)(8.3) = 500 \text{ veh} - \text{sec}$$

$$d_{a2} = \frac{d_{t2}}{vC_2} = \frac{500}{16.7} = 30 \text{ sec/veh}$$

So as we saw graphically, the delay doubles when the cycle length doubles.

Other Considerations

Much of the previous discussion in this reading focused on the effect of longer cycle length on increasing delay. But it is also important to note the impact of cycle length on intersection capacity. When the duration of the green is extended (through a longer maximum green time), the proportion of the cycle that is allocated to the change and clearance intervals (yellow and red clearance times) declines. A small but positive increase in intersection capacity results. Figure 144 shows this concept with three example cases, for cycle lengths of 30 seconds, 60 seconds, and 120 seconds. For each case, fixed yellow and red clearance times totaling 5 seconds (shown together as "red" in the figure) are assumed. For $C = 120$ seconds, the north-south movements would have 55 seconds of green (g_{NS}) followed by 5 seconds of yellow and red clearance times. The east-west movements would also have 55 seconds of green (g_{EW}) again followed by 5 seconds of yellow and red clearance times. This means that there is 110 seconds of green time available to serve the movements out of a cycle length of 120 seconds. Thus 92 percent of the cycle is available to serve traffic movements. However, for $C = 30$ seconds only 67 percent of the cycle is available for green time as the remainder is needed for the yellow and red clearance times.

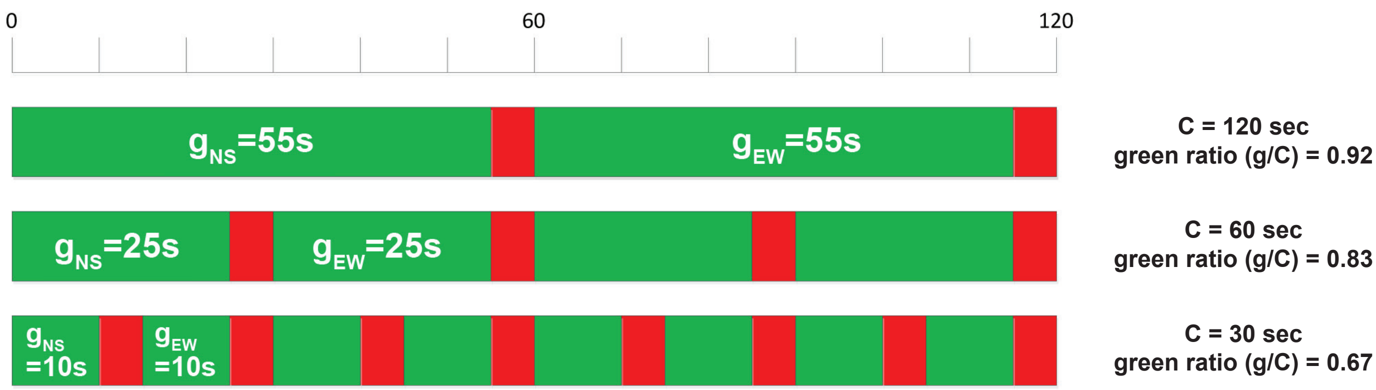

Figure 144. Proportion of green as a function of cycle length

Another consideration in setting the maximum green time is the impact on the way in which a phase terminates. For several reasons, most of which are beyond the scope of this book, it is preferable for a phase to terminate by gapping out. So, if a phase terminates primarily by maxing out, this may indicate that the maximum green time setting may be too low.

Conclusion

So, again we find that setting a signal timing parameter involves a trade-off. We want to set the maximum green time long enough so that in most cases the phase will terminate by gapping out. But we want to make sure that the phase doesn't time so long that delay becomes too high. Finding this balance is the challenge that you will face in the design of the maximum green time parameter later in this chapter. It is important to note that this balance doesn't mean trying to equalize the number of gap outs and max outs: it does mean trying to ensure that the phase gaps out as often as possible, except when volumes are high during peak periods.

Student Notes:

ACTIVITY
40 What Do You Know About Maximum Green Time, Cycle Length, and Delay?

ASSESSMENT

Purpose

The purpose of this activity is to help you understand the role of the maximum green time in providing efficient intersection operations. You will also validate your understanding of how to use the uniform delay equation to determine the relationship between the delay and cycle length (and thus the maximum green time).

Learning Objectives

- Describe the maximum green time setting and timer process
- Determine the optimal maximum green time (based on the optimal cycle length) at a signalized intersection

Deliverable

- Prepare a spreadsheet with the following information:

  Tab 1: Title page with activity number and title, authors, and date completed

  Tab 2: Summary of the results of your analysis from Tasks 1 and 2 and your answers to the Critical Thinking Questions

Task 1

A model for computing the average delay when traffic is arriving at a signalized intersection at a uniform rate was described in Activity #39. It is reproduced below. Using an Excel spreadsheet, develop a VBA function to compute average uniform delay as a function of red time, green time, cycle length, volume, and saturation flow rate. See the Excel Tutorial for assistance in creating a VBA function.

$$d_a = \frac{0.5C(1-g/C)^2}{1-v/s}$$

Task 2

Assuming a volume from one of the major street approaches of your simulation network, compute the average uniform delay per vehicle as a function of cycle length, with a range of cycle lengths from 40 seconds to 100 seconds. Prepare a graph of delay vs. cycle length for this range of values. Assume g/C = 0.5 and s = 1900 vehicles per hour of green.

Critical Thinking Questions

1. Prepare a brief discussion of the implications of your analysis for the maximum green time setting for your network. What limitations exist in this analysis that must be considered when you set the maximum green time? Include the discussion and answer in your spreadsheet.

2. The reading in Activity #39 emphasized the importance of keeping the cycle length (and thus the maximum green time) as low as possible. But what happens when the cycle length becomes too short? List one possible downside of a very short cycle length.

ACTIVITY
41 Determining the Effect of the Minor Street Vehicle Extension Time on Intersection Operations

DISCOVERY

Purpose

The purpose of this activity is to help you to understand how timing parameters on the minor street affect the major street and overall intersection operations.

Learning Objective

- Determine the effect of the minor street vehicle extension setting on the efficiency of major street and intersection operations

Required Resource

- Movie file: A41.wmv

Deliverable

- Prepare a spreadsheet with the following information:

  Tab 1: Title page with activity number and title, authors, and date completed

  Tab 2: Answers to the Critical Thinking Questions and the data that you recorded in Table 20 through Table 24

Critical Thinking Questions

1. How do the eastbound and southbound approach queue lengths vary given the two vehicle extension time values used for the southbound approach?

2. How does an increase in the southbound approach vehicle extension time affect the eastbound green interval duration?

3. How does the increase in the southbound approach vehicle extension time affect the cycle length?

4. What effect does the vehicle extension time have on the delay experienced for these two cases?

Information

In this activity you will observe the operation of both approaches at the intersection of State Highway 8 and Line Street. An aerial view of the intersection is shown in Figure 145. State Highway 8 has a five to six lane cross section, while Line Street has a three lane cross section. In this activity, both approaches have stop bar presence detection with a zone length of 22 feet. The volumes are moderate, with 1400 vehicles per hour on the eastbound approach and 600 vehicles per hour on the southbound approach.

The intent here is to vary the vehicle extension time on phase 4 serving the southbound Line Street (minor street) approach and to observe the effect of each setting on the queuing experienced by motorists on both the major and minor streets. The minimum green time has been set to 5 seconds and will not be varied in this activity.

You will consider two different settings of vehicle extension time: 2 seconds and 5 seconds. Both queue length and green time duration will be considered in evaluating the performance of these alternatives. You will also learn about the relationship of green time duration and cycle length on the delay experienced by motorists at the intersection.

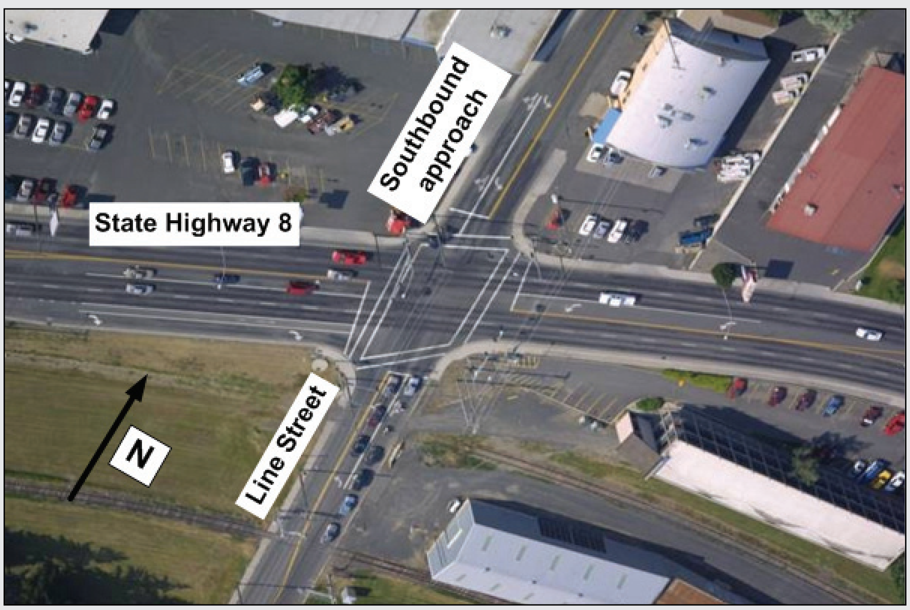

Figure 145. Aerial photo for State Highway 8 and Line Street

The movie (see Figure 146) shows side-by-side windows for the two different cases:

- Left window (case 1): the vehicle extension time for both the southbound approach and eastbound approach is 2 seconds
- Right window (case 2): the vehicle extension time for the southbound approach is set to 5 seconds whereas the vehicle extension time for the eastbound approach remains at 2 seconds

To assess the traffic operations quality in terms of queue length, duration of green time, and cycle length, you need to do the following:

- "Beginning of green" data collection: Once the signal indication for an approach turns green, pause the animation and record the length of the queue and the simulation time the signal indication turns green
- "End of green" data collection: Once the signal indication for the approach turns red, pause the animation and record the simulation time the signal indication turns red

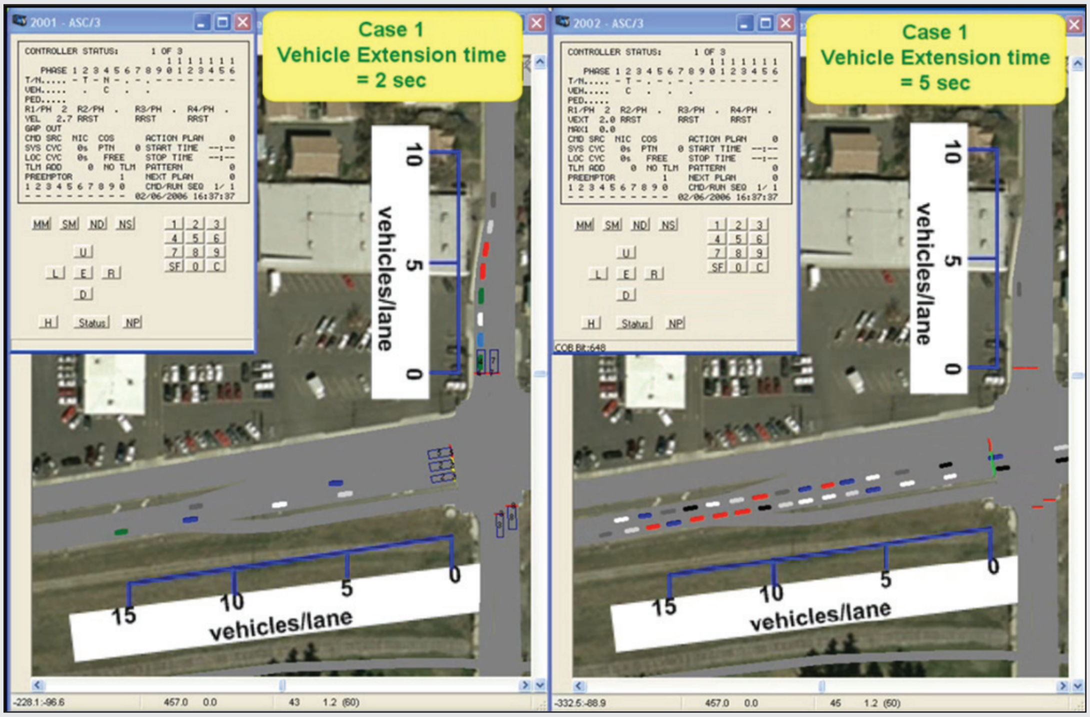

Figure 146. Side-by-side animation window

Task 1

Open the file: "A41.wmv"

Task 2

Observe the operation of both approaches at the intersection as well as the signal status data. Note that Case 1 is in the left window and case 2 is in the right window.

- Before starting the movie file, make sure you identify the simulation time clock in both windows (see circles in Figure 147). You will use this clock to record the beginning and ending of green. This animation starts at the simulation time of $t = 446.8$ seconds and ends at $t = 761.4$, a total time of a little more than five minutes.
- Figure 148 shows the side-by-side animation that you will observe. Scales have been provided to show the length of the queues (in vehicles) along the southbound and eastbound intersection approaches. The ASC/3 controller status windows are also shown so that you can follow the timing processes. Finally, notes will pop up periodically to point out things for you to observe. For example, for case 2, the note in Figure 148 shows that cycle 1 is timing, the eastbound green begins at 450.9 seconds, and there are 31 vehicles in the queue.

- Don't collect any data during this first observation. Just watch and observe. Note especially the differences that you see between case 1 (the left window) and case 2 (the right window). Make notes regarding your observations.

Figure 147. Simulation time in animation windows

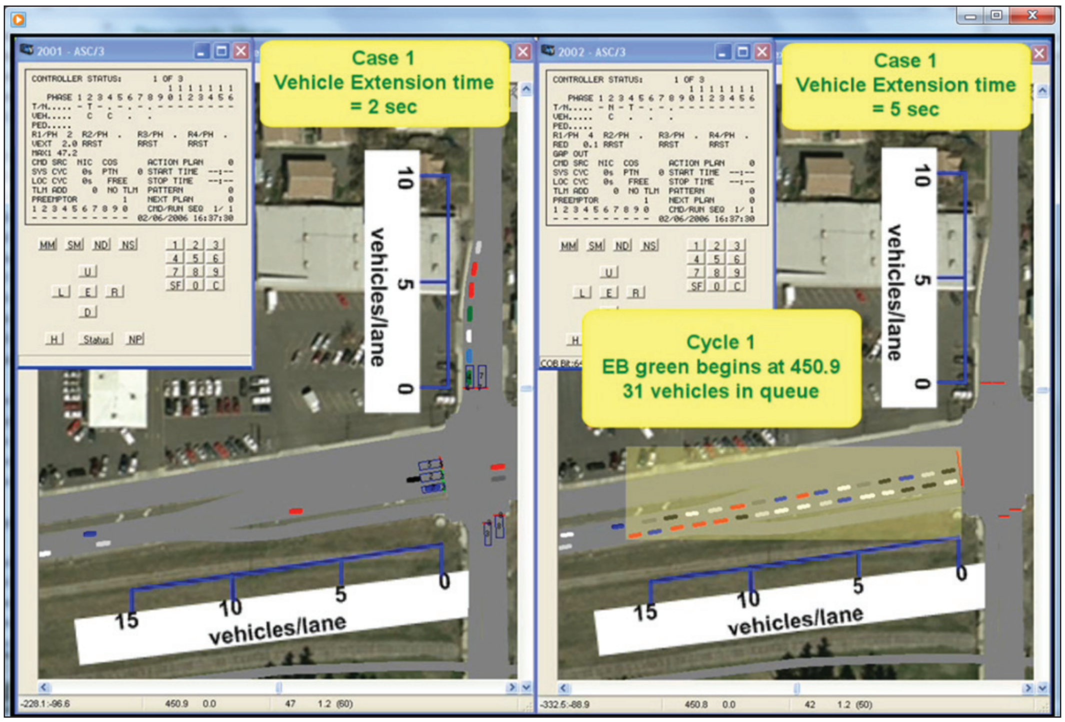

Figure 148. Case 1 and case 2 at t = 450.9

Task 3

Observe and record the queue lengths and start/end of green intervals.

- Start the animation at the beginning. The VISSIM simulation time clock should read t = 446.8
- Record the queue length at the beginning of green and the simulation times for the beginning and ending of green for case 1 (in Table 20) and case 2 (in Table 21)
- For example, for case 2, the green indication for the eastbound approach turns green at t = 450.9 seconds (see Figure 148). If you pause the animation at this point you will see that there are 31 vehicles in the queue at the beginning of green. These two data points have been recorded for you in Table 3.
- Continue recording the queue length and the start and end of green time for each phase for both cases until the final SB phase ends at t = 752.8 seconds. You have space to record data for five cycles for case 1 and four cycles for case 2.
- Compute the green duration by taking the difference between the Green end and the Green begin times
- Compute mean values for the green duration and queue length and record these values in the last row of each table

Cycle	SB				EB			
	Green start, sec	Green end, sec	Vehicles in queue, start of green	Green duration, sec	Green start, sec	Green end, sec	Vehicles in queue, start of green	Green duration, sec
1								
2								
3								
4								
5								
		Mean ⟶				Mean ⟶		

Table 20. Data collection table for queue and display status for case 1 (SB vehicle extension time of 2.0 seconds) (Left window)

Cycle	SB				EB			
	Green start, sec	Green end, sec	Vehicles in queue, start of green	Green duration, sec	Green start, sec	Green end, sec	Vehicles in queue, start of green	Green duration, sec
1					450.9		31	
2								
3								
4								
5								
		Mean ⟶				Mean ⟶		

Table 21. Data collection table for queue and display status for case 2 (SB vehicle extension time of 5.0 seconds) (Right window)

TASK 4

Summarize your data.

- Copy the "green start" data for the southbound and eastbound approaches from Table 20 and Table 21 into the appropriate cells in Table 22 and Table 23. Compute the length for each cycle, by taking the difference between the "green start" for each pair of consecutive cycles. Then compute the mean cycle length for each case.

- Based on the data that you recorded in Table 20, Table 21, Table 22, and Table 23, use Table 24 to summarize the average green duration, cycle length, and queue length for cases 1 and 2
- Study the results shown in the tables and prepare a summary of your observations

Cycle	Case 1		Case 2	
	Green start	Cycle length	Green start	Cycle length
1				
2				
3				
4				
5				
	Mean→		Mean→	

Table 22. Data summary, SB approach

Cycle	Case 1		Case 2	
	Green start	Cycle length	Green start	Cycle length
1				
2				
3				
4				
5				
	Mean→		Mean→	

Table 23. Data summary, EB approach

	SB		EB	
	Case 1	Case 2	Case 1	Case 2
Green duration, sec				
Cycle length, sec				
Queue length, vehicles				

Table 24. Mean values for Cases 1 and 2

Student Notes:

ACTIVITY
42 Determining the Effect of the Maximum Green Time on Intersection Operations

DISCOVERY

Purpose

The purpose of this activity is to help you to understand how the maximum green time settings affect intersection operations.

Learning Objective

- Describe the advantages and disadvantages of increasing maximum green time on intersection operations

Required Resources

- Movie files: A42-1.wmv A42-2.wmv

Deliverable

- Prepare a document with your answers to the Critical Thinking Questions and your observations from Tasks 1 and 2

Critical Thinking Questions

As you begin this experiment, consider the following questions. You will come back to these questions once you have completed the experiment.

1. Are all of the vehicles in the initial queue on the westbound approach served before the end of each green interval?

2. What is the mechanism for termination of the phase serving the westbound approach?

3. What are the advantages and disadvantages of the 40 second maximum green time for the operation of case 1?

4. What are the advantages and disadvantages of the 60 second maximum green time for the operation of case 2?

5. Which maximum green time setting would you select and why?

6. Identify the pros and cons of the two different maximum green time settings on the westbound approach and on the overall performance of the intersection. Consider what you observed and documented for both cases. Summarize the pros and cons of each case.

Information

In this activity, you will observe two cases, each focusing on the westbound approach of the major street, State Highway 8 (See Figure 149). In the first case, the maximum green time is set to 40 seconds. The demand is relatively high (1700 vehicles per hour across two lanes) on the westbound approach and the green time displayed is not sufficient to serve the demand. In the second case, the maximum green time is set at 60 seconds in an effort to serve more of the demand. But this change also has implications that must be considered for the operation of the intersection. Each case includes four cycles, focusing on the westbound approach. You will be asked to look at three things:

- What is the length of the queue at the beginning of each of the four green intervals on the westbound approach?
- How does the westbound phase terminate during each of the four cycles in each case?
- Are there vehicles from the westbound queue still unserved at the end of the green interval?

Figure 149. Activity 42 movie file

Task 1

Open the file: "A42-1.wmv." Observe the operation of case 1 and record your observations.

- Watch the entire video. It is nearly 3.5 minutes in length. Pay attention to the Critical Thinking Questions listed earlier.
- Record your observations

Task 2

Open the file: "A42-2.wmv." Observe the operation of case 2 and record your observations.

- Watch the entire video. It is nearly 4 minutes in length. Pay attention to the Critical Thinking Questions listed earlier.
- Record your observations

Student Notes:

ACTIVITY

43 Setting the Maximum Green Timing Parameter for All Approaches of an Intersection

DESIGN

Purpose

The purpose of this activity is to set the maximum green time for your intersection such that the delay is optimized for all approaches and for the intersection as a whole.

Learning Objective

- Set the maximum green time for both approaches of an intersection, balancing the performance of both the minor street and the major street

Required Resource

- VISSIM file from Activity #37

Deliverable

- Prepare a spreadsheet that includes the analysis and reporting requirements listed in the tasks below:

  Tab 1: Title page with activity number and title, authors, and date completed

  Tab 2: Delay analysis for range of maximum green times

  Tab 3: Prepare a brief report that summarizes your conclusions, your recommended maximum green times, and the data that support your conclusions and recommendations. Include a plot of delay vs cycle length for the results that you generated.

Information

Consider this question: How do you set the timing parameters to balance the risks of early termination of green and inefficiently long green time? Consider the following criteria that could be used to produce efficient phase operations:

- The phase is not extended inefficiently for a very short queue
- The phase extends long enough to clear the standing queue
- The phase doesn't extend beyond the time that it takes for the queue to clear

In addition to these three criteria, the following criteria could also be considered to achieve intersection operational efficiency:

- The major street green time should be extended to serve vehicles arriving after the queue clears without causing excessive delay to the minor street traffic
- The maximum green time should be increased in case of phase failure when a phase consistently terminates by maxing out

Your objective in this activity is to determine the maximum green times such that the phases generally gap out (and not max out) balanced by making sure the cycle times are not excessive and long delay times are produced.

Task 1

Make a new copy of the folder that includes your VISSIM files from Activity #37. Rename this folder "a43". Use this VISSIM file as the basis for your analysis and design of the maximum green time.

Task 2

Set the maximum green time to 60 seconds for all approaches of your intersection. Use the settings for the minimum green time and the vehicle extension time that you determined in Activity #37. Collect delay and queue length data for each approach and for the intersection as a whole based on one simulation run of 3900 seconds (collecting data beginning at 300 seconds to account for network build-up). Observe the operation of the network for this time period and record the number of max outs and gap outs for each approach.

Task 3

Based on your results from Task 2, reduce the maximum green times by 10 seconds and run the simulation again. Again, collect the delay and queue length data for each approach and for the intersection as a whole based on one simulation run of 3900 seconds. Observe the operation of the network for this time period and record the number of max outs and gap outs for each approach.

Task 4

Continue iterating (reducing the maximum green by increments of 10 seconds and re-run the simulation) until you've reached a value of maximum green time that meets the objectives listed previously.

Task 5

Based on the results from Tasks 2, 3, and 4, select your design value for the maximum green time.

ACTIVITY

44 Maximum Green Time

IN PRACTICE

Purpose

The purpose of this activity is to help you to learn how the maximum green time is set in practice.

Learning Objective

- Compare the maximum green time that you selected with the range of values used in practice

Required Resource

- *Traffic Signal Timing Manual*

Deliverables

Prepare a document that includes

- Answers to the Critical Thinking Questions
- Completed Concept Map

Link to Practice

Read the section from the *Traffic Signal Timing Manual* on maximum green times as assigned by your instructor.

Critical Thinking Questions

When you have completed the reading, prepare answers to the following questions:

1. What is the function of the maximum green time?

2. What methods are used to set the maximum green time?

3. How do your design results from Activity #43 compare with the recommendations from the *Traffic Signal Timing Manual*?

In My Practice...

by Tom Urbanik

The selection of the maximum green time starts with an understanding of the traffic volume, usually from a traffic count or traffic projection. These traffic volumes are only a snapshot of traffic conditions and may not reflect peak demand. Traffic at a school, for example, may have extreme peaking at the beginning or end of school, or following a special event like a football game. Typically, maximum green times will be increased to accommodate these extreme conditions. The main risk of larger than needed maximum green times includes extending the phase beyond saturation flow values if the passage time setting is large, thus driving the phase to maximum or in the case of detector failures, sending a continuous call which also extends the phase to maximum.

There are advanced controller features that can respond to fluctuations in traffic volumes. One example is the dynamic maximum which allows the controller to increase the maximum green time if the controller continues to "max out" rather than "gap out." The downside is you need cycle failures to increase the maximum green time.

Another feature which might not be thought of for increasing flexibility of fully actuated control to respond to fluctuations in volume is "soft recall." If the arterial is placed on soft recall, it only calls the arterial in the absence of calls on all other phases. So a large volume of traffic exiting a high school stadium is able to extend beyond its maximum green if there is no traffic on the arterial calling for service. Alternatively, if the arterial is on minimum recall, it will turn on the cross street maximum green timer every cycle even in the absence of traffic on the arterial, forcing the controller to cycle back to the arterial because of the recall.

Concept Map

Terms and variables that should appear in your map are listed below.

cycle length (C) | uniform delay (d_1) | volume (v)

maximum green time | green time (g)

Student Notes: