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.

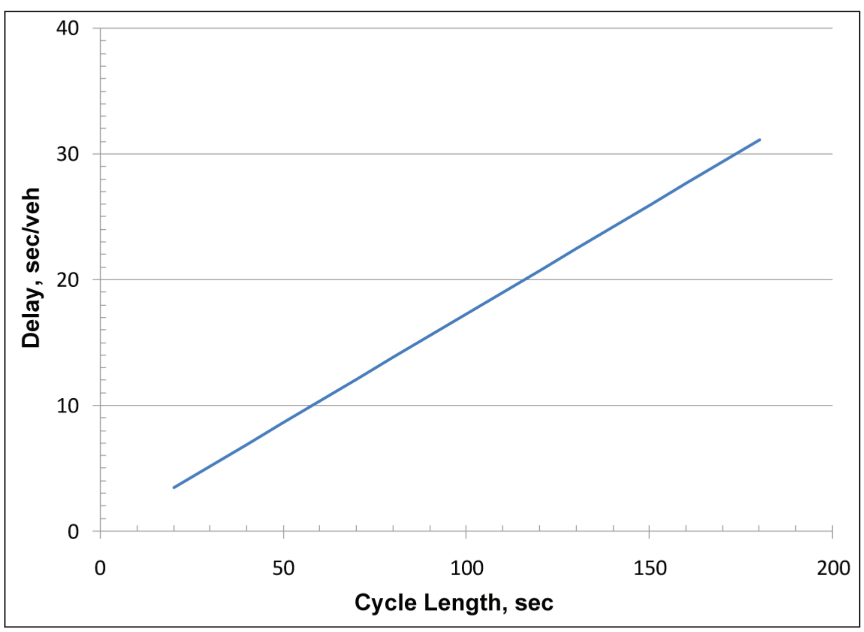

Figure 138. Delay vs. cycle length for one approach

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.

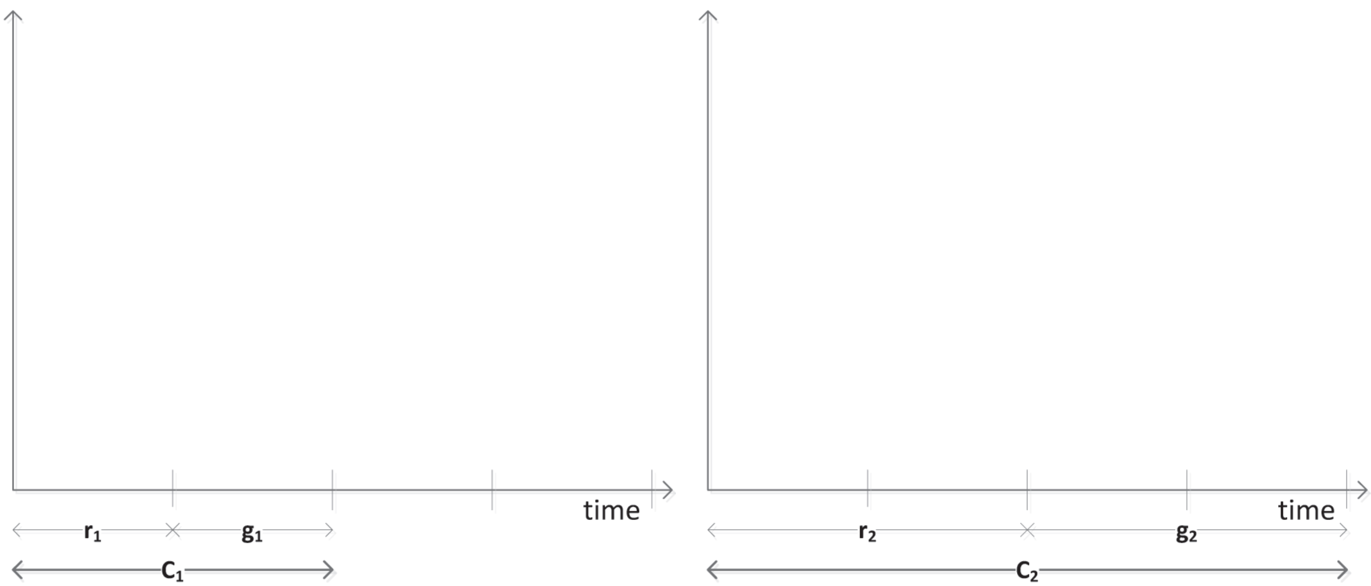

Figure 139. Two cases, with different green time durations

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*.

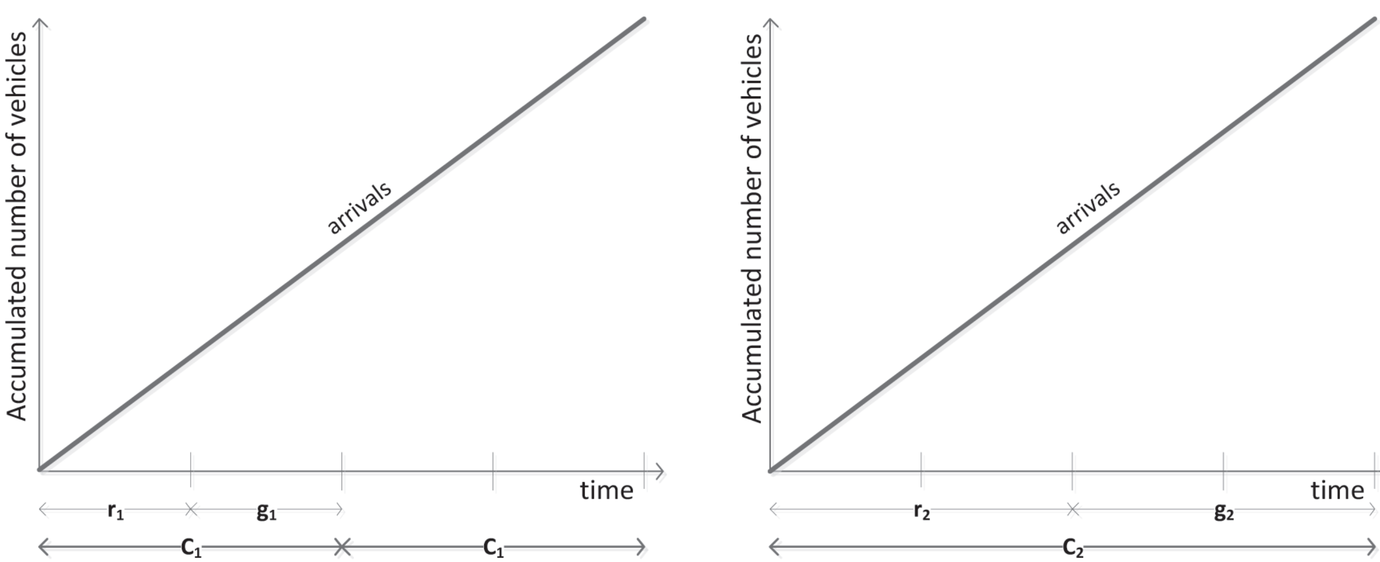

Figure 140. Cumulative vehicle diagrams for two cases

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.

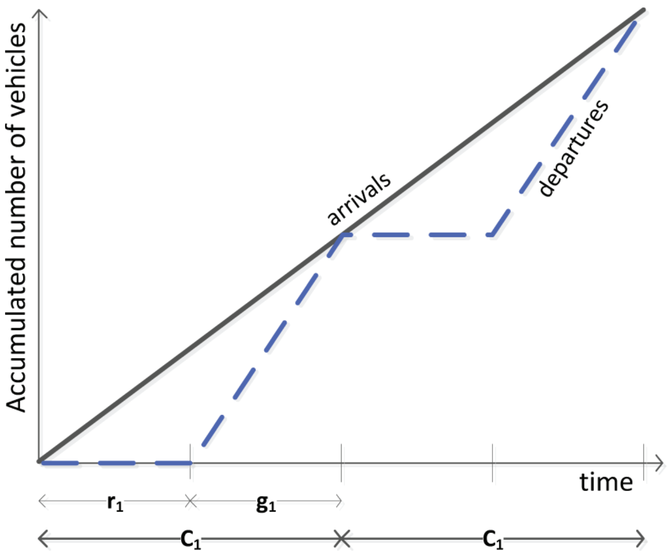

Figure 141. Cumulated Vehicle Diagrams, cases 1 and 2

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.

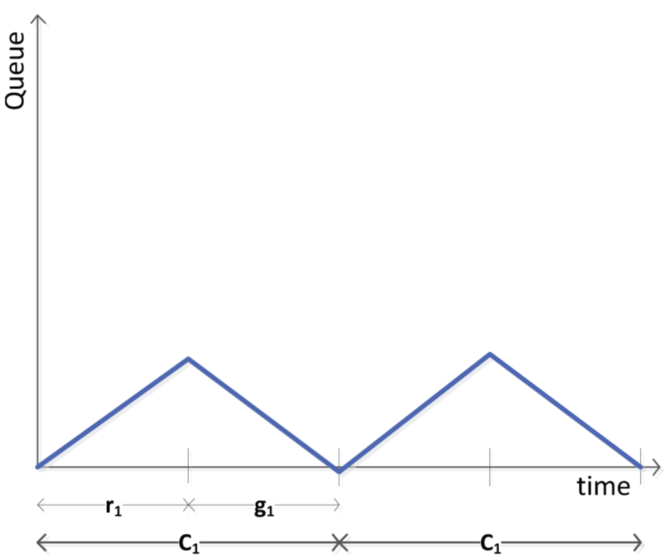

Figure 142. Queue accumulation polygons, cases 1 and 2

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.

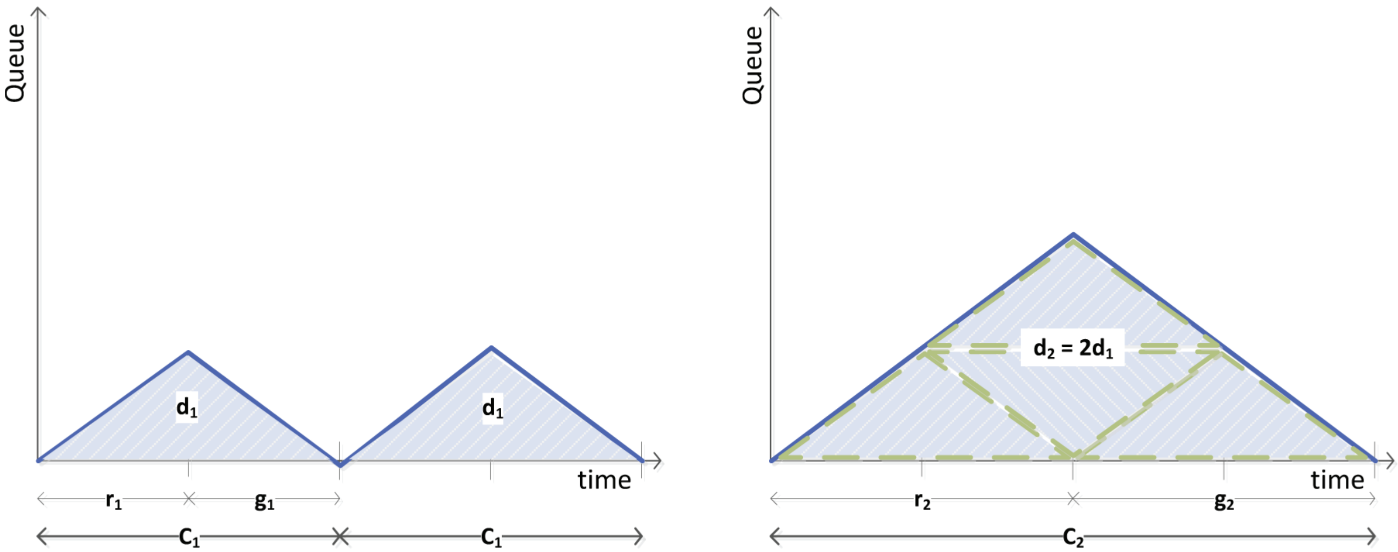

Figure 143. Total delay, cases 1 and 2

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.

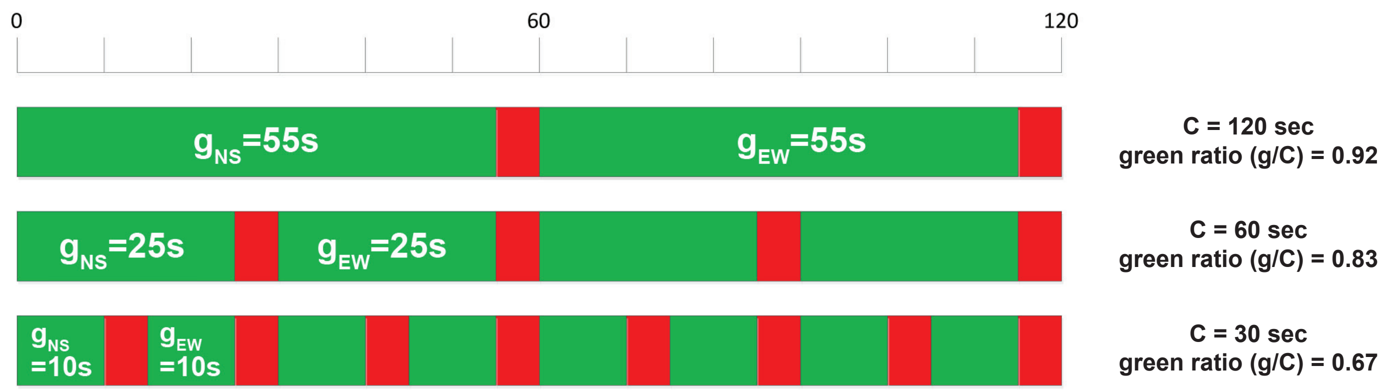

Figure 144. Proportion of green as a function of cycle length

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: