

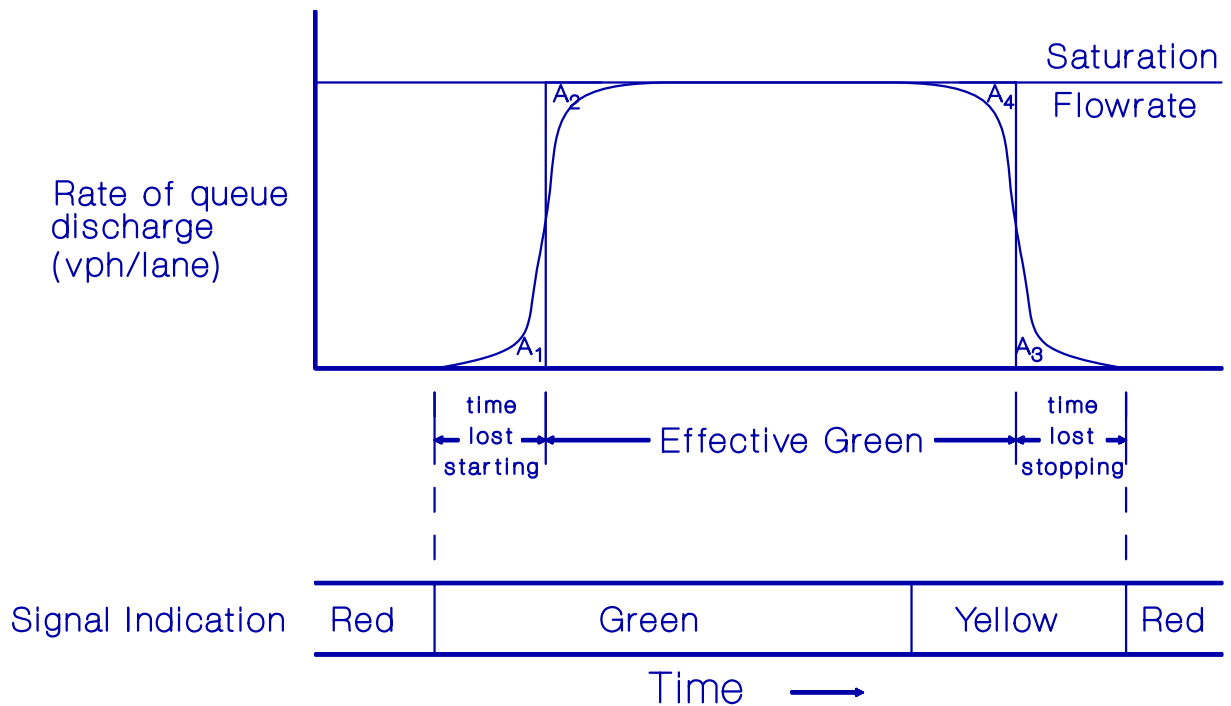
TRAFFIC SIGNAL TIMING: “BASIC PRINCIPLES” OF PRETIMED CONTROL

Objectives of Signal Timing:

- Reduce average delay of all vehicles
- Reduce probability of accidents by minimizing possible conflict points.

Our objectives may conflict with each other. (Reducing the number of phases reduces average delay, but you may need more phases to separate all of the different traffic streams from each other.)

From Intersection Operation:



$$(G+Y+AR) = \text{phase duration (sec)}$$

$$\text{Effective Green} = (G+Y+AR) - t_l$$

$$s = \frac{3600}{h_s}$$

$$\text{max veh. that can pass during a phase} = \frac{\text{effective green}}{h_s}$$

$$\text{lane capacity} = \frac{g}{C} \times s$$

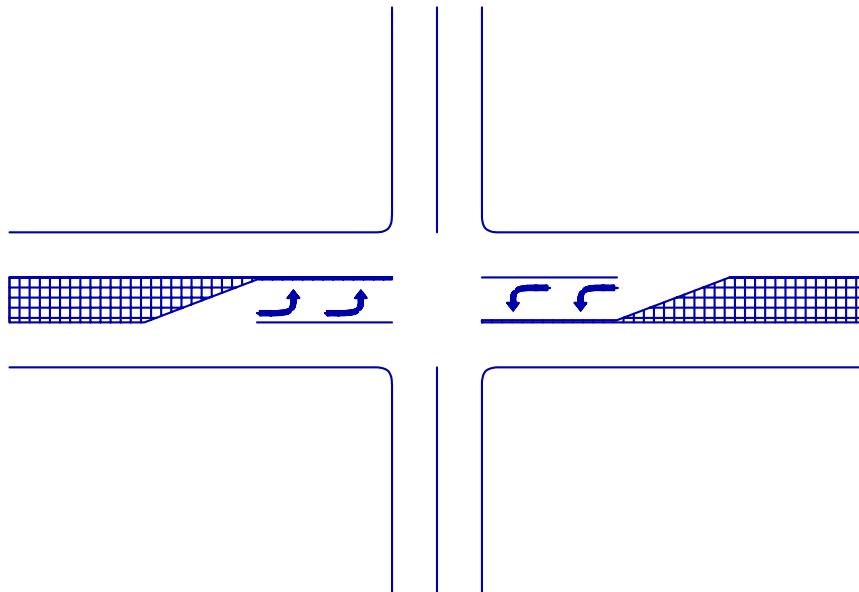
or

$$\text{lane capacity} = \left[\frac{(G + Y + AR) - t_l}{C} \right] \times s$$

Now, suppose we are given the intersection configuration shown below. Let's say that we are given the following:

Two phase operation
 Southbound demand = 500 vph
 $h_s = 2.1$ sec/veh
 $t_l = 4.5$ sec/phase

How much effective green (per hour) will be required to pass the traffic?



Now assume, in addition that Northbound demand is 720 vph (with the same lost time and h_s). How much effective green (per hour) will be required to move the traffic?

How much effective green (per hour) will be required for the North/South phase? Why?

CRITICAL MOVEMENT ANALYSIS

The concept we have just learned is referred to as *critical movement analysis*. For each phase in the cycle, there will be a lane (or lane group) that requires an amount of effective green that is not exceeded by any other lane having right-of-way during that phase. We refer to the flow in this lane as *critical lane volume*, although the thing we are really concerned with is the "critical required green time."

Now, still assuming the same values for h_s and lost time, suppose Eastbound demand is 800 vph with 10% left turns. How much effective green is required for each lane (EB through and EB left turns)?

Make the same calculation for the Westbound approach assuming that westbound demand is 900 vph with 11% left turns.

Now, what is the effective green required for the East/West phase?

SUMMARY OF THINGS UP TO THIS POINT:

1. There is one lane (or lane group) for each phase requiring the maximum amount of effective green time. For this lane or lane group, we have the *critical lane volume*.
2. There is an effective green time requirement and critical lane volume for each phase in the cycle.
3. The "required green" for the cycle is the sum of the effective green requirements for each phase. We must provide at least this amount of effective green (per hour) to pass the traffic (without queueing). Written mathematically,

$$\text{required green} = \sum_{i=1}^n h_{s_i} \times CLV_i \quad (\text{sec/hr})$$

where

n = number of phases in the cycle

h_{s_i} = saturation headway for the flow in the critical lane
for phase i (sec/veh)

CLV_i = critical lane "volume" (flow rate) for phase i (veh/hr)

In design of signal timing:

1. You **MUST** provide enough green time to pass the CLV traffic!!
2. Next, you would like to minimize delays to vehicles stopped at an intersection.
(This means you want to minimize red for each phase)

In order to minimize red, you need to minimize cycle length.

So, we want to find the shortest cycle length that will pass the traffic.

$$N_c = \frac{3600}{C} \text{ (If we minimize } C, \text{ we maximize } N_c, \text{ and thus total amount of lost time per hour.)}$$

where

$$N_c = \text{the number of cycles in an hour}$$

$$C = \text{cycle length (sec)}$$

$$L = \sum_{i=1}^n t_{l_i}$$

where

$$t_{l_i} = \text{lost time for phase } i \text{ (sec)}$$

$$L = \text{lost time for the entire cycle (sec/cycle)}$$

$$\text{Total Lost Time} = L \times N_c$$

For one hour:

$$3600 \text{ sec} = \text{effective green} + \text{total time lost}$$

$$3600 = \text{required green} + L \times N_c$$

Substitute $\frac{3600}{C}$ for N_c and rearrange:

$$C = \frac{L}{1 - \sum \frac{h_{s_i}}{3600} \times CLV_i}$$

Now, substitute s for $\frac{3600}{h_{s_i}}$

$$C = \frac{L}{1 - \sum_{i=1}^n \frac{CLV_i}{s_i}}$$

* $\frac{CLV}{s}$ = flow ratio in HCM (v/s in HCM)

AN EQUATION FOR DETERMINING SPLITS

Finding splits is nothing more than deciding how long we're going to give right-of-way to each phase. We already know that there is a total *required green* time for each phase which will just pass the traffic. We also know that there is a total required green to pass *all* traffic. It seems logical to allocate the effective green part of a cycle (nothing more than $C - L$) in proportion to the required green time of the individual phases. For any phase, i , then,

$$effective\ green_i = \frac{h_{s_i} \times CLV_i}{\sum_{i=1}^n h_{s_i} \times CLV_i} (C - L)$$

Now, the phase length for phase i is $(G + A)_i$. And:

$$(G + A)_i = effective\ green_i + t_{l_i}$$

Or finally,

$$(G + A)_i = \frac{h_{s_i} \times CLV_i}{\sum_{i=1}^n h_{s_i} \times CLV_i} (C - L)_i + t_{l_i}$$

If we use flow ratio to express this, it becomes:

$$(G + A)_i = \frac{\frac{3600}{s_i} \times CLV_i}{\sum_{i=1}^n \frac{3600}{s_i} \times CLV_i} (C - L)_i + t_{l_i}$$

Or

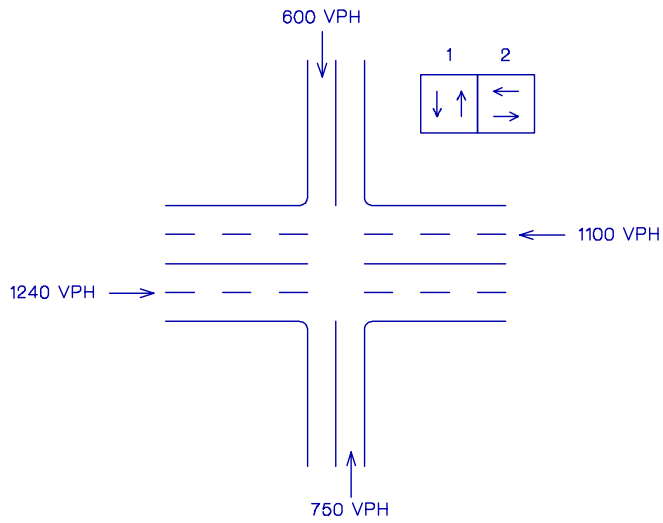
$$(G + A)_i = \frac{\left(\frac{CLV}{s}\right)_i}{\sum_{i=1}^n \left(\frac{CLV}{s}\right)_i} (C - L) + t_{l_i}$$

The equation above determines the splits!

A true check of your calculations is to determine whether or not your timing passes the traffic.

Example:

Find cycle length and splits for the intersection configuration shown below. Assume saturation headways of 2.1 sec/veh-lane and lost times of 5 sec/phase for all approaches.



REAL WORLD CONSIDERATIONS

Unfortunately, the real world has such things as heavy vehicles, pedestrians, left turns, etc. which are not adequately considered in the basic cycle length equation. What follows are some guidelines and approximations.

1. Cycle length constraints:

We would like to implement cycle lengths in the range of 40-120 seconds. Cycle lengths of less than 40 seconds waste too much time (lost time), and for cycles much over 120 seconds, motorists sometimes think that the "light" is malfunctioning, and enter the intersection on red.

2. Display time constraints:

We don't show the driver such things as two second greens ("Show the driver things he's seen before.") Some traffic engineers might use different values, but in this class, we will use minimum (G+A) values of:

12 sec (exclusive left turns)
15 sec (through)

3. Peaking:

We time traffic signals for the peak 15 minute flow rate, just like we made our calculations on for capacity and level of service for uninterrupted flow.

4. Composition:

As a rough approximation, assume that each truck is the equivalent of 2.0 passenger cars (this value is compatible with the Highway Capacity Manual (HCM)). The HCM uses this to adjust saturation flow rate from its "ideal" value of 1900 pcphgpl (passenger cars per hour of green per lane). As an approximation, we will use:

$$s = 1900 \times f_{hv}$$

where

s = saturation flow rate (vphgpl)

$$f_{hv} = \frac{1}{1 + P_T(E_T - 1)} \quad (\text{look familiar?})$$

Where P_T is the proportion of trucks in the stream. Since we are taking $E_T=2$, this reduces to:

$$f_{hv} = \frac{1}{1 + P_T}$$

Our approximation to saturation flow rate, then, is:

$$s = \frac{1900}{1 + P_T}$$

(This is both a slight variation and simplification of the HCM technique for signalized intersections, but it is sufficient for our purposes).

5. Unprotected left turns:

Unprotected left turns are those who turn left on the "green ball." We call those turning left on a green arrow "protected" left turns. As an approximation, assume that each unprotected left turn is the equivalent of 2.0 through vehicles.

6. Pedestrian constraints (where pedestrian volumes are significant):

Ped time = 5 sec + walk time

(Walk rate is about 4 ft/sec)

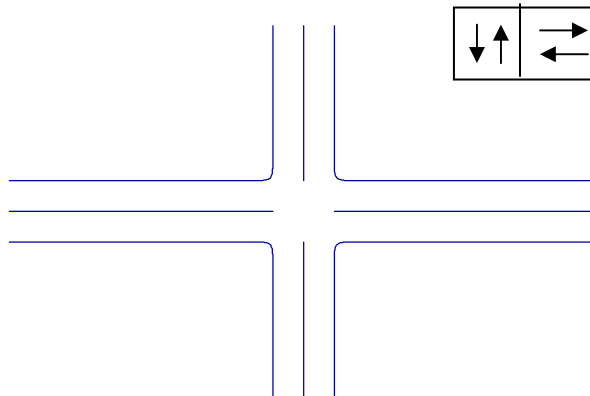
7. All signal timing methods are approximate - checking and adjustments must be made in the field.

EXAMPLES:

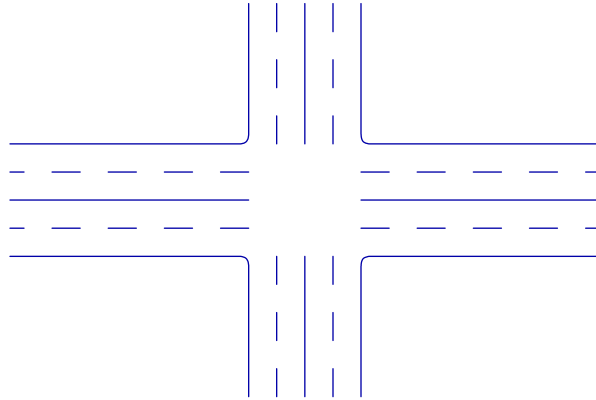
1. As city traffic engineer of Attapulcus, Georgia, you are responsible for timing the town's traffic signal, which operates with two phases. Lost time is 4.5 seconds for each of the two phases and peak hour factor is 0.83. Peak hour data for each of the four approaches is given in the table below.

| <u>APPROACH</u> | <u>Peak Hour Volume</u> | <u>Percent Trucks</u> | <u>Percent Left Turns</u> |
|-----------------|-------------------------|-----------------------|---------------------------|
| EB | 548 | 5 | 6 |
| WB | 672 | 7 | 7 |
| NB | 598 | 4 | 8 |
| SB | 606 | 2 | 6 |

- a. Intersection geometry is as shown below. Find the required cycle length and splits.



- b. The mayor is up for re-election and has promised, if returned to office, to provide funds to significantly improve these two streets. What cycle length and splits would you implement if the intersection was improved by adding lanes as shown below?



- c. Well, the mayor's opponent, who campaigned on a platform of fiscal conservatism, won the election. This means that there will be no major improvements to the intersection. However, the new mayor is willing to foot the bill for a can of paint, and you do have enough pavement width to add left-turn bays for the east-west approaches. For your "new" intersection (shown below), can you re-time the signal to give a more reasonable operation than what you got in part a?

