Chapter 42

Traffic signal design-II

42.1 Overview

In the previous chapter, a simple design of cycle time was discussed. Here we will discuss how the cycle time is divided in a phase. The performance evaluation of a signal is also discussed.

42.2 Green splitting

This is also called apportioning of green time. Some time will be lost as the satr-up lost time and clearance time. Thus green splitting is the proportioning of effective green time in the signal phase. The green splitting is given by,

$$g_i = \left[\frac{V_c i}{\sum_{i=1}^{n} V_{ci}}\right] \times T_G \tag{42.1}$$

where $V_c i$ is the critical lane volume and T_G is the effective green time available. Actual greentime can be now found out as,

$$G_i = g_i - y_i + t_{Li} \tag{42.2}$$

where G_i is the actual green time, g_i is the effective green time available, y_i is the amber time, and L_i is the lost time for phase i.

Problem

The phase diagram of an intersection with two phases are as shown in figure 42:7.

Th lost time and yellow time for the first phase is 2.5 and 3 respectively and that for the second phase are 3.5 and 4 respectively. If the cycle time is 120 seconds, find the green time allocated for the two phases.

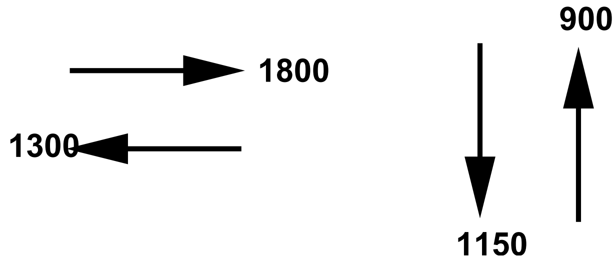

Figure 42:1: Phase diagram for an intersection

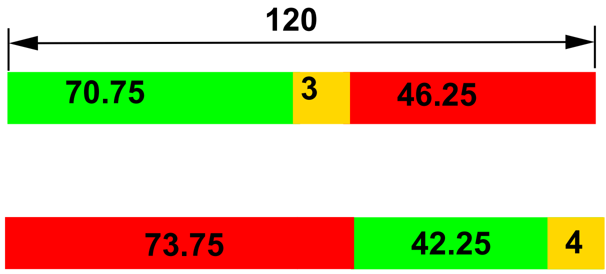

Figure 42:2: Timing diagram

Solution Critical lane volume for the first phase = 1000 vph

Critical lane volume for the second phase = 600 vph

The sum of the critical lane volumes = 1000+600 = 1600 vph

Effective green time can be found out from equation 41.5 as t_g= 120-(2.5-3.5)= 114 seconds

Green splitting for the first phase, g_1 can be found out from equation 42.1 as $g_1 = \frac{1000}{1600} \times 114 = 71.25$ seconds

Green splitting for the second phase, g_2 can be found out from equation 42.1 as $g_2 = \frac{600}{1600} \times 114 = 42.75$ seconds

Actual green time can be found out from equation 42.2. Thus actual green time for the first phase, G_1 = 71.25-3+2.5 = 70.75 seconds

Actual green time for the second phase, G_2 = 42.75-3+2.5 = 42.25 seconds

The phase diagram is as shown in figure 42:2

42.3 Pedestrian crossing requirements

There are two wqys pedestrian crossing requirements has to be taken care i.e, either by proper phase design or by providing an exclusive pedestrian phase. It is possible in some cases to allocate time for the pedestrians without providing an exclusive phase for them. For eg, consider an intersesction in which the traffic moves from north to south and also from east to west. If we are providing a phase which allows the traffic to flow only in north-south direction, then the pedestrians can cross in east-west direction. But in some cases, it may be necessary to provide an exclusive pedestrian phase. In such cases, the procedure involves computation of time duration of allocation of pedestrian phase. If a minimum start-up time of 4 to 7 seconds is assumed, then the minimum time needed for pedestrians to safely cross a street is:

$$G_p = t_s + \frac{dx}{u_P} \tag{42.3}$$

where G_p is the minimum safe time required for the pedestrians to cross, often referred to as the "pedestrian green time", t_s is the start-up lost time, dx is th ecrossing distance in metres, and u_p is the walking speed of pedestrians which is the 15th percentile speed and usually taken as 1.2 m/s.

42.4 Performance measures

It is a measure used to evaluate the effectiveness of the design. There are many parameters involved to evaluate the effectiveness of the design and most common of these include delay, queuing and stops. Delay is a measure

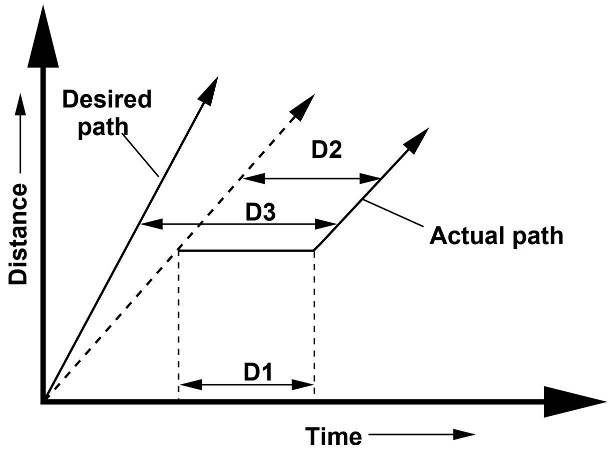

Figure 42:3: Illustration of delay measures

that most directly relates the driver's experience. It describes the amount of time that is consumed while traversing the intersection. The figure 42:3 shows a plot of distance versus time for the progress of one vehicle.

The desired path of the vehicle as well as the actual progress of the vehicle is shown. There are three types of delay as shown in the figure. They are stopped delay, approach delay and controlled delay. *Stopped time delay* includes the time at which the vehicle is actually stopped waiting at the red signal. It starts when the vehicle reaches a full stop, and when the vehicle begins to accelerate. *Approach delay* includes the stopped time as well as the time lost due to acceleration and deceleration. —t is measured as the time scale differential between the actual path of the vehicle, and its actual path extended. *Travel time delay* is measured as the time scale difference between the driver's desired time from the origin, and the actual time. For a signalized intersection, it is measured at the stop-line as the vehicle enters the intersection.

Vehicles are not coming uniformly to an intersection. i.e., they are not approaching the intersection at constant time intervals. They come in a random manner. The modelling of signalised intersection delay is complex. Most fundamental of the delay models is Webster's delay model. It assumes that the vehicles are arriving at a uniform rate. Plotting a graph with time along the x-axis and cumulative vehicles along the y-axis we get a graph as shown in figure 42:4.

Webster derived an expression for delay per cycle based on this, which is as follows.

$$d_i = \frac{\frac{C}{2}[1 - \frac{g_i}{C}]^2}{1 - \frac{V_i}{S}} \tag{42.4}$$

where g_i is the effective green time, C is the cycle length, V_i is the critical flow for that phase, and S is the saturation flow.

Delay is the most frequently used parameter of effectiveness for intersections. Other measures like length of queue at any given time (Q_T) and number of stops are also useful. Length of queue is used to determine when a given intersection will impede the discharge from an adjacent upstream intersection. The number of stops made is an important input parameter in air quality models.

Problem The traffic flow for a four-legged intersection is as shown in figure 42:5.

Given that the lost time per phase is 2.4 seconds, saturation headway is 2.2 seconds, amber time is 3 seconds per phase, find the cycle length, green time and performance measure(delay per cycle). Assume critical V/C ratio as 0.9.

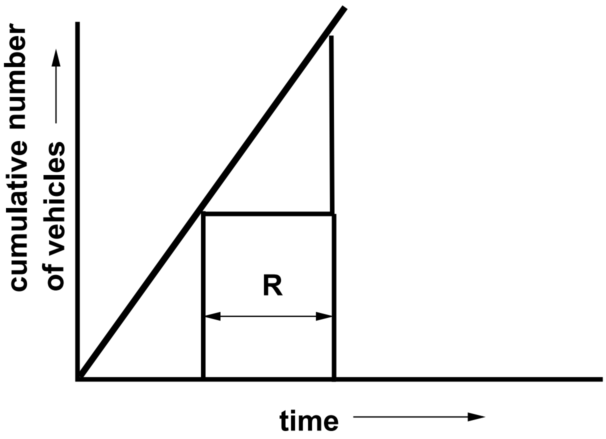

Figure 42:4: Graph between time and cumulative number of vehicles at an intersection

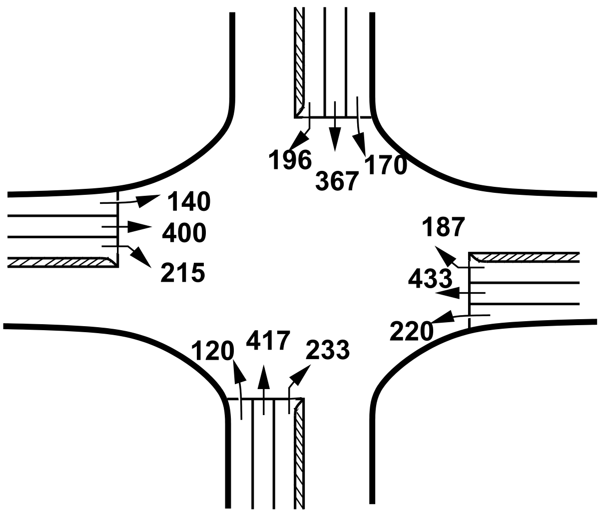

Figure 42:5: Traffic flow for a typical four-legged intersection

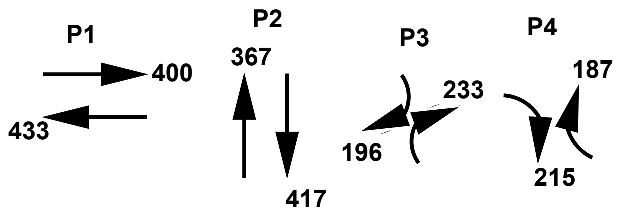

Figure 42:6: Phase plan

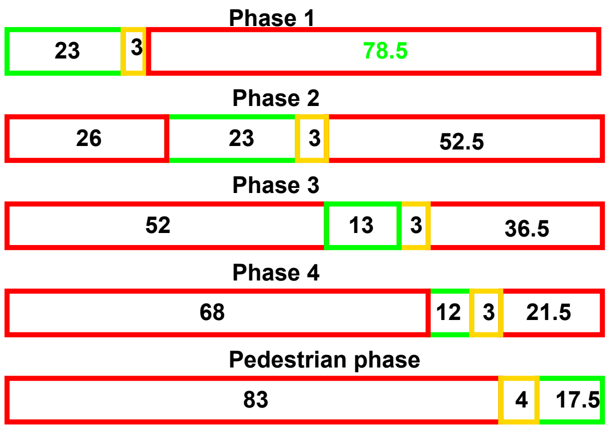

Figure 42:7: Timing diagram

Solution The phase plan is as shown in figure 42:6.

Sum of critical lane volumes is the sum of maximum lane volumes in each phase, ΣV_{Ci} = 433+417+233+215 = 1298 vph.

Saturation flow rate, S_i from equation 41.2 = $\frac{3600}{2.2}$ = 1637 vph.

$\frac{V_c}{S_i} = \frac{433}{1637} + \frac{417}{1637} + \frac{233}{1637} + \frac{1298}{1637} = 0.793$

Cycle length can be found out from the equation 41.12 as C $= \frac{4\times2.4\times0.9}{0.9-\frac{1298}{1637}}$ = 80.68 seconds ≈ 80 seconds

The effective green time can be found out as $G_i = \frac{V_{Ci}}{V_C} \times (C - L)$ = 80-(4×2.4)= 70.4 seconds, where L is the lost time for that phase = 4× 2.4

Green splitting for the phase 1 can be found out from 42.1 as $g_1 = 70.4 \times [\frac{483}{1637}]$ = 22.88 seconds

Similarly green splitting for the phase 2,$g_2 = 70.4 \times [\frac{417}{1637}]$ = 22.02 seconds

Similarly green splitting for the phase 3,$g_3 = 70.4 \times [\frac{233}{1637}]$ = 12.04 seconds

Similarly green splitting for the phase 4,$g_4 = 70.4 \times [\frac{215}{1637}]$ = 11.66 seconds

The actual green time for phase 1 from equation 42.2 as G_1 = 22.88-3+2.4 ≈ 23 seconds

Similarly actual green time for phase 2, G_2 = 22.02-3+2.4 ≈ 23 seconds

Similarly actual green time for phase 3, G_3 = 12.04-3+2.4 ≈ 13 seconds

Similarly actual green time for phase 4, G_4 = 11.66-3+2.4 ≈ 12 seconds

Pedestrian time can be found out from 42.3 as $G_p = 4 + \frac{6\times3.5}{1.2}$ = 21.5 seconds

The phase diagram is shown in figure 42:7

Delay at the intersection in the east-west direction can be found out from equation 42.4 as $d_{EW} = \frac{\frac{104.5}{2}[1-\frac{23-2.4+3}{104.5}]^2}{1-\frac{433}{1637}}$ =42.57 sec/cycle

Delay in 1 hour = 42.57×$\frac{3600}{104.5}$ = 1466.6 sec/hr

Delay at the intersection in the west-east direction can be found out from equation 42.4 as $d_{WE} = \frac{\frac{104.5}{2}[1-\frac{23-2.4+3}{104.5}]^2}{1-\frac{400}{1637}}$=41.44 sec/cycle

Delay in 1 hour = 41.44×$\frac{3600}{104.5}$ = 1427.59 sec/hr

Delay at the intersection in the north-south direction can be found out from equation 42.4 as:

$$d_{NS} = \frac{\frac{104.5}{2}[1 - \frac{23-2.4+3}{104.5}]^2}{1 - \frac{367}{1637}} = 40.36 sec/cycle \tag{42.5}$$

Delay in 1 hour = 40.36×$\frac{3600}{104.5}$ = 1390.39 sec/hr

Delay at the intersection in the south-north direction can be found out from equation 42.4 as:

$$d_{SN} = \frac{\frac{104.5}{2}[1 - \frac{23-2.4+3}{104.5}]^2}{1 - \frac{417}{1637}} = 42.018 sec/cycle \tag{42.6}$$

Delay in 1 hour = 42.018×$\frac{3600}{104.5}$ = 1447.51 sec/hr

Delay at the intersection in the south-east direction can be found out from equation 42.4 as:

$$d_{SE} = \frac{\frac{104.5}{2}[1 - \frac{13-2.4+3}{104.5}]^2}{1 - \frac{233}{1637}} = 46.096 sec/cycle \tag{42.7}$$

Delay in 1 hour = 46.096×$\frac{3600}{104.5}$ = 1587.996 sec/hr

Delay at the intersection in the north-west direction can be found out from equation 42.4 as:

$$d_{NW} = \frac{\frac{104.5}{2}[1 - \frac{13-2.4+3}{104.5}]^2}{1 - \frac{196}{1637}} = 44.912 sec/cycle \tag{42.8}$$

Delay in 1 hour = 44.912×$\frac{3600}{104.5}$ = 1547.21 sec/hr

Delay at the intersection in the west-south direction can be found out from equation 42.4 as:

$$d_{WS} = \frac{\frac{104.5}{2}[1 - \frac{12-2.4+3}{104.5}]^2}{1 - \frac{215}{1637}} = 46.52 sec/cycle \tag{42.9}$$

Delay in 1 hour = 46.52×$\frac{3600}{104.5}$ = 1602.60 sec/hr

Delay at the intersection in the east-north direction can be found out from equation 42.4 as:

$$d_{EN} = \frac{\frac{104.5}{2}[1 - \frac{12-2.4+3}{104.5}]^2}{1 - \frac{187}{1637}} = 45.62 sec/cycle \tag{42.10}$$

Delay in 1 hour = 45.62×$\frac{3600}{104.5}$ = 1571.598 sec/hr

42.5 Summary

Green splitting is done by proportioning the green time among various phases according to the critical volume of the phase. Pedestrian phases are provided by considering the walking speed and start-up lost time. Like other facilities, signals are also assessed for perfomance, delay being th e important parameter used.

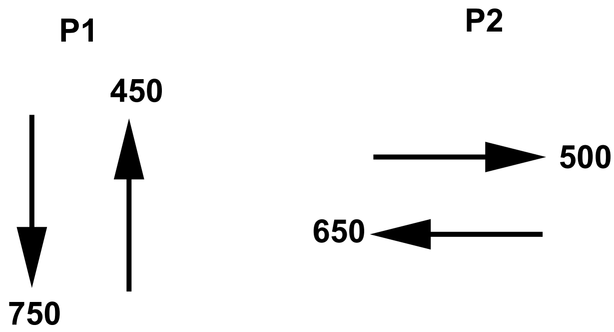

Figure 42:8: Phase diagram

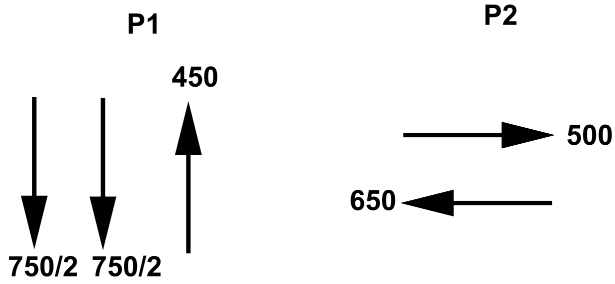

Figure 42:9: Phase diagram

42.6 Problems

1. Table shows the traffic flow for a four-legged intersection. The lost time per phase is 2.4 seconds, saturation headway is 2.2 seconds, amber time is 3 seconds per phase. Find the cycle length, green time and performance measure. Assume critical volume to capacity ratio as 0.85. Draw the phasing and timing diagrams.

From	To	Flow(veh/hr)
North	South	750
East	West	650
West	East	500

Solution

Given, saturation headway is 2.2 seconds, total lost time per phase (t_L) is 2.4 seconds, saturation flow = $\frac{3600}{2.2}$ = 1636.36 veh/hr. Phasing diagram can be assumed as in figure **??** Cycle time C can be found from 41.12 = $\frac{2\times2.4\times0.85}{0.85-\frac{750+650}{1636.36}}$ as negative. Hence the traffic flowing from north to south can be allowed to flow into two lanes. Now cycle time can be find out as $\frac{2\times2.4\times0.85}{0.85-\frac{450+650}{1636.36}}$ = 22.95 or 23 seconds. The effective green time , $t_g = C - (N \times t_L) = 23 - (2 \times 2.4) = 18.2$ seconds. This green time can be split into two phases as, For phase 1, $g_1 = \frac{450\times18.2}{1100}$= 7.45 seconds. For phase 2, $g_2 = \frac{650\times18.2}{1100}$ = 10.75 seconds. Now actual green time ,G_1 = g_1 minus amber time plus lost time. Therefore, G_1 = 7.45-3+2.4 = 6.85 seconds. G_2 = 10.75-3+2.4 = 10.15 seconds. Timing diagram is as shown in figure 42:10 Delay at the intersection in the east-west direction can be found out from equation 42.4 as $d_{EW} = \frac{\frac{23}{2}[1-\frac{10.75-2.4+3}{23}]^2}{1-\frac{650}{1636.36}}$= 4.892sec/cycle

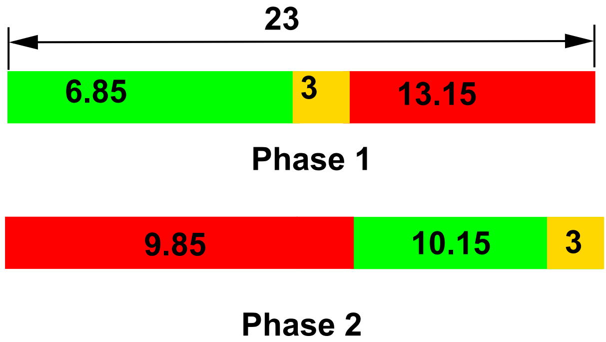

Figure 42:10: Timing diagram

Delay in 1 hour = $\times \frac{3600}{23}$ =765.704 sec/hr

Delay at the intersection in the west-east direction can be found out from equation 42.4 as $d_{WE} = \frac{\frac{23}{2}[1-\frac{10.75-2.4+3}{23}]^2}{1-\frac{500}{1636.36}} = 4.248$sec/cycle

Delay in 1 hour = $\times \frac{3600}{23}$ =664.90 sec/hr

Delay at the intersection in the north-south direction can be found out from equation 42.4 as $d_{NS} = \frac{\frac{23}{2}[1-\frac{7.45-2.4+3}{23}]^2}{1-\frac{750}{1636.36}}$=8.97sec/cycle

Delay in 1 hour = $\times \frac{3600}{23}$ = 1404 sec/hr

Delay at the intersection in the south-north direction can be found out from equation 42.4 as: $d_{SN} = \frac{\frac{23}{2}[1-\frac{7.45-2.4+3}{23}]^2}{1-\frac{450}{1636.36}}$=6.703sec/cycle

Delay in 1 hour = $\times \frac{3600}{23}$ =1049.16 sec/hr