International Journal of Scientific Engineering and Applied Science (IJSEAS) – Volume-8, Issue-2, February 2022
ISSN: 2395-3470
www.ijseas.com

Road Traffic Signal Design By Using Webster Method

Nitin Yadav[1], Parikshit Mathur[1], Piyush Kumar[1], Narad Muni Prasad[2]

[2] Associate Professor, Civil Engineering, Delhi Technological University, Delhi
[1] B.Tech Scholar, Civil Engineering ,Delhi Technological University, Delhi
Email:- piyushkumar_2k18ce079@dtu.ac.in, nitinyadav_2k18ce074@dtu.ac.in , parikshitmathur_2k18ce077 @dtu.ac.in

Abstract

Increased traffic volume at intersections has resulted in a slew of issues, including gridlock, conflict, and traffic accidents. Efficient traffic controllers at crossroads can assist in resolving these issues and ensuring continuous and efficient traffic flow. The signal time, according to the road signal, is very important because it determines how much green traffic time will be given at the intersection as well as how long the pedestrian signal should be given. Traffic volume studies are used to determine the number, movement, and classification of vehicles in a given area. This data is used to determine the normal traffic flow and the impact of heavy vehicles or pedestrians on the volume of traffic. The information gathered is converted into PCUs (Passenger Car Units). Webster's method of signal design is logical. The design is straightforward and entirely based on Webster's formulas. The complete signal cycle is thus determined by what causes the shortest complete delay in the signal.

Keywords :- Phase, PCU, Webster Method, Signal Design

1. Introduction

Urban transportation issues are well-known not only among traffic engineers, but also among people from all walks of life. Overcrowding and congested with all types of vehicles, causing numerous traffic problems and pollution, turning cities into veritable jungles. The current problem can hardly be separated from the issue of town planning and implementation. In fact, urban transportation bottlenecks have increased as cities are not designed or built to support the current population density. In cities, travel has become an inherently dangerous activity. Bidirectional freedom traffic, such as two or three wheeled vehicles, and unidirectional traffic, such as four wheelers, make up the traffic on Indian roads. Alternatively, various modes of traffic may reject you. Conflicting traffic streams are separated in space or time to prevent traffic accidents.

NECESSITY FOR TRAFFIC SIGNALS

Traffic lights are signalling devices that control traffic flow at road intersections, pedestrian crossings, and other locations. By displaying lights of a standard colour (red, amber (yellow), and green) that follow a universal colour code, traffic lights alternate the right of way given to users in the usual order of colour phases.

The green light allows traffic to proceed in the indicated direction if it is safe and there is space on the other side of the intersection.

The amber (yellow) light indicates that the signal is about to change to red. On a yellow light, some jurisdictions require drivers to stop if it is safe to do so, while others allow drivers to proceed through the intersection if it is safe to do so.

A flashing amber indicator serves as a warning.

A flashing red indication is treated as a stop sign, and a red signal prohibits any traffic from proceeding.

2. Study Area

Najafgarh is a town in the National Capital Region of Delhi, India, located in the South West Delhi district. It is one of the Southwest Delhi district's three subdivisions. Najafgarh is a small town on the outskirts of

Delhi's southwestern outskirts, near the Haryana border, about 29 kilometres (18 miles) from the city centre. It is made up of a mix of rural and urban residents from Delhi and Haryana. Najafgarh is one of the fastest growing tehsils (sub-districts) in Delhi's southwest district, owing to the abundance of freehold land. Najafgarh is best known in rural Delhi as an economic and transportation hub. Main Market, Nawada Bazaar, Anaz Mandi, Tura Mandi, and Sabzi Mandi are all major markets in Najafgarh. Inderlok, Chhawla, Khaira, Dhansa, Jharoda, Dichaon, and Nangloi are all accessible via this route. The roads from Chhawla, Dhansa, and Jharoda lead to the Haryana cities of Gurgaon, Jhajjar, and Bahadurgarh.
Below is a screenshot of a Google map. There is a consolidation and separation at the crossing of these roads because it has a cross section, and there will be no organised traffic. There may be traffic congestion and accidents as a result of this.

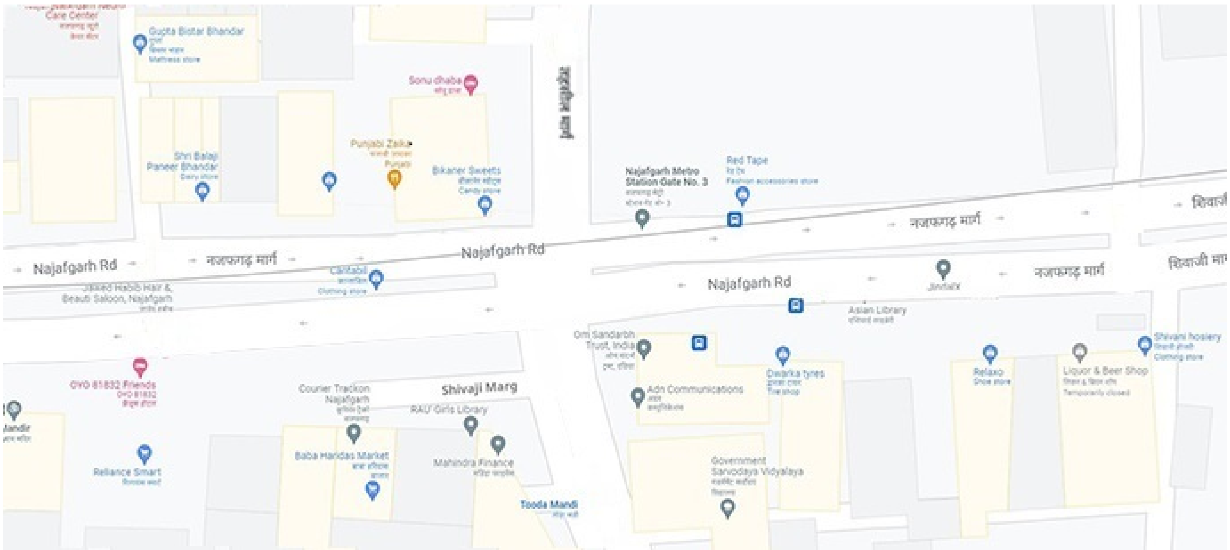


Figure 1. SCREENSHOT OF NAJAFGARH ROAD AND TEHSIL ROAD INTERSECTION

As a result, there is a critical need for traffic management as well as systematic mobility. Signal separation is required to accomplish this. Because it is a Four-road intersection, four road signals are required.
Najafgarh-Tehsil road is an intersection one leading to Tooda Mandi and Rosewood Hospital and the other road leading to Sai Baba Mandir and Najafgarh Metro Station on other hand.

3. Design of Traffic Signal Using Webster Method

Passenger Car Unit

The PCU can be thought of as a measure of a vehicle class's relative space requirement compared to that of a passenger car under a set of road, traffic, and other conditions. The PCU value of a particular vehicle class can be calculated as the ratio of a roadway's capacity when only passenger cars are present to the same roadway's capacity when only vehicles of that class are present.

From irc:106-1990, PCU factor for different types of vehicles:

S. NO.	VEHICLE TYPE	PCU FACTOR
1	2 WHEELERS	0.5
2	3 WHEELERS	1.2
3	CARS	1
4	CARGO VANS	1.4
5	TRUCK AND BUSES	2.2
6	TRACTOR	4

Methodology

Five key steps are included in the signal design technique. They consist of:

1. Designing the phase
2. Clearance and Amber Time Calculation
3. Determining the length of a cycle
4. Apportioning of Green Time
5. Assessing the above-mentioned design's performance

The goal of phase design is to divide conflicting movements in an intersection into different phases in order that movements within each phase don't conflict. A large number of phases are required to separate all of the movements without causing conflicts.

Consider a four-legged intersection with through traffic and right turns to illustrate various phase plan options.

The left turn is not taken into consideration.

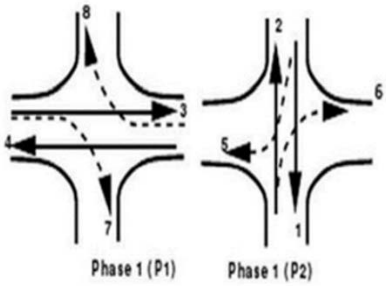


Figure 2. Four Legged Intersection

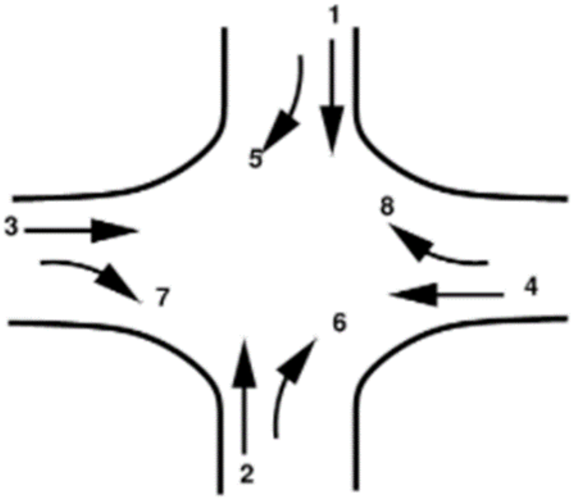


Figure 3. Two Phase Signal

Two Phase Signal

If through traffic is significant in comparison to turning movements, a two-phase system is usually used. Non-conflicting through traffic 3 and 4 are grouped together in one phase in Figure 2, while non-conflicting through traffic 1 and 2 are grouped together in the second phase.

Flows 7 and 8, on the other hand, present some conflicts in the first phase and are referred to as permitted right turns. It goes without saying that such phasing is only possible if the turning movements are small. If the turning movements are significant, on the other hand, a four-phase system is usually used.

Four phase signals

There are at least three phasing options available. The first option, for example, shows the simplest phase plan, in which the flow from each approach is combined into a single phase, avoiding all conflicts. This phase plan is ideal for urban areas where turning movements are comparable to through movements and where through and turning traffic must share the same lane. When turning movements are low, this phase plan could be very inefficient.

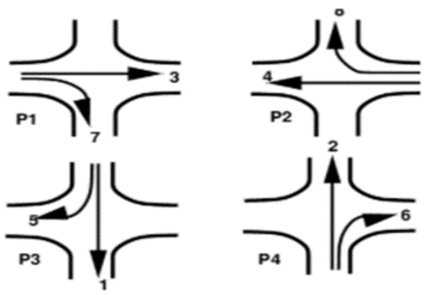


Figure 4. Four Phase Signal (OPTION 1)

A second phase plan option is to put opposing through traffic in the same phase. A third phase is formed by the non-conflicting right turn flows 7 and 8. Similarly, flows 5 and 6 are categorised as part of the fourth phase. When the intersection geometry allows for at least one lane for each movement and the through traffic volume is significant, this type of phasing is very efficient.

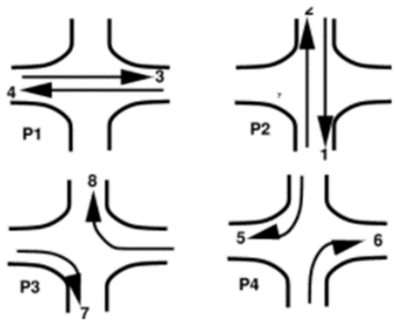


Figure 5. Four Phase Signal (OPTION 2)

The third phase plan is rarely used where traffic that is eager to flow in same direction is allowed to move.

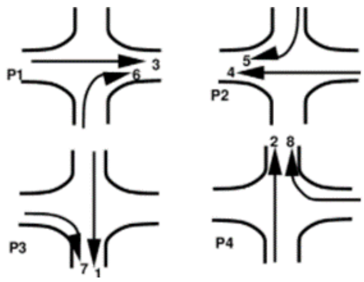
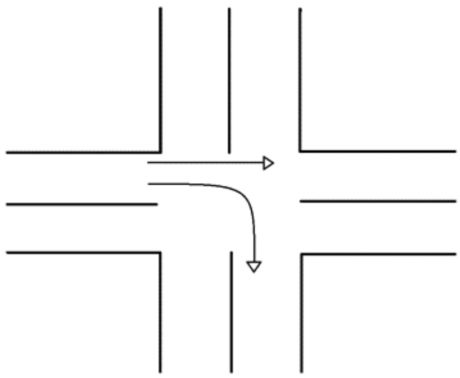


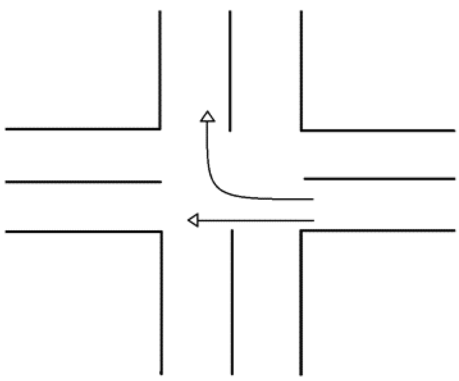
Figure 6. Four Phase Signal (OPTION 3)

Phase Designed

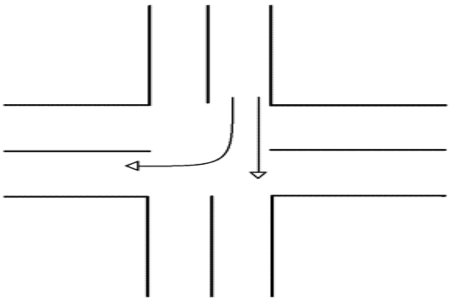
Phase 1: NAJAFGARH RD. TO SAI BABA MANDIR



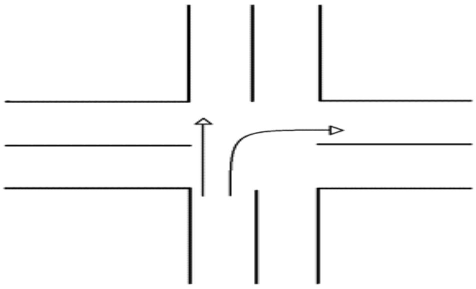
Phase 2: NAJAFGARH RD. TOWARD METRO ST.



Phase 3: TEHSIL ROAD TO KAKROLA ROAD



Phase 4: KAKROLA ROAD TO TEHSIL ROAD



Cycle Length

The average and overall delays to vehicles at a signalised intersection vary with the length of the signal cycle, according to studies. When the cycle length is short, the average delay per vehicle is high because a large proportion of vehicles may not be cleared during the first cycle, causing delays in subsequent cycles. The average delay per vehicle decreases as the signal cycle time is increased up to a certain minimum value, after which the delay begins to increase, indicating that there is an optimum signal cycle time that corresponds to the least overall delay. During the design hours, the optimum cycle time is determined by the intersection's geometric details as well as the volume of traffic approaching the intersection from all approach roads.
The time it takes for a signal to complete one full cycle of iterations, or one complete rotation through all signal indications, is known as cycle time. C_0 is the abbreviation for it. The Webster Method has been used to calculate the least total delay for vehicles at a signalised intersection. This is a sensible strategy. During the design approach, the field work entails determining

i. the saturation flow S per unit time on each approach of the intersection and
ii. the normal flow q on each approach.

According to Webster, the standard values for saturation flow, S, for widths 3 to 5.5 meters are listed in the table below.

Width in m	3.0	3.5	4.0	4.5	5.0	5.5
PCU/hr	1850	1890	1950	2250	2550	2990

And for width 5.5 to 18 meter we use the formula S= 525xW, where W is width of lane.

Formula Used

Optimum Cycle Length, C_0 = (1.5L+5) / (1−Y)
Lost time per cycle, L = 2n+R

Where, **Y**= $y_1 + y_2 + \ldots + y_n$
Y= $(q_1/s_1) + (q_2/s_2) + \ldots\ldots + (q_n/s_n)$
Effective green interval G_N = $Y_N(C_O\text{-}L)/Y$

Traffic Flow Data

The data has been collected between 13[th] December,2021 to 17[th] December,2021. Table 1 shows the traffic flow data in terms of PCU and figure 7 & figure 8 is the graphical representation of traffic flow data showing comparison of traffic on various days at different time interval and percent composition of vehicles respectively.

Table 1. Traffic Flow Data In PCU

TIME/DAY	MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	AVERAGE
8-10 AM	3179.1	3146.5	3268.2	3154.5	3161.2	**3181.9**
12-2 PM	2480.6	2329.1	2438.1	2733.5	2658.8	**2528.02**
5-7 PM	2882.8	2895.9	2810.4	2993.6	2913.9	**2899.32**

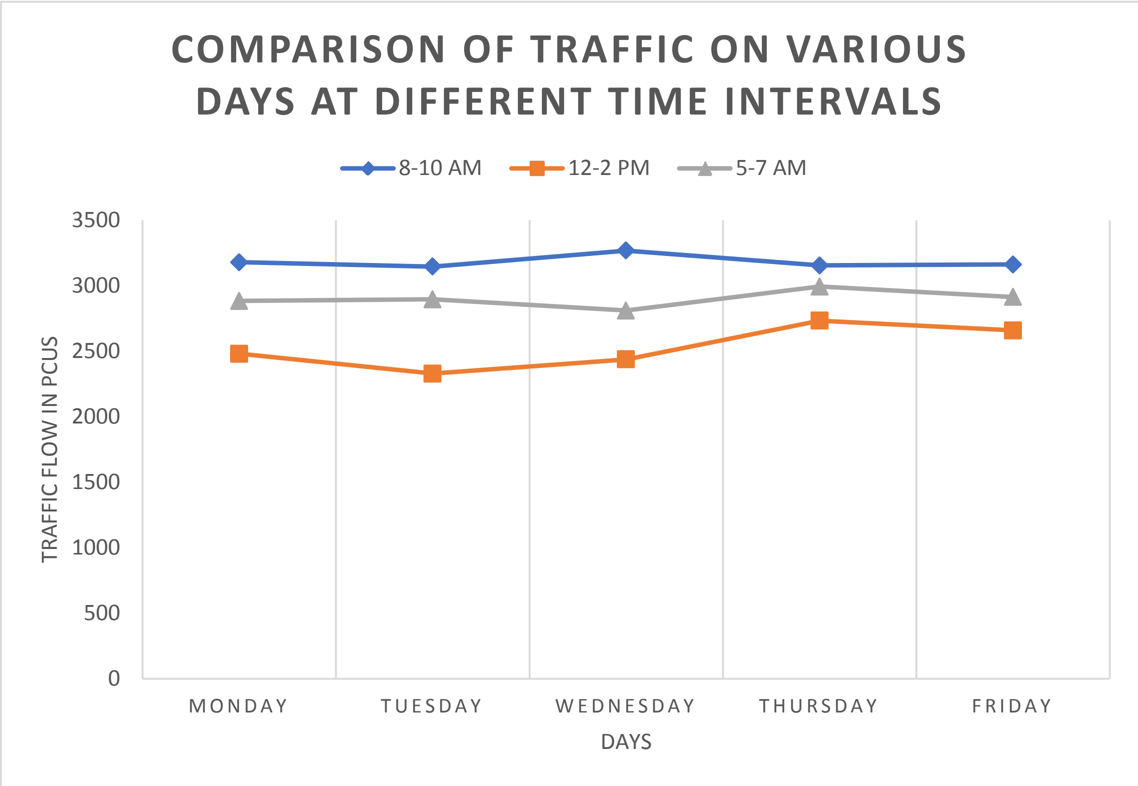


Figure 7. COMPARISON OF TRAFFIC ON VARIOUS DAYS AT DIFFERENT TIME INTERVALS

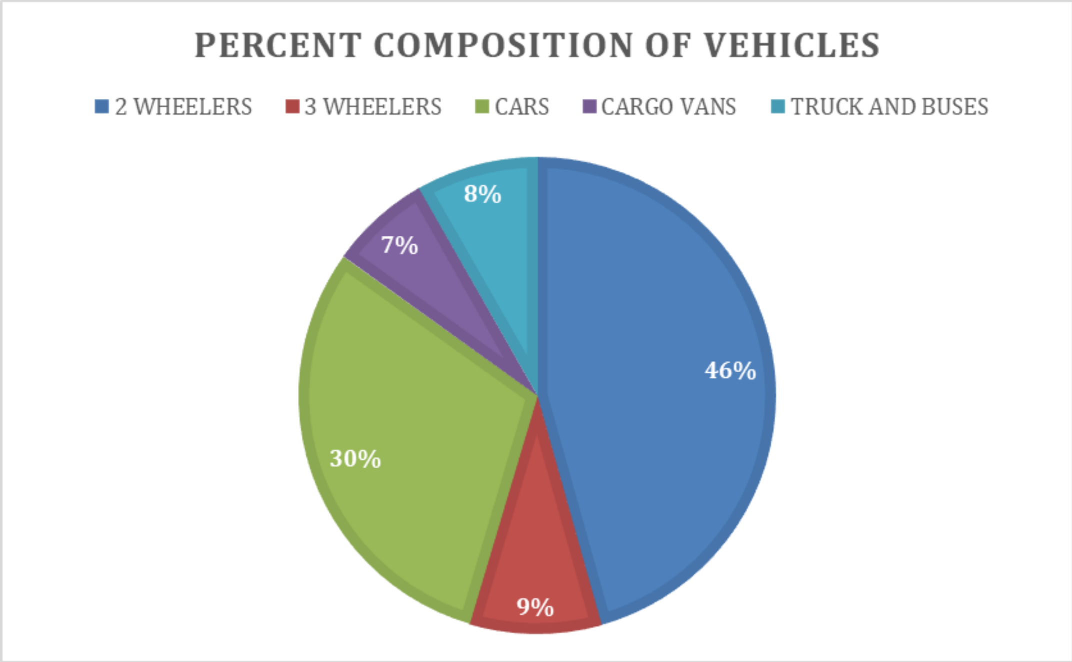


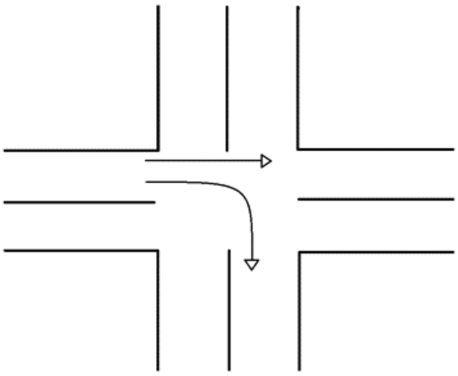
Figure 8. PERCENT COMPOSITION OF VEHICLES

Calculations

As all the lanes are 4.5m wide so,
lane saturation; S = 2250 PCU
Lost Time per cycle, L = 2n+R; where R is the all red time or red time with amber time and n is no. of phase.
n=4
R= 4.5/1.2 + 7 ~ 10 sec
L = 2 * 4 + 10 = 18 sec

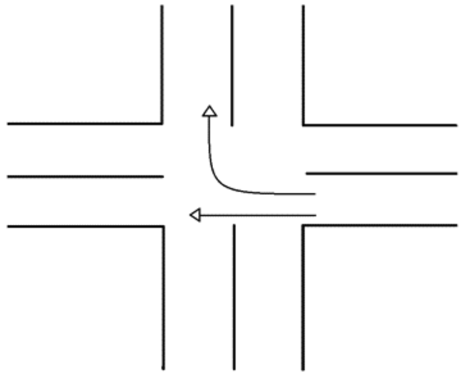
Morning Session Cycle Length

Phase 1:
NORMAL FLOW, q_1= 490.0 PCU PER HOUR



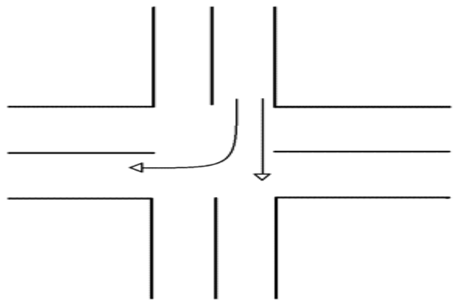
Phase 2:

NORMAL FLOW, q_2= 529.5 PCU PER HOUR

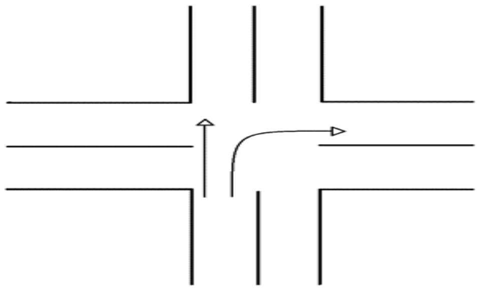


Phase 3:

NORMAL FLOW, q_3= 264.1 PCU PER HOUR



Phase 4:
NORMAL FLOW, q_4= 390.5 PCU PER HOUR



So,
q_1 = 490.0 PCU
q_2 = 529.5 PCU
q_3 = 264.1 PCU
q_4 = 390.5 PCU

$S_1 = S_2 = S_3 = S_4 = 2250$ PCU

Now we know;

Cycle length according to webster method;
$C_O = (1.5*L+5) \div (1-Y)$
$Y = y_1 + y_2 + y_3 + y_4$
$Y = (q_1/S_1) + (q_2/S_2) + (q_3/S_3) + (q_4/S_4)$
Y= 490.0/2250 + 529.5/2250 +264.1/2250 + 390.5/2250
Y= 0.218 + 0.235 + 0.117 + 0.173
Y= 0.743

Optimum Cycle Length, C_0 = (1.5L+5) / (1−Y)
C_O = (1.5*L+5)/(1-Y)
= (1.5 * 18 +5)/(1-0.743)
=125.51 sec ~ 126 sec

Green Time For Different Phases

Effective green interval; G_n = $Y_n*(C_O-L)/Y$; where n is the no. of my phases.
n=4
PHASE 1:
$G_1 = Y_1*(C_O-L)/Y$
G_1 = 0.218*(126-18)/0.743=31.3 ~ 32 sec

PHASE 2:
$G_2 = Y_2*(C_O-L)/Y$
G_2 = 0.235*(126-18)/0.743=33.8 ~ 34 sec

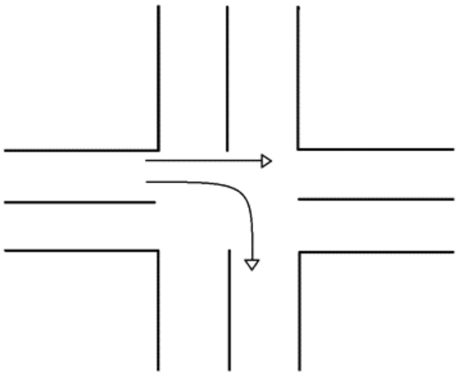
PHASE 3:
$G_3 = Y_3*(C_O-L)/Y$
G_3 = 0.117*(126-18)/0.743=16.8 ~ 17 sec

PHASE 4:
$G_4 = Y_4*(C_O-L)/Y$
G_4 = 0.173*(126-18)/0.743=24.9 ~ 25 sec

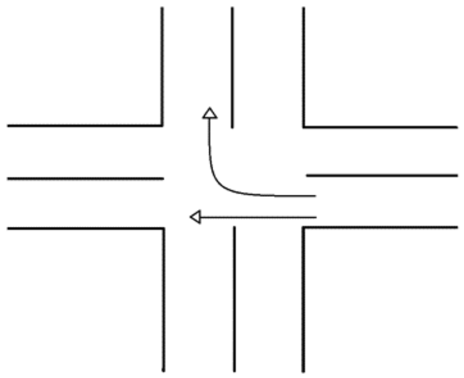
As we know pedestrian time(All Red time); R = 10 sec
Total Amber time= $C_O - G_1 - G_2 - G_3 - G_4$ -R =126-25-34-17-32-10 = 8 sec
Amber time per phase = 8/n = 8/4 = 2 sec

Afternoon Cycle Length

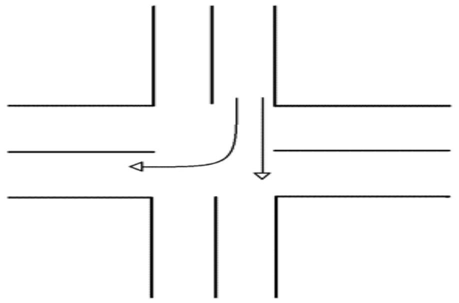
Phase 1:
NORMAL FLOW, q_1= 406.2 PCU PER HOUR



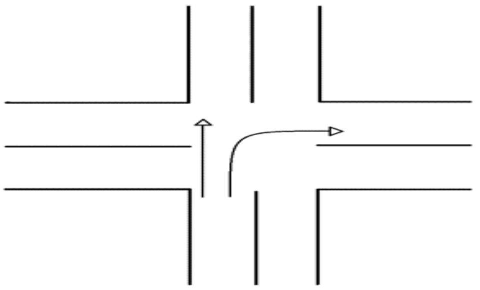
Phase 2:
NORMAL FLOW, q_2= 386.0 PCU PER HOUR



Phase 3:
NORMAL FLOW, q_3= 339.4 PCU PER HOUR



Phase 4:
NORMAL FLOW, q_4= 373.5 PCU PER HOUR



So,
q1 = 406.2 PCU
q2 = 386.0 PCU
q3 = 339.4 PCU
q4 = 373.5 PCU

S1= S2= S3= S4= 2250 PCU

Now we know;
Cycle length according to webster method;
C_O= (1.5*L+5) ÷ (1−Y)
Y= y1+ y2+ y3+ y4
Y= (q1/S1) + (q2/S2) + (q3/S3) + (q4/S4)
Y= 406.2/2250 + 386.0/2250 +339.4/2250 +373.5/2250
Y= 0.181 + 0.172 + 0.151 + 0.166
Y= 0.67

Optimum Cycle Length, C0 = (1.5L+5) / (1−Y)
CO = (1.5*L+5)/(1-Y)
= (1.5 * 18 +5)/(1-0.670)
=96.96 sec ~ 97 sec

Green Time For Different Phases

Effective green interval; $\mathbf{G_n}$ = Y_n*(C_O-L)/Y; where n is the no. of my phases.
n=4

PHASE 1:
$\mathbf{G_1}$ = Y_1*(C_O-L)/Y
$\mathbf{G_1}$ = 0.181*(97-18)/0.670 =21.34 ~ 21 sec

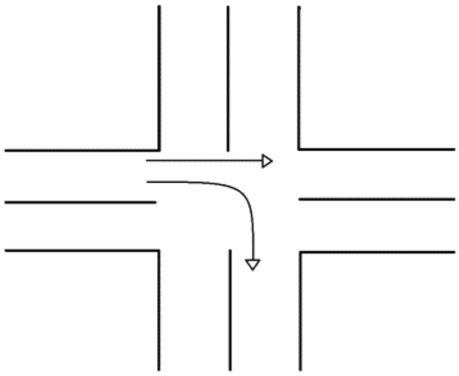
PHASE 2:
$\mathbf{G_2}$ = Y_2*(C_O-L)/Y
$\mathbf{G_2}$ = 0.172*(97-18)/0.670 =20.28 ~ 20 sec

PHASE 3:
$\mathbf{G_3}$ = Y_3*(C_O-L)/Y
$\mathbf{G_3}$ = 0.151*(97-18)/0.670=17.8~ 18 sec
PHASE 4:
$\mathbf{G_4}$ = Y_4*(C_O-L)/Y
$\mathbf{G_4}$ = 0.166*(97-18)/0.670=19.5 ~ 20 sec

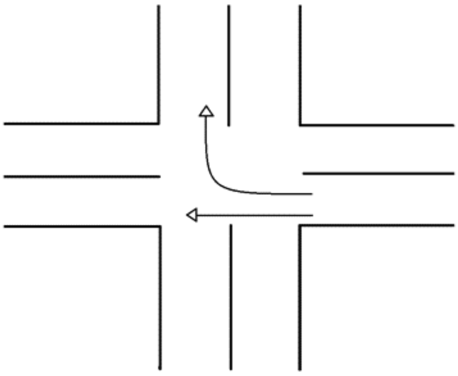
As we know pedestrian time (All Red time); R = 10 sec
Total Amber time= C_O - G_1- G_2- G_3- G_4 -R =97-21-20-18-20-10 = 8 sec
Amber time per phase = 8/n = 8/4 = 2 sec

Evening Cycle Length

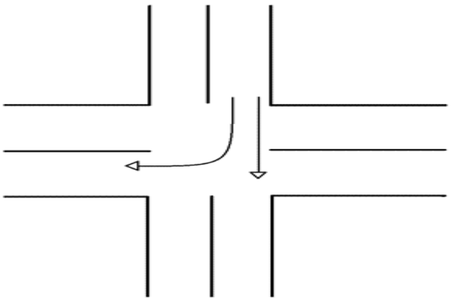
Phase 1:
NORMAL FLOW, $\mathbf{q_1}$= 418.2 PCU PER HOUR



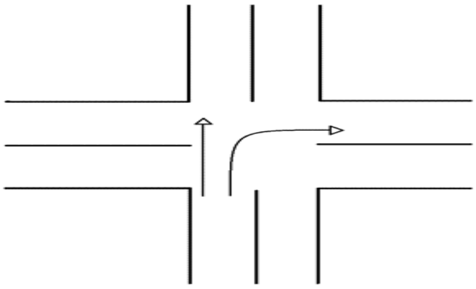
Phase 2:
NORMAL FLOW, q_2= 470.0 PCU PER HOUR



Phase 3:
NORMAL FLOW, q_3= 373.4 PCU PER HOUR



Phase 4:
NORMAL FLOW, q_4= 384.4 PCU PER HOUR



So,
q_1 = 418.2 PCU
q_2 = 470 PCU
q_3 = 373.4 PCU
q_4 = 384.4 PCU

$S_1 = S_2 = S_3 = S_4 = 2250$ PCU

Now we know;
Cycle length according to webster method;
$C_O = (1.5*L+5) \div (1-Y)$
$Y = y_1 + y_2 + y_3 + y_4$
$Y = (q_1/S_1) + (q_2/S_2) + (q_3/S_3) + (q_4/S_4)$
$Y = 418.2/2250 + 470/2250 + 373.4/2250 + 384.4/2250$
$Y = 0.186 + 0.210 + 0.166 + 0.171$

$Y = 0.733$

Optimum Cycle Length, C_0 $= (1.5L+5) / (1-Y)$

$C_O = (1.5*L+5)/(1-Y)$
$= (1.5 * 18 + 5)/ (1-0.733)$
$= 119.8$ sec ~ 120 sec

Green Time For Different Phases

Effective green interval; G_n $= Y_n *(C_O-L)/Y$; where n is the no. of my phases.
n=4

PHASE 1:
$G_1 = Y_1*(C_O-L)/Y$
$G_1 = 0.186*(120-18)/0.733 = 25.88$ ~ 26 SEC

PHASE 2:
$G_2 = Y_2*(C_O-L)/Y$
$G_2 = 0.210*(120-18)/0.733 = 29.22$ ~ 29 SEC

PHASE 3:
$G_3 = Y_3*(C_O-L)/Y$
$G_3 = 0.166*(120-18)/0.733 = 23.09$ ~ 23 SEC

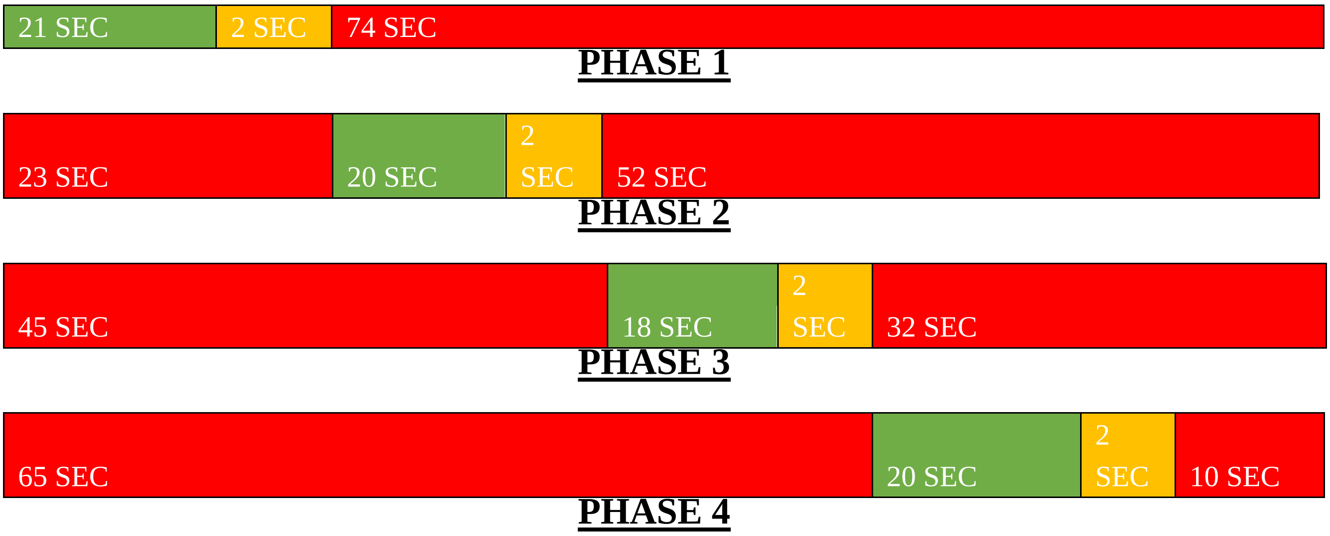
PHASE 4:
$G_4 = Y_4*(C_O-L)/Y$
$G_4 = 0.171*(120-18)/0.733 = 23.79$ ~ 24 SEC

As we know pedestrian time (All Red time); R = 10 sec
Total Amber time= $C_O - G_1 - G_2 - G_3 - G_4 - R = 120-26-29-23-24-10 = 8$ sec
Amber time per phase = 8/n = 8/4 = 2 sec

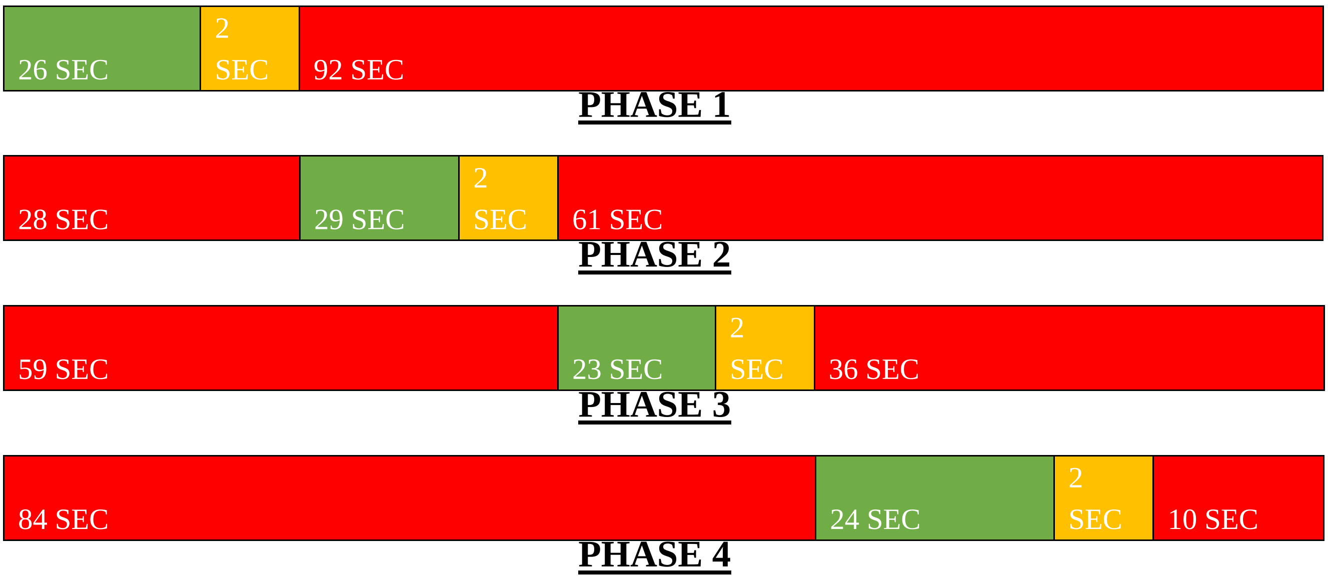
PHASE DIAGRAMS

PHASE DIAGRAM FOR MORNING CYCLE

PHASE DIAGRAM FOR AFTERNOON CYCLE



PHASE DIAGRAM FOR EVENING CYCLE



Result

Existing Cycle Length = 110 SEC

MORNING SESSION

PHASE	DESIGNED CYCLE LENGTH	DESIGNED GREEN TIME	EXISTING GREEN TIME
1	126 SEC	32 SEC	25 SEC
2		34 SEC	28 SEC
3		17 SEC	15 SEC
4		25 SEC	20 SEC

AFTERNOON SESSION

PHASE	DESIGNED CYCLE LENGTH	DESIGNED GREEN TIME	EXISTING GREEN TIME
1	97 SEC	21 SEC	25 SEC
2		20 SEC	28 SEC
3		18 SEC	15 SEC
4		20 SEC	20 SEC

EVENING SESSION

PHASE	DESIGNED CYCLE LENGTH	DESIGNED GREEN TIME	EXISTING GREEN TIME
1	120 SEC	26 SEC	25 SEC
2		29 SEC	28 SEC
3		23 SEC	15 SEC
4		24 SEC	20 SEC

Conclusion

Calculating the signal cycle based on based on Passenger Car Unit values we obtained from Traffic Survey, for Morning session the Signal Cycle Length obtained is 126 seconds, for Afternoon session the Signal Cycle Length obtained is 97 seconds and for Evening session the signal cycle length obtained is 120 seconds and we get separate green time for each phase which will help in Conflict Reduction; & Orderly movement of traffic.

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