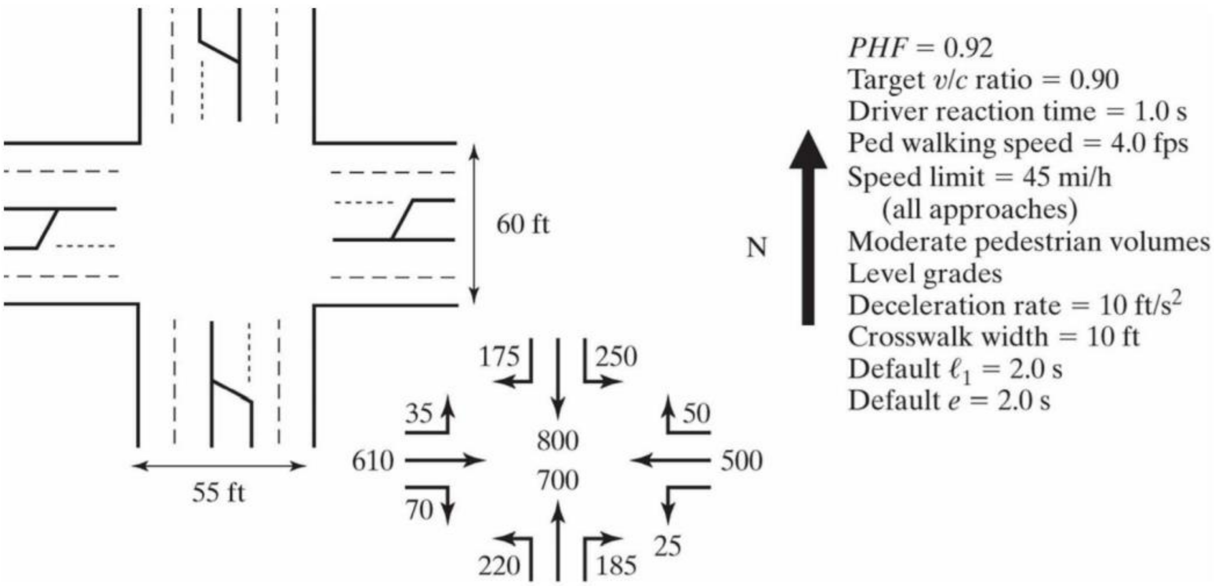
Example 2



Solution:

Step 1: Develop a phase plan, each left turn movement should be checked against the criteria

EB: $V_{LT} = 35 < 200$

$$\text{Xprod}= 35 * \left(\frac{500}{2}\right) = 8750 < 50000$$

So, no protection needed.

WB: $V_{LT} = 25 < 200$

$$\text{Xprod}= 25 * \left(\frac{600}{2}\right) = 22875 < 50000$$

So, no protection needed.

NB: $V_{LT} = 250 > 200$

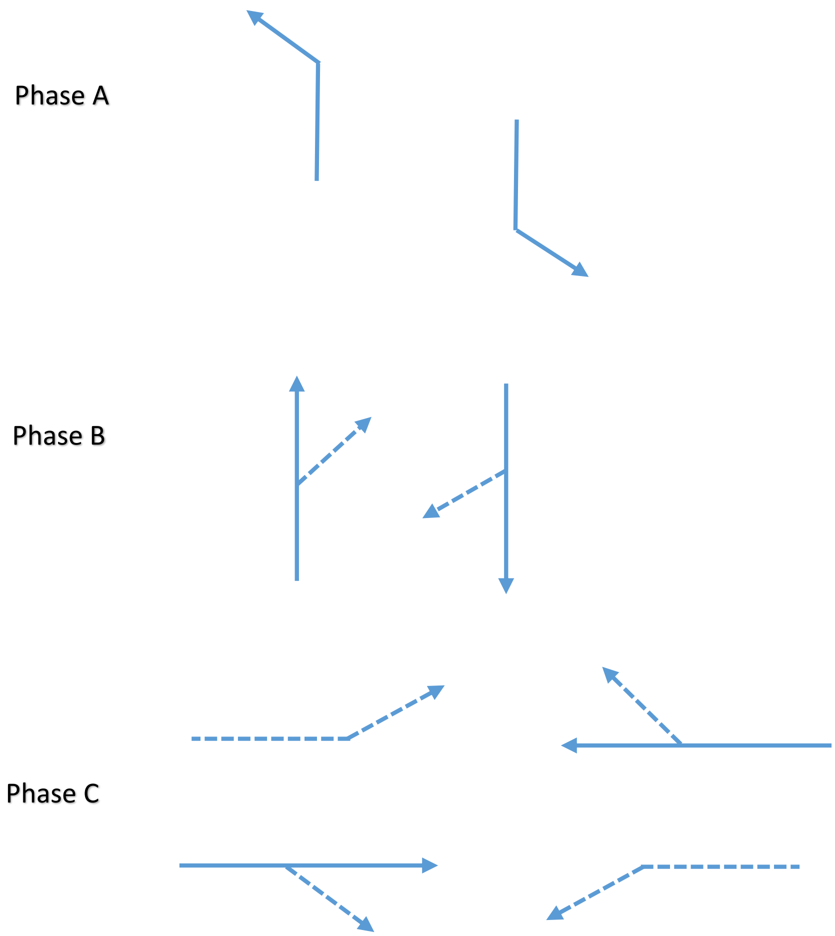
So, protection needed.

SB: $V_{LT} = 220 > 200$

So, protection needed.

Based on the above;

The NB and SB left turns require a protected phase, so an exclusive left turn phase will be used on the N-S arterial. A signal phase using permitted left turns will be used on the E-W arterial.

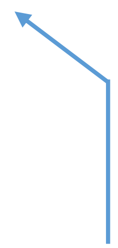
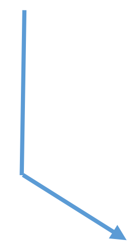
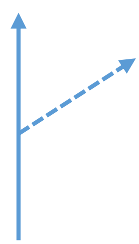
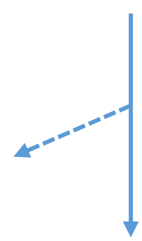
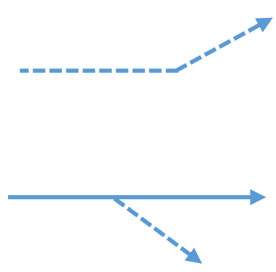
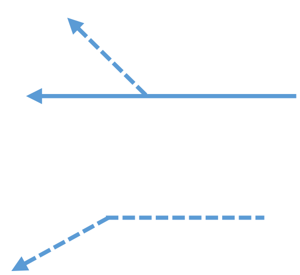


Step 2: Convert volumes to through vehicle equivalent

Approach	Movement	Volume(veh/hr)	Equivalent	Volume (veh/hr)	Lane group volume (tvu/h)	Vol/lane (tvu/hr/ln)
EB	L T R	35 610 70	4.00 1.00 1.32	140 610 92	140 702	140 351
WB	L	25	5.15	128	128	128

	T R	500 50	1.00 1.32	500 66	566	283
NB	L T R	220 700 185	1.05 1.00 1.32	231 700 244	231 944	231 472
SB	L T R	250 800 175	1.05 1.00 1.32	263 800 231	263 1031	263 516

Step 3: Determine the critical lane volumes

	Ring 1	**Ring 2**	**Critical Volume**
Phase A			231 or 263 V_{cA}=263 tuv/hr
Phase B			472 or 516 V_{cB}= 516 tvu/hr
Phase C			140, 351,283,or 128 V_{cC}= 351 tvu/hr

Total critical volume V_c= 263+516+351 = 1130 tvu/hr

Step 4: Determine Yellow and All –Red Intervals

$Y_{A,\,B,\,C}=1.0+\frac{1.47\times 45}{(2\times 10)+(0)}=4.3\ sec.$

The width of the N-S street is 55ft, and the width of the E-W street is 60ft.

The width of a crosswalk is 10ft. During the N-S left turn phase, it will be assumed that a vehicle must clear the entire width of the E-W artery.

Thus, for phase A, the width to be cleared (P) is: 60+10=70 ft.

For phase B, it is also 60+10= 70 ft.

For phase C, the distance to be cleared is 55+10=65ft

Thus,

$ar_{A,\,B}=\frac{70+20}{1.47*45}=1.4 sec.$

$ar_{C}=\frac{65+20}{1.47*45}=1.3 sec.$

Where 20ft is assumed length of a typical vehicle.

Step 5: Determine the lost times

The lost time l_2 and e are both default values of 2 sec.

$Y_{A,B}=t_{LA,B}$=4.3+1.4= 5.7sec.

$Y_C=t_C$= 4.3+1.3=5.6 sec.

Based on this, the total lost time per cycle, L=5.7+5.7+5.6=17.0 sec.

Noting $Y_{A,\,B}$ occurs twice, at the end both phases A and C.

Step 6: Determine the desirable cycle length

The desirable cycle length is found using equation below:

$$C_{des} = \frac{17}{1-(\frac{1130}{1615*0.92*0.9})} = 109.7\ sec.$$

A cycle length of 110 sec. would be selected.

Step 7: Allocate effective green to each phase

In a cycle length of 110 sec. with 17 sec. of lost time per cycle, amount of effective green that must be allocated to the three phases is 110-17 =93 sec.

The effective green time is allocated in proportion to the phase critical –lane volumes:

Thus; g_A=93 $\times \left(\frac{263}{1130}\right) = 21.6\ sec.$

g_B=93 $\times \left(\frac{516}{1130}\right) = 42.5\ sec.$

g_C=93 $\times \left(\frac{351}{1130}\right) = 28.9\ sec.$

The cycle length is now checked to ensure that the sum of all effective green times and the lost time equal 110 sec.

21.6+42.5+28.9+17.0=110 OK

Note that when default values for l_1 and e (both 2 sec.) are used, actual green times, G, equal effective green, g.

G_A=21.6 sec.

G_B=42.5 sec.

G_C=28.9 sec.

Step 8: Check for pedestrian requirements

Note the pedestrians will be permitted to cross the E-W artery only during phase B. Pedestrian will cross the N-S artery during phase C. The number of pedestrians per cycle for all crosswalks is the default pedestrian volume for moderate activity, 200 peds/hr, divided by the number of cycles in an hour (3600/110 = 32.7 cycles/hr). Thus N_{ped}=200/32.7 = 6.1 peds/cycle. Required pedestrian green times are:

G_{pB}=3.2+ (0.27*6.1) + (60/4.0) = 48>2 sec. ok

G_{pC}= 3.2+ (0.27*6.1) + (55/4.0) = 34.5 sec. ok

The minimum requirements are compared to the sum of the green, yellow, and all red times provided for vehicles:

G_{pB}=19.8 sec.< G_B+Y_B = 42.5+5.7 = 48.2 sec. ok

G_{pC}= 18.6 sec. < G_C+ Y_C = 28.9 +5.6 = 34.5 sec. ok

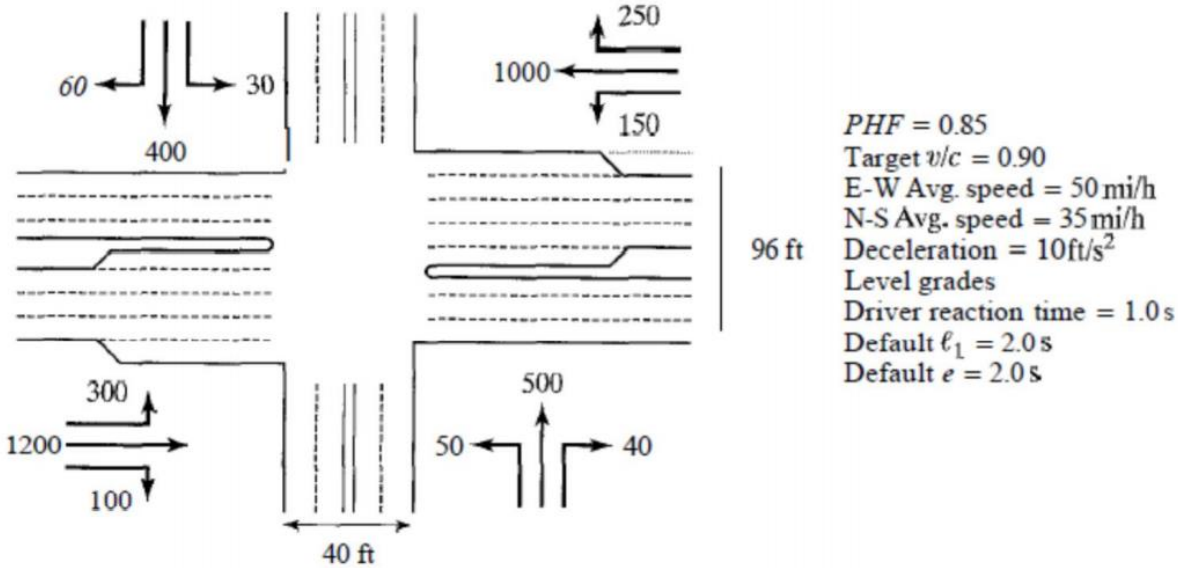
Therefore no changes on signal timing are required to accommodate pedestrians safely.

For major arterials crossing, pedestrian signal would normally be provided. During phase A, all pedestrian signals would indicate “DON, T WALK”. During phase B, the pedestrian clearance interval (the flashing DON, T WALK) would be L\S_p or 60\4.0 = 15.0 sec.

The WALK interval is whatever time is left in G+Y, (or G+y, or G) counting from the end of Y (or y or G): using G+Y, 48.2 – 15.0 = 33.2sec.

During phase C, L/S_p is 55\4.0 = 13.8 sec., and the WALK interval would be 34.5-13.8 = 20.7 sec.

Example 3



Solution:

Step 1: Develop a phase plan, each left turn movement should be checked against the criteria

EB: $V_{LT} = 300 > 200$ veh/hr

So, protection needed.

WB: $V_{LT} = 150 < 200$ veh/hr

$$\text{Xprod} = 150 * \left(\frac{1200}{3}\right) = 60000 > 50000$$

So, protection needed.

NB: $V_{LT} = 50 < 200$ veh/hr

$$\text{Xprod} = 50 * \left(\frac{400}{2}\right) = 10000 < 50000$$

So, protection are not needed.

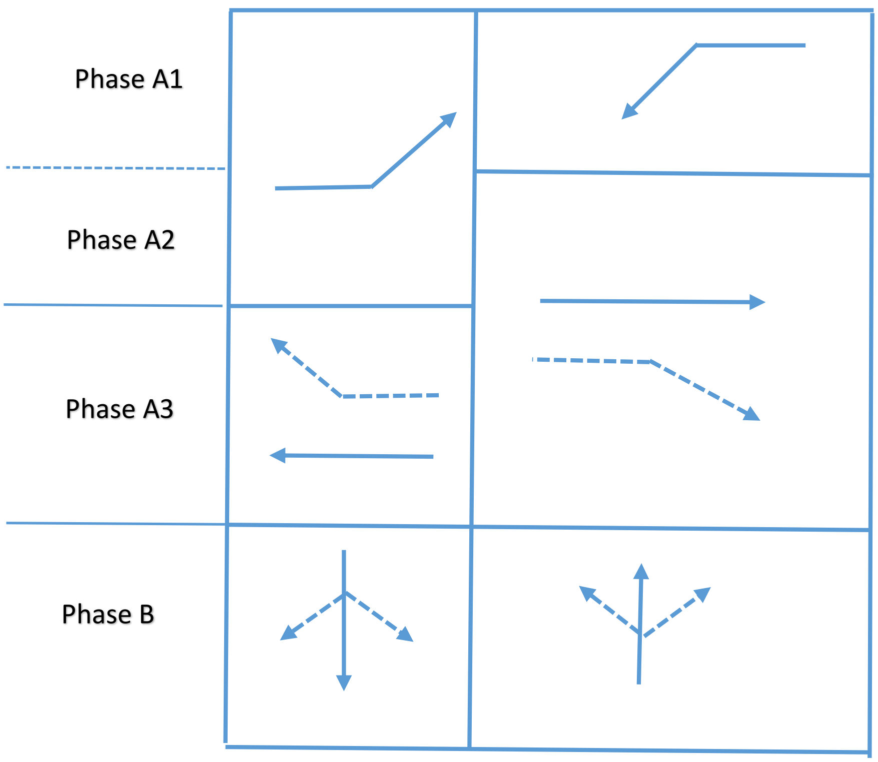
SB: $V_{LT} = 30 < 200$

Xprod= $30 * \left(\frac{500}{2}\right) = 7500 < 50000$

So, protection are not needed.

Based on the above;

The E-W approaches have LT lanes, and protected left turns are needed on both approaches. Because the LT volumes EB and WB are very different (300 veh/hr versus 150 veh/hr), a phase plan that splits the protected LT phases would be advisable. An exclusive LT phase followed by a leading green for the EB direction, will be employed for E-W artery.



Step 2: Convert volumes to through vehicle equivalent

Approach	Movement	Volume(veh/hr)	Equivalent	Volume (veh/hr)	Lane group volume (tvu/h)	Vol/lane (tvu/hr/ln)
EB	L T R	300 1200 100	1.05 1.00 1.18	315 1200 118	315 1200 118	315 400 118
WB	L T R	150 1000 250	1.05 1.00 1.18	158 1000 295	158 1000 295	158 334 295
NB	L T R	50 500 40	3.00 1.00 1.18	150 500 47	697	349
SB	L T R	30 400 60	4.00 1.00 1.18	120 400 71	591	296

Step 3: Determine the critical lane volumes

	Ring 1	Ring 2	Critical Volume
Phase A1	315	158	315+334 = 649 Or 158+400 = 558 V_{cA}=649 tvu/hr
Phase A2		400 118	
Phase A3	295 334		
Phase B	296	349	296 or 349 V_{cB}= 349 tvu/hr

Total critical volume V_c= 649+349 = 998 tvu/hr

Step 4: Determine Yellow and All –Red Intervals

Percentile speeds are estimated from the measured average speeds given:

S_{85EW}=50+5= 55 mile /hr

S_{15EW}=50-5= 45 mile /hr

S_{85NS}=35+5= 40 mile /hr

S_{15NS}=35-5= 30 mile /hr

Then:

$Y_{A1,\ A2,\ A3}=1.0+\frac{1.47\times 55}{(2\times 10)+(0)}=5.0\ sec.$

$Y_B=1.0+\frac{1.47\times 40}{(2\times 10)+(0)}=3.9\ sec.$

$ar_{A1,A2,A3}=\frac{40+20}{1.47*45}=0.9 sec.$

$ar_B=\frac{96+20}{1.47*30}=2.6 sec.$

Where 20ft is assumed length of a typical vehicle.

Step 5: Determine the lost times

Because the problem statement specifies the default values of 2.0sec. each for start-up lost time and extension of effective green into yellow and all-red intervals, the total lost time in each phase, t_L is equal to the sum of the yellow and all –red intervals, Y. Thus:

$t_{LA1/A2}$= $Y_{A1/A2}$=5.0 + 0.9 = 5 sec.

t_{LA3}= Y_{A3}= 5.0+0.9 = 5.9 sec.

t_{LB}=Y_B=3.9+ 2.6= 6.5 sec.

Total lost time per cycle,

L= 5.9+5.9+6.5= 18.3 sec.

Step 6: Determine the desirable cycle length

The desirable cycle length is found using equation below:

$$C_{des} = \frac{18.3}{1-\left(\frac{998}{1615*0.85*0.9}\right)} = 95.3\ sec.$$

A cycle length of 100 sec. would be selected.

Step 7: Allocate effective green to each phase

In a cycle length of 100 sec. with 18.3 sec. of lost time per cycle, amount of effective green that must be allocated to the phases is 100-18.3 =81.7 sec.

Note that in allocating green to the critical path, phases A1 and phase A2 are treated as a single segment.

g_{A1+A2}= 81.7 $*(\frac{315}{998})$ = 25.8 sec.

g_{A3}= 81.7 $*(\frac{334}{998})$ = 27.3 sec.

g_B= 81.7 $*(\frac{349}{998})$ = 28.6 sec.

The specific lengths of phases A1 and A2 are determined by fixing the ring 2 transition between them. This requires consideration of non-critical path through combined phase A, which occurs on ring 2. The total length of combined Phase A is the sum of g_{A1+A2} and g_{A3}:

25.8+27.3= 53.1 sec.

The ring 2 transition is based on the relative values of the lane volumes for phase A1 and the combined phase A2/A3, or:

g_{A1}= 53.1*($\frac{158}{158+400}$) =15.0 sec.

By implication, phase A2 is the total length of combined phase A minus the length of phase A1 and phase A3:

g_{A2} = 53.1-15.0-27.3= 10.8 sec.

With the assumption of default values for l_2 (2.0sec.) and e =2.0 sec., actual green times are equal to effective green times (numerically, although they do not occur simultaneously):

G_{A1}= 15.0 sec.

G_{A2}= 10.8 sec.

$Y_{A1/A2}$ = 5.9 sec.

G_{A3}= 27.3 sec.

Y_{A3} = 5.9 sec.

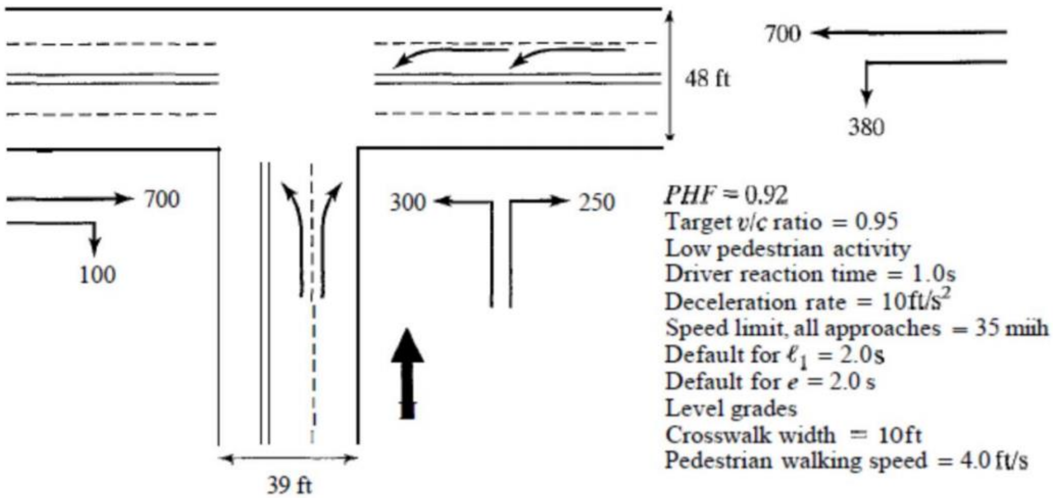
G_B= 28.6 sec.

Y_B = 6.5 sec.

C = 100.0 sec.

There is no step 8 in this example because there are no pedestrians at this intersection and therefore, no pedestrian requirements to be checked.

Example 4

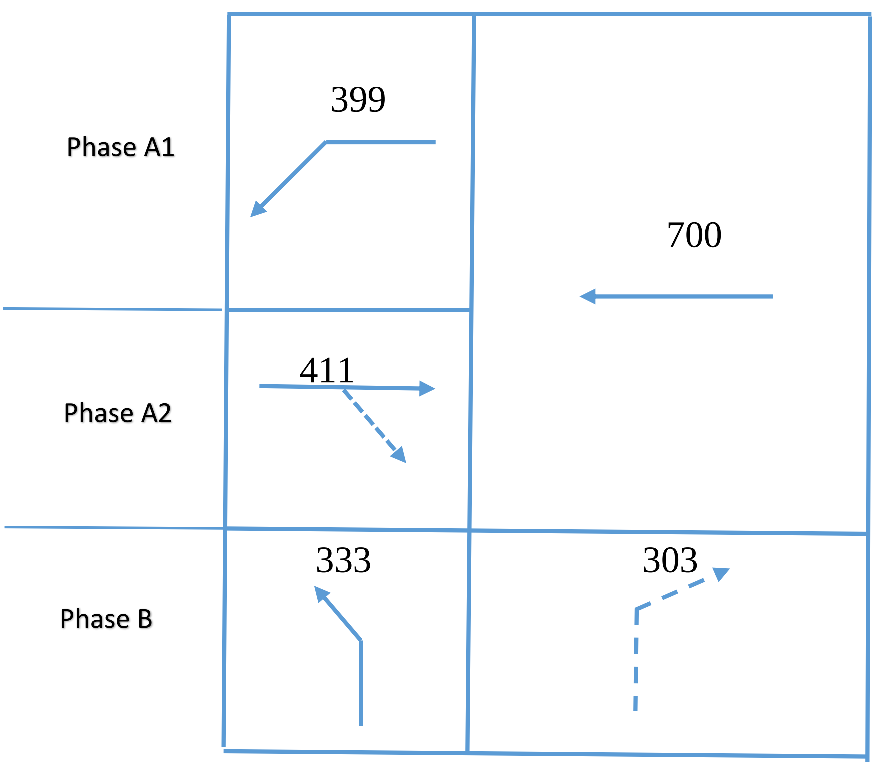


Solution:

Step 1: Develop a phase plan, each left turn movement should be checked against the criteria

WB: $V_{LT} = 300 > 200$ veh/hr

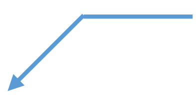
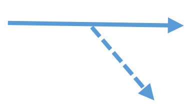
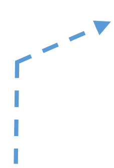
So, protection needed. There is no EB or SB left turn. And the NB left turn is unopposed. So the necessary providing phase would be to use a leading WB green with no logging EB green.



Step 2: Convert volumes to through vehicle equivalent

Approach	**Movement**	**Volume(veh/hr)**	**Equivalent**	**Volume (veh/hr)**	**Lane group volume (tvu/h)**	**Vol/lane (tvu/hr/ln)**
EB	T R	700 100	1.00 1.21	700 121	821	411
WB	L T	380 700	1.05 1.00	399 700	399 700	399 700
NB	L R	300 250	1.10 1.21	330 303	330 303	330 303

Step 3: Determine the critical lane volumes

	Ring 1	**Ring 2**	**Critical Volume**
Phase A1	399 	700 	399+ 411=810 tvu/hr Or 700 tvu/hr V_{cA}= 810 tvu/hr
Phase A2	411 		
Phase B	333 	304 	330 or 303 V_{cB}= 351 tvu/hr

Total critical volume V_c= 810+330 = 1140 tvu/hr

Step 4: Determine Yellow and All –Red Intervals

$Y_{A1,\ A2,\ B}=1.0+\frac{1.47\times35}{(2\times10)+(0)}=3.6\ sec.$

Thus,

$ar_{A1,\ A2}=\frac{39+20}{1.47*35}=1.1sec.$

$ar_B=\frac{48+20}{1.47*35}=1.3sec.$

Where 20ft is assumed length of a typical vehicle.

Step 5: Determine the lost times

The lost time l_2 and e are both default values of 2 sec.

$Y_{A1}=t_{LA1}$=3.6+1.1= 4.7sec.

$Y_{A2}=t_{LA2}$= 3.6+1.1=4.7 sec.

$Y_B=t_{LB}$= 3.6+1.3=4.9 sec.

Based on this, the total lost time per cycle, L=4.7+4.7+4.9=14.3 sec.

Step 6: Determine the desirable cycle length

The desirable cycle length is found using equation below:

$$C_{des}=\frac{14.3}{1-(\frac{1140}{1615*0.92*0.95})}=74.5\ sec.$$

A cycle length of 75 sec. would be selected.

Step 7: Allocate effective green to each phase

In a cycle length of 75 sec. with 14.3 sec. of lost time per cycle, amount of effective green that must be allocated to the three phases is 75-14.3 =60.7 sec.

The effective green time is allocated in proportion to the phase critical –lane volumes:

Thus; $g_{A1}=60.7 \times \left(\frac{399}{1140}\right) = 21.2\ sec.$

$g_{A2}=60.7 \times \left(\frac{411}{1140}\right) = 21.9\ sec.$

$g_{B}=60.7 \times \left(\frac{330}{1140}\right) = 17.6\ sec.$

Note that when default values for l_1 and e (both 2 sec.) are used, actual green times, G, equal effective green, g.

$G_{A1}=21.2\ sec.$

$G_{A2}=21.9\ sec.$

$G_{B}=17.6\ sec.$

Step 8: Check for pedestrian requirements

Although there is low pedestrian activity at this intersection, pedestrian must still be safety accommodated by signal phasing.

It will be assumed the pedestrians cross N-S Street only during phase A2 and that pedestrians crossing the E-W Street will use phase B.

The number of pedestrians per cycle for all crosswalks is the default pedestrian volume for moderate activity, 50 peds/hr, divided by the number of cycles in an hour (3600/75 = 48 cycles/hr). Thus N_{ped}=50/48 = 1.0 peds/cycle. Required pedestrian green times are:

G_{pA2}=3.2+ (0.27*1) + (39/4.0) = 13.2sec.

G_{pB}= 3.2+ (0.27*1) + (48/4.0) = 15.5 sec.

The minimum requirements are compared to the sum of the green, yellow, and all red times provided for vehicles:

G_{pA2}=13.2 sec.< G_{A2}+Y_{A2} = 21.9+4.7 = 26.6 sec. ok

G_{pB}= 15.5 sec. < G_B+ Y_B = 17.6 +4.9 = 22.5 sec. ok

Therefore no changes on signal timing are required to accommodate pedestrians safely.

It is noticed that pedestrians could be entirely accommodated by green and that it is not necessary in this case to allow pedestrians in the cross walk during the y and ar interval.