Cycle Time or Cycle length

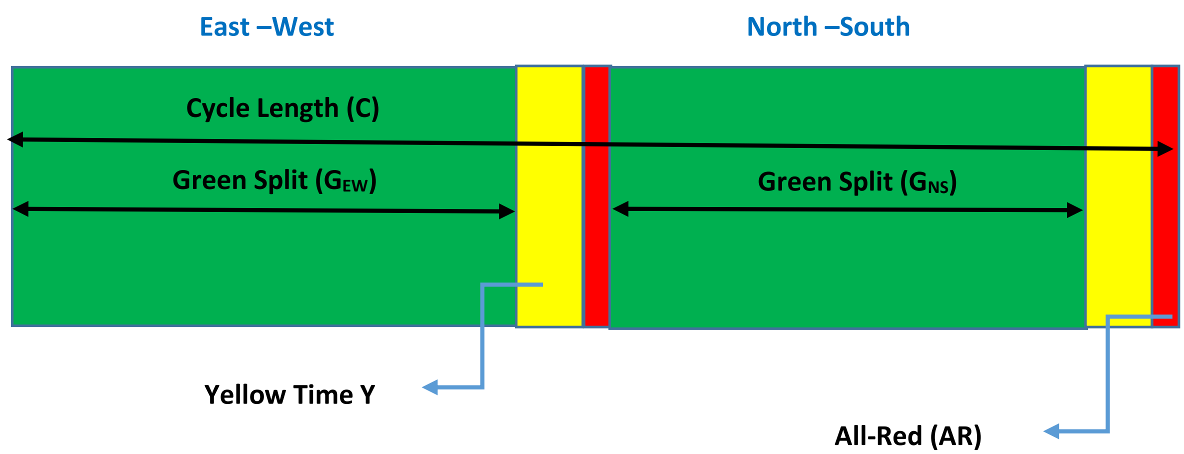
Time required for a complete sequence of a signal indications

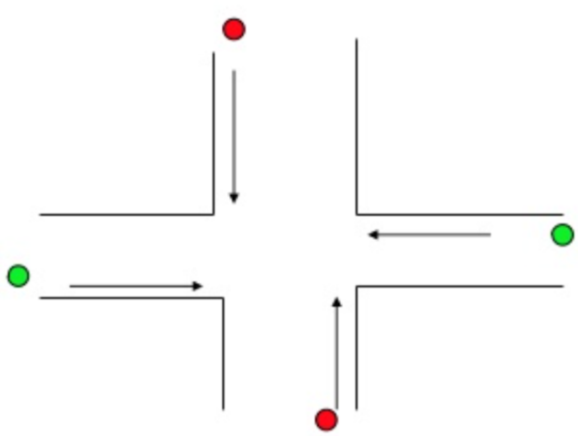
Phase

The part of a cycle allocated to any combination of traffic movements receiving right-of-way simultaneously during one or more time intervals, consisting green, yellow (amber), and or all red.

Split

Percentage of a cycle length allocated to each of the various phases in a signal cycle.



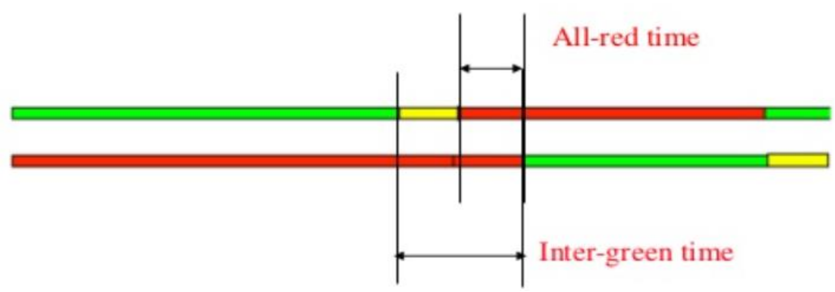


Change Interval

Thus it indicates the change from one stage to another. There are two types of intervals - change interval and clearance interval. *Change interval* is also called the yellow time indicates the interval between the green and red signal indications for an approach. *Clearance interval* is also called *all red* and is provided after each yellow interval indicating a period during which all signal faces show red and is used for clearing off the vehicles in the intersection.

All-Red (Clearance Interval)

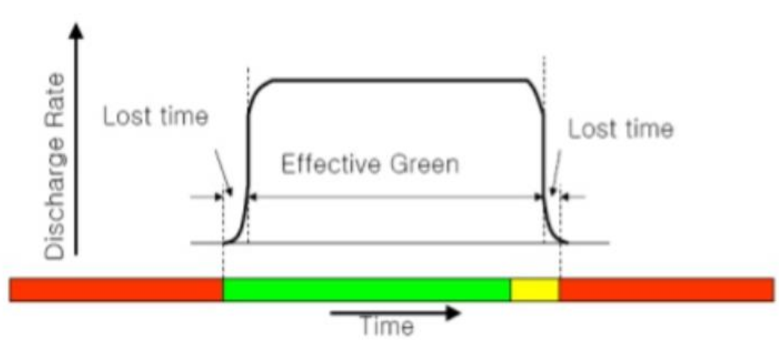
The display time of red indications for all approaches.



Effective Green (g) = Green Time +Change Interval – Lost Time

Lost time

It indicates the time during which the intersection is not effectively utilized for any movement. For example, when the signal for an approach turns from red to green, the driver of the vehicle which is in the front of the queue, will take some time to perceive the signal (usually called as reaction time) and some time will be lost before vehicle actually moves and gains speed.



Capacity

The maximum numbers of vehicles that can be expected to pass over a given roadway or a section of a roadway, in one direction during given time period and under the prevailing conditions of roadway, traffic and signalization conditions.

Saturation Flow Rate

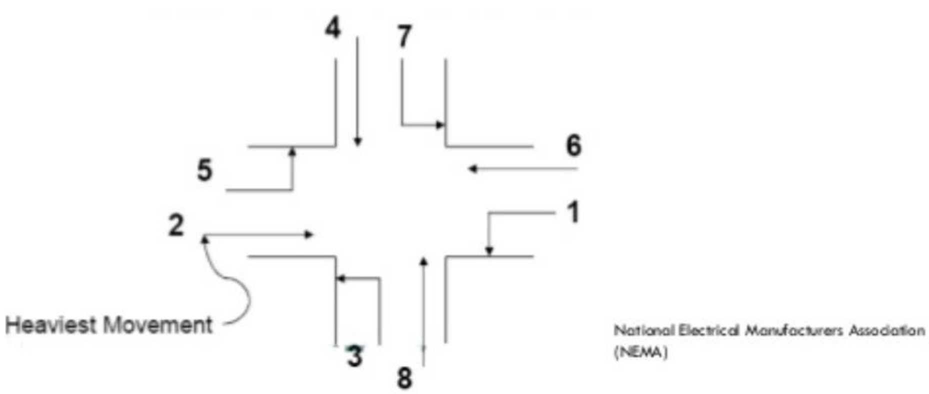
The maximum number of vehicles from a lane group that would pass through the intersection in one hour under the prevailing traffic and roadway conditions if the lane group was given a continuous green signal for that hour.

Signal Time Procedure

1. Develop a phase plan.
2. Convert volumes to through – vehicle equivalents.
3. Determine critical lane- group volumes.
4. Determine yellow and all- red intervals.
5. Determine lost times.
6. Determine cycle length.
7. Allocate effective green to each phase.
8. Check pedestrian requirements.

1. <u>Develop a phase plan</u>

Phase: The part of a cycle allocated to any combination of traffic movements receiving right-of-way simultaneously during one or more time intervals, consisting green, yellow (amber), and or all red.



Left Turn Treatments

Left turn protected should be considered if only of the following criteria is met:

- Left turn demand volume, $V_{LT} \geq 200$ veh/hour
- The cross product rule

$$xprod = V_{LT} * \left(\frac{V0}{N0}\right) \geq 50{,}000$$

Where,

V_{LT}: Left-turn flow rate, veh/hr
V0: Opposing through movement flow rate, veh/hr
N0: Number of lanes for opposing through movement

2. **Convert volumes to through – vehicle equivalents**

Through Vehicle Equivalents-Left Turn vehicles, V_{LT}

Opposing Flow V_o (veh/h)	Number of Opposing Lanes, N_o		
	1	2	3
0	1.1	1.1	1.1
200	2.5	2.0	1.8
400	5.0	3.0	2.5
600	10.0*	5.0	4.0
800	13.0*	8.0	6.0
1,000	15.0*	13.0*	10.0*
≥1,200	15.0*	15.0*	15.0*

E_{LT} for all *protected* left turns = 1.05

*The LT capacity is only available through "sneakers."

Through Vehicle Equivalents Right Turn

Pedestrian Volume in Conflicting Crosswalk, (peds/h)	Equivalent
None (0)	1.18
Low (50)	1.21
Moderate (200)	1.32
High (400)	1.52
Extreme (800)	2.14

Ex.

$$V_{RTE} = V_{RT} * E_{RT}$$

$$V_{LTE} = V_{LT} * E_{LT}$$

3. **Determine critical lane- group volumes.**

	Ring 1	Ring 2	
ϕA	231	263*	231 or 263 Vc A= 263 tvu/h
ϕB	472	516*	472 or 516 Vc B=516 tvu/h
ϕC	140 351*	283 128	140, 351, 283, or 128 Vc C=351 tvu/hr

Vc = 263+516+351 = 1,130 tvu/h

4. Determine yellow and all- red intervals

$$y = t + \frac{1.47 S_{85}}{2a + (64.4 * 0.01G)}$$

t = driver reaction time (sec)
a = deceleration rate (fps^2)
g = grade of approach (decimal)
S85 = 85th percentile speed (mph)

Guideline for Yellow Interval

Yellow time: Minimum = 3 sec
Maximum = 5 sec

- 3 sec => 16 to 56 km/h
- 4 sec => 56 to 80 km/h
- 5 sec => greater than 80 km/h

5. Determine lost times

- Default values from HCM:
  - Start-up lost time: $\ell 1$ = **2.0 s/phase**
  - Motorist use of yellow and all-red: **e = 2.0 s/phase**
- Lost time per phase
  - Clearance lost time: $\ell 2$ = **Y – e**
  - Total length of change and clearance intervals: **Y = y+ ar**
  - Total lost time per phase: **tL** = $\ell 1 + \ell 2$
- Lost time per cycle

$$L = \sum_{i}^{N} t_{Li}$$

6. Determine cycle length

- A *desirable cycle length* using default saturation flow rate (1615 vph)

$$C_{des} = \frac{L}{1 - \frac{V_c}{1615 * PHF * (v/c)}}$$

Where: C_{des} = desirable cycle length

L = total lost time per cycle, s/cycle

PHF = peak-hour factor

v/c = target v/c ratio for the critical movement in the intersection

7. Allocate effective green to each phase

- Splitting the Green
- Available effective green time in the cycle

$$g_{TOT} = C - L$$

- Effective green time for phase *i*

$$g_i = g_{TOT}\left(\frac{V_{Ci}}{V_C}\right)$$

Where:
g_i = effective green time for phase I, second
g_{TOT} = total effective green time in cycle, second
V_{ci} = critical lane volume for phase or sub-phase i, veh/h
V_C = sum of critical –lane volumes, veh/h

8. Check pedestrian requirements

$$G_p = 3.2 + \frac{L}{S_p} + (0.27 N_{ped}) \text{ for } W_E \le 10 ft$$

$$G_p = 3.2 + \frac{L}{S_p} + (2.7 \frac{N_{ped}}{W_E}) \text{ for } W_E > 10 ft$$

$$WALK_{min} = 3.2 + (0.27 N_{ped}) \text{ for } W_E \le 10 ft$$

$$WALK_{min} = 3.2 + (2.7 \frac{N_{ped}}{W_E}) \text{ for } W_E > 10 ft$$

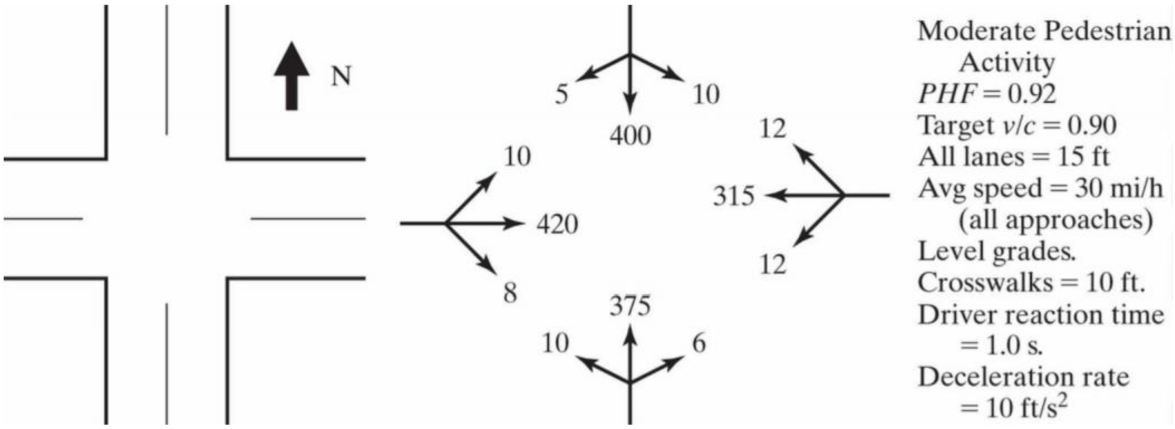
Where:
Gp = min ped crossing time, sec
3.2 = pedestrian start-up time, sec
L = length of the cross walk, ft
Sp = walking speed (4 fps)
N_{ped} = # of ped during an interval
W_E = effective crosswalk width

DON'T WALK = L/Sp

If Min. Ped Grn > Grn for φ ==> Grn for φ must be **increased**

(also increase total cycle length)

Example 1



Signal Time Procedure

1. Develop a phase plan.
2. Convert volumes to through – vehicle equivalents.
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Step .1 Develop a phase plan

Check Left turn

- to determine whether or not it needs to be protected.
- EB: $V_{LT}=35 < 200$
  - Xprod = 35*(500/2) = 8,750 < 50,000
  - No Protection needed
- WB: $V_{LT}=25 < 200$
  - Xprod = 25*(610/2) = 22,875 < 50,000
  - No Protection needed
- NB: $V_{LT}=220 > 200$
  - Protection needed
- SB: $V_{LT}=250 >200$
  - Protection needed

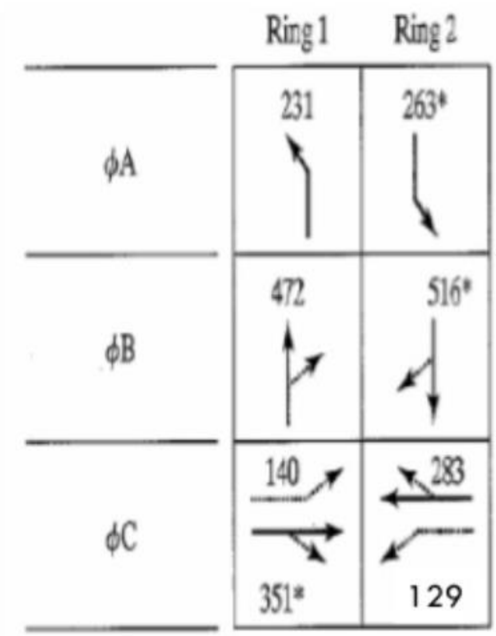
❖As a result, an exclusive left Turn on NB – SB
❖ Permitted left Turn on the EB - WB

Step 2. Convert volumes to through – vehicle equivalents

Approach	Movement	Volume (Veh/h)	Equivalent Tables 18.1, 18.2	Volume (tvu/h)	Lane Group Vol (tvu/h)	Vol/Lane (tvu/h/ln)
EB	L	35	4.00*	140	140	140
	T	610	1.00	610	702	351
	R	70	1.32	92		
WB	L	25	5.15*	129	129	129
	T	500	1.00	500	566	283
	R	50	1.32	66		
NB	L	220	1.05	231	231	231
	T	700	1.00	700	944	472
	R	185	1.32	244		
SB	L	250	1.05	263	263	263
	T	800	1.00	800	1,031	516
	R	175	1.32	231		

*Interpolated by opposing volume.

Step 3. Determine critical lane- group volumes



231 or 263
VcA= 263 tvu/h

472 or 516
VcB=516 tvu/h

140, 351, 283, or 129
VcC=351 tvu/hr

Vc = 263+516+351 = 1,130 tvu/h

Step 4. Determine yellow and all- red intervals

- S_{85} = Speed limit = 45 mph

$$y \quad A,B,C = 1.0 + \frac{1.47*45}{(2*10)+(0)} = 4.3 \quad Second$$

- The all-red interval will reflect the need to clear the full width of the street plus the width of the far crosswalk.
- Phase A ------- P =60+10=70ft
- Phase B -------- P = 60+10=70ft
- Phase C -------- P=55+10=65 ft
- Assume Vehicle length = 20 ft
- ar A,B = (70+20)/(1.47*45) = 1.4 second
- ar C = (65+20)/(1.47*45) = 1.3 second

Note: As a Speed Limit =45 mph, there will no differentiation between the S_{85} and S_{15}.

Step 5. Determine lost times

- Remember: $\ell 1$ and e are both 2.0 seconds
- Y A,B= t_L A,B = 4.3 + 1.4 = 5.7 second
- Y C= t_L C = 4.3 + 1.3 = 5.6 second
- Total lost time per cycle, L, is
- L = 5.7 + 5.7 + 5.6 = 17.0 second

Step 6. Determine cycle length

$$Cdes = \frac{17}{1-\left(\frac{1130}{1650*0.92*0.90}\right)} = \frac{17}{0.155} = 109.7\,second$$

Assuming that this is a pre-timed signal controller, a cycle length of 110 second would be selected.

Step 7. Allocate effective green to each phase

- Effective green time for all phases:
- g_{tot} = 110 – 17 = 93 second
- g_A = 93*(263/1130) = 21.6 sec
- g_B = 93*(516/1130) = 42.5 sec
- g_C = 93*(351/1130) = 28.9 sec
- Check:
  - 21.6 + 42.5 + 28.9 + 17 = 110 ------- ok

Step 8. Check pedestrian requirements

- Note: pedestrian will be permitted to cross the E-W only during phase B
- Pedestrian will cross the N-S during phase C
- Pedestrian Volume = 200 peds/h (for moderate activity)
- Number of cycles per hour = 3600/110 = 32.7 cycles/h
- Nped = 200/32.7 = 6.1 peds/cycle.
- Required pedestrian green times are:
  - Gp B = 3.2 + (60/4) + (0.27*6.1) = 19.8 second
  - Gp C = 3.2 + (55/4) + (0.27*6.1) = 18.6 second
- Compare with sum of (green, yellow, and all-red times), we get:
  - Gp B = 19.8 s < GB +YB = 42.5 + 5.7 = 48.2 s ----- ok
  - Gp C = 18.6 s < GC + YC = 28.9 + 5.6 = 34.5 s ----- ok
- Therefore, no changes to the vehicular signal timing are required to accommodate pedestrian safely

- For major arterial crossings, pedestrians 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/Sp or 60/4 = 15.0s
  - The WALK interval is whatever time is left in G+Y, counting from the end of Y: 48.2 – 15 = 33.2s
- During phase C
  - L/Sp is 55/4 = 13.8s,
  - WALK interval = 34.5 – 13.8 = 20.7s