Traffic Engineering (CIVIL-349)
Nikolas Geroliminis
Exercise 9
Traffic Signal Design
Fall 2025

École Polytechnique Fédérale de Lausanne
School of Architecture, Civil & Environmental Engineering

Step 1: Signal phasing selection

Observing the topology of the intersection, one can note that there is an exclusive lane for a protected left turn coming from the West. Moreover, it shows that, in all other approaches, the channelization does not give exclusive lanes for turning. At the same time, there is no approach coming from the North.

Table 1 shows the volumes per lane of each movement.

Movement	O → D	Lanes	Total Volume	Volume per lane
1	W → E	2	1000	500
2	W → N	1	250	250
3	E → (W,N)	2	$900 + 250$	575
4	S → (W,N,E)	3	$70 + 1100 + 80$	$416.\bar{6}$

Table 1: List of volumes per movement.

To define the best method for phasing, we will test three methods: Approach, Protected left turn, and Overlap (although not introduced in class, this refers to a phasing where a particular movement may be included in two consecutive phases).

Signal Phases	Movements	Volumes	Critical Volume
ϕ_1	4	$416.\bar{6}$	$416.\bar{6}$
ϕ_2	1,2	500,500,250	500
ϕ_3	3	575,575	575
Total			$1491.\bar{6}$

Table 2: Approach method: critical volumes.

Signal Phases	Movements	Volumes	Critical Volume
ϕ_1	4[1]	$416.\bar{6}$	$416.\bar{6}$
ϕ_2	1,3	500,500,575,575	575
ϕ_3	2	250	250
Total			$1241.\bar{6}$

Table 3: Protected left turn method: critical volumes.

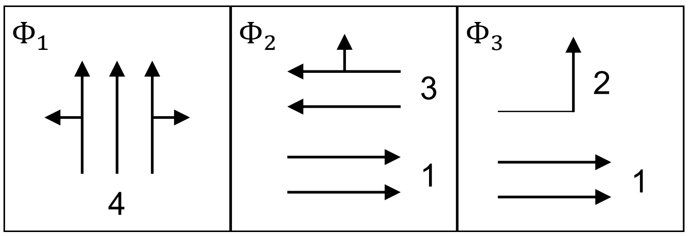
[1] Note that we did not separate the left turn here, because there is no conflicting flow coming from the North.

Note that the method with the worst total critical volume is the Approach method; this will in turn lead to the longest cycle time, and is therefore less desirable. At the same time, there is a tie between the Protected Left turn and Overlap methods. For demonstration, we will proceed with the phases for the overlap method. The figure below

Signal Phases	Movements	Volumes	Critical Volume
ϕ_1	4	$416.\bar{6}$	$416.\bar{6}$
ϕ_2	3,(1)	(500),(500),575,575	575
ϕ_3	(1),2	250,(500),(500)	250
Total			$1241.\bar{6}$

Table 4: Overlap method: critical volumes.

summarizes the choice for the phasing step, where the movement labels from Table 1 are indicated.



Step 2: Determine cycle time

The optimal cycle duration can be computed using Webster Formula.

$$C_o = \frac{1.5 \times L + 5}{1 - \sum_i y_i} \quad (1)$$

The lost time is per phase is given (4 seconds). The only remaining variables to compute are the flow/saturation flow rate for each phase. Table 5 computes the remaining variables.

Phase	Critical flow	Saturation flow	y_i
ϕ_1	$416.\bar{6}$	1800	0.2315
ϕ_2	575	1800	0.3194
ϕ_3	250	1800	0.1389

Table 5: Computation of flow/saturation rates for each phase (y_i).

Hence, the optimal cycle duration is (rounded to the next 5 seconds):

$$C_o = \frac{1.5 \times 4 \times 3 + 5}{1 - (0.2315 + 0.3194 + 0.1389)} = 74.146 \approx 75 \text{seconds}$$

Step 3: Determine green allocation

Using the information from the previous steps, we can use the following formula to compute the *effective* green time allocation of each phase.

$$g_i = \frac{y_i}{\sum_i y_i} \times (C_o - L) \tag{2}$$

Phase	y_i	g_i (rounded)
ϕ_1	0.2315	21 sec
ϕ_2	0.3194	29 sec
ϕ_3	0.1389	13 sec

Table 6: Computation of the green time allocation for each phase (g_i).

As these numbers are rounded, it is interesting to verify whether there was a change in the total green time ($C_o - L$).

$$C_o - L = 75 - 3 \times 4 = 63 = \sum_i g_i = 21 + 29 + 13 = 63 \text{ ok}$$

Step 4: Intergreen time allocation

Step 4.1: Yellow time allocation

Yellow time is defined as:

$$y = T + \frac{v}{2a + 2Gg} \tag{3}$$

Variable	Description	Value
T	Driver reaction time	1.4 seconds
v	Speed of the vehicle	40mph $\approx$ 58.67ft/s
a	Deceleration rate speed	11ft/s^2
G	Inclination (slope)	0

Table 7: Variable description for yellow time computation.

Note that yellow time is the same for all phases. The final value is:

$$y = T + \frac{v}{2a + 2Gg} = 1.4 + \frac{58.67}{2 \times 11} = 4.07 \rightarrow 4.5 \text{ seconds} \tag{4}$$

Step 4.2: All red time allocation

We can compute 'All red time' using the following equation:

$$AR = \frac{w + l}{v} \tag{5}$$

Variable	Description	Value
w	Width of the intersection	12ft/lane and 10ft/crosswalk
l	Length of one vehicle	20ft
v	Speed of the vehicle	40mph $\approx$ 58.67ft/s

Table 8: Variable description for 'all red' time computation.

As the number of lanes is different in both direction, width of the road (w) is also different. Two different all red times are computed:

Phase Φ_1: Vehicles have to cross 5 lanes and 2 crosswalks:

$$AR_1 = \frac{5 \times 12 + 2 \times 10 + 20}{58.67} = 1.7 \rightarrow 2 \text{ seconds} \tag{6}$$

Phase Φ_2 and phase Φ_3: Vehicles have to cross 3 lanes and 2 crosswalks:

$$AR_{2,3} = \frac{3 \times 12 + 2 \times 10 + 20}{58.67} = 1.3 \rightarrow 1.5 \text{ seconds} \tag{7}$$

Summary:

	Phase 1	Phase 2-3
Yellow	4.5	4.5
All Red	2	1.5
Total lost time	6.5	6

Step 5: Pedestrian Requirement (minimum green time)

The minimum green time for pedestrians is computed using the following equation:

$$G_p = 3.2 + \frac{d}{v_{ped}} + 0.27 \times N_{ped} \tag{8}$$

Variable	Description	Value
d	Length of the crosswalk (not width)	12ft/lane
v_{ped}	Speed of pedestrians	4ft/s
N_{ped}	Number of pedestrians per direction	5

Table 9: Variable description for the computation of the minimum green time for pedestrians.

Note that the length of the crosswalk varies depending on the road pedestrians have to cross.

During phase ϕ_1, pedestrians are allowed to cross in the North-South (and South-North) direction, i.e., they have to cross 5 lanes.

$$G_{p1} = 3.2 + \frac{5 \times 12}{4} + 0.27 \times 5 = 19.55 \approx 20 \text{ seconds} \tag{9}$$

To verify whether this is enough time, one must compare with the effective green time of the respective phase. Note that the time needed must be smaller than the effective green time.

$$G_{p1} < g_1 \rightarrow 20 < 21 \text{ ok} \tag{10}$$

Pedestrians can cross in the West-East (or East-West) direction during both phases ϕ_2 and ϕ_3.

$$G_{p2,3} = 3.2 + \frac{3 \times 12}{4} + 0.27 \times 5 = 13.55 \rightarrow 14 \text{ seconds} \tag{11}$$

$$G_{p2,3} < g_2 + g_3 \rightarrow 14 < 29 + 13 = 42 \text{ ok} \tag{12}$$

Step 6: Signal Timing

Now that we have all the parameters for the traffic light at the intersection, we need to assign the proper times for each one of the phases (green, yellow, and all red) in order. The first step for this is to compute the actual time that the signal will display the green light (taking into account the will will lose some of the time for usual losses and the allocation of yellow and red lights).

$$\text{Green display} \;=\; \text{Effective green} \;+\; \text{Lost time} \;-Y-AR \tag{13}$$

Phase Φ_1: $G_1 = g_1 + L - Y - AR_1 = 21 + 4 - 4.5 - 2 = 18.5$ s
Phase Φ_2: $G_2 = g_2 + L - Y - AR_2 = 29 + 4 - 4.5 - 1.5 = 27$ s
Phase Φ_3: $G_3 = g_3 + L - Y - AR_3 = 13 + 4 - 4.5 - 1.5 = 11$ s

As a final step, we must verify whether any rounding we performed so far generated an error in the total cycle length.

$$\begin{aligned} G_1 + G_2 + G_3 + 3 \times Y + \sum_i AR_i = C_o \\ \Rightarrow 18.5 + 27 + 11 + 3 \times 4.5 + (2 + 1.5 + 1.5) = \\ = 75 \text{ s} \;\rightarrow\; \text{ok} \end{aligned} \tag{14}$$

Hence, the final traffic signal diagram becomes as shown below.

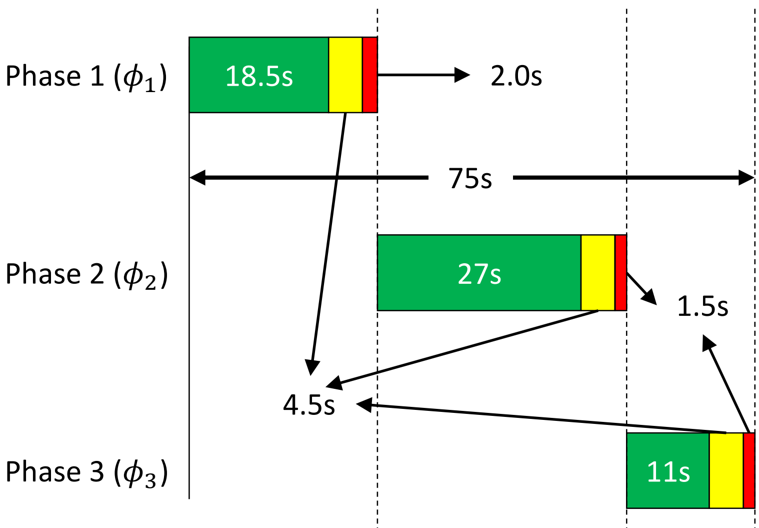


Figure 1: Final traffic signal diagram.