Fleet Size:

$$N = \frac{Demand}{Vehicle\ Occupancy}$$

$$N = qT \quad \rightarrow q = \frac{N}{T} \qquad \rightarrow (4.3.1)$$

$$F = N\left(\frac{T_{rt}}{T}\right) = qT_{rt} \qquad \rightarrow (4.3.2)$$

A transit line employing articulated vehicles is expected to carry 15,000 passengers during the 2.5h morning peak period. Given a round-trip time of 25 minutes and an average vehicle occupancy of 150 passenger, calculate the hourly flow q and the fleet size F. Also, find the headway between vehicles.

Trips required to carry demand:

$$N = \frac{Demand}{Vehicle\ Occupancy}$$

$$N = \frac{15000}{150} = 100\ trips$$

Hourly Flow:

$$q = \frac{N}{T}$$

$$q = \frac{100}{2.5} = 40\ vph$$

Fleet size:

$$F = N\left(\frac{T_{rt}}{T}\right)$$

$$F = 100\left(\frac{25}{150}\right) = 16.7 \rightarrow 17 vehicle$$

$$h = \frac{1}{q} = \frac{1 \times 3600}{40} = 90\ seconds$$

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Peak Hour Factor

$$PHF = \frac{V}{q} = \frac{V}{N_t(60/t)} \qquad \rightarrow (4.5.1)$$

$$PHF = \frac{V}{V_{15} \times 4} \qquad signalized\ intersection\ (0.25 - 1)$$

$$PHF = \frac{V}{V_5 \times 12} \qquad basic\ freeway\ segment (0.83 - 1)$$

A traffic counter in the period 2:00 – 3:00 pm. gave the following results:

Period	2:00 – 2:05	2:05 – 2:10	2:10 – 2:15	2:15 – 2:20	2:20 – 2:25	2:25 – 2:30	2:30 – 2:35	2:35 – 2:40	2:40 – 2:45	2:45 – 2:50	2:50 – 2:55	2:55 – 3:00	total
Traffic	115	120	120	130	150	160	170	175	175	170	150	150	1785

Calculate the PHF if the counter at a) basic freeway segment and b) signalized intersection.

a) basic freeway segment:

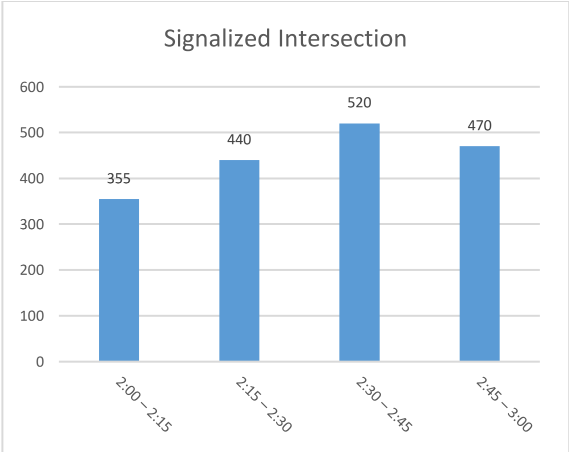
maximum five minutes V_5: 175 vehicles.

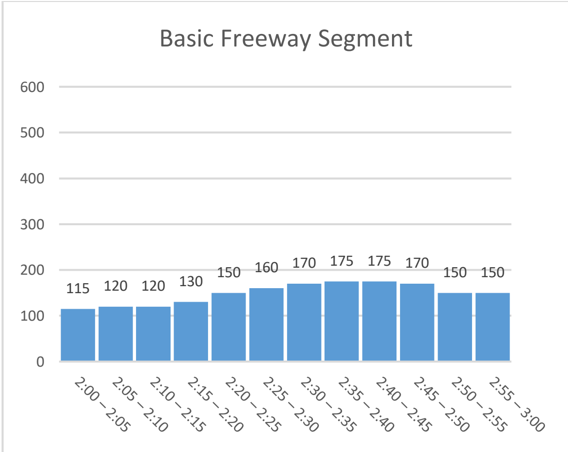
$$PHF = \frac{V}{V_5 \times 12} = \frac{1785}{175 \times 12} = 0.85$$

b) signalized intersection:

maximum fifteen minutes V_{15}: 520 vehicles.

$$PHF = \frac{V}{V_{15} \times 4} = \frac{1785}{520 \times 4} = 0.86$$





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Uninterrupted Flow

$$D = \frac{V_p}{S} \quad \rightarrow (4.5.2)$$

$$V_p = \frac{V}{PHF.N.f_{HV}.f_{dp}} \quad \rightarrow (4.5.3)$$

$$f_{HV} = \frac{1}{1 + P_T(E_T - 1) + P_R(E_R - 1)} \quad \rightarrow (4.5.4)$$

$$FFS = BFFS - f_{LW} - f_{LC} - f_N - f_{ID} \quad \rightarrow (4.5.5)$$

Imperial units:

$$f_{LW} = 3.1 \times (12 - W)^{1.77} \quad \rightarrow (4.5.6)$$

$$f_{LC} = 2.4 - 0.4 \times LC \quad \rightarrow (4.5.6)$$

$$f_N = 7.5 - 1.5 \times N \quad \rightarrow (4.5.6)$$

$$f_{ID} = -(4.4 - 8.45 \times ACCESS) \quad \rightarrow (4.5.6)$$

SI units:

$$f_{LW} = 42 \times (3.65 - W)^{1.77} \quad \rightarrow (4.5.6)$$

$$f_{LC} = 3.86 - 2.11 \times LC \quad \rightarrow (4.5.6)$$

$$f_N = 12.07 - 2.41 \times N \quad \rightarrow (4.5.6)$$

$$f_{ID} = -(7.08 - 21.88 \times ACCESS) \quad \rightarrow (4.5.6)$$

	All commuter motorist	Many unfamiliar motorists
f_{DB}	1.0	0.85

	Imperial, *mph*	SI, *km/h*
BFFS	70	110

Passenger car equivalency	Level terrain	Rolling terrain	Mountainous terrain
E_T	1.5	2.5	4.5
E_R	1.2	2.0	4.0

Base (ideal) conditions	Imperial Units	SI Units
Minimum lane width	12 ft	3.6 m
Minimum right-shoulder lateral clearance	6 ft	1.8 m
Minimum median lateral clearance	2 ft	0.6 m
Minimum number of lanes	5	5
Minimum interchange spacing	2 miles	3 kilometers
Maximum level terrain	2%	2%
Percentage of passenger cars	100% passenger cars	100% passenger cars
Driver population	Commuters	Commuters

Units	Level of Service				
	A	B	C	D	E
Imperial, pc/mi/ln	0 – 11.3	11.3 – 17.7	17.7 – 25.8	25.8 – 35.4	35.4 – 45.1
SI, pc/km/ln	0 – 7	7 – 11	11 – 16	16 – 22	22 – 28

An extended freeway segment with largely level terrain has an observed free flow speed of approximately 70 mph, three lane per direction, an 11 ft lane width, a 3 ft lateral clearance, and about one interchange per mile. It has an observed volume of 3080 veh/h with corresponding PHF = 0.88 and 154 trucks and buses, and no recreational vehicles. An all-commuter motorist composition may be assumed. Estimate the LOS for this set of conditions.

---

1. Estimate V_p:

   No recreational vehicles ➔ $P_R = 0$

   Volume = 3080 veh/h and trucks are 154 ➔ $P_T = 154/3080 = 0.05$

   Level terrain ➔ $E_T = 1.5$ (from table)

$$f_{HV} = \frac{1}{1 + P_T(E_T - 1) + P_R(E_R - 1)}$$

$$f_{HV} = \frac{1}{1 + 0.05(1.5 - 1) + 0(1.2 - 1)} = 0.976$$

   all-commuter motorist composition ➔ $f_{dp} = 1.0$

$$V_p = \frac{V}{PHF.N.f_{HV}.f_{dp}}$$

$$V_p = \frac{3080}{0.88 \times 3 \times 0.976 \times 1} = 1195\ pc/h/ln$$

2. Estimate S:

   Adjustment for lane width:

$$f_{LW} = 3.1 \times (12 - W)^{1.77}$$

$$f_{LW} = 3.1 \times (12 - 11)^{1.77} = 3.1$$

   Adjustment for lateral clearance:

$$f_{LC} = 2.4 - 0.4 \times LC$$

$$f_{LC} = 2.4 - 0.4 \times 3 = 1.2$$

   Adjustment for number of lanes:

$$f_N = 7.5 - 1.5 \times N$$

$$f_N = 7.5 - 1.5 \times 3 = 3$$

   Adjustment for interchange density:

$$f_{ID} = -(4.4 - 8.45 \times ACCESS)$$

$$f_{ID} = -(4.4 - 8.45 \times 1) = 4.05$$

Calculating free flow speed:

$$FFS = BFFS - f_{LW} - f_{LC} - f_N - f_{ID}$$

$$FFS = 70 - 3.1 - 1.2 - 3 - 4.05 = 58.65\ mph$$

3. Estimate Density:

$$D = \frac{V_p}{S}$$

$$D = \frac{1195}{58.65} = 20.38\ pc/mi/ln$$

4. Determine LOS:

From table LOS is C.

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A 14.9 km segment of six-lane free-way (three lanes per direction) has a set of characteristics in the given table.

Lanes	Lane width, m	Right shoulder, m	% trucks	%RVs
3	3.6	1.8	6	1
On-ramps	Off-ramps	Terrain	Volume veh/hr	PHF
6	8	rolling	1700	0.85

An all-commuter motorist composition may be assumed. Estimate the free flow speed and LOS.

1. Estimate V_p:

   %RV = 1% ➔ P_R = 0.01 and % trucks = 6% ➔ P_T = 0.06

   Rolling terrain ➔ E_T = 2.5 and E_R = 2.0 (from table)

$$f_{HV} = \frac{1}{1 + P_T(E_T - 1) + P_R(E_R - 1)}$$

$$f_{HV} = \frac{1}{1 + 0.06(2.5 - 1) + 0.01(2 - 1)} = 0.909$$

   all-commuter motorist composition ➔ f_{dp} = 1.0

$$V_p = \frac{V}{PHF.N.f_{HV}.f_{dp}}$$

$$V_p = \frac{1700}{0.85 \times 3 \times 0.909 \times 1} = 733.4\ pc/h/ln$$

2. Estimate S:

   lane width = 3.6 m ➔ f_{LW} = 0
   lateral clearance = 1.8 m ➔ f_{LC} = 0

   Adjustment for number of lanes:

$$f_N = 12.07 - 2.41 \times N$$
$$f_N = 12.07 - 2.41 \times 3 = 4.84$$

   Adjustment for interchange density:

$$f_{ID} = -(7.08 - 21.88 \times ACCESS)$$
$$f_{ID} = -\left(7.08 - 21.88 \times \frac{6+8}{14.9}\right) = 13.47$$

   Calculating free flow speed:

$$FFS = BFFS - f_{LW} - f_{LC} - f_N - f_{ID}$$

$$FFS = 110 - 0 - 0 - 4.84 - 13.47 = 91.69\ km/h$$

3. Estimate Density:

$$D = \frac{V_p}{S}$$

$$D = \frac{733.4}{91.69} = 8\ pc/km/ln$$

4. Determine LOS:

From table LOS is B.

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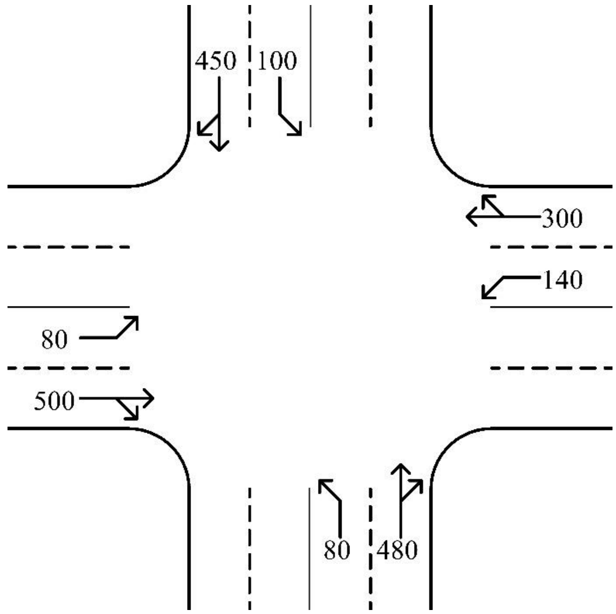
Interrupted Flow

Given:

L = 3 s/ phase Y + AR time = 4 s   lane width = 10 ft. $s_{(TH+RT)}$ = 1700 vph $s_{(LT)}$ = 300 vph



1) Design the signal timing for the following phasing

A	B
	

- Find critical flow ratio for each phase:

  Phase A: max {450/1700, 100/300, 480/1700, 80/300} = 0.333

  Phase B: max {500/1700, 80/300, 300/1700, 140/300} = 0.467

- Find the critical sum of flow ratios:

  CS = 0.333+.467 = 0.8

- Find total lost time:

  L = 2 × 3 = 6 s

- Find optimal cycle length:

$$C_\circ = \frac{1.5L + 5}{1 - CS}$$

$$C_\circ = \frac{1.5 \times 6 + 5}{1 - 0.8} = 70s$$

➔ optimal cycle length = 70 ±30%

- Find minimum pedestrian crossing time:

$$G_P = 7 + \frac{w}{4} - (Y + AR)$$

$$G_P = 7 + \frac{4 \times 10}{4} - (4) = 13\ s$$

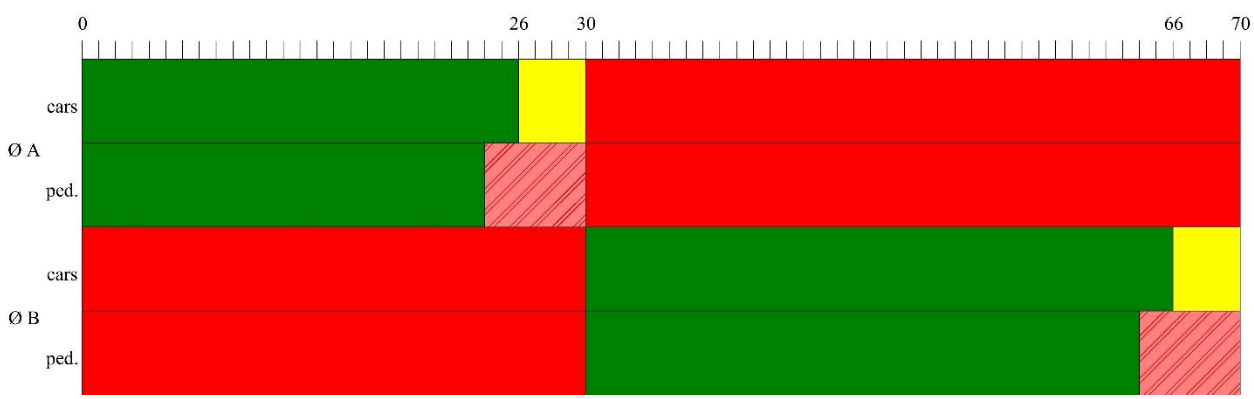
- Find flashing do not walk time:

$$FDW = \max\left\{7, \frac{w}{4} - (Y + AR)\right\}$$

$$FDW = \max\left\{7, \frac{4 \times 10}{4} - (4)\right\} = \max\{7{,}6\} = 7$$

- Allocate green and check if it satisfies pedestrian minimum crossing time

Phase	Cycle length	Y+AR	Available cycle length	Flow ratio	Critical sun	Allocation	Green	Ped. Green	Ped. check
A	70	4	62	0.333	0.8	0.4163	26	13	OK
B		4		0.467		0.5838	36	13	OK



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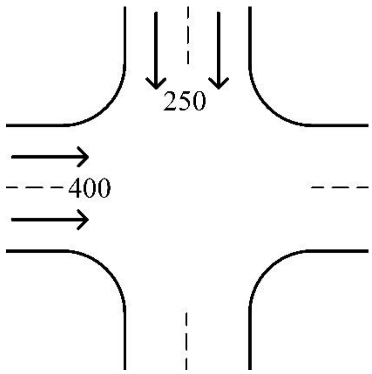
2) The normal flow of traffic on crossroads A and B are 400 and 250 vehicles per hour respectively. The saturation of flow for roads A and B are estimated as 1250 and 1000 vehicles per hour respectively. The yellow time is 2 seconds and all-red time is 4 seconds. Lost time is 2 seconds per approach. Each approach is 10 ft wide. Design a two-phase traffic system.



- Find critical flow ratio for each phase:

  Phase A: max {400/1250} = 0.32

  Phase B: max {250/1000} = 0.25

Find the critical sum of flow ratios:

CS = 0.32+0.25= 0.57

- Find total lost time:

  L = 2 × (2) = 4 s

- Find optimal cycle length:

$$C_\circ = \frac{1.5L + 5}{1 - CS}$$

$$C_\circ = \frac{1.5 \times 4 + 5}{1 - 0.57} = 25.6\ s$$

➔ optimal cycle length = 25.6 ±30%, take 30 seconds.

- Find minimum pedestrian crossing time:

$$G_P = 7 + \frac{w}{4} - (Y + AR)$$

$$G_P = 7 + \frac{10}{4} - (2 + 4) = 3.5\ s$$

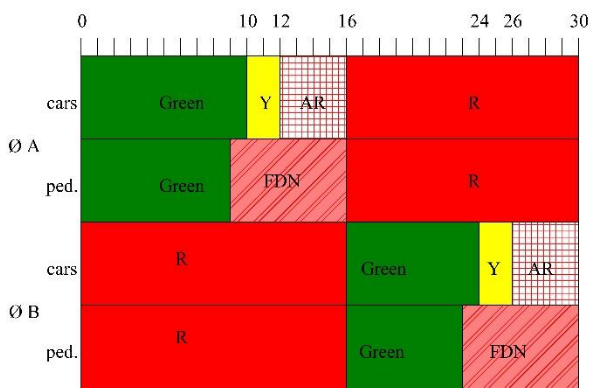
- Find flashing do not walk time:

$$FDW = \max\left\{7, \frac{w}{4} - (Y + AR)\right\}$$

$$FDW = \max\left\{7, \frac{10}{4} - (2 + 4)\right\} = \max\{7, -3.5\} = 7$$

- Allocate green and check if it satisfies pedestrian minimum crossing time

Phase	Cycle length	Y+AR	Available cycle length	Flow ratio	Critical sun	Allocation	Green	Ped. Green	Ped. check
A	30	6	18	0.32	0.57	0.56	10	3.5	OK
B		6		0.25		0.44	8	3.5	OK



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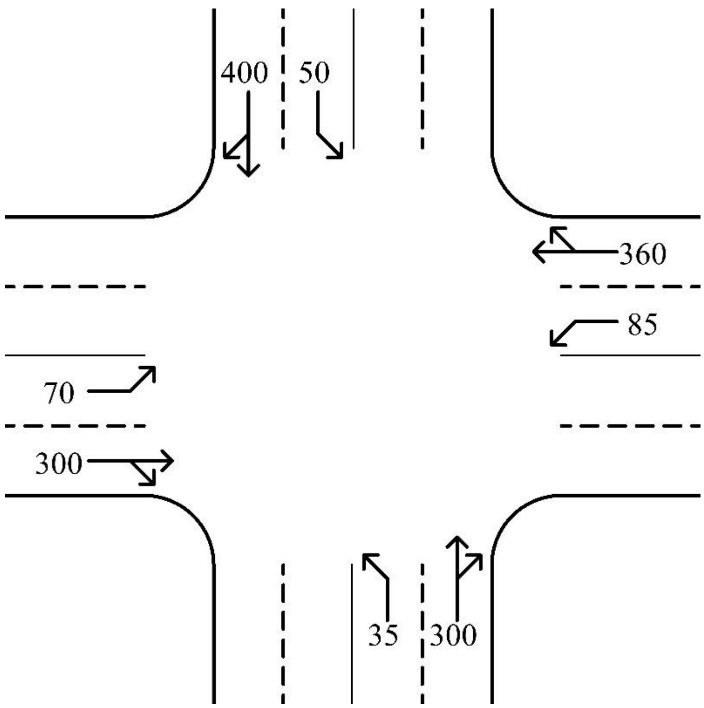
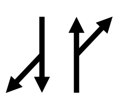
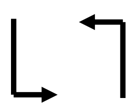
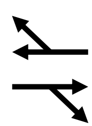
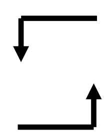
3) The below intersection has the following information, design the signal timing.

All red time = 2 s amber time = 2 lane width = 10 ft lost time = 2 s each.

Movement	Hourly volume, vph	Saturation flow rate, vph
SB (TH+RT)	400	2100
SB (LT)	50	500
NB (TH+RT)	300	2100
NB (LT)	35	500
WB (TH+RT)	360	1800
WB (LT)	85	250
EB (TH+RT)	300	1800
EB (LT)	70	250



A	B	C	D
			

- Find critical flow ratio for each phase:

  Phase A: max {400/2100,300/2100} = 0.19

  Phase B: max {50/500,35/500} = 0.10

  Phase C: max {360/1800,300/1800} = 0.2

  Phase D: max {85/250,70/250} = 0.34

Find the critical sum of flow ratios:

CS = 0.19+0.10+0.20+0.34= 0.83

- Find total lost time:

  Total lost time = 4 × (2) = 8 s

- Find optimal cycle length:

$$C_{\circ} = \frac{1.5L + 5}{1 - CS}$$

$$C_{\circ} = \frac{1.5 \times 8 + 5}{1 - 0.83} = 100\ s$$

➔ optimal cycle length = 100 ±30%, take 100 seconds.

- Find minimum pedestrian crossing time:

$$G_P = 7 + \frac{w}{4} - (Y + AR)$$

$$G_P = 7 + \frac{4 \times 10}{4} - (2 + 2) = 13\ s$$

- Find flashing do not walk time:

$$FDW = \max\left\{7, \frac{w}{4} - (Y + AR)\right\}$$

$$FDW = \max\left\{7, \frac{4 \times 10}{4} - (2 + 2)\right\} = \max\{7,6\} = 7$$

- Allocate green and check if it satisfies pedestrian minimum crossing time.

Phase	Cycle length	Y+AR	Available cycle length	Flow ratio	Critical sun	Allocation	Green	Ped. Green	Ped. check
A	100	4	84	0.19	0.83	0.23	19	13	OK
B		4		0.10		0.12	10	13	NO
C		4		0.20		0.24	20	13	OK
D		4		0.34		0.41	35	13	OK

Phase	Cycle length	Y+AR	Available cycle length	Flow ratio	Critical sun	Allocation	Green	Ped. Green	Ped. check
A	100	4	84	0.19	0.83	0.23	19	13	OK
B		4		0.10		0.12	13	13	OK
C		4		0.20		0.24	20	13	OK
D		4		0.34		0.41	32	13	OK