13- Capacity and Los Analysis of a Signalized Intersection

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HCM- 2000

Scope: Analyze Cap. & Level of Service.

Cap: in terms of v/c ratio

LoS: Control delay sec/veh.

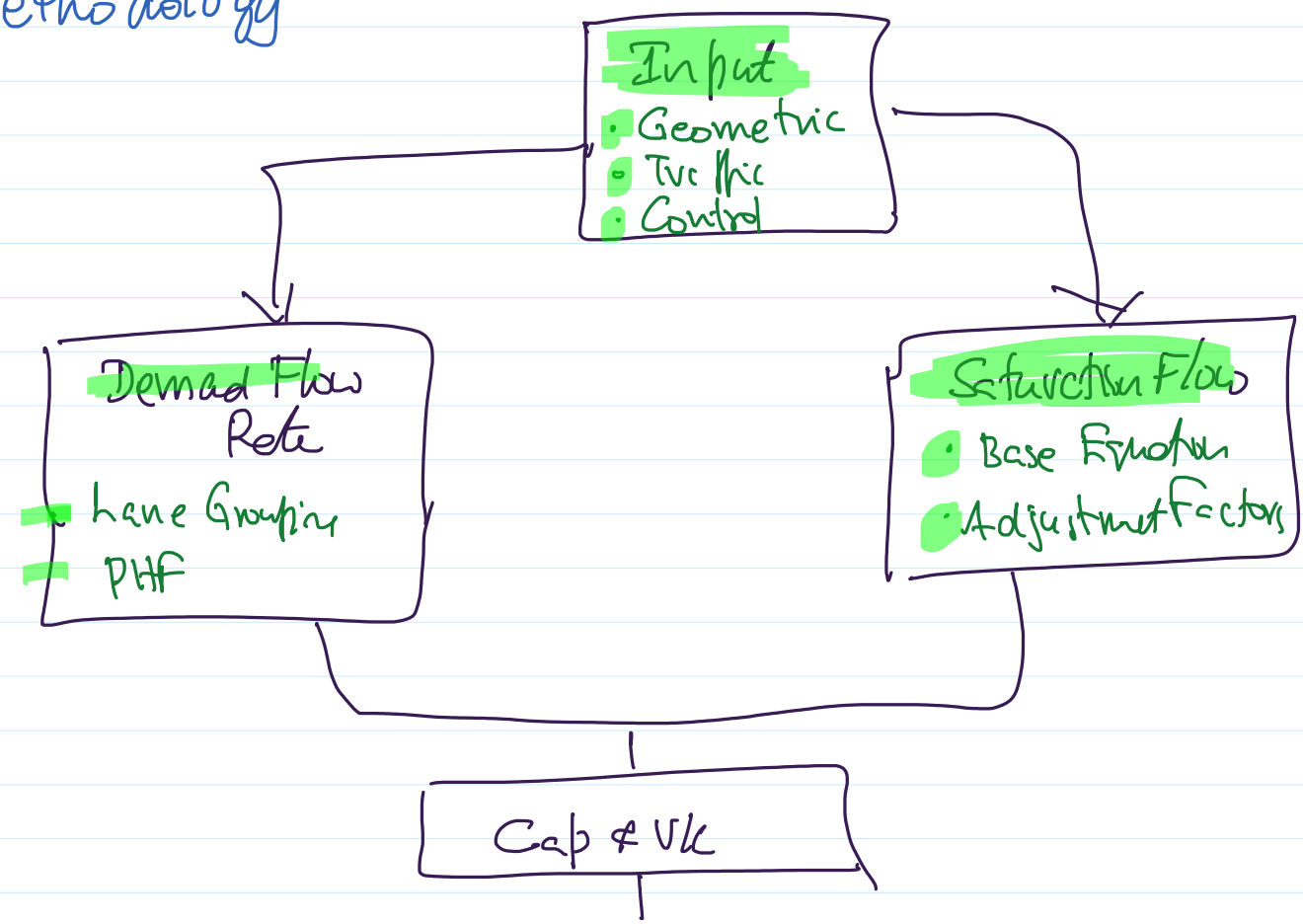
- ↳ queue move up time.
- ↳ dec. delay
- ↳ stopped delay
- ↳ acc. delay.

Note

(1) Each lane group is analysed Separately

i → lane group

Methodology



LoS - Delay
Queue.

LoS

LoS	Control Delay
A	≤ 10 sec/veh.
B	10-20 "
C	20-35
D	35- 55
E	55 - 80
F	> 80

Geometric

- Area Type < CBD / non-CBD
- No. of lanes (N)
- Lane width (w)
- Gradient (G%)
- Exclusive LT ~~or~~ US
  LT/RT -- RT
- Length of the storage Lane (L)
- Parking

Traffic

- Demand Volume v
- Base Sat. flow so
- PHF
- HV%
- Ped. flow rate Vped
- Bus Stopping Spacing NB bus/hr.
- Parking Activity Nm person/hr.
- Arrival type AT.
- Proportion Veh arriving in green.
- Approach Speed.

Control

- Cycle length C
- Type < Actuated

Control

- Cycle length C
- Green time G
- Inter green time.
- Phase plan
- Analysis period T.(h)

Type < Actuated / pre-timed / fixed

- Ped push buttons
- Phase plan
- Min ped. Green G_p

Arrival Type

1. Dense platoon : >80% arrive at the start of red — High
2. Moderate : 40-80% — middle of red
3. Random : <40% — arrive in red
4. Moderate : 40-80% — arrive at middle of green
5. Dense : >80% — start of green.
6. Ideal : 100% — " " — Low

Platoon Ratio:

$$R_p = \frac{P}{g_i / C}$$

P ← proportion of veh. arriving during green.

g_i → green ← cycle length.

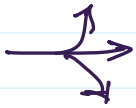
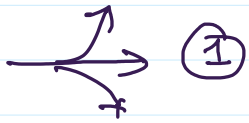
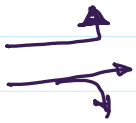
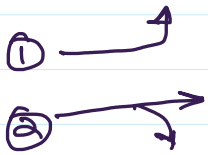
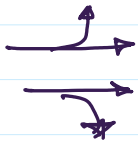
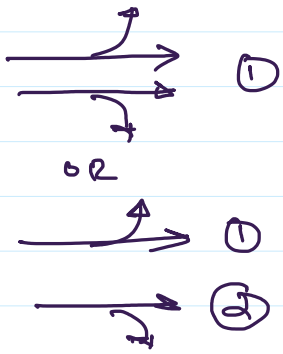
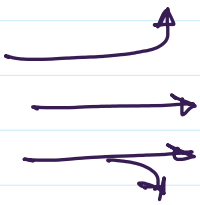
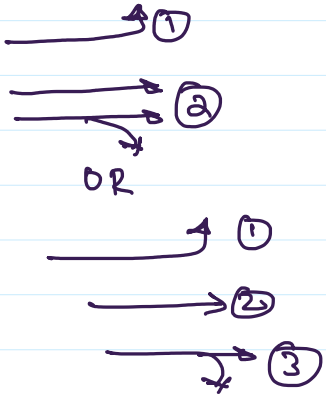
Signalization of Pedestrians.

$$G_p = 3.2 + \frac{L}{S_p} + \left(0.81 \frac{N_{ped}}{W_e}\right)$$

- G_p → ped green time. min.
- 3.2 → start up lost time.
- L → Cross walk length
- S_p → ped. speed. 15th percentile speed.
- N_{ped} → No. of ped. crossing during the interval
- W_e → we > 3.0 m.

$$= 3.2 + \frac{L}{S_p} + 0.27 N_{ped} \quad ; \quad W_e \leq 3.0 \text{ m}$$

Lane Groups

No of lanes	Movements	Lane Group.
1		
2		
2.		
3		

Flow Rate.

$$V_p = \frac{V}{PHF}$$

V_p: peak 15 mts flow rate

V: Hourly Volume.

PHF: peak hour factor.

Saturation Flow

S = Saturation flow rate veh/hr/lane Group.

$S = S_0 \times N$

S_0 = base saturation flow = 1900 veh/hr/lane

N = No of lanes in the lane group.

$S = s_0 \times$ 52 base saturation flow = 1900 veh/hr/lane

$N \times$ No. of lanes in the lane group.

$f_w \times$ Adj. factor for lane width.

$f_{HV} \times$ " heavy vehicle

$f_g \times$ " gradient

$f_p \times$ " parking

$f_{bb} \times$ " bus blockage

$f_a \times$ " area type.

$f_{LT} \times$ " LT in Lane Group

$f_{RT} \times$ " RT in Lane Group

$f_{Lpb} \times$ ped/bicycle movement in LT

f_{Rpb} " " " RT

$f_{LT} * \leftarrow$ Lane utilization

① $f_w = 1 + \dfrac{w - 3.6}{9}$ ← width of lane.

$2.4 \le w \le 4.8$

② $f_{HV} = \dfrac{100}{100 + \%HV(E_T - 1)}$ $E_T = 2.0$ Pass. Car/HV.

↳ % of heavy vehicle in the lane Group.

③ $f_g = 1 - \dfrac{\%G}{200}$ ← % Grade

$-6 \le \%G \le +10$

④ $f_p = N - 0.1 - \dfrac{18 N_m}{3600}$ ← No. of lanes; N_m ← No. of parking operation per hour.

$f_p > 0.050$

$f_p = 1 \Rightarrow$ No. parking.

⑤ $N - 14.4 N_b$ ← N: No. of lanes; N_b: No. of bus stopping per hr.

(5) $$f_{bb} = \frac{N - \frac{14.4\, N_B}{3600}}{N}$$

N: no. of lanes.

N_B: no. of bus stopping per hr.

$0 \le N_B \le 250$

$f_{bb} \ge 0.05$.

(6) $$f_a = \begin{cases} 0.9 & \text{CBD} \\ 1.0 & \text{non-CBD.} \end{cases}$$

(7) $$f_{LU} = \frac{V_j}{V_{j1}}$$

V_j ← demand flow rate for the LG

V_{j1} on no. of lanes.

↳ highest demand flow rate lane.

(8) $$f_{LT} = \begin{cases} 0.95 & \rightarrow \text{Exclusive LT} \\ 1/(1+0.05\, P_{LT}) & \rightarrow \text{Shared LT} \\ * & \text{Supplimentary sheet} \rightarrow \text{Non-protected (2 Phase Signal)} \end{cases}$$

(9) $$f_{RT} = \begin{cases} 0.85 & \text{Exclusive} \\ 1 - 0.15\, P_{RT} & \text{Shared lane.} \\ 1 - 0.135\, P_{RT} & \text{single lane.} \end{cases}$$

P_{RT}: proportion of RT in the LG

(10) $f_{L_{PB}}$ → Supplimentary sheet

(11) $f_{R_{PB}}$ → supplimentary sheet.

Determination of Cap: & LOS

Capacity for the LG

$$c_i = S_i * \frac{g_i}{C}$$

g_i ← green time for i^{th} LG

C ← cycle

S_i → adjusted sat. flow for i^{th} LG.

V/C Ratio

$$X_i = \frac{V_i}{c_i} = \frac{V_i \cdot C}{S_i \cdot g_i}$$

Critical Lane Group's

$$X_c = \sum \left(\frac{V}{S}\right)_{ci} \left(\frac{C}{C-L}\right)$$

Determination of Delay.

d → Control delay perveh (sec/veh)

d_1 ← uniform delay

d_2 ← incremental queue delay

d_3 ← initial queue delay

$$d = d_1 PF + d_2 + d_3$$

PF → progression adj. factor.

Incremental delay due to random arrival.

Prog. Adj. Factor.

P → proportion of vehicle arrive on green.

f_{PA} ← Adj. factor for platoon arriving during green.

$$P_F = \frac{(1-P) f_{PA}}{1 - \frac{g}{C}}$$

S/C	AT1	AT2	AT3	...	AT6
0.2	1.167		1.0		
0.3			1.0		
			1.0		
0.7			1.0		0.00

Uniform Delay

$$d_1 = \frac{\frac{C}{2}(1-S/C)^2}{1-\min(1,X)\times S/C}$$

C → cycle length; S → green time; X → degree of saturation.

$$d_2 = 900T\left[(X-1)+\sqrt{(X-1)^2+\frac{8klX}{cT}}\right]$$

d_2 → incremental delay k → Controller setting 0.5 for pre-timed signal

T → analysis period. l → url filter

X → degree of saturation. (LG's v/c)

d_3 → Initial queue delay / residual queue delay.

Aggregate delay $d_t = \frac{\sum d_i v_i}{\sum v_i}$ weighted average delay of all the lane Group.