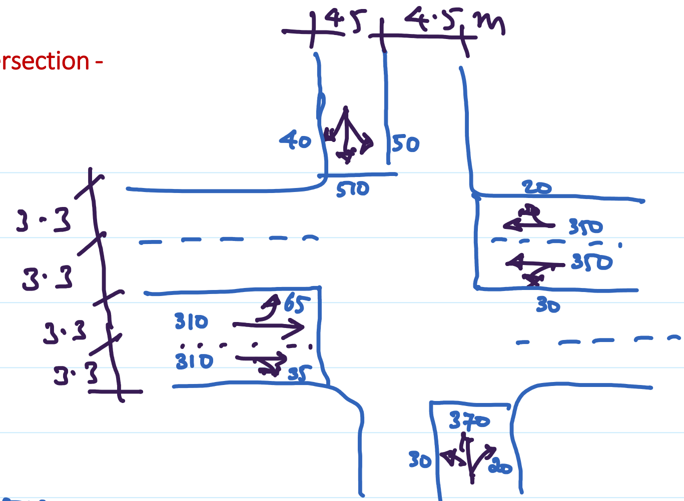
Numerical Example

Find the capacity and LoS of the intersection.



Inputs:

1. EB & WB have HV 5%.
2. NB & SB have HV 8%.
3. PHF = 0.9
5. 2 Phase Signal, at CBD
6. NB-SB green 36 Sec
   EB-WB green 26 Sec
8. Yellow time 4 Sec
15. Arrival Type 4
17. Base Sat. flow 1900 pc/hr/lane
18. Truck Equivalent factor $E_T = 2.0$
19. No Buses
9. Lost time = 4 Sec
10. Cycle time = 70 Sec
11. No parking.
12. Ped. Vol = 100 ped/hr.
13. Bicycle Volume = 20 bic/hr.
14. No grading
16. Cross-walk width = 3.0

Solution

1. Ped/Cycle = $\dfrac{100 \text{ ped/hr}}{(3600/70)} = 1.944$ ped/cycle

2. Min. effective green time. Eq. 16.2

$$G_p = 3.2 + \frac{L}{1.2} + 0.27 N_{ped}$$

$$G_p^{EW} = 3.2 + \frac{9}{1.2} + 0.27 \times 1.944 = 11.2 \text{ Sec}$$

$$G_p^{EW} = 3.2 + \frac{9}{1.2} + 0.27 \times 1.944 = 11.2\ Sec$$

$$G_p^{NS} = 3.2 + \frac{13.2}{1.2} + 0.27 \times 1.944 = 14.7\ Sec.$$

③ Check for green time.

$$G_{EW} = 26\ Sec > G^p_{EW}\ (11.2\ Sec)$$

$$G_{NS} = 36\ Sec > G^p_{NS}\ (14.7\ Sec).$$

④ proportion of Left turn.

$$P_{LT}^{EB} = \frac{65}{65+620+35} = 0.090$$

⑤ Lane width Adj. factor. Ex 16:7

$$f_w^{EB} = 1 + \frac{W-3.6}{9} = 1 + \frac{3.3-3.6}{9} = 0.967$$

⑥ Heavy Vehicle Adj. factor. Ex. 16:7

$$f_{HV}^{EB} = \frac{1}{1+P_T(E_T-1)} = \frac{1}{1+0.05(2-1)} = 0.952$$

⑦ Gradient adj. factor. Ex 16:7

$$f_g = 1.0 \quad \text{(level gradient).}$$

⑧ Parking adj. factor. Ex 16:7

f^{EB} ...

(8) Parking adj. factor. Ex 16:7

$f_p^{EB} = 1$ (No. parking)

(9) Bus Blockage Adj. Factor.

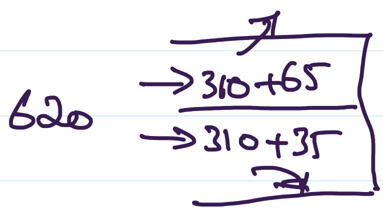
$f_{bb}^{EB} = 1.0$

(10) Area Type. Adj. Factor. Ex 16:7.

$f_a = 0.90$ for CBD.

(11) Adj. Factor for lane utilization. Ex 16:7

$$f_{LU}^{EB} = \frac{V_S}{V_{g1} \times N} = \frac{620+65+35}{2*(310+65)} = 0.96$$



(12) Left-Turn Adj Factor. supplimentary sheet
(0.716) ⇐ Input

(13) Right-turn Adj Factor. shared lane
Ex 16:7

$$f_{RT}^{EB} = 1 - 0.15\, P_{RT}$$

$$= 1 - 0.15 \times \frac{35}{720} = 0.933.$$

(14) Left-turn ped/bicycle adj. factor.

$f_{Lpb}^{EB} = 0.997$

supplimentary sheet
∴ ⇐ Input

(15) Right turn ped/bicycle adj. factor.

$f^{EB} = 0.992$

Suppliment on sheet ∴ ⇐ Input.

(16) Saturation Flow (Adjusted)

$S = S_0 \times$ 1900 ×
N × 2 ×
f_w × 0.967 ×
f_{HV} × 0.952 ×
f_g × 1.0
f_p × 1.0
f_{bb} × 1.0
f_a × 0.9
f_{LU} × 0.96
f_{LT} × 0.716
f_{RT} × 0.991
$f_{LT_{PB}}$ × 0.997.
$f_{RT_{PB}}$ 0.992.

~~1900~~ 3800
19000

= 2103 veh/hr/lane

(17) Lane Group Capacity: $c = S \cdot g/C$

$c^{EB} = 2103 * \frac{26}{70} = 780$ veh/hr/lane.

(18) V/c Ratio.

$X_{EB} = \left(\frac{V}{c}\right) = \frac{800}{780}$ ← $\frac{720}{PHF} = \frac{720}{0.9} = 800.$

$= 1.026$

$= 1.026$

$|||^{ly}$ $X_{WB} = 0.842.$

P1		P2	
EB	WB	NB	SB
1.026	.842	.561	0.779
1.026		0.779	
0.380		0.410	

0.790

(19) Determine Critical LG.

$$Max\{X_{EB}, X_{WB}\} = 1.026.$$

(20) Flow Ratio: $\left(\frac{V}{S}\right)_{EB} = \frac{800}{2103} = 0.380$

$$\left(\frac{V}{S}\right)_{SB} = \frac{667}{1625} = 0.410$$

(21) Sum of $\left(\frac{V}{S}\right)$ ratio of Critical Lane Groups

$$Y_C = 0.380 + 0.410 = 0.790$$

P1 (EB) P2 (SB)

(22) Degree of Saturation X_c

$$X_c = \frac{Y_c \times C}{C - L} = \frac{0.790 \times 70}{(70-8)}$$

$$= \frac{0.790 \times 70}{62} = 0.892.$$

(23) Uniform Delay.

$$d_1 = \frac{0.5\, C\, (1 - g/c)^2}{\min(1, x) \cdot \frac{g}{c}} =$$

. .2

$$d_1^{EB} = \frac{0.5 \times 70 \, (1 - 26/70)}{1 - \min(1, 1.026) \times 26/70}$$

$$= 22.015 \text{ sec/veh.}$$

(24) Incremental Delay.

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

$$= 900 \times \left(\frac{15}{60}\right) \times \left[(1.026-1) + \sqrt{(1.026-1)^2 + \frac{8 \times 1 \times 0.5 \times 1.026}{780 \times (15/60)}} \right]$$

$$= 39.011 \text{ Sec/veh.}$$

(25) Progression Adj. Factor   Ex. 16:12.

$$PF_{EB} = \frac{(1-P) f_{PA}}{1 - g/c}$$

$g/c \rightarrow \frac{26}{70} = 0.371$

Area Type = 4. (input)

$\Rightarrow AT\,4 \Rightarrow$ $f_{PA} = 0.926.$

EXHIBIT 16-12. PROGRESSION ADJUSTMENT FACTOR FOR UNIFORM DELAY CALCULATION

Green Ratio (g/C)	AT 1	AT 2	AT 3	AT 4	AT 5	AT 6
	Arrival Type (AT)					
0.20	1.167	1.007	1.000	1.000	0.833	0.750
0.30	1.286	1.063	1.000	0.986	0.714	0.571
0.40	1.445	1.136	1.000	0.895	0.555	0.333
0.50	1.667	1.240	1.000	0.767	0.333	0.000
0.60	2.001	1.395	1.000	0.576	0.000	0.000
0.70	2.556	1.653	1.000	0.256	0.000	0.000
f_{PA}	1.00	0.93	1.00	1.15	1.00	1.00
Default, R_p	0.333	0.667	1.000	1.333	1.667	2.000

Notes:
PF = (1 - P)f_{PA}/(1 - g/C).
Tabulation is based on default values of f_{PA} and R_p.
P = R_p * g/C (may not exceed 1.0).
PF may not exceed 1.0 for AT 3 through AT 6.

0·3 → 0·986

0·4 → 0·895

∴ 0·371 ⇒ 0·926.

$PF_{EB} = 0{\cdot}926.$

(25) Lane Group Delay.

$$d_{EB} = 22{\cdot}015 * 0{\cdot}926 + d_1 \times PF_{EB}$$

$$39{\cdot}011 \quad + \quad d_2$$

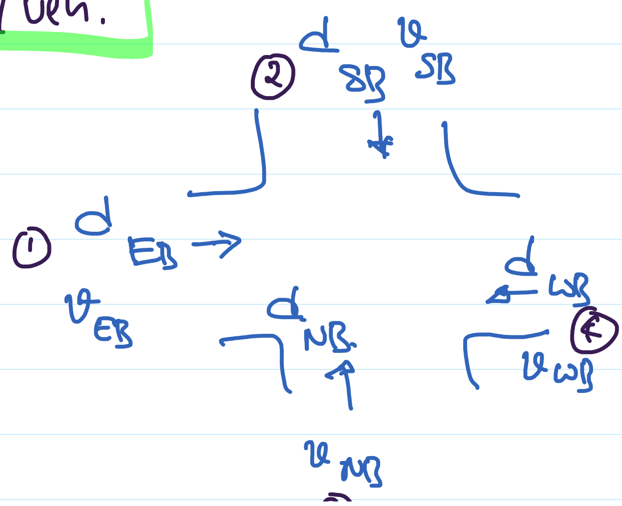
$$0 \qquad d_3$$

→ residual queue from the previous cycle.

$$d_{EB} = 59{\cdot}4 \text{ sec/veh.}$$

(27) Intersection delay.

$$d_{Intersection} = \frac{\sum d_i v_i}{\sum v_i}$$



(3)

= ||||

(28) LoS.

LoS (EB) = E

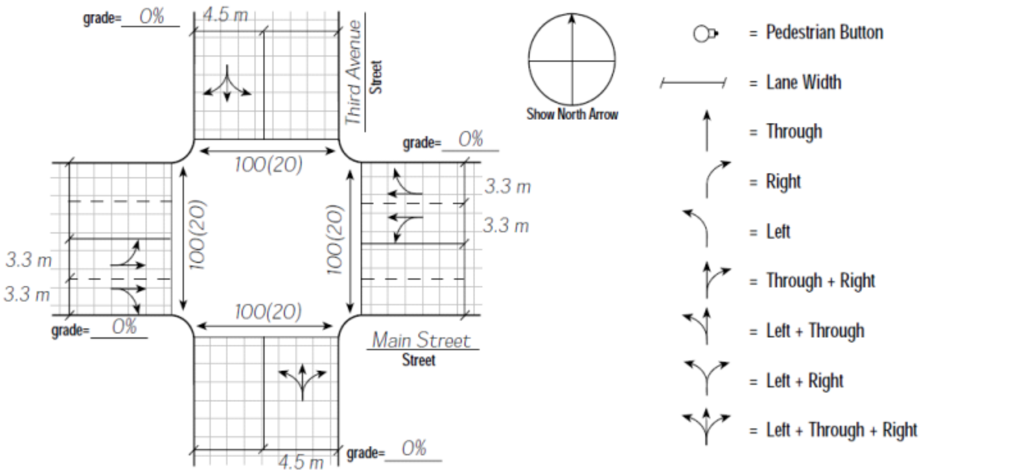
d=59.4

Works Sheet

INPUT WORKSHEET

General Information		Site Information	
Analyst	WLL	Intersection	Third Avenue/Main Street
Agency or Company	CEI	Area Type	☒ CBD ☐ Other
Date Performed	4/12/99	Jurisdiction	
Analysis Time Period	4-6 PM	Analysis Year	1999

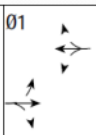
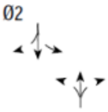
Intersection Geometry



Volume and Timing Input

	EB			WB			NB			SB		
	LT	TH	RT[1]	LT	TH	RT[1]	LT	TH	RT[1]	LT	TH	RT[1]
Volume, V (veh/h)	65	620	35	30	700	20	30	370	20	40	510	50
% heavy vehicles, % HV	5	5	5	5	5	5	8	8	8	8	8	8
Peak-hour factor, PHF		0.90			0.90			0.90			0.90	
Pretimed (P) or actuated (A)		P			P			P			P	
Start-up lost time, l_1 (s)												
Extension of effective green time, e (s)												
Arrival type, AT		4			2			3			3	
Approach pedestrian volume,[2] v_{ped} (p/h)		100			100			100			100	
Approach bicycle volume,[2] v_{bic} (bicycles/h)		20			20			20			20	
Parking (Y or N)		N			N			N			N	
Parking maneuvers, N_m (maneuvers/h)		0			0			0			0	
Bus stopping, N_B (buses/h)		0			0			0			0	
Min. timing for pedestrians,[3] G_p (s)		11.2			11.2			14.7			14.7	

Signal Phasing Plan

	Ø1	Ø2	Ø3	Ø4	Ø5	Ø6	Ø7	Ø8
DIAGRAM								
Timing	G = 26.0 Y = 4.0	G = 36.0 Y = 4.0	G = Y =	G = Y =	G = Y =	G = Y =	G = Y =	G = Y =

Protected turns — Permitted turns — Pedestrian — Cycle length, C = 70.0 s

Notes

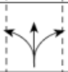
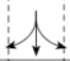
1. RT volumes, as shown, exclude RTOR.
2. Approach pedestrian and bicycle volumes are those that conflict with right turns from the subject approach.
3. Refer to Equation 16-2.

VOLUME ADJUSTMENT AND SATURATION FLOW RATE WORKSHEET

General Information

Project Description *Example Problem 1*

Volume Adjustment

	EB			WB			NB			SB		
	LT	TH	RT	LT	TH	RT	LT	TH	RT	LT	TH	RT
Volume, V (veh/h)	65	620	35	30	700	20	30	370	20	40	510	50
Peak-hour factor, PHF		0.90			0.90			0.90			0.90	
Adjusted flow rate, v_p = V/PHF (veh/h)	72	689	39	33	778	22	33	411	22	44	567	56
Lane group												
Adjusted flow rate in lane group, v (veh/h)		800			833			466			667	
Proportion[1] of LT or RT (P_{LT} or P_{RT})	0.090	-	0.049	0.040	-	0.027	0.071	-	0.048	0.067	-	0.083

Saturation Flow Rate (see Exhibit 16-7 to determine adjustment factors)

Base saturation flow, s_o (pc/h/ln)	1900	1900	1900	1900
Number of lanes, N	2	2	1	1
Lane width adjustment factor, f_w	0.967	0.967	1.100	1.100
Heavy-vehicle adjustment factor, f_{HV}	0.952	0.952	0.926	0.926
Grade adjustment factor, f_g	1.000	1.000	1.000	1.000
Parking adjustment factor, f_p	1.000	1.000	1.000	1.000
Bus blockage adjustment factor, f_{bb}	1.000	1.000	1.000	1.000
Area type adjustment factor, f_a	0.900	0.900	0.900	0.900
Lane utilization adjustment factor, f_{LU}	0.950	0.950	1.000	1.000
Left-turn adjustment factor, f_{LT}	0.716	0.901	0.937	0.951
Right-turn adjustment factor, f_{RT}	0.993	0.996	0.994	0.989
Left-turn ped/bike adjustment factor, f_{Lpb}	0.997	0.998	0.999	0.998
Right-turn ped/bike adjustment factor, f_{Rpb}	0.992	0.995	0.996	0.994
Adjusted saturation flow, s (veh/h) $s = s_o N f_w f_{HV} f_g f_p f_{bb} f_a f_{LU} f_{LT} f_{RT} f_{Lpb} f_{Rpb}$	2103	2665	1614	1625

Notes

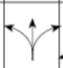
1. P_{LT} = 1.000 for exclusive left-turn lanes, and P_{RT} = 1.000 for exclusive right-turn lanes. Otherwise, they are equal to the proportions of turning volumes in the lane group.

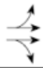
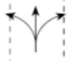
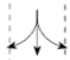
CAPACITY AND LOS WORKSHEET

General information

Project Description *Example Problem 1*

Capacity Analysis

Phase number	1	1	2	2								
Phase type	P	P	P	P								
Lane group												
Adjusted flow rate, v (veh/h)	800	833	466	667								
Saturation flow rate, s (veh/h)	2103	2665	1614	1625								
Lost time, t_L (s), $t_L = I_1 + Y - e$	4	4	4	4								
Effective green time, g (s), $g = G + Y - t_L$	26.0	26.0	36.0	36.0								
Green ratio, g/C	0.371	0.371	0.514	0.514								
Lane group capacity,[1] c = s(g/C), (veh/h)	780	989	830	835								
v/c ratio, X	1.026	0.842	0.561	0.799								
Flow ratio, v/s	0.380			0.410								
Critical lane group/phase (√)	√			√								
Sum of flow ratios for critical lane groups, Y_c $Y_c = \sum$ (critical lane groups, v/s)	0.790											
Total lost time per cycle, L (s)	8											
Critical flow rate to capacity ratio, X_c $X_c = (Y_c)(C)/(C - L)$	0.892											

Lane Group Capacity, Control Delay, and LOS Determination				
	EB	WB	NB	SB
Lane group				
Adjusted flow rate,[2] v (veh/h)	800	833	466	667
Lane group capacity,[2] c (veh/h)	780	989	830	835
v/c ratio,[2] X = v/c	1.026	0.842	0.561	0.799
Total green ratio,[2] g/C	0.371	0.371	0.514	0.514
Uniform delay, $d_1 = \frac{0.50\,C\,[1-(g/C)]^2}{1-[\min(1, X)g/C]}$ (s/veh)	22.015	20.138	11.617	14.028
Incremental delay calibration,[3] k	0.5	0.5	0.5	0.5
Incremental delay,[4] d_2 $d_2 = 900T[(X-1)+\sqrt{(X-1)^2+\frac{8kIX}{cT}}]$ (s/veh)	39.011	8.647	2.734	7.882
Initial queue delay, d_3 (s/veh) (Appendix F)	0	0	0	0
Uniform delay, d_1 (s/veh) (Appendix F)				
Progression adjustment factor, PF	0.926	1.111	1.000	1.000
Delay, $d = d_1(PF) + d_2 + d_3$ (s/veh)	59.4	31.0	14.4	21.9
LOS by lane group (Exhibit 16-2)	E	C	B	C
Delay by approach, $d_A = \frac{\Sigma(d)(v)}{\Sigma v}$ (s/veh)	59.4	31.0	14.4	21.9
LOS by approach (Exhibit 16-2)	E	C	B	C
Approach flow rate, v_A (veh/h)	800	833	466	667
Intersection delay, $d_I = \frac{\Sigma(d_A)(v_A)}{\Sigma v_A}$ (s/veh)	34.2	Intersection LOS (Exhibit 16-2)		C