التقاطعات المجهزة بإشارات ضوئية

SIGNALIZED INTERSECTIONS

إعداد المهندس

سامر برهان زريق

ماجستير في هندسة المرور

مدير أعمال سابق في قسم هندسة المواصلات والنقل – كلية الهندسة المدنية

جامعة تشرين – اللاذقية – سوريا

سلسلة محاضرات عملية ألقيت على طلاب قسم المواصلات والنقل

EXAMPLE PROBLEM 3

The Intersection The intersection of Fifth Avenue (NB/SB) and Twelfth Street (EB/WB) is a major CBD junction of two urban streets.

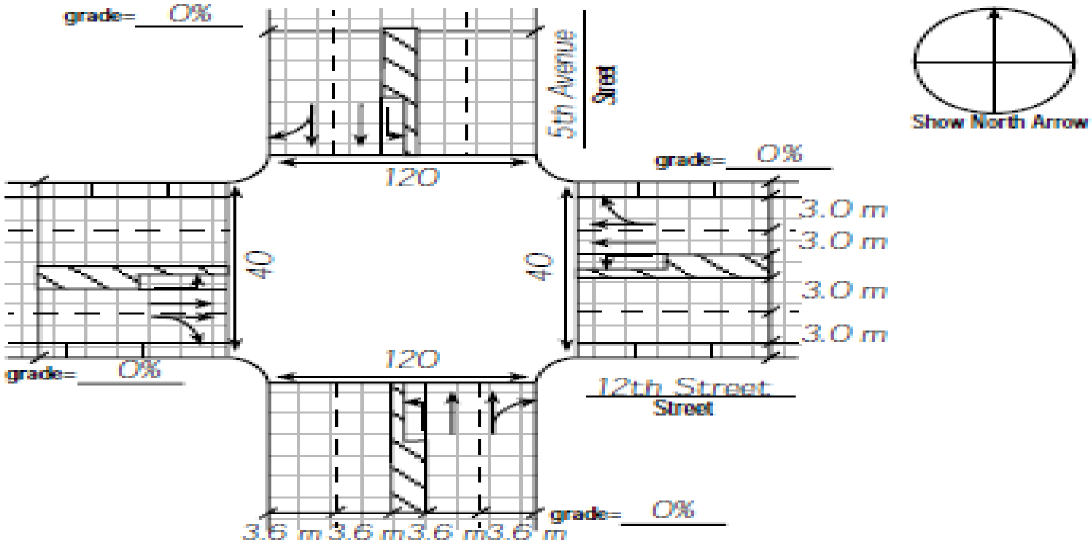
The Question What are the delay and LOS during the peak hour for lane groups, approaches, and the intersection as a whole?

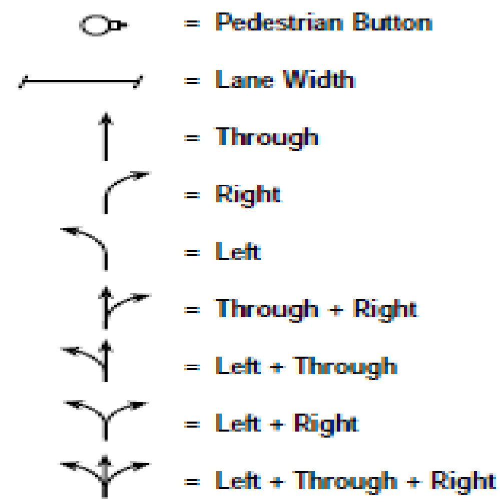
The Facts

√ Twelfth Street HV = 5 percent,
√ Fifth Avenue HV = 2 percent,
√ Twelfth Street PHF = 0.85,
√ Fifth Avenue PHF = 0.90,
√ Actuated signal,
√ Yellow = 4.0 s,
√ Level terrain,
√ 3.0-m lane widths for EB/WB,
√ Pedestrian signals exist,
√ 3.6-m lane widths for NB/SB,
√ Fifth Avenue is a four-lane street,
√ Twelfth Street is a four-lane street,
√ Twelfth Street parking, 5 maneuvers/h,
√ Twelfth Street pedestrian volume = 120 p/h,
√ Fifth Avenue pedestrian volume = 40 p/h,
√ Movement lost time = 4 s,
√ Arrival Type 3,
√ No bicycles, and
√ No buses.

Comments

√ Assume crosswalk width = 3.0 m for all approaches,
√ Assume base saturation flow rate = 1,900 pc/h/ln,
√ Assume E_T = 2.0,
√ No overlaps in signal phasing,
√ 90.0-s cycle length, with green times given, and
√ Assume a unit extension of 2.5 s for all phases.



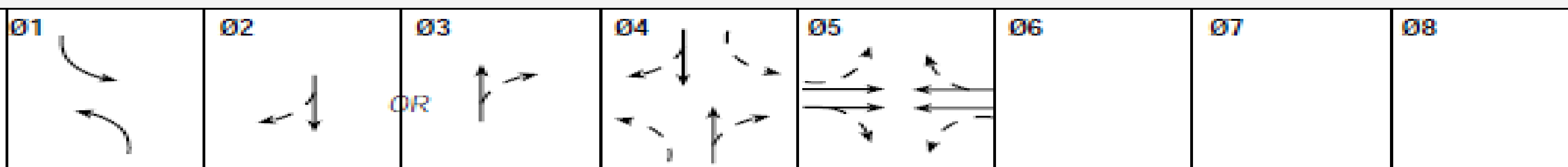


Volume and Timing Input

	EB			WB			NB			SB		
	LT	TH	RT[1]	LT	TH	RT[1]	LT	TH	RT[1]	LT	TH	RT[1]
Volume, V (veh/h)	60	270	90	100	510	20	120	1480	80	175	840	70
% heavy vehicles, % HV		5			5			2			2	
Peak-hour factor, PHF		0.85			0.85			0.90			0.90	
Pretimed (P) or actuated (A)		A			A			A			A	
Start-up lost time, l_1 (s)												
Extension of effective green time, e (s)												
Arrival type, AT		3			3			3			3	
Approach pedestrian volume,[2] v_{ped} (p/h)		120			120			40			40	
Approach bicycle volume,[2] v_{bic} (bicycles/h)		0			0			0			0	
Parking (Y or N)		Y			Y			N			N	
Parking maneuvers, N_m (maneuvers/h)		5			5			0			0	
Bus stopping, N_B (buses/h)		0			0			0			0	
Min. timing for pedestrians,[3] G_p (s)		19.0			19.0			21.0			21.0	

Signal Phasing Plan

DIAGRAM



	Ø1	Ø2	Ø3	Ø4	Ø5	Ø6	Ø7	Ø8
Timing	G = 8.1 Y = 4.0	G = 0.0 Y = 0.0	G = 0.0 Y = 0.0	G = 50.7 Y = 4.0	G = 19.2 Y = 4.0	G = Y =	G = Y =	G = Y =

Protected turns — Permitted turns — Pedestrian — Cycle length, C = 90.0 s

VOLUME ADJUSTMENT AND SATURATION FLOW RATE WORKSHEET

General Information

Project Description *Example Problem 3*

Volume Adjustment

	EB			WB			NB			SB		
	LT	TH	RT	LT	TH	RT	LT	TH	RT	LT	TH	RT
Volume, V (veh/h)	*60*	*270*	*90*	*100*	*510*	*20*	*120*	*1480*	*80*	*175*	*840*	*70*
Peak-hour factor, PHF		*0.85*			*0.85*			*0.90*			*0.90*	
Adjusted flow rate, v_p = V/PHF (veh/h)	*71*	*318*	*106*	*118*	*600*	*24*	*133*	*1644*	*89*	*194*	*933*	*78*
Lane group												
Adjusted flow rate in lane group, v (veh/h)	*71*	*424*		*118*	*624*		*133*		*1733*	*194*		*1011*
Proportion[1] of LT or RT (P_{LT} or P_{RT})	*1.000*	-	*0.250*	*1.000*	-	*0.038*	*1.000*	-	*0.051*	*1.000*	-	*0.077*

1. Pedestrians/cycle.	$120\frac{p}{h} * \frac{1h}{3,600\ s} * 90.0\ s = 3\ p$ (12th St.) $40\frac{p}{h} * \frac{1h}{3,600\ s} * 90.0\ s = 1\ p$ (5th Ave.)
2. Minimum effective green time required for pedestrians (use Equation 16-2).	$G_p = 3.2 + \frac{L}{S_p} + 0.27N_{ped}$ (for $W_E \leq 3.0$ m) $G_p\ (12th) = 3.2 + \frac{18.0}{1.2} + 0.27(3) = 19.0\ s$ $G_p\ (5th) = 3.2 + \frac{21.0}{1.2} + 0.27(1) = 21.0\ s$
3. Compare minimum effective green time required for pedestrians with actual effective green.	g(12th) = 19.2 s, which is > 19.0 s g(5th) = 50.7 s, which is > 21.0 s
4. Proportion of left turns and right turns.	Proportions of left- and right-turn traffic are found by dividing the appropriate turning flow rates by the total lane group flow rate. P_{LT} for exclusive LT lane is 1.000
5. Lane width adjustment factor (use Exhibit 16-7).	$f_w = 1 + \frac{(W - 3.6)}{9}$ $f_w(NB / SB) = 1 + \frac{(3.6 - 3.6)}{9} = 1.000$ $f_w(EB / WB) = 1 + \frac{(3.0 - 3.6)}{9} = 0.933$

6. Heavy-vehicle adjustment factor (use Exhibit 16-7).	$f_{HV} = \frac{100}{100 + \%\,HV(E_T - 1)}$ $f_{HV}(NB/SB) = \frac{100}{100 + 2(2.0 - 1)} = 0.980$ $f_{HV}(EB/WB) = \frac{100}{100 + 5(2.0 - 1)} = 0.952$
7. Percent grade adjustment factor (use Exhibit 16-7).	0% grade, $f_g = 1.000$
8. Parking adjustment factor (use Exhibit 16-7).	$f_p = \frac{N - 0.1 - \frac{18N_m}{3600}}{N}$ $f_p = 0.938$ for EB and WB through/right lane groups
9. Bus blockage adjustment factor (use Exhibit 16-7).	No bus stopping, $f_{bb} = 1.000$
10. Area type adjustment factor (use Exhibit 16-7).	For CBD, $f_a = 0.900$
11. Lane utilization adjustment factor (use Exhibit 10-23).	No specific data are given. Use default of $f_{LU} = 1.000$ for exclusive LT. Use 0.950 for shared LT.
12. Left-turn adjustment factor.	The left turn is permitted. A special procedure is used. All approaches are opposed by multilane approaches. The supplemental worksheet for multilane approaches is used to determine the factor.
13. Right-turn adjustment factor.	For all shared-lane approaches: $f_{RT} = 1.0 - 0.150P_{RT}$ Where P_{RT} is the proportion of right turns in lane group, $f_{RT}(EB) = 1.0 - 0.150(0.250) = 0.963$

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

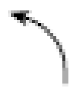
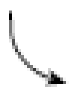
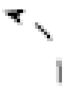
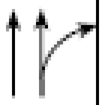
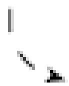
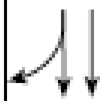
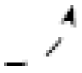
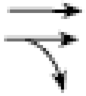
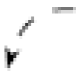
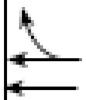
Base saturation flow, s_o (pc/h/ln)	1900	1900		1900	1900		1900	1900	1900	1900	1900	1900
Number of lanes, N	1	2		1	2		1	1	2	1	1	2
Lane width adjustment factor, f_w	0.933	0.933		0.933	0.933		1.000	1.000	1.000	1.000	1.000	1.000
Heavy-vehicle adjustment factor, f_{HV}	0.952	0.952		0.952	0.952		0.980	0.980	0.980	0.980	0.980	0.980
Grade adjustment factor, f_g	1.000	1.000		1.000	1.000		1.000	1.000	1.000	1.000	1.000	1.000
Parking adjustment factor, f_p	1.000	0.938		1.000	0.938		1.000	1.000	1.000	1.000	1.000	1.000
Bus blockage adjustment factor, f_{bb}	1.000	1.000		1.000	1.000		1.000	1.000	1.000	1.000	1.000	1.000
Area type adjustment factor, f_a	0.900	0.900		0.900	0.900		0.900	0.900	0.900	0.900	0.900	0.900
Lane utilization adjustment factor, f_{LU}	1.000	0.950		1.000	0.950		1.000	1.000	0.950	1.000	1.000	0.950
Left-turn adjustment factor, f_{LT}	0.208	1.000		0.343	1.000		0.950	0.200	1.000	0.950	0.073	1.000
Right-turn adjustment factor, f_{RT}	1.000	0.963		1.000	0.994		1.000	1.000	0.992	1.000	1.000	0.988
Left-turn ped/bike adjustment factor, f_{Lpb}	0.951	1.000		0.921	1.000		1.000	0.999	1.000	1.000	1.000	1.000
Right-turn ped/bike adjustment factor, f_{Rpb}	1.000	0.958		1.000	0.994		1.000	1.000	0.999	1.000	1.000	0.998
Adjusted saturation flow, s (veh/h) $s = s_o N f_w f_{HV} f_g f_p f_{bb} f_a f_{LU} f_{LT} f_{RT} f_{Lpb} f_{Rpb}$	300	2497		480	2675		1592	335	3155	1592	122	3140

CAPACITY AND LOS WORKSHEET

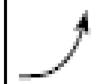
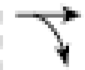
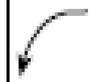
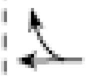
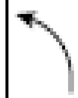
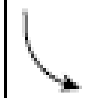
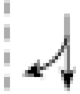
General information

Project Description *Example Problem 3*

Capacity Analysis

Phase number	1	1	4	4	4	4	5	5	5	5		
Phase type												
Lane group												
Adjusted flow rate, v (veh/h)	133	143	0	1733	51	1011	71	424	118	624		
Saturation flow rate, s (veh/h)	1592	1592	335	3155	122	3140	300	2497	480	2675		
Lost time, t_L (s), $t_L = l_1 + Y - e$	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0		
Effective green time, g (s), $g = G + Y - t_L$	8.1	8.1	54.7	50.7	54.7	50.7	19.2	19.2	19.2	19.2		
Green ratio, g/C	0.090	0.090	0.608	0.563	0.608	0.563	0.213	0.213	0.213	0.213		
Lane group capacity,[1] c = s(g/C), (veh/h)	143	143	204	1776	74	1768	64	532	102	570		
v/c ratio, X	0.930	1.000	0.000	0.976	0.689	0.572	1.109	0.797	1.157	1.095		
Flow ratio, v/s		0.090		0.549					0.246			
Critical lane group/phase (√)		√		√					√			
Sum of flow ratios for critical lane groups, Y_c $Y_c = \sum$ (critical lane groups, v/s)						0.885				في الحركة المنعطفة لليسار من الذراع SB		
Total lost time per cycle, L (s)						12.0				أخذ معدل الغزارة (Vp) 143 بدلا من 194		
Critical flow rate to capacity ratio, X_c $X_c = (Y_c)(C)/(C - L)$						1.021				كون سعة مجموعة الحارات هو 143		

Lane Group Capacity, Control Delay, and LOS Determination

	EB		WB		NB		SB	
Lane group								
Adjusted flow rate,[2] v (veh/h)	71	424	118	624	133	1733	194	1011
Lane group capacity,[2] c (veh/h)	64	532	102	570	347	1776	217	1768
v/c ratio,[2] X = v/c	1.109	0.797	1.157	1.095	0.383	0.976	0.894	0.572
Total green ratio,[2] g/C	0.213	0.213	0.213	0.213	0.698	0.563	0.698	0.563
Uniform delay, $d_1 = \frac{0.50\,C\,[1-(g/C)]^2}{1-[\min(1,X)g/C]}$ (s/veh)	35.415	33.571	33.415	35.415	6.582	19.075	25.957	12.676
Incremental delay calibration,[3] k	0.500	0.329	0.500	0.500	0.080	0.480	0.411	0.140
Incremental delay,[4] d_2 $d_2 = 900T[(X-1)+\sqrt{(X-1)^2+\frac{8klX}{cT}}]$ (s/veh)	145.509	8.034	137.481	66.241	0.514	15.966	33.699	0.380
Initial queue delay, d_3 (s/veh) (Appendix F)	0	0	0	0	0	0	0	0
Uniform delay, d_1 (s/veh) (Appendix F)								
Progression adjustment factor, PF	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Delay, $d = d_1(PF) + d_2 + d_3$ (s/veh)	180.9	41.6	172.9	101.7	7.1	35.0	59.7	13.1
LOS by lane group (Exhibit 16-2)	F	D	F	F	A	C	E	B
Delay by approach, $d_A = \frac{\sum(d)(v)}{\sum v}$ (s/veh)	61.6		113.0		33.0		20.6	
LOS by approach (Exhibit 16-2)	E		F		C		C	
Approach flow rate, v_A (veh/h)	495		742		1866		1205	
Intersection delay, $d_I = \frac{\sum(d_A)(v_A)}{\sum v_A}$ (s/veh)	46.6		Intersection LOS (Exhibit 16-2)				D	

19. Determine critical lane group in each timing phase.	Critical lane groups: Phase 1: SB protected left turn Phase 2: NB through + right Phase 3: WB left turn
20. Flow ratio of critical lane groups.	$v/s(SBLT) = \frac{143}{1592} = 0.090$ $v/s(NBTHRT) = \frac{1733}{3155} = 0.549$ $v/s\ (WBLT) = \frac{118}{480} = 0.246$
21. Sum of critical lane group v/s ratios.	$Y_c = 0.090 + 0.549 + 0.246 = 0.885$

22.	Critical flow rate to capacity ratio.	$X_c = \frac{Y_c * C}{C - L}$ $X_c = \frac{0.885(90.0)}{90.0 - 12} = 1.021$
23.	Uniform delay.	$d_1 = \frac{0.50C\left(1-\frac{g}{C}\right)^2}{1-\left[\min(1,X)\frac{g}{C}\right]}$ $d_1(\text{EBLT}) = \frac{0.50(90.0)(1-0.213)^2}{1-(0.213)(1.0)} = 35.415$ s/veh Since NB and SB left turns are contained in two phases, a supplemental uniform delay worksheet is used.
24.	Incremental delay.	$d_2 = 900T\left[(X-1)+\sqrt{(\ldots)}\right]$ $d_2(\text{EBLT}) = 900(0.25)\left[(1.109-1)+\sqrt{(\ldots)}\right] =$ 145.509 s/veh
25.	Progression adjustment factor (use Exhibit 16-12).	PF = 1.000
26.	Lane group delay.	$d = d_1PF + d_2 + d_3$ (d_3 is assumed to be 0 for the first iteration) d (EBLT) = 34.415(1.000) + 145.509 = 180.9 s/veh
27.	Approach delay.	$d_A = \frac{\sum(d)(v)}{\sum v}$ $d_A(\text{EB}) = \frac{(180.9*71)+(41.6*424)}{(71+424)} = 61.6$ s/veh
28.	Intersection delay.	$d_I = \frac{\sum(d_A)(v_A)}{\sum v_A}$ $d_I = \frac{(495*61.6)+(742*113.0)+(1866*33.0)+(1205*20.6)}{(495+742+1866+1205)} =$ 46.6 s/veh
29.	LOS by lane group, approach, and intersection.	LOS (EBLT) = F LOS (EB) = E LOS Intersection = D

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