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 2

The Intersection The intersection of Sixth Street (NB) and Western Boulevard (EB/WB) is located in an outlying area. Intersection geometry and flow characteristics are shown on the Input Worksheet.

The Question What are the delay and peak-hour LOS for this intersection?

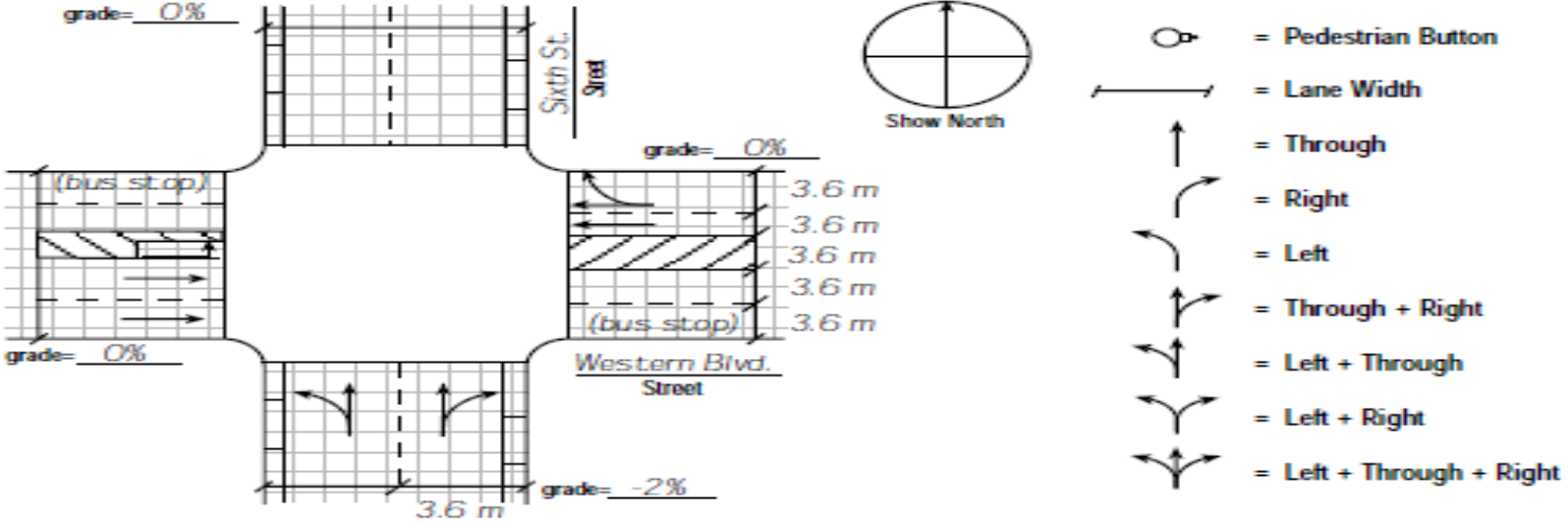
The Facts

- √ EB and WB HV = 10 percent,
- √ NB HV = 5 percent,
- √ PHF = 0.95,
- √ No parking EB/WB,
- √ Arrival Type 3,
- √ Movement lost time = 4 s, each phase
- √ Sixth Street NB grade = -2 percent
- √ Three-phase signal,
- √ Western Blvd. bus stopping = 20 b/h,
- √ Pedestrian volume = 50 p/h, all approaches,
- √ All lane widths are 3.6 m,
- √ Western Boulevard has two lanes in each direction plus an added left-turn lane for EB,
- √ Sixth Street is a NB one-way street with two lanes,
- √ Bicycle volume = 20 bicycles/h, all approaches,
- √ NB parking = 20 maneuvers/h, and
- √ Peak-hour volume data, by approach and movement, are shown on the Input Worksheet.

Comments

- √ Assume a range of cycle lengths of 70 s to 100 s. This range relates to default values given in Chapter 10,
- √ Assume crosswalk width = 3.0 m for all approaches,
- √ Assume N/S crosswalks are 18.0 m long and E/W crosswalks are 13.2 m long,
- √ Assume base saturation flow rate = 1,900 pc/h/ln,
- √ Assume E_T = 2.0, and
- √ Signal timing and cycle length are not given, therefore the quick estimation method is required to determine these two parameters.

The timing for Phases 1, 2, and 3 is 11.2 s, 27.4 s, and 31.4 s, respectively.



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)	120	980			700	100	40	785	25			
% heavy vehicles, % HV		10			10			5				
Peak-hour factor, PHF		0.95			0.95			0.95				
Pretimed (P) or actuated (A)												
Start-up lost time, l_1 (s)												
Extension of effective green time, e (s)												
Arrival type, AT		3			3			3				
Approach pedestrian volume,[2] v_{ped} (p/h)		50			50			50				
Approach bicycle volume,[2] v_{bic} (bicycles/h)		20			20			20				
Parking (Y or N)		N			N			Y				
Parking maneuvers, N_m (maneuvers/h)		-			-			20				
Bus stopping, N_B (buses/h)		20			20			-				
Min. timing for pedestrians,[3] G_p (s)		18.5			18.5			14.5				

Signal Phasing Plan

DIAGRAM	Ø1	Ø2	Ø3	Ø4	Ø5	Ø6	Ø7	Ø8
Timing	G = 7.2 Y = 4	G = 23.4 Y = 4	G = 27.4 Y = 4	G = Y =	G = Y =	G = Y =	G = Y =	G = Y =

Protected turns | Permitted turns | Pedestrian | Cycle length, C = 70 s

Notes

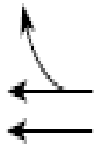
7. Minimum effective green time required for pedestrians (use Equation 16-2).	$G_p = 3.2 + \frac{L}{1.2} + 0.27N_{ped}$ $G_p(\text{Western}) = 3.2 + \frac{18.0}{1.2} + 0.27(0.972) = 18.5\ \text{s}$ $G_p(\text{Sixth}) = 3.2 + \frac{13.2}{1.2} + 0.27(0.972) = 14.5\ \text{s}$
8. Compare minimum effective green time required for pedestrians with actual effective green.	g(Western) = 23.4 s, which is >18.5 s g(Sixth) = 27.4 s, which is >14.5 s
9. Proportion of left turns and right turns.	Proportions of left- and right-turn traffic are found by dividing the appropriate turning volumes by the total lane group volume. P_{LT} (EB) = 1.000 for the exclusive left-turn lane

10. Lane width adjustment factor (use Exhibit 16-7).	$f_w = 1 + \frac{(W - 3.6)}{9}$ $f_w(EB) = 1 + \frac{(3.6 - 3.6)}{9} = 1.000$
11. Heavy-vehicle adjustment factor (use Exhibit 16-7).	$f_{HV} = \frac{100}{100 + \%\,HV(E_T - 1)}$ $f_{HV}(EB) = \frac{100}{100 + 10(2.0 - 1)} = 0.909$
12. Percent grade adjustment factor (use Exhibit 16-7).	0% grade, f_g = 1.000
13. Parking adjustment factor (use Exhibit 16-7).	No parking maneuvers (EB and WB), f_p = 1.000 20 parking maneuvers/hour (NB), f_p = 0.900
14. Bus blockage adjustment factor (use Exhibit 16-7).	No bus stopping (NB), f_{bb} = 1.0 20 buses/hour stopping (EB and WB), f_{bb} = 0.960
15. Area type adjustment factor (use Exhibit 16-7).	For outlying areas, f_a = 1.000

16. Lane utilization adjustment factor (use Exhibit 16-7).	Refer to Exhibit 10-23. This factor is applied to establish the conditions in the worst lane within each lane group. Otherwise, the results would reflect the average of all lanes of the defined lane groups. Use f_{LU} = 0.950 for all through movements.
17. Left-turn adjustment factor (use Exhibit 16-7).	f_{LT} applies to the EB left turn. For protected LT, f_{LT} = 0.950. For permitted LT, the supplemental worksheet for multilane approaches is used. f_{LT} (permitted) = 0.149. NB left turn is treated as a shared lane protected left turn because it has no opposing flow. f_{LT} (NB) = 0.998 (use equation in Exhibit 16-7).
18. Right-turn adjustment factor (use Exhibit 16-7).	f_{RT} is applied to NB and WB right turns. $f_{RT} = 1.0 - 0.150P_{RT}$

VOLUME ADJUSTMENT AND SATURATION FLOW RATE WORKSHEET

Volume Adjustment

	EB			WB			NB			SB		
	LT	TH	RT	LT	TH	RT	LT	TH	RT	LT	TH	RT
Volume, V (veh/h)	120	980			700	100	40	785	25			
Peak-hour factor, PHF		0.95			0.95			0.95				
Adjusted flow rate, v_p = V/PHF (veh/h)	126	1032			737	105	42	826	26			
Lane group												
Adjusted flow rate in lane group, v (veh/h)	126		1032		842			894				
Proportion[1] of LT or RT (P_{LT} or P_{RT})	1.000	-			-	0.125	0.047	-	0.029		-	

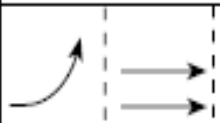
Saturation Flow Rate (see Exhibit 16-7 to determine adjustment factors)												
Base saturation flow, s_o (pc/h/ln)	1900	1900	1900		1900			1900				
Number of lanes, N	1	1	2		2			2				
Lane width adjustment factor, f_w	1.000	1.000	1.000		1.000			1.000				
Heavy-vehicle adjustment factor, f_{HV}	0.909	0.909	0.909		0.909			0.952				
Grade adjustment factor, f_g	1.000	1.000	1.000		1.000			1.010				
Parking adjustment factor, f_p	1.000	1.000	1.000		1.000			0.900				
Bus blockage adjustment factor, f_{bb}	1.000	1.000	0.960		0.960			1.000				
Area type adjustment factor, f_a	1.000	1.000	1.000		1.000			1.000				
Lane utilization adjustment factor, f_{LU}	1.000	1.000	0.950		0.950			0.950				
Left-turn adjustment factor, f_{LT}	0.950	0.149	1.000		1.000			0.998				
Right-turn adjustment factor, f_{RT}	1.000	1.000	1.000		0.981			0.996				
Left-turn ped/bike adjustment factor, f_{Lpb}	1.000	0.999	1.000		1.000			0.998				
Right-turn ped/bike adjustment factor, f_{Rpb}	1.000	1.000	1.000		0.992			0.998				
Adjusted saturation flow, s (veh/h) $s = s_o\ N\ f_w\ f_{HV}\ f_g\ f_p\ f_{bb}\ f_a\ f_{LU}\ f_{LT}\ f_{RT}\ f_{Lpb}\ f_{Rpb}$	1641	257	3150		3066			3074				
Notes												

CAPACITY AND LOS WORKSHEET

Capacity Analysis

Phase number	1	2	1/2	2	3							
Phase type	P	S	P	P	P							
Lane group												
Adjusted flow rate, v (veh/h)	126	0	1032	842	894							
Saturation flow rate, s (veh/h)	1641	257	3150	3066	3090							
Lost time, t_L (s), $t_L = I_1 + Y - e$	4	0	4	4	4							
Effective green time, g (s), $g = G + Y - t_L$	7.2	27.4	34.6	23.4	27.4							
Green ratio, g/C	0.103	0.391	0.494	0.334	0.391							
Lane group capacity,[1] c = s(g/C), (veh/h)	169	100	1556	1024	1208							
v/c ratio, X	0.746	0.000	0.663	0.822	0.740							
Flow ratio, v/s	0.077	0.000	0.328	0.275	0.289							
Critical lane group/phase (√)	√			√	√							
Sum of flow ratios for critical lane groups, Y_c $Y_c = \sum$ (critical lane groups, v/s)	0.641											
Total lost time per cycle, L (s)	12											
Critical flow rate to capacity ratio, X_c $X_c = (Y_c)(C)/(C - L)$	0.774											

Lane Group Capacity, Control Delay, and LOS Determination

	EB		WB	NB	SB
Lane group					
Adjusted flow rate,[2] v (veh/h)	126	1032	842	894	
Lane group capacity,[2] c (veh/h)	269	1556	1024	1208	
v/c ratio,[2] X = v/c	0.468	0.663	0.822	0.740	
Total green ratio,[2] g/C	0.494	0.494	0.334	0.391	
Uniform delay, $d_1 = \frac{0.50\,C\,[1-(g/C)]^2}{1-[\min(1,X)g/C]}$ (s/veh)	11.811	13.326	21.400	18.266	
Incremental delay calibration,[3] k	0.500	0.500	0.500	0.500	
Incremental delay,[4] d_2 $d_2 = 900T[(X-1)+\sqrt{(X-1)^2+\frac{8klX}{cT}}]$ (s/veh)	5.748	2.243	7.429	4.097	
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	1.000	1.000	1.000	1.000	
Delay, $d = d_1(PF) + d_2 + d_3$ (s/veh)	17.6	15.6	28.8	22.4	
LOS by lane group (Exhibit 16-2)	B	B	C	C	
Delay by approach, $d_A = \frac{\sum(d)(v)}{\sum v}$ (s/veh)	15.8		28.8	22.4	
LOS by approach (Exhibit 16-2)	B		C	C	
Approach flow rate, v_A (veh/h)	1158		842	894	
Intersection delay, $d_I = \frac{\sum(d_A)(v_A)}{\sum v_A}$ (s/veh)	21.6		Intersection LOS (Exhibit 16-2)		C

عرض حارة المرور Lane width	$f_w = 1 + \frac{(w - 3.6)}{9}$	W: عرض حارة المرور (m)	$w \geq 2.4$ من أجل $w \geq 4.8$ يعتبر عدد الحارات حارتان
العربات الثقيلة Heavy vehicles	$f_{HV} = \frac{100}{100 + \%HV(E_T - 1)}$	%HV: النسبة المئوية للعربات الثقيلة في مجموعة الحارات	ET=2.0 pc/HV
الميل Grade	$f_g = 1 - \frac{\%G}{200}$	%G: النسبة المئوية للميل الطولي لذراع مجموعة الحارات المدروسة	-6 ? %Gw ?+10 القيمة السالبة تعبر عن الميل الهابط
وقوف العربات Parking	$f_p = \frac{N - \frac{14.4Nm}{3600}}{N}$	N: عدد حارات المرور في المجموعة المدروسة Nm:عدد حركات المناورة للوقوف (man/h)	0 ? N_m ?180 $f_p \geq 0.05$ $f_p = 1.0$حالة عدم وقوف
إعاقة بسبب الباصات Bus blockage	$f_{bb} = \frac{N - \frac{14.4N_B}{3600}}{N}$	N: عدد حارات المرور في المجموعة المدروسة N_B:عدد الباصات المتوقفة خلال ساعة(bus/h)	0 ? N_B ? 250 $F_{bb} \geq 0.05$

نوع المنطقة Type of area	fa = 0.900 مركز المدينة (CBD) fa = 1.000 مناطق أخرى		
استخدام حارة المرور lane utilization	$f_{LU} = v_g/(v_{g1}N)$	v_g:معدل الطلب على الغزارة غير المصحح لمجموعة الحارات veh/h v_{g1}: معدل الطلب على الغزارة لحارة مرور واحدة ضمن مجموعة الحارات ذات الغزارة الأعظمية veh/h N: عدد حارات المرور في المجموعة المدروسة	
الانعطاف لليسار Left turns	طور محمي: حارة مخصصة : $f_{LT} = 0.95$ حارة مشتركة: $f_{LT} = \frac{1}{1.0 + 0.05P_{LT}}$	P_{LT}: نسبة الحركة المنعطفة لليسار في مجموع الحارات المدروسة	
الانعطاف لليمين Right Turns	حارة مخصصة : $f_{RT} = 0.85$ حارة مشتركة: $f_{RT}=1.0-0.15P_{RT}$ حارة مفردة: $f_{RT}=1.0-0.135P_{RT}$	P_{RT}: نسبة الحركة المنعطفة لليمين في مجموع الحارات المدروسة	$f_{RT} \geq 0.05$
إعاقة المشاة والدراجات Pedestrian bicycle blockage	ضبط الانعطاف لليسار LT: $f_{Lpb} = 1.0 - P_{LT}(1 - A_{pbT})(1 - P_{LTA})$ ضبط الانعطاف لليمين RT: $f_{Rpb} = 1.0 - P_{RT}(1 - A_{pbT})(1 - P_{RTA})$	P_{LT}: نسبة الحركة المنعطفة لليسار في مجموع الحارات المدروسة A_{pbT}: تعديل الطور المسموح P_{LTA} : نسبة الانعطاف لليسار خلال الطور الأخضر المخصص P_{RT}: نسبة الحركة المنعطفة لليمين في مجموع الحارات المدروسة P_{RTA}: نسبة الانعطاف لليمين خلال الطور الأخضر المحمي	

حالات الحركة المنعطفة لليسار وطريقة معالجتها		
1	حارة مخصصة + طور محمي Exclusive LT + Protected Phase	0.95
2	حارة مخصصة + طور غير محمي Exclusive LT + Permitted Phase	**طريقة خاصة**
3	حارة مخصصة + (طور محمي + طور غير محمي)	**نطبق (1) للطور المحمي و(2) لغير المحمي**
4	حارة مشتركة + طور محمي Shared LT + Protected Phase	**نطبق العلاقة**
5	حارة مشتركة + طور غير محمي Shared LT + Permitted Phase	**طريقة خاصة**
6	حارة مشتركة + (طور محمي + طور غير محمي)	**نطبق (1) للطور المحمي و(2) لغير المحمي**

Exhibit 16-2. LOS Criteria for Signalized Intersections

LOS	Control Delay per Vehicle (s/veh)
A	≤ 10
B	> 10–20
C	> 20–35
D	> 35–55
E	> 55–80
F	> 80

TYPE ARRAIVAL (AT) شكل الوصول						معدل الزمن الأخضر "g/C"
AT-6	AT-5	AT-4	AT-3	AT-2	AT-1	
0.750	0.833	1.00	1.00	1.007	1.167	0.2
0.571	0.714	0.986	1.00	1.063	1.286	0.3
0.333	0.555	0.895	1.00	1.136	1.445	0.4
0.000	0.333	0.767	1.00	1.240	1.667	0.5
0.000	0.000	0.576	1.00	1.395	2.001	0.6
0.000	0.000	0.256	1.00	1.653	2.556	0.7
1.00	1.00	1.15	1.00	0.93	1.00	القيمة F_{PA}
2.000	1.667	1.333	1.00	0.667	0.333	القيمة R_P
4	8	12	16	12	8	m

$PF = (1 - P)f_{PA}/(1 - g/C)$.

Tabulation is based on default values of f_{PA} and Rp.

$P = R_p * g/C$ (may not exceed 1.0).

PF may not exceed 1.0 for AT 3 through AT 6.

الجدول (5–13) التأخر المنتظم (d1) وعامل التصحيح (DF)لأزمنة التأخير d1

EXHIBIT 16-13. k-VALUES TO ACCOUNT FOR CONTROLLER TYPE

Unit Extension (s)	Degree of Saturation (X)					
	≤ 0.50	0.60	0.70	0.80	0.90	≥ 1.0
≤ 2.0	0.04	0.13	0.22	0.32	0.41	0.50
2.5	0.08	0.16	0.25	0.33	0.42	0.50
3.0	0.11	0.19	0.27	0.34	0.42	0.50
3.5	0.13	0.20	0.28	0.35	0.43	0.50
4.0	0.15	0.22	0.29	0.36	0.43	0.50
4.5	0.19	0.25	0.31	0.38	0.44	0.50
5.0[a]	0.23	0.28	0.34	0.39	0.45	0.50
Pretimed or nonactuated movement	0.50	0.50	0.50	0.50	0.50	0.50

Note:
For a given unit extension and its k_{min} value at X = 0.5: $k = (1 - 2k_{min})(X - 0.5) + k_{min}$, $k \geq k_{min}$, and $k \leq 0.5$.
a. For unit extension > 5.0, extrapolate to find k, keeping $k \leq 0.5$.

للتواصل مع المهندس سامر برهان زريق

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