UNIVERSITI SAINS MALAYSIA

KSCP Examination
2016/2017 Academic Session

August 2017

EAL235 – Highway and Traffic Engineering
[*Kejuruteraan Lebuh Raya dan Lalu Lintas*]

Duration : 2 hours
[*Masa : 2 jam*]

Please check that this examination paper consists of **FIFTEEN (15)** pages of printed material including appendix before you begin the examination.

*[Sila pastikan bahawa kertas peperiksaan ini mengandungi **LIMA BELAS (15)** muka surat yang bercetak termasuk lampiran sebelum anda memulakan peperiksaan ini.]*

Instructions : This paper consists of **FOUR (4)** questions. Answer **ALL** questions.

[***Arahan*** *: Kertas ini mengandungi **EMPAT (4)** soalan. Jawab **SEMUA** soalan.*]

In the event of any discrepancies, the English version shall be used.

[*Sekiranya terdapat percanggahan pada soalan peperiksaan, versi Bahasa Inggeris hendaklah diguna pakai.*]

1. [a] John McAdam discovered that massive foundations of rock upon rock were unnecessary for building roads. He invented a new process, known as "Macadamisation". Nowadays, modern road construction still reflects McAdam's influence. Describe **FIVE (5)** philosophies or principles introduced by McAdam to design roadways.

John McAdam mendapati pembinaan jalan tidak memerlukan batu-batuan besar sebagai asas yang kukuh. Beliau mencipta proses baru, dikenali sebagai "Macadamisation". Pada masa kini, pembinaan jalan raya moden masih dipengaruhi prinsip yang diterapkan oleh McAdam. Huraikan ***LIMA (5)*** *falsafah atau prinsip yang diperkenalkan oleh McAdam untuk merekabentuk jalan raya.*

[10 marks/*markah*]

[b] As a site engineer of a concessionaire that was appointed to construct a new expressway, you are engaged with the earthwork along the road alignment within a designated location. Based on the provided information in **Table 1**, as well as the Shrinkage factor = 1.10, and distance between station = 50 m, you are required to:

Sebagai seorang jurutera tapak sebuah syarikat konsesi yang dilantik untuk membina sebuah lebuhraya baru, anda terlibat dengan kerja tanah di sepanjang penjajaran jalan di lokasi yang telah ditetapkan. Berdasarkan maklumat yang diberikan dalam ***Jadual 1****, serta faktor Pengecutan = 1.10, dan jarak antara stesen = 50 m, anda dikehendaki untuk:*

[i] Calculate the cut and fill volumes
Hitung isipadu potongan dan isi

[ii] Determine the adjusted fill volume
Tentukan isipadu isi larasan

[iii] Compute the exact volume
Kirakan jumlah isipadu tepat

[iv] Analyze the accumulated volume
Analisa jumlah isipadu terkumpul

[v] Based on the allocated stations and the calculated accumulated volumes, plot a mass-haul diagram
Berpandukan stesen yang diperuntukkan dan jumlah isipadu terkumpul yang dikira, plotkan sebuah gambarajah jisim-angkut

[15 marks/*markah*]

Table 1: Earthwork information within station 0-3

Jadual 1: Maklumat kerja tanah diantara stesen 0-3

Station *Stesen*	Area *Luas* (m^2)		Volume *Isipadu* (m^3)		Adjusted Fill *Isi Larasan* (m^3)	Exact volume *Isipadu Tepat* (m^3)	Accumulated Volume *Isipadu Terkumpul* (m^3)
	Cut *Potong*	Fill *Isi*	Cut *Potong*	Fill *Isi*			
0	70	10					
1	120	80					
2	137	110					
3	110	120					

2. [a] Percent time-spent-following (PTSF) and average travel speed (ATS) are the two performance measures used in U.S. HCM (2000) to determine the capacity and level-of-service for Class I, two-lane highway. Please explain the relationship between PTSF and ATS.

Peratusan masa membazir mengekor (PTSF) dan purata kelajuan perjalanan (ATS) merupakan dua ukuran prestasi yang digunakan dalam U.S. HCM (2000) untuk menentukan kapasiti dan aras perkhidmatan untuk lebuhraya dua lorong dua hala, kelas I. Sila terangkan hubungan antara PTSF dan ATS.

[9 marks/*markah*]

[b] In order for a two-lane highway to operate at level-of-service, D or better, the percent-time-spent-following must be in between 60% to 80% and the average travel speed must be more than 70 km/h. Based on the following information, determine the minimum shoulder width required for a highway segment (Class I) with level terrain to operate at the minimum level-of-service, D. Refer to the graph and tables and use the worksheet in the appendix for calculation and **submit the worksheet together with the answer script.**

Segment length = 5.0 km
Two-way hourly volume = 1,700 veh/h
Lane width = 3.6 m
Peak hour factor = 0.95
Percentage of trucks and buses = 12%
Percentage of recreational vehicles = 3%
Percentage of no-passing zone = 0%
Access point density = 6/km
Base free flow speed = 80 km/h

Untuk suatu lebuh raya dua-lorong untuk beroperasi pada aras perkhidmatan D, peratus masa mengikut kenderaan perlu berada dalam julat 65% hingga 80% dan purata kelajuan perjalanan antara 60 hingga 70 km/h. Dengan berdasarkan maklumat yang berikutnya, tentukan lebar bahu jalan minimum yang diperlukan untuk satu segmen lebuh raya datar (Kelas I) untuk mencapai aras perkhidmatan minima, D. Rujuk kepada graf dan jadual dan gunakan borang kerja yang diberikan dalam lampiran untuk pengiraan dan ***hantar sekali borang kerja tersebut dengan skrip jawapan***

Panjang segmen = 5.0 km
Isipadu jaman untuk dua arah = 1,700 kend/j
Lebar lorong = 3.6 m
Faktor waktu puncak = 0.95
Peratusan trak dan bas = 12%
Peratusan kenderaan rekreasi = 3%
Peratusan zon larangan memotong = 0%
Kepadatan akses = 6/km
Kelajuan aliran bebas asas = 80 km/h

[16 marks/*markah*]

3. [a] Explain the differences between free-flow speed and speed limit. Theoretically free-flow speed can't be measured directly at site but can be determined under certain condition. Explain the condition in which the measured speed can be assumed as free-flow speed. Subsequently, with the aid of sketches, discuss the meaning of free-flow in the speed-flow, speed-density and flow-density relationships.

Terangkan perbezaan kelajuan aliran bebas dengan had laju. Secara teori, kelajuan aliran bebas tidak dapat diukur secara langsung di lapangan tetapi boleh ditentukan di bawah keadaan tertentu. Terangkan keadaan di mana kelajuan yang diukur boleh dianggap sebagai kelajuan aliran bebas. Seterusnya, dengan berbantukan lakaran, bincangkan maksud kelajuan aliran-bebas dan ketumpatan sesak dalam hubungan kelajuan-aliran, kelajuan-ketumpatan dan aliran-ketumpatan.

[10 marks/*markah*]

[b] A traffic survey was conducted at mid-block of a multilane road, to determine the relationship of space mean speed, flow and density. Results of the study are shown in **Table 1** and **Figure 1** shows the speed-density graph. Assuming the relationship between speed and density is linear, determine the followings:

*Satu kajian lalu lintas telah dijalankan di pertengahan blok jalan pelbagai lorong, untuk menentukan kehubungan antara laju min ruang, aliran dan ketumpatan. Keputusan kajian ditunjukkan dalam **Jadual 1** dan **Rajah 1** menunjukkan graf kelajuan-ketumpatan. Dengan menganggap hubungan antara laju dengan ketumpatan adalah lelurus, tentukan yang berikut:*

[i] Free flow speed and jam density.
Laju aliran bebas dan ketumpatan sesak.

[ii] Maximum flow (per lane).
Aliran maksimum (per lorong).

[iii] By using graph papers, plot (according to scale) the speed-flow and flow-density graphs and show the values obtained in part (i) and (ii) in both graphs and **submit together with the answer script.**

Dengan menggunakan kertas graf, plot (ikut skala) graf kelajuan-aliran dan aliran-ketumpatan dan tunjukkan nilai-nilai yang diperolehi dalam bahagian (i) dan (ii) dalam kedua-dua graf tersebut dan ***hantar sekali dengan skrip jawapan****.*

[15 marks/*markah*]

Table 1: Results of study
***Jadual 1:* Keputusan kajian**

Space mean speed / *laju min ruang* (km/hr)	Flow/*Aliran* (pcu/hr/lane)
47.8	1350
52.6	1240
50.5	1315
49.8	1291
44.3	1295
45.7	1322
55.2	1205
60.7	1245
57.8	1195
62.4	1178

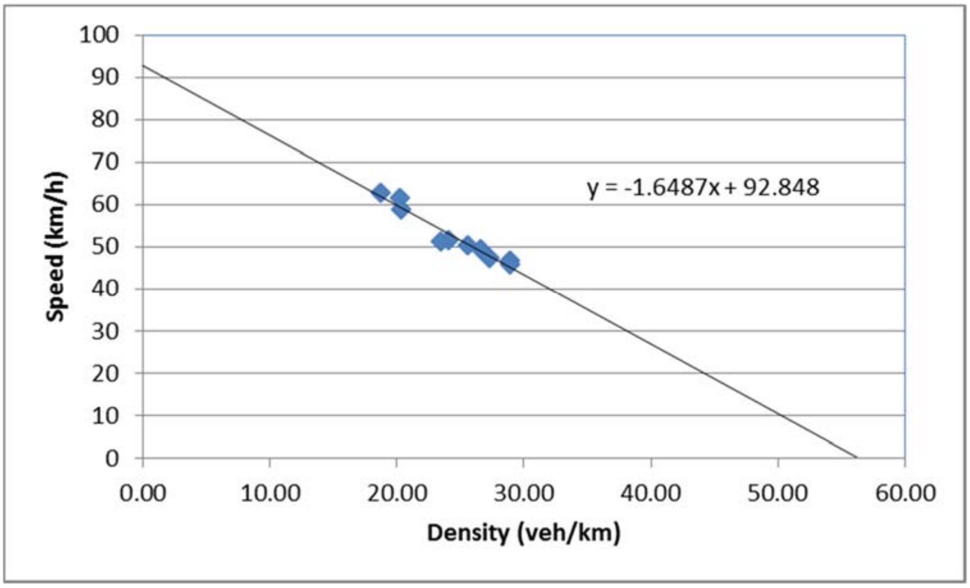

Figure 1: Speed-density graph
Rajah 1: Graf kelajuan-ketumpatan

4. [a] An intersection is an area, shared by two or more roads, whose main function is to provide for the change of route directions. Discuss **FOUR (4)** advantages and **FOUR (4)** disadvantages of signalised intersections. Subsequently, discuss **FOUR (4)** methods which can be used to increase the capacity of a signalised intersection.

Persimpangan merupakan satu kawasan yang dikongsi oleh dua atau lebih jalan yang mana fungsi utamanya adalah untuk menukar arah laluan. Terangkan ***EMPAT (4)*** *kebaikan dan* ***EMPAT (4)*** *keburukan persimpangan berlampu isyarat, Seterusnya, terangkan* ***EMPAT (4)*** *kaedah yang boleh digunakan untuk meningkatkan kapasiti suatu persimpangan berlampu isyarat.*

[12 marks/*markah*]

[b] A signalized intersection as shown in **Figure 2** is proposed. The signal phasing and q/S ratio for each approach for year 2017 are as shown in **Figure 3**. Traffic volumes recorded for year 2017 are as shown in **Table 2**.

Satu persimpangan berlampu isyarat ditunjukkan dalam ***Rajah 2*** *dicadangkan. Fasa lampu isyarat dan nisbah q/S untuk setiap jalan tuju untuk tahun 2017 ditunjukkan dalam* ***Rajah 3****. Isipadu lalulintas yang telah direkod untuk tahun 2017 ditunjukkan dalam* ***Jadual 2****.*

[i] Calculate q/s ratio for year 2027 if the annual traffic growth is 4.5%.
Kira nisbah q/S untuk tahun 2027 sekiranya pertumbuhan lalu lintas adalah 4.5%.

[ii] Sketch the ring diagram.
Lakarkan gambarajah cincin.

[iii] Using the Arahan Teknik (Jalan) method, design the traffic signal for year 2027 if cycle time is given as 154 seconds.

Dengan menggunakan kaedah Arahan Teknik (Jalan), rekabentuk lampu isyarat untuk tahun 2027 sekiranya masa kitar diberikan sebagai 154 saat.

[iv] Sketch the signal timing distribution diagram.

Lakarkan gambarajah agihan masa isyarat.

Given:

Diberi:

$$C_o = \frac{1.5L + 5}{1 - Y}$$

Amber time = 3 seconds

Masa kuning = 3 saat

All-red-interval time = 2 seconds

Masa semua fasa merah = 2 saat

Lost time per phase = 2 seconds

Masa hilang setiap fasa = 2 saat

[13 marks/*markah*]

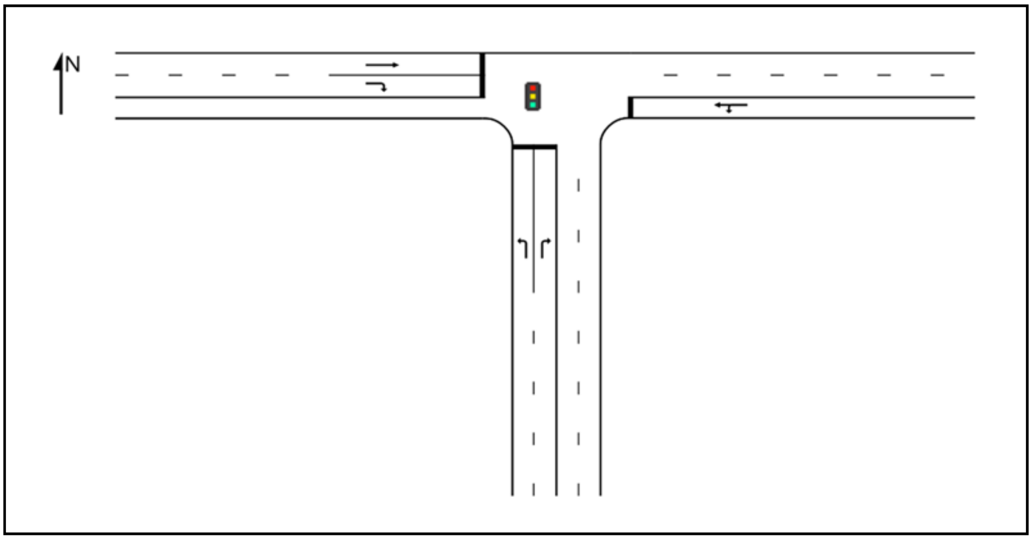

Figure 2: Geometry of junction

Rajah 2: Geometri persimpangan

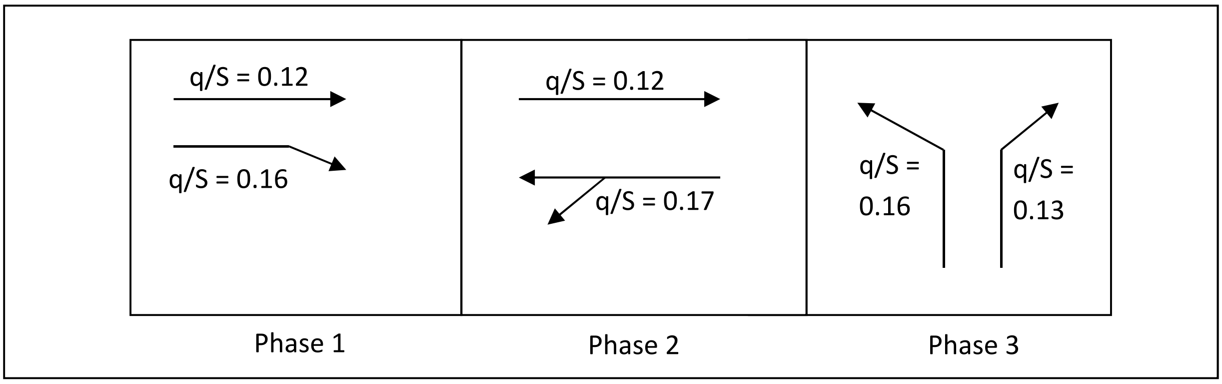

Figure 3: Proposed signal phasing and q/S ratio for year 2017
Rajah 3: Fasa lampu isyarat yang dicadangkan dan nisbah q/S untuk tahun 2017

Table 2: Traffic volume for year 2017
Jadual 2: Isipadu lalulintas untuk tahun 2017

Approach *Jalan*	Direction *Arah*	Traffic volume (pcu/hr) *Isipadu lalulintas (ukp/j)*
South	Left-turn	265
	Right-turn	210
East	Left-turn	38
	Straight through	287
West	Straight through	216
	Right-turn	225

APPENDIX/ *LAMPIRAN*

The following graph, tables and worksheet are extracted from U.S. Highway Capacity Manual 2000.

Graf, jadual dan borang kerja yang berikut diambil daripada U.S. Highway Capacity Manual 2000.

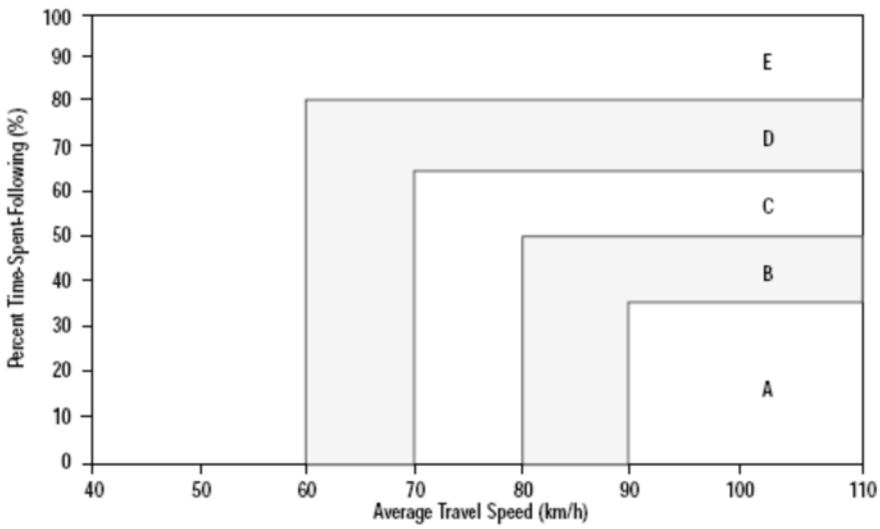

Exhibit 20-3: LOS Criteria for Two-Lane Highway for Class I

Exhibit 20-5: Adjustment (f_{LS}) for Lane Width and Shoulder Width

Lane Width (m)	Reduction in FFS (km/h)			
	Shoulder Width (m)			
	≥ 0.0 < 0.6	≥ 0.6 < 1.2	≥ 1.2 < 1.8	≥ 1.8
2.7 < 3.0	10.3	7.7	5.6	3.5
≥ 3.0 < 3.3	8.5	5.9	3.8	1.7
≥ 3.3 < 3.6	7.5	4.9	2.8	0.7
≥ 3.6	6.8	4.2	2.1	0.0

Exhibit 20-6: Adjustment (f_A) for Access-Point Density

Access Points per km	Reduction in FFS (km/h)
0	0.0
6	4.0
12	8.0
18	12.0
≥ 24	16.0

Exhibit 20-7: Grade Adjustment Factor (f_G) to determine speeds on Two-Way and Directional Segments

Range of Two-Way Flow Rates (pc/h)	Range of Directional Flow Rates (pc/h)	Type of Terrain	
		Level	Rolling
0–600	0–300	1.00	0.71
> 600–1200	> 300–600	1.00	0.93
> 1200	> 600	1.00	0.99

Exhibit 20-8: Grade Adjustment Factor (f_G) to Determine Percent Time-Spent-Following on Two-Way and Directional Segments

Range of Two-Way Flow Rates (pc/h)	Range of Directional Flow Rates (pc/h)	Type of Terrain	
		Level	Rolling
0–600	0–300	1.00	0.77
> 600–1200	> 300–600	1.00	0.94
> 1200	> 600	1.00	1.00

Exhibit 20-9: Passenger-Car Equivalents for Trucks and RVs to Determine Speeds on Two-Way and Directional Segments

Vehicle Type	Range of Two-Way Flow Rates (pc/h)	Range of Directional Flow Rates (pc/h)	Type of Terrain	
			Level	Rolling
Trucks, E_T	0–600	0–300	1.7	2.5
	> 600–1,200	> 300–600	1.2	1.9
	> 1,200	> 600	1.1	1.5
RVs, E_R	0–600	0–300	1.0	1.1
	> 600–1,200	> 300–600	1.0	1.1
	> 1,200	> 600	1.0	1.1

Exhibit 20-10: Passenger-Car Equivalents for Trucks and Rvs to Determine Percent Time-Spent-Following on Two-Way and Directional Segments

Vehicle Type	Range of Two-Way Flow Rates (pc/h)	Range of Directional Flow Rates (pc/h)	Type of Terrain	
			Level	Rolling
Trucks, E_T	0–600	0–300	1.1	1.8
	> 600–1,200	> 300–600	1.1	1.5
	> 1,200	> 600	1.0	1.0
RVs, E_R	0–600	0–300	1.0	1.0
	> 600–1,200	> 300–600	1.0	1.0
	> 1,200	> 600	1.0	1.0

…13/-

Exhibit 20-11: Adjustment (f_{np}) for Effect of No-Passing Zones on Average Travel Speed on Two-Way Segments

Two-Way Demand Flow Rate, v_p (pc/h)	Reduction in Average Travel Speed (km/h)					
	No-Passing Zones (%)					
	0	20	40	60	80	100
0	0.0	0.0	0.0	0.0	0.0	0.0
200	0.0	1.0	2.3	3.8	4.2	5.6
400	0.0	2.7	4.3	5.7	6.3	7.3
600	0.0	2.5	3.8	4.9	5.5	6.2
800	0.0	2.2	3.1	3.9	4.3	4.9
1000	0.0	1.8	2.5	3.2	3.6	4.2
1200	0.0	1.3	2.0	2.6	3.0	3.4
1400	0.0	0.9	1.4	1.9	2.3	2.7
1600	0.0	0.9	1.3	1.7	2.1	2.4
1800	0.0	0.8	1.1	1.6	1.8	2.1
2000	0.0	0.8	1.0	1.4	1.6	1.8
2200	0.0	0.8	1.0	1.4	1.5	1.7
2400	0.0	0.8	1.0	1.3	1.5	1.7
2600	0.0	0.8	1.0	1.3	1.4	1.6
2800	0.0	0.8	1.0	1.2	1.3	1.4
3000	0.0	0.8	0.9	1.1	1.1	1.3
3200	0.0	0.8	0.9	1.0	1.0	1.1

…14/-

Exhibit 20-12: Adjustment ($f_{d/np}$) for Combined Effect of Directional Distribution of Traffic and Percentage of No-Passing Zones on Percent Time-Spent-Following on Two-Way Segments

Two-Way Flow Rate, v_p (pc/h)	Increase in Percent Time-Spent-Following (%)					
	No-Passing Zones (%)					
	0	20	40	60	80	100
Directional Split = 50/50						
≤ 200	0.0	10.1	17.2	20.2	21.0	21.8
400	0.0	12.4	19.0	22.7	23.8	24.8
600	0.0	11.2	16.0	18.7	19.7	20.5
800	0.0	9.0	12.3	14.1	14.5	15.4
1400	0.0	3.6	5.5	6.7	7.3	7.9
2000	0.0	1.8	2.9	3.7	4.1	4.4
2600	0.0	1.1	1.6	2.0	2.3	2.4
3200	0.0	0.7	0.9	1.1	1.2	1.4
Directional Split = 60/40						
≤ 200	1.6	11.8	17.2	22.5	23.1	23.7
400	0.5	11.7	16.2	20.7	21.5	22.2
600	0.0	11.5	15.2	18.9	19.8	20.7
800	0.0	7.6	10.3	13.0	13.7	14.4
1400	0.0	3.7	5.4	7.1	7.6	8.1
2000	0.0	2.3	3.4	3.6	4.0	4.3
≥ 2600	0.0	0.9	1.4	1.9	2.1	2.2
Directional Split = 70/30						
≤ 200	2.8	13.4	19.1	24.8	25.2	25.5
400	1.1	12.5	17.3	22.0	22.6	23.2
600	0.0	11.6	15.4	19.1	20.0	20.9
800	0.0	7.7	10.5	13.3	14.0	14.6
1400	0.0	3.8	5.6	7.4	7.9	8.3
≥ 2000	0.0	1.4	4.9	3.5	3.9	4.2
Directional Split = 80/20						
≤ 200	5.1	17.5	24.3	31.0	31.3	31.6
400	2.5	15.8	21.5	27.1	27.6	28.0
600	0.0	14.0	18.6	23.2	23.9	24.5
800	0.0	9.3	12.7	16.0	16.5	17.0
1400	0.0	4.6	6.7	8.7	9.1	9.5
≥ 2000	0.0	2.4	3.4	4.5	4.7	4.9
Directional Split = 90/10						
≤ 200	5.6	21.6	29.4	37.2	37.4	37.6
400	2.4	19.0	25.6	32.2	32.5	32.8
600	0.0	16.3	21.8	27.2	27.6	28.0
800	0.0	10.9	14.8	18.6	19.0	19.4
≥1400	0.0	5.5	7.8	10.0	10.4	10.7

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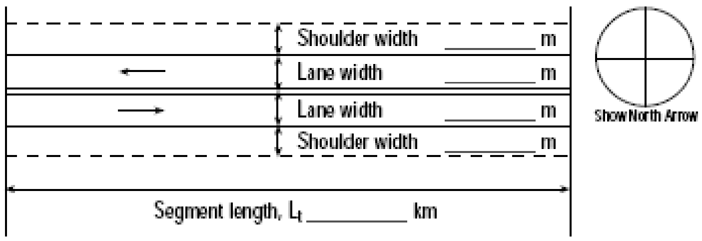
NO ANGKA GILIRAN:________________________

TWO-WAY TWO-LANE HIGHWAY SEGMENT WORKSHEET

General Information		Site Information	
Analyst	____________	Highway	____________
Agency or Company	____________	From/To	____________
Date Performed	____________	Jurisdiction	____________
Analysis Time Period	____________	Analysis Year	____________

❑ Operational (LOS) ❑ Design (v_p) ❑ Planning (LOS) ❑ Planning (v_p)

Input Data



❑ Class I highway ❑ Class II highway

Terrain ❑ Level ❑ Rolling

Two-way hourly volume ________ veh/h

Directional split ______ /_____

Peak-hour factor, PHF ________

% Trucks and buses, P_T ________ %

% Recreational vehicles, P_R ________ %

% No-passing zone ________ %

Access points/km ________/km

Average Travel Speed

Grade adjustment factor, f_G (Exhibit 20-7)	
Passenger-car equivalents for trucks, E_T (Exhibit 20-9)	
Passenger-car equivalents for RVs, E_R (Exhibit 20-9)	
Heavy-vehicle adjustment factor, f_{HV} $f_{HV} = \frac{1}{1 + P_T(E_T - 1) + P_R(E_R - 1)}$	
Two-way flow rate,[1] v_p (pc/h) $v_p = \frac{V}{PHF * f_G * f_{HV}}$	
v_p * highest directional split proportion[2] (pc/h)	

Free-Flow Speed from Field Measurement	Estimated Free-Flow Speed
Field measured speed, S_{FM} ____________ km/h Observed volume, V_f ____________ veh/h Free-flow speed, FFS ____________ km/h $FFS = S_{FM} + 0.0125\left(\frac{V_f}{f_{HV}}\right)$	Base free-flow speed, BFFS ____________ km/h Adj. for lane width and shoulder width, f_{LS} (Exhibit 20-5) ______ km/h Adj. for access points, f_A (Exhibit 20-6) ____________ km/h Free-flow speed, FFS ____________ km/h $FFS = BFFS - f_{LS} - f_A$
Adj. for no-passing zones, f_{np} (km/h) (Exhibit 20-11)	
Average travel speed, ATS (km/h) $ATS = FFS - 0.0125v_p - f_{np}$	

Percent Time-Spent-Following

Grade adjustment factor, f_G (Exhibit 20-8)	
Passenger-car equivalents for trucks, E_T (Exhibit 20-10)	
Passenger-car equivalents for RVs, E_R (Exhibit 20-10)	
Heavy-vehicle adjustment factor, f_{HV} $f_{HV} = \frac{1}{1 + P_T(E_T - 1) + P_R(E_R - 1)}$	
Two-way flow rate,[1] v_p (pc/h) $v_p = \frac{V}{PHF * f_G * f_{HV}}$	
v_p * highest directional split proportion[2] (pc/h)	
Base percent time-spent-following, BPTSF (%) $BPTSF = 100(1 - e^{-0.000879v_p})$	
Adj. for directional distribution and no-passing zone, $f_{d/np}$ (%) (Exhibit 20-12)	
Percent time-spent-following, PTSF (%) $PTSF = BPTSF + f_{d/np}$	

Level of Service and Other Performance Measures

Level of service, LOS (Exhibit 20-3 for Class I or 20-4 for Class II)	
Volume to capacity ratio, v/c $v/c = \frac{v_p}{3,200}$	
Peak 15-min vehicle-kilometers of travel, $VkmT_{15}$ (veh-km) $VkmT_{15} = 0.25L_t\left(\frac{V}{PHF}\right)$	
Peak-hour vehicle-kilometers of travel, $VkmT_{60}$ (veh-km) $VkmT_{60} = V * L_t$	
Peak 15-min total travel time, TT_{15} (veh-h) $TT_{15} = \frac{VkmT_{15}}{ATS}$	

Notes

1. If $v_p \geq 3,200$ pc/h, terminate analysis—the LOS is F.
2. If highest directional split $v_p \geq 1,700$ pc/h, terminate analysis—the LOS is F.