UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
SEMESTER I
SESSION 2011/2012

COURSE NAME	:	TRANSPORTATION ENGINEERING
COURSE CODE	:	BFT 4033/BFT 40303
PROGRAMME	:	4 BFF
DATE	:	JANUARY 2012
DURATION	:	3 HOURS
INSTRUCTION	:	ANSWER **FOUR (4)** FROM **FIVE (5)** QUESTIONS

THIS PAPER CONSISTS OF **TWENTY TWO (22)** PAGES

Q1 (a) Draw the curves that represent the relationships between speed and density, speed and flow, and flow and density. Also, state the location of the maximum flow at curves.

(6 marks)

(b) Explain the difference between space mean speed, v_s and time mean speed, v_t. State the equation for both mean speeds.

(4 marks)

(c) Traffic on a congested two lane- highway in Salak Selatan is following at 1650 veh/h at a speed of 35km/h and a density of 50 veh/km, when an overloaded truck enters this highway and travel for 2 km before exiting. A platoon forms behind the truck at a flow rate of 1200 veh/h and density of 180 veh/km. The rear of platoon is jointed by other vehicles.

(i) Calculate the shock-wave velocities.
(ii) Sketch the shock-wave measurements on the flow-density curve.
(iii) Find the time that the truck spends on the highway.
(iv) Find the time to dissipate the platoon.
(v) Find the time needed for the traffic flow to return to normal.

Assume $k_i = 210$ veh/km and the mean free speed $v_f = 50$ km/h. Also assume that after the truck leaves the highway, the traffic stream picks up speed to 25km/h with density of 105 veh/km.

(15 marks)

Q2 (a) Define the four step models for travel demand forecasting survey in sequential order.

(4 marks)

(b) Before the travel forecasting study being held, the transportation planner needs to define the characteristics of the survey area. Explain the meaning of:

(i) Urban growth boundary,
(ii) Zones,
(ii) Links,
(iii) Nodes.

Describe the meaning of terms above by using a diagram

(6 marks)

(c) A four zones of Batu Pahat city has number of productions and attractions as shown in **Table 1**. The travel time matrix can be referred at **Table 2**. Apply the gravity model to distribute the trips by assuming $K_{ij} = 1$

(15 marks)

Q3 (a) Define the terms that usually used in transportation study as stated below

(i) Shockwave

(ii) Trip generation

(iii) Trip distribution

(iv) Mode choice

(v) Trip assignment

(5 marks)

(b) After a survey was done at 20 zones of residential areas, an analyst in transportation planning came up with the following regression equations. Discuss the relationship between the dependent variable and the independent variables of all equations below.

$Y = 50.5 + 0.80X1$; $R2 = 0.95$
$Y = 308 + 0.79X2$; $R2 = 0.88$
$Y = 52.7 + 0.85X2 + 1.75X3$; $R2 = 0.98$
$Y = -105 + 1.38X2 - 0.4X3 + 0.1X4$; $R2 = 0.97$

Where

Y = trips produces
X1 = total population
X2 = less income population
X3 = high income population
X4 = school children

(15 marks)

Q4 (a) A new suburban freeway is being designed. Determine the number of lanes needed to provide LOS D during the peak hour using the given information and assumptions.

Percentage of trucks = 15 percent
Percentage of RVs = 3 percent
Lane width = 3.6 m
Peak Hour Factor = 0.85
Lateral clearance = 1.8 m
Interchange density = 0.9 interchanges/km
Volume = 4,000 veh/h (one direction)
Terrain = Level

Assume:
Percentage of buses and RVs = 0 percent
Base Free Flow Speed = 120 km/h
The number of lanes affects free-flow speed, since the freeway is being designed in a suburban area.
f_p = 1.00 for commuter traffic.
(Note: Flow rate, speed, density, and LOS are calculated starting with a four-lane freeway and then increasing the number of lanes to six, eight, and so forth until LOS D is achieved)

(10 marks)

(b) Determine level of service (LOS) of a Class I two-lane highway segment for the peak hour using the following information.

Demand volume for the full peak hour = 1,600 veh/h (two-way volume)
Directional split = 50/50
Percentage of trucks and buses = 14 percent
Percentage of RVs = 4 percent
Peak Hour Factor = 0.95
Base Free Flow Speed = 100 km/h
Terrain = Rolling
Lane width = 3.4 m
Shoulder width = 1.2 m
Length = 10 km
Percentage of no-passing zones = 50 percent
Number of access point = 12 points/km.

(15 marks)

Q5 (a) Define Traffic Impact Assessment (TIA).

(3 marks)

(b) Generally, there are two categories of increased trips in TIA namely **non-site traffic** and **site traffic**. Discusses each category.

(4 marks)

(c) The traffic impact caused by the proposed development is defined as the negative change in the following indicators. Describes each indicator.

i) Level of Service (LOS).

(2 marks)

ii) Volume/capacity ration (v/c ratio) or degree of saturation.

(2 marks)

iii) Maximum queue length.

(2 marks)

(d) A development is proposed to have the following land use schedule as shown in **Table 3**. Using the equations in **Table 4**, estimate trip productions and attractions and fill in **Table 5** and **Table 6**.

(12 marks)

S1 (a) Lukis rajah lengkungan yang menunjukkan hubung kait di antara laju dan ketumpatan, laju dan aliran serta aliran dan ketumpatan. Nyatakan juga kedudukan aliran maksimum pada rajah-rajah tersebut.

(6 markah)

(b) Terangkan perbezaan di antara laju purata ruang, v_s dengan laju purata masa, v_t. Tuliskan persamaan bagi kedua-dua laju purata tersebut.

(4 markah)

(c) Aliran trafik di sebuah jalan dua lorong di Salak Selatan bergerak dengan keadaan 1650 kenderaan/jam pada kelajuan 35km/h dan ketumpatan 50 kenderaan/km ketika sebuah lori yang sarat dengan muatan melalui jalan ini sejauh 2 km dan akhirnya menyusur keluar ke jalan lain. Platun telah terbentuk di belakang lori tersebut pada kadar aliran 1200 kenderaan/jam dan ketumpatan 180 kenderaan/km. Pertambahan kenderaan berlaku di belakang platun tersebut.

i) Kira halaju gelombang-kejutan.
ii) Lakar gelombang – kejutan pada lengkung aliran – ketumpatan situasi di atas.
iii) Kira masa yang diperuntukkan oleh lori tersebut di atas jalan tersebut.
iv) Kira masa yang diperlukan untuk menghilangkan platun tersebut.
v) Kira masa yang diperlukan untuk aliran trafik kembali normal.

Anggap k_i =210 kenderaan/km dan laju purata bebas v_f = 50 km/h. Apabila lori meninggalkan jalan tersebut, aliran trafik bertambah kepada 25 km/h dengan ketumpatan 105 kenderaan/km

(15 markah)

S2 (a) Nyatakan model empat langkah bagi unjuran permintaan perjalanan mengikut turutan.

(4 markah)

(b) Sebelum kajian terhadap unjuran perjalanan dilakukan, seorang perancang pengangkutan perlu mengenalpasti kawasan kajian. Terangkan maksud:

(i) Sempadan pertumbuhan bandar,
(ii) Zon,
(ii) Jaringan,
(iii) Nod.

Nyatakan maksud terminologi di atas dengan bantuan gambarajah yang sesuai.

(6 markah)

(c) Empat zon di Bandar Batu Pahat mempunyai kadar pengeluaran dan tarikan seperti di dalam **Jadual 1.** Manakala, matriks bagi masa perjalanan dirujuk pada **Jadual 2.** Agihkan perjalanan menggunakan model graviti. Anggap K_{ij} =1.

(15 markah)

S3 (a) Terangkan maksud terminologi yang digunakan di dalam kajian pengangkutan yang berikut

(i) *Shockwave*

(ii) *Trip generation*

(iii) *Trip distribution*

(iv) *Mode choice*

(v) *Trip assignment*

(5 markah)

(b) Selepas sebuah tinjauan di lakukan di 20 buah kawasan penempatan, seorang penganalisa di dalam bidang perancangan pengankutan telah menghasilkan persamaan regrasi yang berkaitan. Bincangkan hubung kait di antara pemboleh ubah bersandar dengan pemboleh ubah tidak bersandar pada persamaan-persamaan yang berikut.

$Y = 50.5 + 0.80X1$; $R^2 = 0.95$
$Y = 308 + 0.79X2$; $R^2 = 0.88$
$Y = 52.7 + 0.85X2 + 1.75X3$; $R^2 = 0.98$
$Y = -105 + 1.38X2 - 0.4X3 + 0.1X4$; $R^2 = 0.97$

Di mana

Y = bilangan perjalanan terhasil
X1 = total populasi
X2 = populasi berpendapatan rendah
X3 = populasi berpendapatan tinggi
X4 = kanak-kanak sekolah

(15 markah)

S3 (a) Sebuah laluan ekspres baru di kawasan sub-bandar sedang direka bentuk. Tentukan jumlah lorong yang diperlukan untuk mendapatkan aras perkhidmatan D semasa waktu puncak dengan menggunakan maklumat dan andaian yang diberi.

Peratusan Trak = 15 peratus
Peratusan Kenderaan Rekreasi = 3 peratus
Lebar lorong = 3.6 m
Faktor Waktu Puncak = 0.85
Bukaan Lateral = 1.8 m
Ketumpatan persimpangan *(interchange)* = 0.9 *interchange*/km
Isipadu = 4,000 veh/h (satu arah)
Muka bumi = Rata

Andaian:
BFFS = 120 km/h
Jumlah lorong mempengaruhi laju bebas kerana laluan ekspres akan dibina di kawasan pinggir bandar
f_p = 1.00 untuk trafik komuter
(Nota: kadar alir, laju, ketumpatan, dan *LOS* dihitung bermula dengan laluan ekspress empat lorong dan kemudian tambahkan kepada enam, lapan, dan seterusnya sehingga *LOS D* dicapai)

(10 markah)

(b) Tentukan *LOS* lebuhraya dua-lorong Kelas I untuk waktu puncak menggunakan maklumat yang diberi.

Isipadu permintaan untuk waktu puncak penuh = 1,600 kend/j (isipadu dua-arah)
Pembahagian searah = 50/50
Peratusan trak dan bas = 14 peratus
Peratusan kenderaan rekreasi= 4 peratus
Faktor Waktu Puncak = 0.95
BFFS = 100 km/j
Muka bumi = Beralun
Lebar Lorong = 3.4 m
Lebar Bahu Jalan = 1.2 m
Panjang Jalan = 10 km
Peratusan zon dilarang memotong = 50 peratus
Bilangan titik masukan = 12 titik/km.

(15 markah)

S4 (a) Takrifkan Penilaian Impak Trafik *(TIA)*.

(3 markah)

(b) Secara umumnya, ada dua kategori perjalanan yang meningkat dalam TIA iaitu **trafik *non-site*** dan **trafik *site***. Bincangkan setiap kategori.

(4 markah)

(c) Impak atau kesan trafik yang disebabkan oleh pembangunan yang dicadangkan ditakrif sebagai kesan negatif ke atas petunjuk-petunjuk berikut. Terangkan setiap petunjuk.

i) Aras perkhidmatan *(LOS)*.

(2 markah)

ii) Nisbah isipadu/muatan (nisbah *v/c*) atau darjah ketepuan.

(2 markah)

iii) Panjang berbaris maksimum.

(2 markah)

(d) Suatu pembangunan dicadangkan dan mempunyai jadual guna tanah seperti ditunjukkan **Jadual 3.** Berdasarkan persamaan di dalam **Jadual 4**, anggarkan pengeluaran dan tarikan perjalanan dan isikan di dalam **Jadual 5** dan **Jadual 6**.

(12 markah)

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TABLE 1 : Production and Attraction for four zones

Zone	Production	Attraction
1	1000	3000
2	2000	3000
3	3000	2000
4	4000	2000

TABLE 2: Travel time matrix

	Travel time (min)			
Zone	**1**	**2**	**3**	**4**
1	2	5	7	10
2	5	3	8	12
3	7	8	2	11
4	10	12	11	3

Travel time (min)	F_{ij}
2	3.0
3	2.5
5	2.3
7	1.5
8	1.2
11	0.95
12	0.90

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TABLE 3 : Proposed Development Land Use Schedule

Proposed land use	Units of Development	Built up area required per unit (ft^2)	Total built up area thousand ft^2 (tsf)
Residential			
Double-storey terrace type A	100	1560	156.00
Double-storey terrace type B	68	1360	92.48
Single-storey terrace (std)	32	808	25.86
Single-storey (low cost)	234	570	133.38
Industrial			
1.5 storey terrace light industry	34	2112	71.81
1.5 storey semi-detached light industry	24	2550	61.20

TABLE 4 : Trip Generation Equations
(Based on ITE and Malaysian Trip Generation Manual)

Land Use Type	AM/PM Peak	Regression Equation	Variable Type (x)	% in	% out	pcu/ veh
Office/shop	AM PM	ln (T) = 0.777 ln (x) + 1.674 ln (T) = 0.737 ln (x) + 1.831	Thousand ft^2	89 17	11 83	0.83
Light industry	AM PM	T = 1.177 (x) - 60.802 T = 1.422 (x) - 125.200	Thousand ft^2	90 14	10 86	1.0
Bungalow/ Semi-Detached	AM PM	ln (T) = 0.858 ln (x) + 0.464 ln (T) = 0.892 ln (x) + 0.590	Units	26 64	74 36	0.88
Terrace House	AM PM	T = 0.75 (x) + 22.6 T = 0.75 (x) + 22.6	Units	39 65	71 35	0.90
Low Cost	AM PM	T = 0.66 (x) + 26.8 T = 0.66 (x) + 26.8	Units	33 65	67 35	0.68

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TABLE 5: Estimated Trip Generation for the AM Peak

Land use	Units/tsf	Trip generated (vehicles)	% in		% out	
			vehicles	pcu	vehicles	pcu
Terrace houses						
Low cost houses						
Light Industry						
		TOTAL				

TABLE 6: Estimated Trip Generation for the PM Peak

Land use	Units/tsf	Trip generated (vehicles)	% in		% out	
			vehicles	pcu	vehicles	pcu
Terrace houses						
Low cost houses						
Light Industry						
		TOTAL				

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TABLE 7 : LOS Criteria of Two-Lane Highways in Class I

LOS	Percent Time-Spent-Following	Average Travel Speed (km/h)
A	≤ 35	> 90
B	> 35–50	> 80–90
C	> 50–65	> 70–80
D	> 65–80	> 60–70
E	> 80	≤ 60

Note:
LOS F applies whenever the flow rate exceeds the segment capacity.

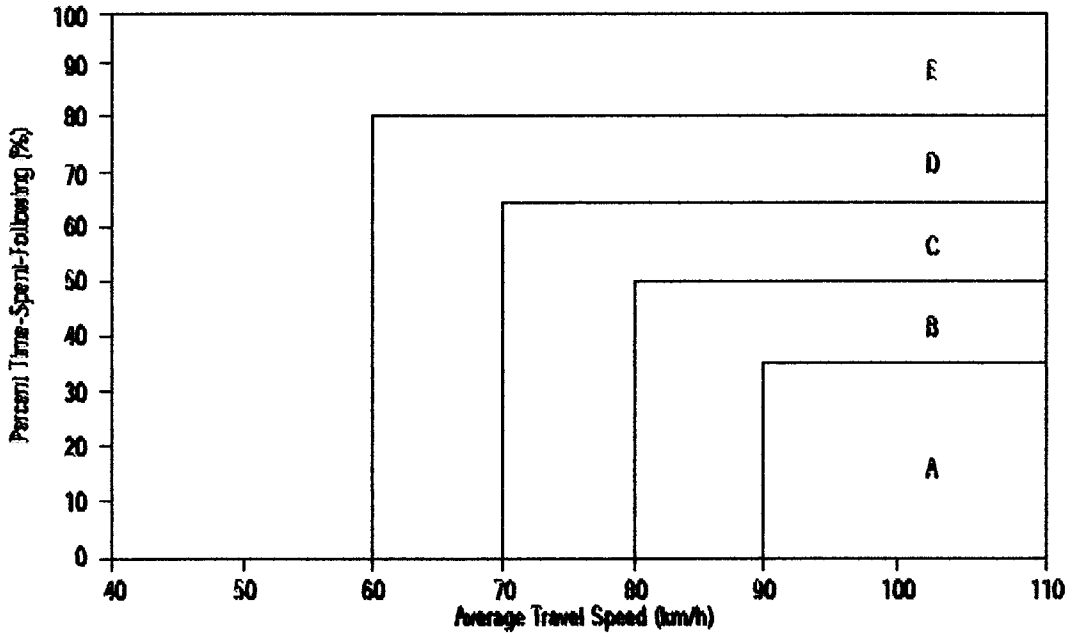

FIGURE 1 : LOS Criteria (Graphical) for Two-Lane Highways in Class I

TABLE 8 : LOS Criteria of Two-Lane Highways in Class II

LOS	Percent Time-Spent-Following
A	≤ 40
B	> 40–55
C	> 55–70
D	> 70–85
E	> 85

Note:
LOS F applies whenever the flow rate exceeds the segment capacity.

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TABLE 9 : Adjustment (f_{LS}) for Lane Width and Shoulder Width

	Reduction in FFS (km/h)			
	Shoulder Width (m)			
Lane 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

TABLE 10 : 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

TABLE 11 : 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

TABLE 12 : 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

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TABLE 13 : 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

TABLE 14 : 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

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TABLE 15 : 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

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TABLE 16 : Adjustment (fd/np)for Combined Effect of Directional Distribution of Traffic and Percentage of No-Passing Zones on Percent Time-Spent-Following on Two-Way Segments

	Increase in Percent Time-Spent-Following (%)					
	No-Passing Zones (%)					
Two-Way Flow Rate, v_p (pc/h)	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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TABLE 17 : LOS Criteria for Basic Freeway Segments

Criteria	LOS				
	A	B	C	D	E
FFS = 120 km/h					
Maximum density (pc/km/ln)	7	11	16	22	28
Minimum speed (km/h)	120.0	120.0	114.6	99.6	85.7
Maximum v/c	0.35	0.55	0.77	0.92	1.00
Maximum service flow rate (pc/h/ln)	840	1320	1840	2200	2400
FFS = 110 km/h					
Maximum density (pc/km/ln)	7	11	16	22	28
Minimum speed (km/h)	110.0	110.0	108.5	97.2	83.9
Maximum v/c	0.33	0.51	0.74	0.91	1.00
Maximum service flow rate (pc/h/ln)	770	1210	1740	2135	2350
FFS = 100 km/h					
Maximum density (pc/km/ln)	7	11	16	22	28
Minimum speed (km/h)	100.0	100.0	100.0	93.8	82.1
Maximum v/c	0.30	0.48	0.70	0.90	1.00
Maximum service flow rate (pc/h/ln)	700	1100	1600	2065	2300
FFS = 90 km/h					
Maximum density (pc/km/ln)	7	11	16	22	28
Minimum speed (km/h)	90.0	90.0	90.0	89.1	80.4
Maximum v/c	0.28	0.44	0.64	0.87	1.00
Maximum service flow rate (pc/h/ln)	630	990	1440	1955	2250

Note:
The exact mathematical relationship between density and v/c has not always been maintained at LOS boundaries because of the use of rounded values. Density is the primary determinant of LOS. The speed criterion is the speed at maximum density for a given LOS.

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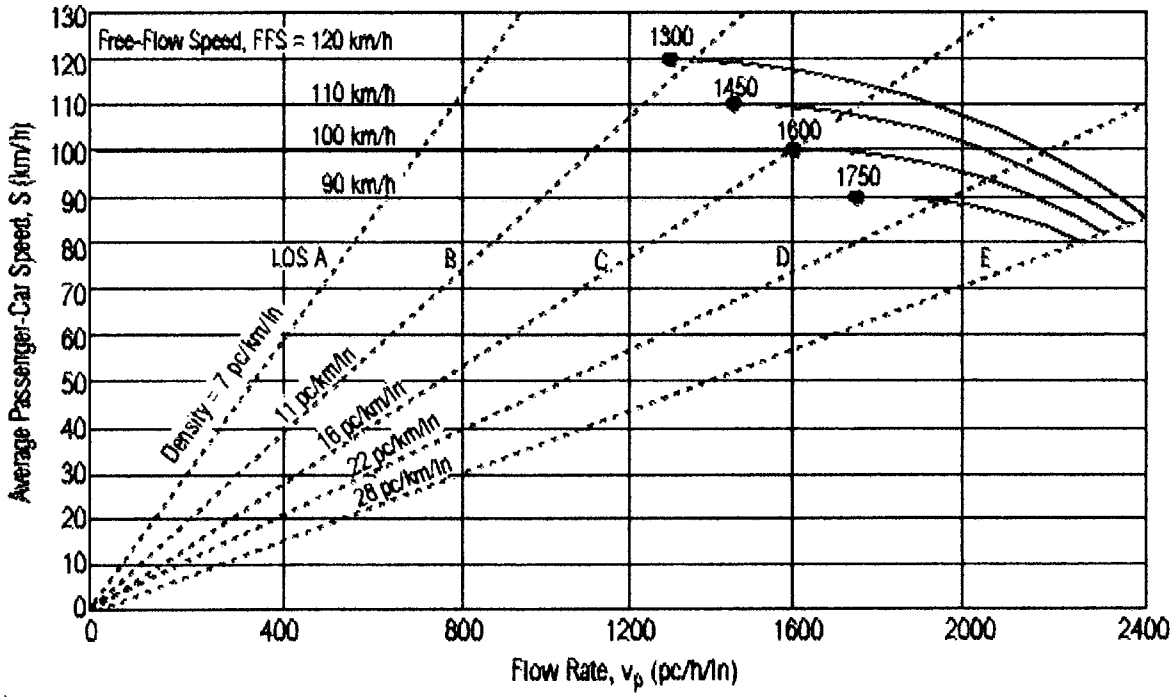

Note:
Capacity varies by free-flow speed. Capacity is 2400, 2350, 2300, and 2250 pc/h/ln at free-flow speeds of 120, 110, 100, and 90 km/h, respectively.

For $90 \le FFS \le 120$ and for flow rate (v_p)
$(3100 - 15FFS) < v_p \le (1800 + 5FFS)$,

$$S = FFS - \left[\frac{1}{28}(23FFS - 1800)\left(\frac{v_p + 15FFS - 3100}{20FFS - 1300}\right)^{2.6}\right]$$

For $90 \le FFS \le 120$ and
$v_p \le (3100 - 15FFS)$,
$S = FFS$

FIGURE 2 : Speed-Flow Curves and LOS for Basic Freeway Segments

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TABLE 18 : Adjustments for Lane Width

Lane Width (m)	Reduction in Free-Flow Speed, f_{LW} (km/h)
3.6	0.0
3.5	1.0
3.4	2.1
3.3	3.1
3.2	5.6
3.1	8.1
3.0	10.6

TABLE 19 : Adjustments for Right-Shoulder Lateral Clearance

Right-Shoulder Lateral Clearance (m)	Reduction in Free-Flow Speed, f_{LC} (km/h)			
	Lanes in One Direction			
	2	3	4	≥ 5
≥ 1.8	0.0	0.0	0.0	0.0
1.5	1.0	0.7	0.3	0.2
1.2	1.9	1.3	0.7	0.4
0.9	2.9	1.9	1.0	0.6
0.6	3.9	2.6	1.3	0.8
0.3	4.8	3.2	1.6	1.1
0.0	5.8	3.9	1.9	1.3

TABLE 20 : Adjustments for Number of Lanes

Number of Lanes (One Direction)	Reduction in Free-Flow Speed, f_N (km/h)
≥ 5	0.0
4	2.4
3	4.8
2	7.3

Note: For all rural freeway segments, f_N is 0.0.

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TABLE 21 : Adjustments for Interchange Density

Interchanges per Kilometer	Reduction in Free-Flow Speed, f_{ID} (km/h)
≤ 0.3	0.0
0.4	1.1
0.5	2.1
0.6	3.9
0.7	5.0
0.8	6.0
0.9	8.1
1.0	9.2
1.1	10.2
1.2	12.1

TABLE 22 : Passenger-Car Equivalents on Extended Freeway Segments

	Type of Terrain		
Factor	Level	Rolling	Mountainous
E_T (trucks and buses)	1.5	2.5	4.5
E_R (RVs)	1.2	2.0	4.0

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FORMULAE

$$Tij = Pi\frac{AjFijKij}{\sum AjFijKij} = \text{Pipj}$$

$$v_p = \frac{V}{PHF * f_G * f_{HV}}$$

$$f_{HV} = \frac{1}{1 + P_T(E_T - 1) + P_R(E_R - 1)}$$

$$PTSF = BPTSF + f_{dmp}$$

$$BPTSF = 100\left(1 - e^{-0.000679 v_p}\right)$$

$$FFS = BFFS - f_{LW} - f_{LC} - f_N - f_{ID}$$

$$v_p = \frac{V}{PHF * N * f_{HV} * f_p}$$

$$f_{HV} = \frac{1}{1 + P_T(E_T - 1) + P_R(E_R - 1)}$$