

وزارت علوم، تحقیقات و فناوری

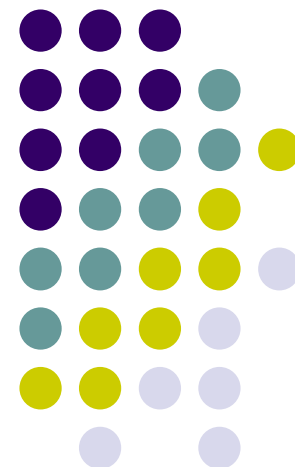


دانشگاه سوره

برنامه ریزی حمل و نقل

آنالیز ظرفیت راه

<http://mnooriamiri.professora.ir/>



Highway Capacity Analysis

- **Definition:** as the maximum number of a vehicles can pass a given point of a roadway facility during a specified period under prevailing roadway, traffic, and control conditions
- Maximum hourly rate (based on 15 minutes)

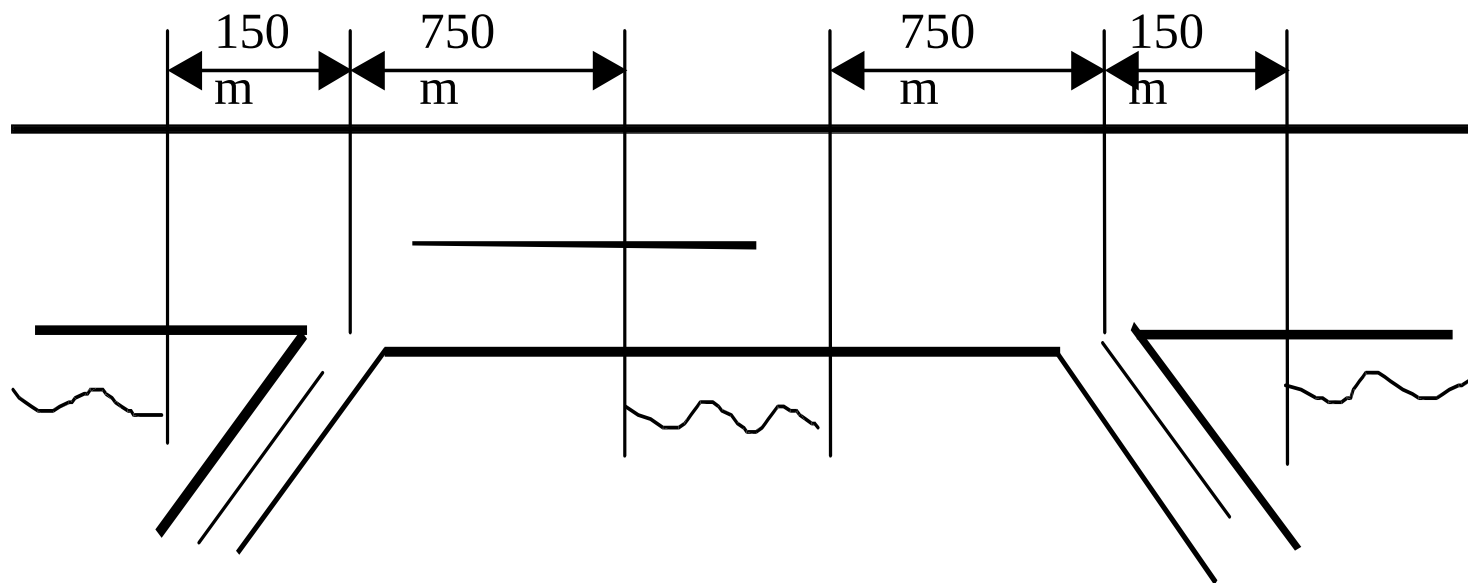
- **Prevailing conditions:** These conditions should be reasonably uniform for any section of facility analyzed. Any change in the prevailing conditions changes the capacity of the facility.
- **Roadway:** width of a lane, clearance, grade
- **Traffic:** composition of traffic flow
- **Control:** stop, yield, signal

Feature of traffic flows

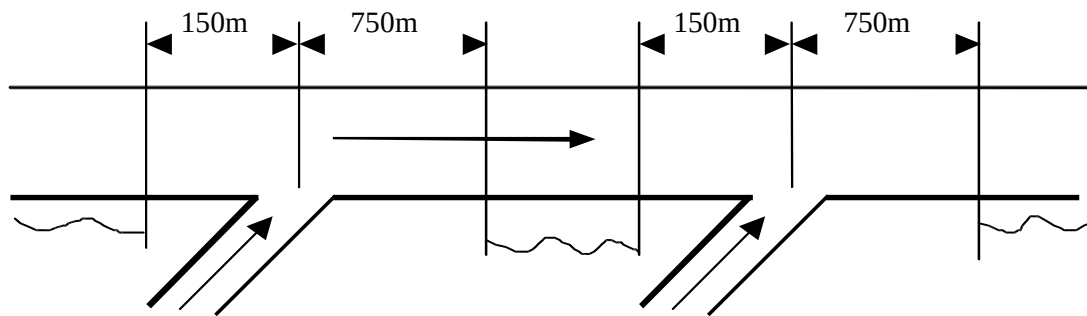
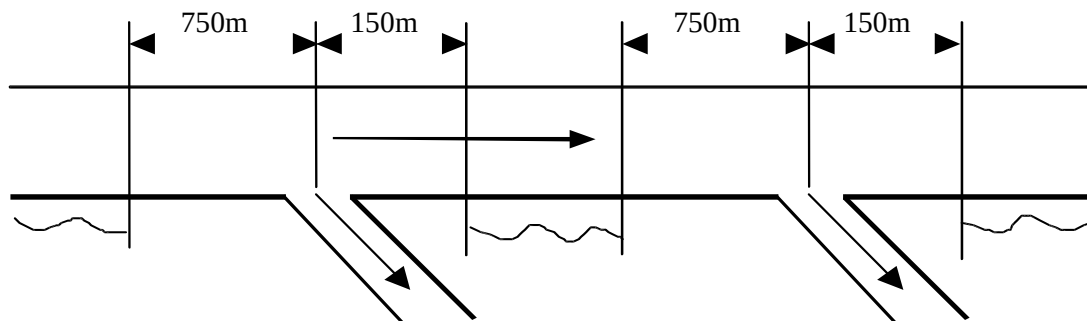
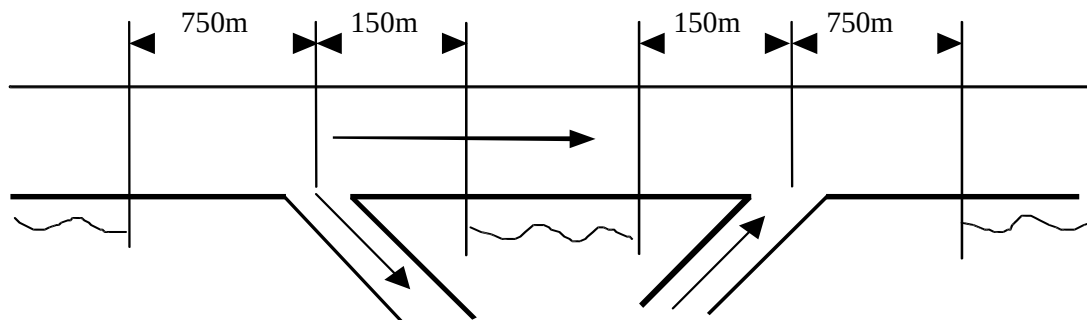
- **Uninterrupted flow** : on which no external factors cause periodic interruption to the traffic stream (e.g., freeway)
- **Interrupted flow** : having external devices that periodically interrupt traffic flow (e.g., **STOP** or **YIELD** signs, signal control)

Main topic to be discussed

- Freeways: basic segment, weaving, merge and diverge
- Intersections: un-signalized, signalized



Basic Segment (M-D)



Concept of level of service

- Defined as a quality measure describing operational conditions within a traffic stream, generally in terms of such service measures as speed and travel time, freedom to maneuver, traffic interruptions, and comfort and convenience.

Capacity of freeway & multilane highway

Table 6-1 Basic Values of Uninterrupted Flow Capacity (HCM2000)

type of facility	free-flow	capacity	approx
	speed (mph)	(pcphpl)	capacity
Freeway	70	2,400	53
	65	2,350	52
	60	2,300	51
	55	2,250	50
Multilane	60	2,200	55
	55	2,100	51
	50	2,000	48
	45	1,900	42

Level of Service at Freeways



LOS
A



LOS B



LOS
C



LOS
D

Level of Service at Freeways



LOS
E



LOS F

Level of Services (China)



Quality-quantifying

■ Measure of Effectiveness (MOE)

defined a parameter that describes traffic operations discernible by motorists and their passengers.

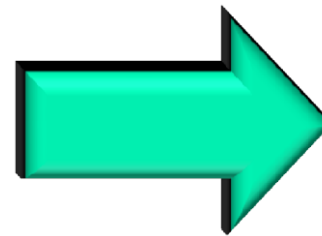
■ 3 major MOEs:

- ✓ Speed or Travel Time;
- ✓ Density;
- ✓ Delay.

Table 6-2 The MOEs of Level of Service Used in Capacity Analysis

Facilities	Measure of Effectiveness	Unit
Freeway Basic Sections	Density	Pc/mi(or km)/ln
Freeway Weaving Section	Density	Pc/mi(or km)/ln
Freeway Ramp Influence Area	Density	Pc/mi(or km)/ln
Multilane Highways	Density (based on Q/S)	Pc/mi(or km)/ln
Two-Way Highway Links	Travel Speed	mi (or km)/h
Signalized Intersections	Control Delay	sec/veh
Unsignalized Intersections	Control Delay	sec/veh
Arterial	Travel Speed	mi (or km)/h

- Three major MOEs:
 - speed or travel time;
 - Density;
 - Delay.



Density

LOS	Density Range (pc/km/ln)
A	0-7
B	7-11
C	11-16
D	16-22
E	22-28
F	> 28

Design analysis:

$$N = \frac{DDHV}{PHF \times MSF_i \times f_{HV} \times f_p}$$

$$DDHV = AADT * K * D$$

□ Average Annual Daily Traffic(AADT):

The average 24-hour traffic volume at a given location over a full 365-day year, i.e. the total number of vehicles passing the site in a year divided by 365.

□ Directional Design-Hour Volume (DDHV):

K is the percentage of the AADT that occurs in the peak hour and D is the directional distribution percentage.

1. Month	2. Total Days in Month (days)	3. Total Monthly Volume (vehs)
Jan	31	425,000
Feb	28	410,000
Mar	31	385,000
Apr	30	400,000
May	31	450,000
Jun	30	500,000
Jul	31	580,000
Aug	31	570,000
Sep	30	490,000
Oct	31	420,000
Nov	30	415,000
Dec	31	400,000
Total	365	5,445,000

$$AADT = 5445000 / 365 = 14,918 \text{ veh/day}$$

$$DDHV = AADT * K * D$$

DDHV

- D and K would decrease by increasing development density (?)
- K and D should be monitored regularly.

Facility Type	Normal Range of Values	
	K-Factor	<i>D</i> -Factor
Rural	0.15–0.25	0.65–0.80
Suburban	0.12–0.15	0.55–0.65
Urban:		
<i>Radial Route</i>	0.07–0.12	0.55–0.60
<i>Circumferential Route</i>	0.07–0.12	0.50–0.55

Example:

Time Interval	Volume for Time Interval (vehs)	Rate of Flow for Time Interval (vehs/h)
5:00–5:15 PM	1,000	$1,000/0.25 = 4,000$
5:15–5:30 PM	1,100	$1,100/0.25 = 4,400$
5:30–5:45 PM	1,200	$1,200/0.25 = 4,800$
5:45–6:00 PM	900	$900/0.25 = 3,600$
5:00–6:00 PM	$\Sigma = 4,200$	

$$\text{DDHV} = 4200$$

PHF (30th peak hour of the year)

- ✓ The ratio of the number of vehicles entering an approach during the peak hour to four times the number of vehicles entering during the peak 15 minute period. In the absence of field information, a value of 0.85 is normally used.
- ✓ The relationship between the hourly volume and the maximum rate of flow within the hour is defined by the peak hour factor, (PHF)

$$PHF = \frac{\text{hourly volume}}{\text{max. rate of flow}} \quad PHF = \frac{V}{4 * V_{m15}}$$

V = hourly volume, vehs

V_{m15} = maximum 15-minute volume within
the hour, vehs

PHF = peak-hour factor

Rates of Flow

Time Interval	Volume for Time Interval (vehs)	Rate of Flow for Time Interval (vehs/h)
5:00–5:15 PM	1,000	$1,000/0.25 = 4,000$
5:15–5:30 PM	1,100	$1,100/0.25 = 4,400$
5:30–5:45 PM	1,200	$1,200/0.25 = 4,800$
5:45–6:00 PM	900	$900/0.25 = 3,600$
5:00–6:00 PM	$\Sigma = 4,200$	

$$PHF=4200/(4*1200)=0.875$$

■ Adjustment factor for heavy vehicles

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

جدول ۵-۹- ضرایب معادل ظرفیت برای وسایل نقلیه سنگین در قطعات ممتد و کلی مطابق با HCM2000

نوع عوارض منطقه			ضرایب خودروی سواری معادل
کوهستان	تپه ماهور	دشت	
۴/۵	۲/۵	۱/۵	برای کامیون (E_T)
۴/۵	۲/۵	۱/۵	برای اتوبوس (E_B)
۴	۲	۱/۲	برای وسایل نقلیه تفریحی (E_R)

جدول ۵-۱۱- ضرایب معادل ظرفیت برای کامیون و اتوبوس در سربالایی‌ها با شیب خاص

شیب سربالایی (%)	طول شیب (km)	E _T , E _B								
		درصد کامیونها و اتوبوسها								
		2	4	5	6	8	10	15	20	25
< 2	All	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
≥ 2-3	0.0-0.4	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
	> 0.4-0.8	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
	> 0.8-1.2	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
	> 1.2-1.6	2.0	2.0	2.0	2.0	1.5	1.5	1.5	1.5	1.5
	> 1.6-2.4	2.5	2.5	2.5	2.5	2.0	2.0	2.0	2.0	2.0
	> 2.4	3.0	3.0	2.5	2.5	2.0	2.0	2.0	2.0	2.0
> 3-4	0.0-0.4	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
	> 0.4-0.8	2.0	2.0	2.0	2.0	2.0	2.0	1.5	1.5	1.5
	> 0.8-1.2	2.5	2.5	2.0	2.0	2.0	2.0	2.0	2.0	2.0
	> 1.2-1.6	3.0	3.0	2.5	2.5	2.5	2.5	2.0	2.0	2.0
	> 1.6-2.4	3.5	3.5	3.0	3.0	3.0	3.0	2.5	2.5	2.5
	> 2.4	4.0	3.5	3.0	3.0	3.0	3.0	2.5	2.5	2.5
> 4-5	0.0-0.4	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
	> 0.4-0.8	3.0	2.5	2.5	2.5	2.0	2.0	2.0	2.0	2.0
	> 0.8-1.2	3.5	3.0	3.0	3.0	2.5	2.5	2.5	2.5	2.5
	> 1.2-1.6	4.0	3.5	3.5	3.5	3.0	3.0	3.0	3.0	3.0
	> 1.6	5.0	4.0	4.0	4.0	3.5	3.5	3.0	3.0	3.0
> 5-6	0.0-0.4	2.0	2.0	1.5	1.5	1.5	1.5	1.5	1.5	1.5
	> 0.4-0.5	4.0	3.0	2.5	2.5	2.0	2.0	2.0	2.0	2.0
	> 0.5-0.8	4.5	4.0	3.5	3.0	2.5	2.5	2.5	2.5	2.5
	> 0.8-1.2	5.0	4.5	4.0	3.5	3.0	3.0	3.0	3.0	3.0
	> 1.2-1.6	5.5	5.0	4.5	4.0	3.0	3.0	3.0	3.0	3.0
	> 1.6	6.0	5.0	5.0	4.5	3.5	3.5	3.5	3.5	3.5
> 6	0.0-0.4	4.0	3.0	2.5	2.5	2.5	2.5	2.0	2.0	2.0
	> 0.4-0.5	4.5	4.0	3.5	3.5	3.5	3.0	2.5	2.5	2.5
	> 0.5-0.8	5.0	4.5	4.0	4.0	3.5	3.0	2.5	2.5	2.5
	> 0.8-1.2	5.5	5.0	4.5	4.5	4.0	3.5	3.0	3.0	3.0
	> 1.2-1.6	6.0	5.5	5.0	5.0	4.5	4.0	3.5	3.5	3.5
	> 1.6	7.0	6.0	5.5	5.5	5.0	4.5	4.0	4.0	4.0

جدول ۵-۱۱- ضرایب معادل ظرفیت برای کامیون و اتوبوس در سربالایی‌ها با شیب خاص

شیب سربالایی (%)	طول شیب (km)	E _T , E _B								
		درصد کامیونها و اتوبوسها								
		2	4	5	6	8	10	15	20	25
< 2	All	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
≥ 2-3	0.0-0.4	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
	> 0.4-0.8	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
	> 0.8-1.2	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
	> 1.2-1.6	2.0	2.0	2.0	2.0	1.5	1.5	1.5	1.5	1.5
	> 1.6-2.4	2.5	2.5	2.5	2.5	2.0	2.0	2.0	2.0	2.0
	> 2.4	3.0	3.0	2.5	2.5	2.0	2.0	2.0	2.0	2.0
> 3-4	0.0-0.4	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
	> 0.4-0.8	2.0	2.0	2.0	2.0	2.0	2.0	1.5	1.5	1.5
	> 0.8-1.2	2.5	2.5	2.0	2.0	2.0	2.0	2.0	2.0	2.0
	> 1.2-1.6	3.0	3.0	2.5	2.5	2.5	2.5	2.0	2.0	2.0
	> 1.6-2.4	3.5	3.5	3.0	3.0	3.0	3.0	2.5	2.5	2.5
	> 2.4	4.0	3.5	3.0	3.0	3.0	3.0	2.5	2.5	2.5
> 4-5	0.0-0.4	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
	> 0.4-0.8	3.0	2.5	2.5	2.5	2.0	2.0	2.0	2.0	2.0
	> 0.8-1.2	3.5	3.0	3.0	3.0	2.5	2.5	2.5	2.5	2.5
	> 1.2-1.6	4.0	3.5	3.5	3.5	3.0	3.0	3.0	3.0	3.0
	> 1.6	5.0	4.0	4.0	4.0	3.5	3.5	3.0	3.0	3.0
> 5-6	0.0-0.4	2.0	2.0	1.5	1.5	1.5	1.5	1.5	1.5	1.5
	> 0.4-0.5	4.0	3.0	2.5	2.5	2.0	2.0	2.0	2.0	2.0
	> 0.5-0.8	4.5	4.0	3.5	3.0	2.5	2.5	2.5	2.5	2.5
	> 0.8-1.2	5.0	4.5	4.0	3.5	3.0	3.0	3.0	3.0	3.0
	> 1.2-1.6	5.5	5.0	4.5	4.0	3.0	3.0	3.0	3.0	3.0
	> 1.6	6.0	5.0	5.0	4.5	3.5	3.5	3.5	3.5	3.5
> 6	0.0-0.4	4.0	3.0	2.5	2.5	2.5	2.5	2.0	2.0	2.0
	> 0.4-0.5	4.5	4.0	3.5	3.5	3.5	3.0	2.5	2.5	2.5
	> 0.5-0.8	5.0	4.5	4.0	4.0	3.5	3.0	2.5	2.5	2.5
	> 0.8-1.2	5.5	5.0	4.5	4.5	4.0	3.5	3.0	3.0	3.0
	> 1.2-1.6	6.0	5.5	5.0	5.0	4.5	4.0	3.5	3.5	3.5
	> 1.6	7.0	6.0	5.5	5.5	5.0	4.5	4.0	4.0	4.0

جدول ۵-۱۲- ضرایب معادل ظرفیت برای وسیله نقلیه تفریحی در سربالایی‌ها با شیب خاص

شیب سربالایی (%)	طول شیب (km)	E_R								
		درصد وسایل نقلیه تفریحی								
		2	4	5	6	8	10	15	20	25
≤ 2	All	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2
> 2-3	0.0-0.8	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2
	> 0.8	3.0	1.5	1.5	1.5	1.5	1.5	1.2	1.2	1.2
> 3-4	0.0-0.4	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2
	> 0.4-0.8	2.5	2.5	2.0	2.0	2.0	2.0	1.5	1.5	1.5
	> 0.8	3.0	2.5	2.5	2.5	2.0	2.0	2.0	1.5	1.5
> 4-5	0.0-0.4	2.5	2.0	2.0	2.0	1.5	1.5	1.5	1.5	1.5
	> 0.4-0.8	4.0	3.0	3.0	3.0	2.5	2.5	2.0	2.0	2.0
	> 0.8	4.5	3.5	3.0	3.0	3.0	2.5	2.5	2.0	2.0
> 5	0.0-0.4	4.0	3.0	2.5	2.5	2.5	2.0	2.0	2.0	1.5
	> 0.4-0.8	6.0	4.0	4.0	3.5	3.0	3.0	2.5	2.5	2.0
	> 0.8	6.0	4.5	4.0	4.5	3.5	3.0	3.0	2.5	2.0

جدول ۵-۱۳- ضرایب معادل ظرفیت برای کامیون و اتوبوس در سربالایی‌ها با شیب خاص

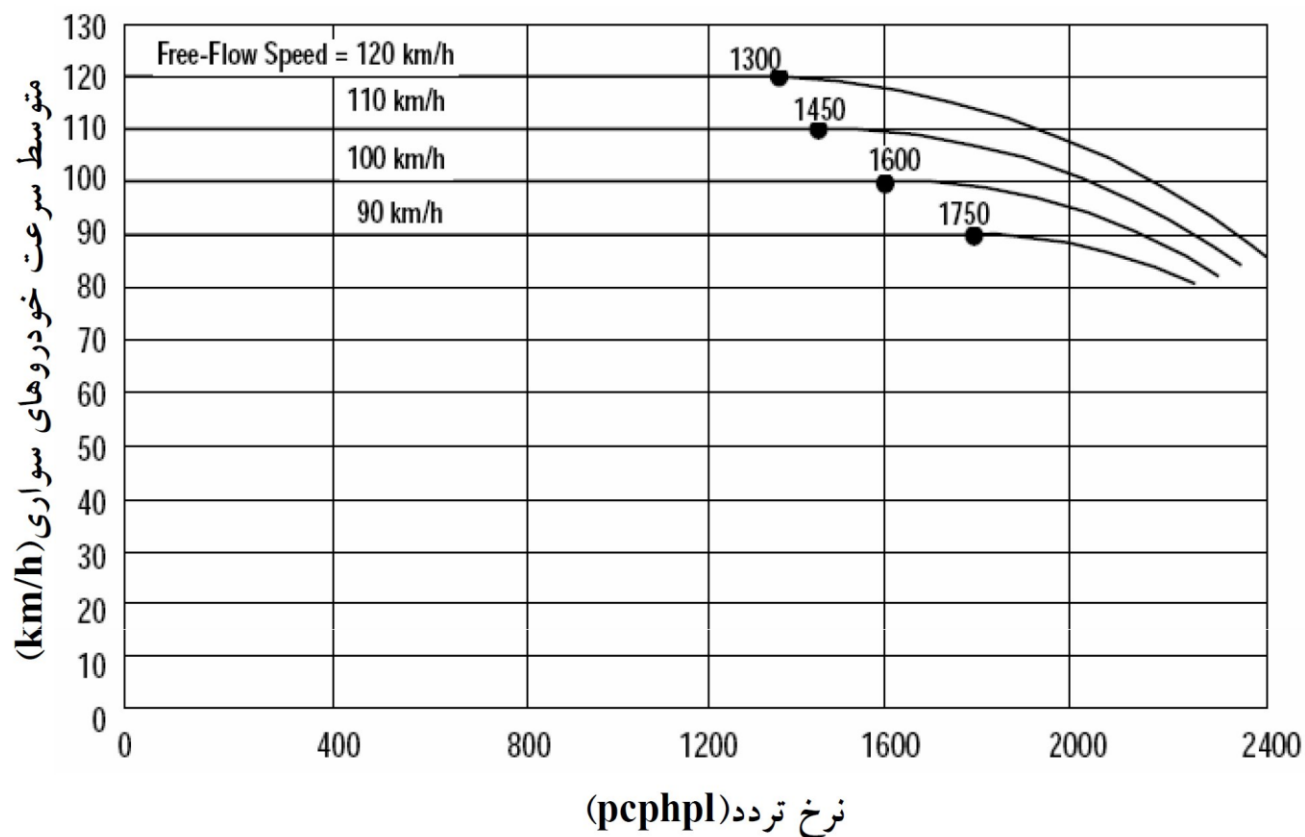
شیب سربالایی (%)	طول شیب (km)	E_T, E_B			
		درصد کامیونها و اتوبوسها			
		5	10	15	20
< 4	All	1.5	1.5	1.5	1.5
4-5	≤ 6.4	1.5	1.5	1.5	1.5
4-5	> 6.4	2.0	2.0	2.0	1.5
> 5-6	≤ 6.4	1.5	1.5	1.5	1.5
> 5-6	> 6.4	5.5	4.0	4.0	3.0
> 6	≤ 6.4	1.5	1.5	1.5	1.5
> 6	> 6.4	7.5	6.0	5.5	4.5

f_p

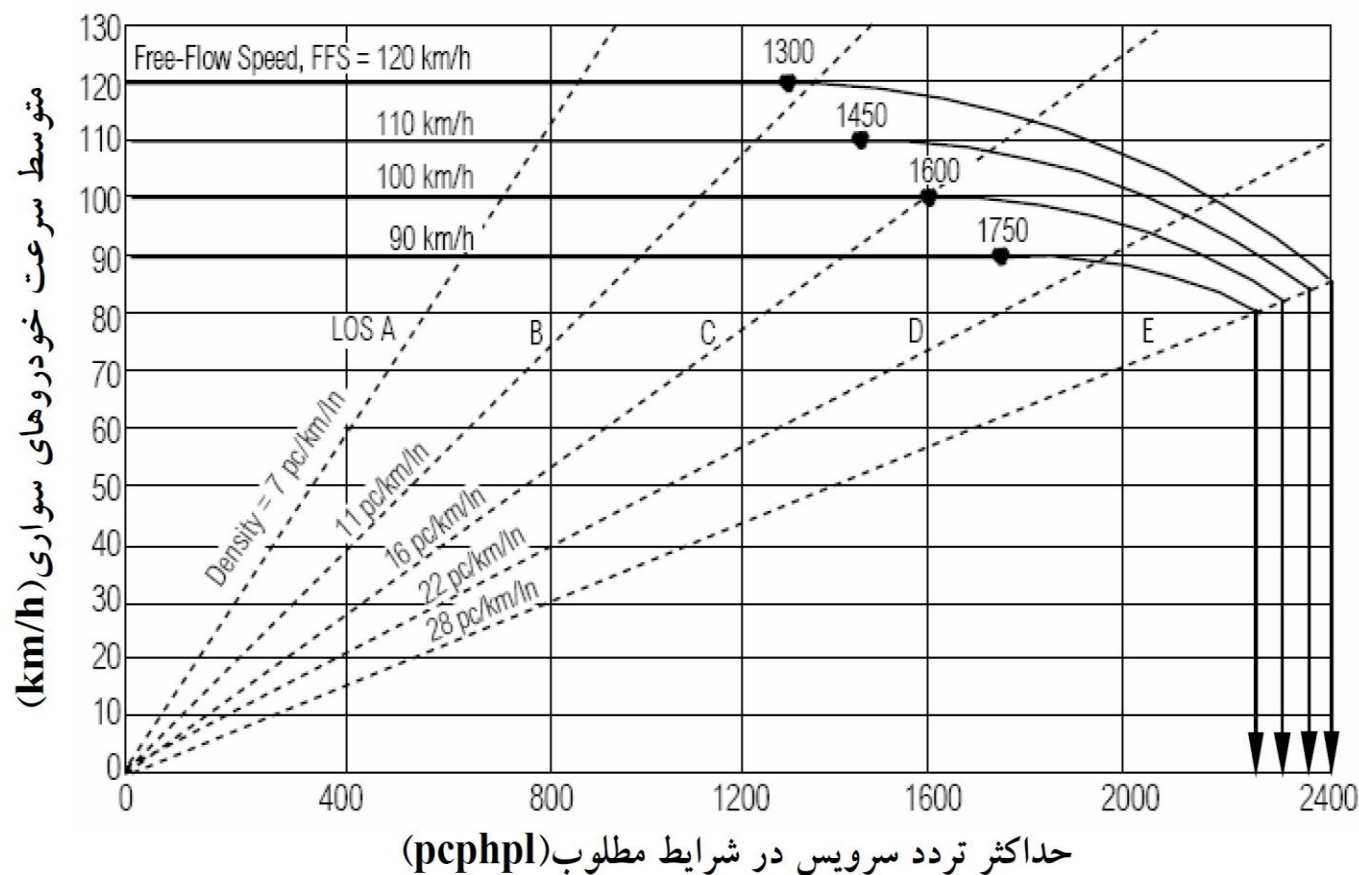
جدول ۵-۳- ضرایب اصلاحی برای تصحیح اثر رانندگان غیر دائمی و نا آشنا به مسیر

نوع ترکیب رانندگان	ضریب تصحیح رانندگان
اکثر رانندگان آشنا و دائمی	۱
اکثر رانندگان نا آشنا و غیر دائمی	۰/۷۵ - ۰/۹

MSF



شکل ۵-۲- منحنیهای سرعت - تردد برای سرعتهای آزاد مختلف در قطعات اصلی آزادراهها



شکل ۵-۳- منحنیهای سرعت - تردد و معیارهای سطح سرویس در قطعات اصلی آزادراهها

جدول ۴-۵- حداکثر تردد سرویس برای سطوح سرویس مختلف در آزادراه‌ها (HCM2000)

معیارهای سطح سرویس	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

- FFS for freeways:

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

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

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

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.

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