Basic Freeway Segments and Multilane Highway

Ref: Lectures of Dr. Shaker Falih, Dr. Zainab Alkaissi

1. Uninterrupted Flow Facility Types

1.1Two Lane Highways

A- Class I. two lane highway that function as the primary arterials, daily commuter routes, and links to other arterials highway. Motorists expectations are that travel will be at relatively high speeds.

B. Class II. two lane highways where the expectation of motorists is that travel speeds will be lower than for Class I roads. These highways may serve as access to Class I two lane highway; they may serve as scenic byways or may be used by motorists for sightseeing. They also may be located in rugged terrain. Average trip length on Class II are shorter than in Class I.

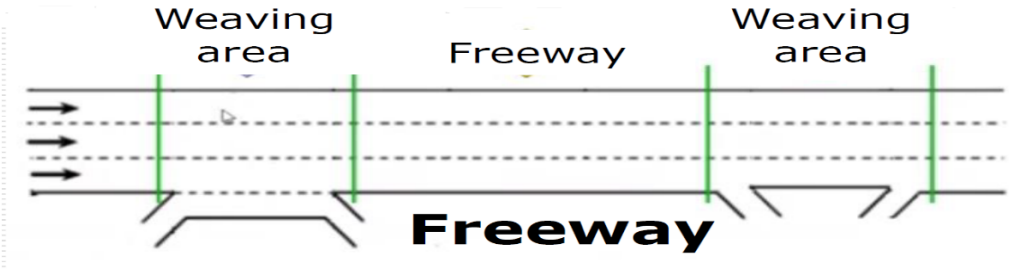
1.2 Multilane Surface Facilities

- The signal spacing is more than two miles.
- consist of four or six lane alignment.
- They can be undivided (i.e. having no median but with double solid yellow marking separating the directions of flow) or divided with a physical median separating the two direction of flow. In suburban areas, a third median treatment is also used: the two way left turn lane. This treatment requires an alignment with an odd number of lanes, most commonly three, five, or seven. The center lane is used as a continuous left turn lane for both directions of flow.



1.3Freeways

Basic Freeway is a length of freeway facilities whose operations are ineffective by weaving, diverging or merging. That is basic freeway segment is outside of influence of area of weaving or ramp.



- The only types of facilities providing pure uninterrupted flow.
- All entries and exits from freeways are made using ramps designed to allow such movements to occur without interruption to the freeway traffic stream.
- There are no at grade intersections (either signalized or unsignalized), no driveway access and no parking permitted within the right of way. Full control of excess is provided.
- Freeways are generally classified by the total number of lanes provided in both directions (e.g., a six lane freeway has three lanes in each direction)

A freeway is composed of three segments.

Basic freeway segments.

Weaving area.

Ramp junctions.

Both the basic freeway sections and multiline highways are categorized by the free flow speed (the speed intercept when flow is zero on speed flow curve.

(a) A Typical 10-Lane Freeway

(b) A Divided Multilane Rural Highway

(c) An Undivided Multilane Highway

(d) Two-lane Highway

2. Freeway Design

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

Where:

MSF_i: is the maximum service flow rate (from the following table).

f_p: is the adjustment factor to account for the fact that all driver of the facility may not be commuters or regular users.

Ni: is the number of lanes required (in one direction) to provide LOS(i).

DDHV: is the directional design hour volume, veh/hr.

FFS (mi/h)	Level of Service				
	A	B	C	D	E
75	820	1,310	1,750	2,110	2,400
70	770	1,250	1,690	2,080	2,400
65	710	1,170	1,630	2,030	2,350
60	660	1,080	1,560	2,010	2,300
55	600	990	1,430	1,900	2,250

Basic Freeway Segment Characteristics

Ideal conditions for maximum service flow rate:

- **Minimum interchange spacing 2 miles.**
- **Only passenger cars.**
- **Lane width≥ 12 ft.**
- **Lateral obstructions ≥ 6ft from roadway edge.**
- **Level terrain (grade < 2%)**
- **Driver typical of weekday (regular) traffic.**
- **10 or more lanes in urban areas.**

Free Flow Speed: Basic Freeway Segments

$$\mathbf{FFS = 75.4 - f_{LW} - f_{LC} - 3.22TRD^{0.84}}$$

Where:

FFS: is the estimated free flow speed in mph.

BFFS: is the estimated base free flow speed in mph(75 mph for rural freeways, and 70 mph for urban)

f_{LW}: is the adjustment for lane width (if less than 12 ft) in mph.

f_{LC}: is the adjustment for right side lateral clearance (if less than 6ft) in mph.

f_N: is the adjustment for number of lanes (if less than 5 in one direction) in mph.

f_{ID}: is the adjustment for interchange density if less than 2 mile, in mph.

TRD: is the total ramp density (rams/mile).

Adjustment for Lane Width in Freeway

Lane Width (ft)	Reduction in Free-Flow Speed, f_{LW} (mi/h)
≥12	0.0
11	1.9
10	6.6

Adjustment for Lateral Clearance in Freeway

Right Shoulder Lateral Clearance (ft)	Reduction in Free-Flow Speed, f_{LC} (mi/h)			
	Lanes in One Direction			
	2	3	4	≥5
≥6	0.0	0.0	0.0	0.0
5	0.6	0.4	0.2	0.1
4	1.2	0.8	0.4	0.2
3	1.8	1.2	0.6	0.3
2	2.4	1.6	0.8	0.4
1	2.0	2.0	1.0	0.5
0	3.6	2.4	1.2	0.6

Total Ramp Density

- Total number of on ramps and off ramps within ± 3 miles of the mid point of the study segment divided by 6 miles.
- Ramp density is a surrogate measure that relates to the intensity of land use activity in the vicinity of study segment.

Heavy Vehicles Effects

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

Where:

PT, PR: is the proportion of trucks and buses, and RV`s.

ET,ER: PCEs for trucks and buses, and RV`s.

Analysis is based on general extended freeway segment.

Level – heavy vehicles maintain same speed as pc`s (grade <2%)

Rolling- heavy vehicles travel at speeds lower than pc.

Mountainous- heavy vehicles operate at crawl speed for significant distances.

When conditions are very severe, we will instead base on grade and length on grade.

Restrictions for use: No grade < 3% for longer than 0.5 mile.

No grade ≥3% for longer than 0.25 mile.

Table (1) Passenger Car Equivalent for Trucks and Buses on Upgrade Multiline Highway and Basic Freeway Sections

Upgrade (%)	Length (mi)	E_T Percentage of Trucks and Buses (%) 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	0.00–0.25	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
	>0.25–0.50	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
	>0.50–0.75	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
	>0.75–1.00	2.0	2.0	2.0	2.0	1.5	1.5	1.5	1.5	1.5
	>1.00–1.50	2.5	2.5	2.5	2.5	2.0	2.0	2.0	2.0	2.0
	>1.50	3.0	3.0	2.5	2.5	2.0	2.0	2.0	2.0	2.0
>3–4	0.00–0.25	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
	>0.25–0.50	2.0	2.0	2.0	2.0	2.0	2.0	1.5	1.5	1.5
	>0.50–0.75	2.5	2.5	2.0	2.0	2.0	2.0	2.0	2.0	2.0
	>0.75–1.00	3.0	3.0	2.5	2.5	2.5	2.5	2.0	2.0	2.0
	>1.00–1.50	3.5	3.5	3.0	3.0	3.0	3.0	2.5	2.5	2.5
	>1.50	4.0	3.5	3.0	3.0	3.0	3.0	2.5	2.5	2.5
>4–5	0.00–0.25	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
	>0.25–0.50	3.0	2.5	2.5	2.5	2.0	2.0	2.0	2.0	2.0
	>050–0.75	3.5	3.0	3.0	3.0	2.5	2.5	2.5	2.5	2.5
	>0.75–1.00	4.0	3.5	3.5	3.5	3.0	3.0	3.0	3.0	3.0
	>1.00	5.0	4.0	4.0	4.0	3.5	2.5	3.0	3.0	3.0
>5–6	0.00–0.25	2.0	2.0	1.5	1.5	1.5	1.5	1.5	1.5	1.5
	>0.25–0.30	4.0	3.0	2.5	2.5	2.0	2.0	2.0	2.0	2.0
	>0.30–0.50	4.5	4.0	3.5	3.0	2.5	2.5	2.5	2.5	2.5
	>0.50–0.75	5.0	4.5	4.0	3.5	3.0	3.0	3.0	3.0	3.0
	>0.75–1.00	5.5	5.0	4.5	4.0	3.0	3.0	3.0	3.0	3.0
	>1.00	6.0	5.0	5.0	4.5	3.5	3.5	3.5	3.5	3.5
>6	0.00–0.25	4.0	3.0	2.5	2.5	2.5	2.5	2.0	2.0	2.0
	>0.25–0.30	4.5	4.0	3.5	3.5	3.5	3.0	2.5	2.5	2.5
	>0.30–0.50	5.0	4.5	4.0	4.0	3.5	3.0	2.5	2.5	2.5
	>0.50–0.75	5.5	5.0	4.5	4.5	4.0	3.5	3.0	3.0	3.0
	>0.75–1.00	6.0	5.5	5.0	5.0	4.5	4.0	3.5	3.5	3.5
	>1.00	7.0	6.0	5.5	5.5	5.0	4.5	4.0	4.0	4.0

Table (2) Passenger Car Equivalent for RVs on Upgrade Multiline Highway and Basic Freeway Sections

Grade (%)	Length (mi)	E_R Percentage of RVs (%)								
		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	0.00–0.50	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2
	>0.50	3.0	1.5	1.5	1.5	1.5	1.5	1.2	1.2	1.2
>3–4	0.00–0.25	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2
	>0.25–0.50	2.5	2.5	2.0	2.0	2.0	2.0	1.5	1.5	1.5
	>0.50	3.0	2.5	2.5	2.5	2.0	2.0	2.0	1.5	1.5
>4–5	0.00–0.25	2.5	2.0	2.0	2.0	1.5	1.5	1.5	1.5	1.5
	>0.25–0.50	4.0	3.0	3.0	3.0	2.5	2.5	2.0	2.0	2.0
	>0.50	4.5	3.5	3.0	3.0	3.0	2.5	2.5	2.0	2.0
>5	0.00–0.25	4.0	3.0	2.5	2.5	2.5	2.5	2.0	2.0	1.5
	>0.25–50	6.0	4.0	4.0	4.0	3.5	3.0	2.5	2.5	2.0
	>0.50	6.0	4.5	4.0	4.0	4.0	3.5	3.0	2.5	2.0

Table (3) Passenger Car Equivalent for Trucks and Buses on Downgrade Multiline Highway and Basic Freeway Sections

Downgrade (%)	Length (mi)	E_T Percentage Trucks and Buses (%)			
		5	10	15	≥20
< 4	All	1.5	1.5	1.5	1.5
≥4–5	≤4	1.5	1.5	1.5	1.5
	>4	2.0	2.0	2.0	1.5
>5–6	≤4	1.5	1.5	1.5	1.5
	>4	5.5	4.0	4.0	3.0
>6	≤4	1.5	1.5	1.5	1.5
	>4	7.5	6.0	5.5	4.5

Example(1)

A long section of suburban highway will be designed on flat terrain. The 5 mile level route was following by a 5% grade and 2 miles long. If the DDHV=2500 veh/hr with 10% trucks and 3% tourist vehicles. How many lanes must be provided for this road.

- On the section with upgrade.
- On the section with downgrade.
- On the section with level surface.

For providing LOS C, assume standard conditions for lane width and side clearance, TRD=0.5 ramps/mile, PHF=0.92.

Solution:

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

$$FFS = 75.4 - f_{LW} - f_{LC} - 3.22TRD^{0.84}$$

$$f_{LW}, f_{LC} = 0, TRD = 0.5$$

$$FFS = 75.4 - 0 - 0 - 3.22(0.5)^{0.84} = 73.6\frac{mile}{hr} \approx 75\frac{mile}{hr}$$

DDHV=2500 veh/ hr, PHF=0.92, f_p=1, then **$MSF_C = 1750$ pc/hr/ln** from the following table

FFS (mi/h)	Level of Service				
	A	B	C	D	E
75	820	1,310	1,750	2,110	2,400
70	770	1,250	1,690	2,080	2,400
65	710	1,170	1,630	2,030	2,350
60	660	1,080	1,560	2,010	2,300
55	600	990	1,430	1,900	2,250

From table (1,2, and 3), the Passenger Car Equivalent are as following:-

Equivalent	Level	Upgrade	Downgrade
E_T	1.5	2.5	1.5
E_R	1.2	4.5	1.2

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

$$f_{HV}(\text{downgrade}) = \frac{1}{1 + 0.1(1.5 - 1) + 0.02(1.2 - 1)} = 0.949$$

$$f_{HV}(\text{upgrade}) = \frac{1}{1 + 0.1(2.5 - 1) + 0.02(4.5 - 1)} = 0.820$$

$$N(\text{level. downgrade}) = \frac{2500}{0.92 \times 1750 \times 0.949 \times 1} = 1.6 \approx 2\text{lane}$$

$$N(\text{upgrade}) = \frac{2500}{0.92 \times 1750 \times 0.820 \times 1} = 1.9 \approx 2\text{lane}$$

If the freeway is designed with 4 lanes will provide the LOS C

Example (2)

Find the free flow speed for 6 lane freeway in suburban area, the lane width=12 ft, the right clearance=2ft, and TRD=3.5 ramps/mile.

Solution:

$FFS = 75.4 - f_{LW} - f_{LC} - 3.22TRD^{0.84}$

f_{LW}=0 mile/hr

f_{LC}=1.6 mile/ hr

TRD=3.5

Lane Width (ft)	Reduction in Free-Flow Speed, f_{LW} (mi/h)
≥12	0.0
11	1.9
10	6.6

Right Shoulder Lateral Clearance (ft)	Reduction in Free-Flow Speed, f_{LC} (mi/h)			
	Lanes in One Direction			
	2	3	4	≥5
≥6	0.0	0.0	0.0	0.0
5	0.6	0.4	0.2	0.1
4	1.2	0.8	0.4	0.2
3	1.8	1.2	0.6	0.3
2	2.4	1.6	0.8	0.4
1	2.0	2.0	1.0	0.5
0	3.6	2.4	1.2	0.6

$$FFS = 75.4 - 0 - 1.6 - 3.22(3.5)^{0.84} = 64.6 \text{ mile/hr}$$