Capacity and LOS

CIVL 4162/6162

Capacity

- The capacity of a facility is the maximum hourly rate at which persons or vehicles reasonably can be expected to traverse a point or a uniform section of a lane or roadway during a given time period under prevailing roadway, traffic, and control conditions. (HCM 2000)

Level of Service

- 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 (HCM 2000).
- Rating scale A-F indicate best to worst operation

Factors Influencing LOS

- Volume
- Lane width
- Lateral obstructions
- Traffic composition
- Grade
- Speed

Measures of Effectiveness for LOS

Type of Flow	Type of Facility	Measure of Effectiveness
Uninterrupted	Freeways (Basic, Weaving, Ramp)	Density (pc/mi/ln)
	Multilane Highway	Density (pc/mi/ln)
	Two-Lane Highway	Avg. Travel Speed (mph); % time spent following
Interrupted Flow	Signalized Intersections	Control Delay (s/veh)
	Unsignalized Intersections	Control Delay (s/veh)
	Urban Streets	Average Travel Speed (mph)

LOS A

LOS B

LOS C

LOS D

LOS E

LOS F

Basic Freeway Segment Characteristics

Ideal conditions for maximum service flow rate:

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

Operational Analysis

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

Where:
FFS = estimated free flow speed in mph.
BFFS = estimated base free flow speed in mph (75 mph for rural freeways, 70 mph for urban based on HCM recommendations).
f_{LW} = adjustment for lane width (if less than 12 ft), mph.
f_{LC} = adjustment for right side lateral clearance (if less than 6 ft), mph.
f_N = adjustment for # of lanes (if less than 5 in one direction), mph.
f_{ID} = adjustment for interchange density if < 2 mi, mph.

Operational Analysis

Flow Rate:

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

Where:

v_p = 15-minute passenger-car equivalent flow rate (pc/h/ln)

V = hourly volume in the given direction of flow (vph)

PHF = peak-hour factor

N = number of lanes in the given direction of flow

f_{HV} = an adjustment factor for th presence of “heavy” vehicles

f_p = an adjustment factor to account for the fact that all drivers of the facility may not be commuters or regular users.

*Basis for analysis is peak 15 min flow rate.

Heavy Vehicle Effects:

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

P_T, P_R = proportion of trucks and buses, and RV's
E_T, E_R = 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 – HVs travel at speeds lower than pc.
Mountainous – HVs operate at crawl speed for significant distances.

When conditions are very severe, we will instead base on grade and length of grade.
Restrictions for use: No grade < 3% for longer than ½ mile.
No grade ≥ 3% for longer than ¼mile.

Operational Analysis

DETERMINING LOS

The first step in determining LOS of a basic freeway segment is to define and segment the freeway facility as appropriate. Second, on the basis of estimated or field-measured FFS, an appropriate speed-flow curve of the same shape as the typical curves (Exhibit 23-3) is constructed. On the basis of the flow rate, v_p, and the constructed speed-flow curve, an average passenger-car speed is read on the y-axis of Exhibit 23-3. The next step is to calculate density using Equation 23-4.

$$D = \frac{v_p}{S} \qquad (23\text{-}4)$$

where

D = density (pc/mi/ln),
v_p = flow rate (pc/h/ln), and
S = average passenger-car speed (mi/h).

LOS of the basic freeway segment is then determined by comparing the calculated density with the density ranges in Exhibit 23-2.

EXHIBIT 23-1. BASIC FREEWAY SEGMENT METHODOLOGY

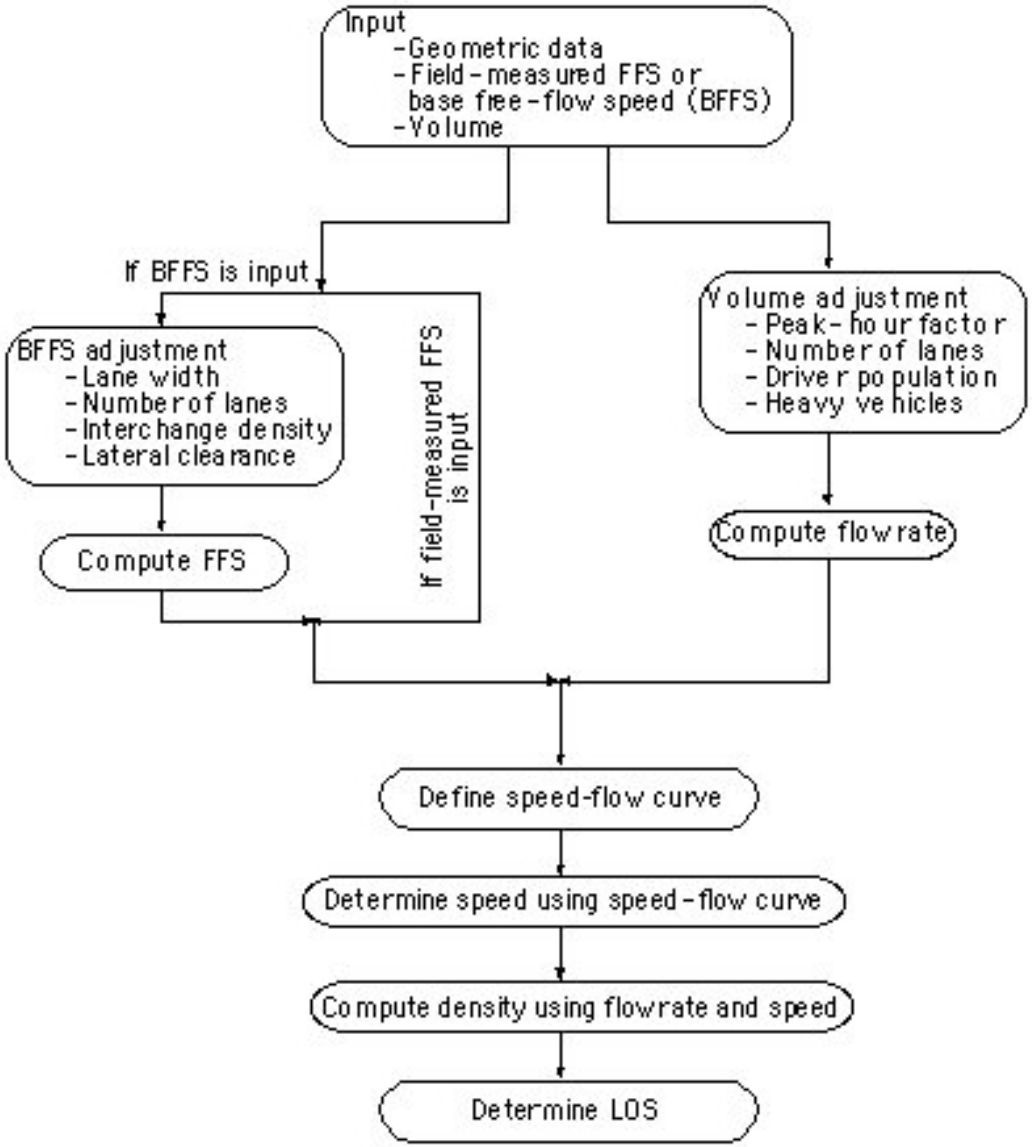
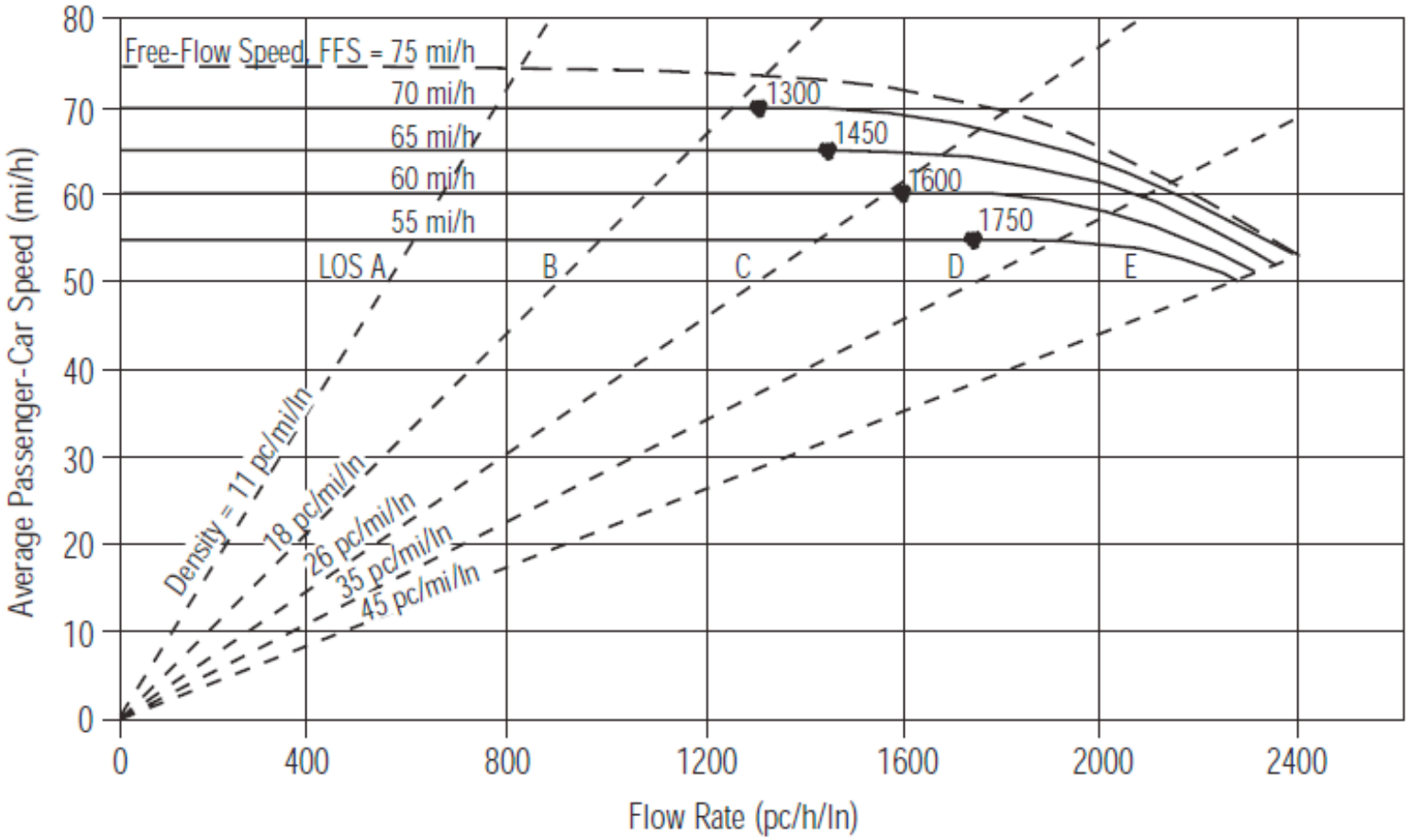


EXHIBIT 23-3. SPEED-FLOW CURVES AND LOS FOR BASIC FREEWAY SEGMENTS



Note:
Capacity varies by free-flow speed. Capacity is 2400, 2350, 2300, and 2250 pc/h/ln at free-flow speeds of 70 and greater, 65, 60, and 55 mi/h, respectively.

EXHIBIT 23-2. LOS CRITERIA FOR BASIC FREEWAY SEGMENTS

Criteria	LOS A	LOS B	LOS C	LOS D	LOS E
FFS = 75 mi/h					
Maximum density (pc/mi/ln)	11	18	26	35	45
Minimum speed (mi/h)	75.0	74.8	70.6	62.2	53.3
Maximum v/c	0.34	0.56	0.76	0.90	1.00
Maximum service flow rate (pc/h/ln)	820	1350	1830	2170	2400
FFS = 70 mi/h					
Maximum density (pc/mi/ln)	11	18	26	35	45
Minimum speed (mi/h)	70.0	70.0	68.2	61.5	53.3
Maximum v/c	0.32	0.53	0.74	0.90	1.00
Maximum service flow rate (pc/h/ln)	770	1260	1770	2150	2400
FFS = 65 mi/h					
Maximum density (pc/mi/ln)	11	18	26	35	45
Minimum speed (mi/h)	65.0	65.0	64.6	59.7	52.2
Maximum v/c	0.30	0.50	0.71	0.89	1.00
Maximum service flow rate (pc/h/ln)	710	1170	1680	2090	2350
FFS = 60 mi/h					
Maximum density (pc/mi/ln)	11	18	26	35	45
Minimum speed (mi/h)	60.0	60.0	60.0	57.6	51.1
Maximum v/c	0.29	0.47	0.68	0.88	1.00
Maximum service flow rate (pc/h/ln)	660	1080	1560	2020	2300
FFS = 55 mi/h					
Maximum density (pc/mi/ln)	11	18	26	35	45
Minimum speed (mi/h)	55.0	55.0	55.0	54.7	50.0
Maximum v/c	0.27	0.44	0.64	0.85	1.00
Maximum service flow rate (pc/h/ln)	600	990	1430	1910	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.

Determining Capacity

Capacity = MSF_E x PHF x N x f_{HV} x f_p

* this is total capacity- maximum service flow rates can also be determined to remain in a specific level of service using MSF_i.

Design Analysis

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

Where:

Ni = number of lanes required (in one direction) to provide LOS “i”

DDHV = directional design hour volume, veh/h

Example

Given-

Older 4-lane freeway

11 ft lanes

Directional peak hour volume = 2100 vph

PHF = 0.95

6% trucks

Interchange density = 1.0/mi

Generally rolling terrain

Obstructions 2 ft from edge of traveled way at both roadside and median.

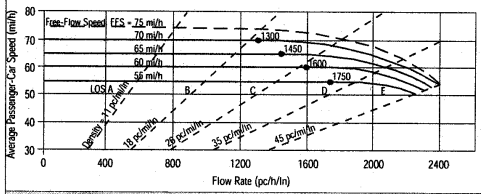
Find-

a. Average speed for prevailing conditions.

b. LOS

c. The amount of additional traffic that the facility can accommodate in the peak hour before reaching capacity.

BASIC FREEWAY SEGMENTS WORKSHEET



Application	Input	Output
Operational (LOS)	FFS, N, v_p	LOS, S, D
Design (N)	FFS, LOS, v_p	N, S, D
Design (v_p)	FFS, LOS, N	v_p, S, D
Planning (LOS)	FFS, N, AADT	LOS, S, D
Planning (N)	FFS, LOS, AADT	N, S, D
Planning (v_p)	FFS, LOS, N	v_p, S, D

General Information

Analyst
Agency or Company
Date Performed
Analysis Time Period

Site Information

Highway/Direction of Travel
From/To
Jurisdiction
Analysis Year

☐ Operational (LOS) ☐ Design (N) ☐ Design (v_p) ☐ Planning (LOS) ☐ Planning (N) ☐ Planning (v_p)

Flow Inputs

Volume, V: 2100 veh/h
Annual avg. daily traffic, AADT: ____ veh/day
Peak-hour proportion of AADT, K: ____
Peak-hour direction proportion, D: ____
DDHV = AADT * K * D: ____ veh/h
Driver type ☐ Commuter/Weekday ☐ Recreational/Weekend

Peak-hour factor, PHF: 0.95
% Trucks and buses, P_T: 6%
% RVs, P_R: 0%
General terrain
☐ Level ☑ Rolling ☐ Mountainous
Grade Length ____ mi Up/Down ____ %

Calculate Flow Adjustments

f_p: 1.0
E_T: 2.5

E_R: 0
$f_{HV} = \frac{1}{1 + P_T(E_T - 1) + P_R(E_R - 1)}$: 0.917

Speed Inputs

Lane width: 11 ft
Rt.-shoulder lateral clearance: 2 ft
Interchange density: 1.0 l/mi
Number of lanes, N: 2
FFS (measured): ____ mi/h
Base free-flow speed, BFFS: 70 mi/h

Calculate Speed Adjustments and FFS

f_{LW}: 1.9 mi/h
f_{LC}: 2.4 mi/h
f_{ID}: 2.3 mi/h
f_N: 4.3 mi/h
FFS = BFFS − f_{LW} − f_{LC} − f_{ID} − f_N: 58.7 mi/h

LOS and Performance Measures

Operational (LOS) or Planning (LOS)

$v_p = \frac{V \text{ or } DDHV}{PHF * N * f_{HV} * f_p}$: 1205.30 pc/h/ln
S: 58.7 mi/h
D = v_p /S: 20.5 pc/mi/ln
LOS: C

Design (v_p) or Planning (v_p)

LOS: ____
v_p: ____ pc/h/ln
V = v_p * PHF * N * f_{HV} * f_p: ____ veh/h
S: ____ mi/h
D = v_p /S: ____ pc/mi/ln

Design (N) or Planning (N) 1st Iteration

N: ____ assumed
$v_p = \frac{V \text{ or } DDHV}{PHF * N * f_{HV} * f_p}$: ____ pc/h/ln
LOS: ____

Design (N) or Planning (N) 2nd Iteration

N: ____ assumed
$v_p = \frac{V \text{ or } DDHV}{PHF * N * f_{HV} * f_p}$: ____ pc/h/ln
S: ____ mi/h
D = v_p /S: ____ pc/mi/ln
LOS: ____

Glossary

N - Number of lanes
V - Hourly volume
v_p - Flow rate
LOS - Level of service
DDHV - Directional design-hour volume
S - Speed
D - Density
FFS - Free-flow speed
BFFS - Base free-flow speed

Factor Location

E_R - Exhibits 23-8, 23-10
E_T - Exhibits 23-8, 23-9, 23-11
f_p - Page 23-12
LOS, S, FFS, v_p - Exhibits 23-2, 23-3
f_{LW} - Exhibit 23-4
f_{LC} - Exhibit 23-5
f_N - Exhibit 23-6
f_{ID} - Exhibit 23-7

Example

Given-

- Urban area
- Level terrain
- Interchange density = 1.0/mi.
- DDHV = 4,500 vph
- PHF = 0.90
- 12% trucks
- Primarily commuter traffic and other regular users

Find the required number of lanes to provide the design LOS.