Highway Capacity and LOS

Reading Assignment: pgs. 170-200

We know from the previous section that traffic flows fairly well when Demand < Capacity. However, when demand approaches capacity, we begin to experience lower speeds, congestion.

Thus in planning and design of highways we are interested in designing facilities that will operate below capacity. We need a good estimate of capacity for this.

Capacity analysis involves the quantitative evaluation of the capability of a freeway section to carry traffic.

We will be concerned in this section with determining the level of service particular freeways provide, and in designing a freeway to operate at an acceptable LOS.

Factors Contributing to LOS:

Traffic volume is the principal factor affecting LOS, however, several other factors contribute.

1. Lane width – When narrower that 12 ft, traffic flow is restricted.

2. Lateral obstructions – When objects are located near the edge of the roadway or in the median, this has the effect of reducing lateral spacing because drivers tend to move away from the object.
   - Effect is eliminated if object is < 6 inches tall and ≥ 6 feet from the roadway edge.
   - Lateral clearances are based on safety considerations, not volume.

3. Traffic composition – Presence of trucks, buses, rv's, in a traffic stream (anything other than passenger cars) reduces flow due to size, operating characteristics, and interactions with other vehicles.

4. Grade – Effect of grade depends on both length and slope of grade. Traffic is significantly affected when grades are ≥ 3% and ¼ mile or longer, or grades <3% are ½ mi or longer.

5. Speed – Space mean speed is considered in LOS analysis because flow has a significant effect on speed.

Six LOS have been established – A-F (A is best).

HCM establishes procedures for determining LOS.

We are going to analyze simplified cases of basic freeway segments and only basic types of terrain and trucks, even though procedures and info for analysis of much more complex situations are outlined in HCM.

<u>Basic Freeway Segments</u>:

Zone of influence for ramp junctions:
- On-ramps: 500 ft upstream and 2500 ft downstream
- Off-ramps: 2500 ft upstream, and 500 ft downstream

Level of service A – Speed of vehicle is controlled only by desires of the driver and the prevailing conditions.

LOS B – Traffic still under free-flow conditions, may experience some restrictions in lane changes.

LOS C- Speeds are still near free-flow, however, flow is heavier, and any increase in volume immediately results in decrease of service.

LOS D – Flow is approaching an unstable level. Minor incidents may result in queuing.

LOS E – Flow is unstable (at or near capacity). Lane changes will disturb traffic stream. Minor incidents cause extensive queuing.

LOS F – Operation is under forced or breakdown conditions.

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 **Criteria removed in HCM 2010

For LOS analysis, we want to convert prevailing conditions to equivalent base conditions.

For base conditions, a free-flow speed of 70 mph or greater is required.

Basic Equation:

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

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.

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.

$$PHF = \frac{Peak\ Hour\ Volume}{Peak\ 15-\min.\ flow\ rate} = \frac{Peak\ Hour\ volume}{4 \times Peak\ 15-\min.\ Volume}$$

Example:

Time (min.)	Count (veh)
0-15	340
15-30	375
30-45	335
45-60	300

Heavy Vehicle Effects:

(trucks, buses, rv's) – These do not perform as well as passenger cars, so they are thought of in passenger car equivalents on a freeway. This equivalent value depends on the type of terrain: level, rolling, mountainous.

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

P_T, P_R = proportion of trucks and buses, and RV's
E_T, E_B, E_R = PCEs for trucks and buses, and RV's
*We will assume that there are no RV's in our traffic stream, thus $P_R = 0$, yielding the above version of the correction factor equation.

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 ½ mile.

Determining LOS:

Graphical – use graph with your calculated v_p, and your free flow speed. You can also estimate average speed from the graph.

Table procedure – calculate v_p, look up LOS for your free-flow speed, your v_p can not be greater than MSF, or you drop to a lower LOS.

MSF_i = maximum possible flow rate we can have to still be at level of service i.

Determining Capacity:

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

*this is total capacity. Other capacity can be determined to remain in a specific level of service using MSF_i.

Determining Lane Requirements:

Based on design level of service. Iterative procedure.

- Use LOS B for rural freeways
- Use LOS C for urban freeways (may be forced to D due to land restrictions).

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

When you calculate design N, you need to round up, otherwise you will drop to a lower LOS.