Chapter 23

Multilane Highways

23.1 Introduction

Increasing traffic flow has forced engineers to increase the number of lanes of highways in order to provide good manoeuvring facilities to the users. The main objectives of this lecture is to analyze LOS which is very important factor for a traffic engineer because it describes the traffic operational conditions within a traffic stream. Also we are going to study the characteristics and capacity for multilane highways. Free-flow speed is an important parameter that is being used extensively for capacity and level-of- service analysis of various types of highway facilities.

23.2 Multilane Highways

A highway is a public road especially a major road connecting two or more destinations. A highway with at least two lanes for the exclusive use of traffic in each direction, with no control or partial control of access, but that may have periodic interruptions to flow at signalized intersections not closer than 3.0 km is called as multilane highway. They are typically located in suburban areas leading to central cities or along high-volume rural corridors that connect two cities or important activity centers that generate a considerable number of daily trips.

23.2.1 Highway Classification

There are various ways of classification of highways; we will see classification of highways according to number of lanes.

- Two lane highways.
- Multilane highways

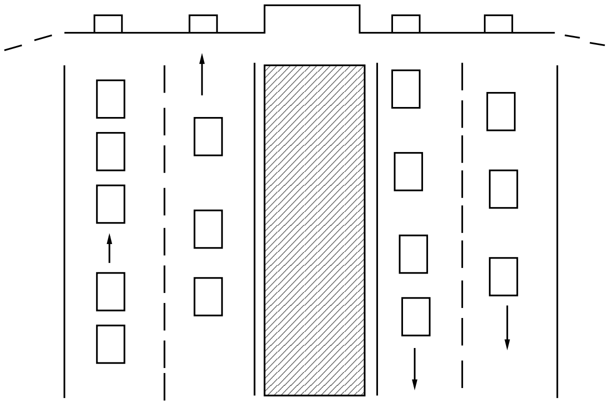

Figure 23:1: Divided multilane highway in a rural/suburban environment

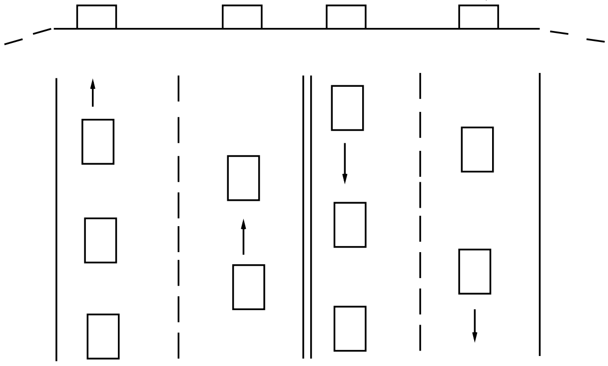

Figure 23:2: Undivided multilane highway in a rural/suburban environment

23.2.2 Highway Characteristics

Multilane highways generally have posted speed limits between 60 km/h and 90 km/h. They usually have four or six lanes, often with physical medians or two-way right turn lanes (TWRTL), although they may also be undivided. The traffic volumes generally varies from 15,000 - 40,000 vehicles per day. It may also go up to 100,000 vehicles per day with grade separations and no cross-median access. Traffic signals at major intersections are possible for multilane highways which facilitate partial control of access. Typical illustrations of multilane highway configurations are provided in Fig. 23:1 and 23:2

23.3 Highway Capacity

An important operation characteristic of any transport facility including the multi lane highways is the concept of capacity. Capacity may be defined as the maximum sustainable flow rate at which vehicles or persons reasonably can be expected to traverse a point or uniform segment of

Table 23:1: Free flow speed and capacity for Multilane highway

Types of facility	Free flow speed(kmph)	Capacity (pcphpl)
Multilane	100	2200
	90	2100
	80	2000
	70	1900

a lane or roadway during a specified time period under given roadway, traffic, environmental, and control conditions; usually expressed as vehicles per hour, passenger cars per hour, or persons per hour. There are two types of capacity, possible capacity and practical capacity. Possible capacity is defined as the maximum number of vehicles that can pass a point in one hour under prevailing roadway and traffic condition. Practical capacity on the other hand is the maximum number that can pass the point without unreasonable delay restriction to the average driver's freedom to pass other vehicles. Procedure for computing practical capacity for the uninterrupted flow condition is as follows:

1. Select an operating speed which is acceptable for the class of highways the terrain and the driver.

2. Determine the appropriate capacity for ideal conditions from table 1.

3. Determine the reduction factor for conditions which reduce capacity (such as width of road, alignment, sight distance, heavy vehicle adjustment factor).

4. Multiply these factors by ideal capacity value obtained from step 2.

23.4 Level of Service

Level of service (LOS) is a qualitative term describing the operational performance of any transportation facility. The qualitative performance measure can be defined using various quantitative terms like:

1. Volume to capacity ratio,

2. Mean passenger car speed,(in km/h)

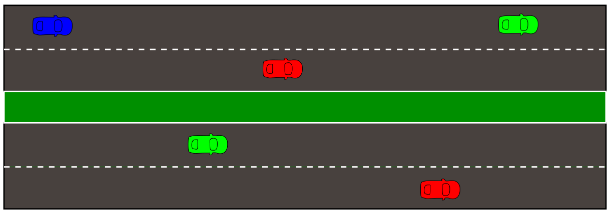

Figure 23:3: LOS A

3. Density, (in p/kmln).

Basically any two of the following three performance characteristics can describe the LOS for a multilane highway. Each of these measures can indicate how well the highway accommodates the traffic demand since speed does not vary over a wide range of flows, it is not a good indicator of service quality. Density which is a measure of proximity of other vehicles in the traffic stream and is directly perceived by drivers and does not vary with all flow levels and therefore density is the most important performance measure for estimating LOS. Based on the quantitative parameter, the LOS of a facility can be divided into six qualitative categories, designated as LOS A,B,C,D,E,F The definition of each level of service, is given below:

23.4.1 Level of Service A

Travel conditions are completely free flow. The only constraint on the operation of vehicles lies in the geometric features of the roadway and individual driver preferences. Lane changing, merging and diverging manoeuvre within the traffic stream is good, and minor disruptions to traffic are easily absorbed without an effect on travel speed. Average spacing between vehicles is a minimum of 150 m or 24 car lengths. Fig. 23:3 shows LOS A.

23.4.2 Level of Service B

Travel conditions are at free flow. The presence of other vehicles is noticed but it is not a constraint on the operation of vehicles as are the geometric features of the roadway and individual driver preferences. Minor disruptions are easily absorbed, although localized reduction in LOS are noted. Average spacing between vehicles is a minimum of 150 m or 24 car lengths. Fig. 23:4 below shows LOS B.

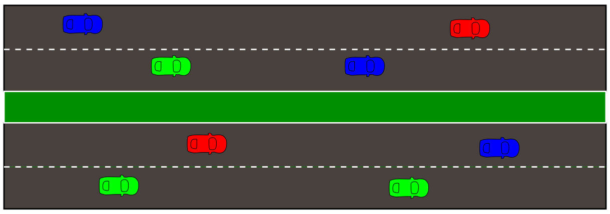

Figure 23:4: LOS B

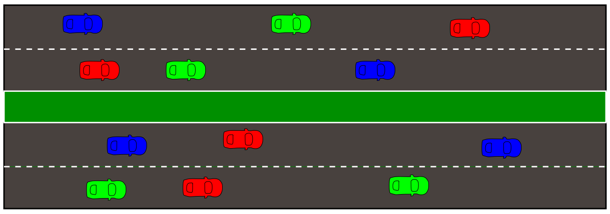

Figure 23:5: LOS C

23.4.3 Level of Service C

Traffic density begins to influence operations. The ability to manoeuvre within the traffic stream is affected by other vehicles. Travel speeds show some reduction when free-flow speeds exceed 80 km/h. Minor disruptions may be expected to cause serious local deterioration in service, and queues may begin to form. Average spacing between vehicles is a minimum of 150 m or 24 car length. Fig. 23:5 shows LOS C.

23.4.4 Level of Service D

The ability to manoeuvre is severely restricted due to congestion. Travel speeds are reduced as volumes increase. Minor disruptions maybe expected to cause serious local deterioration in service, and queues may begin to form. Average spacing between vehicles is a minimum of 150 m or 24 car length. Fig. 23:6 shows LOS D.

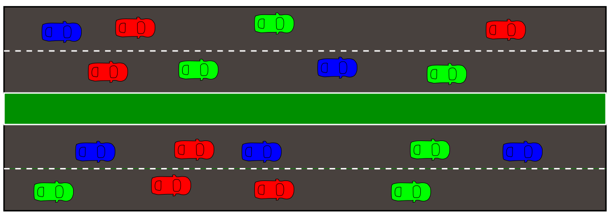

Figure 23:6: LOS D

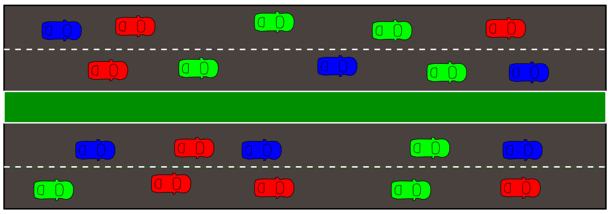

Figure 23:7: LOS E

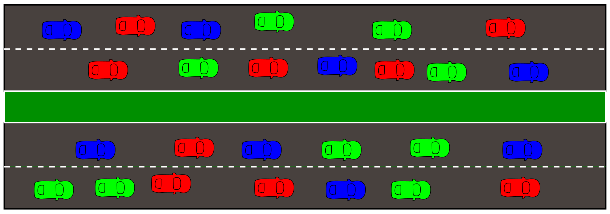

Figure 23:8: LOS F

23.4.5 Level of Service E

Operations are unstable at or near capacity. Densities vary, depending on the free-flow speed. Vehicles operate at the minimum spacing for which uniform flow can be maintained. Disruptions cannot be easily dissipated and usually result in the formation of queues and the deterioration of service to LOS F. For the majority of multilane highways with free-flow speed between 70 and 100km/h, passenger-car mean speeds at capacity range from 68 to 88 km/h but are highly variable and unpredictable. Average spacing between vehicles is a minimum of 150 m or 24 car length. Fig. 23:7 shows LOS E.

23.4.6 Level of Service F

A forced breakdown of flow occurs at the point where the numbers of vehicles that arrive at a point exceed the number of vehicles discharged or when forecast demand exceeds capacity. Queues form at the breakdown point, while at sections downstream they may appear to be at capacity. Operations are highly unstable, with vehicles experiencing brief periods of movement followed by stoppages. Travel speeds within queues are generally less than 48 km/h. Note that the term LOS F may be used to characterize both the point of the breakdown and the operating condition within the queue. Fig. 23:8 shows LOS F.

23.5 Determination of Level of Service

The determination of level of service for a multilane highway involves three steps:

1. Determination of free-flow speed
2. Determination of flow rate
3. Determination of level of service

23.5.1 Free-flow speed

Free-flow speed is the theoretical speed of traffic density, when density approaches zero. It is the speed at which drivers feel comfortable travelling under the physical, environmental and traffic conditions existing on an uncongested section of multilane highway. In practice, free-flow speed is determined by performing travel-time studies during periods of low-to-moderate flow conditions. The upper limit for low to moderate flow conditions is considered 1400 passenger cars per hour per lane(pc/h/ln) for the analyses. Speed-flow and density flow relationships are shown in Fig. 23:9 and Fig. 23:10. These relationships hold for a typical uninterrupted-flow segment on a multilane highway under either base or no base conditions in which free-flow speed is known. Fig. 23:9 indicates that the speed of traffic volume up to a flow rate of 1400 pc/h/ln. It also shows that the capacity of a multilane highway under base conditions is 2200 pc/h/ln for highways with a 90 km/h free-flow speed. At flow rates between 1400 and 2200 pc/h/ln, the speed on a multilane highway drops; for example, by 8 km/h for a highways with a free-flow speed of 90 km/h. Fig. 23:10 shows that density varies continuously throughout the full range of flow rates. The capacity value of 2200 pc/h/ln is representative of the maximum 15-min flow rate that can be accommodated under base conditions for highways with 90 km/h free-flow speed. From various studies of the flow characteristics, base conditions for multilane highways are defined as follows:

1. Lane widths are 3.6 m.
2. Lateral clearance is 1.8 m.
3. A minimum of 3.6 m of total lateral clearance in the direction of travel. Clearances are measured from the edge of the outer travelled lanes (shoulders included) and lateral clearance of 1.8 m or greater are considered to be equal to 1.8 m.
4. No direct access points along the highway.

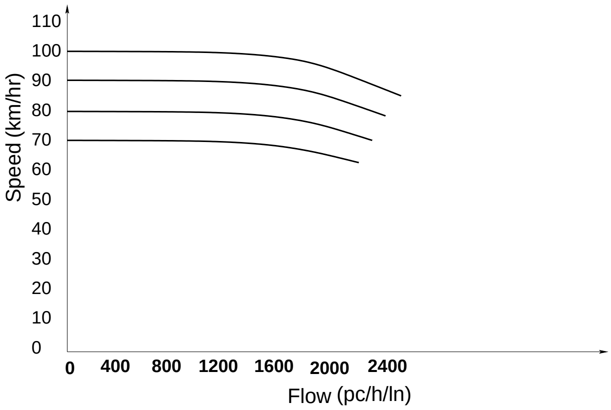

Figure 23:9: Speed-flow relationship on multilane highways

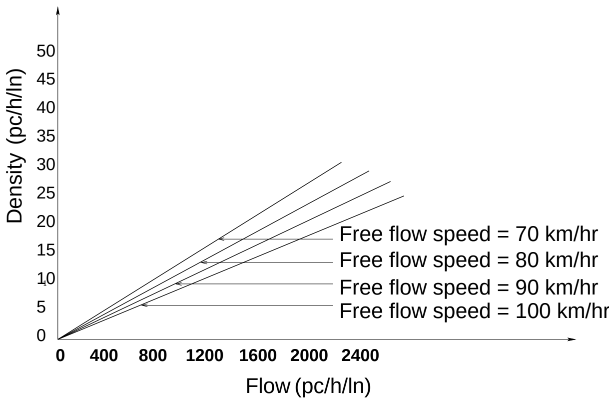

Figure 23:10: Density-flow relationships on multilane highways

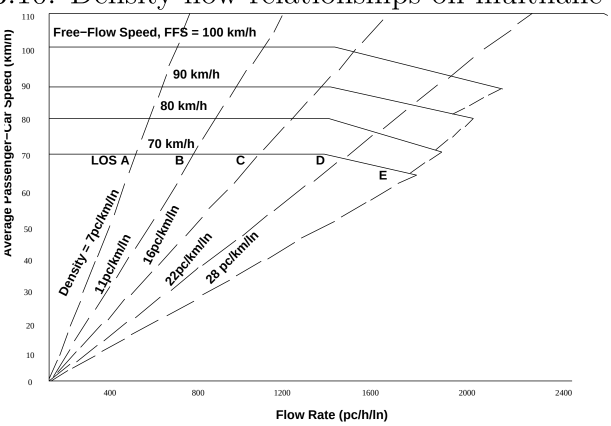

Figure 23:11: Speed-flow curves with LOS criteria for multilane highways

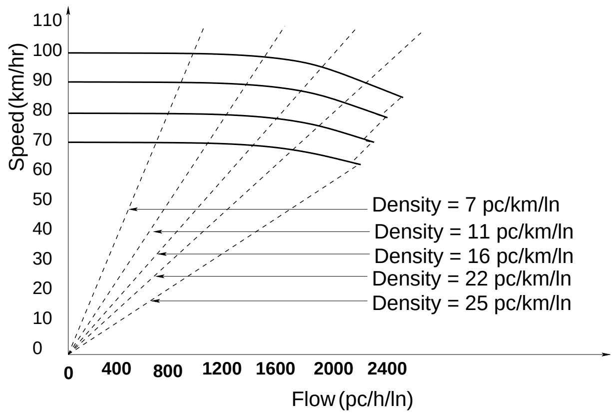

Figure 23:12: Flowchart showing step by step procedure to find density and LOS

5. A divided highway.

6. Only passenger cars in the traffic stream.

7. A free-flow speed of 90 km/h or more.

The average of all passenger-car speeds measured in the field under low volume conditions can be used directly as the free-flow speed if such measurements were taken at flow rates at or below 1400 pc/h/ln. No adjustments are necessary as this speed reflects the net effect of all conditions at the site that influence speed, including lane width, lateral clearance, type of median, access points, posted speed limits, and horizontal and vertical alignment. Free-flow speed also can be estimated from 85th-percentile speed or posted speed limits, research suggests that free-flow speed under base conditions is 11 km/h higher than the speed limit for 65 km/h to 70 km/h speed limits and 8 km/h higher for 80 km/h to 90 km/h speed limits. Fig. 23:12 shows speed-flow curves with LOS criteria for multilane highways, here LOS is easily determined for any value of speed simply by plotting the point which is a intersection of flow and corresponding speed. Note that density is the primary determinant of LOS. LOS F is characterized by highly unstable and variable traffic flow. Prediction of accurate flow rate, density, and speed at LOS F is difficult.

23.5.2 Determination of free-flow speed

When field data are not available, the free-flow speed can be estimated indirectly as follows:

$$FFS = BFFS - f_{LW} - f_{LC} - f_M - f_A \tag{23.1}$$

where, FFS is the estimated FFS (km/h), $BFFS$= base FFS (km/h), f_{LW}= adjustment for lane width, from Table 3 (km/h), f_{LC}= adjustment for lateral clearance, from Table 4 (km/h),

Table 23:2: Level of Service criteria for a typical free flow speed of 100 kmph proposed in HCM 2000

Free-Flow Speed	Criteria	(LOS) A	(LOS) B	(LOS) C	(LOS) D	(LOS) E
100 km/h	Max. density (pc/km/ln)	7	11	16	22	25
	Average speed (kmph)	100	100	98.4	91.5	88
	Max. volume capacity ratio	0.32	0.50	0.72	0.92	1.00
	Max. service flow rate (pc/h/ln)	700	1100	1575	2015	2200

f_M= adjustment for median type, from Table 5 (km/h), and f_A= adjustment for access points, from Table 6 (km/h). FFS on multilane highways under base conditions is approximately 11 km/h higher than the speed limit for 65 and 70 km/h speed limits, and it is 8 km/h higher for 80 and 90 km/h speed limits. BFFS is approximately equal to 62.4 km/h (i.e decrease in 1.6 km/h) when the 85 th percentile speed is 64 km/h, and it is 91.2 km/h (i.e decrease in 4.8 km/h) when the 85 th percentile speed is 96 km/h and the in between speed values is found out by interpolation. According to Table 3, the adjustment in km/h increase as the lane width decreases from a base lane width of 3.6 m. No data exist for lane widths less than 3.0m.

The adjustment for lateral clearance (T_{LC}) is given as:

$$T_{LC} = L_{CL} + L_{CR} \tag{23.2}$$

where, T_{LC} = Total lateral clearance (m), L_{CL} = Lateral clearance (m), from the right edge of the travel lanes to roadside obstructions (if greater than 1.8 m, use 1.8 m), and L_{CR}= Lateral clearance (m), from the left edge of the travel lanes to obstructions in the roadway median (if the lateral clearance is greater than 1.8 m, use 1.8 m). Once the total lateral clearance is computed, the adjustment factor is obtained from Table 4. For undivided highways, there is no adjustment for the right-side lateral clearance as this is already accounted for in the median type. Therefore, in order to use Table 5 for undivided highways, the lateral clearance on the left edge is always 1.8 m, as it for roadways with TWRTLs. The access-point density, which is use in Table 6, for a divided roadway is found by dividing the total number of access points

Table 23:3: Adjustment for lane width (Source: HCM, 2000)

Lane Width (m)	Reduction in FFS(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 23:4: Adjustment for lateral clearance(Source: HCM, 2000)

Four-Lane Highways		Six-Lane Highways	
Total Lateral Clearance a (m)	Reduction in FFS (km/h)	Total Lateral Clearance a (m)	Reduction in FFS (km/h)
3.6	0.0	3.6	0.0
3.0	0.6	3.0	0.6
2.4	1.5	2.4	1.5
1.8	2.1	1.8	2.1
1.2	3.0	1.2	2.7
0.6	5.8	0.6	4.5
0.0	8.7	0.0	6.3

Table 23:5: Adjustment to free flow speed for median type(Source: HCM, 2000)

Median Type	Reduction in FFS (km/h)
Undivided highways	2.6
Divided highways	0.0

Table 23:6: Adjustment to free flow speed for Access-point density(Source: HCM, 2000)

Access Points/Kilometer	Reduction in FFS (km/h)
0	0.0
6	4.0
12	8.0
18	12.0
≥ 24	16.0

(intersections and driveways) on the right side of the roadway in the direction of travel being studied by the length of the segment in kilometers. The adjustment factor for access-point density is given in Table 6. Thus the free flow speed can be computed using equation 1 and applying all the adjustment factors.

23.5.3 Determination of Flow Rate

The next step in the determination of the LOS is the computation of the peak hour factor. The fifteen minute passenger-car equivalent flow rate (pc/h/ln), is determined by using following formula:

$$v_p = \frac{V}{(PHF \times \ N \times \ f_{HV} \times \ f_p)} \tag{23.3}$$

where, v_p is the 15-min passenger-car equivalent flow rate (pc/h/ln), V is the hourly volume (veh/h), PHF is the peak-hour factor, N is the number of lanes, f_{HV} is the heavy-vehicle adjustment factor, and f_p is the driver population factor. PHF represents the variation in traffic flow within an hour. Observations of traffic flow consistently indicate that the flow rates found in the peak 15-min period within an hour are not sustained throughout the entire hour. The PHFs for multilane highways have been observed to be in the range of 0.75 to 0.95. Lower values are typical of rural or off-peak conditions, whereas higher factors are typical of urban and suburban peak-hour conditions. Where local data are not available, 0.88 is a reasonable estimate of the PHF for rural multilane highways and 0.92 for suburban facilities. Besides that, the presence of heavy vehicles in the traffic stream decreases the FFS because base conditions allow a traffic stream of passenger cars only. Therefore, traffic volumes must be adjusted to reflect an equivalent flow rate expressed in passenger cars per hour per lane (pc/h/ln). This is accomplished by applying the heavy-vehicle factor (f_{HV}). Once values for E_T and E_R have

Table 23:7: Passenger-car equivalent on extended general highway segments(Source: HCM, 2000)

Factor	Type of Terrain		
	Level	Rolling	Mountainous
ET (Trucks and Buses)	1.5	2.5	4.5
ER (RVs)	1.2	2.0	4.0

been determined, the adjustment factors for heavy vehicles are applied as follows:

$$f_{HV} = \frac{1}{(1 + P_T(E_T - 1) + P_R(E_R - 1)} \tag{23.4}$$

where, E_T and E_R are the equivalents for trucks and buses and for recreational vehicles (RVs), respectively, P_T and P_R are the proportion of trucks and buses, and RVs, respectively, in the traffic stream (expressed as a decimal fraction), f_HV is the adjustment factor for heavy vehicles. Adjustment for the presence of heavy vehicles in traffic stream applies for three types of vehicles: trucks, buses and recreational vehicles (RVs). Trucks cover a wide range of vehicles, from lightly loaded vans and panel trucks to the most heavily loaded coal, timber, and gravel haulers. An individual truck's operational characteristics vary based on the weight of its load and its engine performance. RVs also include a broad range: campers, self-propelled and towed; motor homes; and passenger cars or small trucks towing a variety of recreational equipment, such as boats, snowmobiles, and motorcycle trailers. There is no evidence to indicate any distinct differences between buses and trucks on multilane highways, and thus the total population is combined.

23.5.4 Determination of Level of Service

The level of service on a multilane highway can be determined directly from Fig. 23:12 or Table-2 based on the free-flow speed (FFS) and the service flow rate (vp) in pc/h/ln. The procedure as follows:

1. Define a segment on the highway as appropriate. The following conditions help to define the segmenting of the highway,
    - Change in median treatment
    - Change in grade of 2% or more or a constant upgrade over 1220 m
    - Change in the number of travel lanes

- The presence of a traffic signal
- A significant change in the density of access points
- Different speed limits
- The presence of bottleneck condition

In general, the minimum length of study section should be 760 m, and the limits should be no closer than 0.4 km from a signalized intersection.

2. On the basis of the measured or estimated free-flow speed on a highway segment, an appropriate speed-flow curve of the same as the typical curves is drawn.

3. Locate the point on the horizontal axis corresponding to the appropriate flow rate (vp) in pc/hr/ln and draw a vertical line.

4. Read up the FFS curve identified in step 2 and determine the average travel speed at the point of intersection.

5. Determine the level of service on the basis of density region in which this point is located. Density of flow can be computed as

$$D = \frac{v_p}{S} \tag{23.5}$$

where, D is the density (pc/km/ln), v_p is the flow rate (pc/h/ln), and S is the average passenger-car travel speed (km/h). The level of service can also be determined by comparing the computed density with the density ranges shown in table given by HCM. To use the procedures for a design, a forecast of future traffic volumes has to be made and the general geometric and traffic control conditions, such as speed limits, must be estimated. With these data and a threshold level of service, an estimate of the number of lanes required for each direction of travel can be determined.

Numerical example 1

A segment of undivided four-lane highway on level terrain has field-measured FFS 74.0-km/h, lane width 3.4-m, peak-hour volume 1,900-veh/h, 13 percent trucks and buses, 2 percent RVs, and 0.90 PHF. What is the peak-hour LOS, speed, and density for the level terrain portion of the highway?

Solution The solution steps are given below:

1. **Data given:** Level terrain, field measured FFS = 74 km/h, lane width is 3.4 m, peak-hour volume = 1900 veh/h, percent trucks and buses pt = 0.13, percent RVs PR = 0.02, and PHF=0.90.

2. **Determination of flow rate(Vp):** LOS can be calculated by knowing flow rate and free flow speed. Flow rate (Vp) is calculated from the equation

$$Vp = \frac{V}{(PHF \times \ N \times \ fHV \times \ fp)}$$

Since f_{HV} is unknown it is calculated from the equation

$$f_{HV} = \frac{1}{(1 + PT(ET - 1) + PR(ER - 1)}$$

where, ET and ER are passenger-car equivalents for trucks and buses and for recreational vehicles (RVs) respectively PT and PR are proportion of trucks and buses, and RVs, respectively, in the traffic stream (expressed as a decimal fraction)

$$\begin{aligned} f_{HV} &= \frac{1}{1 + 0.13(1.5 - 1) + 0.02(1.2 - 1)} \\ &= 0.935. \end{aligned}$$

Assume no RVs, since none is indicated.

$$\begin{aligned} Vp &= \frac{1900}{(0.90 \times \ 2 \times \ 0.935 \times \ 1)} \\ &= 1129 \text{ pc/h/ln.} \end{aligned}$$

3. **Determination of free flow speed(S):** In this example the free flow speed (FFS) measured at the field is given and hence no need to compute free flow speed by indirect method. Therefore, $FFS = S = 74.0 km/h$.

4. **Determination of density(D):** The density of flow is computed from the equation $D = Vp/S = 15.3$

5. **Determination of LOS:** LOS determined from the speed-flow diagram. LOS = C.

Numerical example 2

A segment of an east-west five-lane highway with two travel lanes in each direction separated by a two-way left-turn lane (TWLTL) on a level terrain has- 83.0-km/h 85th-percentile speed ,3.6-m lane width, 1,500-veh/h peak-hour volume, 6 % trucks and buses, 8 access points/km (WB), 6 access points/km (EB), 0.90 PHF, 3.6-m and greater lateral clearance for westbound and eastbound. What is the LOS of the highway on level terrain during the peak hour?

Solution The solution steps are enumerate below:

1. **Data given:** Level terrain, 85th-percentile speed is 83.0 km/h , lane width is 3.6 m, peak-hour volume, v=1500 veh/h percent of trucks and buses PT=0.06, 8 access points/km in WB, 6 access points/km in EB, PHF = 0.90, and lateral clearance for westbound and eastbound is more than 3.6 m.

2. **Determination of flow rate(VP):** LOS can be calculated by knowing flow rate and free flow speed. Flow rate (Vp) is calculated from the equation

$$Vp = \frac{V}{(PHF \times \ N \times \ fHV \times \ fp)}$$

where, Vp = 15-min passenger-car equivalent flow rate (pc/h/ln), V = hourly volume (veh/h), PHF = peak-hour factor, N = number of lanes, fHV = heavy-vehicle adjustment factor, and fp = driver population factor Since f_{HV} is unknown it is calculated from the equation

$$f_{HV} = \frac{1}{(1 + PT(ET - 1) + PR(ER - 1)}$$

where, ET and ER = passenger-car equivalents for trucks and buses and for recreational vehicles (RVs), respectively PT and PR = proportion of trucks and buses, and RVs, respectively, in the traffic stream (expressed as a decimal fraction) Assume no RVs, since none is indicated.

$$\begin{aligned} f_{HV} &= \frac{1}{1 + 0.06(1.5 - 1) + 0} \\ &= 0.970. \end{aligned}$$

$$\begin{aligned} Vp &= \frac{1500}{(0.90 \times \ 2 \times \ 0.970 \times \ 1)} \\ &= 858 \text{ pc/h/lane} \end{aligned}$$

3. **Determination of free flow speed(S):** BFFS is approximately equal to 62.4 km/h when the 85 th percentile speed is 64 km/h, and it is 91.2 km/h when the 85 th percentile speed is 96 km/h and the in between speed values is found out by interpolation. Hence, BFFS = 80 km/h. Now, compute east bound and west bound free-flow speeds

$$\begin{aligned} FFS &= BFFS - f_{LW} - f_{LC} - f_A - f_M \\ &= 80 - 0 - 0 - 4 - 0 \\ &= 76 \text{ kmph (WB)} \\ &= 80 - 0 - 0 - 5.3 - 0 \\ &= 74.7 \text{ kmph (EB)} \end{aligned}$$

4. **Determination of LOS:** LOS determined from the speed-flow diagram. LOS = C (for EB) LOS = C (for WB)

Numerical example 3

A 10 km long 4 lane undivided multilane highway in a suburban area has a segment 1 km long with a 3% upgrade and a segment 1 km long with a 3% downgrade. The section has a volume of 1900 vehicles/hr in each direction with 13% trucks and buses and 2% recreational vehicles. The 85 th percentile speed of passenger car is 80 km/hr on upgrade and 86km/hr on downgrade. There are total of 12 access points on both sides of the roadway. The lane width is 3.6 m, PHF is 0.90 and having a 3m lateral clearance. Determine the LOS of the highway section (upgrade and downgrade) during the peak hour? From HCM, For a 3% upgrade and 1 km length(ET=1.5 , ER=3) For a 3% downgrade and 1 km length(ET=1.5 , ER=1.2)

Solution

1. **Data given:** 3%upgrade and 3%downgrade No of lanes = 4, N = 4, 80.0 km/h 85th-percentile speed for upgrade, 86 km/h 85t h-percentile speed for downgrade, 3.6-m lane width, 1,900-veh/h peak-hour volume, (V =1900 veh/h) 13 % trucks and buses, (PT =0.13) 2 % Recreational vehicles, (Pr=0.02) 12 access points/km, PHF = 0.90 lateral clearance = 3 m

2. **Determination of flow rate(VP):** LOS can be calculated by knowing flow rate and free flow speed.

   For upgrade: Flow rate is calculated from the equation

$$Vp = \frac{V}{(PHF \times \ N \times \ fHV \times \ fp)}$$

   where, Vp = 15-min passenger-car equivalent flow rate (pc/h/ln), V = hourly volume (veh/h), PHF = peak-hour factor, N = number of lanes, fHV = heavy-vehicle adjustment factor, and fp = driver population factor Since fHV is unknown it is calculated from the equation

$$f_{HV} \quad = \quad \frac{1}{(1 + PT(ET - 1) + PR(ER - 1)}$$

   where, ET and ER = passenger-car equivalents for trucks and buses and for recreational vehicles (RVs), respectively PT and PR = proportion of trucks and buses, and RVs, respectively, in the traffic stream (expressed as a decimal fraction) Assume no RVs, since none is indicated.

$$f_{HV} = \frac{1}{1 + 0.13(1.5 - 1) + 0.02(3 - 1)}$$
$$= 0.905.$$
$$Vp = \frac{1900}{(0.90 \times \ 2 \times \ 0.905 * 1)}$$
$$= 1166 \text{ p}c/h/ln$$

For downgrade:

$$f_{HV} = \frac{1}{1 + 0.13(1.5 - 1) + 0.02(1.2 - 1)}$$
$$= 0.935$$
$$Vp = \frac{1900}{(0.90 \times \ 2 \times \ 0.935 \times \ 1)}$$
$$= 1128 \text{ pc/h/ln}$$

3. **Determination of free flow speed(S): For upgrade:** BFFS is approximately equal to 62.4 km/h when the 85 th percentile speed is 64 km/h, and it is 91.2 km/h when the 85 th percentile speed is 96 km/h and the in between speed values is found out by interpolation. Hence for 86 km/hr 85_{th} percentile speed from interpolation we get, BFFS = 77.0 km/h Now, Compute east bound and west bound free-flow speeds

$$FFS = BFFS - f_{LW} - f_{LC} - f_A - f_M$$
$$= 77 - 0 - 0.6 - 8.0 - 2.6$$
$$= 65.8 \text{ km/h}$$

   For downgrade: BFFS is approximately equal to 62.4 km/h when the 85 th percentile speed is 64 km/h, and it is 91.2 km/h when the 85 th percentile speed is 96 km/h and the in between speed values is found out by interpolation. Hence for 86 km/hr 85th percentile speed from interpolation we get, BFFS= 82.0 km/h Now, Compute the free-flow speed

$$FFS = BFFS - f_{LW} - f_{LC} - f_A - f_M$$
$$= 82 - 0 - 0.6 - 8.0 - 2.6$$
$$= 71 \text{ km/h}$$

4. **Determination of LOS** LOS determined from the speed-flow diagram. LOS = D (for upgrade) LOS = D (for downgrade)

23.6 Conclusion

This chapter helps to determine the level of service and capacity for a given road segment. In the first part we studied highways in general there classification and characteristics which gives the overall idea of multilane highways. Then we studied determination of capacity for multilane highway which is again a very important parameter used to determine the level of service, then we studied the concept of level of service and procedure to determine level of service. Also by using its applications, number of lanes required (N), and flow rate achievable (vp), Performance measures related to density (D) and speed (S) can also be determined.

23.7 References

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