PART 6
Level of Service
(LOS)

Highway Capacity

Motivation:

- The underlying objective of traffic analysis is to quantify a roadway's performance with regard to specified traffic volumes.
- This performance can be measured in terms of travel delay (as the roadway becomes increasingly congested) as well as other factors.
- The comparative performance of various roadway segments (which is determined from an analysis of traffic) is important because it can be used as a basis to allocate limited roadway construction and improvement funds.
- The purpose of this chapter is to apply the elements of uninterrupted traffic flow theory to the practical field analysis of traffic flow and capacity on freeways, multilane highways, and two-lane highways.

Highway Capacity

- For example, capacity (q_{cap}) is simply defined as the highest traffic flow rate that the roadway is capable of supporting.
- For applied traffic analysis, a consistent and reasonably precise method of determining capacity must be developed within this definition.
- It can be shown that the capacity of a roadway segment is a function of factors, such as roadway type (freeway, multilane highway, or two-lane highway), free-flow speed, number of lanes, and widths of lanes and shoulders
  - the method of capacity determination clearly must account for a wide variety of physical and operational roadway characteristics.

Highway Capacity

- Additionally, recall that traffic flow is measured on the basis of units of vehicles per hour. Two practical issues arise concerning this unit of measure:
- First, in many cases vehicular traffic consists of a variety of vehicle types (large, slow, etc.) with substantially different performance characteristics.

Ontario Highway 401

Highway Capacity

  - These performance differentials are likely to be magnified by changing roadway geometries, such as upgrades or downgrades, which have a differential effect on the acceleration and deceleration capabilities of the various types of vehicles; for example, grades have a greater impact on the performance of large trucks than automobiles.

- As a result, traffic must be defined not only in terms of vehicles per unit time but also in terms of vehicle composition, because it is clear that a 1500-veh/h traffic flow consisting of 100% automobiles will differ significantly with regard to operating speed and traffic density from a 1500- veh/h traffic flow that consists of 50% automobiles and 50% heavy trucks.

Highway Capacity

- The other flow-related concern is the temporal distribution of traffic.
- In practice, the analysis of roadway traffic usually focuses on the most critical condition, which is the most congested hour within a 24-hour daily period.
    - However, within this most congested peak hour, traffic flow is likely to be non-uniform.
    - It is therefore necessary to arrive at some method of defining and measuring the non-uniformity of flow within the peak hour.

To summarize, the objective of applied traffic analysis is to provide a practical method of quantifying the degree of traffic congestion and to relate this to the overall traffic-related performance of the roadway.

Level-of-Service

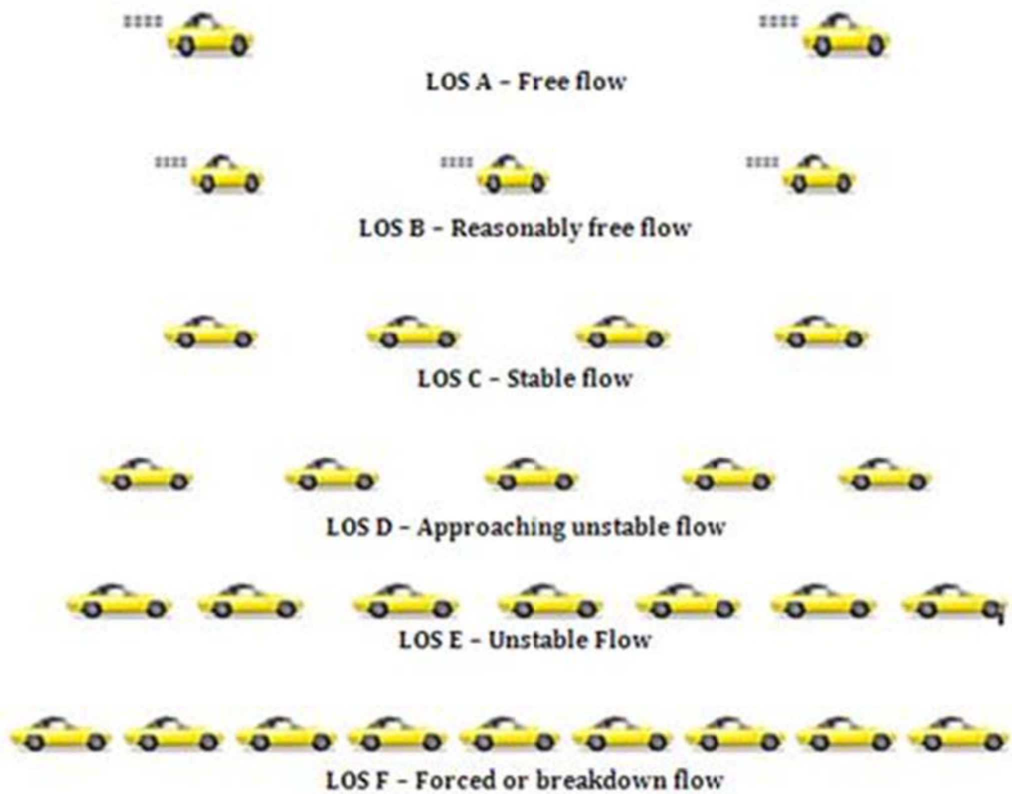
- The Highway Capacity Manual (HCM), produced by the Transportation Research Board [2000], is a synthesis of the state of the art in methodologies for quantifying traffic operational performance and capacity utilization (congestion level) for a variety of transportation facilities.
- One of the foundations of the HCM is the concept of level of service (LOS).
- The level of service represents a qualitative ranking of the traffic operational conditions experienced by users of a facility under specified roadway, traffic, and traffic control (if present) conditions.
- Current practice designates six levels of service ranging from A to F, with level of service A representing the best operating conditions and level of service F the worst.

Level-of-Service

- To apply the level-of-service concept to traffic analysis, it is necessary to select a performance measure that is representative of how motorists actually perceive the quality of service they are receiving on a facility.
- Motorists tend to evaluate their received quality of service in terms of factors such as speed and travel time, freedom to maneuver, traffic interruptions, and comfort and convenience.
- Thus, it is important to select a measure that encompasses some or all of these factors. The performance measure that is selected for level-of-service (LOS) analysis for a particular transportation facility is referred to as the service measure.

The HCM [Transportation Research Board 2000] defines the LOS categories for freeways and multilane highways as follows:

Level-of-Service




LOS A


LOS B


LOS C


LOS D


LOS E


LOS F

Level-of-Service

Roadway and traffic conditions, ranging from "ideal" to forced flow, have been divided into six levels of service for qualitative evaluation.

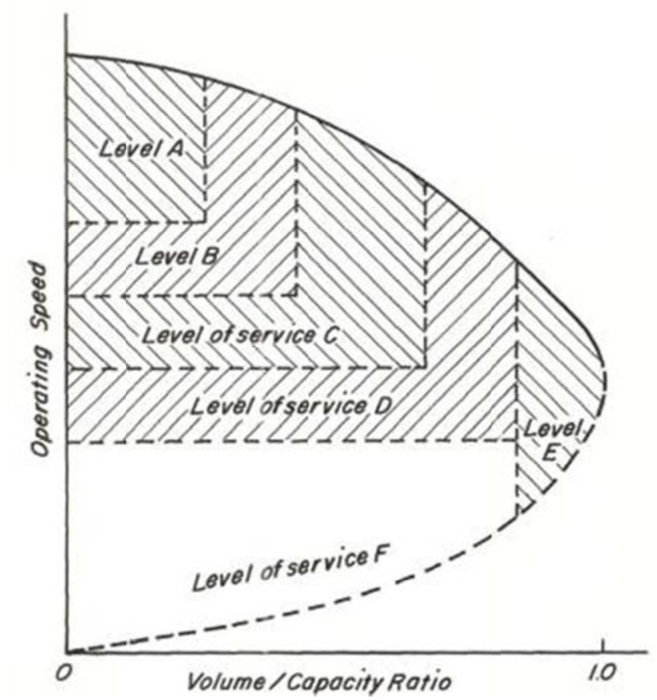


Figure 6.1 Schematic concept relationship of levels of service to operating speed and volume/ capacity ratio

Level-of-Service

For uninterrupted flow, the levels are defined as follows:

- **Level of Service A** — free flow, low volumes and densities, high speeds. Drivers can maintain their desired speeds with little or no delay.
- **Level of Service B** — stable flow, operating speeds beginning to be restricted somewhat by traffic conditions. Drivers still have reasonable freedom to select their speed. Suitable for rural design standards.
- **Level of Service C** — stable flow, but speeds and maneuverability are more closely controlled by higher volumes. Suitable for urban design standards.

Level-of-Service

- **Level of Service D** — approaches unstable flow, tolerable operating speeds which are, however, considerably affected by operating conditions. Drivers have little freedom to maneuver.
- **Level of Service E** — Unstable flow, with yet lower operating speeds and, perhaps, stoppages of momentary duration. Volumes at or near capacity.
- **Level of Service F** — forced flow, low volumes. Both speed and volumes can drop to zero. Stoppages may occur for short or long periods. These conditions usually result from queues of vehicles backing up from a restriction downstream.

Level-of-Service

- In dealing with level of service it is important to remember that when the traffic volume is at or near the roadway capacity (which will be shown as a function of the prevailing traffic and physical characteristics of the roadway), the roadway is operating at LOS E.
- This, however, is not a desirable condition because under LOS E conditions there is considerable driver discomfort, which could increase the likelihood of vehicular crashes and overall delay.
- In roadway design, the possibility of degradation of level of service to LOS E should be avoided, although this is not always possible due to financial and environmental constraints that may limit the design speed, number of lanes, and other factors affecting roadway capacity.

Determination of Level-of-Service

Base Conditions and Capacity

- The determination of a roadway's level of service begins with the specification of base roadway conditions.
- For uninterrupted-flow roadways, base conditions can be categorized as those relating to roadway conditions, such as lane widths, lateral clearances, access frequency, and terrain; and traffic stream conditions such as the effects of heavy vehicles (large trucks, buses, and RVs) and driver population characteristics.
- Base conditions are defined as those conditions that represent unrestrictive geometric and traffic conditions.

Determination of Level-of-Service

- Additionally, base conditions are assumed to consist of favorable environmental conditions (such as dry roadways).
- The capacity of a particular roadway segment will be greatest when all roadway and traffic conditions meet or exceed their base values.
- Empirical studies have identified the values of these base conditions for which the capacity of a roadway segment is maximized.
- Values in excess of the base conditions will not increase the capacity of the roadway, but values more restrictive than the base conditions will result in a lower capacity.
    - For example, studies have identified a base lane width of 12 ft (**3.6 m**). <u>That is, lane widths in excess of 12 ft (3.6 m) will not result in increased capacity; however, lane widths less than 12 ft (3.6 m) will result in a reduction in capacity.</u>

Determination of Level-of-Service

- Capacity values for base conditions have been determined for all uninterrupted-flow facility types from field studies.
    - It should be noted that for purposes of level-of-service analysis, capacity is defined not as the absolute maximum flow rate ever observed for a particular facility type, but rather as the maximum flow rate that can be reasonably expected on a recurring basis.

- Because all base conditions for a particular roadway type are seldom realized in practice, methods for converting the measured flow rate into an equivalent analysis flow rate in terms of passenger cars for the given traffic conditions and estimating the actual free-flow speed for the given roadway conditions are needed.

Determination of Level-of-Service

Determine Free-Flow Speed

- Free-flow speed (FFS) is defined as the speed of traffic as the traffic density approaches zero.
- In practice, FFS is governed by roadway design characteristics (horizontal and vertical curves, lane and shoulder widths, and median design), the frequency of access points, the complexity of the driving environment (possible distractions from roadway signs and the like), and posted speed limits.
- The free-flow speed must be determined given the characteristics of the roadway segment.
- FFS is the mean speed of traffic as measured when flow rates are low to moderate (specific values are given under the individual sections for each roadway type).

Determination of Level-of-Service

Determine Free-Flow Speed (continued)

- Ideally, FFS should be measured directly in the field at the site of interest.
- However, if this is not possible or feasible, an alternative method can be employed to arrive at an estimate of FFS under the prevailing conditions.
- This method makes adjustments to a base FFS (BFFS) depending on the physical characteristics of the roadway segment, such as lane width, shoulder width, and access frequency.
- This method has the same basic structure for the various roadway types, but contains adjustment factors and values appropriate for each roadway type.

Determination of Level-of-Service

Determine Analysis Flow Rate

- One of the fundamental inputs to a traffic analysis is the actual traffic volume on the roadway, in vehicles per hour, which is given the symbol ***V***.
- Generally, the highest volume in a 24-hour period (the peak-hour volume) is used for ***V*** in traffic analysis computations.
- However, this hourly volume needs to be adjusted to reflect the temporal variation of traffic demand within the analysis hour, the impacts due to heavy vehicles, and, in the case of freeway and multilane roadways, the characteristics of the driving population.
- To account for these effects, the hourly volume is divided by adjustment factors to obtain an equivalent **flow rate in terms of passenger cars per hour (pc/h).** Additionally, **the flow rate is expressed on a per-lane basis (pc/h/ln) by dividing by the number of lanes in the analysis segment.**

Determination of Level-of-Service

Calculate Service Measure(s) and Determine LOS

- Once the previous steps have been completed, all that remains is to calculate the value of the service measure and then determine the LOS from the service measure value.
- For freeways and multilane highways, this is a relatively straightforward task.
- However, for two-lane highways, there are actually two service measures, and the calculation of these and the subsequent LOS determination are more involved.

LOS for Two-Lane Highways

Two-lane highways are defined as roadways with one lane available in each direction. For level-of-service determination, a key distinction between two-lane highways and the freeways and multilane highways is that traffic in both directions must now be considered in the former, as traffic in an opposing direction has a strong influence on level of service.

For example, a high opposing traffic volume limits the opportunity to pass slow-moving vehicles (because such a pass requires the passing vehicle to occupy the opposing lane) and thus forces a lower traffic speed — and, as a consequence, a lower level of service. It also follows that any geometric features that restrict passing sight distance (such as sight distance on horizontal and vertical curves) will have an adverse impact on the level of service. Finally, the type of terrain (level, rolling, or mountainous) plays a more critical role in level-of-service calculations, relative to freeways and multilane highways, because of the sometimes limited ability to pass slower-moving vehicles on grades in areas where passing is prohibited due to sight distance restrictions or where opposing traffic does not permit safe passing.

LOS for Two-Lane Highways

- The Highway Capacity Manual [Transportation Research Board 2000] has defined two classes of two-lane highway:
  - **Class I:** Two-lane highways on which motorists expect to travel at high speeds (such as, inter-city routes, primary arterials connecting major traffic generators, daily commuter routes, and primary links in state or national highway networks)
  - **Class II:** Two-lane highways on which motorists do not necessarily expect to travel at high speeds (such as, scenic or recreational routes, or routes that pass through rugged terrain) and these routes generally serve shorter trip lengths than Class I routes.
- The service measure, and corresponding thresholds, that govern the determination of level of service depends on the functional classification of the two- lane highway.

LOS for Two-Lane Highways

Service Measure

Two service measures have been identified for two-lane highways:

(1) **percent time spent following** and
(2) **average travel speed.**

- Percent time spent following (PTSF) is the average percentage of travel time that vehicles must travel behind slower vehicles due to the lack of passing opportunities (because of geometry and/or opposing traffic).
- PTSF is difficult to measure in the field; thus, it is recommended that the percentage of vehicles traveling with headways less than 3 seconds at a representative location be used as a surrogate measure.
- PTSF is generally representative of a driver's freedom to maneuver in the traffic stream.

LOS for Two-Lane Highways

- Average travel speed (ATS) is simply the length of the analysis segment divided by the average travel time of all vehicles traversing the segment during the analysis period. ATS is an indicator of the mobility on a two-lane highway.

For Class I type

- Service measure : both ATS and PTSF must be calculated.

For Class II type

- Service measure : only PTSF needs to be calculated.

LOS for Two-Lane Highways

The 2000 edition of the Highway Capacity Manual [Transportation Research Board 2000] contains two procedures for operational analysis and level-of-service determination:

- one for both directions of travel combined, termed **a two-way analysis**, and
- another for just one of the two directions of travel, termed a directional analysis.

This section covers only the two-way analysis procedure. The directional analysis procedure has many aspects in common with the two-way analysis procedure, but coverage of both procedures is beyond the scope of this course.

LOS for Two-Lane Highways

Base Conditions and Capacity

The base conditions for two-lane highways are defined as [TRB 2000]

- 12-ft (3.6-m) minimum lane widths
- 6-ft (1.8-m) minimum shoulder widths
- 0% no-passing zones on the highway segment
- Only passenger cars in the traffic stream
- No direct access points along the roadway
- No impediments to through traffic due to traffic control or turning vehicles
- Level terrain (no grades greater than 2%)
- A 50/50 directional split of traffic (50% traveling one direction and 50% traveling the opposite direction) for two-way analysis

The capacity of extended lengths of two-lane highway under base conditions is 3200 passenger cars per hour (pc/h), total, both directions. The capacity of a single direction of a two-lane highway is 1700 pc/h.

LOS for Two-Lane Highways

Determining Free-Flow Speed (FFS)

- FFS for two-lane highways is the mean speed of all vehicles operating in flow rates up to 200 pc/h total for both directions.
- Free-flow speeds on two-lane highways typically range from 70 to 105 km/h.
- If field measurement of FFS cannot be made under conditions with a flow rate of 200 pc/h or less, an adjustment can be made with the following equation.

$$FFS = S_{FM} + 0.0125\frac{V_f}{f_{HV}} \tag{6.1}$$

where

FFS **=** estimated free-flow speed in km/h,

$\boldsymbol{S_{FM}}$ **=** mean speed of traffic measured in the field in km/h,

$\mathbf{V}_{\boldsymbol{f}}$ **=** observed flow rate, in veh/h, for the period when field data were obtained, and

$\boldsymbol{f}_{\mathbf{HV}}$ **=** heavy-vehicle adjustment factor as determined as follow:

LOS for Two-Lane Highways

Heavy Vehicle Adjustment

$$f_{HV} = \frac{1}{1+P_T(E_T-1)+P_R(E_\mathrm{R}-1)} \tag{6.2}$$

where

f$_{\mathbf{HV}}$ = heavy-vehicle adjustment factor,

P$_{T}$ = proportion of trucks and buses in the traffic stream,

P$_{R}$ = proportion of recreational vehicles in the traffic stream,

E$_{T}$ = passenger car equivalent for trucks and buses, from Table 6.2

E$_{R}$ = passenger car equivalent for recreational vehicles, from Table 6.2

LOS for Two-Lane Highways

Determining Analysis Flow Rate

The hourly volume must be adjusted to account for the peak 15-minute flow rate, the terrain, and the presence of heavy vehicles in the traffic stream. The **two-way analysis flow rate is calculated with the following equation.**

$$V_p = \frac{V}{PHF\ x f_G x f_{HV}} \tag{6.3}$$

where

V_p = 15-min passenger car equivalent flow rate (pc/h),
V = hourly volume (veh/h),
PHF = peak-hour factor,
f_{HV} = heavy-vehicle adjustment factor,
f_G = grade adjustment factor

LOS for Two-Lane Highways

Peak-Hour Factor

PHF for two-lane highways is calculated as

$$PHF = \frac{V}{V_{15} x 4} \tag{6.4}$$

where

V = hourly volume for hour of analysis,

V_{15} =maximum 15-min flow rate within hour of analysis and

4 = number of 15-min periods per hour.

Because the two-lane highway analysis methodology deals with a combined volume of the two (opposing) traffic streams, PHF should be calculated for both directions of traffic flow combined.

LOS for Two-Lane Highways

Grade Adjustment Factor

The grade adjustment factor accounts for the effect of terrain on the traffic flow.

Table 6.1 Grade adjustment factor for Average Travel Speed (ATS) and Percent Time Spent Following (PTSF)

Range of two-way flow rates (pc/h)	Average travel speed		Percent time spent following	
	Level terrain	Rolling terrain	Level terrain	Rolling terrain
0 – 600	1.00	0.71	1.00	0.77
> 600 – 1200	1.00	0.93	1.00	0.94
> 1200	1.00	0.99	1.00	1.00

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LOS for Two-Lane Highways

Heavy-Vehicle Adjustment Factor

The heavy-vehicle adjustment factor accounts for the effect on traffic flow due to the presence of trucks, buses, and recreational vehicles in the traffic stream.

Table 6.2 Passenger Car Equivalents for Heavy Vehicles for Average Travel Speed (ATS) and Percent Time Spent Following (PTSF)

Vehicle type	Range of two-way flow rates (pc/h)	Average travel speed		Percent time spent following	
		Level terrain	Rolling terrain	Level terrain	Rolling terrain
Trucks and buses, E_T	0 – 600	1.7	2.5	1.1	1.8
	> 600 – 1200	1.2	1.9	1.1	1.5
	> 1200	1.1	1.5	1.0	1.0
RVs, E_R	0 – 600	1.0	1.1	1.0	1.0
	> 600 – 1200	1.0	1.1	1.0	1.0
	> 1200	1.0	1.1	1.0	1.0

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LOS for Two-Lane Highways

Calculate Service Measures:

Average Travel Speed

The average travel speed depends on the free-flow speed, the analysis flow rate, and an adjustment factor for the percentage of no-passing zones, and is calculated by

$$\mathrm{ATS} = FFS - 0.0125 v_P - f_{\mathrm{np}} \tag{6.5}$$

where

ATS = estimated average travel speed in km/h, for both directions of travel combined,

FFS = free-flow speed in km/h, as measured in the field and possibly adjusted by Eq. 6.1,

v_p = analysis flow rate in pc/h, as calculated from Eq. 6.3, and

f_{np} = adjustment factor for the percentage of no-passing zones, which is determined from Table 6.3 given below

LOS for Two-Lane Highways

Table 6.3 Adjustment for Effect of No-Passing Zones on Average Travel Speed

Two-way flow rate, v_p (pc/h)	Reduction in average travel speed (km/h)					
	No-passing zones (%)					
	0	20	40	60	80	100
0	0.0	0.0	0.0	0.0	0.0	0.0
200	0.0	1.0	2.3	3.8	4.2	5.6
400	0.0	2.7	4.3	5.7	6.3	7.3
600	0.0	2.5	3.8	4.9	5.5	6.2
800	0.0	2.2	3.1	3.9	4.3	4.9
1000	0.0	1.8	2.5	3.2	3.6	4.2
1200	0.0	1.3	2.0	2.6	3.0	3.4
1400	0.0	0.9	1.4	1.9	2.3	2.7
1600	0.0	0.9	1.3	1.7	2.1	2.4
1800	0.0	0.8	1.1	1.6	1.8	2.1
2000	0.0	0.8	1.0	1.4	1.6	1.8
2200	0.0	0.8	1.0	1.4	1.5	1.7
2400	0.0	0.8	1.0	1.3	1.5	1.7
2600	0.0	0.8	1.0	1.3	1.4	1.6
2800	0.0	0.8	1.0	1.2	1.3	1.4
3000	0.0	0.8	0.9	1.1	1.1	1.3
3200	0.0	0.8	0.9	1.0	1.0	1.1

LOS for Two-Lane Highways

Percent Time Spent Following

The average travel speed depends on the free-flow speed, the analysis flow rate, and an adjustment factor for the percentage of no-passing zones, and is calculated by

$$\mathrm{PTSF} = BPTSF + f_{\mathrm{dlnp}} \tag{6.6}$$

$$\mathrm{BPTSF} = 100(1 - e^{-0.000879 v_p}) \tag{6.7}$$

where

PTSF = percent time spent following

BPTSF = base percent time spent following

v_p = analysis flow rate in pc/h, as calculated from Eq. 6.3, and

f_{dlnp} = adjustment factor for the combined effect of directional traffic and the percentage of no-passing zones, which is determined from Table 6.4 given below

Table 6.4 Adjustment for Combined Effect of Directional Distribution of Traffic and Percentage of No-Passing Zones on Percent Time Spent Following

Two-way flow rate, v_p (pc/h)	No-passing zones (%)					
	0	20	40	60	80	100
			Directional split = 50/50			
≤ 200	0.0	10.1	17.2	20.2	21.0	21.8
400	0.0	12.4	19.0	22.7	23.8	24.8
600	0.0	11.2	16.0	18.7	19.7	20.5
800	0.0	9.0	12.3	14.1	14.5	15.4
1400	0.0	3.6	5.5	6.7	7.3	7.9
2000	0.0	1.8	2.9	3.7	4.1	4.4
2600	0.0	1.1	1.6	2.0	2.3	2.4
3200	0.0	0.7	0.9	1.1	1.2	1.4
			Directional split = 60/40			
≤ 200	1.6	11.8	17.2	22.5	23.1	23.7
400	0.5	11.7	16.2	20.7	21.5	22.2
600	0.0	11.5	15.2	18.9	19.8	20.7
800	0.0	7.6	10.3	13.0	13.7	14.4
1400	0.0	3.7	5.4	7.1	7.6	8.1
2000	0.0	2.3	3.4	3.6	4.0	4.3
≥ 2600	0.0	0.9	1.4	1.9	2.1	2.2

			Directional split = 70/30			
≤ 200	2.8	13.4	19.1	24.8	25.2	25.5
400	1.1	12.5	17.3	22.0	22.6	23.2
600	0.0	11.6	15.4	19.1	20.0	20.9
800	0.0	7.7	10.5	13.3	14.0	14.6
1400	0.0	3.8	5.6	7.4	7.9	8.3
≥ 2000	0.0	1.4	4.9	3.5	3.9	4.2
			Directional split = 80/20			
≤ 200	5.1	17.5	24.3	31.0	31.3	31.6
400	2.5	15.8	21.5	27.1	27.6	28.0
600	0.0	14.0	18.6	23.2	23.9	24.5
800	0.0	9.3	12.7	16.0	16.5	17.0
1400	0.0	4.6	6.7	8.7	9.1	9.5
≥ 2000	0.0	2.4	3.4	4.5	4.7	4.9
			Directional split = 90/10			
≤ 200	5.6	21.6	29.4	37.2	37.4	37.6
400	2.4	19.0	25.6	32.2	32.5	32.8
600	0.0	16.3	21.8	27.2	27.6	28.0
800	0.0	10.9	14.8	18.6	19.0	19.4
≥ 1400	0.0	5.5	7.8	10.0	10.4	10.7

LOS for Two-Lane Highways

Determine Level of Service

- First compare the analysis flow rate v_p to the base case two-way capacity of 3200 pc/hr; **if v_p exceeds 3200 pc → LOS is F**
- Additionaly, the directional flow rates must be checked against the directional capacity of 1700 pc/h; **if either exceeds 1700, LOS is F and the analysis is finished !**

- If capacity is not exceeded, the calculated ATS and PTSF are used with Table 6.5 (for Class I) and 6.6 (for Class II).
  - For Class I, both limits must be satisfied for a given LOS

Table 6.5 LOS Criteria for Class I Two-Lane Highways

LOS	Percent time spent following (*PTSF*)	Average travel speed (*ATS*) mi/h	km/h
A	≤ 35	> 55	> 90
B	≤ 50	> 50	> 80
C	≤ 65	> 45	> 70
D	≤ 80	> 40	> 60
E	> 80	≤ 40	≤ 60

Note: LOS F applies whenever the flow rate exceeds the segment capacity.

LOS	Percent time spent following (*PTSF*)
A	≤ 40
B	≤ 55
C	≤ 70
D	≤ 85
E	> 85

Note: LOS F applies whenever the flow rate exceeds the segment capacity.

LOS for Two-Lane Highways

Example 6.1 (from Mannering et al., p. 214)

One segment of a Class I two-lane highway is on rolling terrain and has an hourly volume of 500 veh/h with $PHF =$ 0.94, and the traffic stream contains 5% large trucks, 2% buses, and 6% recreational vehicles. For these conditions, determine the analysis flow rate for *A TS* and *PTSF.*

Solution:

The first step is to calculate the flow rate, in veh/h, that will be used to determine the grade adjustment and PCE values. This is done by dividing the hourly volume by the

$$\frac{V}{\mathrm{PHF}} = \frac{500}{0.94} = 532$$

The values for ATS will be selected first

For rolling terrain,

f_G = 0.71 (Table 6.1) ; E_T =2.5 (Table 6.2) ; E_R =1.1 (Table 6.2)

Substituting the PCE values into Eq. 6.2 gives

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

$$f_{HV} = \frac{1}{1 + 0.07(2.5 - 1) + 0.06(1.1 - 1)} = 0.90$$

Substituting f_G and f_{HV} into Eq.6.3 → $v_p = \frac{500}{(0.94)(0.71)(0.90)}$=832 pc/h

→ this flow rate is higher than the first flow rate (832 > 600) for which the correction factors were chosen; calculations must be repeated using the second flow rate category (600-1200) for Tables 6.1 and 6.2

For rolling terrain,

f_G = 0.93 (Table 6.1) ; E_T =1.9 (Table 6.2) ; E_R =1.1 (Table 6.2)

$$f_{HV} = \frac{1}{1 + 0.07(1.9 - 1) + 0.06(1.1 - 1)} = 0.935$$

Substituting f_G and f_{HV} → $v_p = \frac{500}{(0.94)(0.93)(0.935)}$=612 pc/h

Since this flow rate is in the range for which the values from Tables 6.1 and 6.2 were selected (600 < 612 < 1200), this will be the analysis flow rate.

Repeating this process for PTSF, results in the following final values:

f_G = 0.94 (Table 6.1) ; E_T =1.5 (Table 6.2) ; E_R =1 (Table 6.2) → f_{HV} = 0. 966

v_P= 586 pc/h

Example 6.2

The two-lane highway segment in Example 6.1 has the following additional characteristics: 3.4-m lanes, 0.6-m shoulders, access frequency of 6 per km, 50% no-passing zones, a measured free-flow speed value of 81 km/h, and a directional traffic split of 60/40.

Using the analysis flow rates for ATS and PTSF computed in Example 6.1, determine the level of service for this two-lane highway.

Solution:

1) We begin by checking whether the highway segment is over capacity.
   - The analysis flow rates of 612 and 586 pc/h for ATS and PTSF, respectively, are both well below the two-way capacity of 3200 pc/h.
   - Because both two-way flow rates are also below the directional capacity of 1700 pc/h, it is clear just by inspection that the directional capacity is also not exceeded.

2) <u>Since the facility is not over capacity, we can proceed with the LOS determination.</u>

- As the free-flow speed is measured, no need to estimate it, so

  $FFS = 81\ km/h$ (given)

- The average travel speed will be calculated first, using Eq.6.5:

$$\text{ATS} = FFS - 0.0125v_P - f_{\text{np}}$$

where , *FFS*=81 km/h; v_p= 612 pc/h (computed in Example 6.1) ; f_{np} = = 4.3 km/h (from Table 6.3, by linear interpolation for v_p and 50% no- passing zones)

so, **ATS** = 81-0.0125(612)-4.3 = **69.05 km/h**

Two-way flow rate, v_p (pc/h)	Reduction in average travel speed (mi/h)						Reduction in average travel speed (km/h)					
	No-passing zones (%)						No-passing zones (%)					
	0	20	40	60	80	100	0	20	40	60	80	100
0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
200	0.0	0.6	1.4	2.4	2.6	3.5	0.0	1.0	2.3	3.8	4.2	5.6
400	0.0	1.7	2.7	3.5	3.9	4.5	0.0	2.7	4.3	5.7	6.3	7.3
600	0.0	1.6	2.4	3.0	3.4	3.9	0.0	2.5	3.8	4.9	5.5	6.2
800	0.0	1.4	1.9	2.4	2.7	3.0	0.0	2.2	3.1	3.9	4.3	4.9

- The percent time spent following is calculated using Eqs.6.6 and 6.7, and v_p= 586 pc/h (computed in Example 6.1)

$$\mathrm{PTSF} = BPTSF + f_{\mathrm{d/np}}$$
$$\mathrm{BPTSF} = 100(1 - e^{-0.000879 v_p})$$

and $f_{\mathrm{d/np}}$ = 17.0 % from Table 6.4, again by linear interpolation of flow rate and 50% no-passing zones.

Two-way flow rate, v_p (pc/h)	No-passing zones (%)					
	0	20	40	60	80	100
	Directional split = 60/40					
≤ 200	1.6	11.8	17.2	22.5	23.1	23.7
400	0.5	11.7	16.2	20.7	21.5	22.2
600	0.0	11.5	15.2	18.9	19.8	20.7
800	0.0	7.6	10.3	13.0	13.7	14.4
1400	0.0	3.7	5.4	7.1	7.6	8.1
2000	0.0	2.3	3.4	3.6	4.0	4.3
≥ 2600	0.0	0.9	1.4	1.9	2.1	2.2

$$\text{BPTSF} = 100(1 - e^{-0.000879*586}) = 40.3\ \%$$

$$\textbf{PTSF} = \text{BPTSF} + f_{\text{d/np}} = 40.3\ \% + 17.0\% = \mathbf{57.3\%}$$

- We now determine the LOS for the calculated **ATS = 69.05 km/h** and **PTSF=57.3%** values using Table 6.5. Because it is a Class I highway → **LOS D**
  - Although PTSF falls within the LOS C category, ATS falls within the LOS D category; thus, ATS governs the level of service for this two-lane highway under these roadway and traffic conditions.

LOS	Percent time spent following (*PTSF*)	Average travel speed (*ATS*) mi/h	km/h
A	≤ 35	> 55	> 90
B	≤ 50	> 50	> 80
C	≤ 65	> 45	> 70
D	≤ 80	> 40	> 60
E	> 80	≤ 40	≤ 60

Note: LOS F applies whenever the flow rate exceeds the segment capacity.

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