Chapter 9
Capacity and Level of Service for Highway Segments

Dr. Yahya Sarraj
Faculty of Engineering
The Islamic University of Gaza

Traffic flows reasonably well when the flow rate is less than at capacity, but ... excessive delay and congestion can occur when the flow rate is at or near capacity.
Capacity and Level of Service

- Capacity analysis involves the quantitative evaluation of the capability of a road section to carry traffic, and
- it uses a set of procedures to determine the maximum flow of traffic that a given section of highway will carry under prevailing roadway traffic and control conditions.

Capacity and Level of Service

- The measure of quality of flow is the “level of service” (LOS), a qualitative measure, ranging from A to F,
- This chapter presents procedures for determining the level of service on:
  - two-lane and
  - multilane highways and
  - freeways.
Figure 9.1 Typical Two-Lane, Two-Way Highway in a Rural Environment

Two-Lane, Two-Way Highway in a Rural Environment

9.1 TWO-LANE HIGHWAYS

- The procedures developed for two-lane highway segments provide the basis to evaluate level of service and capacity.
- Two levels of analysis:
  1. Operational;
  2. Planning applications.
Planning applications

- Use estimates and default values in calculations.
- Two classes of two-lane highways are analyzed.
  - **Class I.** Primary arterials, daily commuter routes, and links to other arterial highways. Travel will be at relatively high speeds.
  - **Class II.** Travel speeds will be lower than for Class I roads.

Operational applications

- At an *operational level* of analysis, level of service is determined based on:
  - existing traffic conditions or
  - future traffic conditions and
  - specific roadway characteristics.
The Highway Capacity Manual (HCM) procedure is designed to analyze two-lane highway segments for:

1. two-way traffic,
2. for a specific direction, or
3. for a directional segment with a passing lane.

There are two measures used to describe the service quality of a two-lane highway.

These are:

1. (PTSF) percent time following another vehicle, &
2. (ATS) average travel speed.
1. Percent time-spent-following another vehicle (PTSF) is the average percentage of time that vehicles are traveling behind slower vehicles.
- When “headway” is < 3 seconds, the trailing vehicle is considered to be following the lead vehicle.
- PTSF is a measure of the quality of service provided by the highway.

2. Average travel speed (ATS) is the space mean speed of vehicles in the traffic stream.
- ATS is a measure of the degree of providing efficient mobility.
Figure 9.2 Speed-Flow and Percent Time-Spent-Following Flow Relationships for Two-Way Segments with Base Conditions
Figure 9.3 Speed-Flow and Percent Time-Spent-Following Flow Relationships for Directional Segments with Base Conditions
The relationships shown in these figures are for:

- base conditions defined as:
- the absence of restrictive geometric, traffic, or environmental factors.

Capacity and Level of Service

Base conditions exist for the following characteristics:
- Level terrain
- Lane widths 3.6m or greater
- Clear shoulders 1.8m wide or greater
- Passing permitted with absence of no-passing zones
- No impediments to through traffic due to traffic control or turning vehicles
- Passenger cars only in the traffic stream
- Equal volume in both directions (for analysis of two-way flow)
Capacity and Level of Service

- Capacity of a two-lane highway is 1700 passenger cars per hour (pc/h) for each direction of travel and is nearly independent of the directional distribution of traffic.
- For extended segments, the capacity of a two-lane highway will not exceed a combined total of 3200 pc/h.
- Short sections of two-lane highway, such as a tunnel or bridge, may reach a capacity of 3200 to 3400 pc/h.

Capacity and Level of Service

- Level of Service (LOS) expresses the performance of a highway at traffic volumes less than capacity.
- LOS for Class I highways is based on two measures: PTSF and ATS.
- LOS for Class II highways is based on a single measure: PTSF.
Level-of-service criteria are applied to travel during the peak 15 minutes of travel and on highway segments of significant length.

Level-of-service designations are from A (highest) to F (lowest).

**Level of Service A:**
- This is the highest quality of service.
- desired speed.
- passing other vehicles.
- few (if any) platoons of three or more cars.
Capacity and Level of Service

Class I:
- highway average travel speed (ATS) is 88km/h (55 mi/h) or greater, and
- travel delays (PTSF) occur no more than 35% of the time.

Class II:
- highway maximum delay (PTSF) is 40% of the time.
- Maximum service flow rate (two-way) under base conditions is 490 pc/h.
Capacity and Level of Service

- **Level of Service A:**

Capacity and Level of Service

- **Level of Service B:**
Capacity and Level of Service

Level of Service C:

Level of Service D:
Capacity and Level of Service

**Level of Service E:**

- Traffic is congested with demand exceeding capacity.
- Volumes are lower than capacity and speeds are variable.

Capacity and Level of Service

**Level of Service F:**

- Traffic is congested with demand exceeding capacity.
- Volumes are lower than capacity and speeds are variable.
Level of Service F:

Table 9.1 (Appendix) summarizes the ranges in values of PTSF and ATS for each level of service category for Class I two-lane roads.

For Class I highways, two criteria apply:

1. percent time-spent-following (PTSF), and
2. average travel speed (ATS).
Table 9.1 Level-of-Service Criteria for Two-Lane Highways in Class I

<table>
<thead>
<tr>
<th>LOS</th>
<th>Percent Time-Spent-Following</th>
<th>Average Travel Speed (mph)</th>
<th>Km/h</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>$\leq 35$</td>
<td>$&gt; 55$</td>
<td>$&gt; 88$</td>
</tr>
<tr>
<td>B</td>
<td>$&gt; 35 – 50$</td>
<td>$&gt; 50 – 55$</td>
<td>$&gt; 80 – 88$</td>
</tr>
<tr>
<td>C</td>
<td>$&gt; 50 – 65$</td>
<td>$&gt; 45 – 50$</td>
<td>$&gt; 72 – 80$</td>
</tr>
<tr>
<td>D</td>
<td>$&gt; 65 – 80$</td>
<td>$&gt; 40 – 45$</td>
<td>$&gt; 64 – 72$</td>
</tr>
<tr>
<td>E</td>
<td>$&gt; 80$</td>
<td>$\leq 40$</td>
<td>$\leq 64$</td>
</tr>
</tbody>
</table>

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

Capacity and Level of Service

- **Table 9.2** summarizes the ranges in values of PTSF for each level of service category for Class II two-lane roads.
- For **Class II highways**, a single criterion is used: percent time-spent-following (PTSF).
Table 9.2  Level-of-Service Criteria for Two-Lane Highways in Class II

<table>
<thead>
<tr>
<th>LOS</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>≤ 40</td>
</tr>
<tr>
<td>B</td>
<td>40 &lt; PTSF ≤ 55</td>
</tr>
<tr>
<td>C</td>
<td>55 &lt; PTSF ≤ 70</td>
</tr>
<tr>
<td>D</td>
<td>70 &lt; PTSF ≤ 85</td>
</tr>
<tr>
<td>E</td>
<td>&gt; 85</td>
</tr>
</tbody>
</table>

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

Capacity and Level of Service

Example 9.1  Determining the Level of Service of Two-Lane Roads if PTSF and ATS are Known

The following values of PTSF and ATS have been determined based on the analysis of four roadway segments. (Methods for performing the analysis are described later in this chapter.) Determine the LOS if the roadway segments are: (a) Class I and (b) Class II.

<table>
<thead>
<tr>
<th>Segment</th>
<th>PTSF (%)</th>
<th>ATS (km/h)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>36</td>
<td>87</td>
</tr>
<tr>
<td>2</td>
<td>54</td>
<td>96</td>
</tr>
<tr>
<td>3</td>
<td>72</td>
<td>68</td>
</tr>
<tr>
<td>4</td>
<td>90</td>
<td>48</td>
</tr>
</tbody>
</table>
Capacity and Level of Service

Solution:

(a) Use the values in Table 9.1 (Appendix) to determine Class I LOS. The results are:
   - Segment 1: LOS B
   - Segment 2: LOS C
   - Segment 3: LOS D
   - Segment 4: LOS E
   *Note:* If values of PTSF and ATS do not correspond to the same LOS, the lower LOS value is used.

(b) Use the values in Table 9.2 to determine Class II LOS. The results are:
   - Segment 1: LOS A
   - Segment 2: LOS B
   - Segment 3: LOS D
   - Segment 4: LOS E
   *Note:* LOS values for Class II highways are often higher than for Class I highways because average travel speed (ATS) is not considered.

9.1.1 Procedures for Determining Level of Service

- Two-way segments located in level or rolling terrain. Grades are 1 to 2 percent,
- and heavy vehicles maintain the same speed as passenger cars.
Analysis of two-lane roads for two-way segments is usually performed on:

- extended lengths at least 2.0 mi (3.2 km) and
- the segment is located in level or rolling terrain.

1. **Level terrain** flat grades of 2 % or less. Heavy vehicles maintain the same speed as passenger cars.

2. **Rolling terrain** short or medium length grades of 4 % or less. Heavy truck speeds are lower than passenger cars but are not at crawl speed.

If the grade > 4 %, must be analyzed using the specific grade procedure for directional segments.

Calculating the value of PTSF of a two-lane two way segment

\[
PTSF = BPTSF + f_{d/np}
\]  
(9.1)

where

\[
BPTSF = \text{the base percent time spent following for both directions and is computed using Eq. 9.2}
\]

\[
BPTSF = 100\left(1 - e^{-0.000879v_p}\right)
\]  
(9.2)

\[
f_{d/np} = \text{adjustment in PTSF to account for the combined effect of (1) percent of directional distribution of traffic and (2) percent of no-passing zones. (Table 9.3)}
\]

\[
v_p = \frac{V}{(PHF)(f_G)(f_{HV})}
\]  
(9.3)

\[
V
\]
\[ V = \text{demand volume for the entire peak hour, veh/h} \]

\[ PHF = \text{peak hour factor, } V/(4) \text{ (peak 15-min volume)} \]

\[ f_G = \text{grade adjustment factor for level or rolling terrain (Table 9.4)} \]

\[ f_{IV} = \text{adjustment factor to account for heavy vehicles in the traffic stream and is computed using Eq. 9.4} \]

\[ f_{IV} = \frac{1}{1 + P_T(E_T - 1) + P_R(E_R - 1)} \quad (9.4) \]

\[ P_T \text{ and } P_R = \text{the decimal portion of trucks (and buses) and RVs in the traffic stream. For example, if there are 22 percent trucks in the traffic stream, then } P_T = 0.22 \]

\[ E_T \text{ and } E_R = \text{the passenger-car equivalent for trucks and RVs respectively. Values are provided in Table 9.5.} \]

Since the values of \( E_T \) and \( E_R \) are functions of two-way flow rates in pc/h, an iterative process is required in which a trial value of \( v_T \) is based on the PHF only. Then a new value of \( v_T \) is computed using appropriate values of \( E_T \) and \( E_R \). If the second value of \( v_T \) is within the range used to determine truck and \( E_T \) equivalents, the computed value is correct. If not, a second iteration is required using the next higher range of flow rate.

---

**Example 9.2** Computing the Value of Percent Time-Spent-Following (PTSF) for a Two-Way, Two-Lane Highway

Determine the value of PTSF for a 9.6 km two-lane highway in rolling terrain. Traffic data are as follows. (Similar problems are solved using a tabular format in HCM 2000.)

- Volume = 1600 veh/h (two-way)
- Percent trucks = 14
- Percent RVs = 4
- Peak hour factor = 0.95
- Percent directional split = 50 - 50
- Percent no-passing zones = 50
Solution:

**Step 1.** Compute peak 15-min hourly passenger car equivalent $v_p$.

Trail value for $v_p$ is $V/PHF = 1600/0.95 = 1684$ pc/h

Determine $f_G = 1.00$ (Table 9.4)

Determine $E_T = 1.00$ and $E_R = 1.00$ (Table 9.5)

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

$$f_{HV} = \frac{1}{1 + (0.14)(1.0 - 1.0) + (0.04)(1.0 - 1.0)} = 1.00$$

$$v_p = \frac{v}{(PHF)(f_G)(f_{HV})} = \frac{1600}{(0.95)(1.00)(1.00)} = 1684 \text{ pc/h}$$

**Note:** Since $1684 < 3200$, this section is operating below capacity.

**Step 2.** Compute base percent time-spent-following (BPTSF)

$$BPTSF = 100[1 - e^{-0.000879v_p}] = 100[1 - e^{-0.000879(1684)}] = 77.2\%$$

**Step 3.** Compute percent time-spent-following (PTSF)

$$PTSF = BPTSF + f_{d\text{/np}}$$

$f_{d\text{/np}} = 4.8$ (by interpolation from Table 9.3)

$$PTSF = 77.2 + 4.8 = 82.0\%$$
<table>
<thead>
<tr>
<th>Vp (pc/h)</th>
<th>40</th>
<th>50</th>
<th>60</th>
</tr>
</thead>
<tbody>
<tr>
<td>1400</td>
<td>5.5</td>
<td>6.1</td>
<td>6.7</td>
</tr>
<tr>
<td>1684</td>
<td>4.27</td>
<td>4.77</td>
<td>5.28</td>
</tr>
<tr>
<td>2000</td>
<td>2.9</td>
<td>3.3</td>
<td>3.7</td>
</tr>
</tbody>
</table>
Calculating the Value of ATS for Two-Way Segments

The average travel speed (ATS) for a two-way segment is completed using Eq. 9.5

\[ ATS = FFS - 0.0125v_p - f_{np} \]  \hspace{1cm} (9.5)

where

ATS = average travel speed for both directions of travel combined (km/h)

FFS = free-flow speed, the mean speed at low flow when volumes are < 200 pc/h

\( f_{np} \) = adjustment for the percentage of no-passing zones (Table 9.6)

\( v_p \) = passenger-car equivalent flow rate for the peak 15-min period

(Equation 9.3 is used to compute \( v_p \) with values of \( f_c \) from Table 9.7 and \( E_T \) and \( E_H \) from Table 9.8.)

The determination of free-flow speed can be completed in three ways:

- Field measurements at volumes < 200 pc/h, \( S_{FM} \).
- Field measurements at volumes > 200 pc/h, computed using Eq. 9.6.

\[ FFS = S_{FM} + 0.01249 \frac{V_f}{f_{HV}} \]  \hspace{1cm} (9.6)

where

\( S_{FM} \) = mean speed of traffic measured in the field (km/h)

\( V_f \) = observed flow rate, veh/h for the period when speed data were obtained

\( f_{HV} \) = heavy-vehicle adjustment factor (Eq. 9.4)
• Indirect estimation, when field data are unavailable, is computed using Eq. 9.7.

\[ FFS = BFFS - f_{LS} - f_A \]  

(9.7)

where

\( FFS \) = estimated free-flow speed (km/h)

\( BFFS \) = base free-flow speed (km/h)

\( f_{LS} \) = adjustment for lane and shoulder width (Table 9.9)

\( f_A \) = adjustment for number of access points per mi (Table 9.10)

The base free-flow speed \( (BFFS) \) depends upon local conditions regarding the desired speeds of drivers. The transportation engineer estimates \( BFFS \) based on knowledge of the area and the speeds on similar facilities. The range of \( BFFS \) is 45 to 65 mi/h (72 to 104 km/h). Posted speed limits or design speeds may serve as surrogates for \( BFFS \).

---

**Example 9.3** Computing the Value of Average Travel Speed for a Two-Directional, Two-Lane Highway

Use the data provided in Example 9.2 to estimate the average travel speed \( (ATS) \). Assume that the base free-flow speed \( (BFFS) \) is the posted speed of (96 km/h). The section length is 9.6 km, lane width is 3.35 m, shoulder width is 1.2 m, and there are 20 access points per km.

**Solution:**

**Step 1.** Compute the free-flow speed under the given conditions using Eq. 9.7.

\[ FFS = BFFS - f_{LS} - f_A \]

\[ f_{LS} = (2.7 \text{ km/h}) \text{ (Table 9.9)} \]

\[ f_A = (8.0 \text{ km/h}) \text{ (Table 9.10)} \]

\[ FFS = 96 - (2.7) - (8.0) = (85.3 \text{ km/h}) \]

**Step 2.** Compute average travel speed using Eq. 9.5.

\[ ATS = FFS - 0.01249 \nu_F - f_{np} \]

\[ FFS = (85.3 \text{ km/h}) \]
### Table 9.9 Adjustment ($f_{ld}$) for Lane Width and Shoulder Width

<table>
<thead>
<tr>
<th>Lane Width (ft)</th>
<th>Shoulder Width (ft)</th>
<th>$\geq 0 &lt; 2$</th>
<th>$\geq 2 &lt; 4$</th>
<th>$\geq 4 &lt; 6$</th>
<th>$\geq 6$</th>
</tr>
</thead>
<tbody>
<tr>
<td>9 &lt; 10</td>
<td></td>
<td>6.4</td>
<td>4.8</td>
<td>3.5</td>
<td>2.2</td>
</tr>
<tr>
<td>$\geq 10 &lt; 11$</td>
<td></td>
<td>5.3</td>
<td>3.7</td>
<td>2.4</td>
<td>1.1</td>
</tr>
<tr>
<td>$\geq 11 &lt; 12$</td>
<td></td>
<td>4.7</td>
<td>3.0</td>
<td>1.7</td>
<td>0.4</td>
</tr>
<tr>
<td>$\geq 12$</td>
<td></td>
<td>4.2</td>
<td>2.6</td>
<td>1.3</td>
<td>0.0</td>
</tr>
</tbody>
</table>

### Table 9.10 Adjustment ($f_{pa}$) for Access-Point Density

<table>
<thead>
<tr>
<th>Access Points per mi</th>
<th>Reduction in FFS (mi/h)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0.0</td>
</tr>
<tr>
<td>10</td>
<td>2.5</td>
</tr>
<tr>
<td>20</td>
<td>5.0</td>
</tr>
<tr>
<td>30</td>
<td>7.5</td>
</tr>
<tr>
<td>40</td>
<td>10.0</td>
</tr>
</tbody>
</table>
Calculate $v_p$ using Eq. 9.3.

$$v_p = \frac{V}{(PHF)(f_c)(f_{hv})} = \frac{1600}{(0.95)(0.99)(0.931)} = 1827 \text{ pc/h}$$

Determine the value of $f_{hv}$ using Eq. 9.4.

$f_c = 0.99$ (Table 9.7, since $v > 1200$, rolling terrain)

$E_T = 1.5$
$E_R = 1.1$ (Table 9.8, since $v > 1200$, rolling terrain)

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

$$f_{hv} = \frac{1}{1 + (0.14)(1.5 - 1.0) + (0.04)(1.1 - 1.0)} = 0.931$$

$f_{np} = 1.28$ (Table 9.6, since $v_p = 1827$ and percent no-passing zones = 50)

$A_TS = (85.3) - (0.01249)(1827) - (1.28) = (85.3 - 22.82 - 1.28) = 61.2 \text{ km/h}$

**Table 9.4** Grade Adjustment Factor ($f_g$) to Determine Percent Time-Spent-Following on Two-Way and Directional Segments

<table>
<thead>
<tr>
<th>Range of Two-Way Flow Rates (pc/h)</th>
<th>Range of Directional Flow Rates (pc/h)</th>
<th>Type of Terrain</th>
</tr>
</thead>
<tbody>
<tr>
<td>0–600</td>
<td>0–300</td>
<td>Level</td>
</tr>
<tr>
<td>&gt; 600–1200</td>
<td>&gt; 300–600</td>
<td>1.00</td>
</tr>
<tr>
<td>&gt; 1200</td>
<td>&gt; 600</td>
<td>1.00</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Level</th>
<th>Rolling</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.00</td>
<td>0.77</td>
</tr>
<tr>
<td>1.00</td>
<td>0.94</td>
</tr>
<tr>
<td>1.00</td>
<td>1.00</td>
</tr>
</tbody>
</table>
### Table 9.5
Passenger-Car Equivalents for Trucks ($E_T$) and RVs ($E_R$) to Determine Percent Time-Spent-Following on Two-Way and Directional Segments

<table>
<thead>
<tr>
<th>Vehicle Type</th>
<th>Range of Two-Way Flow Rates (pc/h)</th>
<th>Range of Directional Flow Rates (pc/h)</th>
<th>Level</th>
<th>Rolling</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trucks, $E_T$</td>
<td>0–600</td>
<td>0–300</td>
<td>1.1</td>
<td>1.8</td>
</tr>
<tr>
<td></td>
<td>&gt; 600–1,200</td>
<td>&gt; 300–600</td>
<td>1.1</td>
<td>1.5</td>
</tr>
<tr>
<td></td>
<td>&gt; 1,200</td>
<td>&gt; 600</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td>RVs, $E_R$</td>
<td>0–600</td>
<td>0–300</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td></td>
<td>&gt; 600–1,200</td>
<td>&gt; 300–600</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td></td>
<td>&gt; 1,200</td>
<td>&gt; 600</td>
<td>1.0</td>
<td>1.0</td>
</tr>
</tbody>
</table>

### Table 9.6
Adjustment ($f_{20}$) for Effect of No-Passing Zones on Average Travel Speed on Two-Way Segments

<table>
<thead>
<tr>
<th>Two-Way Demand Flow Rate, $v_d$ (pc/h)</th>
<th>0</th>
<th>20</th>
<th>40</th>
<th>60</th>
<th>80</th>
<th>100</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>200</td>
<td>0.0</td>
<td>0.6</td>
<td>1.4</td>
<td>2.4</td>
<td>2.6</td>
<td>3.5</td>
</tr>
<tr>
<td>400</td>
<td>0.0</td>
<td>1.7</td>
<td>2.7</td>
<td>3.5</td>
<td>3.9</td>
<td>4.5</td>
</tr>
<tr>
<td>600</td>
<td>0.0</td>
<td>1.6</td>
<td>2.4</td>
<td>3.0</td>
<td>3.4</td>
<td>3.9</td>
</tr>
<tr>
<td>800</td>
<td>0.0</td>
<td>1.4</td>
<td>1.9</td>
<td>2.4</td>
<td>2.7</td>
<td>3.0</td>
</tr>
<tr>
<td>1000</td>
<td>0.0</td>
<td>1.1</td>
<td>1.6</td>
<td>2.0</td>
<td>2.2</td>
<td>2.6</td>
</tr>
<tr>
<td>1200</td>
<td>0.0</td>
<td>0.8</td>
<td>1.2</td>
<td>1.6</td>
<td>1.9</td>
<td>2.1</td>
</tr>
<tr>
<td>1400</td>
<td>0.0</td>
<td>0.6</td>
<td>0.9</td>
<td>1.2</td>
<td>1.4</td>
<td>1.7</td>
</tr>
<tr>
<td>1600</td>
<td>0.0</td>
<td>0.6</td>
<td>0.8</td>
<td>1.1</td>
<td>1.3</td>
<td>1.5</td>
</tr>
<tr>
<td>1800</td>
<td>0.0</td>
<td>0.5</td>
<td>0.7</td>
<td>1.0</td>
<td>1.1</td>
<td>1.3</td>
</tr>
<tr>
<td>2000</td>
<td>0.0</td>
<td>0.5</td>
<td>0.6</td>
<td>0.9</td>
<td>1.0</td>
<td>1.1</td>
</tr>
<tr>
<td>2200</td>
<td>0.0</td>
<td>0.5</td>
<td>0.6</td>
<td>0.9</td>
<td>0.9</td>
<td>1.1</td>
</tr>
<tr>
<td>2400</td>
<td>0.0</td>
<td>0.5</td>
<td>0.6</td>
<td>0.8</td>
<td>0.9</td>
<td>1.1</td>
</tr>
<tr>
<td>2600</td>
<td>0.0</td>
<td>0.5</td>
<td>0.6</td>
<td>0.8</td>
<td>0.9</td>
<td>1.0</td>
</tr>
<tr>
<td>2800</td>
<td>0.0</td>
<td>0.5</td>
<td>0.6</td>
<td>0.7</td>
<td>0.8</td>
<td>0.9</td>
</tr>
<tr>
<td>3000</td>
<td>0.0</td>
<td>0.5</td>
<td>0.6</td>
<td>0.7</td>
<td>0.7</td>
<td>0.8</td>
</tr>
<tr>
<td>3200</td>
<td>0.0</td>
<td>0.5</td>
<td>0.6</td>
<td>0.6</td>
<td>0.6</td>
<td>0.7</td>
</tr>
</tbody>
</table>
### Table 9.7 Grade Adjustment Factor \( (f_g) \) to Determine Average Travel Speeds on Two-Way and Directional Segments

<table>
<thead>
<tr>
<th>Range of Two-Way Flow Rates (pc/h)</th>
<th>Range of Directional Flow Rates (pc/h)</th>
<th>Type of Terrain</th>
</tr>
</thead>
<tbody>
<tr>
<td>0–600</td>
<td>0–300</td>
<td>1.00</td>
</tr>
<tr>
<td>&gt; 600–1200</td>
<td>&gt; 300–600</td>
<td>1.00</td>
</tr>
<tr>
<td>&gt; 1200</td>
<td>&gt; 600</td>
<td>1.00</td>
</tr>
</tbody>
</table>

### Calculating Other Traffic Performance Measures for Two-Way, Two-Lane Highways

Additional measures that can be computed are as follows:

\[
v/c = \text{volume-to-capacity ratio}
\]

\[
VMT_{15} = \text{total number of vehicle-miles traveled during the peak 15-minute period}
\]

\[
VMT_{60} = \text{Total number of vehicle-miles traveled during the peak hour}
\]

\[
TT_{15} = \text{Total travel time, vehicle-hour, during the peak 15-min period}
\]

The formula for each performance measure is

\[
v/c = \frac{v_p}{c}
\]

(9.8)
where

\[ V_{MT_{15}} = 0.25 \left( \frac{V}{PHF} \right) L_i \]  \hspace{1cm} (9.9)

where

- \( V_{MT_{15}} \) = total travel on the analysis segment during the peak 15-minute (veh-km)
- \( L_i \) = total length of the analysis segment (km)
- \( V \) = hourly volume (veh/h)
- \( PHF \) = Peak hour factor = \( V/(4) \) (peak 15-min volume)

\[ V_{MT_{60}} = V(L_i) \]  \hspace{1cm} (9.10)

\[ TT_{15} = \frac{V_{MT_{15}}}{ATS} \]  \hspace{1cm} (9.11)

---

**Example 9.4** Level of Service and Performance Measures for Two-Lane, Two-Directional Highways

Use the data and results in Examples 9.2 and 9.3 to determine the following:

- a. Level of service if the segment is a Class I or a Class II highway
- b. Volume-to-capacity ratio, \( \nu/c \)
- c. Total number of veh-km during the peak 15-min period, \( V_{MT_{15}} \)
- d. Total number of veh-km during the peak hour, \( V_{MT_{60}} \)
- e. Total travel time veh-km during the peak 15-min period, \( TT_{15} \)

Solution:

- a. Level of service if the segment is a Class I or a Class II highway from Example 9.2 and 9.3 is

  \[ PTSF = 82.0\% \]

  \[ ATS = 61.2 \text{ km/h} \]

  Class I LOS = \( E \) (Table 9.1)

  Class II LOS = \( D \) (Table 9.2)
b. For the volume-to-capacity ratio, \( v/c \) use Eq. 9.8.

\[
v/c = \frac{v}{c} = \frac{1827}{3200} = 0.57
\]

c. For the total number of veh-km during the peak 15-min period, \( VMT_{15} \), use Eq. 9.9.

\[
VMT_{15} = 0.25 \left( \frac{V}{PHF} \right) L_t = 0.25 \left( \frac{1600}{0.95} \right)(9.6) = 4042 \text{ veh-km}
\]

d. For the total number of veh-km during the peak hour, \( VMT_{60} \), use Eq. 9.10.

\[
VMT_{60} = V L_t = 1600(9.6) = 15360 \text{ veh-km}
\]

e. For the total travel time during the peak 15 min period, \( TT_{15} \), use Eq. 9.11.

\[
TT_{15} = \frac{VMT_{15}}{ATS} = \frac{4042}{61.2} = 66 \text{ veh-h}
\]