Chapter 9
Capacity and Level of Service for Highway Segments

Definitions and Concepts

Types of Facilities
Facilities may generally be classified into one of two categories:
Uninterrupted Flow Facilities
They have no fixed elements, such as traffic signals and stop signs, that cause interruption to traffic flow. Examples of Uninterrupted flow facilities are freeway two-lane highway and multilane highway.

Interrupted Flow Facilities
They have fixed elements causing periodic interruption to traffic flow. Examples of interrupted flow facilities are signalised intersections, Unsignalized intersections (stop or yield controlled approach), and arterial.
Level of Service

Level of service is a qualitative measure that describes operational conditions within a traffic stream and their perception by drivers or/ and passengers.

These conditions are in terms of such factors as:

- speed and travel time,
- traffic interruption,
- comfort and convenience,
- and safety.

Six LOS’s are defined for each type of facilities. They are given letter A to F, with LOS A representing the best operating conditions and LOS F the worst.
Definitions and Concepts

Level of Service

**Level A:** Represents free flow at low concentration with no restriction due to traffic conditions.

**Level B:** the lower limit of which is often used for the design of rural highways, is the zone of stable flow with more marked restriction.
**Definitions and Concepts**

**Level of Service**

**Level C:** denote the zone of stable flow with more marked restriction on the driver’s selection of speed and with reduced ability to pass.

**Level D:** reflect little freedom for driver maneuverability.
Definitions and Concepts

Level of Service

Level E: Low operating speeds and volumes near or at capacity, which the area is of unstable flow.

Level F: provided by the familiar traffic jam with frequent interruptions and breakdown of flow.
Definitions and Concepts

Capacity

In general, the capacity of a facility is defined as:

the maximum hourly rate at which persons or vehicles can be reasonably expected to traverse a point during a given time period under prevailing roadway,

traffic and

control conditions.
Definitions and Concepts

Capacity

Prevailing road conditions:

Physical features that cause reductions in traffic flow

- Narrow traffic lanes
- Inadequate shoulders
- Side obstructions (poles, bridges, retaining wall)
- Parked cars close to edge of the carriageway
- Imperfect horizontal or vertical curvature
- The layout of intersection on roads
Definitions and Concepts

Capacity (continue)

Prevailing traffic conditions:

They are not fixed but vary from hour to hour throughout the day. Hence the flows at any particular time are a function of:

- The speed of vehicles
- The composition of the traffic streams
- The manner in which they interact with each other
- The physical features of the roadway itself
- Type of driver population
- Directional distribution of traffic
Definitions and Concepts

Capacity (continue)

Prevailing control conditions:

They refer to the types and specific design of control devices and traffic regulations present on a given facility.

- the location, type, and timing of traffic signals;
- stop and yield signs;
- lane use restrictions; and
- turn restrictions.
Basic Principles of traffic flow

Traffic flow measures

The operational state of any given traffic stream is defined by three primarily measures:

- Speed. (Studied in chapter 2).
- Volume and/or rate of flow. (Studied in chapter 2).
- Density. (Studied in chapter 6).
Capacity Analysis And Design for a Freeway Segment

For the analysis of basic freeway segments.
The primary output of the method is LOS.

For the design of basic freeway segments.
The primary output of the method is number of lanes (road width).
Capacity Analysis and Design for a Freeway Segment

Methodology

The methodology described in this section is for the analysis of basic freeway segments.

The following Figure illustrates:

• input to and

• the basic computation order

of the method for basic freeway segments.

The primary output of the method is LOS.
Basic Freeway Segment Methodology

Input
- Geometric data
- Field-measured FFS or base free-flow speed (BFFS)
- Volume

If BFFS is input

BFFS adjustment
- Lane width
- Number of lanes
- Interchange density
- Lateral clearance

Compute FFS

If field-measured FFS is input

Volume adjustment
- Peak-hour factor
- Number of lanes
- Driver population
- Heavy vehicles

Compute flow rate
Continue:

Basic Freeway Segment Methodology

1. Define speed-flow curve
2. Determine speed using speed-flow curve
3. Compute density using flow rate and speed
4. Determine LOS
Continue:

Basic Freeway Segment Methodology

1. Define speed-flow curve
2. Determine speed using speed-flow curve
3. Compute density using flow rate and speed
4. Determine LOS
Definition

• This section treats the capacity analysis of **multilane highway** that cannot be classified as a freeways because they are: undivided, lack control of access, or both.
• Between points of fixed interruption, multilane highways operate under uninterrupted conditions.
Definition

Multilane highways may exhibit some of the following characteristics:

- Posted speed limits are usually between 60 and 100 km/h
- They may be undivided or include medians
- They are located in suburban areas or in high-volume rural corridors
- They may include a two-way, left-turn median lane (TWLTL)
- Traffic volumes range from 15,000 to 40,000/day
- Volumes are up to 100,000/day with grade separations and no cross-median access
- Traffic signals at major crossing points are possible
- There is partial control of access
(a) Divided multilane highway in a rural environment.

(b) Divided multilane highway in a suburban environment.

(c) Undivided multilane highway in a rural environment.

(d) Undivided multilane highway in a suburban environment.

Figure 9.14 Typical Multilane Highways
Highways & Transportation I (ECIV 4333)
BASE CONDITIONS FOR MULTILANE HIGHWAYS

• The procedures in this chapter determine the reduction in travel speed that occurs for less-than-base conditions.

• Under base conditions, the full speed and capacity of a multilane highway are achieved.
• These conditions include good weather, good visibility, and no incidents or accidents.

• Studies of the flow characteristics of multilane highways have defined base conditions for developing flow relationships and adjustments to speed.
BASE CONDITIONS FOR MULTILANE HIGHWAYS

The base conditions for multilane highways are as follows:
• 3.6-m minimum lane widths;
• 3.6-m minimum total lateral clearance in the direction of travel—this represents the total lateral clearances from the edge of the travelled lanes to obstructions along the edge of the road and in the median (in computations, lateral clearances greater than 1.8 m are considered in computations to be equal to 1.8 m);
• Only passenger cars in the traffic stream;
• No direct access points along the roadway;
• A divided highway; and
• Free-flow speed (FFS) higher than 100 km/h.
Capacity Analysis and Design for a Multilane Highway

5.4.3 Methodology

The same methodology used in the freeway section is applied to the multilane highway.

Determining FFS

\[ FFS = BFFS - f_{LW} - f_{LC} - f_M - f_A \]

Determining Flow Rate

\[ v_p = \frac{V}{PHF \times N \times f_{HV} \times f_p} \]
## Adjustment for Lane Width

### Exhibit 21-4. Adjustments for Lane Width

<table>
<thead>
<tr>
<th>Lane Width (m)</th>
<th>Reduction in FFS (km/h)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.6</td>
<td>0.0</td>
</tr>
<tr>
<td>3.5</td>
<td>1.0</td>
</tr>
<tr>
<td>3.4</td>
<td>2.1</td>
</tr>
<tr>
<td>3.3</td>
<td>3.1</td>
</tr>
<tr>
<td>3.2</td>
<td>5.6</td>
</tr>
<tr>
<td>3.1</td>
<td>8.1</td>
</tr>
<tr>
<td>3.0</td>
<td>10.6</td>
</tr>
</tbody>
</table>
DETERMINING LOS

The LOS on a multilane highway can be determined directly from Exhibit 21-3 on the basis of the FFS and the service flow rate \( v_p \) in pc/h/ln. The procedure is as follows:

- Step 1. Define and segment the highway as appropriate.
- Step 2. On the basis of the measured or estimated FFS, construct an appropriate speed-flow curve of the same shape as the typical curves shown in Exhibit 21-3. The curve should intercept the y-axis at the FFS.
- Step 3. Based on the flow rate \( v_p \), read up to the FFS curve identified in Step 2 and determine the average passenger-car speed and LOS corresponding to that point.
• Step 4. Determine the density of flow according to Equation 21-5.

\[ D = \frac{V_p}{S} \]  

(21-5)

where

- \( D \) = density (pc/km/ln),
- \( V_p \) = flow rate (pc/h/ln), and
- \( S \) = average passenger-car travel speed (km/h).

The LOS also can be determined by comparing the computed density with the density ranges provided in Exhibit 21-2.
Exhibit 21-3. Speed-Flow Curves and LOS for Multilane Highway
<table>
<thead>
<tr>
<th>Free-Flow Speed</th>
<th>Criteria</th>
<th>LOS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>A</td>
</tr>
<tr>
<td>100 km/h</td>
<td>Maximum density (pc/km/ln)</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>Average speed (km/h)</td>
<td>100.0</td>
</tr>
<tr>
<td></td>
<td>Maximum volume to capacity ratio (v/c)</td>
<td>0.32</td>
</tr>
<tr>
<td></td>
<td>Maximum service flow rate (pc/h/ln)</td>
<td>700</td>
</tr>
<tr>
<td>90 km/h</td>
<td>Maximum density (pc/km/ln)</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>Average speed (km/h)</td>
<td>90.0</td>
</tr>
<tr>
<td></td>
<td>Maximum v/c</td>
<td>0.30</td>
</tr>
<tr>
<td></td>
<td>Maximum service flow rate (pc/h/ln)</td>
<td>630</td>
</tr>
<tr>
<td>80 km/h</td>
<td>Maximum density (pc/km/ln)</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>Average speed (km/h)</td>
<td>80.0</td>
</tr>
<tr>
<td></td>
<td>Maximum v/c</td>
<td>0.28</td>
</tr>
<tr>
<td></td>
<td>Maximum service flow rate (pc/h/ln)</td>
<td>560</td>
</tr>
<tr>
<td>70 km/h</td>
<td>Maximum density (pc/km/ln)</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>Average speed (km/h)</td>
<td>70.0</td>
</tr>
<tr>
<td></td>
<td>Maximum v/c</td>
<td>0.26</td>
</tr>
<tr>
<td></td>
<td>Maximum service flow rate (pc/h/ln)</td>
<td>490</td>
</tr>
</tbody>
</table>

**Exhibit 21-2. LOS Criteria for multilane Highway**
Free-Flow Speed = 100 km/h

Average Passenger-Car Speed (km/h)

Flow Rate (pc/h/ln)

LOS A
7 pc/km/ln
11 pc/km/ln
16 pc/km/ln
22 pc/km/ln
28 pc/km/ln
Examples

Design of a New Highway

Determine the number of lanes (Road Width)