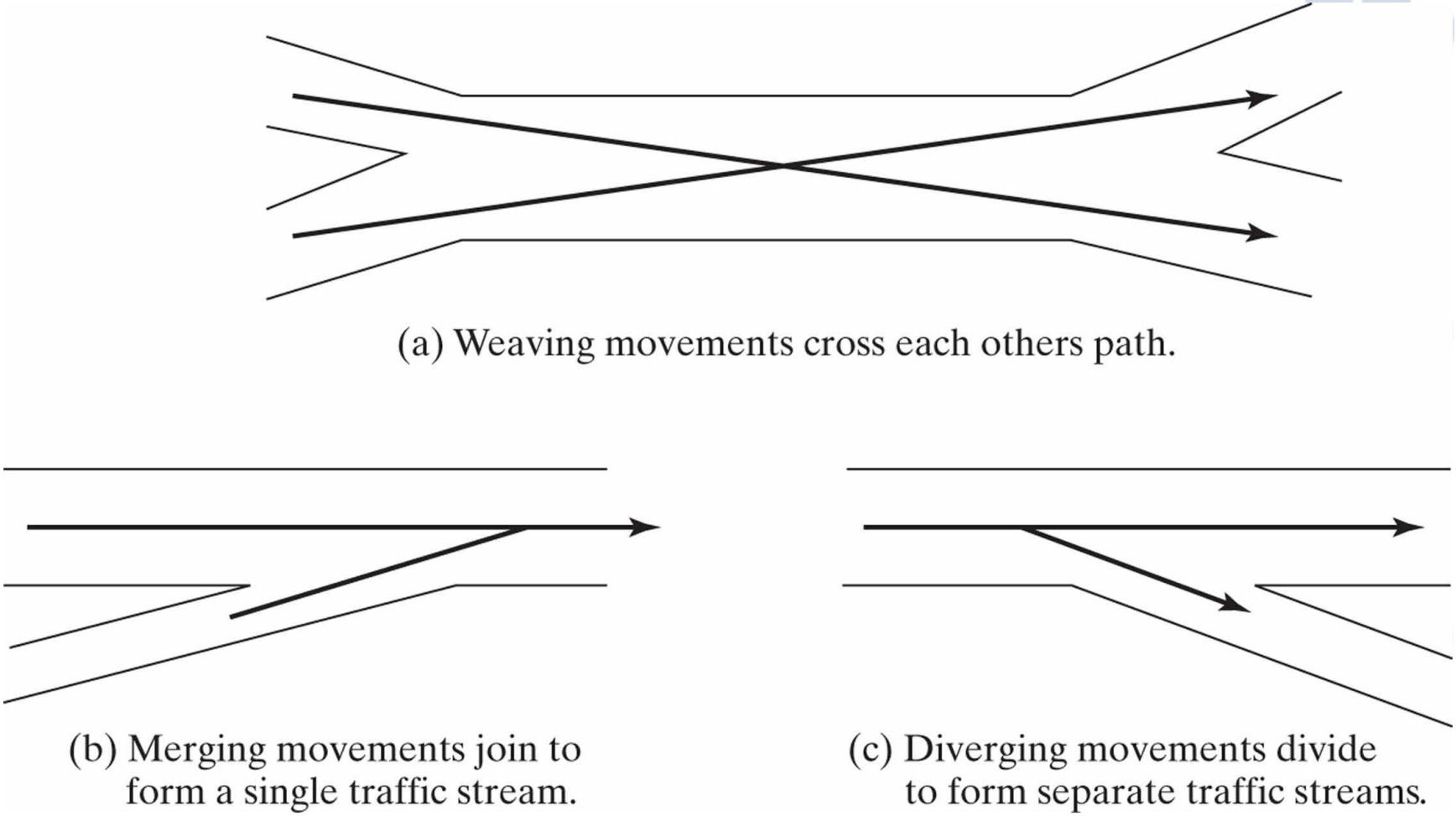
Analysis of Weaving, Merging, and Diverging Movements

CIVL 4162/6162

Weaving, Diverging, Merging Segments

- Weaving – one movement must cross the path of another along a length of facility without the aid of signals or other traffic control devices
- Merging – two separate traffic streams join to form a single one
- Diverging – one traffic stream separates to form two separate traffic streams
- Why do we consider these separately from BFS/Multilane Segments?

Figure 15.1 Weaving, Merging, and Diverging Movements Illustrated



LOS for W/M/D Segments

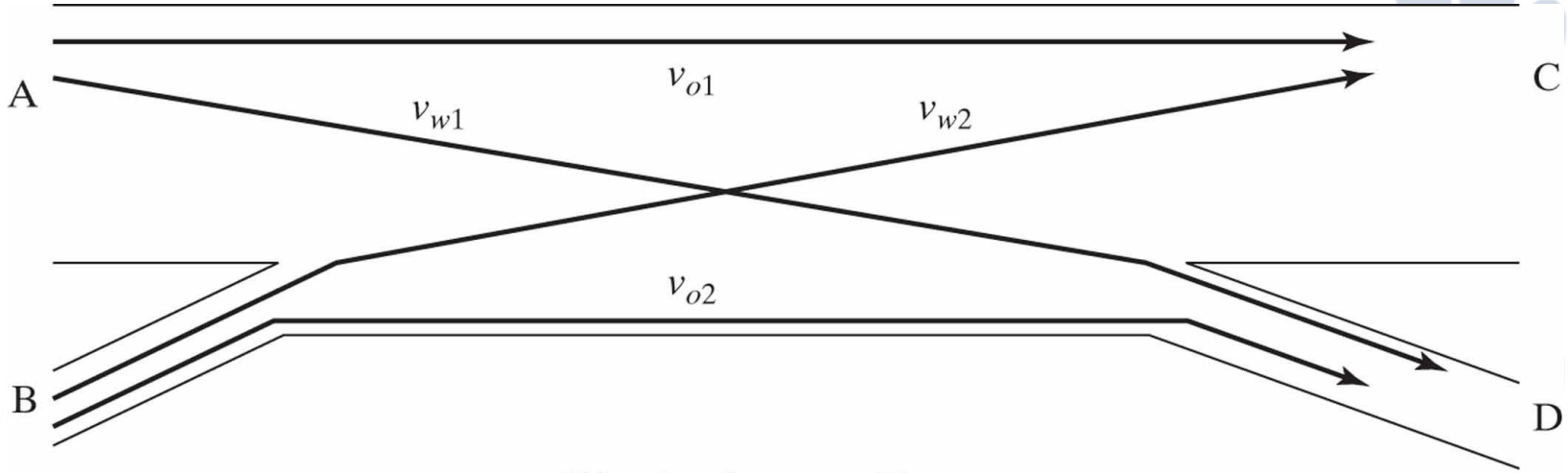
Table 15.1: Level-of-Service Criteria for Weaving, Merging, and Diverging Segments

Level of Service	Weaving Areas		Merge or Diverge Areas
	Density Range (pc/mi/ln)		
	On Freeways	On Multilane Highways or C-D Roadways	On Freeways, Multilane Highways, or C-D Roadways
A	0–10	0–12	0–10
B	>10–20	>12–24	>10–20
C	>20–28	>24–32	>20–28
D	>28–35	>32–36	>28–35
E	>35	>36	>35
F	Demand Exceeds Capacity		

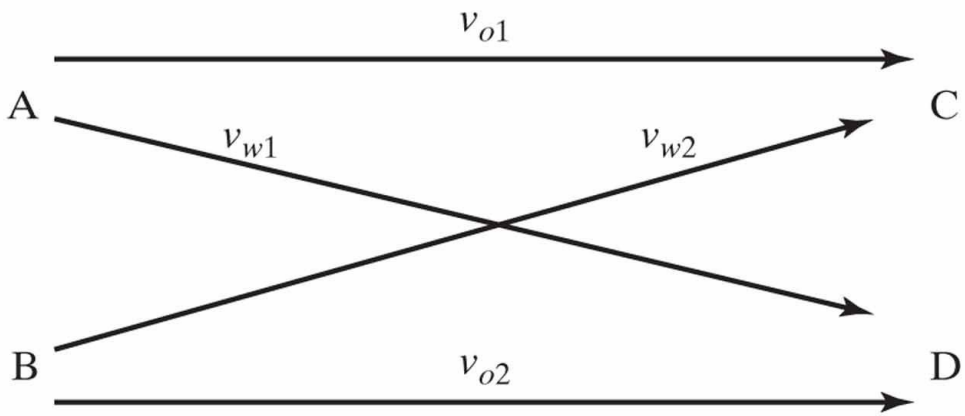
(*Source:* Used with permission of Transportation Research Board, National Research Council, *Highway Capacity Manual*, 2000. Compiled from Exhibit 24-2, p. 24-3, and Exhibit 25-4, p. 25-5.)

Table 15.1 Level-of-Service Criteria for Weaving, Merging, and Diverging Segments

Flows in a Weaving Segment and the Weaving Diagram

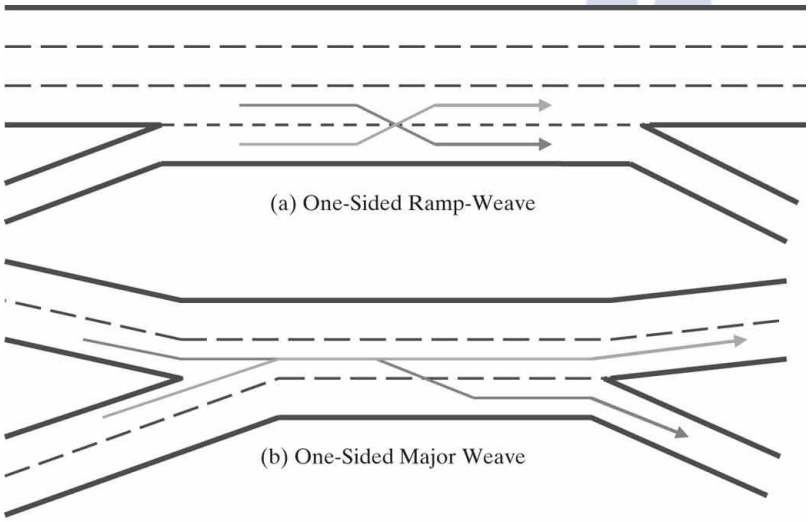


Weaving Segment Flows

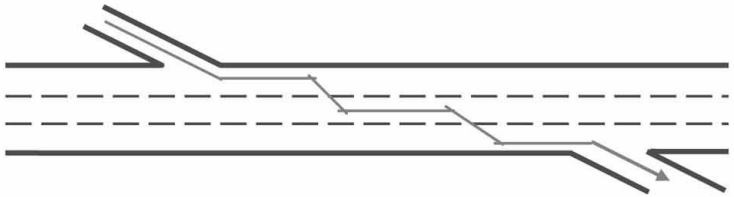


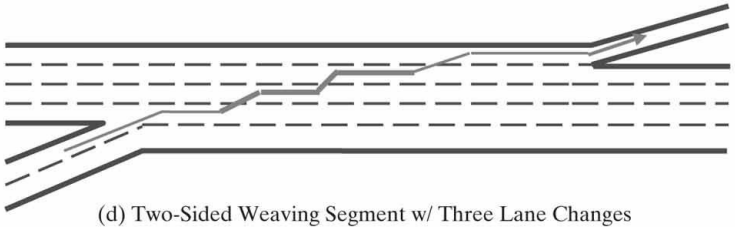
Weaving Diagram

Weaving Configurations


(a) One-Sided Ramp-Weave

(b) One-Sided Major Weave


(c) Two-Sided Weaving Segment w/ Single-Lane Raps


(d) Two-Sided Weaving Segment w/ Three Lane Changes

Weaving Configuration Parameters

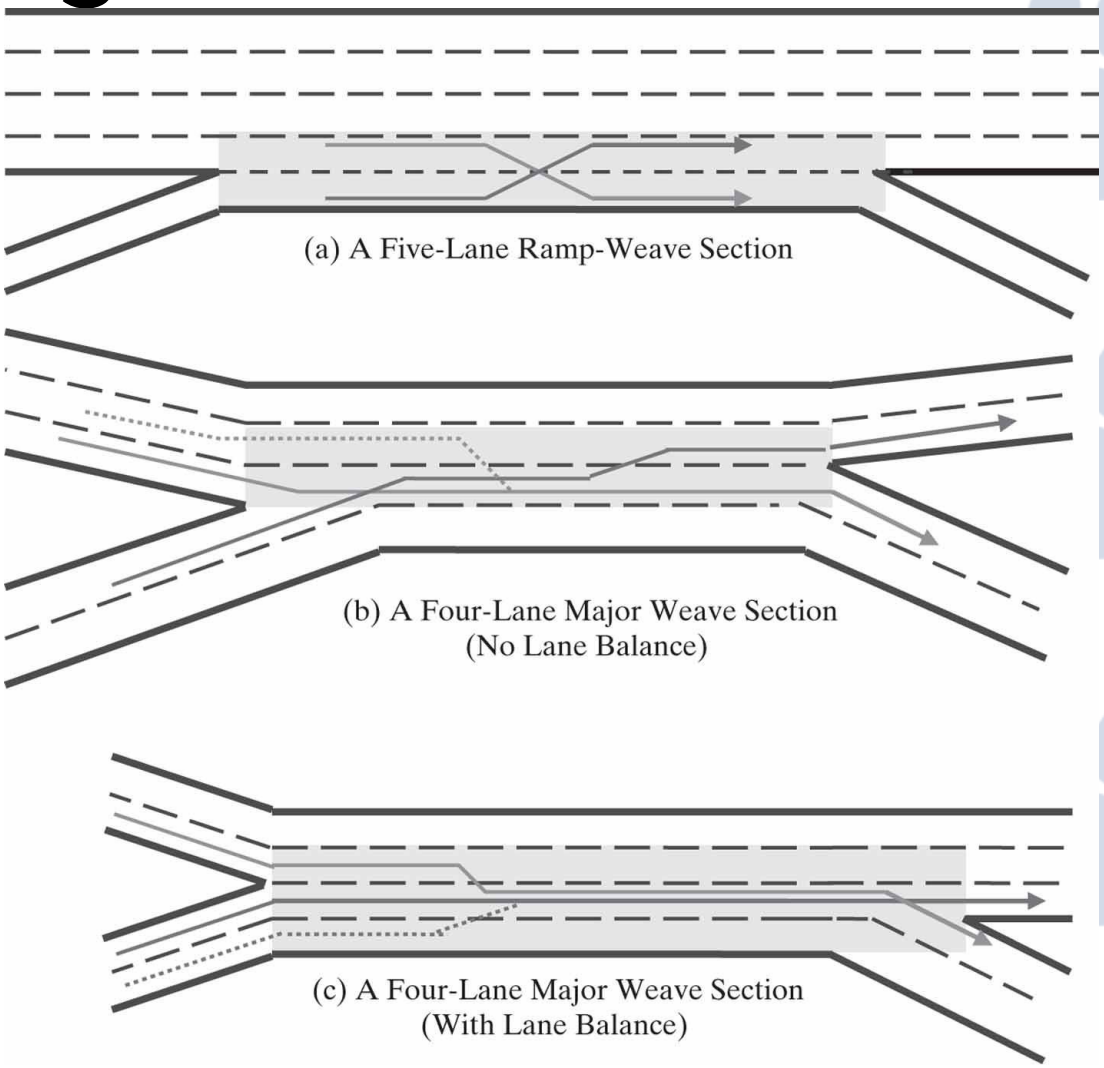
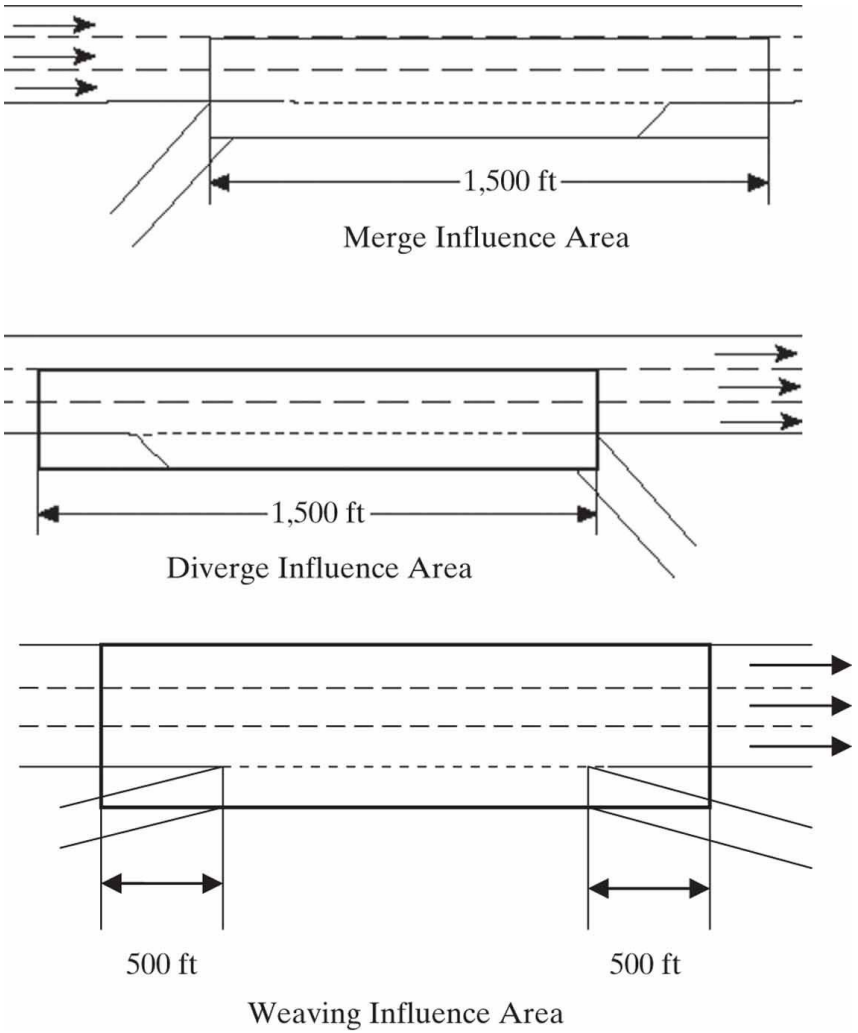


Figure 15.2 Influence Areas for Merge, Diverge, and Weaving Segments *(Source:* Used with permission of Transportation Research Board, National Research Council, modified from *Highway Capacity Manual,* 2000, Exhibit 13-13, p. 13-21*.)*



Weaving Analysis- Input Requirements

- Existing roadway and traffic conditions are required, including:
  - Length and width of weaving area
  - Number of lanes
  - Type of configuration
  - Terrain/grade conditions
  - FFS
  - Hourly volumes

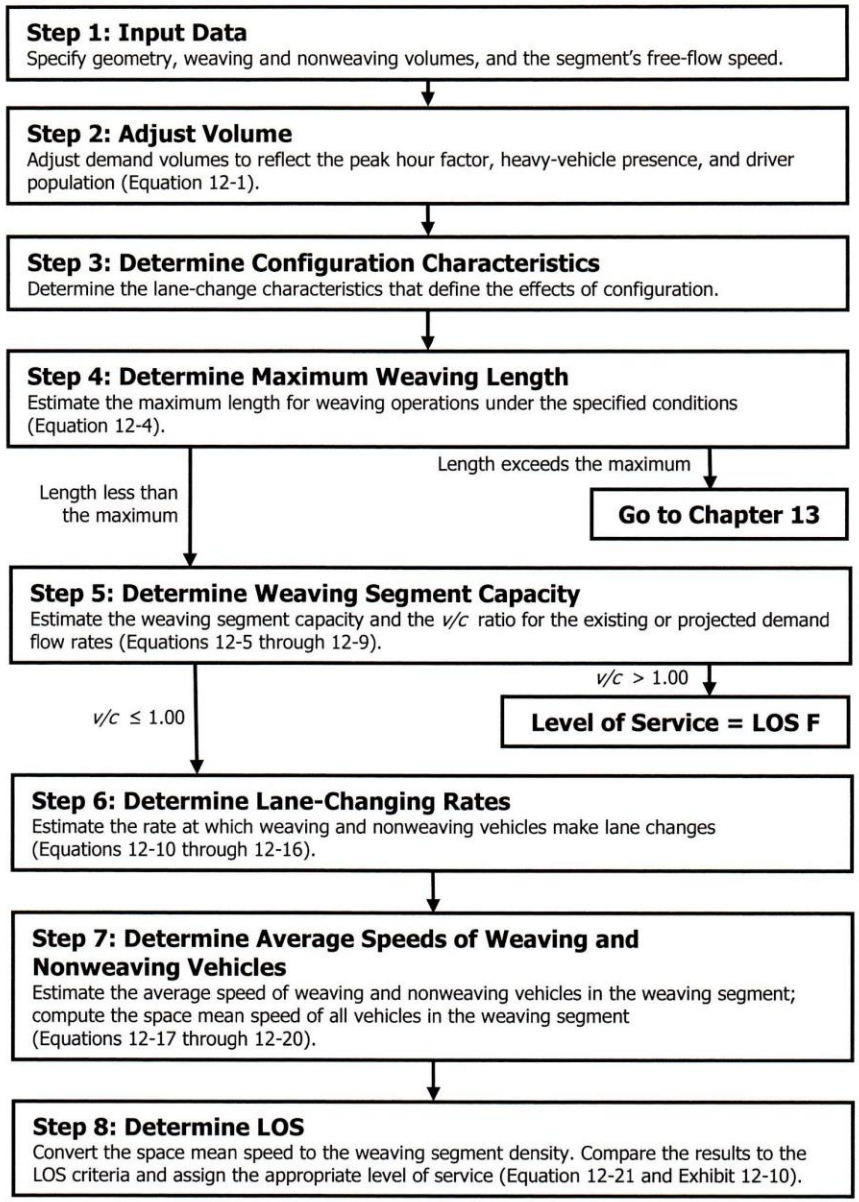

Step 1: Input Data
Specify geometry, weaving and nonweaving volumes, and the segment's free-flow speed.
Step 2: Adjust Volume
Adjust demand volumes to reflect the peak hour factor, heavy-vehicle presence, and driver population (Equation 12-1).
Step 3: Determine Configuration Characteristics
Determine the lane-change characteristics that define the effects of configuration.
Step 4: Determine Maximum Weaving Length
Estimate the maximum length for weaving operations under the specified conditions (Equation 12-4).
Length exceeds the maximum
Go to Chapter 13
Length less than the maximum
Step 5: Determine Weaving Segment Capacity
Estimate the weaving segment capacity and the v/c ratio for the existing or projected demand flow rates (Equations 12-5 through 12-9).
v/c > 1.00
Level of Service = LOS F
v/c ≤ 1.00
Step 6: Determine Lane-Changing Rates
Estimate the rate at which weaving and nonweaving vehicles make lane changes (Equations 12-10 through 12-16).
Step 7: Determine Average Speeds of Weaving and Nonweaving Vehicles
Estimate the average speed of weaving and nonweaving vehicles in the weaving segment; compute the space mean speed of all vehicles in the weaving segment (Equations 12-17 through 12-20).
Step 8: Determine LOS
Convert the space mean speed to the weaving segment density. Compare the results to the LOS criteria and assign the appropriate level of service (Equation 12-21 and Exhibit 12-10).

Figure 15.8 (continued) Weaving Variables Defined for One-Sided Weaving Segments (*Source:* Roess, R., et al., *Analysis of Freeway Weaving Sections,* Final Report, Draft Chapter for the HCM, National Cooperative Highway Research Program Project 3-75, Polytechnic University and Kittelson and Associates, Brooklyn, NY, September 2007, Exhibit 24-7, p. 12.)

Symbol	Definition
v_{FF}	freeway-to-freeway demand flow rate in the weaving section (pc/h)
v_{RF}	ramp-to-freeway demand flow rate in the weaving section (pc/h)
v_{FR}	freeway-to-ramp demand flow rate in the weaving section (pc/h)
v_{RR}	ramp-to-ramp demand flow rate in the weaving section (pc/h)
v_W	weaving demand flow rate in the weaving section (pc/h): $v_W = v_{RF} + v_{FR}$
v_{NW}	non-weaving demand flow rate in the weaving section (pc/h); $v_{NW} = v_{FF} + v_{RR}$
v	total demand flow rate in the weaving section (pc/h), $v = v_W + v_{NW}$
VR	volume ratio: $VR = v_W/v$
N	number of lanes within the weaving section
N_W	number of lanes *from which* a weaving maneuver may be made with one or no lane changes.
S_W	average speed of weaving vehicles within the weaving section (mi/h)
S_{NW}	average speed of non-weaving vehicles within the weaving section (mi/h)
S	average speed of all vehicles within the weaving section (mi/h)
FFS	free-flow speed of the weaving section (mi/h)

Figure 15.8 (continued) Weaving Variables Defined for One-Sided Weaving Segments (*Source:* Roess, R., et al*., Analysis of Freeway Weaving Sections,* Final Report, Draft Chapter for the HCM, National Cooperative Highway Research Program Project 3-75, Polytechnic University and Kittelson and Associates, Brooklyn, NY, September 2007, Exhibit 24-7, p. 12.)

Symbol	Definition
D	average density of all vehicles within the weaving section (pc/mi/ln)
W	weaving intensity factor
L_S	length of the weaving section (ft), based on short length definition.
LC_{RF}	minimum number of lane changes that must be made by a single weaving vehicle moving from the on-ramp to the facility.
LC_{FR}	minimum number of lane changes that must be made by a single weaving vehicle moving from the facility to the ramp.
LC_{MIN}	minimum rate of lane changing that must exist for *all* weaving vehicles to successfully complete their weaving maneuvers (lc/h) $LC_{MIN} = (LC_{RF} \times v_{RF}) + (LC_{FR} \times v_{FR})$
LC_W	total rate of lane changing by weaving vehicles within the weaving section (lc/h)
LC_{NW}	total rate of lane changing by non-weaving vehicles within the weaving section (lc/h)
LC_{ALL}	total lane-changing rate of all vehicles within the weaving section (lc/h) $LC_{ALL} = LC_W + LC_{NW}$

Step-1: Input Data

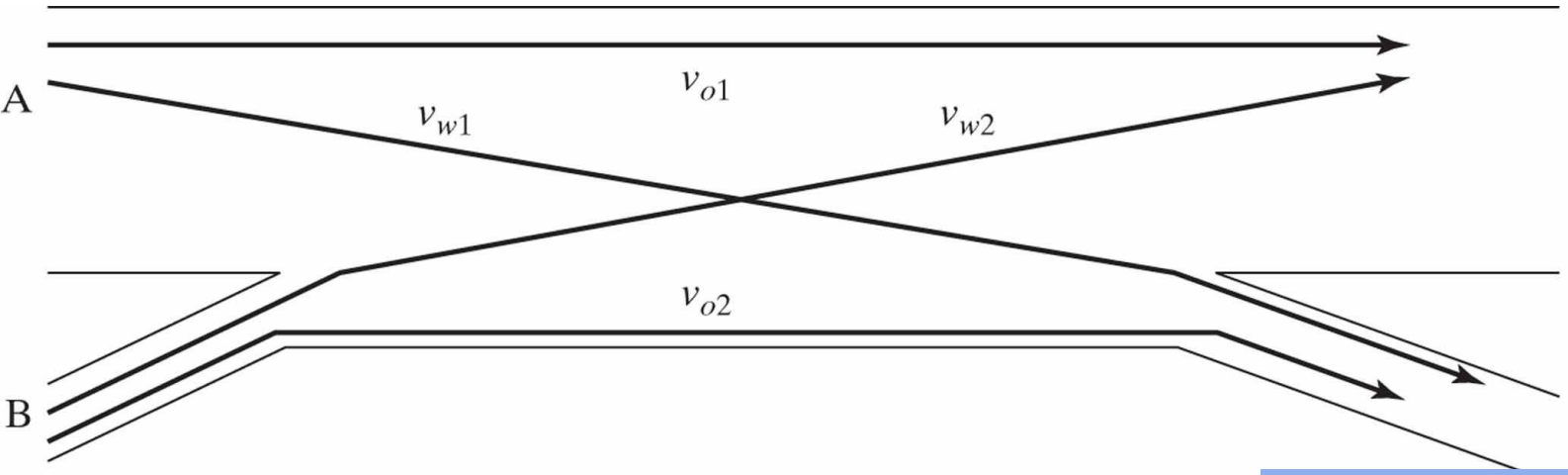
- Ensure to write all the input data in one place before analyzing the weaving section

Step-2: Determining Flow Rate

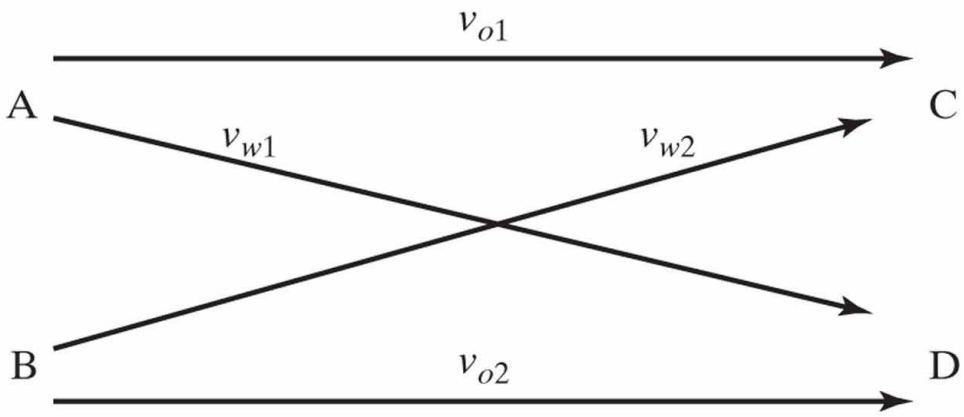
$$v_i = \frac{V_i}{PHF \times N \times f_{HV} \times f_p}$$

v_i: Demand flow rate, pc/h, under equivalent based conditions
Vi: Demand volume, veh/hr under prevailing conditions
PHF: Peak Hour Factor
f_{HV}: Heavy-vehicle adjustment factor
f_p: Driver-population adjustment factor

Figure 15.3 Flows in a Weaving Segment and the Weaving Diagram



Weaving Segment Flows



Weaving Diagram

v_{o1}: larger outer flow
v_{o2}: smaller outer flow
v_{w1}: larger weaving flow
v_{w2}: smaller weaving flow
v_w :Total weaving= v_{w1+} v_{w2}
vn_w:Total non-weaving= v_{o1+} v_{o2}
V: Total Demand = v_w+ v_{nw}
VR:Volume Ratio = v_w/V
R: Weaving Ratio = v_{w2}/ v_w

Step-3: Determine Configuration Characteristics

- **One Sided Weaving**
  - LC_{RF} – minimum # of lane changes that a ramp-to-facility weaving vehicle must make to successfully complete the ramp-to-facility movement.
  - LC_{FR}- minimum # of lane changes that a facility-to-ramp weaving vehicle must make to successfully complete the facility-to-ramp movement.
  - N_{WV}- number of lanes from which a weaving maneuver may be completed with one lane change, or no lane change.

$$LC_{MIN} = \left(LC_{FR} \acute{} \ u_{FR}\right) + \left(LC_{RF} \acute{} \ u_{RF}\right)$$

Step-3: Determine Configuration Characteristics

- **Two Sided Weaving**
  - L_{RR} – minimum number of lane changes required for 'ramp-to-ramp' movement.
  - N_{WV}=0 (only vehicles moving ramp to ramp are considered to be weaving

$$LC_{MIN} = \left(LC_{RR} \acute{} \; u_{RR}\right)$$

Symbol Definition

v_W	total weaving demand flow rate within the weaving section (pc/h) $v_W = v_{RR}$
v_{NW}	total non-weaving demand flow rate within the weaving section (pc/h) $v_{NW} = v_{FR} + v_{RF} + v_{FF}$
LC_{RR}	minimum number of lane changes that must be made by *one* ramp-to-ramp vehicle to complete a weaving maneuver.
LC_{MIN}	minimum rate of lane changing that must exist for *all* weaving vehicles to successfully complete their weaving maneuvers (lc/h) $LC_{MIN} = (LC_{RR} \times v_{RR})$

Figure 15.8 Weaving Variables Defined for One-Sided Weaving Segments (*Source:* Roess, R., et al., *Analysis of Freeway Weaving Sections,* Final Report, Draft Chapter for the HCM, National Cooperative Highway Research Program Project 3-75, Polytechnic University and Kittelson and Associates, Brooklyn, NY, September 2007, Exhibit 24-7, p. 12.)

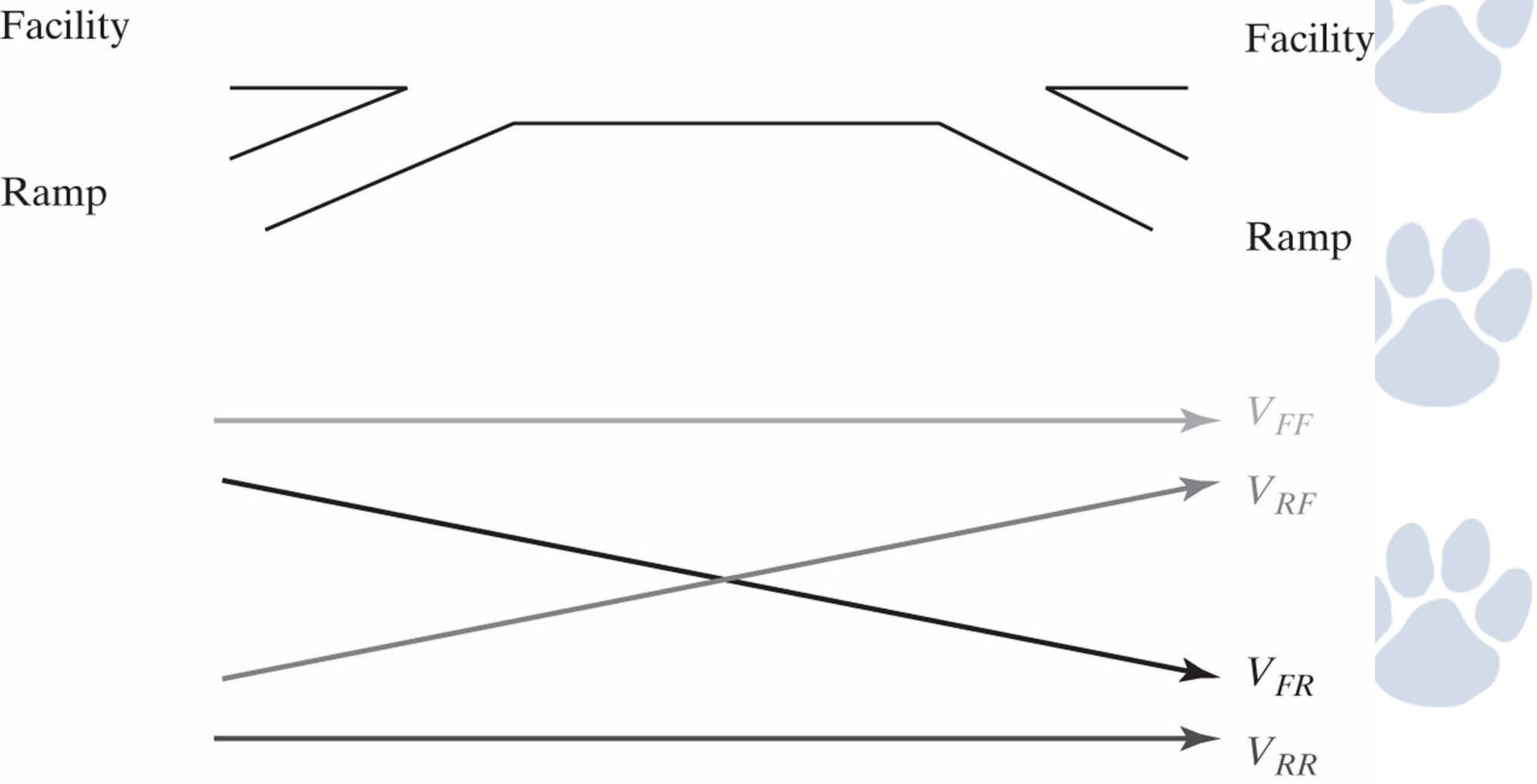
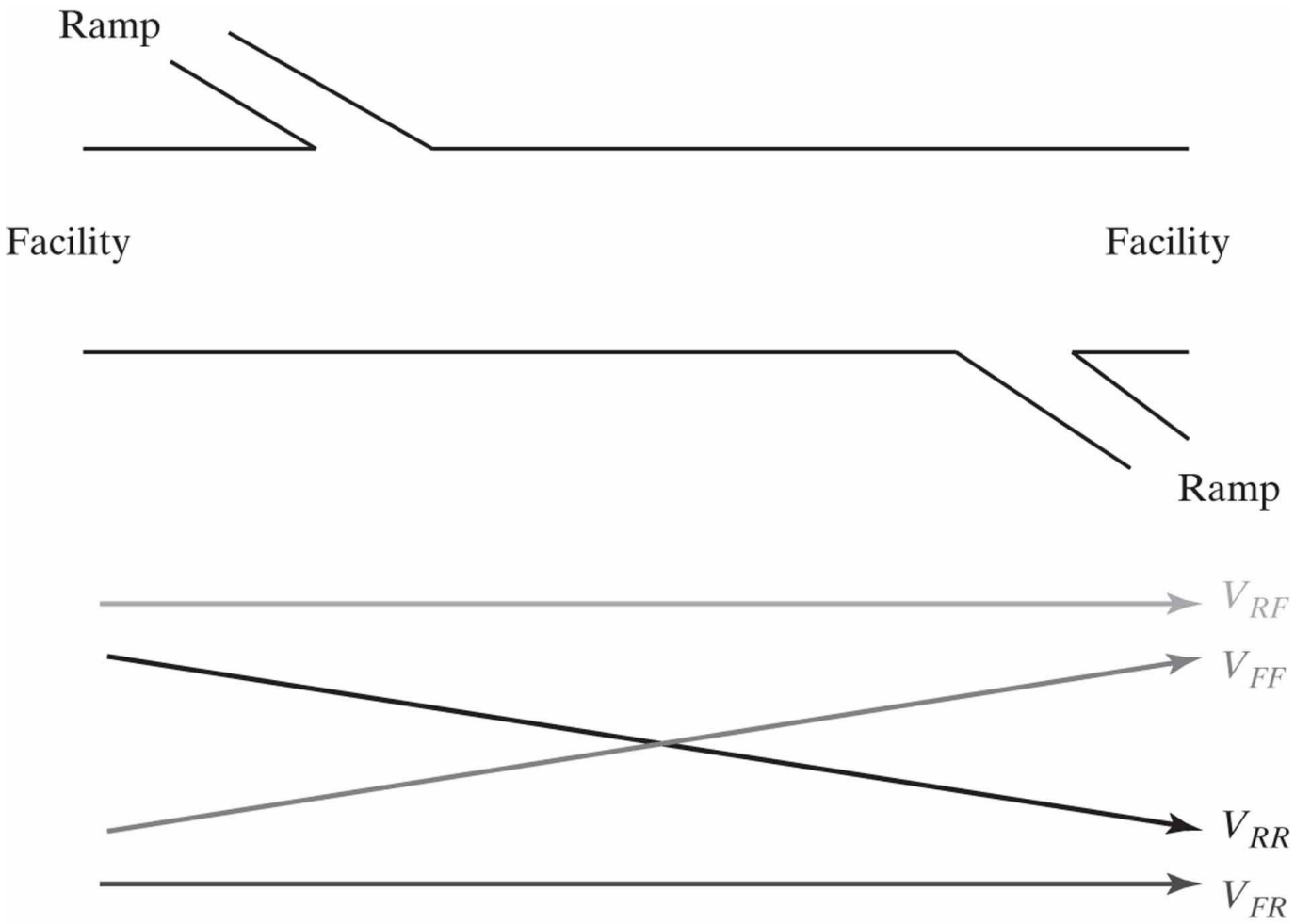


Figure 15.9 Weaving Variables Defined for Two-Sided Weaving Segments (*Source:* Roess, R., et al*., Analysis of Freeway Weaving Sections,* Final Report, Draft Chapter for the HCM, National Cooperative Highway Research Program Project 3-75, Polytechnic University and Kittelson and Associates, Brooklyn, NY, September 2007, Exhibit 24-8, p. 13.)



Step-4: Maximum Weaving Length

$$L_{MAX} = \left[5,728\left(1 + VR\right)^{1.6} \right] - 1,566 N_{VW}$$

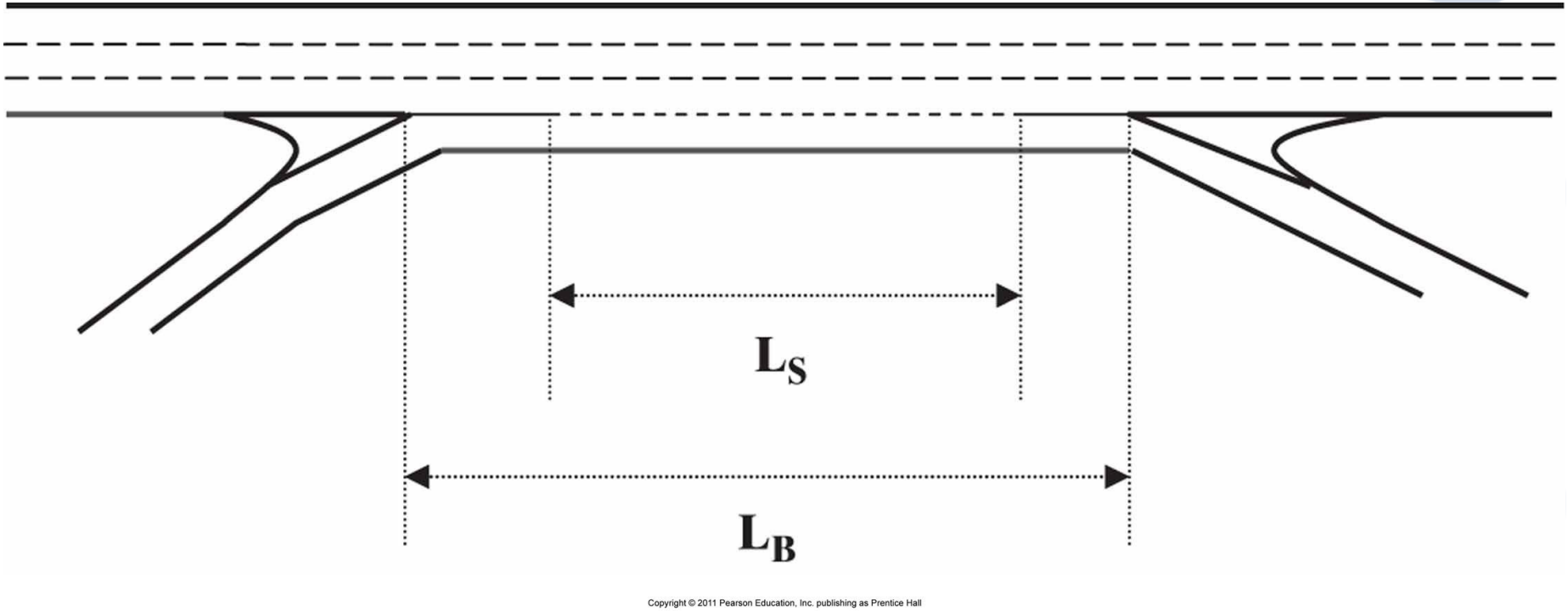


Figure 15.6 Measuring the Length of a Weaving Segment (*Source:* Roess, R., et al.*, Analysis of Freeway Weaving Sections,* Final Report, Draft Chapter for the HCM, National Cooperative Highway Research Program Project 3-75, Polytechnic University and Kittelson and Associates, Brooklyn, NY, September 2007, Exhibit 24-2, p. 2.)

Step-5: Capacity of the Weaving Segment

- **Based on Breakdown Density**

Calculate C_{IWL} (cap per lane of weaving section under ideal conditions:

$$c_{IWL} = c_{IFL} - \left[438.2(1+VR)^{1.6}\right] + \left[0.0765 L_S\right] + \left[119.8 N_{WV}\right]$$

Convert C_{IWL} to total capacity for the weaving segment under prevailing conditions:

$$c_{W1} = c_{IWL} \times N \times f_{HV} \times f_p$$

Capacity Values - C_{IFL}

Table 15.2: Basic Facility Capacity Values (c_{IFL}) for Use in Equation 15-5

Freeways		Multilane Highways and C–D Roadways	
FFS (mi/h)	Capacity (pc/h/ln)	FFS (mi/h)	Capacity (pc/h/ln)
≥ 70	2,400	≥ 60	2,200
65	2,350	55	2,100
60	2,300	50	2,000
55	2,250	45	1,900

Step-5: Capacity of the Weaving Segment

- **Based on Maximum Weaving Flow Rate**

Calculate C_{IW} (based on # weaving lanes):

$$c_{IW} = \frac{2,400}{VR} for \quad N_{WL} = 2\ lanes$$

$$c_{IW} = \frac{3,500}{VR} for \quad N_{WL} = 3 lanes$$

Convert C_{IW} to total capacity for the weaving segment under prevailing conditions:

$$c_{W2} = c_{IWL} \times f_{HV} \times f_p$$

- **Final Capacity and v/C ratio**

c_W = Min (cw1, cw2)

$$\upsilon / c = \frac{\upsilon f_{HV} f_p}{c_w}$$

If v/c >1.0. LOS =F, and STOP

Step-6: Total Lane Changing

- **For Weaving Vehicles**

Total lane changing rate for weaving vehicles

$$LC_W = LC_{MIN} + 0.39[(L_S - 300)^{0.5} N^2 (1 + ID)^{0.8}]$$

- **For Non-Weaving Vehicles**

$$LC_{NW1} = 0.206 v_{NW} + 0.542 L_S - (192.6N)$$

$$LC_{NW2} = 2135 + 0.223(v_{NW} - 2000)$$

Step-6: Total Lane Changing

- **Lane Changing Index**

Total lane changing rate for weaving vehicles

$$I_{NW} = \frac{L_S ID v_{NW}}{10{,}000}$$

- **I_{NW} Ranges**
  - If I_{NW} <1,300
    - $LC_{NW} = LC_{NW1}$
  - If If I_{NW} >1,950
    - $LC_{NW} = LC_{NW2}$
  - If 1300<I_{NW} <1,950

$$LC_{NW} = LC_{NW1} + (LC_{NW2} - LC_{NW1})\left(\frac{I_{NW} - 1300}{650}\right)$$

- **Total Lane Changing**

$$LC_{ALL} = LC_{NW1} + LC_{NW2}$$

Step-7: Average Speed

- **Weaving Vehicles**

$$S_W = S_{MIN} + \left(\frac{S_{MAX} - S_{MIN}}{1 + W}\right)$$

$$W = 0.226\left(\frac{LC_{ALL}}{L_S}\right)^{0.789}$$

$$S_W = 15 + \left(\frac{FFS - 15}{1 + W}\right)$$

- **Non-Weaving Vehicles**

$$S_{NW} = FFS - (0.0072LC_{MIN}) + (0.0048v/N)$$

- **Average Speed**

$$S = \frac{v_W + v_{NW}}{\frac{v_W}{S_W} + \frac{v_{NW}}{S_{NW}}}$$

Step-8: Determine Density

$$D = \frac{\left(\frac{v}{N}\right)}{S}$$

where D is the average density for all vehicles in the weaving segment (pc/mi/ln).

LOS for W/M/D Segments

Table 15.1: Level-of-Service Criteria for Weaving, Merging, and Diverging Segments

Level of Service	Weaving Areas		Merge or Diverge Areas
	Density Range (pc/mi/ln)		
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C	>20–28	>24–32	>20–28
D	>28–35	>32–36	>28–35
E	>35	>36	>35
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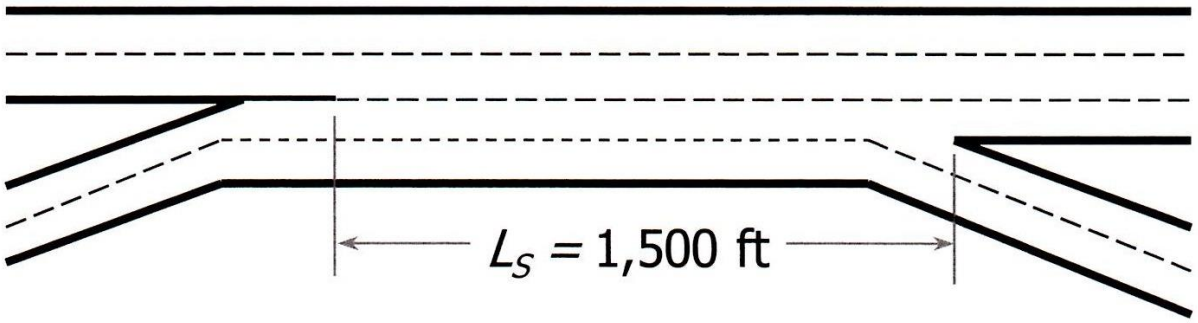
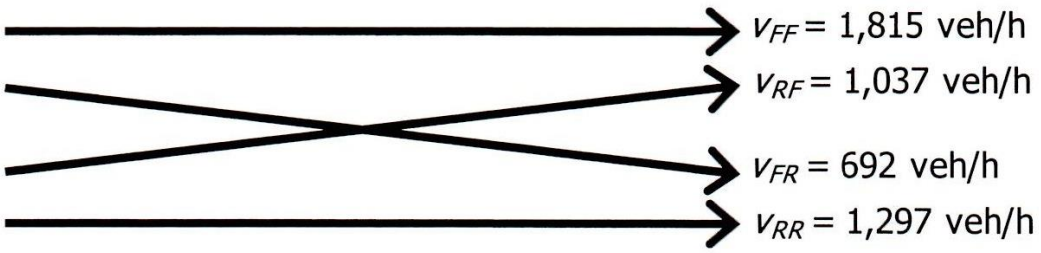
(*Source:* Used with permission of Transportation Research Board, National Research Council, *Highway Capacity Manual*, 2000. Compiled from Exhibit 24-2, p. 24-3, and Exhibit 25-4, p. 25-5.)

Table 15.1 Level-of-Service Criteria for Weaving, Merging, and Diverging Segments

Example

What are the level of service and capacity of the weaving segment on the urban freeway shown below? ID = 0.8 int./mi -10 percent trucks; PHF=0.91; level terrain; fp=1, FFS=65 mph





Example

- A typical ramp weave section on a six lane freeway (three lanes in each direction). Determine LOS under prevailing conditions