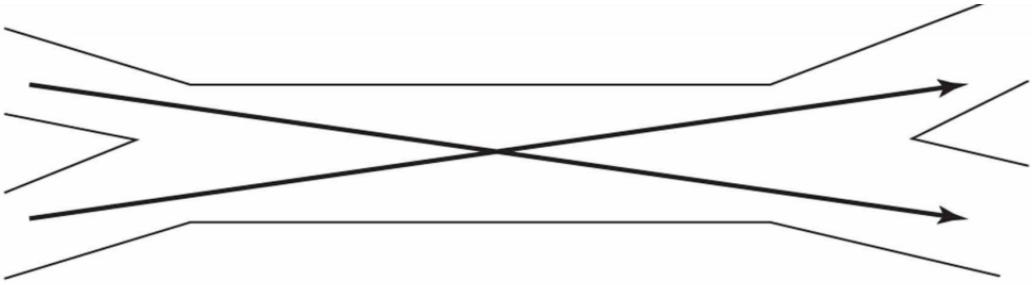
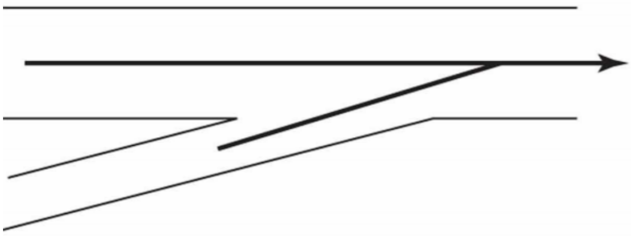
Analysis of Weaving, Merging, and Diverging Movements

Weaving, Diverging, Merging Segments

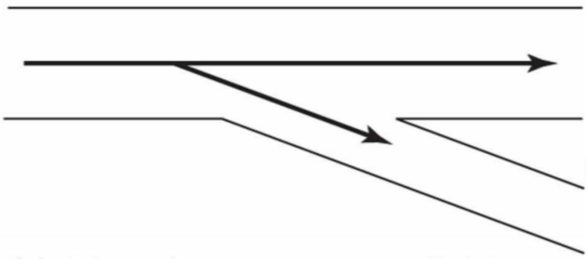
- Weaving – one movement must cross the path of another along a length of facility without the aid of signals or other traffic control devices
- Merging – two separate traffic streams join to form a single one
- Diverging – one traffic stream separates to form two separate traffic streams
- Why do we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



(a) Weaving movements cross each others path.



(b) Merging movements join to form a single traffic stream.



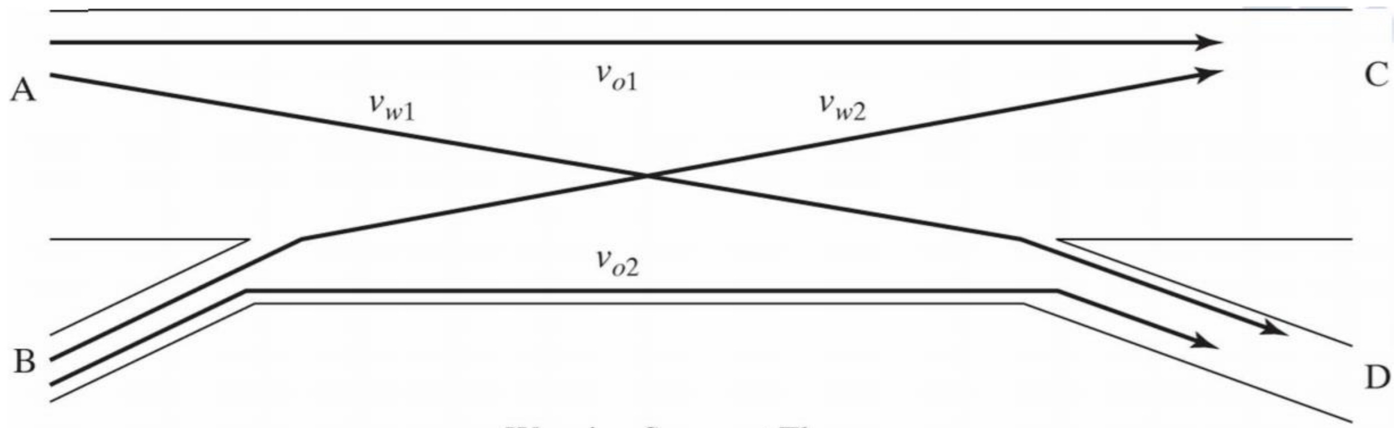
(c) Diverging movements divide to form separate traffic streams.

LOS for W/M/D Segments

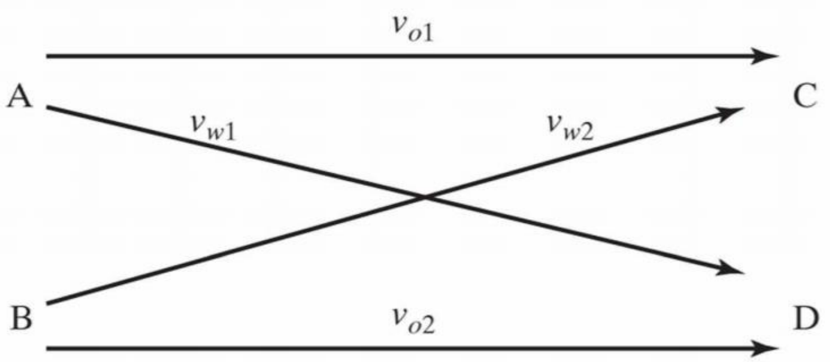
Level of Service	Weaving Areas		Merge or Diverge Areas
	Density Range (pc/mi/ln)		
	On Freeways	On Multilane Highways or C-D Roadways	On Freeways, Multilane Highways, or C-D Roadways
A	0–10	0–12	0–10
B	>10–20	>12–24	>10–20
C	>20–28	>24–32	>20–28
D	>28–35	>32–36	>28–35
E	>35	>36	>35
F	Demand Exceeds Capacity		

(*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.)

Flows in a Weaving Segment and the Weaving Diagram

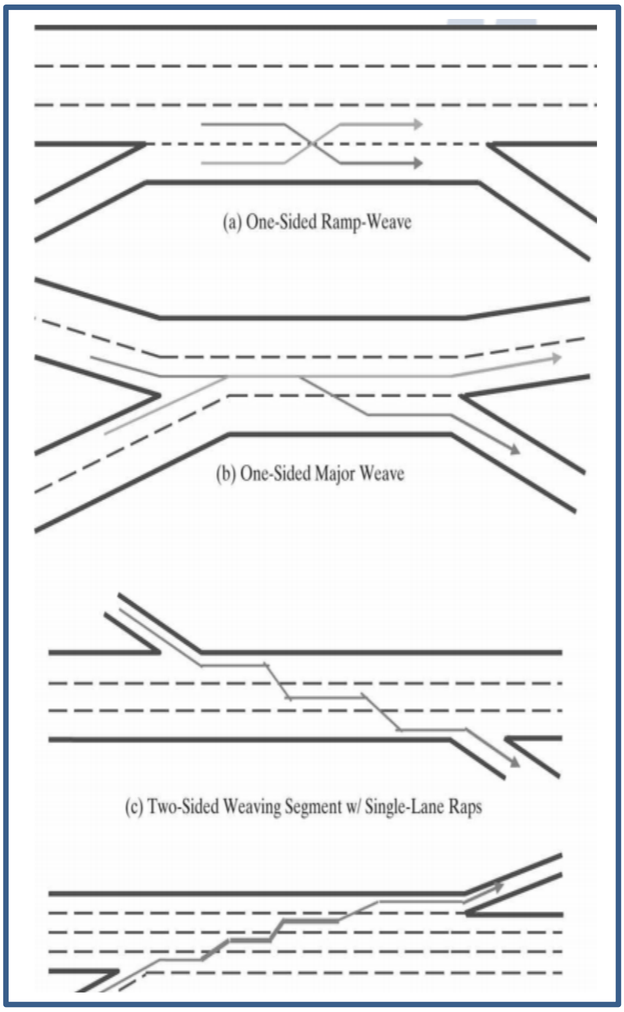


Weaving Segment Flows

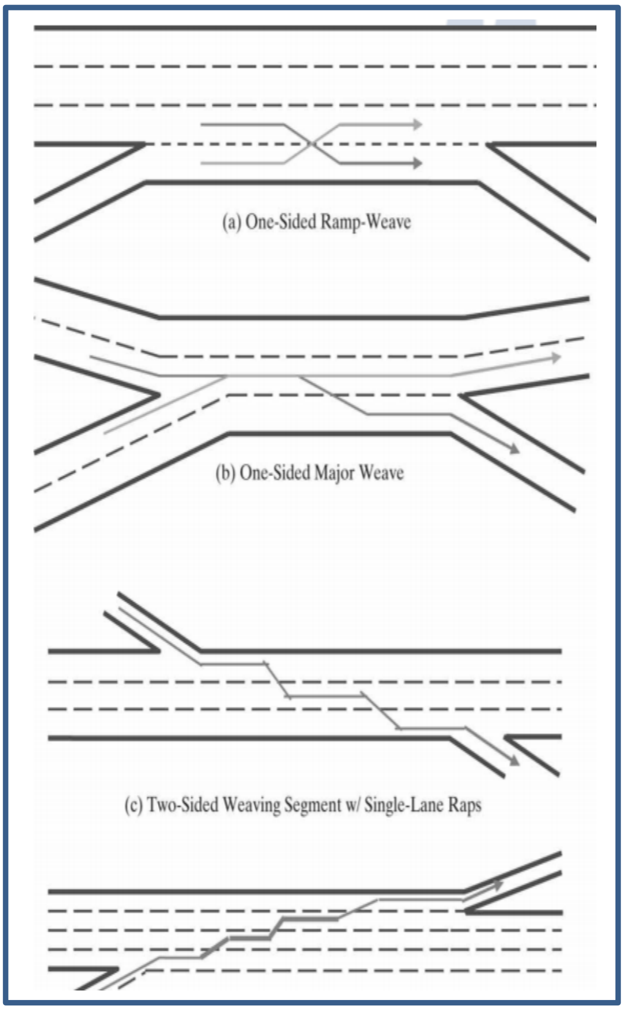


Weaving Diagram

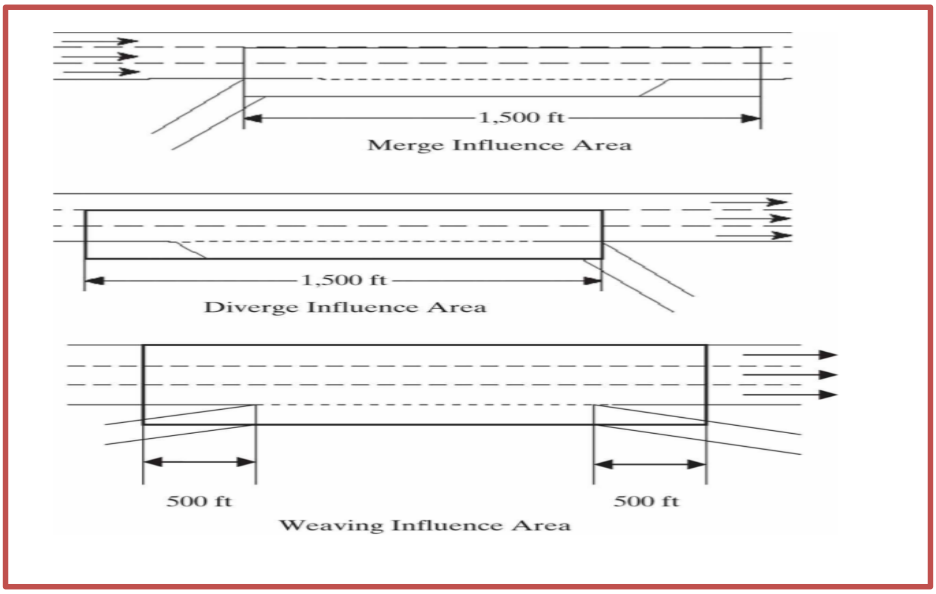
Weaving Configurations



Weaving Configuration Parameters



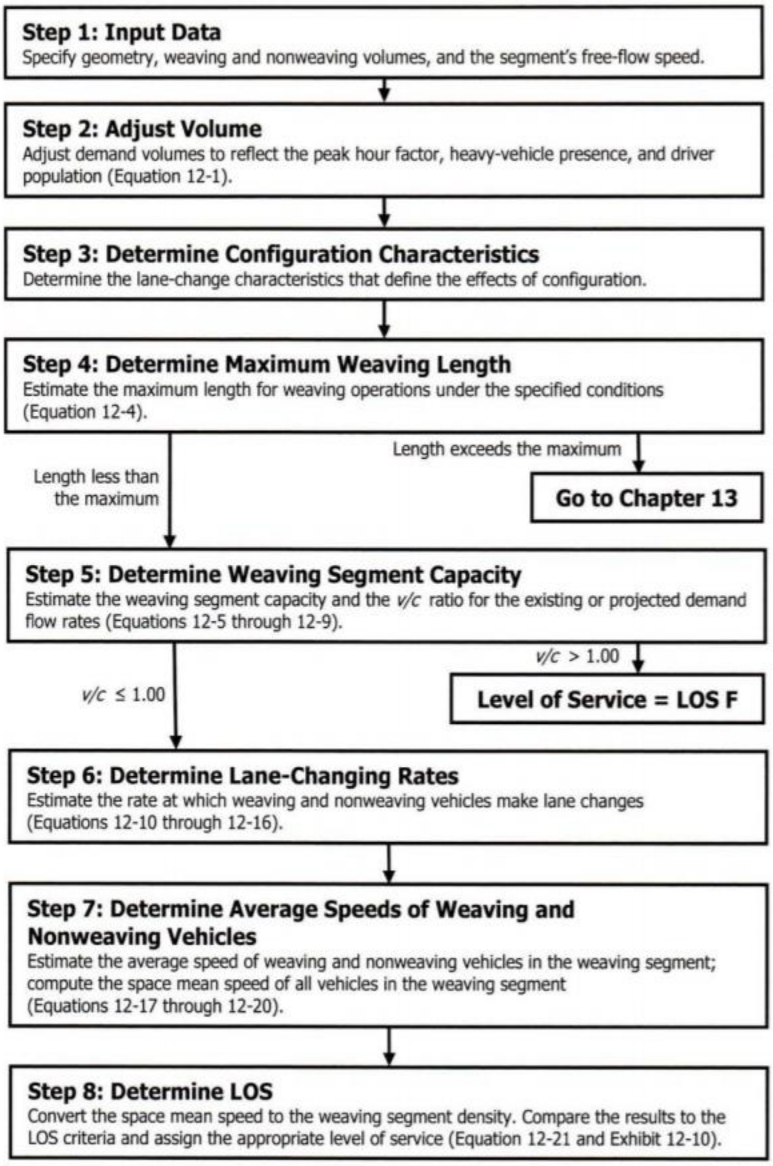
Influence Areas for Merge, Diverge, and Weaving Segments (Source: Used with permission of Transportation Research Board, National Research Council, modified from Highway Capacity Manual, 2000, Exhibit 13-13, p. 13-21.)



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



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)

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

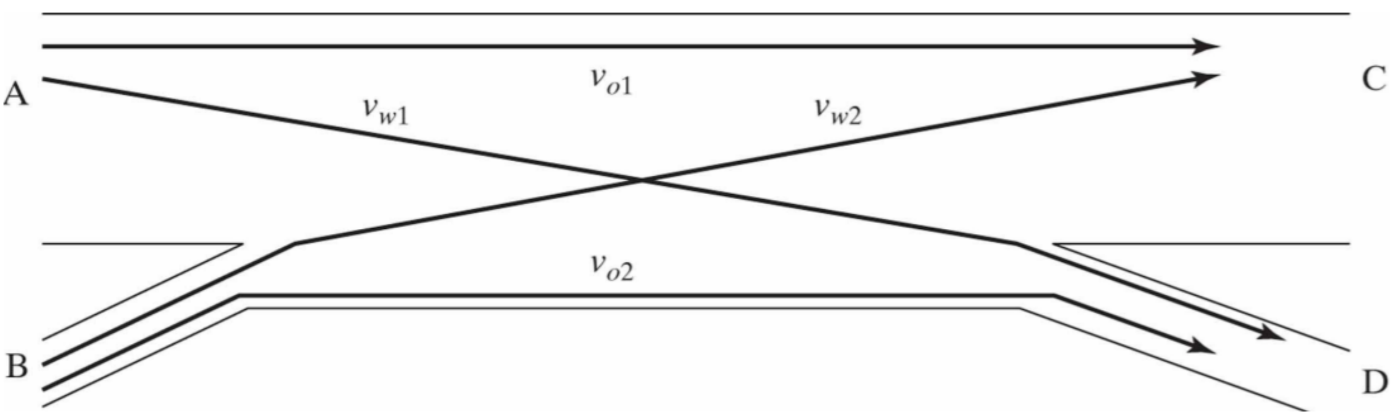
Ensure to write all the input data in one place before analyzing the weaving section

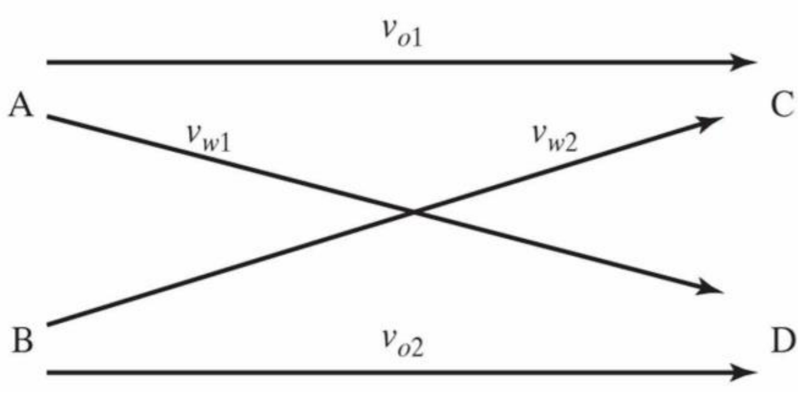
Step-2: Determining Flow Rate

$$\mathbf{v_i = \frac{V}{PHF * N * f_{HV} * f_p}}$$

- ✓ vi: 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

Weaving Flows





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.

$$LC_{MIN} = (LC_{FR} \leftrightarrow v_{FR}) + (LCRF \leftrightarrow v_{RF})$$

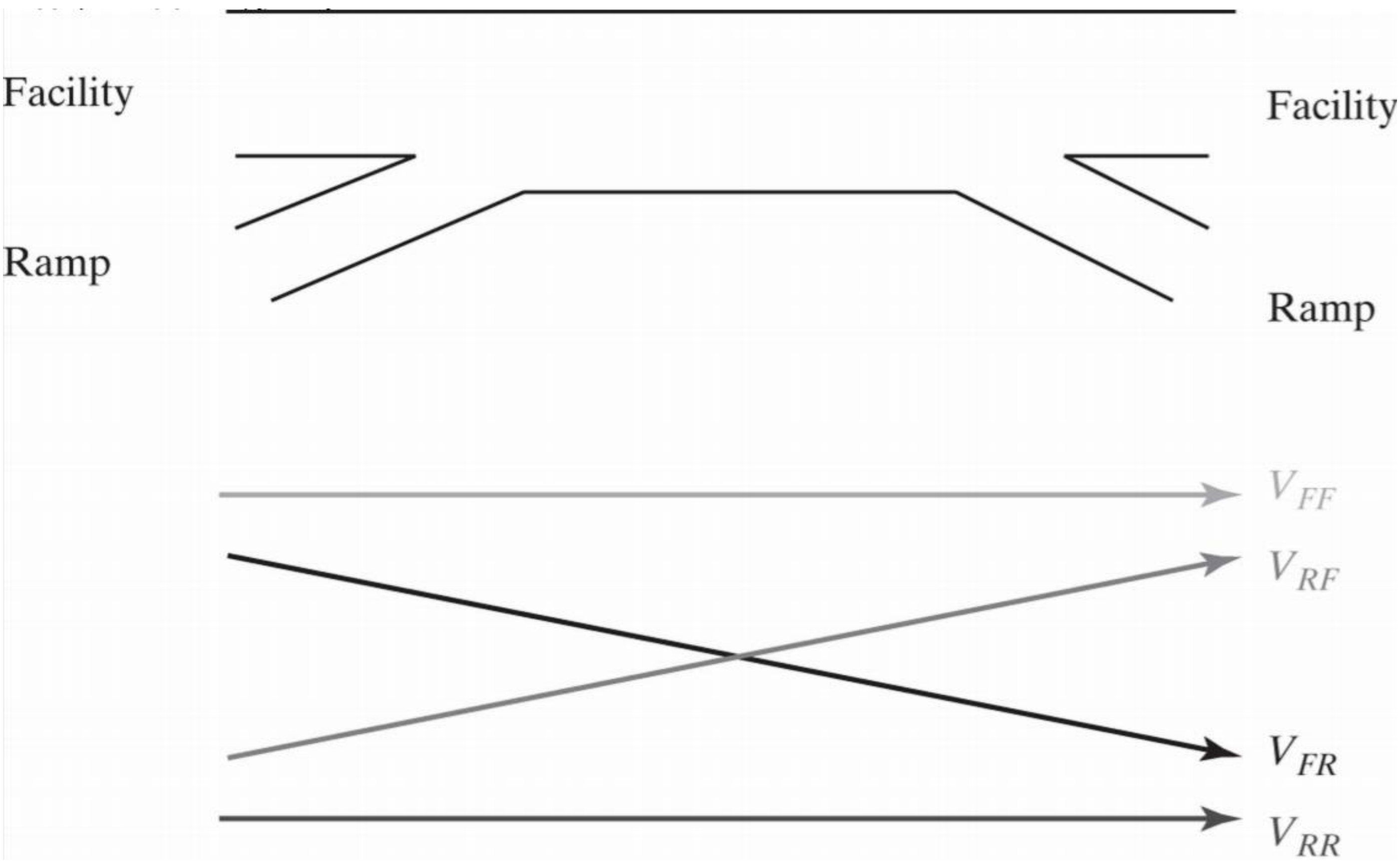
• Two Sided Weaving

- 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

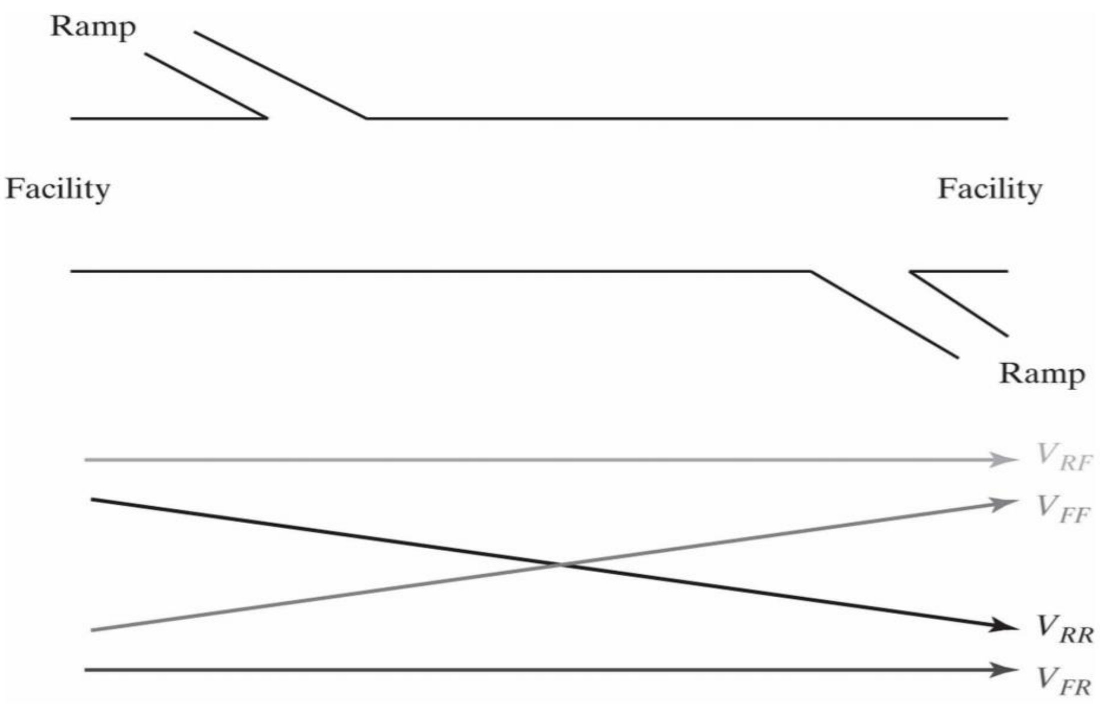
$$LC_{MIN} = (LC_{RR} \leftrightarrow u_{RR})$$

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) $LC_{MIN} = (LC_{RR} \times v_{RR})$

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.)



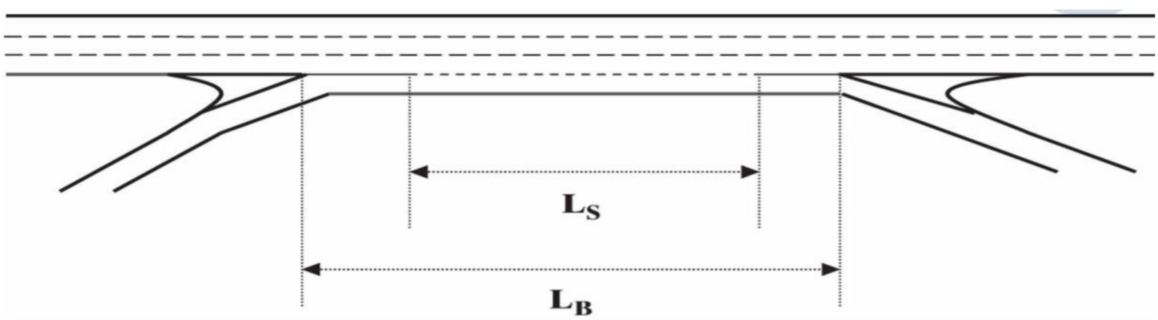
Weaving Variables Defined for Two-Sided Weaving Segments (Source: Roess, R., et al., Analysis of Freeway Weaving Sections, Final Report, Draft Chapter for the HCM, National Cooperative Highway Research Program Project 3-75, Polytechnic University and Kittelson and Associates, Brooklyn, NY, September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



Step-4: Maximum Weaving Length

$$L_{MAX} = [5728(1 + VR)^{1.6}] - 1.566N_{VW}$$

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):

$$\mathbf{C_{IWL} = C_{IFL} - [438.2(1 + VR)^{1.6}] + [0.0765L_s] + [119.8N_{WV}]}$$

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

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

Capacity Values – CIFL

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

• Based on Maximum Weaving Flow Rate

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

$$C_{IW} = \frac{2400}{VR} \quad \text{For} \quad N_{WL} = 2 \ lanes$$

$$C_{IW} = \frac{3500}{VR} \quad \text{For} \quad N_{WL} = 3 \ lanes$$

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

$$\mathbf{C_{W2} = C_{IWL} \times f_{HV} \times f_p}$$

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

$$C_W = Min\ (CW_1, CW_2)$$

$$v/c = \frac{v f_{HV} f_p}{C_W}$$

$$\text{if } v/c > 1.0 \ \ LOS = F, \text{and STOP}$$

Step-6: Total Lane Changing

- **For Weaving Vehicles**

Total lane changing rate for weaving vehicles

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

- **For Non-Weaving Vehicles**

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

$$LC_{NW2} = 02135 + 0.2234(v_{NW} - 2000)$$

- **Lane Changing Index**

Total lane changing rate for weaving vehicles

- **For Non-Weaving Vehicles**

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

- If $I_{NW} < 1300 \ \ LC_{NW} = LC_{NW1}$
- If $I_{NW} > 1950 \ \ LC_{NW} = LC_{NW2}$
- If $1300 < I_{NW} < 1950$

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

- **Total Lane Changing**

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

Step-7: Average Speed

- **Weaving Vehicles**

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

$$W = 0.226(\frac{LC_{ALL}}{L_s})^{0.789}$$

- **Non-Weaving vehicles**

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

- **Average Speed**

$$S = \frac{V_W + V_{NW}}{\frac{V_W}{S_W} + \frac{V_{NW}}{S_{NW}}}$$

Step-8: Determine Density

$$D = \frac{(\frac{V}{N})}{S}$$

Where:

- ✓ D is the density for all vehicles in the weaving segment $(pc\backslash mile\backslash ln)$

LOS for W/M/D Segments

Table: 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
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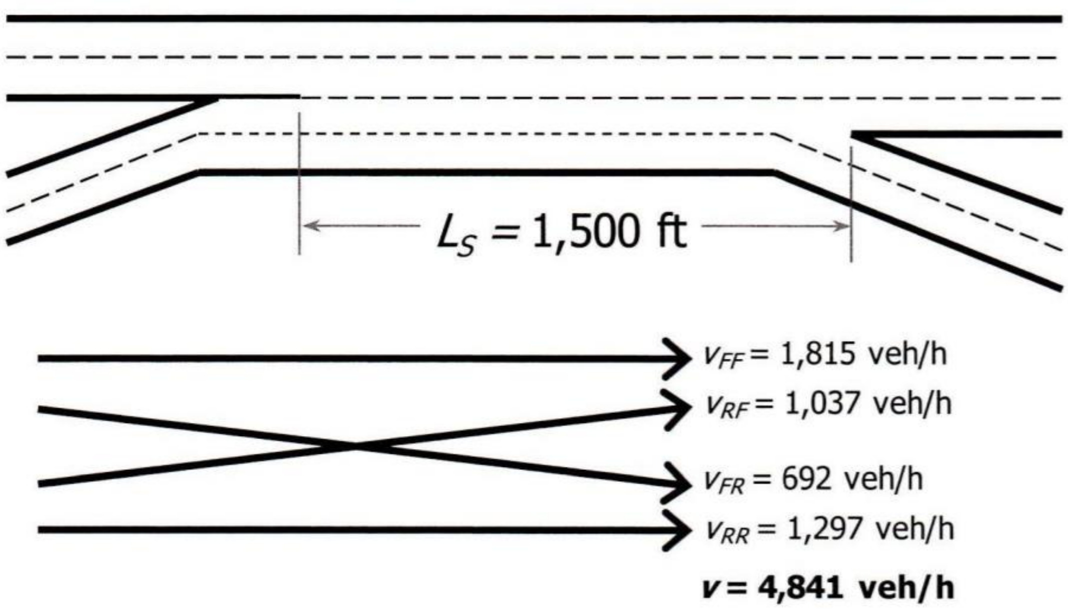
B	>10–20	>12–24	>10–20
C	>20–28	>24–32	>20–28
D	>28–35	>32–36	>28–35
E	>35	>36	>35
F	Demand Exceeds Capacity		

(*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.)

HW1.

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



HW2.

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