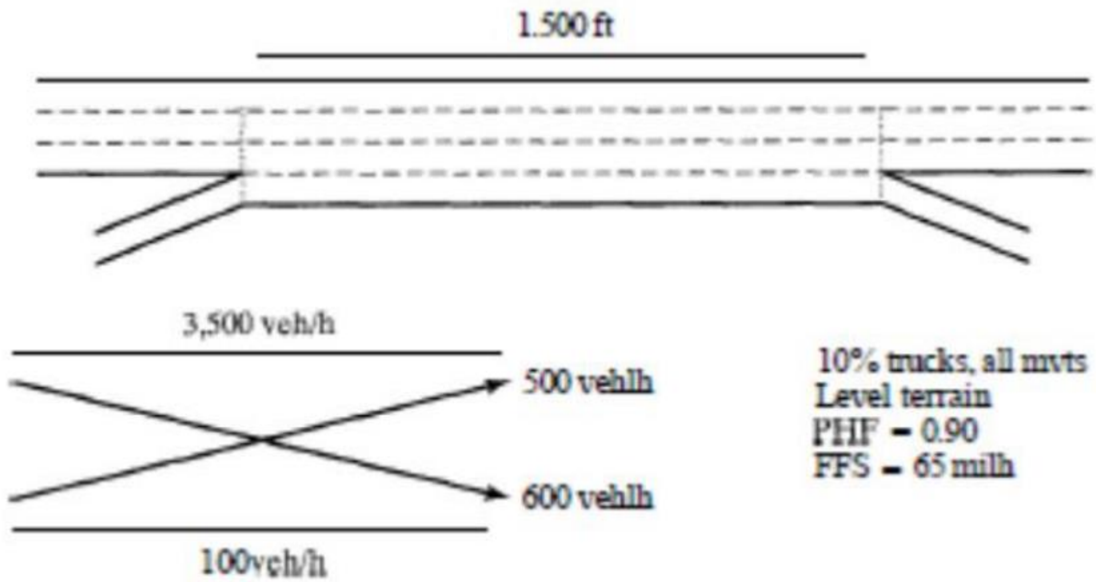
H.W2

Figure below illustrates a typical ramp-weave section on six-lane freeway (three lanes in each direction). The analysis is to determine the expected level of service (LOS) and capacity for the prevailing conditions?



Solution:

Step 1 and 2:

Convert all demand volumes to flow rates in pc/j under equivalent base conditions. Each if the component demand volumes is converted to a demand flow rate in pc/hr under equivalent base conditions using equation below:

$$v_p = \frac{V}{PHF \times f_{HV} \times f_p}$$

Where:

PHF=0.9

f_p= 1.00 (assume drivers are familiar with the site)

The heavy vehicle factor f_{HV} is computed and a value is selected from Table in lect.14 for trucks on level grade, E_T=1.5

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

$$f_{HV} = \frac{1}{1 - 0.1(1.5 - 1)}$$

= 0.952

$$v_{01} = \frac{3500}{0.9 \times 0.952 \times 1.00} = 4085\ pc/hr$$

$$v_{02} = \frac{100}{0.9 \times 0.952 \times 1.00} = 117 pc/hr$$

$$v_{w1} = \frac{600}{0.9 \times 0.952 \times 1.00} = 700\ pc/hr$$

$$v_{w2} = \frac{500}{0.9 \times 0.952 \times 1.00} = 584\ pc/hr$$

Other variables are:

$v_w = 700 + 584 = 1284\ pc/hr$

$v_{nw} = 4085 + 117 = 4202 pc/hr$

$v = 1284 + 4202 = 5486\ pc/hr$

$v/N = 5486/4 = 1372\ pc/hr$

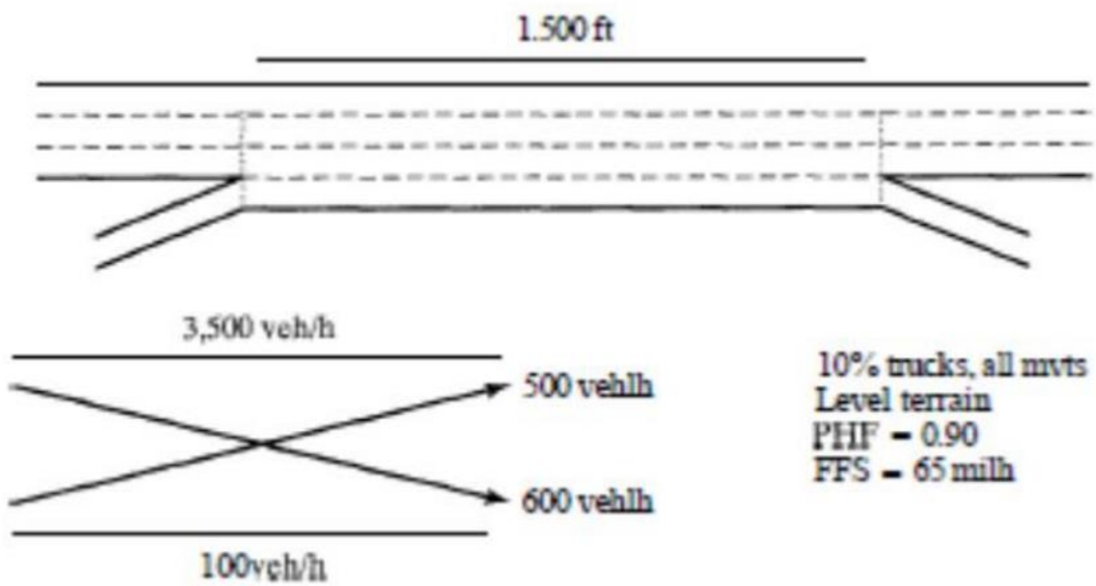
$VR = 1284/5485 = 0.23$

L= 1500ft

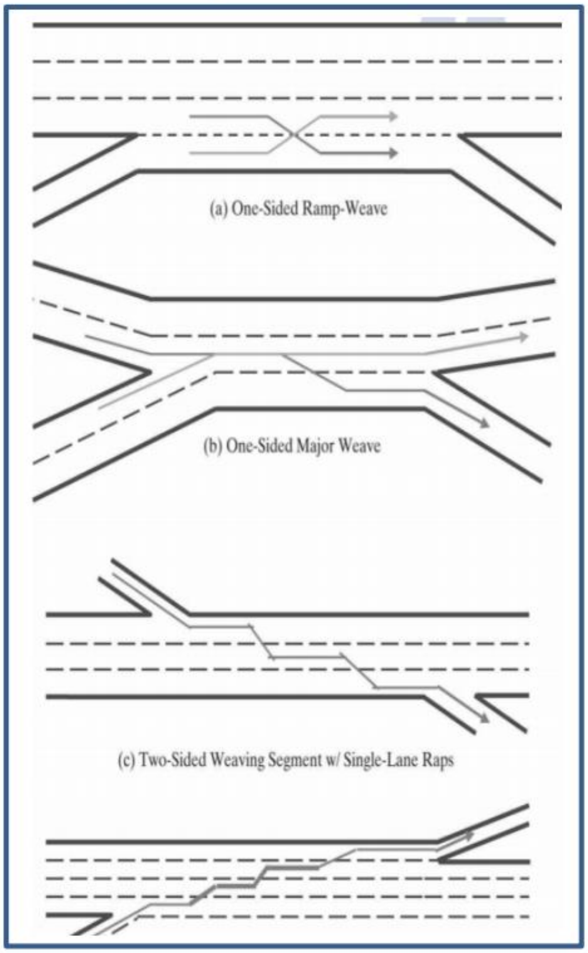
Step3: Determine configuration Characteristics

The two critical numeric variables that defined configuration are N_{VW} the number of lanes from which a weaving movement can be successfully executed with no more than one lane change, and LC_{MIN} the minimum number of lane changes that must be made by all weaving vehicles to complete their maneuvers successfully.

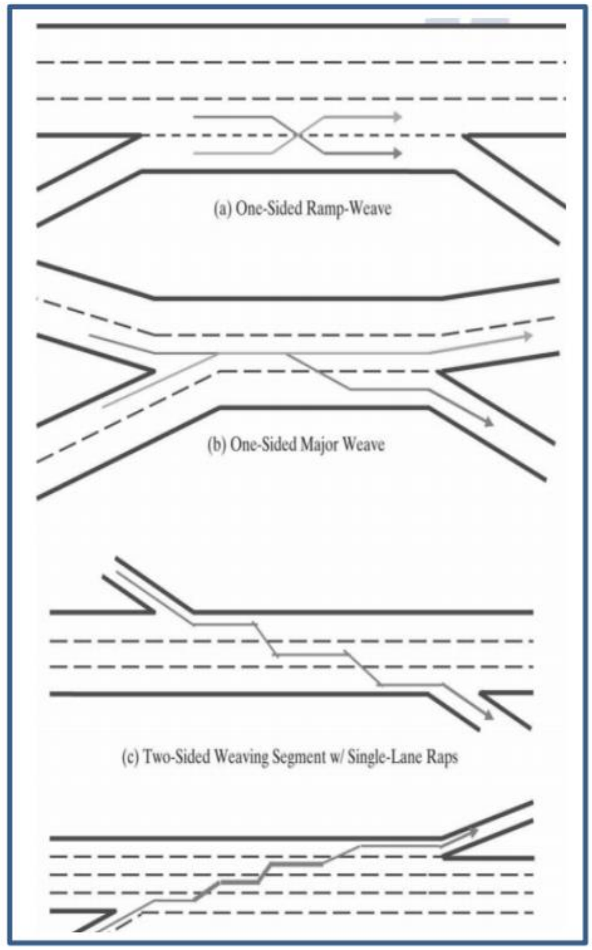
The number of weaving lanes, N_{WV} is determined by perusing the site drawing and comparing it to the illustration of figure below:



Weaving Configurations



Weaving Configuration Parameters



As a ramp –weave, the value of N_{WV} is 2. The value of LC_{MIN} is found from Equation below:

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

Where:

LC_{MIN}: minimum number of lane changes for a free way to ramp vehicle needed to execute a weaving maneuver successfully, this value is 1.

v_{FR}: Freeway to ramp demand flow rate, pc/hr = v_{w1} = 700 pc/hr

LC_{RF}: Minimum number of lane changes for a ramp to freeway vehicle needed to execute a weaving maneuver successfully; this value is 1 from figure above.

v_{RF}: Ramp to freeway demand flow rate, pc/hr = v_{w2}= 584 pc/hr

Then:

$LC_{MIN} = (1 \times 700) + (1 \times 584)$= 1284 lc/hr

Step 4: Determine the Maximum Weaving Length

The maximum length for which this segment may be considered to be a weaving segment is estimated using Equ:

$L_{MAX} = [5728(1 + VR)^{1.6}] - [1566N_{WV}]$

$L_{MAX} = [5728(1 + 0.23)^{1.6}] - [1566 * 2]$= 4845 ft

Because the actual length of the segment, 1500ft, is far less than this maximum, the segment is operating as a weaving segment, and the analysis may continue.

Step 5: Determine the Capacity of the Weaving Segment

The capacity of the weaving segment can be determined by overall operation at a density of 43 pc/h/ln, the density at which it is believed breakdown occurs in weaving segments, or on the capacity of the segment to handle weaving flows. The former is estimated using Equ.

$c_{IWL} = c_{IFL} - [438.2(1 + VR)^{1.6}] + [0.0765L_s] + [119.9N_{WV}]$

$c_{IWL} = 2350 - [438.2(1 + 0.23)^{1.6}] + [0.0765 * 1500] + [119.9 * 2]$

= 2094 pc/hr/ln

This value must be converted to a capacity under prevailing conditions using Equ.

$c_{w1} = c_{IWL} N f_{HV} f_p$

$c_{w1} = 2094 * 4 * 0.952 * 1$

= 7974 veh/hr

The capacity based on maximum weaving demand flow rate based on N_{WV}=2 is estimated using Equ.

$$C_{IW} = \frac{2400}{VR}$$

$$C_{IW} = \frac{2400}{0.23} = 10235\ pc/hr$$

This value must be converted to prevailing conditions,

$$C_{w2} = C_{IW} \times f_{HV} \times f_p = 10235 * 0.952 * 1 = 9744\ veh/hr$$

The limitation capacity is obviously based on the density conditions (7974veh/hr). As with any capacity, this is defined in terms of a maximum demand flow rate that the segment can accommodate without breakdown. This must be compared with the demand flow rate, also under prevailing conditions. The total demand volume, V, is given as 4700 veh/hr. This must be converted to a flow rate:

v=V/PHF= 4700/0.90=5222 veh/hr

Because the demand flow rate is less than the capacity of the segment (v/c = 5222/7974= 0.655), operation will be stable, and LOS F does not exist in the segment. The analysis may move forward to estimate density, LOS, and speed within the segment.

Step 6: Determine Lane- Changing Rates

To estimate and density in the weaving segment, total lane-changing rates within the segment must be estimated. Lane-changing rates for weaving and non-weaving vehicles are separately.

The lane –changing rate for weaving vehicles is computed using Equ.

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

$$LC_W = 1284 + 0.39[(1500 - 300)^{0.5} 4^2 (1 + 1.2)^{0.8}] = 1690.4 \text{ lc/hr}$$

The lane changing rate for non-weaving vehicles is obtained and need to estimate the nonweaving lane change index as below:

$$I_{NW} = \frac{L_s I D v_{NW}}{10000} = \frac{1500 * 1.2 * 4200}{10000} = 756.4$$

For this value, $I_{NW} \leq 1300$ is used

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

$$LC_{NW} = (0.206 * 4202) + (0.542 * 1500) - (192.6 * 4) = 899.2 \text{ lc/hr}$$

The total lane changing rate in the segment is the sum of the weaving vehicle rate and the nonweaving vehicles rate, or:

$$LC_{ALL} = LC_W + LC_{NW} = 1690.4 + 899.2 = 2589.6\ lc/hr$$

Step 7: Determine the Average Speed of Weaving and Nonweaving Vehicles

The average speed of weaving vehicles in the weaving segment is estimated using Equations below and theses equation need to estimate weaving intensity W:

$$W = 0.226\left(\frac{LC_{ALL}}{L_s}\right)^{0.789} = 0.226\left(\frac{2589.6}{1500}\right)^{0.789} = 0.348$$

Then:

$$S_w = 15 + \left(\frac{FFS - 15}{1 + W}\right) = 15 + \left(\frac{65 - 15}{1 + 0.348}\right) = 52.1\ mile/hr$$

The average speed of non-weaving vehicles in the weaving segment is estimated:

$$S_{NW} = FFS - (0.0072 LC_{MIN}) - \left(0.0084 \frac{v}{N}\right)$$

$$S_{NW} = 65 - (0.0072 * 1284) - \left(0.0084 * \frac{5486}{4}\right) = 49.2\ mile/hr$$

These results indicate that weaving vehicles are actually travelling somewhat faster than nonweaving vehicles within the weaving segment.

Although unusual for ramp weaving segment, this entirely possible given the dominance of the through freeway flow in the segment. Nonweaving vehicles may be crowding into the two outer freeway lanes to avoid the weaving turbulence, and they may therefore experience slightly lower speeds (and higher densities) than weaving vehicles.

The average speed of all vehicles in the segment is computed:

$$S = \frac{v_W + v_{NW}}{\left(\frac{v_W}{S_W}\right) + \left(\frac{v_{NW}}{S_{NW}}\right)} = \frac{1284 + 4202}{\left(\frac{1284}{52.1}\right) + \left(\frac{4202}{49.2}\right)} = 49.9\ mile/hr$$

Step 8: Determine Density and level of Service in the Weaving Segment

The average density in the weaving segment is computed as follows:

$$D = \frac{(v/N)}{S} = \frac{5486/4}{49.9} = 27.5 \text{ Pc/mile/ln}$$

Form LOS table, the LOS is C but is very close to LOS D boundary of 28 pc/mile/hr

The ramp weave segment is operating acceptably at LOS C. Because density is very close to LOS D boundary, virtually any growth in demand will cause the segment to enter LOS D operations. The capacity of the segment is 2752 veh/hr versus 5222 pc/hr, so that demand can grow by 52.7% (2752*100/5222) before capacity is reached.