Basic (1)

Input Values

**FwyVolNew and %Trucks$_{FNew}$ from the previous upstream segment are the input values for FwyVol and %Trucks$_F$ (if there is a previous upstream segment).*

Traffic

$FwyVol := 3036 \quad PHF := 0.95$

$f_p := 1.0 \quad FFS := 65$

$\%Trucks_F := 5 \quad P_R := 0$

$P_T := \frac{\%Trucks_F}{100} = 0.05$

Roadway

$N := 3 \quad LaneWidth := 12 \quad LatClear := 6 \quad IntDens := 0.87$

$Terrain := 1$ 1 = Level, 2 = Rolling, 3 = Mountainous

$AreaType := 2$ 1 = Rural, 2 = Urban

**FREEPLAN finds IntDens by counting parclos and diamond as 1 interchange each, full as 2, and on and off as 1/2 each and adds them. Then, it divides that total number of interchanges by the total length of the facility.*

Find f_{HV} (using Exhibit 23-8 and Eq. 23-3)

$$E_T(Terrain) := \begin{array}{|l} out \leftarrow 1.5 \ \text{ if } Terrain = 1 \\ out \leftarrow 2.5 \ \text{ if } Terrain = 2 \\ out \leftarrow 4.5 \ \text{ if } Terrain = 3 \\ out \end{array} \qquad E_R(Terrain) := \begin{array}{|l} out \leftarrow 1.2 \ \text{ if } Terrain = 1 \\ out \leftarrow 2.0 \ \text{ if } Terrain = 2 \\ out \leftarrow 4.0 \ \text{ if } Terrain = 3 \\ out \end{array}$$

$E_T(Terrain) = 1.5 \quad E_T := E_T(Terrain) \quad E_R(Terrain) = 1.2 \quad E_R := E_R(Terrain)$

$$f_{HV} := \frac{1}{1 + P_T \cdot (E_T - 1) + P_R \cdot (E_R - 1)} \qquad f_{HV} = 0.9756$$

Find v_p (using Eq. 23-2)

$$v_p := \frac{FwyVol}{PHF \cdot N \cdot f_{HV} \cdot f_p} \qquad v_p = 1091.9 \text{ pc/h/ln}$$

Determine S

$S_1 := FFS$

$$S_2 := FFS - \left[\left(FFS - \frac{160}{3}\right) \cdot \left(\frac{v_p + 30 \cdot FFS - 3400}{30 \cdot FFS - 1000}\right)^{2.6}\right]$$

$$S_3 := FFS - \left[\frac{1}{9} \cdot (7 \cdot FFS - 340) \cdot \left(\frac{v_p + 30 \cdot FFS - 3400}{40 \cdot FFS - 1700}\right)^{2.6}\right]$$

$$S_{cont2} := \text{if}\left[(55 \le FFS \le 75) \land \left[v_p \le (3400 - 30 \cdot FFS)\right], S_1, \text{"Cannot Compute"}\right]$$

$$S_{cont1} := \text{if}\left[(55 \le FFS \le 70) \land \left[(3400 - 30 \cdot FFS) < v_p \le (1700 + 10 \cdot FFS)\right], S_3, S_{cont2}\right]$$

$$S := \text{if}\left[(70 < FFS \le 75) \wedge \left[(3400 - 30 \cdot FFS) < v_p \le 2400\right], S_2, S_{cont1}\right]$$

$S = 65$ mi/h

Density (using Eq. 23-4)

$$D := \frac{v_p}{S} \qquad D = 16.8 \quad \text{pc/mi/ln}$$

Determine level of service (using Exhibit 23-2)

$$\text{LOS}(D) := \begin{array}{|l} \text{out} \leftarrow \text{"F"} \quad \text{if } D > 45 \\ \text{out} \leftarrow \text{"E"} \quad \text{if } 45 \ge D > 35 \\ \text{out} \leftarrow \text{"D"} \quad \text{if } 35 \ge D > 26 \\ \text{out} \leftarrow \text{"C"} \quad \text{if } 26 \ge D > 18 \\ \text{out} \leftarrow \text{"B"} \quad \text{if } 18 \ge D > 11 \\ \text{out} \leftarrow \text{"A"} \quad \text{if } 11 \ge D \\ \text{out} \end{array}$$

$\text{LOS}(D) = \text{"B"}$

Determine Input Vol and %HV for Next Downstream Segment

$FwyVolNew := FwyVol = 3036$

$\%Trucks_{FNew} := \%Trucks_F = 5$

**FwyVolNew and %Trucks$_{FNew}$ are the input values for FwyVol and %Trucks$_F$ for the next downstream segment if there is one. If the next segment is a weave, then %Trucks$_{FNew}$ is the input value for %Trucks_FF and %Trucks_FR.*

Full Off (2a)

Step 1. Data Inputs and Volume Adjusments

**FwyVolNew and %Trucks$_{FNew}$ from the previous upstream segment are the input values for FwyVol and %Truck$_{SF}$ (if there is a previous upstream segment).*

A. Inputs

$FwyVol := 3036$ veh/h $RampVol := 300$ veh/h

$\%Trucks_F := 5$ $\%RV_F := 0$ $PHF := 0.95$ $f_p := 1$ $FFS := 65$ mi/h

$\%Trucks_R := 2$ $\%RV_R := 0$

$NumLanes := 3$ Number of mainline freeway lanes $NRamp := 1$ Number of lanes on ramp roadway

$Terrain := 1$ 1 = Level, 2 = Rolling, 3 = Mountainous

$L_D := 450$ ft Total length of Deceleration Lane

$S_{FR} := 40$ mi/h Freeflow speed of the ramp at the junction point

$AdjUp := 0$ $AdjDn := 1$ 0 = none, 1 = on-ramp, 2 = off-ramp for Adjacent Upstream/Downstream Ramps

$L_{up} := 5280$ ft $L_{down} := 500$ ft

$VolumeUp := 455$ veh/h Volume on adjacent upstream ramp

$VolumeDown := 700$ veh/h Volume on adjacent downstream ramp

B. Heavy Vehicle Adjustments

Passenger Car Equivalents

$$E_T(Terrain) := \left| \begin{array}{l} out \leftarrow 1.5 \text{ if } Terrain = 1 \\ out \leftarrow 2.5 \text{ if } Terrain = 2 \\ out \leftarrow 4.5 \text{ if } Terrain = 3 \end{array} \right. \qquad E_R(Terrain) := \left| \begin{array}{l} out \leftarrow 1.2 \text{ if } Terrain = 1 \\ out \leftarrow 2.0 \text{ if } Terrain = 2 \\ out \leftarrow 4.0 \text{ if } Terrain = 3 \end{array} \right.$$

$E_T(Terrain) = 1.5$ $E_R(Terrain) = 1.2$

$E_T := E_T(Terrain)$ $E_T = 1.5$ $E_R := E_R(Terrain)$ $E_R = 1.2$

$$f\_HV_F := \frac{100}{100 + \%Trucks_F(E_T - 1) + \%RV_F(E_R - 1)} \qquad f\_HV_F = 0.976$$

$$f\_HV_R := \frac{100}{100 + \%Trucks_R(E_T - 1) + \%RV_R(E_R - 1)} \qquad f\_HV_R = 0.99$$

C. Demand Flow Rate

$$V_f := \frac{FwyVol}{PHF \cdot f\_HV_F \cdot f_p} \quad V_f = 3276 \text{ pc/h} \qquad V_r := \frac{RampVol}{PHF \cdot f\_HV_R \cdot f_p} \quad V_r = 319 \text{ pc/h}$$

$$V_u := \frac{VolumeUp}{PHF \cdot f\_HV_R \cdot f_p} \quad V_u = 484 \text{ pc/h} \qquad V_d := \frac{VolumeDown}{PHF \cdot f\_HV_R \cdot f_p} \quad V_d = 744 \text{ pc/h}$$

Step 2. Determine the Approaching Flow Rate in Lanes 1 and 2

A. Equilibrium Seperation Distance for Adjacent Upstream On-Ramp or Downstream Off-Ramps on a Six Lane Freeway

$$L_{EQup} := \frac{V_u}{0.071 + 0.000023 \cdot V_f - 0.000076 \cdot V_r} \qquad L_{EQup} = 3962 \quad \text{ft}$$

$$L_{EQdown} := \frac{V_d}{1.15 - 0.000032 \cdot V_f - 0.000369 \cdot V_r} \qquad L_{EQdown} = 802 \quad \text{ft}$$

B. Estimating Proportion of Freeway Vehicles Remaining in lanes 1 and 2

$$Eqn1 := 0.760 - 0.000025 \cdot V_f - 0.000046 \cdot V_r \qquad Eqn1 = 0.663$$

$$Eqn2 := 0.717 - 0.000039 \cdot V_f + 0.604 \cdot \frac{V_u}{L_{up}} \qquad Eqn2 = 0.645$$

$$Eqn3 := 0.616 - 0.000021 \cdot V_f + 0.124 \cdot \frac{V_d}{L_{down}} \qquad Eqn3 = 0.732$$

$$
P_{FD}(\text{Numlanes}) := \left|
\begin{array}{l}
out \leftarrow 1.00 \quad \text{if} \quad NumLanes = 2 \\
out \leftarrow Eqn1 \quad \text{if} \quad AdjUp = 0 \wedge AdjDn = 0 \wedge NumLanes = 3 \\
out \leftarrow Eqn1 \quad \text{if} \quad AdjUp = 0 \wedge AdjDn = 1 \wedge NumLanes = 3 \\
out \leftarrow Eqn1 \quad \text{if} \quad AdjUp = 0 \wedge AdjDn = 2 \wedge L_{down} \geq L_{EQdown} \wedge NumLanes = 3 \\
out \leftarrow Eqn3 \quad \text{if} \quad AdjUp = 0 \wedge AdjDn = 2 \wedge L_{down} < L_{EQdown} \wedge NumLanes = 3 \\
out \leftarrow Eqn1 \quad \text{if} \quad AdjUp = 1 \wedge AdjDn = 0 \wedge L_{up} \geq L_{EQup} \wedge NumLanes = 3 \\
out \leftarrow Eqn2 \quad \text{if} \quad AdjUp = 1 \wedge AdjDn = 0 \wedge L_{up} < L_{EQup} \wedge NumLanes = 3 \\
out \leftarrow Eqn1 \quad \text{if} \quad AdjUp = 2 \wedge AdjDn = 0 \wedge NumLanes = 3 \\
out \leftarrow Eqn1 \quad \text{if} \quad AdjUp = 1 \wedge AdjDn = 1 \wedge L_{up} \geq L_{EQup} \wedge NumLanes = 3 \\
out \leftarrow Eqn2 \quad \text{if} \quad AdjUp = 1 \wedge AdjDn = 1 \wedge L_{up} < L_{EQup} \wedge NumLanes = 3 \\
out \leftarrow \max(Eqn2, Eqn3) \quad \text{if} \quad AdjUp = 1 \wedge AdjDn = 2 \wedge L_{up} < L_{EQup} \wedge L_{down} < L_{EQdown} \wedge NumLanes = 3 \\
out \leftarrow \max(Eqn2, Eqn1) \quad \text{if} \quad AdjUp = 1 \wedge AdjDn = 2 \wedge L_{up} < L_{EQup} \wedge L_{down} \geq L_{EQdown} \wedge NumLanes = 3 \\
out \leftarrow Eqn1 \quad \text{if} \quad AdjUp = 1 \wedge AdjDn = 2 \wedge L_{up} \geq L_{EQup} \wedge L_{down} \geq L_{EQdown} \wedge NumLanes = 3 \\
out \leftarrow \max(Eqn3, Eqn1) \quad \text{if} \quad AdjUp = 1 \wedge AdjDn = 2 \wedge L_{up} \geq L_{EQup} \wedge L_{down} < L_{EQdown} \wedge NumLanes = 3 \\
out \leftarrow Eqn1 \quad \text{if} \quad AdjUp = 2 \wedge AdjDn = 1 \wedge NumLanes = 3 \\
out \leftarrow Eqn1 \quad \text{if} \quad AdjUp = 2 \wedge AdjDn = 2 \wedge L_{down} \geq L_{EQdown} \wedge NumLanes = 3 \\
out \leftarrow Eqn3 \quad \text{if} \quad AdjUp = 2 \wedge AdjDn = 2 \wedge L_{down} < L_{EQdown} \wedge NumLanes = 3 \\
out \leftarrow 0.436 \quad \text{if} \quad NumLanes = 4
\end{array}
\right.
$$

$$P_{FD} := P_{FD}(\text{NumLanes}) \qquad P_{FD} = 0.663$$

C. Estimating Flow in Lanes 1 and 2

$$V_{12} := V_r + (V_f - V_r) \cdot P_{FD} \qquad V_{12} = 2281 \quad \text{pc/h}$$

D. Checking the Reasonableness of the Lane Distribution Prediction

Six Lane Freeways *Eight Lane Freeways*

$V_3 := V_f - V_{12}$ $\quad V_3 = 995$ pc/h $\quad V_{av34} := \frac{V_f - V_{12}}{2}$ $\quad V_{av34} = 498$ pc/h

$$V12a(NumLanes) := \left| \begin{array}{l} out \leftarrow V_{12} \ \text{ if } \ NumLanes = 2 \\ out \leftarrow V_f - 2700 \ \text{ if } \ V_3 > 2700 \wedge V_3 \le 1.5 \cdot \frac{V_{12}}{2} \vee NumLanes = 3 \\ out \leftarrow \frac{V_f}{1.75} \ \text{ if } \ V_3 \le 2700 \wedge V_3 > 1.5 \cdot \frac{V_{12}}{2} \wedge NumLanes = 3 \\ out \leftarrow \max\left(V_f - 2700, \frac{V_f}{1.75}\right) \ \text{ if } \ V_3 > 2700 \wedge V_3 > 1.5 \cdot \frac{V_{12}}{2} \wedge NumLanes = 3 \\ out \leftarrow V_{12} \ \text{ if } \ V_3 \le 2700 \wedge V_3 \le 1.5 \cdot \frac{V_{12}}{2} \wedge NumLanes = 3 \\ out \leftarrow V_f - 5400 \ \text{ if } \ V_{av34} > 2700 \wedge V_{av34} \le 1.5 \cdot \frac{V_{12}}{2} \wedge NumLanes = 4 \\ out \leftarrow \frac{V_f}{2.50} \ \text{ if } \ V_{av34} \le 2700 \wedge V_{av34} > 1.5 \cdot \frac{V_{12}}{2} \wedge NumLanes = 4 \\ out \leftarrow \max\left(V_f - 5400, \frac{V_f}{2.50}\right) \ \text{ if } \ V_{av34} > 2700 \wedge V_{av34} > 1.5 \cdot \frac{V_{12}}{2} \wedge NumLanes = 4 \\ out \leftarrow V_{12} \ \text{ if } \ V_{av34} \le 2700 \wedge V_{av34} \le 1.5 \cdot \frac{V_{12}}{2} \wedge NumLanes = 4 \end{array} \right.$$

C. Final Flow in Lanes 1 and 2

$V_{12} := V12a(NumLanes)$ $\quad V_{12} = 2281$ pc/h

Step 3. Determine Capacity of Ramp-Freeway Junction

$$\text{CapUpFreewaySegment}(\text{NumLanes}, \text{FFS}) := \left\| \begin{array}{l} \text{out} \leftarrow 4800 \quad \text{if} \quad \text{FFS} \geq 70 \wedge \text{NumLanes} = 2 \\ \text{out} \leftarrow 4700 \quad \text{if} \quad \text{FFS} = 65 \wedge \text{NumLanes} = 2 \\ \text{out} \leftarrow 4600 \quad \text{if} \quad \text{FFS} = 60 \wedge \text{NumLanes} = 2 \\ \text{out} \leftarrow 4600 \quad \text{if} \quad \text{FFS} = 55 \wedge \text{NumLanes} = 2 \\ \text{out} \leftarrow 7200 \quad \text{if} \quad \text{FFS} = 70 \wedge \text{NumLanes} = 3 \\ \text{out} \leftarrow 7050 \quad \text{if} \quad \text{FFS} = 65 \wedge \text{NumLanes} = 3 \\ \text{out} \leftarrow 6900 \quad \text{if} \quad \text{FFS} = 60 \wedge \text{NumLanes} = 3 \\ \text{out} \leftarrow 6750 \quad \text{if} \quad \text{FFS} = 55 \wedge \text{NumLanes} = 3 \\ \text{out} \leftarrow 9600 \quad \text{if} \quad \text{FFS} = 70 \wedge \text{NumLanes} = 4 \\ \text{out} \leftarrow 9400 \quad \text{if} \quad \text{FFS} = 65 \wedge \text{NumLanes} = 4 \\ \text{out} \leftarrow 9200 \quad \text{if} \quad \text{FFS} = 60 \wedge \text{NumLanes} = 4 \\ \text{out} \leftarrow 9000 \quad \text{if} \quad \text{FFS} = 55 \wedge \text{NumLanes} = 4 \\ \text{out} \leftarrow 2400 \cdot \text{NumLanes} \quad \text{if} \quad \text{FFS} = 70 \wedge \text{NumLanes} > 4 \\ \text{out} \leftarrow 2350 \cdot \text{NumLanes} \quad \text{if} \quad \text{FFS} = 65 \wedge \text{NumLanes} > 4 \\ \text{out} \leftarrow 2300 \cdot \text{NumLanes} \quad \text{if} \quad \text{FFS} = 60 \wedge \text{NumLanes} > 4 \\ \text{out} \leftarrow 2250 \cdot \text{NumLanes} \quad \text{if} \quad \text{FFS} = 55 \wedge \text{NumLanes} > 4 \end{array} \right.$$

$\text{CapUpFreewaySegment}(\text{NumLanes}, \text{FFS}) = 7050$ Capacity of Ramp Freeway Junction

MaxV12 = 4400 Maximum Desirable Flow Rate Entering Merge Influence Area

$$\text{CapacityRampRoadway} := \left| \begin{array}{l} \text{out} \leftarrow 2200 \quad \text{if} \quad (\text{NRamp} = 1) \wedge (S_{FR} > 50) \\ \text{out} \leftarrow 2100 \quad \text{if} \quad (\text{NRamp} = 1) \wedge (40 < S_{FR} \leq 50) \\ \text{out} \leftarrow 2000 \quad \text{if} \quad (\text{NRamp} = 1) \wedge (30 < S_{FR} \leq 40) \\ \text{out} \leftarrow 1900 \quad \text{if} \quad (\text{NRamp} = 1) \wedge (20 \leq S_{FR} \leq 30) \\ \text{out} \leftarrow 1800 \quad \text{if} \quad (\text{NRamp} = 1) \wedge (20 > S_{FR}) \\ \text{out} \leftarrow 4400 \quad \text{if} \quad (\text{NRamp} = 2) \wedge (S_{FR} > 50) \\ \text{out} \leftarrow 4200 \quad \text{if} \quad (\text{NRamp} = 2) \wedge (40 < S_{FR} \leq 50) \\ \text{out} \leftarrow 4000 \quad \text{if} \quad (\text{NRamp} = 2) \wedge (30 < S_{FR} \leq 40) \\ \text{out} \leftarrow 3800 \quad \text{if} \quad (\text{NRamp} = 2) \wedge (20 \leq S_{FR} \leq 30) \\ \text{out} \leftarrow 3600 \quad \text{if} \quad (\text{NRamp} = 2) \wedge (20 > S_{FR}) \end{array} \right.$$

$\text{CapacityRampRoadway} = 2000$

$V_f = 3276$ pc/h

Volume immediatley upstream of off-ramp influence area

Ramp Freeway Junction Checkpoint

Volume immediatley upstream of off-ramp influence area is chekced against freeway capacity. Failure of ramp freeway junction checkpoint (i.e. demand exceeds capacity) results in LOS F

Ramp Roadway Capacity Checkpoint	If the off-ramp demand flow rate (Vr) exceeds the capacity of the off-ramp, LOS F prevails.
Maximum Desirable Flow Entering Ramp Influence Area Checkpoint	While the V12 values is checked against the maximum desirable, failure does not result in assignment of LOS F. Failing this checkpoint generally means that there will be more turbulance in influence area than predicted by this methodology. Thus, predicted densities are most likely lower than those that will exist, and predicted speeds are most likely to be predicted as higher than those that will actually occur.

Step 4. Determine Speeds in the Vicinity of Ramp-Freeway Junction

A. Average Speed in the Ramp Influence Area

$$S_R := FFS - (FFS - 42)\cdot(0.883 + 0.00009\cdot V_r - 0.013\cdot S_{FR})$$

$S_R = 55.99$ mi/h

B. Average Speed in the Outer Lanes of Freeway

Average Flow in Outer Lanes

$$N_o := \begin{array}{|l} out \leftarrow 1 \quad \text{if} \quad NumLanes = 3 \\ out \leftarrow 2 \quad \text{if} \quad NumLanes = 4 \\ out \leftarrow \infty \quad \text{if} \quad NumLanes = 2 \end{array} \qquad V_{OA} := \frac{V_f - V_{12}}{N_o} \qquad V_{OA} = 995$$

$$S_O(V_{OA}) := \begin{array}{|l} out \leftarrow 1.097\cdot FFS \quad \text{if} \quad V_{OA} < 1000 \\ out \leftarrow 1.097\cdot FFS - 0.0039\cdot(V_{OA} - 1000) \quad \text{if} \quad 1000 \le V_{OA} \end{array}$$

$S_O := S_O(V_{OA})$ $S_O = 71.30$ mi/h

C. Average Speed for Off-Ramp Junction

$$Speed := \frac{V_{12} + V_{OA}\cdot N_o}{\left(\frac{V_{12}}{S_R}\right) + \left(\frac{V_{OA}\cdot N_o}{S_O}\right)} \qquad Speed = 59.9 \quad \text{mi/h}$$

Step 5. Determine the Density and Level of Service

A. Density in Off-Ramp Influence Area

$$Density_R := 4.252 + 0.0086 \cdot V_{12} - 0.009 \cdot L_D \qquad Density_R = 19.8 \quad \text{pc/mi/ln}$$

B. Density in Outer Lanes

$$Density_O := \frac{V_{OA}}{S_O} \qquad Density_O = 14 \quad \text{pc/mi/ln}$$

C. Density of Entire Cross-Section

$$Density := \left| \begin{array}{l} out \leftarrow Density_R \quad \text{if} \quad NumLanes \le 2 \\ out \leftarrow \dfrac{\left[Density_R \cdot (2) + Density_O \cdot (NumLanes - 2)\right]}{NumLanes} \quad \text{if} \quad NumLanes > 2 \end{array} \right. \qquad Density = 17.9 \quad \text{pc/mi/ln}$$

D. Level of Service

$$LOS(Density) := \left| \begin{array}{l} out \leftarrow \text{"A"} \quad \text{if} \quad 0 \le Density \le 10 \\ out \leftarrow \text{"B"} \quad \text{if} \quad 10 < Density \le 20 \\ out \leftarrow \text{"C"} \quad \text{if} \quad 20 < Density \le 28 \\ out \leftarrow \text{"D"} \quad \text{if} \quad 28 < Density \le 35 \\ out \leftarrow \text{"E"} \quad \text{if} \quad 35 < Density \end{array} \right. \qquad LOS(Density) = \text{"B"}$$

Step 6. Determine Input Vol and %HV for Next Downstream Segment

$$FwyVol_{Cars} := FwyVol \cdot \left(1 - \frac{\%Trucks_F}{100}\right) = 2884.2$$

$$RampVol_{Cars} := RampVol \cdot \left(1 - \frac{\%Trucks_R}{100}\right) = 294$$

$$FwyVol_{CarsNew} := FwyVol_{Cars} - RampVol_{Cars} = 2590.2$$

$$FwyVol_{Trucks} := FwyVol \cdot \frac{\%Trucks_F}{100} = 151.8$$

$$RampVol_{Trucks} := RampVol \cdot \left(\frac{\%Trucks_R}{100}\right) = 6$$

$$FwyVol_{TrucksNew} := FwyVol_{Trucks} - RampVol_{Trucks} = 145.8$$

$$FwyVolNew := FwyVol_{CarsNew} + FwyVol_{TrucksNew} = 2736$$

$$\%Trucks_{FNew} := \frac{FwyVol_{TrucksNew}}{FwyVolNew} \cdot 100 = 5.3289$$

**FwyVolNew and $\%Trucks_{FNew}$ are the input values for FwyVol and $\%Trucks_F$ for the next downstream segment if there is one. If the next segment is a weave, then $\%Trucks_{FNew}$ is the input value for %Trucks_FF and %Trucks_FR.*

Full Basic (2b)

Input Values

**FwyVolNew and $\%Trucks_{FNew}$ from the previous upstream segment are the input values for FwyVol and $\%Trucks_F$ (if there is a previous upstream segment).*

Traffic

$FwyVol := 2736 \quad PHF := 0.95$

$f_p := 1.0 \quad FFS := 65$

$\%Trucks_F := 5.3289 \quad P_R := 0$

$$P_T := \frac{\%Trucks_F}{100} = 0.0533$$

Roadway

$N := 3 \quad LaneWidth := 12 \quad LatClear := 6 \quad IntDens := 0.87$

$Terrain := 1$ 1 = Level, 2 = Rolling, 3 = Mountainous

$AreaType := 2$ 1 = Rural, 2 = Urban

**FREEPLAN finds IntDens by counting parclos and diamond as 1 interchange each, full as 2, and on and off as 1/2 each and adds them. Then, it divides that total number of interchanges by the total length of the facility.*

Find f_{HV} (using Exhibit 23-8 and Eq. 23-3)

$$E_T(Terrain) := \left| \begin{array}{l} out \leftarrow 1.5 \ \text{ if } Terrain = 1 \\ out \leftarrow 2.5 \ \text{ if } Terrain = 2 \\ out \leftarrow 4.5 \ \text{ if } Terrain = 3 \\ out \end{array} \right. \qquad E_R(Terrain) := \left| \begin{array}{l} out \leftarrow 1.2 \ \text{ if } Terrain = 1 \\ out \leftarrow 2.0 \ \text{ if } Terrain = 2 \\ out \leftarrow 4.0 \ \text{ if } Terrain = 3 \\ out \end{array} \right.$$

$E_T(Terrain) = 1.5 \qquad E_T := E_T(Terrain) \qquad E_R(Terrain) = 1.2 \qquad E_R := E_R(Terrain)$

$$f_{HV} := \frac{1}{1 + P_T \cdot (E_T - 1) + P_R \cdot (E_R - 1)} \qquad f_{HV} = 0.974$$

Find v_p (using Eq. 23-2)

$$v_p := \frac{FwyVol}{PHF \cdot N \cdot f_{HV} \cdot f_p} \qquad v_p = 985.6 \quad \text{pc/h/ln}$$

Determine S

$S_1 := FFS$

$$S_2 := FFS - \left[\left(FFS - \frac{160}{3} \right) \cdot \left(\frac{v_p + 30 \cdot FFS - 3400}{30 \cdot FFS - 1000} \right)^{2.6} \right]$$

$$S_3 := FFS - \left[\frac{1}{9} \cdot (7 \cdot FFS - 340) \cdot \left(\frac{v_p + 30 \cdot FFS - 3400}{40 \cdot FFS - 1700} \right)^{2.6} \right]$$

$$S_{cont2} := \text{if}\left[(55 \le FFS \le 75) \wedge \left[v_p \le (3400 - 30 \cdot FFS) \right], S_1, \text{"Cannot Compute"} \right]$$

$$S_{cont1} := \text{if}\left[(55 \le FFS \le 70) \wedge \left[(3400 - 30 \cdot FFS) < v_p \le (1700 + 10 \cdot FFS) \right], S_3, S_{cont2} \right]$$

$$S := \text{if}\left[(70 < FFS \le 75) \wedge \left[(3400 - 30 \cdot FFS) < v_p \le 2400 \right], S_2, S_{cont1} \right]$$

$S = 65$ mi/h

Density (using Eq. 23-4)

$$D := \frac{v_p}{S} \qquad D = 15.2 \quad \text{pc/mi/ln}$$

Determine level of service (using Exhibit 23-2)

$$LOS(D) := \left| \begin{array}{l} out \leftarrow \text{"F"} \quad \text{if } D > 45 \\ out \leftarrow \text{"E"} \quad \text{if } 45 \geq D > 35 \\ out \leftarrow \text{"D"} \quad \text{if } 35 \geq D > 26 \\ out \leftarrow \text{"C"} \quad \text{if } 26 \geq D > 18 \\ out \leftarrow \text{"B"} \quad \text{if } 18 \geq D > 11 \\ out \leftarrow \text{"A"} \quad \text{if } 11 \geq D \\ out \end{array} \right.$$

$$LOS(D) = \text{"B"}$$

Determine Input Vol and %HV for Next Downstream Segment

$$FwyVolNew := FwyVol = 2736$$

$$\%Trucks_{FNew} := \%Trucks_F = 5.3289$$

**FwyVolNew and %Trucks*$_{FNew}$ *are the input values for FwyVol and %Trucks*$_F$ *for the next downstream segment if there is one. If the next segment is a weave, then %Trucks*$_{FNew}$ *is the input value for %Trucks_FF and %Trucks_FR.*

Full Weave (2c)

**FwyVolNew and %Trucks$_{FNew}$ from the previous upstream segment are the input values for SegInputVol and SegInput%HV if there is a previous upstream segment.*

Step 1. Data Inputs

OnRampVol := 700   OffRampVol := 455   SegInputVol := 2736   Int_Density := 0.87 int/mi

OnRamp%HV := 2   OffRamp%HV := 2   SegInput%HV := 5.3289

L_B := 3000 ft   FFS := 65 mi/h   PHF := .95   fp := 1

**FREEPLAN finds Int_Density by counting parclos and diamond as 1 interchange each, full as 2, and on and off as 1/2 each and adds them. Then, it divides that total number of interchanges by the total length of the facility.*

Terrain := 1   1 = Level, 2 = Rolling, 3 = Mountainous

Config := 1   1 = one-sided weaving segment, 2 = two-sided weaving segment

NumLanes := 4   Number of lanes in weaving section

C_IFL := 2350 pc/h/ln   Capacity of basic freeway segment with same FFS as the weaving segment under equivalent ideal conditions

N_WL := 2   Number of lanes from which weaving maneuvers may be made with one lane change or no lane change. 2 or 3 for one sided and 0 for two sided weaving configuration

LC_RF := 1   Minimum number of lane changes that must be made by a single weaving vehicle from the on-ramp to freeway

LC_FR := 1   Minimum number of lane changes that must be made by a single weaving vehicle from freeway to the off-ramp

LC_RR := 0   Minimum number of lane changes that must be made by one ramp-to-ramp to complete a weaving maneuver

Step 2. Volume Adjustment

A. Heavy Vehicle and Volume Adjustments

Passenger Car Equivalents

$$\text{E\_T}(\text{Terrain}) := \left| \begin{array}{lll} \text{out} \leftarrow 1.5 & \text{if} & \text{Terrain} = 1 \\ \text{out} \leftarrow 2.5 & \text{if} & \text{Terrain} = 2 \\ \text{out} \leftarrow 4.5 & \text{if} & \text{Terrain} = 3 \end{array} \right.$$

$$\text{E\_T} := \text{E\_T}(\text{Terrain}) \qquad \text{E\_T} = 1.5$$

**FREEPLAN assumes trucks make up all of the heavy vehicles. Therefore, RV calculations have been left out.*

$$\text{f\_HV\_FF} := \frac{100}{100 + \text{SegInput\%HV}(\text{E\_T} - 1)} \qquad \text{f\_HV\_FR} := \frac{100}{100 + \text{OffRamp\%HV}(\text{E\_T} - 1)}$$

$$\text{f\_HV\_RF} := \frac{100}{100 + \text{OnRamp\%HV}(\text{E\_T} - 1)} \qquad \text{f\_HV\_RR} := \frac{100}{100 + \text{OnRamp\%HV}(\text{E\_T} - 1)}$$

$$\text{SegInputVolAdj} := \frac{\text{SegInputVol}}{\text{PHF} \cdot \text{f\_HV\_FF} \cdot \text{fp}} = 2956.736 \qquad \text{OffRampVolAdj} := \frac{\text{OffRampVol}}{\text{PHF} \cdot \text{f\_HV\_FR} \cdot \text{fp}} = 483.737$$

$$\text{OnRampVolAdj} := \frac{\text{OnRampVol}}{\text{PHF} \cdot \text{f\_HV\_RF} \cdot \text{fp}} = 744.211$$

**Freeplan assumes the Freeway to Ramp Volume will have the same %HV as the Off Ramp and that the Freeway to Freeway Volume will have the same %HV as the Segment Input Volume*

$$\text{f\_HV} := \frac{(\text{f\_HV\_FF} + \text{f\_HV\_FR} + \text{f\_HV\_RF} + \text{f\_HV\_RR})}{4} \qquad \text{f\_HV} = 0.986$$

B. Volumes for Weaving Segments

$v\_RR := .05 \cdot OnRampVolAdj = 37.211$ veh/h ** Freeplan assumes the v_RR is 5% of the total On-Ramp volume.*

$v\_FR := OffRampVolAdj - v\_RR = 446.526$ veh/h

$v\_RF := .95 \cdot OnRampVolAdj = 707$ veh/h

$v\_FF := SegInputVolAdj - v\_FR = 2510.21$ veh/h

$v\_Total := v\_FF + v\_RF + v\_FR + v\_RR = 3.701 \times 10^{3}$ veh/h

C. Weaving Demand Flow Rate

$$WeavingDemand(N\_WL) := \left| \begin{array}{l} out \leftarrow v\_RF + v\_FR \quad \text{if} \quad N\_WL \neq 0 \\ out \leftarrow v\_RR \quad \text{if} \quad N\_WL = 0 \end{array} \right.$$

$WeavingFlowRate := WeavingDemand(N\_WL)$

$\boxed{WeavingFlowRate = 1154}$ pc/h

D. Non-Weaving Demand Flow Rate

$$NonWeavingDemand(N\_WL) := \left| \begin{array}{l} out \leftarrow v\_FF + v\_RR \quad \text{if} \quad N\_WL \neq 0 \\ out \leftarrow v\_FF + v\_FR + v\_RF \quad \text{if} \quad N\_WL = 0 \end{array} \right.$$

$NonWeavingFlowRate := NonWeavingDemand(N\_WL)$

$\boxed{NonWeavingFlowRate = 2547}$ pc/h

E. Total Demand Flow Rate

$TotalFlowRate := WeavingFlowRate + NonWeavingFlowRate$

$\boxed{TotalFlowRate = 3701}$ pc/h

F. Volume Ratio

$VR := \frac{WeavingFlowRate}{TotalFlowRate}$ $\boxed{VR = 0.312}$

Step 3. Determine the Maximum Weaving Length

$$MaximumLength := \left[5728(1 + VR)^{1.6}\right] - 1566 \cdot N\_WL$$

$\boxed{MaximumLength = 5710}$ ft $Ls := L_B \cdot .77 = 2310$

If Maximum Length < Ls, then STOP
Analyze ramp junctions separately

Step 4. Determine the Capacity of Weaving Segment

A. Weaving segment capacity determined by density

$$C\_IWL := C\_IFL - \left[438.2 \cdot (1 + VR)^{1.6}\right] + (0.0765 \cdot Ls) + (119.8 \cdot N\_WL)$$

$C\_IWL = 2090$ pc/h/ln C_IWL is the capacity per lane under equivalent ideal conditions

$$Cw1 := C\_IWL \cdot NumLanes \cdot f\_HV \cdot fp$$

$Cw1 = 8243$ veh/h Cw1 is the density based capacity of weaving segment under prevailing conditions

B. Weaving segment capacity determined by weaving demand flows

$$C\_IW(N\_WL) := \left| \begin{array}{ll} out \leftarrow \frac{2400}{VR} & \text{if } N\_WL = 2 \\ out \leftarrow \frac{3500}{VR} & \text{if } N\_WL = 3 \\ out \leftarrow \frac{Cw1}{f\_HV \cdot fp} & \text{if } N\_WL = 0 \end{array} \right.$$

For two sided segments, no limiting value on flow rate is proposed and thus capacity based on density only is estimated for the segment. Therefore same capacity value is used here to get the final as capacity determined by density for two sided segments.

$C\_IW := C\_IW(N\_WL)$ $C\_IW = 7700$ pc/h C_IW is the capacity of the weaving segment under ideal conditions

$$Cw2 := C\_IW \cdot f\_HV \cdot fp$$

$Cw2 = 7593$ veh/h Cw2 is the flow based capacity of weaving segment under prevailing conditions

C. Final Capacity of Weaving Segment

$$WeavingCapacity := if(Cw1 > Cw2, Cw2, Cw1)$$

$\boxed{WeavingCapacity = 7593}$ veh/h

D. Volume to Capacity (v/c) Ratio

$$VolumeToCapacity := \frac{TotalFlowRate \cdot f\_HV \cdot fp}{WeavingCapacity}$$

$\boxed{VolumeToCapacity = 0.481}$

If v/c ratio >1 then LOS is F
Terminate

Step 5. Determine Configuration Characteristics

$$LC\_MIN(Config) := \left| \begin{array}{ll} out \leftarrow (LC\_RF \cdot v\_RF) + (LC\_FR \cdot v\_FR) & \text{if } Config = 1 \\ out \leftarrow (LC\_RR \cdot v\_RR) & \text{if } Config = 2 \end{array} \right.$$

$$LC\_MIN := LC\_MIN(Config)$$

$\boxed{LC\_MIN = 1154}$ lc/h Minimum Lane Changes

Step 6. Determine Lane-Changing Rates

A. Lane-Changing Rate for Weaving Vehicles

$$LC\_W(Ls) := \left| \begin{array}{l} out \leftarrow LC\_MIN + 0.39 \cdot \left[(Ls - 300)^{0.5} \cdot NumLanes^{2} \cdot (1 + Int\_Density)^{0.8} \right] \quad \text{if} \quad Ls \geq 300 \\ out \leftarrow LC\_MIN \quad \text{if} \quad Ls < 300 \end{array} \right.$$

$$LaneChangingWeaving := LC\_W(Ls)$$

$$\boxed{LaneChangingWeaving = 1615} \quad \text{lc/h}$$

B. Lane-Changing Rate for Non-Weaving Vehicles

$$I\_NW := \frac{Ls \cdot Int\_Density \cdot NonWeavingFlowRate}{10000} \qquad I\_NW = 512 \qquad \text{Non Weaving Vehicle Index}$$

$$LC\_NW1 := (0.206 \cdot NonWeavingFlowRate) + (0.542 \cdot Ls) - (192.6 \cdot NumLanes)$$

$$LC\_NW2 := 2135 + 0.233 \cdot (NonWeavingFlowRate - 2000)$$

$$LC\_NW3 := LC\_NW1 + (LC\_NW2 - LC\_NW1) \cdot \frac{(I\_NW - 1300)}{650}$$

$$LC\_NW(I\_NW) := \left| \begin{array}{lll} out \leftarrow LC\_NW1 & \text{if} & I\_NW < 1300 \\ out \leftarrow LC\_NW2 & \text{if} & I\_NW \geq 1950 \\ out \leftarrow LC\_NW3 & \text{if} & 1300 < I\_NW < 1950 \\ out \leftarrow LC\_NW2 & \text{if} & LC\_NW1 \geq LC\_NW2 \end{array} \right.$$

$$LaneChangingNonWeaving := LC\_NW(I\_NW)$$

$$\boxed{LaneChangingNonWeaving = 1006} \quad \text{lc/h}$$

C. Total Lane-Changing Rate

$$TotalLaneChanging := LaneChangingWeaving + LaneChangingNonWeaving$$

$$\boxed{TotalLaneChanging = 2622} \quad \text{lc/h}$$

Step 7. Determine Average Speed of Weaving and Non-Weaving Vehicles

A. Average Speed of Weaving Vehicles

$$WeavingIntensityFactor := 0.226 \left(\frac{TotalLaneChanging}{Ls} \right)^{0.789}$$

$$WeavingIntensityFactor = 0.25$$

$$AverageWeavingSpeed := 15 + \left(\frac{FFS - 15}{1 + WeavingIntensityFactor} \right)$$

$$\boxed{AverageWeavingSpeed = 55.01} \quad \text{mi/h}$$

B. Average Speed of Non-Weaving Vehicles

$$\text{AverageNonWeavingSpeed} := \text{FFS} - (0.0072 \cdot \text{LC\_MIN}) - \left(0.0048 \cdot \frac{\text{TotalFlowRate}}{\text{NumLanes}}\right)$$

$\boxed{\text{AverageNonWeavingSpeed} = 52.25}$ mi/h

C. Average Speed of All Vehicles

$$\text{AverageSpeed} := \frac{\text{WeavingFlowRate} + \text{NonWeavingFlowRate}}{\left(\frac{\text{WeavingFlowRate}}{\text{AverageWeavingSpeed}}\right) + \left(\frac{\text{NonWeavingFlowRate}}{\text{AverageNonWeavingSpeed}}\right)}$$

$\boxed{\text{AverageSpeed} = 53.08}$ mi/h

Step 8. Determine the Level of Service

$$\text{Density} := \frac{\left(\frac{\text{TotalFlowRate}}{\text{NumLanes}}\right)}{\text{AverageSpeed}}$$

$\boxed{\text{Density} = 17.4}$ pc/mi/ln

$$\text{LOS}(\text{Density}) := \left| \begin{array}{lll} \text{out} \leftarrow \text{"A"} & \text{if} & 0 \le \text{Density} \le 10 \\ \text{out} \leftarrow \text{"B"} & \text{if} & 10 < \text{Density} \le 20 \\ \text{out} \leftarrow \text{"C"} & \text{if} & 20 < \text{Density} \le 28 \\ \text{out} \leftarrow \text{"D"} & \text{if} & 28 < \text{Density} \le 35 \\ \text{out} \leftarrow \text{"E"} & \text{if} & 35 < \text{Density} \\ \text{out} \leftarrow \text{"F"} & \text{if} & \text{VolumeToCapacity} > 1 \end{array} \right.$$

$\boxed{\text{LOS}(\text{Density}) = \text{"B"}}$

Step 9. Determine the Input Vol and %HV for the Next Downstream Segment

$$\text{FwyVolNew} := \text{SegInputVol} + (\text{OnRampVol} - \text{v\_RR}) - (\text{OffRampVol} - \text{v\_RR}) = 2981$$

$$\%\text{Trucks}_{\text{FNew}} := \frac{\text{SegInputVol} \cdot \text{SegInput\%HV} + (\text{OnRampVol} - \text{v\_RR}) \cdot \text{OnRamp\%HV} - (\text{OffRampVol} - \text{v\_RR}) \cdot \text{OffRamp\%HV}}{\text{FwyVolNew}}$$

$\%\text{Trucks}_{\text{FNew}} = 5.055$

**FwyVolNew and %Trucks$_{FNew}$ are the input values for FwyVol and %Trucks$_F$ for the next downstream segment if there is one. If the next segment is a weave, then %Trucks$_{FNew}$ is the input value for SegInput%HV and FwyVolNew is the input value for SegInputVol.*

Full Basic (2d)

Input Values

Traffic

$FwyVol := 2981 \quad PHF := 0.95$

$f_p := 1.0 \quad FFS := 65$

$\%Trucks_F := 5.055 \quad P_R := 0$

$$P_T := \frac{\%Trucks_F}{100} = 0.0505$$

**FwyVolNew and %Trucks$_{FNew}$ from the previous upstream segment are the input values for FwyVol and %Trucks$_F$ (if there is a previous upstream segment).*

Roadway

$N := 3 \quad LaneWidth := 12 \quad LatClear := 6 \quad IntDens := 0.87$

$Terrain := 1$ 1 = Level, 2 = Rolling, 3 = Mountainous

$AreaType := 2$ 1 = Rural, 2 = Urban

**FREEPLAN finds IntDens by counting parclos and diamond as 1 interchange each, full as 2, and on and off as 1/2 each and adds them. Then, it divides that total number of interchanges by the total length of the facility.*

Find f_{HV} (using Exhibit 23-8 and Eq. 23-3)

$$E_T(Terrain) := \left| \begin{array}{l} out \leftarrow 1.5 \ \text{ if } Terrain = 1 \\ out \leftarrow 2.5 \ \text{ if } Terrain = 2 \\ out \leftarrow 4.5 \ \text{ if } Terrain = 3 \\ out \end{array} \right. \qquad E_R(Terrain) := \left| \begin{array}{l} out \leftarrow 1.2 \ \text{ if } Terrain = 1 \\ out \leftarrow 2.0 \ \text{ if } Terrain = 2 \\ out \leftarrow 4.0 \ \text{ if } Terrain = 3 \\ out \end{array} \right.$$

$E_T(Terrain) = 1.5 \quad E_T := E_T(Terrain) \quad E_R(Terrain) = 1.2 \quad E_R := E_R(Terrain)$

$$f_{HV} := \frac{1}{1 + P_T \cdot (E_T - 1) + P_R \cdot (E_R - 1)} \qquad f_{HV} = 0.9753$$

Find v_p (using Eq. 23-2)

$$v_p := \frac{FwyVol}{PHF \cdot N \cdot f_{HV} \cdot f_p} \qquad v_p = 1072.4 \text{ pc/h/ln}$$

Determine S

$S_1 := FFS$

$$S_2 := FFS - \left[\left(FFS - \frac{160}{3} \right) \cdot \left(\frac{v_p + 30 \cdot FFS - 3400}{30 \cdot FFS - 1000} \right)^{2.6} \right]$$

$$S_3 := FFS - \left[\frac{1}{9} \cdot (7 \cdot FFS - 340) \cdot \left(\frac{v_p + 30 \cdot FFS - 3400}{40 \cdot FFS - 1700} \right)^{2.6} \right]$$

$$S_{cont2} := \text{if}\left[(55 \le FFS \le 75) \wedge \left[v_p \le (3400 - 30 \cdot FFS) \right], S_1, \text{"Cannot Compute"} \right]$$

$$S_{cont1} := \text{if}\left[(55 \le FFS \le 70) \wedge \left[(3400 - 30 \cdot FFS) < v_p \le (1700 + 10 \cdot FFS) \right], S_3, S_{cont2} \right]$$

$$S := \text{if}\left[(70 < FFS \le 75) \wedge \left[(3400 - 30 \cdot FFS) < v_p \le 2400 \right], S_2, S_{cont1} \right]$$

$S = 65$

Density (using Eq. 23-4)

$$D := \frac{v_p}{S} \qquad D = 16.5 \qquad \text{pc/mi/ln}$$

Determine level of service (using Exhibit 23-2)

$$\text{LOS}(D) := \left| \begin{array}{l} \text{out} \leftarrow \text{"F"} \;\; \text{if } D > 45 \\ \text{out} \leftarrow \text{"E"} \;\; \text{if } 45 \ge D > 35 \\ \text{out} \leftarrow \text{"D"} \;\; \text{if } 35 \ge D > 26 \\ \text{out} \leftarrow \text{"C"} \;\; \text{if } 26 \ge D > 18 \\ \text{out} \leftarrow \text{"B"} \;\; \text{if } 18 \ge D > 11 \\ \text{out} \leftarrow \text{"A"} \;\; \text{if } 11 \ge D \\ \text{out} \end{array} \right.$$

$\text{LOS}(D) = \text{"B"}$

Determine Input Vol and %HV for Next Downstream Segment

$\text{FwyVolNew} := \text{FwyVol} = 2981$

$\%\text{Trucks}_{\text{FNew}} := \%\text{Trucks}_{\text{F}} = 5.055$

**FwyVolNew and %Trucks$_{FNew}$ are the input values for FwyVol and %Trucks$_F$ for the next downstream segment if there is one. If the next segment is a weave, then %Trucks$_{FNew}$ is the input value for %Trucks_FF and %Trucks_FR.*

Full On (2e)

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Step 1. Data Inputs and Volume Adjusments

**FwyVolNew and %Truck$_{SFNew}$ from the previous upstream segment are the input values for FwyVol and %Truck$_{SF}$ (if there is a previous upstream segment).*

A. Inputs

FwyVol := 2981 veh/h RampVol := 455 veh/h

$\%Trucks_F := 5.055$ $\%RV_F := 0$ PHF := 0.95 $f_p := 1$ FFS := 65 mi/h

$\%Trucks_R := 2$ $\%RV_R := 0$

NumLanes := 3 Number of mainline freeway lanes NRamp := 1 Number of lanes on ramp roadway

Terrain := 1 1 = Level, 2 = Rolling, 3 = Mountainous

$L_A := 1000$ ft Total length of Acceleration Lane

$S_{FR} := 40$ mi/h Freeflow speed of the ramp at the junction point

AdjUp := 2 AdjDn := 2 0 = none, 1 = on-ramp, 2 = off-ramp for Adjacent Upstream/Downstream Ramps

$L_{up} := 500$ ft $L_{down} := 8280$ ft

VolumeUp := 455 veh/h Volume on adjacent upstream ramp

VolumeDown := 455 veh/h Volume on adjacent downstream ramp

B. Heavy Vehicle Adjustments

Passenger Car Equivalents

$$E_T(Terrain) := \left| \begin{array}{lll} out \leftarrow 1.5 & \text{if} & Terrain = 1 \\ out \leftarrow 2.5 & \text{if} & Terrain = 2 \\ out \leftarrow 4.5 & \text{if} & Terrain = 3 \end{array} \right. \qquad E_R(Terrain) := \left| \begin{array}{lll} out \leftarrow 1.2 & \text{if} & Terrain = 1 \\ out \leftarrow 2.0 & \text{if} & Terrain = 2 \\ out \leftarrow 4.0 & \text{if} & Terrain = 3 \end{array} \right.$$

$E_T(Terrain) = 1.5$ $E_R(Terrain) = 1.2$

$E_T := E_T(Terrain)$ $E_T = 1.5$ $E_R := E_R(Terrain)$ $E_R = 1.2$

$$f\_HV_F := \frac{100}{100 + \%Trucks_F(E_T - 1) + \%RV_F(E_R - 1)} = 0.975 \qquad f\_HV_F = 0.975$$

$$f\_HV_R := \frac{100}{100 + \%Trucks_R(E_T - 1) + \%RV_R(E_R - 1)} \qquad f\_HV_R = 0.99$$

C. Demand Flow Rate

$$V_f := \frac{FwyVol}{PHF \cdot f\_HV_F \cdot f_p} \qquad V_f = 3217 \text{ pc/h} \qquad V_r := \frac{RampVol}{PHF \cdot f\_HV_R \cdot f_p} \qquad V_r = 484 \text{ pc/h}$$

$$V_u := \frac{VolumeUp}{PHF \cdot f\_HV_R \cdot f_p} \qquad V_u = 484 \text{ pc/h} \qquad V_d := \frac{VolumeDown}{PHF \cdot f\_HV_R \cdot f_p} \qquad V_d = 484 \text{ pc/h}$$

Step 2. Determine the Approaching Flow Rate in Lanes 1 and 2

A. Equilibrium Seperation Distance for Adjacent Off-Ramp on a Six Lane Freeway

$$L_{EQup} := 0.214(V_f + V_r) + 0.444 \cdot L_A + 53.32 \cdot S_{FR} - 2403 \qquad L_{EQup} = 966 \text{ ft}$$

$$L_{EQdown} := \frac{V_d}{0.1096 + 0.000107 \cdot L_A} \qquad L_{EQdown} = 2233 \text{ ft}$$

B. Estimating Proportion of Freeway Vehicles Remaining in lanes 1 and 2

$$Eqn1 := 0.5775 + 0.000028 \cdot L_A \qquad Eqn1 = 0.606$$

$$Eqn2 := 0.7289 - 0.0000135 \cdot (V_f + V_r) - 0.003296 \cdot S_{FR} + 0.000063 \cdot L_{up} \qquad Eqn2 = 0.579$$

$$Eqn3 := 0.5487 + 0.2628 \cdot \frac{V_d}{L_{down}} \qquad Eqn3 = 0.564$$

$$P_{FM}(NumLanes) := \left| \begin{array}{l}
out \leftarrow 1.00 \text{ if } NumLanes = 2 \\
out \leftarrow Eqn1 \text{ if } AdjUp \neq 2 \wedge AdjDn \neq 2 \wedge NumLanes = 3 \\
out \leftarrow Eqn3 \text{ if } AdjUp = 0 \wedge AdjDn = 2 \wedge L_{down} < L_{EQdown} \wedge NumLanes = 3 \\
out \leftarrow Eqn1 \text{ if } AdjUp = 0 \wedge AdjDn = 2 \wedge L_{down} \geq L_{EQdown} \wedge NumLanes = 3 \\
out \leftarrow Eqn2 \text{ if } AdjUp = 2 \wedge AdjDn = 0 \wedge L_{up} < L_{EQup} \wedge NumLanes = 3 \\
out \leftarrow Eqn1 \text{ if } AdjUp = 2 \wedge AdjDn = 0 \wedge L_{up} \geq L_{EQup} \wedge NumLanes = 3 \\
out \leftarrow Eqn1 \text{ if } AdjUp = 1 \wedge AdjDn = 1 \wedge NumLanes = 3 \\
out \leftarrow Eqn3 \text{ if } AdjUp = 1 \wedge AdjDn = 2 \wedge L_{down} < L_{EQdown} \wedge NumLanes = 3 \\
out \leftarrow Eqn1 \text{ if } AdjUp = 1 \wedge AdjDn = 2 \wedge L_{down} \geq L_{EQdown} \wedge NumLanes = 3 \\
out \leftarrow Eqn2 \text{ if } AdjUp = 2 \wedge AdjDn = 1 \wedge L_{up} < L_{EQup} \wedge NumLanes = 3 \\
out \leftarrow Eqn1 \text{ if } AdjUp = 2 \wedge AdjDn = 1 \wedge L_{up} \geq L_{EQup} \wedge NumLanes = 3 \\
out \leftarrow \max(Eqn1, Eqn2) \text{ if } AdjUp = 2 \wedge AdjDn = 2 \wedge L_{up} < L_{EQup} \wedge L_{down} \geq L_{EQdown} \wedge NumLanes = 3 \\
out \leftarrow \max(Eqn3, Eqn2) \text{ if } AdjUp = 2 \wedge AdjDn = 2 \wedge L_{up} < L_{EQup} \wedge L_{down} < L_{EQdown} \wedge NumLanes = 3 \\
out \leftarrow Eqn1 \text{ if } AdjUp = 2 \wedge AdjDn = 2 \wedge L_{up} \geq L_{EQup} \wedge L_{down} \geq L_{EQdown} \wedge NumLanes = 3 \\
out \leftarrow \max(Eqn1, Eqn3) \text{ if } AdjUp = 2 \wedge AdjDn = 2 \wedge L_{up} \geq L_{EQup} \wedge L_{down} < L_{EQdown} \wedge NumLanes = 3 \\
out \leftarrow 0.2178 - 0.0000125 \cdot V_r + -0.0115 \cdot \frac{L_A}{S_{FR}} \text{ if } \left(\frac{V_f}{S_{FR}} \leq 72\right) \wedge (NumLanes = 4) \\
out \leftarrow 0.2178 - 0.0000125 \cdot V_r \text{ if } \left(\frac{V_f}{S_{FR}} > 72\right) \wedge (NumLanes = 4)
\end{array} \right.$$

$$P_{FM} := P_{FM}(NumLanes) \qquad P_{FM} = 0.606$$

C. Estimating Flow in Lanes 1 and 2

$$V_{12} := V_f \cdot P_{FM} \qquad V_{12} = 1948 \text{ pc/h}$$

D. Checking the Reasonableness of the Lane Distribution Prediction

Six Lane Freeways

$$V_3 := V_f - V_{12} \qquad V_3 = 1269 \text{ pc/h}$$

Eight Lane Freeways

$$V_{av34} := \frac{V_f - V_{12}}{2} \qquad V_{av34} = 635 \text{ pc/h}$$

$$\text{V12a(NumLanes)} := \left|\begin{array}{l}
out \leftarrow V_{12} \quad \text{if} \quad NumLanes = 2 \\
out \leftarrow V_f - 2700 \quad \text{if} \quad V_3 > 2700 \wedge V_3 \le 1.5\cdot\frac{V_{12}}{2} \vee NumLanes = 3 \\
out \leftarrow \frac{V_f}{1.75} \quad \text{if} \quad V_3 \le 2700 \wedge V_3 > 1.5\cdot\frac{V_{12}}{2} \wedge NumLanes = 3 \\
out \leftarrow \max\left(V_f - 2700, \frac{V_f}{1.75}\right) \quad \text{if} \quad V_3 > 2700 \wedge V_3 > 1.5\cdot\frac{V_{12}}{2} \wedge NumLanes = 3 \\
out \leftarrow V_{12} \quad \text{if} \quad V_3 \le 2700 \wedge V_3 \le 1.5\cdot\frac{V_{12}}{2} \wedge NumLanes = 3 \\
out \leftarrow V_f - 5400 \quad \text{if} \quad V_{av34} > 2700 \wedge V_{av34} \le 1.5\cdot\frac{V_{12}}{2} \wedge NumLanes = 4 \\
out \leftarrow \frac{V_f}{2.50} \quad \text{if} \quad V_{av34} \le 2700 \wedge V_{av34} > 1.5\cdot\frac{V_{12}}{2} \wedge NumLanes = 4 \\
out \leftarrow \max\left(V_f - 5400, \frac{V_f}{2.50}\right) \quad \text{if} \quad V_{av34} > 2700 \wedge V_{av34} > 1.5\cdot\frac{V_{12}}{2} \wedge NumLanes = 4 \\
out \leftarrow V_{12} \quad \text{if} \quad V_{av34} \le 2700 \wedge V_{av34} \le 1.5\cdot\frac{V_{12}}{2} \wedge NumLanes = 4
\end{array}\right.$$

C. Final Flow in Lanes 1 and 2

$V_{12} := \text{V12a(NumLanes)}$ $\quad V_{12} = 1948$ pc/h

Step 3. Determine Capacity of Ramp-Freeway Junction

$V_{R12} := V_{12} + V_r$ $\quad V_{R12} = 2432$ pc/h $\quad$ Flow entering the ramp influence area

$$\text{CapUpFreewaySegment(NumLanes, FFS)} := \left|\begin{array}{l}
out \leftarrow 4800 \quad \text{if} \quad FFS \ge 70 \wedge NumLanes = 2 \\
out \leftarrow 4700 \quad \text{if} \quad FFS = 65 \wedge NumLanes = 2 \\
out \leftarrow 4600 \quad \text{if} \quad FFS = 60 \wedge NumLanes = 2 \\
out \leftarrow 4600 \quad \text{if} \quad FFS = 55 \wedge NumLanes = 2 \\
out \leftarrow 7200 \quad \text{if} \quad FFS = 70 \wedge NumLanes = 3 \\
out \leftarrow 7050 \quad \text{if} \quad FFS = 65 \wedge NumLanes = 3 \\
out \leftarrow 6900 \quad \text{if} \quad FFS = 60 \wedge NumLanes = 3 \\
out \leftarrow 6750 \quad \text{if} \quad FFS = 55 \wedge NumLanes = 3 \\
out \leftarrow 9600 \quad \text{if} \quad FFS = 70 \wedge NumLanes = 4 \\
out \leftarrow 9400 \quad \text{if} \quad FFS = 65 \wedge NumLanes = 4 \\
out \leftarrow 9200 \quad \text{if} \quad FFS = 60 \wedge NumLanes = 4 \\
out \leftarrow 9000 \quad \text{if} \quad FFS = 55 \wedge NumLanes = 4 \\
out \leftarrow 2400\cdot NumLanes \quad \text{if} \quad FFS = 70 \wedge NumLanes > 4 \\
out \leftarrow 2350\cdot NumLanes \quad \text{if} \quad FFS = 65 \wedge NumLanes > 4 \\
out \leftarrow 2300\cdot NumLanes \quad \text{if} \quad FFS = 60 \wedge NumLanes > 4 \\
out \leftarrow 2250\cdot NumLanes \quad \text{if} \quad FFS = 55 \wedge NumLanes > 4
\end{array}\right.$$

$\text{CapUpFreewaySegment}(\text{NumLanes}, \text{FFS}) = 7050$ Capacity of Ramp Freeway Junction

MaxV12 = 4600 Maximum Desirable Flow Rate Entering Merge Influence Area

$$\text{CapacityRampRoadway} := \left| \begin{array}{l} \text{out} \leftarrow 2200 \quad \text{if} \quad (\text{NRamp} = 1) \wedge (S_{FR} > 50) \\ \text{out} \leftarrow 2100 \quad \text{if} \quad (\text{NRamp} = 1) \wedge (40 < S_{FR} \le 50) \\ \text{out} \leftarrow 2000 \quad \text{if} \quad (\text{NRamp} = 1) \wedge (30 < S_{FR} \le 40) \\ \text{out} \leftarrow 1900 \quad \text{if} \quad (\text{NRamp} = 1) \wedge (20 \le S_{FR} \le 30) \\ \text{out} \leftarrow 1800 \quad \text{if} \quad (\text{NRamp} = 1) \wedge (20 > S_{FR}) \\ \text{out} \leftarrow 4400 \quad \text{if} \quad (\text{NRamp} = 2) \wedge (S_{FR} > 50) \\ \text{out} \leftarrow 4200 \quad \text{if} \quad (\text{NRamp} = 2) \wedge (40 < S_{FR} \le 50) \\ \text{out} \leftarrow 4000 \quad \text{if} \quad (\text{NRamp} = 2) \wedge (30 < S_{FR} \le 40) \\ \text{out} \leftarrow 3800 \quad \text{if} \quad (\text{NRamp} = 2) \wedge (20 \le S_{FR} \le 30) \\ \text{out} \leftarrow 3600 \quad \text{if} \quad (\text{NRamp} = 2) \wedge (20 > S_{FR}) \end{array} \right.$$

$\text{CapacityRampRoadway} = 2000$

$V_{FO} := V_f + V_r$ $V_{FO} = 3701$ pc/h Volume immediatley downstream of on-ramp influence area

Ramp Freeway Junction Checkpoint Volume immediatley downstream of on-ramp influence area is chekced against freeway capacity. Failure of ramp freeway junction checkpoint (i.e. demand exceeds capacity) results in LOS F

Ramp Roadway Capacity Checkpoint Capacity or ramp roadway should always be checked against the demand flow rate on the ramp. It is rarely a problem for the on-ramp

Maximum Desirable Flow Entering Ramp Influence Area Checkpoint While the V_{R12} values is checked against the maximum desirable, failure does not result in assignment of LOS F. Failing this checkpoint generally means that there will be more turbulance in influence area than predicted by this methodology. Thus, predicted densities are most likely lower than those that will exist, and predicted speeds are most likely to be predicted as higher than those that will actually occur.

Step 4. Determine Speeds in the Vicinity of Ramp-Freeway Junction

A. Average Speed in the Ramp Influence Area

$$S_R := FFS - (FFS - 42) \cdot \left[0.321 + 0.0039 \exp\left(\frac{V_{R12}}{1000}\right) - 0.002 \cdot \left(L_A \frac{S_{FR}}{1000}\right)\right] \qquad S_R = 58.44 \quad \text{mi/h}$$

B. Average Speed in the Outer Lanes of Freeway

Average Flow in Outer Lanes

$$No := \begin{array}{|l} out \leftarrow 1 \quad \text{if} \quad NumLanes = 3 \\ out \leftarrow 2 \quad \text{if} \quad NumLanes = 4 \\ out \leftarrow \infty \quad \text{if} \quad NumLanes = 2 \end{array} \qquad V_{OA} := \frac{V_f - V_{12}}{No} \qquad V_{OA} = 1269$$

$$S_O(V_{OA}) := \begin{array}{|l} out \leftarrow FFS \quad \text{if} \quad V_{OA} < 500 \\ out \leftarrow FFS - 0.0036 \cdot (V_{OA} - 500) \quad \text{if} \quad 500 \le V_{OA} \le 2300 \\ out \leftarrow FFS - 6.53 - 0.006 \cdot (V_{OA} - 2300) \quad \text{if} \quad V_{OA} > 2300 \end{array}$$

$$S_O := S_O(V_{OA}) \qquad S_O = 62.23 \quad \text{mi/h}$$

C. Average Speed for On-Ramp Junction

$$Speed := \frac{V_{R12} + V_{OA} \cdot No}{\left(\frac{V_{R12}}{S_R}\right) + \left(\frac{V_{OA} \cdot No}{S_O}\right)} \qquad Speed = 59.68 \quad \text{mi/h}$$

Step 5. Determine the Density and Level of Service

A. Density in On-Ramp Influence Area

$$Density_R := 5.475 + 0.00734 \cdot V_r + 0.0078 \cdot V_{12} - 0.00627 \cdot L_A \qquad Density_R = 18 \quad \text{pc/mi/ln}$$

B. Density in Outer Lanes

$$Density_O := \frac{V_{OA}}{S_O} \qquad Density_O = 20.4 \quad \text{pc/mi/ln}$$

C. Density of Entire Cross-Section

$$Density := \begin{array}{|l} out \leftarrow Density_R \quad \text{if} \quad NumLanes \le 2 \\ out \leftarrow \frac{\left[Density_R \cdot (2) + Density_O \cdot (NumLanes - 2)\right]}{NumLanes} \quad \text{if} \quad NumLanes > 2 \end{array} \qquad Density = 18.8 \quad \text{pc/mi/ln}$$

D. Level of Service

$$LOS(Density) := \begin{array}{|l} out \leftarrow \text{"A"} \quad \text{if} \quad 0 \le Density \le 10 \\ out \leftarrow \text{"B"} \quad \text{if} \quad 10 < Density \le 20 \\ out \leftarrow \text{"C"} \quad \text{if} \quad 20 < Density \le 28 \\ out \leftarrow \text{"D"} \quad \text{if} \quad 28 < Density \le 35 \\ out \leftarrow \text{"E"} \quad \text{if} \quad 35 < Density \end{array} \qquad LOS(Density) = \text{"B"}$$

Step 6. Determine Input Vol and %HV for Next Downstream Segment

$$FwyVol_{Cars} := FwyVol \cdot \left(1 - \frac{\%Trucks_F}{100}\right) = 2830.3$$

$$RampVol_{Cars} := RampVol \cdot \left(1 - \frac{\%Trucks_R}{100}\right) = 445.9$$

$$FwyVol_{CarsNew} := FwyVol_{Cars} + RampVol_{Cars} = 3276.2$$

$$FwyVol_{Trucks} := FwyVol \cdot \frac{\%Trucks_F}{100} = 150.69$$

$$RampVol_{Trucks} := RampVol \cdot \left(\frac{\%Trucks_R}{100}\right) = 9.1$$

$$FwyVol_{TrucksNew} := FwyVol_{Trucks} + RampVol_{Trucks} = 159.79$$

$$FwyVolNew := FwyVol_{CarsNew} + FwyVol_{TrucksNew} = 3436$$

$$\%Trucks_{FNew} := \frac{FwyVol_{TrucksNew}}{FwyVolNew} \cdot 100 = 4.6505$$

**FwyVolNew and $\%Trucks_{FNew}$ are the input values for FwyVol and $\%Trucks_F$ for the next downstream segment if there is one. If the next segment is a weave, then $\%Trucks_{FNew}$ is the input value for %Trucks_FF and %Trucks_FR.*

Basic (3)

Input Values

$FwyVolNew$ and $\%Trucks_{FNew}$ from the previous upstream segment are the input values for FwyVol and $\%Trucks_F$ (if there is a previous upstream segment).

Traffic

$FwyVol := 3436 \quad PHF := 0.95$

$f_p := 1.0 \quad FFS := 65$

$\%Trucks_F := 4.6505 \quad P_R := 0$

$$P_T := \frac{\%Trucks_F}{100} = 0.0465$$

Roadway

$N := 3 \quad LaneWidth := 12 \quad LatClear := 6 \quad IntDens := 0.87$

$Terrain := 1$ 1 = Level, 2 = Rolling, 3 = Mountainous

$AreaType := 2$ 1 = Rural, 2 = Urban

**FREEPLAN finds IntDens by counting parclos and diamond as 1 interchange each, full as 2, and on and off as 1/2 each and adds them. Then, it divides that total number of interchanges by the total length of the facility.*

Find f_{HV} (using Exhibit 23-8 and Eq. 23-3)

$$E_T(Terrain) := \left| \begin{array}{l} out \leftarrow 1.5 \ \text{ if } Terrain = 1 \\ out \leftarrow 2.5 \ \text{ if } Terrain = 2 \\ out \leftarrow 4.5 \ \text{ if } Terrain = 3 \\ out \end{array} \right. \qquad E_R(Terrain) := \left| \begin{array}{l} out \leftarrow 1.2 \ \text{ if } Terrain = 1 \\ out \leftarrow 2.0 \ \text{ if } Terrain = 2 \\ out \leftarrow 4.0 \ \text{ if } Terrain = 3 \\ out \end{array} \right.$$

$E_T(Terrain) = 1.5 \quad E_T := E_T(Terrain) \qquad E_R(Terrain) = 1.2 \quad E_R := E_R(Terrain)$

$$f_{HV} := \frac{1}{1 + P_T \cdot (E_T - 1) + P_R \cdot (E_R - 1)} \qquad f_{HV} = 0.9773$$

Find v_p (using Eq. 23-2)

$$v_p := \frac{FwyVol}{PHF \cdot N \cdot f_{HV} \cdot f_p} \qquad v_p = 1233.6 \ \text{pc/h/ln}$$

Determine S

$S_1 := FFS$

$$S_2 := FFS - \left[\left(FFS - \frac{160}{3}\right) \cdot \left(\frac{v_p + 30 \cdot FFS - 3400}{30 \cdot FFS - 1000}\right)^{2.6}\right]$$

$$S_3 := FFS - \left[\frac{1}{9} \cdot (7 \cdot FFS - 340) \cdot \left(\frac{v_p + 30 \cdot FFS - 3400}{40 \cdot FFS - 1700}\right)^{2.6}\right]$$

$$S_{cont2} := \text{if}\left[(55 \le FFS \le 75) \wedge \left[v_p \le (3400 - 30 \cdot FFS)\right], S_1, \text{"Cannot Compute"}\right]$$

$$S_{cont1} := \text{if}\left[(55 \le FFS \le 70) \wedge \left[(3400 - 30 \cdot FFS) < v_p \le (1700 + 10 \cdot FFS)\right], S_3, S_{cont2}\right]$$

$$S := \text{if}\left[(70 < FFS \le 75) \wedge \left[(3400 - 30 \cdot FFS) < v_p \le 2400\right], S_2, S_{cont1}\right]$$

$S = 65$

Density (using Eq. 23-4)

$D := \frac{v_p}{S}$ $\qquad D = 19$ $\qquad$ pc/mi/ln

Determine level of service (using Exhibit 23-2)

$$
LOS(D) := \left|
\begin{array}{l}
out \leftarrow \text{"F"} \quad \text{if } D > 45 \\
out \leftarrow \text{"E"} \quad \text{if } 45 \ge D > 35 \\
out \leftarrow \text{"D"} \quad \text{if } 35 \ge D > 26 \\
out \leftarrow \text{"C"} \quad \text{if } 26 \ge D > 18 \\
out \leftarrow \text{"B"} \quad \text{if } 18 \ge D > 11 \\
out \leftarrow \text{"A"} \quad \text{if } 11 \ge D \\
out
\end{array}
\right.
$$

$LOS(D) = \text{"C"}$

Determine Input Vol and %HV for Next Downstream Segment

$FwyVolNew := FwyVol = 3436$

$\%Trucks_{FNew} := \%Trucks_F = 4.6505$

**FwyVolNew and %Trucks$_{FNew}$ are the input values for FwyVol and %Trucks$_F$ for the next downstream segment if there is one. If the next segment is a weave, then %Trucks$_{FNew}$ is the input value for %Trucks_FF and %Trucks_FR.*

Diamond Off (4a)

Step 1. Data Inputs and Volume Adjusments

**FwyVolNew and %Truck$_{SFNew}$ from the previous upstream segment are the input values for FwyVol and %Truck$_{SF}$ (if there is a previous upstream segment).*

A. Inputs

$FwyVol := 3436$ veh/h $\quad$ $RampVol := 455$ veh/h

$\%Trucks_F := 4.6505$ $\quad$ $\%RV_F := 0$ $\quad$ $PHF := 0.95$ $\quad$ $f_p := 1$ $\quad$ $FFS := 65$ mi/h

$\%Trucks_R := 2$ $\quad$ $\%RV_R := 0$

$NumLanes := 3$ Number of mainline freeway lanes $\quad$ $NRamp := 1$ Number of lanes on ramp roadway

$Terrain := 1$ 1 = Level, 2 = Rolling, 3 = Mountainous

$L_D := 450$ ft Total length of Deceleration Lane

$S_{FR} := 40$ mi/h Freeflow speed of the ramp at the junction point

$AdjUp := 2$ $\quad$ $AdjDn := 1$ $\quad$ 0 = none, 1 = on-ramp, 2 = off-ramp for Adjacent Upstream/Downstream Ramps

$L_{up} := 8280$ ft $\quad$ $L_{down} := 2280$ ft

$VolumeUp := 455$ veh/h Volume on adjacent upstream ramp

$VolumeDown := 700$ veh/h Volume on adjacent downstream ramp

B. Heavy Vehicle Adjustments

Passenger Car Equivalents

$$E_T(Terrain) := \begin{array}{|l} out \leftarrow 1.5 \text{ if } Terrain = 1 \\ out \leftarrow 2.5 \text{ if } Terrain = 2 \\ out \leftarrow 4.5 \text{ if } Terrain = 3 \end{array} \qquad E_R(Terrain) := \begin{array}{|l} out \leftarrow 1.2 \text{ if } Terrain = 1 \\ out \leftarrow 2.0 \text{ if } Terrain = 2 \\ out \leftarrow 4.0 \text{ if } Terrain = 3 \end{array}$$

$E_T(Terrain) = 1.5$ $\quad$ $E_R(Terrain) = 1.2$

$E_T := E_T(Terrain)$ $\quad$ $E_T = 1.5$ $\quad$ $E_R := E_R(Terrain)$ $\quad$ $E_R = 1.2$

$$f\_HV_F := \frac{100}{100 + \%Trucks_F(E_T - 1) + \%RV_F(E_R - 1)} \qquad f\_HV_F = 0.977$$

$$f\_HV_R := \frac{100}{100 + \%Trucks_R(E_T - 1) + \%RV_R(E_R - 1)} \qquad f\_HV_R = 0.99$$

C. Demand Flow Rate

$$V_f := \frac{FwyVol}{PHF \cdot f\_HV_F \cdot f_p} \qquad V_f = 3701 \text{ pc/h} \qquad V_r := \frac{RampVol}{PHF \cdot f\_HV_R \cdot f_p} \qquad V_r = 484 \text{ pc/h}$$

$$V_u := \frac{VolumeUp}{PHF \cdot f\_HV_R \cdot f_p} \qquad V_u = 484 \text{ pc/h} \qquad V_d := \frac{VolumeDown}{PHF \cdot f\_HV_R \cdot f_p} \qquad V_d = 744 \text{ pc/h}$$

Step 2. Determine the Approaching Flow Rate in Lanes 1 and 2

A. Equilibrium Seperation Distance for Adjacent Upstream On-Ramp or Downstream Off-Ramps on a Six Lane

Freeway

$$L_{EQup} := \frac{V_u}{0.071 + 0.000023 \cdot V_f - 0.000076 \cdot V_r} \qquad L_{EQup} = 4053 \quad \text{ft}$$

$$L_{EQdown} := \frac{V_d}{1.15 - 0.000032 \cdot V_f - 0.000369 \cdot V_r} \qquad L_{EQdown} = 872 \quad \text{ft}$$

B. Estimating Proportion of Freeway Vehicles Remaining in lanes 1 and 2

$$Eqn1 := 0.760 - 0.000025 \cdot V_f - 0.000046 \cdot V_r \qquad Eqn1 = 0.645$$

$$Eqn2 := 0.717 - 0.000039 \cdot V_f + 0.604 \cdot \frac{V_u}{L_{up}} \qquad Eqn2 = 0.608$$

$$Eqn3 := 0.616 - 0.000021 \cdot V_f + 0.124 \cdot \frac{V_d}{L_{down}} \qquad Eqn3 = 0.579$$

$$P_{FD}(\text{Numlanes}) := \left| \begin{array}{l}
out \leftarrow 1.00 \quad \text{if} \quad NumLanes = 2 \\
out \leftarrow Eqn1 \quad \text{if} \quad AdjUp = 0 \wedge AdjDn = 0 \wedge NumLanes = 3 \\
out \leftarrow Eqn1 \quad \text{if} \quad AdjUp = 0 \wedge AdjDn = 1 \wedge NumLanes = 3 \\
out \leftarrow Eqn1 \quad \text{if} \quad AdjUp = 0 \wedge AdjDn = 2 \wedge L_{down} \geq L_{EQdown} \wedge NumLanes = 3 \\
out \leftarrow Eqn3 \quad \text{if} \quad AdjUp = 0 \wedge AdjDn = 2 \wedge L_{down} < L_{EQdown} \wedge NumLanes = 3 \\
out \leftarrow Eqn1 \quad \text{if} \quad AdjUp = 1 \wedge AdjDn = 0 \wedge L_{up} \geq L_{EQup} \wedge NumLanes = 3 \\
out \leftarrow Eqn2 \quad \text{if} \quad AdjUp = 1 \wedge AdjDn = 0 \wedge L_{up} < L_{EQup} \wedge NumLanes = 3 \\
out \leftarrow Eqn1 \quad \text{if} \quad AdjUp = 2 \wedge AdjDn = 0 \wedge NumLanes = 3 \\
out \leftarrow Eqn1 \quad \text{if} \quad AdjUp = 1 \wedge AdjDn = 1 \wedge L_{up} \geq L_{EQup} \wedge NumLanes = 3 \\
out \leftarrow Eqn2 \quad \text{if} \quad AdjUp = 1 \wedge AdjDn = 1 \wedge L_{up} < L_{EQup} \wedge NumLanes = 3 \\
out \leftarrow \max(Eqn2, Eqn3) \quad \text{if} \quad AdjUp = 1 \wedge AdjDn = 2 \wedge L_{up} < L_{EQup} \wedge L_{down} < L_{EQdown} \wedge NumLanes = 3 \\
out \leftarrow \max(Eqn2, Eqn1) \quad \text{if} \quad AdjUp = 1 \wedge AdjDn = 2 \wedge L_{up} < L_{EQup} \wedge L_{down} \geq L_{EQdown} \wedge NumLanes = 3 \\
out \leftarrow Eqn1 \quad \text{if} \quad AdjUp = 1 \wedge AdjDn = 2 \wedge L_{up} \geq L_{EQup} \wedge L_{down} \geq L_{EQdown} \wedge NumLanes = 3 \\
out \leftarrow \max(Eqn3, Eqn1) \quad \text{if} \quad AdjUp = 1 \wedge AdjDn = 2 \wedge L_{up} \geq L_{EQup} \wedge L_{down} < L_{EQdown} \wedge NumLanes = 3 \\
out \leftarrow Eqn1 \quad \text{if} \quad AdjUp = 2 \wedge AdjDn = 1 \wedge NumLanes = 3 \\
out \leftarrow Eqn1 \quad \text{if} \quad AdjUp = 2 \wedge AdjDn = 2 \wedge L_{down} \geq L_{EQdown} \wedge NumLanes = 3 \\
out \leftarrow Eqn3 \quad \text{if} \quad AdjUp = 2 \wedge AdjDn = 2 \wedge L_{down} < L_{EQdown} \wedge NumLanes = 3 \\
out \leftarrow 0.436 \quad \text{if} \quad NumLanes = 4
\end{array} \right.$$

$$P_{FD} := P_{FD}(\text{NumLanes}) \qquad P_{FD} = 0.645$$

C. Estimating Flow in Lanes 1 and 2

$$V_{12} := V_r + (V_f - V_r) \cdot P_{FD} \qquad V_{12} = 2560 \quad \text{pc/h}$$

D. Checking the Reasonableness of the Lane Distribution Prediction

Six Lane Freeways *Eight Lane Freeways*

$V_3 := V_f - V_{12}$ $\quad$ $V_3 = 1141$ pc/h $\qquad$ $V_{av34} := \dfrac{V_f - V_{12}}{2}$ $\quad$ $V_{av34} = 571$ pc/h

$$
\text{V12a}(\text{NumLanes}) := \left|
\begin{array}{l}
\text{out} \leftarrow V_{12} \quad \text{if} \quad \text{NumLanes} = 2 \\
\text{out} \leftarrow V_f - 2700 \quad \text{if} \quad V_3 > 2700 \wedge V_3 \le 1.5 \cdot \dfrac{V_{12}}{2} \vee \text{NumLanes} = 3 \\
\text{out} \leftarrow \dfrac{V_f}{1.75} \quad \text{if} \quad V_3 \le 2700 \wedge V_3 > 1.5 \cdot \dfrac{V_{12}}{2} \wedge \text{NumLanes} = 3 \\
\text{out} \leftarrow \max\left(V_f - 2700, \dfrac{V_f}{1.75}\right) \quad \text{if} \quad V_3 > 2700 \wedge V_3 > 1.5 \cdot \dfrac{V_{12}}{2} \wedge \text{NumLanes} = 3 \\
\text{out} \leftarrow V_{12} \quad \text{if} \quad V_3 \le 2700 \wedge V_3 \le 1.5 \cdot \dfrac{V_{12}}{2} \wedge \text{NumLanes} = 3 \\
\text{out} \leftarrow V_f - 5400 \quad \text{if} \quad V_{av34} > 2700 \wedge V_{av34} \le 1.5 \cdot \dfrac{V_{12}}{2} \wedge \text{NumLanes} = 4 \\
\text{out} \leftarrow \dfrac{V_f}{2.50} \quad \text{if} \quad V_{av34} \le 2700 \wedge V_{av34} > 1.5 \cdot \dfrac{V_{12}}{2} \wedge \text{NumLanes} = 4 \\
\text{out} \leftarrow \max\left(V_f - 5400, \dfrac{V_f}{2.50}\right) \quad \text{if} \quad V_{av34} > 2700 \wedge V_{av34} > 1.5 \cdot \dfrac{V_{12}}{2} \wedge \text{NumLanes} = 4 \\
\text{out} \leftarrow V_{12} \quad \text{if} \quad V_{av34} \le 2700 \wedge V_{av34} \le 1.5 \cdot \dfrac{V_{12}}{2} \wedge \text{NumLanes} = 4
\end{array}
\right.
$$

C. Final Flow in Lanes 1 and 2

$V_{12} := \text{V12a}(\text{NumLanes})$ $\qquad$ $V_{12} = 2560$ pc/h

Step 3. Determine Capacity of Ramp-Freeway Junction

$$\text{CapUpFreewaySegment}(\text{NumLanes}, \text{FFS}) := \begin{array}{|l} \text{out} \leftarrow 4800 \quad \text{if} \quad \text{FFS} \geq 70 \wedge \text{NumLanes} = 2 \\ \text{out} \leftarrow 4700 \quad \text{if} \quad \text{FFS} = 65 \wedge \text{NumLanes} = 2 \\ \text{out} \leftarrow 4600 \quad \text{if} \quad \text{FFS} = 60 \wedge \text{NumLanes} = 2 \\ \text{out} \leftarrow 4600 \quad \text{if} \quad \text{FFS} = 55 \wedge \text{NumLanes} = 2 \\ \text{out} \leftarrow 7200 \quad \text{if} \quad \text{FFS} = 70 \wedge \text{NumLanes} = 3 \\ \text{out} \leftarrow 7050 \quad \text{if} \quad \text{FFS} = 65 \wedge \text{NumLanes} = 3 \\ \text{out} \leftarrow 6900 \quad \text{if} \quad \text{FFS} = 60 \wedge \text{NumLanes} = 3 \\ \text{out} \leftarrow 6750 \quad \text{if} \quad \text{FFS} = 55 \wedge \text{NumLanes} = 3 \\ \text{out} \leftarrow 9600 \quad \text{if} \quad \text{FFS} = 70 \wedge \text{NumLanes} = 4 \\ \text{out} \leftarrow 9400 \quad \text{if} \quad \text{FFS} = 65 \wedge \text{NumLanes} = 4 \\ \text{out} \leftarrow 9200 \quad \text{if} \quad \text{FFS} = 60 \wedge \text{NumLanes} = 4 \\ \text{out} \leftarrow 9000 \quad \text{if} \quad \text{FFS} = 55 \wedge \text{NumLanes} = 4 \\ \text{out} \leftarrow 2400 \cdot \text{NumLanes} \quad \text{if} \quad \text{FFS} = 70 \wedge \text{NumLanes} > 4 \\ \text{out} \leftarrow 2350 \cdot \text{NumLanes} \quad \text{if} \quad \text{FFS} = 65 \wedge \text{NumLanes} > 4 \\ \text{out} \leftarrow 2300 \cdot \text{NumLanes} \quad \text{if} \quad \text{FFS} = 60 \wedge \text{NumLanes} > 4 \\ \text{out} \leftarrow 2250 \cdot \text{NumLanes} \quad \text{if} \quad \text{FFS} = 55 \wedge \text{NumLanes} > 4 \end{array}$$

$\text{CapUpFreewaySegment}(\text{NumLanes}, \text{FFS}) = 7050$ Capacity of Ramp Freeway Junction

MaxV12 = 4400 Maximum Desirable Flow Rate Entering Merge Influence Area

$$\text{CapacityRampRoadway} := \begin{array}{|l} \text{out} \leftarrow 2200 \quad \text{if} \quad (\text{NRamp} = 1) \wedge (S_{FR} > 50) \\ \text{out} \leftarrow 2100 \quad \text{if} \quad (\text{NRamp} = 1) \wedge (40 < S_{FR} \leq 50) \\ \text{out} \leftarrow 2000 \quad \text{if} \quad (\text{NRamp} = 1) \wedge (30 < S_{FR} \leq 40) \\ \text{out} \leftarrow 1900 \quad \text{if} \quad (\text{NRamp} = 1) \wedge (20 \leq S_{FR} \leq 30) \\ \text{out} \leftarrow 1800 \quad \text{if} \quad (\text{NRamp} = 1) \wedge (20 > S_{FR}) \\ \text{out} \leftarrow 4400 \quad \text{if} \quad (\text{NRamp} = 2) \wedge (S_{FR} > 50) \\ \text{out} \leftarrow 4200 \quad \text{if} \quad (\text{NRamp} = 2) \wedge (40 < S_{FR} \leq 50) \\ \text{out} \leftarrow 4000 \quad \text{if} \quad (\text{NRamp} = 2) \wedge (30 < S_{FR} \leq 40) \\ \text{out} \leftarrow 3800 \quad \text{if} \quad (\text{NRamp} = 2) \wedge (20 \leq S_{FR} \leq 30) \\ \text{out} \leftarrow 3600 \quad \text{if} \quad (\text{NRamp} = 2) \wedge (20 > S_{FR}) \end{array}$$

$\text{CapacityRampRoadway} = 2000$

$V_f = 3701$ pc/h Volume immediatley upstream of off-ramp influence area

Ramp Freeway Junction Checkpoint — Volume immediatley upstream of off-ramp influence area is chekced against freeway capacity. Failure of ramp freeway junction checkpoint (i.e. demand exceeds capacity) results in LOS F

Ramp Roadway Capacity Checkpoint — If the off-ramp demand flow rate (Vr) exceeds the capacity of the off-ramp, LOS F prevails.

Maximum Desirable Flow Entering Ramp Influence Area Checkpoint

While the V12 values is checked against the maximum desirable, failure does not result in assignment of LOS F. Failing this checkpoint generally means that there will be more turbulance in influence area than predicted by this methodology. Thus, predicted densities are most likely lower than those that will exist, and predicted speeds are most likely to be predicted as higher than those that will actually occur.

Step 4. Determine Speeds in the Vicinity of Ramp-Freeway Junction

A. Average Speed in the Ramp Influence Area

$$S_R := FFS - (FFS - 42)\cdot(0.883 + 0.00009 \cdot V_r - 0.013 \cdot S_{FR})$$

$S_R = 55.65$ mi/h

B. Average Speed in the Outer Lanes of Freeway

Average Flow in Outer Lanes

$$N_o := \left| \begin{array}{l} out \leftarrow 1 \quad \text{if} \quad NumLanes = 3 \\ out \leftarrow 2 \quad \text{if} \quad NumLanes = 4 \\ out \leftarrow \infty \quad \text{if} \quad NumLanes = 2 \end{array} \right.$$

$$V_{OA} := \frac{V_f - V_{12}}{N_o}$$

$V_{OA} = 1141$

$$S_O(V_{OA}) := \left| \begin{array}{l} out \leftarrow 1.097 \cdot FFS \quad \text{if} \quad V_{OA} < 1000 \\ out \leftarrow 1.097 \cdot FFS - 0.0039 \cdot (V_{OA} - 1000) \quad \text{if} \quad 1000 \le V_{OA} \end{array} \right.$$

$S_O := S_O(V_{OA})$ $\qquad$ $S_O = 70.75$ mi/h

C. Average Speed for Off-Ramp Junction

$$Speed := \frac{V_{12} + V_{OA} \cdot N_o}{\left(\frac{V_{12}}{S_R}\right) + \left(\frac{V_{OA} \cdot N_o}{S_O}\right)}$$

$Speed = 59.57$ mi/h

Step 5. Determine the Density and Level of Service

A. Density in Off-Ramp Influence Area

$$Density_R := 4.252 + 0.0086 \cdot V_{12} - 0.009 \cdot L_D$$ $Density_R = 22.2$ pc/mi/ln

B. Density in Outer Lanes

$$Density_O := \frac{V_{OA}}{S_O}$$ $Density_O = 16.1$ pc/mi/ln

C. Density of Entire Cross-Section

$$Density := \begin{array}{|l} out \leftarrow Density_R \quad \text{if} \quad NumLanes \le 2 \\ out \leftarrow \dfrac{\left[Density_R \cdot (2) + Density_O \cdot (NumLanes - 2)\right]}{NumLanes} \quad \text{if} \quad NumLanes > 2 \end{array}$$ $Density = 20.2$ pc/mi/ln

D. Level of Service

$$LOS(Density) := \begin{array}{|l} out \leftarrow \text{"A"} \quad \text{if} \quad 0 \le Density \le 10 \\ out \leftarrow \text{"B"} \quad \text{if} \quad 10 < Density \le 20 \\ out \leftarrow \text{"C"} \quad \text{if} \quad 20 < Density \le 28 \\ out \leftarrow \text{"D"} \quad \text{if} \quad 28 < Density \le 35 \\ out \leftarrow \text{"E"} \quad \text{if} \quad 35 < Density \end{array}$$ $LOS(Density) = \text{"C"}$

Step 6. Determine Input Vol and %HV for Next Downstream Segment

$$FwyVol_{Cars} := FwyVol \cdot \left(1 - \frac{\%Trucks_F}{100}\right) = 3276.2$$

$$RampVol_{Cars} := RampVol \cdot \left(1 - \frac{\%Trucks_R}{100}\right) = 445.9$$

$$FwyVol_{CarsNew} := FwyVol_{Cars} - RampVol_{Cars} = 2830.3$$

$$FwyVol_{Trucks} := FwyVol \cdot \frac{\%Trucks_F}{100} = 159.791$$

$$RampVol_{Trucks} := RampVol \cdot \left(\frac{\%Trucks_R}{100}\right) = 9.1$$

$$FwyVol_{TrucksNew} := FwyVol_{Trucks} - RampVol_{Trucks} = 150.691$$

$$FwyVolNew := FwyVol_{CarsNew} + FwyVol_{TrucksNew} = 2981$$

$$\%Trucks_{FNew} := \frac{FwyVol_{TrucksNew}}{FwyVolNew} \cdot 100 = 5.0551$$

**FwyVolNew and %Trucks_{FNew} are the input values for FwyVol and %Trucks_F for the next downstream segment if there is one. If the next segment is a weave, then %Trucks_{FNew} is the input value for %Trucks_FF and %Trucks_FR.*

Diamond Basic (4b)

**FwyVolNew and %Trucks$_{FNew}$ from the previous upstream segment are the input values for FwyVol and %Trucks$_F$ (if there is a previous upstream segment).*

Input Values

Traffic

$FwyVol := 2981 \quad PHF := 0.95$

$f_p := 1.0 \quad FFS := 65$

$\%Trucks_F := 5.0551 \quad P_R := 0$

$$P_T := \frac{\%Trucks_F}{100} = 0.0506$$

Roadway

$N := 3 \quad LaneWidth := 12 \quad LatClear := 6 \quad IntDens := 0.87$

$Terrain := 1$ 1 = Level, 2 = Rolling, 3 = Mountainous

$AreaType := 2$ 1 = Rural, 2 = Urban

**FREEPLAN finds IntDens by counting parclos and diamond as 1 interchange each, full as 2, and on and off as 1/2 each and adds them. Then, it divides that total number of interchanges by the total length of the facility.*

Find f_{HV} (using Exhibit 23-8 and Eq. 23-3)

$$E_T(Terrain) := \left| \begin{array}{l} out \leftarrow 1.5 \ \text{ if } Terrain = 1 \\ out \leftarrow 2.5 \ \text{ if } Terrain = 2 \\ out \leftarrow 4.5 \ \text{ if } Terrain = 3 \\ out \end{array} \right. \qquad E_R(Terrain) := \left| \begin{array}{l} out \leftarrow 1.2 \ \text{ if } Terrain = 1 \\ out \leftarrow 2.0 \ \text{ if } Terrain = 2 \\ out \leftarrow 4.0 \ \text{ if } Terrain = 3 \\ out \end{array} \right.$$

$E_T(Terrain) = 1.5 \quad E_T := E_T(Terrain) \qquad E_R(Terrain) = 1.2 \quad E_R := E_R(Terrain)$

$$f_{HV} := \frac{1}{1 + P_T \cdot (E_T - 1) + P_R \cdot (E_R - 1)} \qquad f_{HV} = 0.9753$$

Find v_p (using Eq. 23-2)

$$v_p := \frac{FwyVol}{PHF \cdot N \cdot f_{HV} \cdot f_p} \qquad v_p = 1072.4 \ \text{pc/h/ln}$$

Determine S

$S_1 := FFS$

$$S_2 := FFS - \left[\left(FFS - \frac{160}{3} \right) \cdot \left(\frac{v_p + 30 \cdot FFS - 3400}{30 \cdot FFS - 1000} \right)^{2.6} \right]$$

$$S_3 := FFS - \left[\frac{1}{9} \cdot (7 \cdot FFS - 340) \cdot \left(\frac{v_p + 30 \cdot FFS - 3400}{40 \cdot FFS - 1700} \right)^{2.6} \right]$$

$S_{cont2} := \text{if}\left[(55 \le FFS \le 75) \wedge \left[v_p \le (3400 - 30 \cdot FFS)\right], S_1, \text{"Cannot Compute"}\right]$

$S_{cont1} := \text{if}\left[(55 \le FFS \le 70) \wedge \left[(3400 - 30 \cdot FFS) < v_p \le (1700 + 10 \cdot FFS)\right], S_3, S_{cont2}\right]$

$S := \text{if}\left[(70 < FFS \le 75) \wedge \left[(3400 - 30 \cdot FFS) < v_p \le 2400\right], S_2, S_{cont1}\right]$

$S = 65$ mi/h

Density (using Eq. 23-4)

$D := \frac{v_p}{S}$ $D = 16.5$ pc/mi/ln

Determine level of service (using Exhibit 23-2)

$$\text{LOS}(D) := \left| \begin{array}{l} \text{out} \leftarrow \text{"F"} \quad \text{if } D > 45 \\ \text{out} \leftarrow \text{"E"} \quad \text{if } 45 \geq D > 35 \\ \text{out} \leftarrow \text{"D"} \quad \text{if } 35 \geq D > 26 \\ \text{out} \leftarrow \text{"C"} \quad \text{if } 26 \geq D > 18 \\ \text{out} \leftarrow \text{"B"} \quad \text{if } 18 \geq D > 11 \\ \text{out} \leftarrow \text{"A"} \quad \text{if } 11 \geq D \\ \text{out} \end{array} \right.$$

$\text{LOS}(D) = \text{"B"}$

Determine Input Vol and %HV for Next Downstream Segment

$\text{FwyVolNew} := \text{FwyVol} = 2981$

$\%\text{Trucks}_{\text{FNew}} := \%\text{Trucks}_{\text{F}} = 5.0551$

**FwyVolNew and %Trucks$_{FNew}$ are the input values for FwyVol and %Trucks$_F$ for the next downstream segment if there is one. If the next segment is a weave, then %Trucks$_{FNew}$ is the input value for %Trucks_FF and %Trucks_FR.*

Weave (Diamond On 4c, Basic 5, and Partial Clover Off 6a)

Step 1. Data Inputs

**FwyVolNew and %Trucks$_{FNew}$ from the previous upstream segment are the input values for SegInputVol and SegInput%HV if there is a previous upstream segment.*

OnRampVol := 700 OffRampVol := 700 SegInputVol := 2981 Int_Density := 0.87 int/mi

OnRamp%HV := 2 OffRamp%HV := 2 SegInput%HV := 5.0551

L_B := 4000 ft FFS := 65 mi/h PHF := .95 fp := 1

Terrain := 1 1 = Level, 2 = Rolling, 3 = Mountainous

**FREEPLAN finds Int_Density by counting parclos and diamond as 1 interchange each, full as 2, and on and off as 1/2 each and adds them. Then, it divides that total number of interchanges by the total length of the facility.*

Config := 1 1 = one-sided weaving segment, 2 = two-sided weaving segment

NumLanes := 4 Number of lanes in weaving section

C_IFL := 2350 pc/h/ln Capacity of basic freeway segment with same FFS as the weaving segment under equivalent ideal conditions

N_WL := 2 Number of lanes from which weaving maneuvers may be made with one lane change or no lane change. 2 or 3 for one sided and 0 for two sided weaving configuration

LC_RF := 1 Minimum number of lane changes that must be made by a single weaving vehicle from the on-ramp to freeway

LC_FR := 1 Minimum number of lane changes that must be made by a single weaving vehicle from freeway to the off-ramp

LC_RR := 0 Minimum number of lane changes that must be made by one ramp-to-ramp to complete a weaving maneuver

Step 2. Volume Adjustment

A. Heavy Vehicle and Volume Adjustments

Passenger Car Equivalents

$$\text{E\_T}(\text{Terrain}) := \left|\begin{array}{lll} \text{out} \leftarrow 1.5 & \text{if} & \text{Terrain} = 1 \\ \text{out} \leftarrow 2.5 & \text{if} & \text{Terrain} = 2 \\ \text{out} \leftarrow 4.5 & \text{if} & \text{Terrain} = 3 \end{array}\right.$$

$$\text{E\_T} := \text{E\_T}(\text{Terrain})$$

$$\text{E\_T} = 1.5$$

**FREEPLAN assumes trucks make up all of the heavy vehicles. Therefore, RV calculations have been left out.*

$$\text{f\_HV\_FF} := \frac{100}{100 + \text{SegInput\%HV}(\text{E\_T} - 1)}$$

$$\text{f\_HV\_FR} := \frac{100}{100 + \text{OffRamp\%HV}(\text{E\_T} - 1)}$$

$$\text{f\_HV\_RF} := \frac{100}{100 + \text{OnRamp\%HV}(\text{E\_T} - 1)}$$

$$\text{f\_HV\_RR} := \frac{100}{100 + \text{OnRamp\%HV}(\text{E\_T} - 1)}$$

$$\text{SegInputVolAdj} := \frac{\text{SegInputVol}}{\text{PHF} \cdot \text{f\_HV\_FF} \cdot \text{fp}} = 3217.207$$

$$\text{OffRampVolAdj} := \frac{\text{OffRampVol}}{\text{PHF} \cdot \text{f\_HV\_FR} \cdot \text{fp}} = 744.211$$

$$\text{OnRampVolAdj} := \frac{\text{OnRampVol}}{\text{PHF} \cdot \text{f\_HV\_RF} \cdot \text{fp}} = 744.211$$

**Freeplan assumes the Freeway to Ramp Volume will have the same %HV as the Off Ramp and that the Freeway to Freeway Volume will have the same %HV as the Segment Input Volume*

$$\text{f\_HV} := \frac{(\text{f\_HV\_FF} + \text{f\_HV\_FR} + \text{f\_HV\_RF} + \text{f\_HV\_RR})}{4}$$

$$\text{f\_HV} = 0.986$$

B. Volumes for Weaving Segments

$v\_RR := .05 \cdot OnRampVolAdj = 37.211$ veh/h ** Freeplan assumes the v_RR is 5% of the total On-Ramp volume.*

$v\_FR := OffRampVolAdj - v\_RR = 707$ veh/h

$v\_RF := .95 \cdot OnRampVolAdj = 707$ veh/h

$v\_FF := SegInputVolAdj - v\_FR = 2510.21$ veh/h

$v\_Total := v\_FF + v\_RF + v\_FR + v\_RR = 3.961 \times 10^{3}$ veh/h

C. Weaving Demand Flow Rate

$$WeavingDemand(N\_WL) := \left| \begin{array}{l} out \leftarrow v\_RF + v\_FR \quad \text{if} \quad N\_WL \neq 0 \\ out \leftarrow v\_RR \quad \text{if} \quad N\_WL = 0 \end{array} \right.$$

$WeavingFlowRate := WeavingDemand(N\_WL)$

$\boxed{WeavingFlowRate = 1414}$ pc/h

D. Non-Weaving Demand Flow Rate

$$NonWeavingDemand(N\_WL) := \left| \begin{array}{l} out \leftarrow v\_FF + v\_RR \quad \text{if} \quad N\_WL \neq 0 \\ out \leftarrow v\_FF + v\_FR + v\_RF \quad \text{if} \quad N\_WL = 0 \end{array} \right.$$

$NonWeavingFlowRate := NonWeavingDemand(N\_WL)$

$\boxed{NonWeavingFlowRate = 2547}$ pc/h

E. Total Demand Flow Rate

$TotalFlowRate := WeavingFlowRate + NonWeavingFlowRate$

$\boxed{TotalFlowRate = 3961}$ pc/h

F. Volume Ratio

$VR := \dfrac{WeavingFlowRate}{TotalFlowRate}$ $\boxed{VR = 0.357}$

Step 3. Determine the Maximum Weaving Length

$MaximumLength := \left[5728\,(1 + VR)^{1.6}\right] - 1566 \cdot N\_WL$

$\boxed{MaximumLength = 6203}$ ft $Ls := L_B \cdot .77 = 3080$

If Maximum Length < Ls, then STOP
Analyze ramp junctions separately

Step 4. Determine the Capacity of Weaving Segment

A. Weaving segment capacity determined by density

$$C\_IWL := C\_IFL - \left[438.2 \cdot (1 + VR)^{1.6}\right] + (0.0765 \cdot Ls) + (119.8 \cdot N\_WL)$$

$C\_IWL = 2111$ pc/h/ln C_IWL is the capacity per lane under equivalent ideal conditions

$$Cw1 := C\_IWL \cdot NumLanes \cdot f\_HV \cdot fp$$

$Cw1 = 8330$ veh/h Cw1 is the density based capacity of weaving segment under prevailing conditions

B. Weaving segment capacity determined by weaving demand flows

$$C\_IW(N\_WL) := \begin{array}{|l} out \leftarrow \dfrac{2400}{VR} \quad \text{if} \quad N\_WL = 2 \\ out \leftarrow \dfrac{3500}{VR} \quad \text{if} \quad N\_WL = 3 \\ out \leftarrow \dfrac{Cw1}{f\_HV \cdot fp} \quad \text{if} \quad N\_WL = 0 \end{array}$$

For two sided segments, no limiting value on flow rate is proposed and thus capacity based on density only is estimated for the segment. Therefore same capacity value is used here to get the final as capacity determined by density for two sided segments.

$C\_IW := C\_IW(N\_WL)$ $C\_IW = 6724$ pc/h C_IW is the capacity of the weaving segment under ideal conditions

$$Cw2 := C\_IW \cdot f\_HV \cdot fp$$

$Cw2 = 6632$ veh/h Cw2 is the flow based capacity of weaving segment under prevailing conditions

C. Final Capacity of Weaving Segment

$$WeavingCapacity := if(Cw1 > Cw2, Cw2, Cw1)$$

$\boxed{WeavingCapacity = 6632}$ veh/h

D. Volume to Capacity (v/c) Ratio

$$VolumeToCapacity := \frac{TotalFlowRate \cdot f\_HV \cdot fp}{WeavingCapacity}$$

$\boxed{VolumeToCapacity = 0.589}$

If v/c ratio >1 then LOS is F
Terminate

Step 5. Determine Configuration Characteristics

$$LC\_MIN(Config) := \begin{array}{|l} out \leftarrow (LC\_RF \cdot v\_RF) + (LC\_FR \cdot v\_FR) \quad \text{if} \quad Config = 1 \\ out \leftarrow (LC\_RR \cdot v\_RR) \quad \text{if} \quad Config = 2 \end{array}$$

$$LC\_MIN := LC\_MIN(Config)$$

$\boxed{LC\_MIN = 1414}$ lc/h Minimum Lane Changes

Step 6. Determine Lane-Changing Rates

A. Lane-Changing Rate for Weaving Vehicles

$$LC\_W(Ls) := \left| \begin{array}{l} out \leftarrow LC\_MIN + 0.39 \cdot \left[(Ls - 300)^{0.5} \cdot NumLanes^2 \cdot (1 + Int\_Density)^{0.8} \right] \quad \text{if} \quad Ls \geq 300 \\ out \leftarrow LC\_MIN \quad \text{if} \quad Ls < 300 \end{array} \right.$$

$$LaneChangingWeaving := LC\_W(Ls)$$

$$\boxed{LaneChangingWeaving = 1957} \quad \text{lc/h}$$

B. Lane-Changing Rate for Non-Weaving Vehicles

$$I\_NW := \frac{Ls \cdot Int\_Density \cdot NonWeavingFlowRate}{10000} \qquad I\_NW = 683 \qquad \text{Non Weaving Vehicle Index}$$

$$LC\_NW1 := (0.206 \cdot NonWeavingFlowRate) + (0.542 \cdot Ls) - (192.6 \cdot NumLanes)$$

$$LC\_NW2 := 2135 + 0.233 \cdot (NonWeavingFlowRate - 2000)$$

$$LC\_NW3 := LC\_NW1 + (LC\_NW2 - LC\_NW1) \cdot \frac{(I\_NW - 1300)}{650}$$

$$LC\_NW(I\_NW) := \left| \begin{array}{l} out \leftarrow LC\_NW1 \quad \text{if} \quad I\_NW < 1300 \\ out \leftarrow LC\_NW2 \quad \text{if} \quad I\_NW \geq 1950 \\ out \leftarrow LC\_NW3 \quad \text{if} \quad 1300 < I\_NW < 1950 \\ out \leftarrow LC\_NW2 \quad \text{if} \quad LC\_NW1 \geq LC\_NW2 \end{array} \right.$$

$$LaneChangingNonWeaving := LC\_NW(I\_NW)$$

$$\boxed{LaneChangingNonWeaving = 1424} \quad \text{lc/h}$$

C. Total Lane-Changing Rate

$$TotalLaneChanging := LaneChangingWeaving + LaneChangingNonWeaving$$

$$\boxed{TotalLaneChanging = 3381} \quad \text{lc/h}$$

Step 7. Determine Average Speed of Weaving and Non-Weaving Vehicles

A. Average Speed of Weaving Vehicles

$$WeavingIntensityFactor := 0.226 \left(\frac{TotalLaneChanging}{Ls} \right)^{0.789}$$

$$WeavingIntensityFactor = 0.243$$

$$AverageWeavingSpeed := 15 + \left(\frac{FFS - 15}{1 + WeavingIntensityFactor} \right)$$

$$\boxed{AverageWeavingSpeed = 55.22} \quad \text{mi/h}$$

B. Average Speed of Non-Weaving Vehicles

$$AverageNonWeavingSpeed := FFS - (0.0072 \cdot LC\_MIN) - \left(0.0048 \cdot \frac{TotalFlowRate}{NumLanes}\right)$$

$\boxed{AverageNonWeavingSpeed = 50.07}$ mi/h

C. Average Speed of All Vehicles

$$AverageSpeed := \frac{WeavingFlowRate + NonWeavingFlowRate}{\left(\frac{WeavingFlowRate}{AverageWeavingSpeed}\right) + \left(\frac{NonWeavingFlowRate}{AverageNonWeavingSpeed}\right)}$$

$\boxed{AverageSpeed = 51.79}$ mi/h

Step 8. Determine the Level of Service

$$Density := \frac{\left(\frac{TotalFlowRate}{NumLanes}\right)}{AverageSpeed}$$

$\boxed{Density = 19.1}$ pc/mi/ln

$$LOS(Density) := \left| \begin{array}{lll} out \leftarrow \text{"A"} & \text{if} & 0 \le Density \le 10 \\ out \leftarrow \text{"B"} & \text{if} & 10 < Density \le 20 \\ out \leftarrow \text{"C"} & \text{if} & 20 < Density \le 28 \\ out \leftarrow \text{"D"} & \text{if} & 28 < Density \le 35 \\ out \leftarrow \text{"E"} & \text{if} & 35 < Density \\ out \leftarrow \text{"F"} & \text{if} & VolumeToCapacity > 1 \end{array} \right.$$

$\boxed{LOS(Density) = \text{"B"}}$

Step 9. Determine the Input Vol and %HV for the Next Downstream Segment

$$FwyVolNew := SegInputVol + (OnRampVol - v\_RR) - (OffRampVol - v\_RR) = 2981$$

$$\%Trucks_{FNew} := \frac{SegInputVol \cdot SegInput\%HV + (OnRampVol - v\_RR) \cdot OnRamp\%HV - (OffRampVol - v\_RR) \cdot OffRamp\%HV}{FwyVolNew}$$

$\%Trucks_{FNew} = 5.055$

**FwyVolNew and %Trucks$_{FNew}$ are the input values for FwyVol and %Trucks$_F$ for the next downstream segment if there is one. If the next segment is a weave, then %Trucks$_{FNew}$ is the input value for SegInput%HV and FwyVolNew is the input value for SegInputVol.*

Partial Cloverleaf Basic 6b

Input Values

**FwyVolNew and %Trucks$_{FNew}$ from the previous upstream segment are the input values for FwyVol and %Trucks$_F$ (if there is a previous upstream segment).*

Traffic

$FwyVol := 2981 \quad PHF := 0.95$

$f_p := 1.0 \quad FFS := 65$

$\%Trucks_F := 5.055 \quad P_R := 0$

$P_T := \frac{\%Trucks_F}{100} = 0.0505$

Roadway

$N := 3 \quad LaneWidth := 12 \quad LatClear := 6 \quad IntDens := 0.87$

$Terrain := 1$ 1 = Level, 2 = Rolling, 3 = Mountainous

$AreaType := 2$ 1 = Rural, 2 = Urban

**FREEPLAN finds IntDens by counting parclos and diamond as 1 interchange each, full as 2, and on and off as 1/2 each and adds them. Then, it divides that total number of interchanges by the total length of the facility.*

Find f_{HV} (using Exhibit 23-8 and Eq. 23-3)

$$E_T(Terrain) := \left| \begin{array}{l} out \leftarrow 1.5 \text{ if } Terrain = 1 \\ out \leftarrow 2.5 \text{ if } Terrain = 2 \\ out \leftarrow 4.5 \text{ if } Terrain = 3 \\ out \end{array} \right. \qquad E_R(Terrain) := \left| \begin{array}{l} out \leftarrow 1.2 \text{ if } Terrain = 1 \\ out \leftarrow 2.0 \text{ if } Terrain = 2 \\ out \leftarrow 4.0 \text{ if } Terrain = 3 \\ out \end{array} \right.$$

$E_T(Terrain) = 1.5 \quad E_T := E_T(Terrain) \quad E_R(Terrain) = 1.2 \quad E_R := E_R(Terrain)$

$$f_{HV} := \frac{1}{1 + P_T \cdot (E_T - 1) + P_R \cdot (E_R - 1)} \qquad f_{HV} = 0.9753$$

Find v_p (using Eq. 23-2)

$$v_p := \frac{FwyVol}{PHF \cdot N \cdot f_{HV} \cdot f_p} \qquad v_p = 1072.4 \text{ pc/h/ln}$$

Determine S

$S_1 := FFS$

$$S_2 := FFS - \left[\left(FFS - \frac{160}{3} \right) \cdot \left(\frac{v_p + 30 \cdot FFS - 3400}{30 \cdot FFS - 1000} \right)^{2.6} \right]$$

$$S_3 := FFS - \left[\frac{1}{9} \cdot (7 \cdot FFS - 340) \cdot \left(\frac{v_p + 30 \cdot FFS - 3400}{40 \cdot FFS - 1700} \right)^{2.6} \right]$$

$S_{cont2} := if[(55 \le FFS \le 75) \wedge [v_p \le (3400 - 30 \cdot FFS)], S_1, \text{"Cannot Compute"}]$

$S_{cont1} := if[(55 \le FFS \le 70) \wedge [(3400 - 30 \cdot FFS) < v_p \le (1700 + 10 \cdot FFS)], S_3, S_{cont2}]$

$S := if[(70 < FFS \le 75) \wedge [(3400 - 30 \cdot FFS) < v_p \le 2400], S_2, S_{cont1}]$

$S = 65$ mi/h

Density (using Eq. 23-4)

$D := \frac{v_p}{S}$ $\quad D = 16.5 \quad$ pc/mi/ln

Determine level of service (using Exhibit 23-2)

$$LOS(D) := \left| \begin{array}{l} out \leftarrow \text{"F"} \quad \text{if } D > 45 \\ out \leftarrow \text{"E"} \quad \text{if } 45 \ge D > 35 \\ out \leftarrow \text{"D"} \quad \text{if } 35 \ge D > 26 \\ out \leftarrow \text{"C"} \quad \text{if } 26 \ge D > 18 \\ out \leftarrow \text{"B"} \quad \text{if } 18 \ge D > 11 \\ out \leftarrow \text{"A"} \quad \text{if } 11 \ge D \\ out \end{array} \right.$$

$LOS(D) = \text{"B"}$

Determine Input Vol and %HV for Next Downstream Segment

$FwyVolNew := FwyVol = 2981$

$\%Trucks_{FNew} := \%Trucks_F = 5.055$

**FwyVolNew and %Trucks$_{FNew}$ are the input values for FwyVol and %Trucks$_F$ for the next downstream segment if there is one. If the next segment is a weave, then %Trucks$_{FNew}$ is the input value for %Trucks_FF and %Trucks_FR.*

Partial Cloverleaf On (6c)

Step 1. Data Inputs and Volume Adjusments

**FwyVolNew and %Truck$_{SFNew}$ from the previous upstream segment are the input values for FwyVol and %Truck$_{SF}$ (if there is a previous upstream segment).*

A. Inputs

$FwyVol := 2981$ veh/h $RampVol := 455$ veh/h

$\%Trucks_F := 5.055$ $\%RV_F := 0$ $PHF := 0.95$ $f_p := 1$ $FFS := 65$ mi/h

$\%Trucks_R := 2$ $\%RV_R := 0$

$NumLanes := 3$ Number of mainline freeway lanes $NRamp := 1$ Number of lanes on ramp roadway

$Terrain := 1$ 1 = Level, 2 = Rolling, 3 = Mountainous

$L_A := 1000$ ft Total length of Acceleration Lane

$S_{FR} := 40$ mi/h Freeflow speed of the ramp at the junction point

$AdjUp := 2$ $AdjDn := 2$ 0 = none, 1 = on-ramp, 2 = off-ramp for Adjacent Upstream/Downstream Ramps

$L_{up} := 2280$ ft $L_{down} := 3000$ ft

$VolumeUp := 800$ veh/h Volume on adjacent upstream ramp

$VolumeDown := 455$ veh/h Volume on adjacent downstream ramp

B. Heavy Vehicle Adjustments

Passenger Car Equivalents

$$E_T(Terrain) := \left| \begin{array}{lll} out \leftarrow 1.5 & \text{if} & Terrain = 1 \\ out \leftarrow 2.5 & \text{if} & Terrain = 2 \\ out \leftarrow 4.5 & \text{if} & Terrain = 3 \end{array} \right. \qquad E_R(Terrain) := \left| \begin{array}{lll} out \leftarrow 1.2 & \text{if} & Terrain = 1 \\ out \leftarrow 2.0 & \text{if} & Terrain = 2 \\ out \leftarrow 4.0 & \text{if} & Terrain = 3 \end{array} \right.$$

$E_T(Terrain) = 1.5$ $E_R(Terrain) = 1.2$

$E_T := E_T(Terrain)$ $E_T = 1.5$ $E_R := E_R(Terrain)$ $E_R = 1.2$

$$f\_HV_F := \frac{100}{100 + \%Trucks_F(E_T - 1) + \%RV_F(E_R - 1)} = 0.975 \qquad f\_HV_F = 0.975$$

$$f\_HV_R := \frac{100}{100 + \%Trucks_R(E_T - 1) + \%RV_R(E_R - 1)} \qquad f\_HV_R = 0.99$$

C. Demand Flow Rate

$$V_f := \frac{FwyVol}{PHF \cdot f\_HV_F \cdot f_p} \qquad V_f = 3217 \text{ pc/h} \qquad V_r := \frac{RampVol}{PHF \cdot f\_HV_R \cdot f_p} \qquad V_r = 484 \text{ pc/h}$$

$$V_u := \frac{VolumeUp}{PHF \cdot f\_HV_R \cdot f_p} \qquad V_u = 851 \text{ pc/h} \qquad V_d := \frac{VolumeDown}{PHF \cdot f\_HV_R \cdot f_p} \qquad V_d = 484 \text{ pc/h}$$

Step 2. Determine the Approaching Flow Rate in Lanes 1 and 2

A. Equilibrium Seperation Distance for Adjacent Off-Ramp on a Six Lane Freeway

$$L_{EQup} := 0.214(V_f + V_r) + 0.444 \cdot L_A + 53.32 \cdot S_{FR} - 2403 \qquad L_{EQup} = 966 \text{ ft}$$

$$L_{EQdown} := \frac{V_d}{0.1096 + 0.000107 \cdot L_A} \qquad L_{EQdown} = 2233 \quad \text{ft}$$

B. Estimating Proportion of Freeway Vehicles Remaining in lanes 1 and 2

$$Eqn1 := 0.5775 + 0.000028 \cdot L_A \qquad Eqn1 = 0.606$$

$$Eqn2 := 0.7289 - 0.0000135 \cdot (V_f + V_r) - 0.003296 \cdot S_{FR} + 0.000063 \cdot L_{up} \qquad Eqn2 = 0.691$$

$$Eqn3 := 0.5487 + 0.2628 \cdot \frac{V_d}{L_{down}} \qquad Eqn3 = 0.591$$

$$P_{FM}(NumLanes) := \left| \begin{array}{l}
out \leftarrow 1.00 \quad \text{if} \quad NumLanes = 2 \\
out \leftarrow Eqn1 \quad \text{if} \quad AdjUp \neq 2 \wedge AdjDn \neq 2 \wedge NumLanes = 3 \\
out \leftarrow Eqn3 \quad \text{if} \quad AdjUp = 0 \wedge AdjDn = 2 \wedge L_{down} < L_{EQdown} \wedge NumLanes = 3 \\
out \leftarrow Eqn1 \quad \text{if} \quad AdjUp = 0 \wedge AdjDn = 2 \wedge L_{down} \geq L_{EQdown} \wedge NumLanes = 3 \\
out \leftarrow Eqn2 \quad \text{if} \quad AdjUp = 2 \wedge AdjDn = 0 \wedge L_{up} < L_{EQup} \wedge NumLanes = 3 \\
out \leftarrow Eqn1 \quad \text{if} \quad AdjUp = 2 \wedge AdjDn = 0 \wedge L_{up} \geq L_{EQup} \wedge NumLanes = 3 \\
out \leftarrow Eqn1 \quad \text{if} \quad AdjUp = 1 \wedge AdjDn = 1 \wedge NumLanes = 3 \\
out \leftarrow Eqn3 \quad \text{if} \quad AdjUp = 1 \wedge AdjDn = 2 \wedge L_{down} < L_{EQdown} \wedge NumLanes = 3 \\
out \leftarrow Eqn1 \quad \text{if} \quad AdjUp = 1 \wedge AdjDn = 2 \wedge L_{down} \geq L_{EQdown} \wedge NumLanes = 3 \\
out \leftarrow Eqn2 \quad \text{if} \quad AdjUp = 2 \wedge AdjDn = 1 \wedge L_{up} < L_{EQup} \wedge NumLanes = 3 \\
out \leftarrow Eqn1 \quad \text{if} \quad AdjUp = 2 \wedge AdjDn = 1 \wedge L_{up} \geq L_{EQup} \wedge NumLanes = 3 \\
out \leftarrow \max(Eqn1, Eqn2) \quad \text{if} \quad AdjUp = 2 \wedge AdjDn = 2 \wedge L_{up} < L_{EQup} \wedge L_{down} \geq L_{EQdown} \wedge NumLanes = 3 \\
out \leftarrow \max(Eqn3, Eqn2) \quad \text{if} \quad AdjUp = 2 \wedge AdjDn = 2 \wedge L_{up} < L_{EQup} \wedge L_{down} < L_{EQdown} \wedge NumLanes = 3 \\
out \leftarrow Eqn1 \quad \text{if} \quad AdjUp = 2 \wedge AdjDn = 2 \wedge L_{up} \geq L_{EQup} \wedge L_{down} \geq L_{EQdown} \wedge NumLanes = 3 \\
out \leftarrow \max(Eqn1, Eqn3) \quad \text{if} \quad AdjUp = 2 \wedge AdjDn = 2 \wedge L_{up} \geq L_{EQup} \wedge L_{down} < L_{EQdown} \wedge NumLanes = 3 \\
out \leftarrow 0.2178 - 0.0000125 \cdot V_r + -0.0115 \cdot \frac{L_A}{S_{FR}} \quad \text{if} \quad \left(\frac{V_f}{S_{FR}} \leq 72 \right) \wedge (NumLanes = 4) \\
out \leftarrow 0.2178 - 0.0000125 \cdot V_r \quad \text{if} \quad \left(\frac{V_f}{S_{FR}} > 72 \right) \wedge (NumLanes = 4)
\end{array} \right.$$

$$P_{FM} := P_{FM}(NumLanes) \qquad P_{FM} = 0.606$$

C. Estimating Flow in Lanes 1 and 2

$$V_{12} := V_f \cdot P_{FM} \qquad V_{12} = 1948 \quad \text{pc/h}$$

D. Checking the Reasonableness of the Lane Distribution Prediction

Six Lane Freeways

$$V_3 := V_f - V_{12} \qquad V_3 = 1269 \quad \text{pc/h}$$

Eight Lane Freeways

$$V_{av34} := \frac{V_f - V_{12}}{2} \qquad V_{av34} = 635 \quad \text{pc/h}$$

$$V12a(NumLanes) := \begin{array}{|l} out \leftarrow V_{12} \quad \text{if} \quad NumLanes = 2 \\ out \leftarrow V_f - 2700 \quad \text{if} \quad V_3 > 2700 \wedge V_3 \le 1.5\cdot\frac{V_{12}}{2} \vee NumLanes = 3 \\ out \leftarrow \frac{V_f}{1.75} \quad \text{if} \quad V_3 \le 2700 \wedge V_3 > 1.5\cdot\frac{V_{12}}{2} \wedge NumLanes = 3 \\ out \leftarrow \max\left(V_f - 2700, \frac{V_f}{1.75}\right) \quad \text{if} \quad V_3 > 2700 \wedge V_3 > 1.5\cdot\frac{V_{12}}{2} \wedge NumLanes = 3 \\ out \leftarrow V_{12} \quad \text{if} \quad V_3 \le 2700 \wedge V_3 \le 1.5\cdot\frac{V_{12}}{2} \wedge NumLanes = 3 \\ out \leftarrow V_f - 5400 \quad \text{if} \quad V_{av34} > 2700 \wedge V_{av34} \le 1.5\cdot\frac{V_{12}}{2} \wedge NumLanes = 4 \\ out \leftarrow \frac{V_f}{2.50} \quad \text{if} \quad V_{av34} \le 2700 \wedge V_{av34} > 1.5\cdot\frac{V_{12}}{2} \wedge NumLanes = 4 \\ out \leftarrow \max\left(V_f - 5400, \frac{V_f}{2.50}\right) \quad \text{if} \quad V_{av34} > 2700 \wedge V_{av34} > 1.5\cdot\frac{V_{12}}{2} \wedge NumLanes = 4 \\ out \leftarrow V_{12} \quad \text{if} \quad V_{av34} \le 2700 \wedge V_{av34} \le 1.5\cdot\frac{V_{12}}{2} \wedge NumLanes = 4 \end{array}$$

C. Final Flow in Lanes 1 and 2

$V_{12} := V12a(NumLanes)$ $\qquad V_{12} = 1948$ pc/h

Step 3. Determine Capacity of Ramp-Freeway Junction

$V_{R12} := V_{12} + V_r$ $\qquad V_{R12} = 2432$ pc/h $\qquad$ Flow entering the ramp influence area

$$CapUpFreewaySegment(NumLanes, FFS) := \begin{array}{|l} out \leftarrow 4800 \quad \text{if} \quad FFS \ge 70 \wedge NumLanes = 2 \\ out \leftarrow 4700 \quad \text{if} \quad FFS = 65 \wedge NumLanes = 2 \\ out \leftarrow 4600 \quad \text{if} \quad FFS = 60 \wedge NumLanes = 2 \\ out \leftarrow 4600 \quad \text{if} \quad FFS = 55 \wedge NumLanes = 2 \\ out \leftarrow 7200 \quad \text{if} \quad FFS = 70 \wedge NumLanes = 3 \\ out \leftarrow 7050 \quad \text{if} \quad FFS = 65 \wedge NumLanes = 3 \\ out \leftarrow 6900 \quad \text{if} \quad FFS = 60 \wedge NumLanes = 3 \\ out \leftarrow 6750 \quad \text{if} \quad FFS = 55 \wedge NumLanes = 3 \\ out \leftarrow 9600 \quad \text{if} \quad FFS = 70 \wedge NumLanes = 4 \\ out \leftarrow 9400 \quad \text{if} \quad FFS = 65 \wedge NumLanes = 4 \\ out \leftarrow 9200 \quad \text{if} \quad FFS = 60 \wedge NumLanes = 4 \\ out \leftarrow 9000 \quad \text{if} \quad FFS = 55 \wedge NumLanes = 4 \\ out \leftarrow 2400\cdot NumLanes \quad \text{if} \quad FFS = 70 \wedge NumLanes > 4 \\ out \leftarrow 2350\cdot NumLanes \quad \text{if} \quad FFS = 65 \wedge NumLanes > 4 \\ out \leftarrow 2300\cdot NumLanes \quad \text{if} \quad FFS = 60 \wedge NumLanes > 4 \\ out \leftarrow 2250\cdot NumLanes \quad \text{if} \quad FFS = 55 \wedge NumLanes > 4 \end{array}$$

$\text{CapUpFreewaySegment}(\text{NumLanes}, \text{FFS}) = 7050$ Capacity of Ramp Freeway Junction

MaxV12 = 4600 Maximum Desirable Flow Rate Entering Merge Influence Area

$$
\text{CapacityRampRoadway} := \left|
\begin{array}{lll}
\text{out} \leftarrow 2200 & \text{if} & (\text{NRamp} = 1) \wedge (S_{FR} > 50) \\
\text{out} \leftarrow 2100 & \text{if} & (\text{NRamp} = 1) \wedge (40 < S_{FR} \le 50) \\
\text{out} \leftarrow 2000 & \text{if} & (\text{NRamp} = 1) \wedge (30 < S_{FR} \le 40) \\
\text{out} \leftarrow 1900 & \text{if} & (\text{NRamp} = 1) \wedge (20 \le S_{FR} \le 30) \\
\text{out} \leftarrow 1800 & \text{if} & (\text{NRamp} = 1) \wedge (20 > S_{FR}) \\
\text{out} \leftarrow 4400 & \text{if} & (\text{NRamp} = 2) \wedge (S_{FR} > 50) \\
\text{out} \leftarrow 4200 & \text{if} & (\text{NRamp} = 2) \wedge (40 < S_{FR} \le 50) \\
\text{out} \leftarrow 4000 & \text{if} & (\text{NRamp} = 2) \wedge (30 < S_{FR} \le 40) \\
\text{out} \leftarrow 3800 & \text{if} & (\text{NRamp} = 2) \wedge (20 \le S_{FR} \le 30) \\
\text{out} \leftarrow 3600 & \text{if} & (\text{NRamp} = 2) \wedge (20 > S_{FR})
\end{array}
\right.
$$

$\text{CapacityRampRoadway} = 2000$

$V_{FO} := V_f + V_r$ $V_{FO} = 3701$ pc/h Volume immediatley downstream of on-ramp influence area

Ramp Freeway Junction Checkpoint

Volume immediatley downstream of on-ramp influence area is chekced against freeway capacity. Failure of ramp freeway junction checkpoint (i.e. demand exceeds capacity) results in LOS F

Ramp Roadway Capacity Checkpoint

Capacity or ramp roadway should always be checked against the demand flow rate on the ramp. It is rarely a problem for the on-ramp

Maximum Desirable Flow Entering Ramp Influence Area Checkpoint

While the V_{R12} values is checked against the maximum desirable, failure does not result in assignment of LOS F. Failing this checkpoint generally means that there will be more turbulance in influence area than predicted by this methodology. Thus, predicted densities are most likely lower than those that will exist, and predicted speeds are most likely to be predicted as higher than those that will actually occur.

Step 4. Determine Speeds in the Vicinity of Ramp-Freeway Junction

A. Average Speed in the Ramp Influence Area

$$S_R := FFS - (FFS - 42)\cdot\left[0.321 + 0.0039\exp\left(\frac{V_{R12}}{1000}\right) - 0.002\cdot\left(L_A\frac{S_{FR}}{1000}\right)\right]$$

$S_R = 58.44$ mi/h

B. Average Speed in the Outer Lanes of Freeway

Average Flow in Outer Lanes

$$No := \begin{array}{|l} out \leftarrow 1 \quad \text{if} \quad NumLanes = 3 \\ out \leftarrow 2 \quad \text{if} \quad NumLanes = 4 \\ out \leftarrow \infty \quad \text{if} \quad NumLanes = 2 \end{array}$$

$$V_{OA} := \frac{V_f - V_{12}}{No}$$

$V_{OA} = 1269$

$$S_O(V_{OA}) := \begin{array}{|l} out \leftarrow FFS \quad \text{if} \quad V_{OA} < 500 \\ out \leftarrow FFS - 0.0036\cdot(V_{OA} - 500) \quad \text{if} \quad 500 \le V_{OA} \le 2300 \\ out \leftarrow FFS - 6.53 - 0.006\cdot(V_{OA} - 2300) \quad \text{if} \quad V_{OA} > 2300 \end{array}$$

$$S_O := S_O(V_{OA})$$

$S_O = 62.23$ mi/h

C. Average Speed for On-Ramp Junction

$$Speed := \frac{V_{R12} + V_{OA}\cdot No}{\left(\frac{V_{R12}}{S_R}\right) + \left(\frac{V_{OA}\cdot No}{S_O}\right)}$$

$Speed = 59.68$ mi/h

Step 5. Determine the Density and Level of Service

A. Density in On-Ramp Influence Area

$$Density_R := 5.475 + 0.00734\cdot V_r + 0.0078\cdot V_{12} - 0.00627\cdot L_A$$

$Density_R = 18$ pc/mi/ln

B. Density in Outer Lanes

$$Density_O := \frac{V_{OA}}{S_O}$$

$Density_O = 20.4$ pc/mi/ln

C. Density of Entire Cross-Section

$$Density := \begin{array}{|l} out \leftarrow Density_R \quad \text{if} \quad NumLanes \le 2 \\ out \leftarrow \frac{\left[Density_R\cdot(2) + Density_O\cdot(NumLanes - 2)\right]}{NumLanes} \quad \text{if} \quad NumLanes > 2 \end{array}$$

$Density = 18.8$ pc/mi/ln

D. Level of Service

$$LOS(Density) := \begin{array}{|l} out \leftarrow \text{"A"} \quad \text{if} \quad 0 \le Density \le 10 \\ out \leftarrow \text{"B"} \quad \text{if} \quad 10 < Density \le 20 \\ out \leftarrow \text{"C"} \quad \text{if} \quad 20 < Density \le 28 \\ out \leftarrow \text{"D"} \quad \text{if} \quad 28 < Density \le 35 \\ out \leftarrow \text{"E"} \quad \text{if} \quad 35 < Density \end{array}$$

$LOS(Density) = \text{"B"}$

Step 6. Determine Input Vol and %HV for Next Downstream Segment

$$FwyVol_{Cars} := FwyVol \cdot \left(1 - \frac{\%Trucks_F}{100}\right) = 2830.3$$

$$RampVol_{Cars} := RampVol \cdot \left(1 - \frac{\%Trucks_R}{100}\right) = 445.9$$

$$FwyVol_{CarsNew} := FwyVol_{Cars} + RampVol_{Cars} = 3276.2$$

$$FwyVol_{Trucks} := FwyVol \cdot \frac{\%Trucks_F}{100} = 150.69$$

$$RampVol_{Trucks} := RampVol \cdot \left(\frac{\%Trucks_R}{100}\right) = 9.1$$

$$FwyVol_{TrucksNew} := FwyVol_{Trucks} + RampVol_{Trucks} = 159.79$$

$$FwyVolNew := FwyVol_{CarsNew} + FwyVol_{TrucksNew} = 3436$$

$$\%Trucks_{FNew} := \frac{FwyVol_{TrucksNew}}{FwyVolNew} \cdot 100 = 4.6505$$

**FwyVolNew and $\%Trucks_{FNew}$ are the input values for FwyVol and $\%Trucks_F$ for the next downstream segment if there is one. If the next segment is a weave, then $\%Trucks_{FNew}$ is the input value for %Trucks_FF and %Trucks_FR.*

Full Clover Off (7a)

Step 1. Data Inputs and Volume Adjusments

**FwyVolNew and %Truck$_{SFNew}$ from the previous upstream segment are the input values for FwyVol and %Truck$_{SF}$ (if there is a previous upstream segment).*

A. Inputs

$FwyVol := 3436$ veh/h $RampVol := 455$ veh/h

$\%Trucks_F := 4.6505$ $\%RV_F := 0$ $PHF := 0.95$ $f_p := 1$ $FFS := 65$ mi/h

$\%Trucks_R := 2$ $\%RV_R := 0$

$NumLanes := 3$ Number of mainline freeway lanes $NRamp := 1$ Number of lanes on ramp roadway

$Terrain := 1$ 1 = Level, 2 = Rolling, 3 = Mountainous

$L_D := 450$ ft Total length of Deceleration Lane

$S_{FR} := 40$ mi/h Freeflow speed of the ramp at the junction point

$AdjUp := 1$ $AdjDn := 1$ 0 = none, 1 = on-ramp, 2 = off-ramp for Adjacent Upstream/Downstream Ramps

$L_{up} := 3000$ ft $L_{down} := 1500$ ft

$VolumeUp := 455$ veh/h Volume on adjacent upstream ramp

$VolumeDown := 600$ veh/h Volume on adjacent downstream ramp

B. Heavy Vehicle Adjustments

Passenger Car Equivalents

$$E_T(Terrain) := \left| \begin{array}{l} out \leftarrow 1.5 \text{ if } Terrain = 1 \\ out \leftarrow 2.5 \text{ if } Terrain = 2 \\ out \leftarrow 4.5 \text{ if } Terrain = 3 \end{array} \right. \qquad E_R(Terrain) := \left| \begin{array}{l} out \leftarrow 1.2 \text{ if } Terrain = 1 \\ out \leftarrow 2.0 \text{ if } Terrain = 2 \\ out \leftarrow 4.0 \text{ if } Terrain = 3 \end{array} \right.$$

$E_T(Terrain) = 1.5$ $E_R(Terrain) = 1.2$

$E_T := E_T(Terrain)$ $E_T = 1.5$ $E_R := E_R(Terrain)$ $E_R = 1.2$

$$f\_HV_F := \frac{100}{100 + \%Trucks_F(E_T - 1) + \%RV_F(E_R - 1)} \qquad f\_HV_F = 0.977$$

$$f\_HV_R := \frac{100}{100 + \%Trucks_R(E_T - 1) + \%RV_R(E_R - 1)} \qquad f\_HV_R = 0.99$$

C. Demand Flow Rate

$$V_f := \frac{FwyVol}{PHF \cdot f\_HV_F \cdot f_p} \qquad V_f = 3701 \text{ pc/h} \qquad V_r := \frac{RampVol}{PHF \cdot f\_HV_R \cdot f_p} \qquad V_r = 484 \text{ pc/h}$$

$$V_u := \frac{VolumeUp}{PHF \cdot f\_HV_R \cdot f_p} \qquad V_u = 484 \text{ pc/h} \qquad V_d := \frac{VolumeDown}{PHF \cdot f\_HV_R \cdot f_p} \qquad V_d = 638 \text{ pc/h}$$

Step 2. Determine the Approaching Flow Rate in Lanes 1 and 2

A. Equilibrium Seperation Distance for Adjacent Upstream On-Ramp or Downstream Off-Ramps on a Six Lane Freeway

$$L_{EQup} := \frac{V_u}{0.071 + 0.000023 \cdot V_f - 0.000076 \cdot V_r} \qquad L_{EQup} = 4053 \quad \text{ft}$$

$$L_{EQdown} := \frac{V_d}{1.15 - 0.000032 \cdot V_f - 0.000369 \cdot V_r} \qquad L_{EQdown} = 748 \quad \text{ft}$$

B. Estimating Proportion of Freeway Vehicles Remaining in lanes 1 and 2

$$Eqn1 := 0.760 - 0.000025 \cdot V_f - 0.000046 \cdot V_r \qquad Eqn1 = 0.645$$

$$Eqn2 := 0.717 - 0.000039 \cdot V_f + 0.604 \cdot \frac{V_u}{L_{up}} \qquad Eqn2 = 0.67$$

$$Eqn3 := 0.616 - 0.000021 \cdot V_f + 0.124 \cdot \frac{V_d}{L_{down}} \qquad Eqn3 = 0.591$$

$$P_{FD}(Numlanes) := \left| \begin{array}{l}
out \leftarrow 1.00 \quad \text{if} \quad NumLanes = 2 \\
out \leftarrow Eqn1 \quad \text{if} \quad AdjUp = 0 \wedge AdjDn = 0 \wedge NumLanes = 3 \\
out \leftarrow Eqn1 \quad \text{if} \quad AdjUp = 0 \wedge AdjDn = 1 \wedge NumLanes = 3 \\
out \leftarrow Eqn1 \quad \text{if} \quad AdjUp = 0 \wedge AdjDn = 2 \wedge L_{down} \geq L_{EQdown} \wedge NumLanes = 3 \\
out \leftarrow Eqn3 \quad \text{if} \quad AdjUp = 0 \wedge AdjDn = 2 \wedge L_{down} < L_{EQdown} \wedge NumLanes = 3 \\
out \leftarrow Eqn1 \quad \text{if} \quad AdjUp = 1 \wedge AdjDn = 0 \wedge L_{up} \geq L_{EQup} \wedge NumLanes = 3 \\
out \leftarrow Eqn2 \quad \text{if} \quad AdjUp = 1 \wedge AdjDn = 0 \wedge L_{up} < L_{EQup} \wedge NumLanes = 3 \\
out \leftarrow Eqn1 \quad \text{if} \quad AdjUp = 2 \wedge AdjDn = 0 \wedge NumLanes = 3 \\
out \leftarrow Eqn1 \quad \text{if} \quad AdjUp = 1 \wedge AdjDn = 1 \wedge L_{up} \geq L_{EQup} \wedge NumLanes = 3 \\
out \leftarrow Eqn2 \quad \text{if} \quad AdjUp = 1 \wedge AdjDn = 1 \wedge L_{up} < L_{EQup} \wedge NumLanes = 3 \\
out \leftarrow \max(Eqn2, Eqn3) \quad \text{if} \quad AdjUp = 1 \wedge AdjDn = 2 \wedge L_{up} < L_{EQup} \wedge L_{down} < L_{EQdown} \wedge NumLanes = 3 \\
out \leftarrow \max(Eqn2, Eqn1) \quad \text{if} \quad AdjUp = 1 \wedge AdjDn = 2 \wedge L_{up} < L_{EQup} \wedge L_{down} \geq L_{EQdown} \wedge NumLanes = 3 \\
out \leftarrow Eqn1 \quad \text{if} \quad AdjUp = 1 \wedge AdjDn = 2 \wedge L_{up} \geq L_{EQup} \wedge L_{down} \geq L_{EQdown} \wedge NumLanes = 3 \\
out \leftarrow \max(Eqn3, Eqn1) \quad \text{if} \quad AdjUp = 1 \wedge AdjDn = 2 \wedge L_{up} \geq L_{EQup} \wedge L_{down} < L_{EQdown} \wedge NumLanes = 3 \\
out \leftarrow Eqn1 \quad \text{if} \quad AdjUp = 2 \wedge AdjDn = 1 \wedge NumLanes = 3 \\
out \leftarrow Eqn1 \quad \text{if} \quad AdjUp = 2 \wedge AdjDn = 2 \wedge L_{down} \geq L_{EQdown} \wedge NumLanes = 3 \\
out \leftarrow Eqn3 \quad \text{if} \quad AdjUp = 2 \wedge AdjDn = 2 \wedge L_{down} < L_{EQdown} \wedge NumLanes = 3 \\
out \leftarrow 0.436 \quad \text{if} \quad NumLanes = 4
\end{array} \right.$$

$$P_{FD} := P_{FD}(NumLanes) \qquad P_{FD} = 0.67$$

C. Estimating Flow in Lanes 1 and 2

$$V_{12} := V_r + (V_f - V_r) \cdot P_{FD} \qquad V_{12} = 2639 \quad \text{pc/h}$$

D. Checking the Reasonableness of the Lane Distribution Prediction

Six Lane Freeways *Eight Lane Freeways*

$V_3 := V_f - V_{12}$ $\quad V_3 = 1061$ pc/h $\quad V_{av34} := \frac{V_f - V_{12}}{2}$ $\quad V_{av34} = 531$ pc/h

$$
V12a(NumLanes) := \left|
\begin{array}{l}
out \leftarrow V_{12} \quad \text{if} \quad NumLanes = 2 \\
out \leftarrow V_f - 2700 \quad \text{if} \quad V_3 > 2700 \wedge V_3 \le 1.5 \cdot \frac{V_{12}}{2} \vee NumLanes = 3 \\
out \leftarrow \frac{V_f}{1.75} \quad \text{if} \quad V_3 \le 2700 \wedge V_3 > 1.5 \cdot \frac{V_{12}}{2} \wedge NumLanes = 3 \\
out \leftarrow \max\left(V_f - 2700, \frac{V_f}{1.75}\right) \quad \text{if} \quad V_3 > 2700 \wedge V_3 > 1.5 \cdot \frac{V_{12}}{2} \wedge NumLanes = 3 \\
out \leftarrow V_{12} \quad \text{if} \quad V_3 \le 2700 \wedge V_3 \le 1.5 \cdot \frac{V_{12}}{2} \wedge NumLanes = 3 \\
out \leftarrow V_f - 5400 \quad \text{if} \quad V_{av34} > 2700 \wedge V_{av34} \le 1.5 \cdot \frac{V_{12}}{2} \wedge NumLanes = 4 \\
out \leftarrow \frac{V_f}{2.50} \quad \text{if} \quad V_{av34} \le 2700 \wedge V_{av34} > 1.5 \cdot \frac{V_{12}}{2} \wedge NumLanes = 4 \\
out \leftarrow \max\left(V_f - 5400, \frac{V_f}{2.50}\right) \quad \text{if} \quad V_{av34} > 2700 \wedge V_{av34} > 1.5 \cdot \frac{V_{12}}{2} \wedge NumLanes = 4 \\
out \leftarrow V_{12} \quad \text{if} \quad V_{av34} \le 2700 \wedge V_{av34} \le 1.5 \cdot \frac{V_{12}}{2} \wedge NumLanes = 4
\end{array}
\right.
$$

C. Final Flow in Lanes 1 and 2

$V_{12} := V12a(NumLanes)$ $\quad V_{12} = 2639$ pc/h

Step 3. Determine Capacity of Ramp-Freeway Junction

$$\text{CapUpFreewaySegment}(\text{NumLanes}, \text{FFS}) := \left| \begin{array}{l} \text{out} \leftarrow 4800 \quad \text{if} \quad \text{FFS} \geq 70 \wedge \text{NumLanes} = 2 \\ \text{out} \leftarrow 4700 \quad \text{if} \quad \text{FFS} = 65 \wedge \text{NumLanes} = 2 \\ \text{out} \leftarrow 4600 \quad \text{if} \quad \text{FFS} = 60 \wedge \text{NumLanes} = 2 \\ \text{out} \leftarrow 4600 \quad \text{if} \quad \text{FFS} = 55 \wedge \text{NumLanes} = 2 \\ \text{out} \leftarrow 7200 \quad \text{if} \quad \text{FFS} = 70 \wedge \text{NumLanes} = 3 \\ \text{out} \leftarrow 7050 \quad \text{if} \quad \text{FFS} = 65 \wedge \text{NumLanes} = 3 \\ \text{out} \leftarrow 6900 \quad \text{if} \quad \text{FFS} = 60 \wedge \text{NumLanes} = 3 \\ \text{out} \leftarrow 6750 \quad \text{if} \quad \text{FFS} = 55 \wedge \text{NumLanes} = 3 \\ \text{out} \leftarrow 9600 \quad \text{if} \quad \text{FFS} = 70 \wedge \text{NumLanes} = 4 \\ \text{out} \leftarrow 9400 \quad \text{if} \quad \text{FFS} = 65 \wedge \text{NumLanes} = 4 \\ \text{out} \leftarrow 9200 \quad \text{if} \quad \text{FFS} = 60 \wedge \text{NumLanes} = 4 \\ \text{out} \leftarrow 9000 \quad \text{if} \quad \text{FFS} = 55 \wedge \text{NumLanes} = 4 \\ \text{out} \leftarrow 2400 \cdot \text{NumLanes} \quad \text{if} \quad \text{FFS} = 70 \wedge \text{NumLanes} > 4 \\ \text{out} \leftarrow 2350 \cdot \text{NumLanes} \quad \text{if} \quad \text{FFS} = 65 \wedge \text{NumLanes} > 4 \\ \text{out} \leftarrow 2300 \cdot \text{NumLanes} \quad \text{if} \quad \text{FFS} = 60 \wedge \text{NumLanes} > 4 \\ \text{out} \leftarrow 2250 \cdot \text{NumLanes} \quad \text{if} \quad \text{FFS} = 55 \wedge \text{NumLanes} > 4 \end{array} \right.$$

$\text{CapUpFreewaySegment}(\text{NumLanes}, \text{FFS}) = 7050$ Capacity of Ramp Freeway Junction

MaxV12 = 4400 Maximum Desirable Flow Rate Entering Merge Influence Area

$$\text{CapacityRampRoadway} := \left| \begin{array}{l} \text{out} \leftarrow 2200 \quad \text{if} \quad (\text{NRamp} = 1) \wedge (S_{FR} > 50) \\ \text{out} \leftarrow 2100 \quad \text{if} \quad (\text{NRamp} = 1) \wedge (40 < S_{FR} \leq 50) \\ \text{out} \leftarrow 2000 \quad \text{if} \quad (\text{NRamp} = 1) \wedge (30 < S_{FR} \leq 40) \\ \text{out} \leftarrow 1900 \quad \text{if} \quad (\text{NRamp} = 1) \wedge (20 \leq S_{FR} \leq 30) \\ \text{out} \leftarrow 1800 \quad \text{if} \quad (\text{NRamp} = 1) \wedge (20 > S_{FR}) \\ \text{out} \leftarrow 4400 \quad \text{if} \quad (\text{NRamp} = 2) \wedge (S_{FR} > 50) \\ \text{out} \leftarrow 4200 \quad \text{if} \quad (\text{NRamp} = 2) \wedge (40 < S_{FR} \leq 50) \\ \text{out} \leftarrow 4000 \quad \text{if} \quad (\text{NRamp} = 2) \wedge (30 < S_{FR} \leq 40) \\ \text{out} \leftarrow 3800 \quad \text{if} \quad (\text{NRamp} = 2) \wedge (20 \leq S_{FR} \leq 30) \\ \text{out} \leftarrow 3600 \quad \text{if} \quad (\text{NRamp} = 2) \wedge (20 > S_{FR}) \end{array} \right.$$

$\text{CapacityRampRoadway} = 2000$

$V_f = 3701$ pc/h Volume immediatley upstream of off-ramp influence area

Ramp Freeway Junction Checkpoint Volume immediatley upstream of off-ramp influence area is chekced against freeway capacity. Failure of ramp freeway junction checkpoint (i.e. demand exceeds capacity) results in LOS F

Ramp Roadway Capacity Checkpoint If the off-ramp demand flow rate (Vr) exceeds the capacity of the off-ramp, LOS F prevails.

Maximum Desirable Flow Entering Ramp Influence Area Checkpoint

While the V12 values is checked against the maximum desirable, failure does not result in assignment of LOS F. Failing this checkpoint generally means that there will be more turbulance in influence area than predicted by this methodology. Thus, predicted densities are most likely lower than those that will exist, and predicted speeds are most likely to be predicted as higher than those that will actually occur.

Step 4. Determine Speeds in the Vicinity of Ramp-Freeway Junction

A. Average Speed in the Ramp Influence Area

$$S_R := FFS - (FFS - 42)\cdot(0.883 + 0.00009\cdot V_r - 0.013\cdot S_{FR})$$

$S_R = 55.65$ mi/h

B. Average Speed in the Outer Lanes of Freeway

Average Flow in Outer Lanes

$$N_o := \begin{cases} out \leftarrow 1 & \text{if } NumLanes = 3 \\ out \leftarrow 2 & \text{if } NumLanes = 4 \\ out \leftarrow \infty & \text{if } NumLanes = 2 \end{cases}$$

$$V_{OA} := \frac{V_f - V_{12}}{N_o} \qquad V_{OA} = 1061$$

$$S_O(V_{OA}) := \begin{cases} out \leftarrow 1.097\cdot FFS & \text{if } V_{OA} < 1000 \\ out \leftarrow 1.097\cdot FFS - 0.0039\cdot(V_{OA} - 1000) & \text{if } 1000 \le V_{OA} \end{cases}$$

$S_O := S_O(V_{OA})$ $\qquad S_O = 71.07$ mi/h

C. Average Speed for Off-Ramp Junction

$$Speed := \frac{V_{12} + V_{OA}\cdot N_o}{\left(\frac{V_{12}}{S_R}\right) + \left(\frac{V_{OA}\cdot N_o}{S_O}\right)}$$

$Speed = 59.34$ mi/h

Step 5. Determine the Density and Level of Service

A. Density in Off-Ramp Influence Area

$$\text{Density}_R := 4.252 + 0.0086 \cdot V_{12} - 0.009 \cdot L_D \qquad \text{Density}_R = 22.9 \quad \text{pc/mi/ln}$$

B. Density in Outer Lanes

$$\text{Density}_O := \frac{V_{OA}}{S_O} \qquad \text{Density}_O = 14.9 \quad \text{pc/mi/ln}$$

C. Density of Entire Cross-Section

$$\text{Density} := \left| \begin{array}{l} \text{out} \leftarrow \text{Density}_R \quad \text{if} \quad \text{NumLanes} \le 2 \\ \text{out} \leftarrow \dfrac{\left[\text{Density}_R \cdot (2) + \text{Density}_O \cdot (\text{NumLanes} - 2)\right]}{\text{NumLanes}} \quad \text{if} \quad \text{NumLanes} > 2 \end{array} \right. \qquad \text{Density} = 20.2 \quad \text{pc/mi/ln}$$

D. Level of Service

$$\text{LOS}(\text{Density}) := \left| \begin{array}{l} \text{out} \leftarrow \text{"A"} \quad \text{if} \quad 0 \le \text{Density} \le 10 \\ \text{out} \leftarrow \text{"B"} \quad \text{if} \quad 10 < \text{Density} \le 20 \\ \text{out} \leftarrow \text{"C"} \quad \text{if} \quad 20 < \text{Density} \le 28 \\ \text{out} \leftarrow \text{"D"} \quad \text{if} \quad 28 < \text{Density} \le 35 \\ \text{out} \leftarrow \text{"E"} \quad \text{if} \quad 35 < \text{Density} \end{array} \right. \qquad \text{LOS}(\text{Density}) = \text{"C"}$$

Step 6. Determine Input Vol and %HV for Next Downstream Segment

$$\text{FwyVol}_{Cars} := \text{FwyVol} \cdot \left(1 - \frac{\%\text{Trucks}_F}{100}\right) = 3276.2$$

$$\text{RampVol}_{Cars} := \text{RampVol} \cdot \left(1 - \frac{\%\text{Trucks}_R}{100}\right) = 445.9$$

$$\text{FwyVol}_{CarsNew} := \text{FwyVol}_{Cars} - \text{RampVol}_{Cars} = 2830.3$$

$$\text{FwyVol}_{Trucks} := \text{FwyVol} \cdot \frac{\%\text{Trucks}_F}{100} = 159.791$$

$$\text{RampVol}_{Trucks} := \text{RampVol} \cdot \left(\frac{\%\text{Trucks}_R}{100}\right) = 9.1$$

$$\text{FwyVol}_{TrucksNew} := \text{FwyVol}_{Trucks} - \text{RampVol}_{Trucks} = 150.691$$

$$\text{FwyVolNew} := \text{FwyVol}_{CarsNew} + \text{FwyVol}_{TrucksNew} = 2981$$

$$\%\text{Trucks}_{FNew} := \frac{\text{FwyVol}_{TrucksNew}}{\text{FwyVolNew}} \cdot 100 = 5.0551$$

**FwyVolNew and %Trucks$_{FNew}$ are the input values for FwyVol and %Trucks$_F$ for the next downstream segment if there is one. If the next segment is a weave, then %Trucks$_{FNew}$ is the input value for %Trucks_FF and %Trucks_FR.*

Full Clover Basic (7b)

**FwyVolNew and %Trucks$_{FNew}$ from the previous upstream segment are the input values for FwyVol and %Trucks$_F$ (if there is a previous upstream segment).*

Input Values

Traffic

$FwyVol := 2981 \quad PHF := 0.95$

$f_p := 1.0 \quad FFS := 65$

$\%Trucks_F := 5.0551 \quad P_R := 0$

$P_T := \frac{\%Trucks_F}{100} = 0.0506$

Roadway

$N := 3 \quad LaneWidth := 12 \quad LatClear := 6 \quad IntDens := 0.87$

$Terrain := 1$ 1 = Level, 2 = Rolling, 3 = Mountainous

$AreaType := 2$ 1 = Rural, 2 = Urban

**FREEPLAN finds IntDens by counting parclos and diamond as 1 interchange each, full as 2, and on and off as 1/2 each and adds them. Then, it divides that total number of interchanges by the total length of the facility.*

Find f_{HV} (using Exhibit 23-8 and Eq. 23-3)

$$E_T(Terrain) := \left| \begin{array}{l} out \leftarrow 1.5 \ \text{ if } Terrain = 1 \\ out \leftarrow 2.5 \ \text{ if } Terrain = 2 \\ out \leftarrow 4.5 \ \text{ if } Terrain = 3 \\ out \end{array} \right. \qquad E_R(Terrain) := \left| \begin{array}{l} out \leftarrow 1.2 \ \text{ if } Terrain = 1 \\ out \leftarrow 2.0 \ \text{ if } Terrain = 2 \\ out \leftarrow 4.0 \ \text{ if } Terrain = 3 \\ out \end{array} \right.$$

$E_T(Terrain) = 1.5 \quad E_T := E_T(Terrain) \quad E_R(Terrain) = 1.2 \quad E_R := E_R(Terrain)$

$$f_{HV} := \frac{1}{1 + P_T \cdot (E_T - 1) + P_R \cdot (E_R - 1)} \qquad f_{HV} = 0.9753$$

Find v_p (using Eq. 23-2)

$$v_p := \frac{FwyVol}{PHF \cdot N \cdot f_{HV} \cdot f_p} \qquad v_p = 1072.4 \text{ pc/h/ln}$$

Determine S

$S_1 := FFS$

$$S_2 := FFS - \left[\left(FFS - \frac{160}{3} \right) \cdot \left(\frac{v_p + 30 \cdot FFS - 3400}{30 \cdot FFS - 1000} \right)^{2.6} \right]$$

$$S_3 := FFS - \left[\frac{1}{9} \cdot (7 \cdot FFS - 340) \cdot \left(\frac{v_p + 30 \cdot FFS - 3400}{40 \cdot FFS - 1700} \right)^{2.6} \right]$$

$S_{cont2} := \text{if}\left[(55 \le FFS \le 75) \wedge \left[v_p \le (3400 - 30 \cdot FFS) \right], S_1, \text{"Cannot Compute"} \right]$

$S_{cont1} := \text{if}\left[(55 \le FFS \le 70) \wedge \left[(3400 - 30 \cdot FFS) < v_p \le (1700 + 10 \cdot FFS) \right], S_3, S_{cont2} \right]$

$S := \text{if}\left[(70 < FFS \le 75) \wedge \left[(3400 - 30 \cdot FFS) < v_p \le 2400 \right], S_2, S_{cont1} \right]$

$S = 65$ mi/h

Density (using Eq. 23-4)

$D := \frac{v_p}{S}$ $D = 16.5$ pc/mi/ln

Determine level of service (using Exhibit 23-2)

$$\text{LOS}(D) := \left| \begin{array}{l} \text{out} \leftarrow \text{"F"} \quad \text{if } D > 45 \\ \text{out} \leftarrow \text{"E"} \quad \text{if } 45 \geq D > 35 \\ \text{out} \leftarrow \text{"D"} \quad \text{if } 35 \geq D > 26 \\ \text{out} \leftarrow \text{"C"} \quad \text{if } 26 \geq D > 18 \\ \text{out} \leftarrow \text{"B"} \quad \text{if } 18 \geq D > 11 \\ \text{out} \leftarrow \text{"A"} \quad \text{if } 11 \geq D \\ \text{out} \end{array} \right.$$

$\text{LOS}(D) = \text{"B"}$

Determine Input Vol and %HV for Next Downstream Segment

$\text{FwyVolNew} := \text{FwyVol} = 2981$

$\%\text{Trucks}_{\text{FNew}} := \%\text{Trucks}_F = 5.0551$

**FwyVolNew and %$Trucks_{FNew}$ are the input values for FwyVol and %$Trucks_F$ for the next downstream segment if there is one. If the next segment is a weave, then %$Trucks_{FNew}$ is the input value for %Trucks_FF and %Trucks_FR.*

Full Clover On (7c)

Step 1. Data Inputs and Volume Adjusments

**FwyVolNew and %Truck$_{SFNew}$ from the previous upstream segment are the input values for FwyVol and %Truck$_{SF}$ (if there is a previous upstream segment).*

A. Inputs

$FwyVol := 2981$ veh/h $RampVol := 600$ veh/h

$\%Trucks_F := 5.0551$ $\%RV_F := 0$ $PHF := 0.95$ $f_p := 1$ $FFS := 65$ mi/h

$\%Trucks_R := 2$ $\%RV_R := 0$

$NumLanes := 3$ Number of mainline freeway lanes $NRamp := 1$ Number of lanes on ramp roadway

$Terrain := 1$ 1 = Level, 2 = Rolling, 3 = Mountainous

$L_A := 1000$ ft Total length of Acceleration Lane

$S_{FR} := 40$ mi/h Freeflow speed of the ramp at the junction point

$AdjUp := 2$ $AdjDn := 2$ 0 = none, 1 = on-ramp, 2 = off-ramp for Adjacent Upstream/Downstream Ramps

$L_{up} := 1500$ ft $L_{down} := 4000$ ft

$VolumeUp := 455$ veh/h Volume on adjacent upstream ramp

$VolumeDown := 700$ veh/h Volume on adjacent downstream ramp

B. Heavy Vehicle Adjustments

Passenger Car Equivalents

$$E_T(Terrain) := \left| \begin{array}{l} out \leftarrow 1.5 \text{ if } Terrain = 1 \\ out \leftarrow 2.5 \text{ if } Terrain = 2 \\ out \leftarrow 4.5 \text{ if } Terrain = 3 \end{array} \right. \qquad E_R(Terrain) := \left| \begin{array}{l} out \leftarrow 1.2 \text{ if } Terrain = 1 \\ out \leftarrow 2.0 \text{ if } Terrain = 2 \\ out \leftarrow 4.0 \text{ if } Terrain = 3 \end{array} \right.$$

$E_T(Terrain) = 1.5$ $E_R(Terrain) = 1.2$

$E_T := E_T(Terrain)$ $E_T = 1.5$ $E_R := E_R(Terrain)$ $E_R = 1.2$

$$f\_HV_F := \frac{100}{100 + \%Trucks_F(E_T - 1) + \%RV_F(E_R - 1)} = 0.975 \qquad f\_HV_F = 0.975$$

$$f\_HV_R := \frac{100}{100 + \%Trucks_R(E_T - 1) + \%RV_R(E_R - 1)} \qquad f\_HV_R = 0.99$$

C. Demand Flow Rate

$$V_f := \frac{FwyVol}{PHF \cdot f\_HV_F \cdot f_p} \quad V_f = 3217 \text{ pc/h} \qquad V_r := \frac{RampVol}{PHF \cdot f\_HV_R \cdot f_p} \quad V_r = 638 \text{ pc/h}$$

$$V_u := \frac{VolumeUp}{PHF \cdot f\_HV_R \cdot f_p} \quad V_u = 484 \text{ pc/h} \qquad V_d := \frac{VolumeDown}{PHF \cdot f\_HV_R \cdot f_p} \quad V_d = 744 \text{ pc/h}$$

Step 2. Determine the Approaching Flow Rate in Lanes 1 and 2

A. Equilibrium Seperation Distance for Adjacent Off-Ramp on a Six Lane Freeway

$$L_{EQup} := 0.214(V_f + V_r) + 0.444 \cdot L_A + 53.32 \cdot S_{FR} - 2403 \qquad L_{EQup} = 999 \text{ ft}$$

$$L_{EQdown} := \frac{V_d}{0.1096 + 0.000107 \cdot L_A} \qquad L_{EQdown} = 3436 \quad \text{ft}$$

B. Estimating Proportion of Freeway Vehicles Remaining in lanes 1 and 2

$$Eqn1 := 0.5775 + 0.000028 \cdot L_A \qquad Eqn1 = 0.606$$

$$Eqn2 := 0.7289 - 0.0000135 \cdot (V_f + V_r) - 0.003296 \cdot S_{FR} + 0.000063 \cdot L_{up} \qquad Eqn2 = 0.64$$

$$Eqn3 := 0.5487 + 0.2628 \cdot \frac{V_d}{L_{down}} \qquad Eqn3 = 0.598$$

$$P_{FM}(NumLanes) := \left| \begin{array}{l}
out \leftarrow 1.00 \quad \text{if} \quad NumLanes = 2 \\
out \leftarrow Eqn1 \quad \text{if} \quad AdjUp \neq 2 \wedge AdjDn \neq 2 \wedge NumLanes = 3 \\
out \leftarrow Eqn3 \quad \text{if} \quad AdjUp = 0 \wedge AdjDn = 2 \wedge L_{down} < L_{EQdown} \wedge NumLanes = 3 \\
out \leftarrow Eqn1 \quad \text{if} \quad AdjUp = 0 \wedge AdjDn = 2 \wedge L_{down} \geq L_{EQdown} \wedge NumLanes = 3 \\
out \leftarrow Eqn2 \quad \text{if} \quad AdjUp = 2 \wedge AdjDn = 0 \wedge L_{up} < L_{EQup} \wedge NumLanes = 3 \\
out \leftarrow Eqn1 \quad \text{if} \quad AdjUp = 2 \wedge AdjDn = 0 \wedge L_{up} \geq L_{EQup} \wedge NumLanes = 3 \\
out \leftarrow Eqn1 \quad \text{if} \quad AdjUp = 1 \wedge AdjDn = 1 \wedge NumLanes = 3 \\
out \leftarrow Eqn3 \quad \text{if} \quad AdjUp = 1 \wedge AdjDn = 2 \wedge L_{down} < L_{EQdown} \wedge NumLanes = 3 \\
out \leftarrow Eqn1 \quad \text{if} \quad AdjUp = 1 \wedge AdjDn = 2 \wedge L_{down} \geq L_{EQdown} \wedge NumLanes = 3 \\
out \leftarrow Eqn2 \quad \text{if} \quad AdjUp = 2 \wedge AdjDn = 1 \wedge L_{up} < L_{EQup} \wedge NumLanes = 3 \\
out \leftarrow Eqn1 \quad \text{if} \quad AdjUp = 2 \wedge AdjDn = 1 \wedge L_{up} \geq L_{EQup} \wedge NumLanes = 3 \\
out \leftarrow \max(Eqn1, Eqn2) \quad \text{if} \quad AdjUp = 2 \wedge AdjDn = 2 \wedge L_{up} < L_{EQup} \wedge L_{down} \geq L_{EQdown} \wedge NumLanes = 3 \\
out \leftarrow \max(Eqn3, Eqn2) \quad \text{if} \quad AdjUp = 2 \wedge AdjDn = 2 \wedge L_{up} < L_{EQup} \wedge L_{down} < L_{EQdown} \wedge NumLanes = 3 \\
out \leftarrow Eqn1 \quad \text{if} \quad AdjUp = 2 \wedge AdjDn = 2 \wedge L_{up} \geq L_{EQup} \wedge L_{down} \geq L_{EQdown} \wedge NumLanes = 3 \\
out \leftarrow \max(Eqn1, Eqn3) \quad \text{if} \quad AdjUp = 2 \wedge AdjDn = 2 \wedge L_{up} \geq L_{EQup} \wedge L_{down} < L_{EQdown} \wedge NumLanes = 3 \\
out \leftarrow 0.2178 - 0.0000125 \cdot V_r + -0.0115 \cdot \frac{L_A}{S_{FR}} \quad \text{if} \quad \left(\frac{V_f}{S_{FR}} \leq 72 \right) \wedge (NumLanes = 4) \\
out \leftarrow 0.2178 - 0.0000125 \cdot V_r \quad \text{if} \quad \left(\frac{V_f}{S_{FR}} > 72 \right) \wedge (NumLanes = 4)
\end{array} \right.$$

$$P_{FM} := P_{FM}(NumLanes) \qquad P_{FM} = 0.606$$

C. Estimating Flow in Lanes 1 and 2

$$V_{12} := V_f \cdot P_{FM} \qquad V_{12} = 1948 \quad \text{pc/h}$$

D. Checking the Reasonableness of the Lane Distribution Prediction

Six Lane Freeways

$$V_3 := V_f - V_{12} \qquad V_3 = 1269 \quad \text{pc/h}$$

Eight Lane Freeways

$$V_{av34} := \frac{V_f - V_{12}}{2} \qquad V_{av34} = 635 \quad \text{pc/h}$$

$$V12a(NumLanes) := \left| \begin{array}{l} out \leftarrow V_{12} \quad \text{if} \quad NumLanes = 2 \\ out \leftarrow V_f - 2700 \quad \text{if} \quad V_3 > 2700 \land V_3 \le 1.5 \cdot \frac{V_{12}}{2} \lor NumLanes = 3 \\ out \leftarrow \frac{V_f}{1.75} \quad \text{if} \quad V_3 \le 2700 \land V_3 > 1.5 \cdot \frac{V_{12}}{2} \land NumLanes = 3 \\ out \leftarrow \max\left(V_f - 2700, \frac{V_f}{1.75}\right) \quad \text{if} \quad V_3 > 2700 \land V_3 > 1.5 \cdot \frac{V_{12}}{2} \land NumLanes = 3 \\ out \leftarrow V_{12} \quad \text{if} \quad V_3 \le 2700 \land V_3 \le 1.5 \cdot \frac{V_{12}}{2} \land NumLanes = 3 \\ out \leftarrow V_f - 5400 \quad \text{if} \quad V_{av34} > 2700 \land V_{av34} \le 1.5 \cdot \frac{V_{12}}{2} \land NumLanes = 4 \\ out \leftarrow \frac{V_f}{2.50} \quad \text{if} \quad V_{av34} \le 2700 \land V_{av34} > 1.5 \cdot \frac{V_{12}}{2} \land NumLanes = 4 \\ out \leftarrow \max\left(V_f - 5400, \frac{V_f}{2.50}\right) \quad \text{if} \quad V_{av34} > 2700 \land V_{av34} > 1.5 \cdot \frac{V_{12}}{2} \land NumLanes = 4 \\ out \leftarrow V_{12} \quad \text{if} \quad V_{av34} \le 2700 \land V_{av34} \le 1.5 \cdot \frac{V_{12}}{2} \land NumLanes = 4 \end{array} \right.$$

C. Final Flow in Lanes 1 and 2

$V_{12} := V12a(NumLanes)$ $V_{12} = 1948$ pc/h

Step 3. Determine Capacity of Ramp-Freeway Junction

$V_{R12} := V_{12} + V_r$ $V_{R12} = 2586$ pc/h Flow entering the ramp influence area

$$CapUpFreewaySegment(NumLanes, FFS) := \left| \begin{array}{l} out \leftarrow 4800 \quad \text{if} \quad FFS \ge 70 \land NumLanes = 2 \\ out \leftarrow 4700 \quad \text{if} \quad FFS = 65 \land NumLanes = 2 \\ out \leftarrow 4600 \quad \text{if} \quad FFS = 60 \land NumLanes = 2 \\ out \leftarrow 4600 \quad \text{if} \quad FFS = 55 \land NumLanes = 2 \\ out \leftarrow 7200 \quad \text{if} \quad FFS = 70 \land NumLanes = 3 \\ out \leftarrow 7050 \quad \text{if} \quad FFS = 65 \land NumLanes = 3 \\ out \leftarrow 6900 \quad \text{if} \quad FFS = 60 \land NumLanes = 3 \\ out \leftarrow 6750 \quad \text{if} \quad FFS = 55 \land NumLanes = 3 \\ out \leftarrow 9600 \quad \text{if} \quad FFS = 70 \land NumLanes = 4 \\ out \leftarrow 9400 \quad \text{if} \quad FFS = 65 \land NumLanes = 4 \\ out \leftarrow 9200 \quad \text{if} \quad FFS = 60 \land NumLanes = 4 \\ out \leftarrow 9000 \quad \text{if} \quad FFS = 55 \land NumLanes = 4 \\ out \leftarrow 2400 \cdot NumLanes \quad \text{if} \quad FFS = 70 \land NumLanes > 4 \\ out \leftarrow 2350 \cdot NumLanes \quad \text{if} \quad FFS = 65 \land NumLanes > 4 \\ out \leftarrow 2300 \cdot NumLanes \quad \text{if} \quad FFS = 60 \land NumLanes > 4 \\ out \leftarrow 2250 \cdot NumLanes \quad \text{if} \quad FFS = 55 \land NumLanes > 4 \end{array} \right.$$

CapUpFreewaySegment(NumLanes , FFS) = 7050 Capacity of Ramp Freeway Junction

MaxV12 = 4600 Maximum Desirable Flow Rate Entering Merge Influence Area

$$
\text{CapacityRampRoadway} := \left|
\begin{array}{l}
\text{out} \leftarrow 2200 \quad \text{if} \quad (\text{NRamp} = 1) \wedge (S_{FR} > 50) \\
\text{out} \leftarrow 2100 \quad \text{if} \quad (\text{NRamp} = 1) \wedge (40 < S_{FR} \le 50) \\
\text{out} \leftarrow 2000 \quad \text{if} \quad (\text{NRamp} = 1) \wedge (30 < S_{FR} \le 40) \\
\text{out} \leftarrow 1900 \quad \text{if} \quad (\text{NRamp} = 1) \wedge (20 \le S_{FR} \le 30) \\
\text{out} \leftarrow 1800 \quad \text{if} \quad (\text{NRamp} = 1) \wedge (20 > S_{FR}) \\
\text{out} \leftarrow 4400 \quad \text{if} \quad (\text{NRamp} = 2) \wedge (S_{FR} > 50) \\
\text{out} \leftarrow 4200 \quad \text{if} \quad (\text{NRamp} = 2) \wedge (40 < S_{FR} \le 50) \\
\text{out} \leftarrow 4000 \quad \text{if} \quad (\text{NRamp} = 2) \wedge (30 < S_{FR} \le 40) \\
\text{out} \leftarrow 3800 \quad \text{if} \quad (\text{NRamp} = 2) \wedge (20 \le S_{FR} \le 30) \\
\text{out} \leftarrow 3600 \quad \text{if} \quad (\text{NRamp} = 2) \wedge (20 > S_{FR})
\end{array}
\right.
$$

CapacityRampRoadway = 2000

$V_{FO} := V_f + V_r$ $V_{FO} = 3855$ pc/h Volume immediatley downstream of on-ramp influence area

Ramp Freeway Junction Checkpoint

Volume immediatley downstream of on-ramp influence area is chekced against freeway capacity. Failure of ramp freeway junction checkpoint (i.e. demand exceeds capacity) results in LOS F

Ramp Roadway Capacity Checkpoint

Capacity or ramp roadway should always be checked against the demand flow rate on the ramp. It is rarely a problem for the on-ramp

Maximum Desirable Flow Entering Ramp Influence Area Checkpoint

While the V_{R12} values is checked against the maximum desirable, failure does not result in assignment of LOS F. Failing this checkpoint generally means that there will be more turbulance in influence area than predicted by this methodology. Thus, predicted densities are most likely lower than those that will exist, and predicted speeds are most likely to be predicted as higher than those that will actually occur.

Step 4. Determine Speeds in the Vicinity of Ramp-Freeway Junction

A. Average Speed in the Ramp Influence Area

$$S_R := FFS - (FFS - 42) \cdot \left[0.321 + 0.0039 \exp\left(\frac{V_{R12}}{1000}\right) - 0.002 \cdot \left(L_A \frac{S_{FR}}{1000}\right) \right] \qquad S_R = 58.27 \quad \text{mi/h}$$

B. Average Speed in the Outer Lanes of Freeway

Average Flow in Outer Lanes

$$No := \begin{array}{|l} out \leftarrow 1 \quad \text{if} \quad NumLanes = 3 \\ out \leftarrow 2 \quad \text{if} \quad NumLanes = 4 \\ out \leftarrow \infty \quad \text{if} \quad NumLanes = 2 \end{array} \qquad V_{OA} := \frac{V_f - V_{12}}{No} \qquad V_{OA} = 1269$$

$$S_O(V_{OA}) := \begin{array}{|l} out \leftarrow FFS \quad \text{if} \quad V_{OA} < 500 \\ out \leftarrow FFS - 0.0036 \cdot (V_{OA} - 500) \quad \text{if} \quad 500 \le V_{OA} \le 2300 \\ out \leftarrow FFS - 6.53 - 0.006 \cdot (V_{OA} - 2300) \quad \text{if} \quad V_{OA} > 2300 \end{array}$$

$$S_O := S_O(V_{OA}) \qquad S_O = 62.23 \quad \text{mi/h}$$

C. Average Speed for On-Ramp Junction

$$Speed := \frac{V_{R12} + V_{OA} \cdot No}{\left(\frac{V_{R12}}{S_R}\right) + \left(\frac{V_{OA} \cdot No}{S_O}\right)} \qquad Speed = 59.51 \quad \text{mi/h}$$

Step 5. Determine the Density and Level of Service

A. Density in On-Ramp Influence Area

$$Density_R := 5.475 + 0.00734 \cdot V_r + 0.0078 \cdot V_{12} - 0.00627 \cdot L_A \qquad Density_R = 19.1 \quad \text{pc/mi/ln}$$

B. Density in Outer Lanes

$$Density_O := \frac{V_{OA}}{S_O} \qquad Density_O = 20.4 \quad \text{pc/mi/ln}$$

C. Density of Entire Cross-Section

$$Density := \begin{array}{|l} out \leftarrow Density_R \quad \text{if} \quad NumLanes \le 2 \\ out \leftarrow \frac{\left[Density_R \cdot (2) + Density_O \cdot (NumLanes - 2)\right]}{NumLanes} \quad \text{if} \quad NumLanes > 2 \end{array} \qquad Density = 19.5 \quad \text{pc/mi/ln}$$

D. Level of Service

$$LOS(Density) := \begin{array}{|l} out \leftarrow \text{"A"} \quad \text{if} \quad 0 \le Density \le 10 \\ out \leftarrow \text{"B"} \quad \text{if} \quad 10 < Density \le 20 \\ out \leftarrow \text{"C"} \quad \text{if} \quad 20 < Density \le 28 \\ out \leftarrow \text{"D"} \quad \text{if} \quad 28 < Density \le 35 \\ out \leftarrow \text{"E"} \quad \text{if} \quad 35 < Density \end{array} \qquad LOS(Density) = \text{"B"}$$

Step 6. Determine Input Vol and %HV for Next Downstream Segment

$$FwyVol_{Cars} := FwyVol \cdot \left(1 - \frac{\%Trucks_F}{100}\right) = 2830.3$$

$$RampVol_{Cars} := RampVol \cdot \left(1 - \frac{\%Trucks_R}{100}\right) = 588$$

$$FwyVol_{CarsNew} := FwyVol_{Cars} + RampVol_{Cars} = 3418.3$$

$$FwyVol_{Trucks} := FwyVol \cdot \frac{\%Trucks_F}{100} = 150.693$$

$$RampVol_{Trucks} := RampVol \cdot \left(\frac{\%Trucks_R}{100}\right) = 12$$

$$FwyVol_{TrucksNew} := FwyVol_{Trucks} + RampVol_{Trucks} = 162.693$$

$$FwyVolNew := FwyVol_{CarsNew} + FwyVol_{TrucksNew} = 3581$$

$$\%Trucks_{FNew} := \frac{FwyVol_{TrucksNew}}{FwyVolNew} \cdot 100 = 4.5432$$

**FwyVolNew and %Trucks$_{FNew}$ are the input values for FwyVol and %Trucks$_F$ for the next downstream segment if there is one. If the next segment is a weave, then %Trucks$_{FNew}$ is the input value for %Trucks_FF and %Trucks_FR.*

Full Clover Basic (7d)

Input Values

**FwyVolNew and %Trucks$_{FNew}$ from the previous upstream segment are the input values for FwyVol and %Trucks$_F$ (if there is a previous upstream segment).*

Traffic

$FwyVol := 3581 \quad PHF := 0.95$

$f_p := 1.0 \quad FFS := 65$

$\%Trucks_F := 4.5432 \quad P_R := 0$

$$P_T := \frac{\%Trucks_F}{100} = 0.0454$$

Roadway

$N := 3 \quad LaneWidth := 12 \quad LatClear := 6 \quad IntDens := 0.87$

$Terrain := 1$ 1 = Level, 2 = Rolling, 3 = Mountainous

$AreaType := 2$ 1 = Rural, 2 = Urban

**FREEPLAN finds IntDens by counting parclos and diamond as 1 interchange each, full as 2, and on and off as 1/2 each and adds them. Then, it divides that total number of interchanges by the total length of the facility.*

Find f_{HV} (using Exhibit 23-8 and Eq. 23-3)

$$E_T(Terrain) := \begin{array}{|l} out \leftarrow 1.5 \text{ if } Terrain = 1 \\ out \leftarrow 2.5 \text{ if } Terrain = 2 \\ out \leftarrow 4.5 \text{ if } Terrain = 3 \\ out \end{array} \qquad E_R(Terrain) := \begin{array}{|l} out \leftarrow 1.2 \text{ if } Terrain = 1 \\ out \leftarrow 2.0 \text{ if } Terrain = 2 \\ out \leftarrow 4.0 \text{ if } Terrain = 3 \\ out \end{array}$$

$E_T(Terrain) = 1.5 \quad E_T := E_T(Terrain) \qquad E_R(Terrain) = 1.2 \quad E_R := E_R(Terrain)$

$$f_{HV} := \frac{1}{1 + P_T \cdot (E_T - 1) + P_R \cdot (E_R - 1)} \qquad f_{HV} = 0.9778$$

Find v_p (using Eq. 23-2)

$$v_p := \frac{FwyVol}{PHF \cdot N \cdot f_{HV} \cdot f_p} \qquad v_p = 1285 \text{ pc/h/ln}$$

Determine S

$S_1 := FFS$

$$S_2 := FFS - \left[\left(FFS - \frac{160}{3}\right) \cdot \left(\frac{v_p + 30 \cdot FFS - 3400}{30 \cdot FFS - 1000}\right)^{2.6}\right]$$

$$S_3 := FFS - \left[\frac{1}{9} \cdot (7 \cdot FFS - 340) \cdot \left(\frac{v_p + 30 \cdot FFS - 3400}{40 \cdot FFS - 1700}\right)^{2.6}\right]$$

$$S_{cont2} := if\left[(55 \le FFS \le 75) \wedge \left[v_p \le (3400 - 30 \cdot FFS)\right], S_1, \text{"Cannot Compute"}\right]$$

$$S_{cont1} := if\left[(55 \le FFS \le 70) \wedge \left[(3400 - 30 \cdot FFS) < v_p \le (1700 + 10 \cdot FFS)\right], S_3, S_{cont2}\right]$$

$$S := if\left[(70 < FFS \le 75) \wedge \left[(3400 - 30 \cdot FFS) < v_p \le 2400\right], S_2, S_{cont1}\right]$$

$S = 65$

Density (using Eq. 23-4)

$$D := \frac{v_p}{S} \qquad D = 19.8 \qquad \text{pc/mi/ln}$$

Determine level of service (using Exhibit 23-2)

$$LOS(D) := \left| \begin{array}{l} out \leftarrow \text{"F"} \ \text{ if } D > 45 \\ out \leftarrow \text{"E"} \ \text{ if } 45 \geq D > 35 \\ out \leftarrow \text{"D"} \ \text{ if } 35 \geq D > 26 \\ out \leftarrow \text{"C"} \ \text{ if } 26 \geq D > 18 \\ out \leftarrow \text{"B"} \ \text{ if } 18 \geq D > 11 \\ out \leftarrow \text{"A"} \ \text{ if } 11 \geq D \\ out \end{array} \right.$$

$LOS(D) = \text{"C"}$

Determine Input Vol and %HV for Next Downstream Segment

$FwyVolNew := FwyVol = 3581$

$\%Trucks_{FNew} := \%Trucks_F = 4.5432$

**FwyVolNew and %Trucks$_{FNew}$ are the input values for FwyVol and %Trucks$_F$ for the next downstream segment if there is one. If the next segment is a weave, then %Trucks$_{FNew}$ is the input value for %Trucks_FF and %Trucks_FR.*

Full Clover Off (7e)

Step 1. Data Inputs and Volume Adjusments

**FwyVolNew and %Truck$_{SFNew}$ from the previous upstream segment are the input values for FwyVol and %Truck$_{SF}$ (if there is a previous upstream segment).*

A. Inputs

$FwyVol := 3581$ veh/h $RampVol := 700$ veh/h

$\%Trucks_F := 4.5432$ $\%RV_F := 0$ $PHF := 0.95$ $f_p := 1$ $FFS := 65$ mi/h

$\%Trucks_R := 2$ $\%RV_R := 0$

$NumLanes := 3$ Number of mainline freeway lanes $NRamp := 1$ Number of lanes on ramp roadway

$Terrain := 1$ 1 = Level, 2 = Rolling, 3 = Mountainous

$L_D := 450$ ft Total length of Deceleration Lane

$S_{FR} := 40$ mi/h Freeflow speed of the ramp at the junction point

$AdjUp := 1$ $AdjDn := 1$ 0 = none, 1 = on-ramp, 2 = off-ramp for Adjacent Upstream/Downstream Ramps

$L_{up} := 4000$ ft $L_{down} := 1500$ ft

$VolumeUp := 600$ veh/h Volume on adjacent upstream ramp

$VolumeDown := 455$ veh/h Volume on adjacent downstream ramp

B. Heavy Vehicle Adjustments

Passenger Car Equivalents

$$E_T(Terrain) := \begin{array}{|l} out \leftarrow 1.5 \text{ if } Terrain = 1 \\ out \leftarrow 2.5 \text{ if } Terrain = 2 \\ out \leftarrow 4.5 \text{ if } Terrain = 3 \end{array} \qquad E_R(Terrain) := \begin{array}{|l} out \leftarrow 1.2 \text{ if } Terrain = 1 \\ out \leftarrow 2.0 \text{ if } Terrain = 2 \\ out \leftarrow 4.0 \text{ if } Terrain = 3 \end{array}$$

$E_T(Terrain) = 1.5$ $E_R(Terrain) = 1.2$

$E_T := E_T(Terrain)$ $E_T = 1.5$ $E_R := E_R(Terrain)$ $E_R = 1.2$

$$f\_HV_F := \frac{100}{100 + \%Trucks_F(E_T - 1) + \%RV_F(E_R - 1)} \qquad f\_HV_F = 0.978$$

$$f\_HV_R := \frac{100}{100 + \%Trucks_R(E_T - 1) + \%RV_R(E_R - 1)} \qquad f\_HV_R = 0.99$$

C. Demand Flow Rate

$$V_f := \frac{FwyVol}{PHF \cdot f\_HV_F \cdot f_p} \qquad V_f = 3855 \text{ pc/h} \qquad V_r := \frac{RampVol}{PHF \cdot f\_HV_R \cdot f_p} \qquad V_r = 744 \text{ pc/h}$$

$$V_u := \frac{VolumeUp}{PHF \cdot f\_HV_R \cdot f_p} \qquad V_u = 638 \text{ pc/h} \qquad V_d := \frac{VolumeDown}{PHF \cdot f\_HV_R \cdot f_p} \qquad V_d = 484 \text{ pc/h}$$

Step 2. Determine the Approaching Flow Rate in Lanes 1 and 2

A. Equilibrium Seperation Distance for Adjacent Upstream On-Ramp or Downstream Off-Ramps on a Six Lane Freeway

$$L_{EQup} := \frac{V_u}{0.071 + 0.000023 \cdot V_f - 0.000076 \cdot V_r} \qquad L_{EQup} = 6187 \quad \text{ft}$$

$$L_{EQdown} := \frac{V_d}{1.15 - 0.000032 \cdot V_f - 0.000369 \cdot V_r} \qquad L_{EQdown} = 643 \quad \text{ft}$$

B. Estimating Proportion of Freeway Vehicles Remaining in lanes 1 and 2

$$Eqn1 := 0.760 - 0.000025 \cdot V_f - 0.000046 \cdot V_r \qquad Eqn1 = 0.629$$

$$Eqn2 := 0.717 - 0.000039 \cdot V_f + 0.604 \cdot \frac{V_u}{L_{up}} \qquad Eqn2 = 0.663$$

$$Eqn3 := 0.616 - 0.000021 \cdot V_f + 0.124 \cdot \frac{V_d}{L_{down}} \qquad Eqn3 = 0.575$$

$$P_{FD}(\text{Numlanes}) := \left| \begin{array}{l}
out \leftarrow 1.00 \quad \text{if} \quad NumLanes = 2 \\
out \leftarrow Eqn1 \quad \text{if} \quad AdjUp = 0 \wedge AdjDn = 0 \wedge NumLanes = 3 \\
out \leftarrow Eqn1 \quad \text{if} \quad AdjUp = 0 \wedge AdjDn = 1 \wedge NumLanes = 3 \\
out \leftarrow Eqn1 \quad \text{if} \quad AdjUp = 0 \wedge AdjDn = 2 \wedge L_{down} \geq L_{EQdown} \wedge NumLanes = 3 \\
out \leftarrow Eqn3 \quad \text{if} \quad AdjUp = 0 \wedge AdjDn = 2 \wedge L_{down} < L_{EQdown} \wedge NumLanes = 3 \\
out \leftarrow Eqn1 \quad \text{if} \quad AdjUp = 1 \wedge AdjDn = 0 \wedge L_{up} \geq L_{EQup} \wedge NumLanes = 3 \\
out \leftarrow Eqn2 \quad \text{if} \quad AdjUp = 1 \wedge AdjDn = 0 \wedge L_{up} < L_{EQup} \wedge NumLanes = 3 \\
out \leftarrow Eqn1 \quad \text{if} \quad AdjUp = 2 \wedge AdjDn = 0 \wedge NumLanes = 3 \\
out \leftarrow Eqn1 \quad \text{if} \quad AdjUp = 1 \wedge AdjDn = 1 \wedge L_{up} \geq L_{EQup} \wedge NumLanes = 3 \\
out \leftarrow Eqn2 \quad \text{if} \quad AdjUp = 1 \wedge AdjDn = 1 \wedge L_{up} < L_{EQup} \wedge NumLanes = 3 \\
out \leftarrow \max(Eqn2, Eqn3) \quad \text{if} \quad AdjUp = 1 \wedge AdjDn = 2 \wedge L_{up} < L_{EQup} \wedge L_{down} < L_{EQdown} \wedge NumLanes = 3 \\
out \leftarrow \max(Eqn2, Eqn1) \quad \text{if} \quad AdjUp = 1 \wedge AdjDn = 2 \wedge L_{up} < L_{EQup} \wedge L_{down} \geq L_{EQdown} \wedge NumLanes = 3 \\
out \leftarrow Eqn1 \quad \text{if} \quad AdjUp = 1 \wedge AdjDn = 2 \wedge L_{up} \geq L_{EQup} \wedge L_{down} \geq L_{EQdown} \wedge NumLanes = 3 \\
out \leftarrow \max(Eqn3, Eqn1) \quad \text{if} \quad AdjUp = 1 \wedge AdjDn = 2 \wedge L_{up} \geq L_{EQup} \wedge L_{down} < L_{EQdown} \wedge NumLanes = 3 \\
out \leftarrow Eqn1 \quad \text{if} \quad AdjUp = 2 \wedge AdjDn = 1 \wedge NumLanes = 3 \\
out \leftarrow Eqn1 \quad \text{if} \quad AdjUp = 2 \wedge AdjDn = 2 \wedge L_{down} \geq L_{EQdown} \wedge NumLanes = 3 \\
out \leftarrow Eqn3 \quad \text{if} \quad AdjUp = 2 \wedge AdjDn = 2 \wedge L_{down} < L_{EQdown} \wedge NumLanes = 3 \\
out \leftarrow 0.436 \quad \text{if} \quad NumLanes = 4
\end{array} \right.$$

$$P_{FD} := P_{FD}(\text{NumLanes}) \qquad P_{FD} = 0.663$$

C. Estimating Flow in Lanes 1 and 2

$$V_{12} := V_r + (V_f - V_r) \cdot P_{FD} \qquad V_{12} = 2807 \quad \text{pc/h}$$

D. Checking the Reasonableness of the Lane Distribution Prediction

Six Lane Freeways *Eight Lane Freeways*

$V_3 := V_f - V_{12}$ $\quad V_3 = 1048$ pc/h $\quad V_{av34} := \frac{V_f - V_{12}}{2}$ $\quad V_{av34} = 524$ pc/h

$$
V12a(NumLanes) := \begin{array}{|l}
out \leftarrow V_{12} \quad \text{if} \quad NumLanes = 2 \\
out \leftarrow V_f - 2700 \quad \text{if} \quad V_3 > 2700 \wedge V_3 \le 1.5 \cdot \frac{V_{12}}{2} \vee NumLanes = 3 \\
out \leftarrow \frac{V_f}{1.75} \quad \text{if} \quad V_3 \le 2700 \wedge V_3 > 1.5 \cdot \frac{V_{12}}{2} \wedge NumLanes = 3 \\
out \leftarrow \max\left(V_f - 2700, \frac{V_f}{1.75}\right) \quad \text{if} \quad V_3 > 2700 \wedge V_3 > 1.5 \cdot \frac{V_{12}}{2} \wedge NumLanes = 3 \\
out \leftarrow V_{12} \quad \text{if} \quad V_3 \le 2700 \wedge V_3 \le 1.5 \cdot \frac{V_{12}}{2} \wedge NumLanes = 3 \\
out \leftarrow V_f - 5400 \quad \text{if} \quad V_{av34} > 2700 \wedge V_{av34} \le 1.5 \cdot \frac{V_{12}}{2} \wedge NumLanes = 4 \\
out \leftarrow \frac{V_f}{2.50} \quad \text{if} \quad V_{av34} \le 2700 \wedge V_{av34} > 1.5 \cdot \frac{V_{12}}{2} \wedge NumLanes = 4 \\
out \leftarrow \max\left(V_f - 5400, \frac{V_f}{2.50}\right) \quad \text{if} \quad V_{av34} > 2700 \wedge V_{av34} > 1.5 \cdot \frac{V_{12}}{2} \wedge NumLanes = 4 \\
out \leftarrow V_{12} \quad \text{if} \quad V_{av34} \le 2700 \wedge V_{av34} \le 1.5 \cdot \frac{V_{12}}{2} \wedge NumLanes = 4
\end{array}
$$

C. Final Flow in Lanes 1 and 2

$V_{12} := V12a(NumLanes)$ $\quad V_{12} = 2807$ pc/h

Step 3. Determine Capacity of Ramp-Freeway Junction

$$\text{CapUpFreewaySegment}(\text{NumLanes}, \text{FFS}) := \left| \begin{array}{l} \text{out} \leftarrow 4800 \quad \text{if} \quad \text{FFS} \geq 70 \wedge \text{NumLanes} = 2 \\ \text{out} \leftarrow 4700 \quad \text{if} \quad \text{FFS} = 65 \wedge \text{NumLanes} = 2 \\ \text{out} \leftarrow 4600 \quad \text{if} \quad \text{FFS} = 60 \wedge \text{NumLanes} = 2 \\ \text{out} \leftarrow 4600 \quad \text{if} \quad \text{FFS} = 55 \wedge \text{NumLanes} = 2 \\ \text{out} \leftarrow 7200 \quad \text{if} \quad \text{FFS} = 70 \wedge \text{NumLanes} = 3 \\ \text{out} \leftarrow 7050 \quad \text{if} \quad \text{FFS} = 65 \wedge \text{NumLanes} = 3 \\ \text{out} \leftarrow 6900 \quad \text{if} \quad \text{FFS} = 60 \wedge \text{NumLanes} = 3 \\ \text{out} \leftarrow 6750 \quad \text{if} \quad \text{FFS} = 55 \wedge \text{NumLanes} = 3 \\ \text{out} \leftarrow 9600 \quad \text{if} \quad \text{FFS} = 70 \wedge \text{NumLanes} = 4 \\ \text{out} \leftarrow 9400 \quad \text{if} \quad \text{FFS} = 65 \wedge \text{NumLanes} = 4 \\ \text{out} \leftarrow 9200 \quad \text{if} \quad \text{FFS} = 60 \wedge \text{NumLanes} = 4 \\ \text{out} \leftarrow 9000 \quad \text{if} \quad \text{FFS} = 55 \wedge \text{NumLanes} = 4 \\ \text{out} \leftarrow 2400 \cdot \text{NumLanes} \quad \text{if} \quad \text{FFS} = 70 \wedge \text{NumLanes} > 4 \\ \text{out} \leftarrow 2350 \cdot \text{NumLanes} \quad \text{if} \quad \text{FFS} = 65 \wedge \text{NumLanes} > 4 \\ \text{out} \leftarrow 2300 \cdot \text{NumLanes} \quad \text{if} \quad \text{FFS} = 60 \wedge \text{NumLanes} > 4 \\ \text{out} \leftarrow 2250 \cdot \text{NumLanes} \quad \text{if} \quad \text{FFS} = 55 \wedge \text{NumLanes} > 4 \end{array} \right.$$

$\text{CapUpFreewaySegment}(\text{NumLanes}, \text{FFS}) = 7050$ Capacity of Ramp Freeway Junction

MaxV12 = 4400 Maximum Desirable Flow Rate Entering Merge Influence Area

$$\text{CapacityRampRoadway} := \left| \begin{array}{l} \text{out} \leftarrow 2200 \quad \text{if} \quad (\text{NRamp} = 1) \wedge (S_{FR} > 50) \\ \text{out} \leftarrow 2100 \quad \text{if} \quad (\text{NRamp} = 1) \wedge (40 < S_{FR} \leq 50) \\ \text{out} \leftarrow 2000 \quad \text{if} \quad (\text{NRamp} = 1) \wedge (30 < S_{FR} \leq 40) \\ \text{out} \leftarrow 1900 \quad \text{if} \quad (\text{NRamp} = 1) \wedge (20 \leq S_{FR} \leq 30) \\ \text{out} \leftarrow 1800 \quad \text{if} \quad (\text{NRamp} = 1) \wedge (20 > S_{FR}) \\ \text{out} \leftarrow 4400 \quad \text{if} \quad (\text{NRamp} = 2) \wedge (S_{FR} > 50) \\ \text{out} \leftarrow 4200 \quad \text{if} \quad (\text{NRamp} = 2) \wedge (40 < S_{FR} \leq 50) \\ \text{out} \leftarrow 4000 \quad \text{if} \quad (\text{NRamp} = 2) \wedge (30 < S_{FR} \leq 40) \\ \text{out} \leftarrow 3800 \quad \text{if} \quad (\text{NRamp} = 2) \wedge (20 \leq S_{FR} \leq 30) \\ \text{out} \leftarrow 3600 \quad \text{if} \quad (\text{NRamp} = 2) \wedge (20 > S_{FR}) \end{array} \right.$$

$\text{CapacityRampRoadway} = 2000$

$V_f = 3855$ pc/h Volume immediatley upstream of off-ramp influence area

Ramp Freeway Junction Checkpoint

Volume immediatley upstream of off-ramp influence area is chekced against freeway capacity. Failure of ramp freeway junction checkpoint (i.e. demand exceeds capacity) results in LOS F

Ramp Roadway Capacity Checkpoint

If the off-ramp demand flow rate (Vr) exceeds the capacity of the off-ramp, LOS F prevails.

Maximum Desirable Flow Entering Ramp Influence Area Checkpoint

While the V12 values is checked against the maximum desirable, failure does not result in assignment of LOS F. Failing this checkpoint generally means that there will be more turbulance in influence area than predicted by this methodology. Thus, predicted densities are most likely lower than those that will exist, and predicted speeds are most likely to be predicted as higher than those that will actually occur.

Step 4. Determine Speeds in the Vicinity of Ramp-Freeway Junction

A. Average Speed in the Ramp Influence Area

$$S_R := FFS - (FFS - 42)\cdot(0.883 + 0.00009\cdot V_r - 0.013\cdot S_{FR})$$

$S_R = 55.11$ mi/h

B. Average Speed in the Outer Lanes of Freeway

Average Flow in Outer Lanes

$$N_o := \begin{cases} out \leftarrow 1 & \text{if } NumLanes = 3 \\ out \leftarrow 2 & \text{if } NumLanes = 4 \\ out \leftarrow \infty & \text{if } NumLanes = 2 \end{cases}$$

$$V_{OA} := \frac{V_f - V_{12}}{N_o}$$

$V_{OA} = 1048$

$$S_O(V_{OA}) := \begin{cases} out \leftarrow 1.097\cdot FFS & \text{if } V_{OA} < 1000 \\ out \leftarrow 1.097\cdot FFS - 0.0039\cdot(V_{OA} - 1000) & \text{if } 1000 \le V_{OA} \end{cases}$$

$S_O := S_O(V_{OA})$ $\quad$ $S_O = 71.12$ mi/h

C. Average Speed for Off-Ramp Junction

$$Speed := \frac{V_{12} + V_{OA}\cdot N_o}{\left(\frac{V_{12}}{S_R}\right) + \left(\frac{V_{OA}\cdot N_o}{S_O}\right)}$$

$Speed = 58.7$ mi/h

Step 5. Determine the Density and Level of Service

A. Density in Off-Ramp Influence Area

$$Density_R := 4.252 + 0.0086 \cdot V_{12} - 0.009 \cdot L_D \qquad Density_R = 24.3 \quad \text{pc/mi/ln}$$

B. Density in Outer Lanes

$$Density_O := \frac{V_{OA}}{S_O} \qquad Density_O = 14.7 \quad \text{pc/mi/ln}$$

C. Density of Entire Cross-Section

$$Density := \begin{array}{|l} out \leftarrow Density_R \quad \text{if} \quad NumLanes \le 2 \\ out \leftarrow \dfrac{\left[Density_R \cdot (2) + Density_O \cdot (NumLanes - 2)\right]}{NumLanes} \quad \text{if} \quad NumLanes > 2 \end{array} \qquad Density = 21.1 \quad \text{pc/mi/ln}$$

D. Level of Service

$$LOS(Density) := \begin{array}{|l} out \leftarrow \text{"A"} \quad \text{if} \quad 0 \le Density \le 10 \\ out \leftarrow \text{"B"} \quad \text{if} \quad 10 < Density \le 20 \\ out \leftarrow \text{"C"} \quad \text{if} \quad 20 < Density \le 28 \\ out \leftarrow \text{"D"} \quad \text{if} \quad 28 < Density \le 35 \\ out \leftarrow \text{"E"} \quad \text{if} \quad 35 < Density \end{array} \qquad LOS(Density) = \text{"C"}$$

Step 6. Determine Input Vol and %HV for Next Downstream Segment

$$FwyVol_{Cars} := FwyVol \cdot \left(1 - \frac{\%Trucks_F}{100}\right) = 3418.3$$

$$RampVol_{Cars} := RampVol \cdot \left(1 - \frac{\%Trucks_R}{100}\right) = 686$$

$$FwyVol_{CarsNew} := FwyVol_{Cars} - RampVol_{Cars} = 2732.3$$

$$FwyVol_{Trucks} := FwyVol \cdot \frac{\%Trucks_F}{100} = 162.692$$

$$RampVol_{Trucks} := RampVol \cdot \left(\frac{\%Trucks_R}{100}\right) = 14$$

$$FwyVol_{TrucksNew} := FwyVol_{Trucks} - RampVol_{Trucks} = 148.692$$

$$FwyVolNew := FwyVol_{CarsNew} + FwyVol_{TrucksNew} = 2881$$

$$\%Trucks_{FNew} := \frac{FwyVol_{TrucksNew}}{FwyVolNew} \cdot 100 = 5.1611$$

**FwyVolNew and $\%Trucks_{FNew}$ are the input values for FwyVol and $\%Trucks_F$ for the next downstream segment if there is one. If the next segment is a weave, then $\%Trucks_{FNew}$ is the input value for %Trucks_FF and %Trucks_FR.*

Full Clover Basic (7f)

Input Values

**FwyVolNew and %Trucks$_{FNew}$ from the previous upstream segment are the input values for FwyVol and %Trucks$_F$ (if there is a previous upstream segment).*

Traffic

$FwyVol := 2881 \quad PHF := 0.95$

$f_p := 1 \quad FFS := 65$

$\%Trucks_F := 5.1611 \quad P_R := 0$

$$P_T := \frac{\%Trucks_F}{100} = 0.0516$$

Roadway

$N := 3 \quad LaneWidth := 12 \quad LatClear := 6 \quad IntDens := 0.87$

$Terrain := 1$ 1 = Level, 2 = Rolling, 3 = Mountainous

$AreaType := 2$ 1 = Rural, 2 = Urban

**FREEPLAN finds IntDens by counting parclos and diamond as 1 interchange each, full as 2, and on and off as 1/2 each and adds them. Then, it divides that total number of interchanges by the total length of the facility.*

Find f_{HV} (using Exhibit 23-8 and Eq. 23-3)

$$E_T(Terrain) := \left| \begin{array}{l} out \leftarrow 1.5 \ \text{ if } Terrain = 1 \\ out \leftarrow 2.5 \ \text{ if } Terrain = 2 \\ out \leftarrow 4.5 \ \text{ if } Terrain = 3 \\ out \end{array} \right. \qquad E_R(Terrain) := \left| \begin{array}{l} out \leftarrow 1.2 \ \text{ if } Terrain = 1 \\ out \leftarrow 2.0 \ \text{ if } Terrain = 2 \\ out \leftarrow 4.0 \ \text{ if } Terrain = 3 \\ out \end{array} \right.$$

$E_T(Terrain) = 1.5 \quad E_T := E_T(Terrain) \quad E_R(Terrain) = 1.2 \quad E_R := E_R(Terrain)$

$$f_{HV} := \frac{1}{1 + P_T \cdot (E_T - 1) + P_R \cdot (E_R - 1)} \qquad f_{HV} = 0.9748$$

Find v_p (using Eq. 23-2)

$$v_p := \frac{FwyVol}{PHF \cdot N \cdot f_{HV} \cdot f_p} \qquad v_p = 1037 \text{ pc/h/ln}$$

Determine S

$S_1 := FFS$

$$S_2 := FFS - \left[\left(FFS - \frac{160}{3}\right) \cdot \left(\frac{v_p + 30 \cdot FFS - 3400}{30 \cdot FFS - 1000}\right)^{2.6}\right]$$

$$S_3 := FFS - \left[\frac{1}{9} \cdot (7 \cdot FFS - 340) \cdot \left(\frac{v_p + 30 \cdot FFS - 3400}{40 \cdot FFS - 1700}\right)^{2.6}\right]$$

$S_{cont2} := if[(55 \le FFS \le 75) \wedge [v_p \le (3400 - 30 \cdot FFS)], S_1, \text{"Cannot Compute"}]$

$S_{cont1} := if[(55 \le FFS \le 70) \wedge [(3400 - 30 \cdot FFS) < v_p \le (1700 + 10 \cdot FFS)], S_3, S_{cont2}]$

$S := if[(70 < FFS \le 75) \wedge [(3400 - 30 \cdot FFS) < v_p \le 2400], S_2, S_{cont1}]$

$S = 65$ mi/h

Density (using Eq. 23-4)

$D := \frac{v_p}{S}$ $\qquad D = 16$ $\qquad$ pc/mi/ln

Determine level of service (using Exhibit 23-2)

$$
LOS(D) := \left|
\begin{array}{l}
out \leftarrow \text{"F"} \;\; \text{if } D > 45 \\
out \leftarrow \text{"E"} \;\; \text{if } 45 \ge D > 35 \\
out \leftarrow \text{"D"} \;\; \text{if } 35 \ge D > 26 \\
out \leftarrow \text{"C"} \;\; \text{if } 26 \ge D > 18 \\
out \leftarrow \text{"B"} \;\; \text{if } 18 \ge D > 11 \\
out \leftarrow \text{"A"} \;\; \text{if } 11 \ge D \\
out
\end{array}
\right.
$$

$LOS(D) = \text{"B"}$

Determine Input Vol and %HV for Next Downstream Segment

$FwyVolNew := FwyVol = 2881$

$\%Trucks_{FNew} := \%Trucks_F = 5.1611$

**FwyVolNew and %Trucks$_{FNew}$ are the input values for FwyVol and %Trucks$_F$ for the next downstream segment if there is one. If the next segment is a weave, then %Trucks$_{FNew}$ is the input value for %Trucks_FF and %Trucks_FR.*

Weave (Full On 7g and Off 8)

**FwyVolNew and %Trucks$_{FNew}$ from the previous upstream segment are the input values for SegInputVol and SegInput%HV if there is a previous upstream segment.*

Step 1. Data Inputs

OnRampVol := 455   OffRampVol := 300   SegInputVol := 2881   Int_Density := 0.87   int/mi

OnRamp%HV := 2   OffRamp%HV := 2   SegInput%HV := 5.1611

**FREEPLAN finds Int_Density by counting parclos and diamond as 1 interchange each, full as 2, and on and off as 1/2 each and adds them. Then, it divides that total number of interchanges by the total length of the facility.*

L_B := 1500   ft   FFS := 65 mi/h   PHF := .95   fp := 1

Terrain := 1   1 = Level, 2 = Rolling, 3 = Mountainous

Config := 1   1 = one-sided weaving segment, 2 = two-sided weaving segment

NumLanes := 4   Number of lanes in weaving section

C_IFL := 2350   pc/h/ln   Capacity of basic freeway segment with same FFS as the weaving segment under equivalent ideal conditions

N_WL := 2   Number of lanes from which weaving maneuvers may be made with one lane change or no lane change. 2 or 3 for one sided and 0 for two sided weaving configuration

LC_RF := 1   Minimum number of lane changes that must be made by a single weaving vehicle from the on-ramp to freeway

LC_FR := 1   Minimum number of lane changes that must be made by a single weaving vehicle from freeway to the off-ramp

LC_RR := 0   Minimum number of lane changes that must be made by one ramp-to-ramp to complete a weaving maneuver

Step 2. Volume Adjustment

A. Heavy Vehicle and Volume Adjustments

Passenger Car Equivalents

$$\text{E\_T(Terrain)} := \left| \begin{array}{lll} \text{out} \leftarrow 1.5 & \text{if} & \text{Terrain} = 1 \\ \text{out} \leftarrow 2.5 & \text{if} & \text{Terrain} = 2 \\ \text{out} \leftarrow 4.5 & \text{if} & \text{Terrain} = 3 \end{array} \right.$$

$$\text{E\_T} := \text{E\_T(Terrain)}$$

$$\text{E\_T} = 1.5$$

**FREEPLAN assumes trucks make up all of the heavy vehicles. Therefore, RV calculations have been left out.*

$$\text{f\_HV\_FF} := \frac{100}{100 + \text{SegInput\%HV}(\text{E\_T} - 1)}$$

$$\text{f\_HV\_FR} := \frac{100}{100 + \text{OffRamp\%HV}(\text{E\_T} - 1)}$$

$$\text{f\_HV\_RF} := \frac{100}{100 + \text{OnRamp\%HV}(\text{E\_T} - 1)}$$

$$\text{f\_HV\_RR} := \frac{100}{100 + \text{OnRamp\%HV}(\text{E\_T} - 1)}$$

$$\text{SegInputVolAdj} := \frac{\text{SegInputVol}}{\text{PHF} \cdot \text{f\_HV\_FF} \cdot \text{fp}} = 3110.89$$

$$\text{OffRampVolAdj} := \frac{\text{OffRampVol}}{\text{PHF} \cdot \text{f\_HV\_FR} \cdot \text{fp}} = 318.9474$$

$$\text{OnRampVolAdj} := \frac{\text{OnRampVol}}{\text{PHF} \cdot \text{f\_HV\_RF} \cdot \text{fp}} = 483.7368$$

**Freeplan assumes the Freeway to Ramp Volume will have the same %HV as the Off Ramp and that the Freeway to Freeway Volume will have the same %HV as the Segment Input Volume*

$$\text{f\_HV} := \frac{(\text{f\_HV\_FF} + \text{f\_HV\_FR} + \text{f\_HV\_RF} + \text{f\_HV\_RR})}{4}$$

$$\text{f\_HV} = 0.9863$$

B. Volumes for Weaving Segments

v_RR := .05 · OnRampVolAdj = 24.1868 veh/h ** Freeplan assumes the v_RR is 5% of the total On-Ramp volume.*

v_FR := OffRampVolAdj − v_RR = 294.7605 veh/h

v_RF := .95 · OnRampVolAdj = 459.55 veh/h

v_FF := SegInputVolAdj − v_FR = 2816.13 veh/h

v_Total := v_FF + v_RF + v_FR + v_RR = 3.5946×10^{3} veh/h

C. Weaving Demand Flow Rate

WeavingDemand(N_WL) :=
| out ← v_RF + v_FR if N_WL ≠ 0
| out ← v_RR if N_WL = 0

WeavingFlowRate := WeavingDemand(N_WL)

WeavingFlowRate = 754 pc/h

D. Non-Weaving Demand Flow Rate

NonWeavingDemand(N_WL) :=
| out ← v_FF + v_RR if N_WL ≠ 0
| out ← v_FF + v_FR + v_RF if N_WL = 0

NonWeavingFlowRate := NonWeavingDemand(N_WL)

NonWeavingFlowRate = 2840 pc/h

E. Total Demand Flow Rate

TotalFlowRate := WeavingFlowRate + NonWeavingFlowRate

TotalFlowRate = 3595 pc/h

F. Volume Ratio

$$VR := \frac{WeavingFlowRate}{TotalFlowRate}$$

VR = 0.2098

Step 3. Determine the Maximum Weaving Length

$$MaximumLength := \left[5728\left(1 + VR\right)^{1.6}\right] - 1566 \cdot N\_WL$$

MaximumLength = 4637 ft

$Ls := L_B \cdot .77 = 1155$

If Maximum Length < Ls, then STOP
Analyze ramp junctions separately

Step 4. Determine the Capacity of Weaving Segment

A. Weaving segment capacity determined by density

$$C\_IWL := C\_IFL - \left[438.2\cdot(1 + VR)^{1.6}\right] + (0.0765\cdot Ls) + (119.8\cdot N\_WL)$$

$C\_IWL = 2084$ pc/h/ln   C_IWL is the capacity per lane under equivalent ideal conditions

$$Cw1 := C\_IWL\cdot NumLanes\cdot f\_HV\cdot fp$$

$Cw1 = 8220$ veh/h   Cw1 is the density based capacity of weaving segment under prevailing conditions

B. Weaving segment capacity determined by weaving demand flows

$$C\_IW(N\_WL) := \left|\begin{array}{l} out \leftarrow \dfrac{2400}{VR} \quad \text{if} \quad N\_WL = 2 \\ out \leftarrow \dfrac{3500}{VR} \quad \text{if} \quad N\_WL = 3 \\ out \leftarrow \dfrac{Cw1}{f\_HV\cdot fp} \quad \text{if} \quad N\_WL = 0 \end{array}\right.$$

For two sided segments, no limiting value on flow rate is proposed and thus capacity based on density only is estimated for the segment. Therefore same capacity value is used here to get the final as capacity determined by density for two sided segments.

$C\_IW := C\_IW(N\_WL)$ $C\_IW = 11437$ pc/h   C_IW is the capacity of the weaving segment under ideal conditions

$$Cw2 := C\_IW\cdot f\_HV\cdot fp$$

$Cw2 = 11280$ veh/h   Cw2 is the flow based capacity of weaving segment under prevailing conditions

C. Final Capacity of Weaving Segment

$$WeavingCapacity := \text{if}(Cw1 > Cw2, Cw2, Cw1)$$

$\boxed{WeavingCapacity = 8220}$ veh/h

D. Volume to Capacity (v/c) Ratio

$$VolumeToCapacity := \frac{TotalFlowRate\cdot f\_HV\cdot fp}{WeavingCapacity}$$

$\boxed{VolumeToCapacity = 0.4313}$ If v/c ratio >1 then LOS is F Terminate

Step 5. Determine Configuration Characteristics

$$LC\_MIN(Config) := \left|\begin{array}{l} out \leftarrow (LC\_RF\cdot v\_RF) + (LC\_FR\cdot v\_FR) \quad \text{if} \quad Config = 1 \\ out \leftarrow (LC\_RR\cdot v\_RR) \quad \text{if} \quad Config = 2 \end{array}\right.$$

$$LC\_MIN := LC\_MIN(Config)$$

$\boxed{LC\_MIN = 754}$ lc/h   Minimum Lane Changes

Step 6. Determine Lane-Changing Rates

A. Lane-Changing Rate for Weaving Vehicles

$$LC\_W(Ls) := \begin{array}{|l} out \leftarrow LC\_MIN + 0.39 \cdot \left[(Ls - 300)^{0.5} \cdot NumLanes^{2} \cdot (1 + Int\_Density)^{0.8} \right] \quad \text{if} \quad Ls \geq 300 \\ out \leftarrow LC\_MIN \quad \text{if} \quad Ls < 300 \end{array}$$

$$LaneChangingWeaving := LC\_W(Ls)$$

$$\boxed{LaneChangingWeaving = 1055} \quad \text{lc/h}$$

B. Lane-Changing Rate for Non-Weaving Vehicles

$$I\_NW := \frac{Ls \cdot Int\_Density \cdot NonWeavingFlowRate}{10000} \qquad I\_NW = 285$$

Non Weaving Vehicle Index

$$LC\_NW1 := (0.206 \cdot NonWeavingFlowRate) + (0.542 \cdot Ls) - (192.6 \cdot NumLanes)$$

$$LC\_NW2 := 2135 + 0.233 \cdot (NonWeavingFlowRate - 2000)$$

$$LC\_NW3 := LC\_NW1 + (LC\_NW2 - LC\_NW1) \cdot \frac{(I\_NW - 1300)}{650}$$

$$LC\_NW(I\_NW) := \begin{array}{|l} out \leftarrow LC\_NW1 \quad \text{if} \quad I\_NW < 1300 \\ out \leftarrow LC\_NW2 \quad \text{if} \quad I\_NW \geq 1950 \\ out \leftarrow LC\_NW3 \quad \text{if} \quad 1300 < I\_NW < 1950 \\ out \leftarrow LC\_NW2 \quad \text{if} \quad LC\_NW1 \geq LC\_NW2 \end{array}$$

$$LaneChangingNonWeaving := LC\_NW(I\_NW)$$

$$\boxed{LaneChangingNonWeaving = 441} \quad \text{lc/h}$$

C. Total Lane-Changing Rate

$$TotalLaneChanging := LaneChangingWeaving + LaneChangingNonWeaving$$

$$\boxed{TotalLaneChanging = 1496} \quad \text{lc/h}$$

Step 7. Determine Average Speed of Weaving and Non-Weaving Vehicles

A. Average Speed of Weaving Vehicles

$$WeavingIntensityFactor := 0.226 \left(\frac{TotalLaneChanging}{Ls} \right)^{0.789}$$

$$WeavingIntensityFactor = 0.2772$$

$$AverageWeavingSpeed := 15 + \left(\frac{FFS - 15}{1 + WeavingIntensityFactor} \right)$$

$$\boxed{AverageWeavingSpeed = 54.15} \quad \text{mi/h}$$

B. Average Speed of Non-Weaving Vehicles

$$\text{AverageNonWeavingSpeed} := \text{FFS} - (0.0072 \cdot \text{LC\_MIN}) - \left(0.0048 \cdot \frac{\text{TotalFlowRate}}{\text{NumLanes}}\right)$$

$\boxed{\text{AverageNonWeavingSpeed} = 55.26}$ mi/h

C. Average Speed of All Vehicles

$$\text{AverageSpeed} := \frac{\text{WeavingFlowRate} + \text{NonWeavingFlowRate}}{\left(\frac{\text{WeavingFlowRate}}{\text{AverageWeavingSpeed}}\right) + \left(\frac{\text{NonWeavingFlowRate}}{\text{AverageNonWeavingSpeed}}\right)}$$

$\boxed{\text{AverageSpeed} = 55.02}$ mi/h

Step 8. Determine the Level of Service

$$\text{Density} := \frac{\left(\frac{\text{TotalFlowRate}}{\text{NumLanes}}\right)}{\text{AverageSpeed}}$$

$\boxed{\text{Density} = 16.3}$ pc/mi/ln

$$\text{LOS(Density)} := \left| \begin{array}{lll} \text{out} \leftarrow \text{"A"} & \text{if} & 0 \le \text{Density} \le 10 \\ \text{out} \leftarrow \text{"B"} & \text{if} & 10 < \text{Density} \le 20 \\ \text{out} \leftarrow \text{"C"} & \text{if} & 20 < \text{Density} \le 28 \\ \text{out} \leftarrow \text{"D"} & \text{if} & 28 < \text{Density} \le 35 \\ \text{out} \leftarrow \text{"E"} & \text{if} & 35 < \text{Density} \\ \text{out} \leftarrow \text{"F"} & \text{if} & \text{VolumeToCapacity} > 1 \end{array} \right.$$

$\boxed{\text{LOS(Density)} = \text{"B"}}$

Step 9. Determine the Input Vol and %HV for the Next Downstream Segment

$$\text{FwyVolNew} := \text{SegInputVol} + (\text{OnRampVol} - \text{v\_RR}) - (\text{OffRampVol} - \text{v\_RR}) = 3036$$

$$\%\text{Trucks}_{\text{FNew}} := \frac{\text{SegInputVol} \cdot \text{SegInput\%HV} + (\text{OnRampVol} - \text{v\_RR}) \cdot \text{OnRamp\%HV} - (\text{OffRampVol} - \text{v\_RR}) \cdot \text{OffRamp\%HV}}{\text{FwyVolNew}}$$

$\%\text{Trucks}_{\text{FNew}} = 5$

**FwyVolNew and %Trucks$_{FNew}$ are the input values for FwyVol and %Trucks$_F$ for the next downstream segment if there is one. If the next segment is a weave, then %Trucks$_{FNew}$ is the input value for SegInput%HV and FwyVolNew is the input value for SegInputVol.*

Basic 9

Input Values

Traffic

$FwyVol := 3036 \quad PHF := 0.95$

$f_p := 1 \quad FFS := 65$

$\%Trucks_F := 5 \quad P_R := 0$

$P_T := \frac{\%Trucks_F}{100} = 0.05$

$*FwyVolNew$ and $\%Trucks_{FNew}$ from the previous upstream segment are the input values for FwyVol and $\%Trucks_F$ (if there is a previous upstream segment).

Roadway

$N := 3 \quad LaneWidth := 12 \quad LatClear := 6 \quad IntDens := 0.87$

$Terrain := 1$ 1 = Level, 2 = Rolling, 3 = Mountainous

$AreaType := 2$ 1 = Rural, 2 = Urban

**FREEPLAN finds IntDens by counting parclos and diamond as 1 interchange each, full as 2, and on and off as 1/2 each and adds them. Then, it divides that total number of interchanges by the total length of the facility.*

Find f_{HV} (using Exhibit 23-8 and Eq. 23-3)

$$E_T(Terrain) := \left| \begin{array}{l} out \leftarrow 1.5 \ \text{ if } Terrain = 1 \\ out \leftarrow 2.5 \ \text{ if } Terrain = 2 \\ out \leftarrow 4.5 \ \text{ if } Terrain = 3 \\ out \end{array} \right. \qquad E_R(Terrain) := \left| \begin{array}{l} out \leftarrow 1.2 \ \text{ if } Terrain = 1 \\ out \leftarrow 2.0 \ \text{ if } Terrain = 2 \\ out \leftarrow 4.0 \ \text{ if } Terrain = 3 \\ out \end{array} \right.$$

$E_T(Terrain) = 1.5 \quad E_T := E_T(Terrain) \qquad E_R(Terrain) = 1.2 \quad E_R := E_R(Terrain)$

$$f_{HV} := \frac{1}{1 + P_T \cdot (E_T - 1) + P_R \cdot (E_R - 1)} \qquad f_{HV} = 0.9756$$

Find v_p (using Eq. 23-2)

$$v_p := \frac{FwyVol}{PHF \cdot N \cdot f_{HV} \cdot f_p} \qquad v_p = 1091.9 \ \text{pc/h/ln}$$

Determine S

$S_1 := FFS$

$$S_2 := FFS - \left[\left(FFS - \frac{160}{3} \right) \cdot \left(\frac{v_p + 30 \cdot FFS - 3400}{30 \cdot FFS - 1000} \right)^{2.6} \right]$$

$$S_3 := FFS - \left[\frac{1}{9} \cdot (7 \cdot FFS - 340) \cdot \left(\frac{v_p + 30 \cdot FFS - 3400}{40 \cdot FFS - 1700} \right)^{2.6} \right]$$

$$S_{cont2} := if\left[(55 \le FFS \le 75) \wedge \left[v_p \le (3400 - 30 \cdot FFS) \right], S_1, \text{"Cannot Compute"} \right]$$

$$S_{cont1} := if\left[(55 \le FFS \le 70) \wedge \left[(3400 - 30 \cdot FFS) < v_p \le (1700 + 10 \cdot FFS) \right], S_3, S_{cont2} \right]$$

$$S := if\left[(70 < FFS \le 75) \wedge \left[(3400 - 30 \cdot FFS) < v_p \le 2400 \right], S_2, S_{cont1} \right]$$

$S = 65$

Density (using Eq. 23-4)

$$D := \frac{v_p}{S} \qquad D = 16.8 \quad \text{pc/mi/ln}$$

Determine level of service (using Exhibit 23-2)

$$LOS(D) := \left| \begin{array}{l} out \leftarrow \text{"F"} \ \ \text{if } D > 45 \\ out \leftarrow \text{"E"} \ \ \text{if } 45 \geq D > 35 \\ out \leftarrow \text{"D"} \ \ \text{if } 35 \geq D > 26 \\ out \leftarrow \text{"C"} \ \ \text{if } 26 \geq D > 18 \\ out \leftarrow \text{"B"} \ \ \text{if } 18 \geq D > 11 \\ out \leftarrow \text{"A"} \ \ \text{if } 11 \geq D \\ out \end{array} \right.$$

$LOS(D) = \text{"B"}$

Determine Input Vol and %HV for Next Downstream Segment

$FwyVolNew := FwyVol = 3036$

$\%Trucks_{FNew} := \%Trucks_F = 5$

**FwyVolNew and %Trucks$_{FNew}$ are the input values for FwyVol and %Trucks$_F$ for the next downstream segment if there is one. If the next segment is a weave, then %Trucks$_{FNew}$ is the input value for %Trucks_FF and %Trucks_FR.*

Full Off 10a

Step 1. Data Inputs and Volume Adjusments

**FwyVolNew and %Trucks$_{FNew}$ from the previous upstream segment are the input values for FwyVol and %Trucks$_F$ (if there is a previous upstream segment).*

A. Inputs

$FwyVol := 3036$ veh/h $RampVol := 400$ veh/h

$\%Trucks_F := 5$ $\%RV_F := 0$ $PHF := 0.95$ $f_p := 1$ $FFS := 65$ mi/h

$\%Trucks_R := 2$ $\%RV_R := 0$

$NumLanes := 3$ Number of mainline freeway lanes $NRamp := 1$ Number of lanes on ramp roadway

$Terrain := 1$ 1 = Level, 2 = Rolling, 3 = Mountainous

$L_D := 450$ ft Total length of Deceleration Lane

$S_{FR} := 40$ mi/h Freeflow speed of the ramp at the junction point

$AdjUp := 2$ $AdjDn := 1$ 0 = none, 1 = on-ramp, 2 = off-ramp for Adjacent Upstream/Downstream Ramps

$L_{up} := 8280$ ft $L_{down} := 1000$ ft

$VolumeUp := 300$ veh/h Volume on adjacent upstream ramp

$VolumeDown := 700$ veh/h Volume on adjacent downstream ramp

B. Heavy Vehicle Adjustments

Passenger Car Equivalents

$$E_T(Terrain) := \begin{vmatrix} out \leftarrow 1.5 & \text{if} & Terrain = 1 \\ out \leftarrow 2.5 & \text{if} & Terrain = 2 \\ out \leftarrow 4.5 & \text{if} & Terrain = 3 \end{vmatrix} \qquad E_R(Terrain) := \begin{vmatrix} out \leftarrow 1.2 & \text{if} & Terrain = 1 \\ out \leftarrow 2.0 & \text{if} & Terrain = 2 \\ out \leftarrow 4.0 & \text{if} & Terrain = 3 \end{vmatrix}$$

$E_T(Terrain) = 1.5$ $E_R(Terrain) = 1.2$

$E_T := E_T(Terrain)$ $E_T = 1.5$ $E_R := E_R(Terrain)$ $E_R = 1.2$

$$f\_HV_F := \frac{100}{100 + \%Trucks_F(E_T - 1) + \%RV_F(E_R - 1)} \qquad f\_HV_F = 0.976$$

$$f\_HV_R := \frac{100}{100 + \%Trucks_R(E_T - 1) + \%RV_R(E_R - 1)} \qquad f\_HV_R = 0.99$$

C. Demand Flow Rate

$$V_f := \frac{FwyVol}{PHF \cdot f\_HV_F \cdot f_p} \qquad V_f = 3276 \text{ pc/h} \qquad V_r := \frac{RampVol}{PHF \cdot f\_HV_R \cdot f_p} \qquad V_r = 425 \text{ pc/h}$$

$$V_u := \frac{VolumeUp}{PHF \cdot f\_HV_R \cdot f_p} \qquad V_u = 319 \text{ pc/h} \qquad V_d := \frac{VolumeDown}{PHF \cdot f\_HV_R \cdot f_p} \qquad V_d = 744 \text{ pc/h}$$

Step 2. Determine the Approaching Flow Rate in Lanes 1 and 2

A. Equilibrium Seperation Distance for Adjacent Upstream On-Ramp or Downstream Off-Ramps on a Six Lane Freeway

$$L_{EQup} := \frac{V_u}{0.071 + 0.000023 \cdot V_f - 0.000076 \cdot V_r} \qquad L_{EQup} = 2797 \quad \text{ft}$$

$$L_{EQdown} := \frac{V_d}{1.15 - 0.000032 \cdot V_f - 0.000369 \cdot V_r} \qquad L_{EQdown} = 838 \quad \text{ft}$$

B. Estimating Proportion of Freeway Vehicles Remaining in lanes 1 and 2

$$Eqn1 := 0.760 - 0.000025 \cdot V_f - 0.000046 \cdot V_r \qquad Eqn1 = 0.659$$

$$Eqn2 := 0.717 - 0.000039 \cdot V_f + 0.604 \cdot \frac{V_u}{L_{up}} \qquad Eqn2 = 0.613$$

$$Eqn3 := 0.616 - 0.000021 \cdot V_f + 0.124 \cdot \frac{V_d}{L_{down}} \qquad Eqn3 = 0.639$$

$$P_{FD}(\text{Numlanes}) := \left| \begin{array}{l}
out \leftarrow 1.00 \quad \text{if} \quad NumLanes = 2 \\
out \leftarrow Eqn1 \quad \text{if} \quad AdjUp = 0 \wedge AdjDn = 0 \wedge NumLanes = 3 \\
out \leftarrow Eqn1 \quad \text{if} \quad AdjUp = 0 \wedge AdjDn = 1 \wedge NumLanes = 3 \\
out \leftarrow Eqn1 \quad \text{if} \quad AdjUp = 0 \wedge AdjDn = 2 \wedge L_{down} \geq L_{EQdown} \wedge NumLanes = 3 \\
out \leftarrow Eqn3 \quad \text{if} \quad AdjUp = 0 \wedge AdjDn = 2 \wedge L_{down} < L_{EQdown} \wedge NumLanes = 3 \\
out \leftarrow Eqn1 \quad \text{if} \quad AdjUp = 1 \wedge AdjDn = 0 \wedge L_{up} \geq L_{EQup} \wedge NumLanes = 3 \\
out \leftarrow Eqn2 \quad \text{if} \quad AdjUp = 1 \wedge AdjDn = 0 \wedge L_{up} < L_{EQup} \wedge NumLanes = 3 \\
out \leftarrow Eqn1 \quad \text{if} \quad AdjUp = 2 \wedge AdjDn = 0 \wedge NumLanes = 3 \\
out \leftarrow Eqn1 \quad \text{if} \quad AdjUp = 1 \wedge AdjDn = 1 \wedge L_{up} \geq L_{EQup} \wedge NumLanes = 3 \\
out \leftarrow Eqn2 \quad \text{if} \quad AdjUp = 1 \wedge AdjDn = 1 \wedge L_{up} < L_{EQup} \wedge NumLanes = 3 \\
out \leftarrow \max(Eqn2, Eqn3) \quad \text{if} \quad AdjUp = 1 \wedge AdjDn = 2 \wedge L_{up} < L_{EQup} \wedge L_{down} < L_{EQdown} \wedge NumLanes = 3 \\
out \leftarrow \max(Eqn2, Eqn1) \quad \text{if} \quad AdjUp = 1 \wedge AdjDn = 2 \wedge L_{up} < L_{EQup} \wedge L_{down} \geq L_{EQdown} \wedge NumLanes = 3 \\
out \leftarrow Eqn1 \quad \text{if} \quad AdjUp = 1 \wedge AdjDn = 2 \wedge L_{up} \geq L_{EQup} \wedge L_{down} \geq L_{EQdown} \wedge NumLanes = 3 \\
out \leftarrow \max(Eqn3, Eqn1) \quad \text{if} \quad AdjUp = 1 \wedge AdjDn = 2 \wedge L_{up} \geq L_{EQup} \wedge L_{down} < L_{EQdown} \wedge NumLanes = 3 \\
out \leftarrow Eqn1 \quad \text{if} \quad AdjUp = 2 \wedge AdjDn = 1 \wedge NumLanes = 3 \\
out \leftarrow Eqn1 \quad \text{if} \quad AdjUp = 2 \wedge AdjDn = 2 \wedge L_{down} \geq L_{EQdown} \wedge NumLanes = 3 \\
out \leftarrow Eqn3 \quad \text{if} \quad AdjUp = 2 \wedge AdjDn = 2 \wedge L_{down} < L_{EQdown} \wedge NumLanes = 3 \\
out \leftarrow 0.436 \quad \text{if} \quad NumLanes = 4
\end{array} \right.$$

$$P_{FD} := P_{FD}(\text{NumLanes}) \qquad P_{FD} = 0.659$$

C. Estimating Flow in Lanes 1 and 2

$$V_{12} := V_r + (V_f - V_r) \cdot P_{FD} \qquad V_{12} = 2302 \quad \text{pc/h}$$

D. Checking the Reasonableness of the Lane Distribution Prediction

Six Lane Freeways *Eight Lane Freeways*

$V_3 := V_f - V_{12}$ $V_3 = 973$ pc/h $V_{av34} := \frac{V_f - V_{12}}{2}$ $V_{av34} = 487$ pc/h

$$
V12a(NumLanes) := \left|
\begin{array}{l}
out \leftarrow V_{12} \ \text{ if } \ NumLanes = 2 \\
out \leftarrow V_f - 2700 \ \text{ if } \ V_3 > 2700 \land V_3 \le 1.5 \cdot \frac{V_{12}}{2} \lor NumLanes = 3 \\
out \leftarrow \frac{V_f}{1.75} \ \text{ if } \ V_3 \le 2700 \land V_3 > 1.5 \cdot \frac{V_{12}}{2} \land NumLanes = 3 \\
out \leftarrow \max\left(V_f - 2700, \frac{V_f}{1.75}\right) \ \text{ if } \ V_3 > 2700 \land V_3 > 1.5 \cdot \frac{V_{12}}{2} \land NumLanes = 3 \\
out \leftarrow V_{12} \ \text{ if } \ V_3 \le 2700 \land V_3 \le 1.5 \cdot \frac{V_{12}}{2} \land NumLanes = 3 \\
out \leftarrow V_f - 5400 \ \text{ if } \ V_{av34} > 2700 \land V_{av34} \le 1.5 \cdot \frac{V_{12}}{2} \land NumLanes = 4 \\
out \leftarrow \frac{V_f}{2.50} \ \text{ if } \ V_{av34} \le 2700 \land V_{av34} > 1.5 \cdot \frac{V_{12}}{2} \land NumLanes = 4 \\
out \leftarrow \max\left(V_f - 5400, \frac{V_f}{2.50}\right) \ \text{ if } \ V_{av34} > 2700 \land V_{av34} > 1.5 \cdot \frac{V_{12}}{2} \land NumLanes = 4 \\
out \leftarrow V_{12} \ \text{ if } \ V_{av34} \le 2700 \land V_{av34} \le 1.5 \cdot \frac{V_{12}}{2} \land NumLanes = 4
\end{array}
\right.
$$

C. Final Flow in Lanes 1 and 2

$V_{12} := V12a(NumLanes)$ $V_{12} = 2302$ pc/h

Step 3. Determine Capacity of Ramp-Freeway Junction

$$\text{CapUpFreewaySegment}(\text{NumLanes}, \text{FFS}) := \left| \begin{array}{ll} \text{out} \leftarrow 4800 & \text{if } \text{FFS} \geq 70 \wedge \text{NumLanes} = 2 \\ \text{out} \leftarrow 4700 & \text{if } \text{FFS} = 65 \wedge \text{NumLanes} = 2 \\ \text{out} \leftarrow 4600 & \text{if } \text{FFS} = 60 \wedge \text{NumLanes} = 2 \\ \text{out} \leftarrow 4600 & \text{if } \text{FFS} = 55 \wedge \text{NumLanes} = 2 \\ \text{out} \leftarrow 7200 & \text{if } \text{FFS} = 70 \wedge \text{NumLanes} = 3 \\ \text{out} \leftarrow 7050 & \text{if } \text{FFS} = 65 \wedge \text{NumLanes} = 3 \\ \text{out} \leftarrow 6900 & \text{if } \text{FFS} = 60 \wedge \text{NumLanes} = 3 \\ \text{out} \leftarrow 6750 & \text{if } \text{FFS} = 55 \wedge \text{NumLanes} = 3 \\ \text{out} \leftarrow 9600 & \text{if } \text{FFS} = 70 \wedge \text{NumLanes} = 4 \\ \text{out} \leftarrow 9400 & \text{if } \text{FFS} = 65 \wedge \text{NumLanes} = 4 \\ \text{out} \leftarrow 9200 & \text{if } \text{FFS} = 60 \wedge \text{NumLanes} = 4 \\ \text{out} \leftarrow 9000 & \text{if } \text{FFS} = 55 \wedge \text{NumLanes} = 4 \\ \text{out} \leftarrow 2400 \cdot \text{NumLanes} & \text{if } \text{FFS} = 70 \wedge \text{NumLanes} > 4 \\ \text{out} \leftarrow 2350 \cdot \text{NumLanes} & \text{if } \text{FFS} = 65 \wedge \text{NumLanes} > 4 \\ \text{out} \leftarrow 2300 \cdot \text{NumLanes} & \text{if } \text{FFS} = 60 \wedge \text{NumLanes} > 4 \\ \text{out} \leftarrow 2250 \cdot \text{NumLanes} & \text{if } \text{FFS} = 55 \wedge \text{NumLanes} > 4 \end{array} \right.$$

$\text{CapUpFreewaySegment}(\text{NumLanes}, \text{FFS}) = 7050$ Capacity of Ramp Freeway Junction

MaxV12 = 4400 Maximum Desirable Flow Rate Entering Merge Influence Area

$$\text{CapacityRampRoadway} := \left| \begin{array}{ll} \text{out} \leftarrow 2200 & \text{if } (\text{NRamp} = 1) \wedge (S_{FR} > 50) \\ \text{out} \leftarrow 2100 & \text{if } (\text{NRamp} = 1) \wedge (40 < S_{FR} \leq 50) \\ \text{out} \leftarrow 2000 & \text{if } (\text{NRamp} = 1) \wedge (30 < S_{FR} \leq 40) \\ \text{out} \leftarrow 1900 & \text{if } (\text{NRamp} = 1) \wedge (20 \leq S_{FR} \leq 30) \\ \text{out} \leftarrow 1800 & \text{if } (\text{NRamp} = 1) \wedge (20 > S_{FR}) \\ \text{out} \leftarrow 4400 & \text{if } (\text{NRamp} = 2) \wedge (S_{FR} > 50) \\ \text{out} \leftarrow 4200 & \text{if } (\text{NRamp} = 2) \wedge (40 < S_{FR} \leq 50) \\ \text{out} \leftarrow 4000 & \text{if } (\text{NRamp} = 2) \wedge (30 < S_{FR} \leq 40) \\ \text{out} \leftarrow 3800 & \text{if } (\text{NRamp} = 2) \wedge (20 \leq S_{FR} \leq 30) \\ \text{out} \leftarrow 3600 & \text{if } (\text{NRamp} = 2) \wedge (20 > S_{FR}) \end{array} \right.$$

$\text{CapacityRampRoadway} = 2000$

$V_f = 3276$ pc/h Volume immediatley upstream of off-ramp influence area

Ramp Freeway Junction Checkpoint Volume immediatley upstream of off-ramp influence area is chekced against freeway capacity. Failure of ramp freeway junction checkpoint (i.e. demand exceeds capacity) results in LOS F

Ramp Roadway Capacity Checkpoint If the off-ramp demand flow rate (Vr) exceeds the capacity of the off-ramp, LOS F prevails.

Maximum Desirable Flow Entering Ramp Influence Area Checkpoint

While the V12 values is checked against the maximum desirable, failure does not result in assignment of LOS F. Failing this checkpoint generally means that there will be more turbulance in influence area than predicted by this methodology. Thus, predicted densities are most likely lower than those that will exist, and predicted speeds are most likely to be predicted as higher than those that will actually occur.

Step 4. Determine Speeds in the Vicinity of Ramp-Freeway Junction

A. Average Speed in the Ramp Influence Area

$$S_R := FFS - (FFS - 42)\cdot(0.883 + 0.00009\cdot V_r - 0.013\cdot S_{FR})$$

$S_R = 55.77$ mi/h

B. Average Speed in the Outer Lanes of Freeway

Average Flow in Outer Lanes

$$N_o := \begin{cases} out \leftarrow 1 & \text{if } NumLanes = 3 \\ out \leftarrow 2 & \text{if } NumLanes = 4 \\ out \leftarrow \infty & \text{if } NumLanes = 2 \end{cases} \qquad V_{OA} := \frac{V_f - V_{12}}{N_o} \qquad V_{OA} = 973$$

$$S_O(V_{OA}) := \begin{cases} out \leftarrow 1.097\cdot FFS & \text{if } V_{OA} < 1000 \\ out \leftarrow 1.097\cdot FFS - 0.0039\cdot(V_{OA} - 1000) & \text{if } 1000 \le V_{OA} \end{cases}$$

$S_O := S_O(V_{OA})$ $\qquad S_O = 71.30$ mi/h

C. Average Speed for Off-Ramp Junction

$$Speed := \frac{V_{12} + V_{OA}\cdot N_o}{\left(\frac{V_{12}}{S_R}\right) + \left(\frac{V_{OA}\cdot N_o}{S_O}\right)} \qquad Speed = 59.63 \text{ mi/h}$$

Step 5. Determine the Density and Level of Service

A. Density in Off-Ramp Influence Area

$$\text{Density}_R := 4.252 + 0.0086 \cdot V_{12} - 0.009 \cdot L_D \qquad \text{Density}_R = 20 \quad \text{pc/mi/ln}$$

B. Density in Outer Lanes

$$\text{Density}_O := \frac{V_{OA}}{S_O} \qquad \text{Density}_O = 13.6 \quad \text{pc/mi/ln}$$

C. Density of Entire Cross-Section

$$\text{Density} := \left| \begin{array}{l} \text{out} \leftarrow \text{Density}_R \quad \text{if} \quad \text{NumLanes} \le 2 \\ \text{out} \leftarrow \dfrac{\left[\text{Density}_R \cdot (2) + \text{Density}_O \cdot (\text{NumLanes} - 2)\right]}{\text{NumLanes}} \quad \text{if} \quad \text{NumLanes} > 2 \end{array} \right. \qquad \text{Density} = 17.9 \quad \text{pc/mi/ln}$$

D. Level of Service

$$\text{LOS}(\text{Density}) := \left| \begin{array}{l} \text{out} \leftarrow \text{"A"} \quad \text{if} \quad 0 \le \text{Density} \le 10 \\ \text{out} \leftarrow \text{"B"} \quad \text{if} \quad 10 < \text{Density} \le 20 \\ \text{out} \leftarrow \text{"C"} \quad \text{if} \quad 20 < \text{Density} \le 28 \\ \text{out} \leftarrow \text{"D"} \quad \text{if} \quad 28 < \text{Density} \le 35 \\ \text{out} \leftarrow \text{"E"} \quad \text{if} \quad 35 < \text{Density} \end{array} \right. \qquad \text{LOS}(\text{Density}) = \text{"B"}$$

Step 6. Determine Input Vol and %HV for Next Downstream Segment

$$\text{FwyVol}_{Cars} := \text{FwyVol} \cdot \left(1 - \frac{\%\text{Trucks}_F}{100}\right) = 2884.2$$

$$\text{RampVol}_{Cars} := \text{RampVol} \cdot \left(1 - \frac{\%\text{Trucks}_R}{100}\right) = 392$$

$$\text{FwyVol}_{CarsNew} := \text{FwyVol}_{Cars} - \text{RampVol}_{Cars} = 2492.2$$

$$\text{FwyVol}_{Trucks} := \text{FwyVol} \cdot \frac{\%\text{Trucks}_F}{100} = 151.8$$

$$\text{RampVol}_{Trucks} := \text{RampVol} \cdot \left(\frac{\%\text{Trucks}_R}{100}\right) = 8$$

$$\text{FwyVol}_{TrucksNew} := \text{FwyVol}_{Trucks} - \text{RampVol}_{Trucks} = 143.8$$

$$\text{FwyVolNew} := \text{FwyVol}_{CarsNew} + \text{FwyVol}_{TrucksNew} = 2636$$

$$\%\text{Trucks}_{FNew} := \frac{\text{FwyVol}_{TrucksNew}}{\text{FwyVolNew}} \cdot 100 = 5.4552$$

**FwyVolNew and %Trucks$_{FNew}$ are the input values for FwyVol and %Trucks$_F$ for the next downstream segment if there is one. If the next segment is a weave, then %Trucks$_{FNew}$ is the input value for %Trucks_FF and %Trucks_FR.*

Full Basic 10b

Input Values

**FwyVolNew and %Trucks$_{FNew}$ from the previous upstream segment are the input values for FwyVol and %Trucks$_F$ (if there is a previous upstream segment).*

Traffic

$FwyVol := 2636 \quad PHF := 0.95$

$f_p := 1.0 \quad FFS := 65$

$\%Trucks_F := 5.4552 \quad P_R := 0$

$$P_T := \frac{\%Trucks_F}{100} = 0.0546$$

Roadway

$N := 3 \quad LaneWidth := 12 \quad LatClear := 6 \quad IntDens := 0.861$

$Terrain := 1$ 1 = Level, 2 = Rolling, 3 = Mountainous

$AreaType := 2$ 1 = Rural, 2 = Urban

**FREEPLAN finds IntDens by counting parclos and diamond as 1 interchange each, full as 2, and on and off as 1/2 each and adds them. Then, it divides that total number of interchanges by the total length of the facility.*

Find f_{HV} (using Exhibit 23-8 and Eq. 23-3)

$$E_T(Terrain) := \left| \begin{array}{l} out \leftarrow 1.5 \ \text{ if } Terrain = 1 \\ out \leftarrow 2.5 \ \text{ if } Terrain = 2 \\ out \leftarrow 4.5 \ \text{ if } Terrain = 3 \\ out \end{array} \right. \qquad E_R(Terrain) := \left| \begin{array}{l} out \leftarrow 1.2 \ \text{ if } Terrain = 1 \\ out \leftarrow 2.0 \ \text{ if } Terrain = 2 \\ out \leftarrow 4.0 \ \text{ if } Terrain = 3 \\ out \end{array} \right.$$

$E_T(Terrain) = 1.5 \quad E_T := E_T(Terrain) \qquad E_R(Terrain) = 1.2 \quad E_R := E_R(Terrain)$

$$f_{HV} := \frac{1}{1 + P_T \cdot (E_T - 1) + P_R \cdot (E_R - 1)} \qquad f_{HV} = 0.9734$$

Find v_p (using Eq. 23-2)

$$v_p := \frac{FwyVol}{PHF \cdot N \cdot f_{HV} \cdot f_p} \qquad v_p = 950.1 \ \text{pc/h/ln}$$

Determine S

$S_1 := FFS$

$$S_2 := FFS - \left[\left(FFS - \frac{160}{3} \right) \cdot \left(\frac{v_p + 30 \cdot FFS - 3400}{30 \cdot FFS - 1000} \right)^{2.6} \right]$$

$$S_3 := FFS - \left[\frac{1}{9} \cdot (7 \cdot FFS - 340) \cdot \left(\frac{v_p + 30 \cdot FFS - 3400}{40 \cdot FFS - 1700} \right)^{2.6} \right]$$

$$S_{cont2} := if\left[(55 \le FFS \le 75) \wedge \left[v_p \le (3400 - 30 \cdot FFS) \right], S_1, \text{"Cannot Compute"} \right]$$

$$S_{cont1} := if\left[(55 \le FFS \le 70) \wedge \left[(3400 - 30 \cdot FFS) < v_p \le (1700 + 10 \cdot FFS) \right], S_3, S_{cont2} \right]$$

$$S := if\left[(70 < FFS \le 75) \wedge \left[(3400 - 30 \cdot FFS) < v_p \le 2400 \right], S_2, S_{cont1} \right]$$

$S = 65$

Density (using Eq. 23-4)

$D := \dfrac{v_p}{S}$ $\quad D = 14.6$ pc/mi/ln

Determine level of service (using Exhibit 23-2)

$$LOS(D) := \left| \begin{array}{l} out \leftarrow \text{"F"} \ \text{ if } D > 45 \\ out \leftarrow \text{"E"} \ \text{ if } 45 \geq D > 35 \\ out \leftarrow \text{"D"} \ \text{ if } 35 \geq D > 26 \\ out \leftarrow \text{"C"} \ \text{ if } 26 \geq D > 18 \\ out \leftarrow \text{"B"} \ \text{ if } 18 \geq D > 11 \\ out \leftarrow \text{"A"} \ \text{ if } 11 \geq D \\ out \end{array} \right.$$

$LOS(D) = \text{"B"}$

Determine Input Vol and %HV for Next Downstream Segment

$FwyVolNew := FwyVol = 2636$

$\%Trucks_{FNew} := \%Trucks_F = 5.4552$

**FwyVolNew and %Trucks$_{FNew}$ are the input values for FwyVol and %Trucks$_F$ for the next downstream segment if there is one. If the next segment is a weave, then %Trucks$_{FNew}$ is the input value for %Trucks_FF and %Trucks_FR.*

Full On 10c

Step 1. Data Inputs and Volume Adjusments

**FwyVolNew and %Trucks$_{FNew}$ from the previous upstream segment are the input values for FwyVol and %Trucks$_F$ (if there is a previous upstream segment).*

A. Inputs

$FwyVol := 2636$ veh/h $RampVol := 700$ veh/h

$\%Trucks_F := 5.4552$ $\%RV_F := 0$ $PHF := 0.95$ $f_p := 1$ $FFS := 65$ mi/h

$\%Trucks_R := 2$ $\%RV_R := 0$

$NumLanes := 3$ Number of mainline freeway lanes $NRamp := 1$ Number of lanes on ramp roadway

$Terrain := 1$ 1 = Level, 2 = Rolling, 3 = Mountainous

$L_A := 500$ ft   Total length of Acceleration Lane

$S_{FR} := 40$ mi/h   Freeflow speed of the ramp at the junction point

$AdjUp := 2$ $AdjDn := 2$ 0 = none, 1 = on-ramp, 2 = off-ramp for Adjacent Upstream/Downstream Ramps

$L_{up} := 1000$ ft $L_{down} := 1800$ ft

$VolumeUp := 400$ veh/h   Volume on adjacent upstream ramp

$VolumeDown := 500$ veh/h   Volume on adjacent downstream ramp

B. Heavy Vehicle Adjustments

Passenger Car Equivalents

$$E_T(Terrain) := \begin{vmatrix} out \leftarrow 1.5 & \text{if} & Terrain = 1 \\ out \leftarrow 2.5 & \text{if} & Terrain = 2 \\ out \leftarrow 4.5 & \text{if} & Terrain = 3 \end{vmatrix} \qquad E_R(Terrain) := \begin{vmatrix} out \leftarrow 1.2 & \text{if} & Terrain = 1 \\ out \leftarrow 2.0 & \text{if} & Terrain = 2 \\ out \leftarrow 4.0 & \text{if} & Terrain = 3 \end{vmatrix}$$

$E_T(Terrain) = 1.5$ $E_R(Terrain) = 1.2$

$E_T := E_T(Terrain)$ $E_T = 1.5$ $E_R := E_R(Terrain)$ $E_R = 1.2$

$$f\_HV_F := \frac{100}{100 + \%Trucks_F(E_T - 1) + \%RV_F(E_R - 1)} = 0.973 \qquad f\_HV_F = 0.973$$

$$f\_HV_R := \frac{100}{100 + \%Trucks_R(E_T - 1) + \%RV_R(E_R - 1)} \qquad f\_HV_R = 0.99$$

C. Demand Flow Rate

$$V_f := \frac{FwyVol}{PHF \cdot f\_HV_F \cdot f_p} \qquad V_f = 2850 \text{ pc/h} \qquad V_r := \frac{RampVol}{PHF \cdot f\_HV_R \cdot f_p} \qquad V_r = 744 \text{ pc/h}$$

$$V_u := \frac{VolumeUp}{PHF \cdot f\_HV_R \cdot f_p} \qquad V_u = 425 \text{ pc/h} \qquad V_d := \frac{VolumeDown}{PHF \cdot f\_HV_R \cdot f_p} \qquad V_d = 532 \text{ pc/h}$$

Step 2. Determine the Approaching Flow Rate in Lanes 1 and 2

A. Equilibrium Seperation Distance for Adjacent Off-Ramp on a Six Lane Freeway

$$L_{EQup} := 0.214(V_f + V_r) + 0.444 \cdot L_A + 53.32 \cdot S_{FR} - 2403 \qquad L_{EQup} = 721 \text{ ft}$$

$$L_{EQdown} := \frac{V_d}{0.1096 + 0.000107 \cdot L_A} \qquad L_{EQdown} = 3259 \quad \text{ft}$$

B. Estimating Proportion of Freeway Vehicles Remaining in lanes 1 and 2

$$Eqn1 := 0.5775 + 0.000028 \cdot L_A \qquad Eqn1 = 0.592$$

$$Eqn2 := 0.7289 - 0.0000135 \cdot (V_f + V_r) - 0.003296 \cdot S_{FR} + 0.000063 \cdot L_{up} \qquad Eqn2 = 0.612$$

$$Eqn3 := 0.5487 + 0.2628 \cdot \frac{V_d}{L_{down}} \qquad Eqn3 = 0.626$$

$$P_{FM}(NumLanes) := \left| \begin{array}{l}
out \leftarrow 1.00 \quad \text{if} \quad NumLanes = 2 \\
out \leftarrow Eqn1 \quad \text{if} \quad AdjUp \neq 2 \wedge AdjDn \neq 2 \wedge NumLanes = 3 \\
out \leftarrow Eqn3 \quad \text{if} \quad AdjUp = 0 \wedge AdjDn = 2 \wedge L_{down} < L_{EQdown} \wedge NumLanes = 3 \\
out \leftarrow Eqn1 \quad \text{if} \quad AdjUp = 0 \wedge AdjDn = 2 \wedge L_{down} \geq L_{EQdown} \wedge NumLanes = 3 \\
out \leftarrow Eqn2 \quad \text{if} \quad AdjUp = 2 \wedge AdjDn = 0 \wedge L_{up} < L_{EQup} \wedge NumLanes = 3 \\
out \leftarrow Eqn1 \quad \text{if} \quad AdjUp = 2 \wedge AdjDn = 0 \wedge L_{up} \geq L_{EQup} \wedge NumLanes = 3 \\
out \leftarrow Eqn1 \quad \text{if} \quad AdjUp = 1 \wedge AdjDn = 1 \wedge NumLanes = 3 \\
out \leftarrow Eqn3 \quad \text{if} \quad AdjUp = 1 \wedge AdjDn = 2 \wedge L_{down} < L_{EQdown} \wedge NumLanes = 3 \\
out \leftarrow Eqn1 \quad \text{if} \quad AdjUp = 1 \wedge AdjDn = 2 \wedge L_{down} \geq L_{EQdown} \wedge NumLanes = 3 \\
out \leftarrow Eqn2 \quad \text{if} \quad AdjUp = 2 \wedge AdjDn = 1 \wedge L_{up} < L_{EQup} \wedge NumLanes = 3 \\
out \leftarrow Eqn1 \quad \text{if} \quad AdjUp = 2 \wedge AdjDn = 1 \wedge L_{up} \geq L_{EQup} \wedge NumLanes = 3 \\
out \leftarrow \max(Eqn1, Eqn2) \quad \text{if} \quad AdjUp = 2 \wedge AdjDn = 2 \wedge L_{up} < L_{EQup} \wedge L_{down} \geq L_{EQdown} \wedge NumLanes = 3 \\
out \leftarrow \max(Eqn3, Eqn2) \quad \text{if} \quad AdjUp = 2 \wedge AdjDn = 2 \wedge L_{up} < L_{EQup} \wedge L_{down} < L_{EQdown} \wedge NumLanes = 3 \\
out \leftarrow Eqn1 \quad \text{if} \quad AdjUp = 2 \wedge AdjDn = 2 \wedge L_{up} \geq L_{EQup} \wedge L_{down} \geq L_{EQdown} \wedge NumLanes = 3 \\
out \leftarrow \max(Eqn1, Eqn3) \quad \text{if} \quad AdjUp = 2 \wedge AdjDn = 2 \wedge L_{up} \geq L_{EQup} \wedge L_{down} < L_{EQdown} \wedge NumLanes = 3 \\
out \leftarrow 0.2178 - 0.0000125 \cdot V_r + -0.0115 \cdot \frac{L_A}{S_{FR}} \quad \text{if} \quad \left(\frac{V_f}{S_{FR}} \leq 72 \right) \wedge (NumLanes = 4) \\
out \leftarrow 0.2178 - 0.0000125 \cdot V_r \quad \text{if} \quad \left(\frac{V_f}{S_{FR}} > 72 \right) \wedge (NumLanes = 4)
\end{array} \right.$$

$$P_{FM} := P_{FM}(NumLanes) \qquad P_{FM} = 0.626$$

C. Estimating Flow in Lanes 1 and 2

$$V_{12} := V_f \cdot P_{FM} \qquad V_{12} = 1785 \quad \text{pc/h}$$

D. Checking the Reasonableness of the Lane Distribution Prediction

Six Lane Freeways

$$V_3 := V_f - V_{12} \qquad V_3 = 1065 \quad \text{pc/h}$$

Eight Lane Freeways

$$V_{av34} := \frac{V_f - V_{12}}{2} \qquad V_{av34} = 533 \quad \text{pc/h}$$

$$V12a(NumLanes) := \left| \begin{array}{l} out \leftarrow V_{12} \ \text{ if } \ NumLanes = 2 \\ out \leftarrow V_f - 2700 \ \text{ if } \ V_3 > 2700 \wedge V_3 \le 1.5 \cdot \frac{V_{12}}{2} \vee NumLanes = 3 \\ out \leftarrow \frac{V_f}{1.75} \ \text{ if } \ V_3 \le 2700 \wedge V_3 > 1.5 \cdot \frac{V_{12}}{2} \wedge NumLanes = 3 \\ out \leftarrow \max\left(V_f - 2700, \frac{V_f}{1.75}\right) \ \text{ if } \ V_3 > 2700 \wedge V_3 > 1.5 \cdot \frac{V_{12}}{2} \wedge NumLanes = 3 \\ out \leftarrow V_{12} \ \text{ if } \ V_3 \le 2700 \wedge V_3 \le 1.5 \cdot \frac{V_{12}}{2} \wedge NumLanes = 3 \\ out \leftarrow V_f - 5400 \ \text{ if } \ V_{av34} > 2700 \wedge V_{av34} \le 1.5 \cdot \frac{V_{12}}{2} \wedge NumLanes = 4 \\ out \leftarrow \frac{V_f}{2.50} \ \text{ if } \ V_{av34} \le 2700 \wedge V_{av34} > 1.5 \cdot \frac{V_{12}}{2} \wedge NumLanes = 4 \\ out \leftarrow \max\left(V_f - 5400, \frac{V_f}{2.50}\right) \ \text{ if } \ V_{av34} > 2700 \wedge V_{av34} > 1.5 \cdot \frac{V_{12}}{2} \wedge NumLanes = 4 \\ out \leftarrow V_{12} \ \text{ if } \ V_{av34} \le 2700 \wedge V_{av34} \le 1.5 \cdot \frac{V_{12}}{2} \wedge NumLanes = 4 \end{array} \right.$$

C. Final Flow in Lanes 1 and 2

$V_{12} := V12a(NumLanes)$ $\quad V_{12} = 1785$ pc/h

Step 3. Determine Capacity of Ramp-Freeway Junction

$V_{R12} := V_{12} + V_r$ $\quad V_{R12} = 2529$ pc/h $\quad$ Flow entering the ramp influence area

$$CapUpFreewaySegment(NumLanes, FFS) := \left| \begin{array}{l} out \leftarrow 4800 \ \text{ if } \ FFS \ge 70 \wedge NumLanes = 2 \\ out \leftarrow 4700 \ \text{ if } \ FFS = 65 \wedge NumLanes = 2 \\ out \leftarrow 4600 \ \text{ if } \ FFS = 60 \wedge NumLanes = 2 \\ out \leftarrow 4600 \ \text{ if } \ FFS = 55 \wedge NumLanes = 2 \\ out \leftarrow 7200 \ \text{ if } \ FFS = 70 \wedge NumLanes = 3 \\ out \leftarrow 7050 \ \text{ if } \ FFS = 65 \wedge NumLanes = 3 \\ out \leftarrow 6900 \ \text{ if } \ FFS = 60 \wedge NumLanes = 3 \\ out \leftarrow 6750 \ \text{ if } \ FFS = 55 \wedge NumLanes = 3 \\ out \leftarrow 9600 \ \text{ if } \ FFS = 70 \wedge NumLanes = 4 \\ out \leftarrow 9400 \ \text{ if } \ FFS = 65 \wedge NumLanes = 4 \\ out \leftarrow 9200 \ \text{ if } \ FFS = 60 \wedge NumLanes = 4 \\ out \leftarrow 9000 \ \text{ if } \ FFS = 55 \wedge NumLanes = 4 \\ out \leftarrow 2400 \cdot NumLanes \ \text{ if } \ FFS = 70 \wedge NumLanes > 4 \\ out \leftarrow 2350 \cdot NumLanes \ \text{ if } \ FFS = 65 \wedge NumLanes > 4 \\ out \leftarrow 2300 \cdot NumLanes \ \text{ if } \ FFS = 60 \wedge NumLanes > 4 \\ out \leftarrow 2250 \cdot NumLanes \ \text{ if } \ FFS = 55 \wedge NumLanes > 4 \end{array} \right.$$

$\text{CapUpFreewaySegment}(\text{NumLanes}, \text{FFS}) = 7050$ Capacity of Ramp Freeway Junction

MaxV12 = 4600 Maximum Desirable Flow Rate Entering Merge Influence Area

$$\text{CapacityRampRoadway} := \left|\begin{array}{l} \text{out} \leftarrow 2200 \quad \text{if} \quad (\text{NRamp} = 1) \wedge (S_{FR} > 50) \\ \text{out} \leftarrow 2100 \quad \text{if} \quad (\text{NRamp} = 1) \wedge (40 < S_{FR} \le 50) \\ \text{out} \leftarrow 2000 \quad \text{if} \quad (\text{NRamp} = 1) \wedge (30 < S_{FR} \le 40) \\ \text{out} \leftarrow 1900 \quad \text{if} \quad (\text{NRamp} = 1) \wedge (20 \le S_{FR} \le 30) \\ \text{out} \leftarrow 1800 \quad \text{if} \quad (\text{NRamp} = 1) \wedge (20 > S_{FR}) \\ \text{out} \leftarrow 4400 \quad \text{if} \quad (\text{NRamp} = 2) \wedge (S_{FR} > 50) \\ \text{out} \leftarrow 4200 \quad \text{if} \quad (\text{NRamp} = 2) \wedge (40 < S_{FR} \le 50) \\ \text{out} \leftarrow 4000 \quad \text{if} \quad (\text{NRamp} = 2) \wedge (30 < S_{FR} \le 40) \\ \text{out} \leftarrow 3800 \quad \text{if} \quad (\text{NRamp} = 2) \wedge (20 \le S_{FR} \le 30) \\ \text{out} \leftarrow 3600 \quad \text{if} \quad (\text{NRamp} = 2) \wedge (20 > S_{FR}) \end{array}\right.$$

$\text{CapacityRampRoadway} = 2000$

$V_{FO} := V_f + V_r$ $V_{FO} = 3595$ pc/h Volume immediatley downstream of on-ramp influence area

Ramp Freeway Junction Checkpoint

Volume immediatley downstream of on-ramp influence area is chekced against freeway capacity. Failure of ramp freeway junction checkpoint (i.e. demand exceeds capacity) results in LOS F

Ramp Roadway Capacity Checkpoint

Capacity or ramp roadway should always be checked against the demand flow rate on the ramp. It is rarely a problem for the on-ramp

Maximum Desirable Flow Entering Ramp Influence Area Checkpoint

While the V_{R12} values is checked against the maximum desirable, failure does not result in assignment of LOS F. Failing this checkpoint generally means that there will be more turbulance in influence area than predicted by this methodology. Thus, predicted densities are most likely lower than those that will exist, and predicted speeds are most likely to be predicted as higher than those that will actually occur.

Step 4. Determine Speeds in the Vicinity of Ramp-Freeway Junction

A. Average Speed in the Ramp Influence Area

$$S_R := FFS - (FFS - 42) \cdot \left[0.321 + 0.0039\,\exp\left(\frac{V_{R12}}{1000}\right) - 0.002 \cdot \left(L_A \frac{S_{FR}}{1000}\right)\right]$$

$S_R = 57.41$ mi/h

B. Average Speed in the Outer Lanes of Freeway

Average Flow in Outer Lanes

$$No := \begin{vmatrix} out \leftarrow 1 & \text{if} & NumLanes = 3 \\ out \leftarrow 2 & \text{if} & NumLanes = 4 \\ out \leftarrow \infty & \text{if} & NumLanes = 2 \end{vmatrix}$$

$$V_{OA} := \frac{V_f - V_{12}}{No}$$

$V_{OA} = 1065$

$$S_O(V_{OA}) := \begin{vmatrix} out \leftarrow FFS & \text{if} \quad V_{OA} < 500 \\ out \leftarrow FFS - 0.0036 \cdot (V_{OA} - 500) & \text{if} \quad 500 \le V_{OA} \le 2300 \\ out \leftarrow FFS - 6.53 - 0.006 \cdot (V_{OA} - 2300) & \text{if} \quad V_{OA} > 2300 \end{vmatrix}$$

$$S_O := S_O(V_{OA})$$

$S_O = 62.97$ mi/h

C. Average Speed for On-Ramp Junction

$$Speed := \frac{V_{R12} + V_{OA} \cdot No}{\left(\frac{V_{R12}}{S_R}\right) + \left(\frac{V_{OA} \cdot No}{S_O}\right)}$$

$Speed = 58.95$ mi/h

Step 5. Determine the Density and Level of Service

A. Density in On-Ramp Influence Area

$$Density_R := 5.475 + 0.00734 \cdot V_r + 0.0078 \cdot V_{12} - 0.00627 \cdot L_A$$

$Density_R = 21.7$ pc/mi/ln

B. Density in Outer Lanes

$$Density_O := \frac{V_{OA}}{S_O}$$

$Density_O = 16.9$ pc/mi/ln

C. Density of Entire Cross-Section

$$Density := \begin{vmatrix} out \leftarrow Density_R & \text{if} \quad NumLanes \le 2 \\ out \leftarrow \dfrac{\left[Density_R \cdot (2) + Density_O \cdot (NumLanes - 2)\right]}{NumLanes} & \text{if} \quad NumLanes > 2 \end{vmatrix}$$

$Density = 20.1$ pc/mi/ln

D. Level of Service

$$LOS(Density) := \begin{vmatrix} out \leftarrow \text{"A"} & \text{if} \quad 0 \le Density \le 10 \\ out \leftarrow \text{"B"} & \text{if} \quad 10 < Density \le 20 \\ out \leftarrow \text{"C"} & \text{if} \quad 20 < Density \le 28 \\ out \leftarrow \text{"D"} & \text{if} \quad 28 < Density \le 35 \\ out \leftarrow \text{"E"} & \text{if} \quad 35 < Density \end{vmatrix}$$

$LOS(Density) = \text{"C"}$

Step 6. Determine Input Vol and %HV for Next Downstream Segment

$$FwyVol_{Cars} := FwyVol \cdot \left(1 - \frac{\%Trucks_F}{100}\right) = 2492.2$$

$$RampVol_{Cars} := RampVol \cdot \left(1 - \frac{\%Trucks_R}{100}\right) = 686$$

$$FwyVol_{CarsNew} := FwyVol_{Cars} + RampVol_{Cars} = 3178.2$$

$$FwyVol_{Trucks} := FwyVol \cdot \frac{\%Trucks_F}{100} = 143.799$$

$$RampVol_{Trucks} := RampVol \cdot \left(\frac{\%Trucks_R}{100}\right) = 14$$

$$FwyVol_{TrucksNew} := FwyVol_{Trucks} + RampVol_{Trucks} = 157.799$$

$$FwyVolNew := FwyVol_{CarsNew} + FwyVol_{TrucksNew} = 3336$$

$$\%Trucks_{FNew} := \frac{FwyVol_{TrucksNew}}{FwyVolNew} \cdot 100 = 4.7302$$

**FwyVolNew and $\%Trucks_{FNew}$ are the input values for FwyVol and $\%Trucks_F$ for the next downstream segment if there is one. If the next segment is a weave, then $\%Trucks_{FNew}$ is the input value for %Trucks_FF and %Trucks_FR.*

Full Off 10d

Step 1. Data Inputs and Volume Adjusments

**FwyVolNew and %Trucks$_{FNew}$ from the previous upstream segment are the input values for FwyVol and %Trucks$_F$ (if there is a previous upstream segment).*

A. Inputs

$FwyVol := 3336$ veh/h $RampVol := 500$ veh/h

$\%Trucks_F := 4.7302$ $\%RV_F := 0$ $PHF := 0.95$ $f_p := 1$ $FFS := 65$ mi/h

$\%Trucks_R := 2$ $\%RV_R := 0$

$NumLanes := 3$ Number of mainline freeway lanes $NRamp := 1$ Number of lanes on ramp roadway

$Terrain := 1$ 1 = Level, 2 = Rolling, 3 = Mountainous

$L_D := 350$ ft   Total length of Deceleration Lane

$S_{FR} := 40$ mi/h   Freeflow speed of the ramp at the junction point

$AdjUp := 1$ $AdjDn := 1$ 0 = none, 1 = on-ramp, 2 = off-ramp for Adjacent Upstream/Downstream Ramps

$L_{up} := 1800$ ft $L_{down} := 1000$ ft

$VolumeUp := 700$ veh/h   Volume on adjacent upstream ramp

$VolumeDown := 700$ veh/h   Volume on adjacent downstream ramp

B. Heavy Vehicle Adjustments

Passenger Car Equivalents

$$E_T(Terrain) := \left| \begin{array}{lll} out \leftarrow 1.5 & \text{if} & Terrain = 1 \\ out \leftarrow 2.5 & \text{if} & Terrain = 2 \\ out \leftarrow 4.5 & \text{if} & Terrain = 3 \end{array} \right. \qquad E_R(Terrain) := \left| \begin{array}{lll} out \leftarrow 1.2 & \text{if} & Terrain = 1 \\ out \leftarrow 2.0 & \text{if} & Terrain = 2 \\ out \leftarrow 4.0 & \text{if} & Terrain = 3 \end{array} \right.$$

$E_T(Terrain) = 1.5$ $E_R(Terrain) = 1.2$

$E_T := E_T(Terrain)$ $E_T = 1.5$ $E_R := E_R(Terrain)$ $E_R = 1.2$

$$f\_HV_F := \frac{100}{100 + \%Trucks_F(E_T - 1) + \%RV_F(E_R - 1)} \qquad f\_HV_F = 0.977$$

$$f\_HV_R := \frac{100}{100 + \%Trucks_R(E_T - 1) + \%RV_R(E_R - 1)} \qquad f\_HV_R = 0.99$$

C. Demand Flow Rate

$$V_f := \frac{FwyVol}{PHF \cdot f\_HV_F \cdot f_p} \qquad V_f = 3595 \text{ pc/h} \qquad V_r := \frac{RampVol}{PHF \cdot f\_HV_R \cdot f_p} \qquad V_r = 532 \text{ pc/h}$$

$$V_u := \frac{VolumeUp}{PHF \cdot f\_HV_R \cdot f_p} \qquad V_u = 744 \text{ pc/h} \qquad V_d := \frac{VolumeDown}{PHF \cdot f\_HV_R \cdot f_p} \qquad V_d = 744 \text{ pc/h}$$

Step 2. Determine the Approaching Flow Rate in Lanes 1 and 2

A. Equilibrium Seperation Distance for Adjacent Upstream On-Ramp or Downstream Off-Ramps on a Six Lane Freeway

$$L_{EQup} := \frac{V_u}{0.071 + 0.000023 \cdot V_f - 0.000076 \cdot V_r} \qquad L_{EQup} = 6570 \quad \text{ft}$$

$$L_{EQdown} := \frac{V_d}{1.15 - 0.000032 \cdot V_f - 0.000369 \cdot V_r} \qquad L_{EQdown} = 887 \quad \text{ft}$$

B. Estimating Proportion of Freeway Vehicles Remaining in lanes 1 and 2

$$Eqn1 := 0.760 - 0.000025 \cdot V_f - 0.000046 \cdot V_r \qquad Eqn1 = 0.646$$

$$Eqn2 := 0.717 - 0.000039 \cdot V_f + 0.604 \cdot \frac{V_u}{L_{up}} \qquad Eqn2 = 0.827$$

$$Eqn3 := 0.616 - 0.000021 \cdot V_f + 0.124 \cdot \frac{V_d}{L_{down}} \qquad Eqn3 = 0.633$$

$$P_{FD}(Numlanes) := \left|
\begin{array}{l}
out \leftarrow 1.00 \quad \text{if} \quad NumLanes = 2 \\
out \leftarrow Eqn1 \quad \text{if} \quad AdjUp = 0 \land AdjDn = 0 \land NumLanes = 3 \\
out \leftarrow Eqn1 \quad \text{if} \quad AdjUp = 0 \land AdjDn = 1 \land NumLanes = 3 \\
out \leftarrow Eqn1 \quad \text{if} \quad AdjUp = 0 \land AdjDn = 2 \land L_{down} \ge L_{EQdown} \land NumLanes = 3 \\
out \leftarrow Eqn3 \quad \text{if} \quad AdjUp = 0 \land AdjDn = 2 \land L_{down} < L_{EQdown} \land NumLanes = 3 \\
out \leftarrow Eqn1 \quad \text{if} \quad AdjUp = 1 \land AdjDn = 0 \land L_{up} \ge L_{EQup} \land NumLanes = 3 \\
out \leftarrow Eqn2 \quad \text{if} \quad AdjUp = 1 \land AdjDn = 0 \land L_{up} < L_{EQup} \land NumLanes = 3 \\
out \leftarrow Eqn1 \quad \text{if} \quad AdjUp = 2 \land AdjDn = 0 \land NumLanes = 3 \\
out \leftarrow Eqn1 \quad \text{if} \quad AdjUp = 1 \land AdjDn = 1 \land L_{up} \ge L_{EQup} \land NumLanes = 3 \\
out \leftarrow Eqn2 \quad \text{if} \quad AdjUp = 1 \land AdjDn = 1 \land L_{up} < L_{EQup} \land NumLanes = 3 \\
out \leftarrow \max(Eqn2, Eqn3) \quad \text{if} \quad AdjUp = 1 \land AdjDn = 2 \land L_{up} < L_{EQup} \land L_{down} < L_{EQdown} \land NumLanes = 3 \\
out \leftarrow \max(Eqn2, Eqn1) \quad \text{if} \quad AdjUp = 1 \land AdjDn = 2 \land L_{up} < L_{EQup} \land L_{down} \ge L_{EQdown} \land NumLanes = 3 \\
out \leftarrow Eqn1 \quad \text{if} \quad AdjUp = 1 \land AdjDn = 2 \land L_{up} \ge L_{EQup} \land L_{down} \ge L_{EQdown} \land NumLanes = 3 \\
out \leftarrow \max(Eqn3, Eqn1) \quad \text{if} \quad AdjUp = 1 \land AdjDn = 2 \land L_{up} \ge L_{EQup} \land L_{down} < L_{EQdown} \land NumLanes = 3 \\
out \leftarrow Eqn1 \quad \text{if} \quad AdjUp = 2 \land AdjDn = 1 \land NumLanes = 3 \\
out \leftarrow Eqn1 \quad \text{if} \quad AdjUp = 2 \land AdjDn = 2 \land L_{down} \ge L_{EQdown} \land NumLanes = 3 \\
out \leftarrow Eqn3 \quad \text{if} \quad AdjUp = 2 \land AdjDn = 2 \land L_{down} < L_{EQdown} \land NumLanes = 3 \\
out \leftarrow 0.436 \quad \text{if} \quad NumLanes = 4
\end{array}
\right.$$

$$P_{FD} := P_{FD}(NumLanes) \qquad P_{FD} = 0.827$$

C. Estimating Flow in Lanes 1 and 2

$$V_{12} := V_r + (V_f - V_r) \cdot P_{FD} \qquad V_{12} = 3063 \quad \text{pc/h}$$

D. Checking the Reasonableness of the Lane Distribution Prediction

Six Lane Freeways *Eight Lane Freeways*

$V_3 := V_f - V_{12}$ $\quad V_3 = 531$ pc/h $\qquad V_{av34} := \dfrac{V_f - V_{12}}{2}$ $\quad V_{av34} = 266$ pc/h

$$
V12a(NumLanes) := \left|
\begin{array}{l}
out \leftarrow V_{12} \ \text{ if } \ NumLanes = 2 \\
out \leftarrow V_f - 2700 \ \text{ if } \ V_3 > 2700 \wedge V_3 \le 1.5 \cdot \dfrac{V_{12}}{2} \vee NumLanes = 3 \\
out \leftarrow \dfrac{V_f}{1.75} \ \text{ if } \ V_3 \le 2700 \wedge V_3 > 1.5 \cdot \dfrac{V_{12}}{2} \wedge NumLanes = 3 \\
out \leftarrow \max\left(V_f - 2700, \dfrac{V_f}{1.75}\right) \ \text{ if } \ V_3 > 2700 \wedge V_3 > 1.5 \cdot \dfrac{V_{12}}{2} \wedge NumLanes = 3 \\
out \leftarrow V_{12} \ \text{ if } \ V_3 \le 2700 \wedge V_3 \le 1.5 \cdot \dfrac{V_{12}}{2} \wedge NumLanes = 3 \\
out \leftarrow V_f - 5400 \ \text{ if } \ V_{av34} > 2700 \wedge V_{av34} \le 1.5 \cdot \dfrac{V_{12}}{2} \wedge NumLanes = 4 \\
out \leftarrow \dfrac{V_f}{2.50} \ \text{ if } \ V_{av34} \le 2700 \wedge V_{av34} > 1.5 \cdot \dfrac{V_{12}}{2} \wedge NumLanes = 4 \\
out \leftarrow \max\left(V_f - 5400, \dfrac{V_f}{2.50}\right) \ \text{ if } \ V_{av34} > 2700 \wedge V_{av34} > 1.5 \cdot \dfrac{V_{12}}{2} \wedge NumLanes = 4 \\
out \leftarrow V_{12} \ \text{ if } \ V_{av34} \le 2700 \wedge V_{av34} \le 1.5 \cdot \dfrac{V_{12}}{2} \wedge NumLanes = 4
\end{array}
\right.
$$

C. Final Flow in Lanes 1 and 2

$V_{12} := V12a(NumLanes)$ $\qquad V_{12} = 3063$ pc/h

Step 3. Determine Capacity of Ramp-Freeway Junction

$$\text{CapUpFreewaySegment}(\text{NumLanes}, \text{FFS}) := \left| \begin{array}{l} \text{out} \leftarrow 4800 \quad \text{if} \quad \text{FFS} \geq 70 \wedge \text{NumLanes} = 2 \\ \text{out} \leftarrow 4700 \quad \text{if} \quad \text{FFS} = 65 \wedge \text{NumLanes} = 2 \\ \text{out} \leftarrow 4600 \quad \text{if} \quad \text{FFS} = 60 \wedge \text{NumLanes} = 2 \\ \text{out} \leftarrow 4600 \quad \text{if} \quad \text{FFS} = 55 \wedge \text{NumLanes} = 2 \\ \text{out} \leftarrow 7200 \quad \text{if} \quad \text{FFS} = 70 \wedge \text{NumLanes} = 3 \\ \text{out} \leftarrow 7050 \quad \text{if} \quad \text{FFS} = 65 \wedge \text{NumLanes} = 3 \\ \text{out} \leftarrow 6900 \quad \text{if} \quad \text{FFS} = 60 \wedge \text{NumLanes} = 3 \\ \text{out} \leftarrow 6750 \quad \text{if} \quad \text{FFS} = 55 \wedge \text{NumLanes} = 3 \\ \text{out} \leftarrow 9600 \quad \text{if} \quad \text{FFS} = 70 \wedge \text{NumLanes} = 4 \\ \text{out} \leftarrow 9400 \quad \text{if} \quad \text{FFS} = 65 \wedge \text{NumLanes} = 4 \\ \text{out} \leftarrow 9200 \quad \text{if} \quad \text{FFS} = 60 \wedge \text{NumLanes} = 4 \\ \text{out} \leftarrow 9000 \quad \text{if} \quad \text{FFS} = 55 \wedge \text{NumLanes} = 4 \\ \text{out} \leftarrow 2400 \cdot \text{NumLanes} \quad \text{if} \quad \text{FFS} = 70 \wedge \text{NumLanes} > 4 \\ \text{out} \leftarrow 2350 \cdot \text{NumLanes} \quad \text{if} \quad \text{FFS} = 65 \wedge \text{NumLanes} > 4 \\ \text{out} \leftarrow 2300 \cdot \text{NumLanes} \quad \text{if} \quad \text{FFS} = 60 \wedge \text{NumLanes} > 4 \\ \text{out} \leftarrow 2250 \cdot \text{NumLanes} \quad \text{if} \quad \text{FFS} = 55 \wedge \text{NumLanes} > 4 \end{array} \right.$$

$\text{CapUpFreewaySegment}(\text{NumLanes}, \text{FFS}) = 7050$ Capacity of Ramp Freeway Junction

MaxV12 = 4400 Maximum Desirable Flow Rate Entering Merge Influence Area

$$\text{CapacityRampRoadway} := \left| \begin{array}{l} \text{out} \leftarrow 2200 \quad \text{if} \quad (\text{NRamp} = 1) \wedge (S_{FR} > 50) \\ \text{out} \leftarrow 2100 \quad \text{if} \quad (\text{NRamp} = 1) \wedge (40 < S_{FR} \leq 50) \\ \text{out} \leftarrow 2000 \quad \text{if} \quad (\text{NRamp} = 1) \wedge (30 < S_{FR} \leq 40) \\ \text{out} \leftarrow 1900 \quad \text{if} \quad (\text{NRamp} = 1) \wedge (20 \leq S_{FR} \leq 30) \\ \text{out} \leftarrow 1800 \quad \text{if} \quad (\text{NRamp} = 1) \wedge (20 > S_{FR}) \\ \text{out} \leftarrow 4400 \quad \text{if} \quad (\text{NRamp} = 2) \wedge (S_{FR} > 50) \\ \text{out} \leftarrow 4200 \quad \text{if} \quad (\text{NRamp} = 2) \wedge (40 < S_{FR} \leq 50) \\ \text{out} \leftarrow 4000 \quad \text{if} \quad (\text{NRamp} = 2) \wedge (30 < S_{FR} \leq 40) \\ \text{out} \leftarrow 3800 \quad \text{if} \quad (\text{NRamp} = 2) \wedge (20 \leq S_{FR} \leq 30) \\ \text{out} \leftarrow 3600 \quad \text{if} \quad (\text{NRamp} = 2) \wedge (20 > S_{FR}) \end{array} \right.$$

$\text{CapacityRampRoadway} = 2000$

$V_f = 3595$ pc/h Volume immediatley upstream of off-ramp influence area

Ramp Freeway Junction Checkpoint Volume immediatley upstream of off-ramp influence area is chekced against freeway capacity. Failure of ramp freeway junction checkpoint (i.e. demand exceeds capacity) results in LOS F

Ramp Roadway Capacity Checkpoint If the off-ramp demand flow rate (Vr) exceeds the capacity of the off-ramp, LOS F prevails.

Maximum Desirable Flow Entering Ramp Influence Area Checkpoint

While the V12 values is checked against the maximum desirable, failure does not result in assignment of LOS F. Failing this checkpoint generally means that there will be more turbulance in influence area than predicted by this methodology. Thus, predicted densities are most likely lower than those that will exist, and predicted speeds are most likely to be predicted as higher than those that will actually occur.

Step 4. Determine Speeds in the Vicinity of Ramp-Freeway Junction

A. Average Speed in the Ramp Influence Area

$$S_R := FFS - (FFS - 42)\cdot(0.883 + 0.00009\cdot V_r - 0.013\cdot S_{FR})$$

$S_R = 55.55$ mi/h

B. Average Speed in the Outer Lanes of Freeway

Average Flow in Outer Lanes

$$N_o := \begin{cases} out \leftarrow 1 & \text{if } NumLanes = 3 \\ out \leftarrow 2 & \text{if } NumLanes = 4 \\ out \leftarrow \infty & \text{if } NumLanes = 2 \end{cases} \qquad V_{OA} := \frac{V_f - V_{12}}{N_o} \qquad V_{OA} = 531$$

$$S_O(V_{OA}) := \begin{cases} out \leftarrow 1.097\cdot FFS & \text{if } V_{OA} < 1000 \\ out \leftarrow 1.097\cdot FFS - 0.0039\cdot(V_{OA} - 1000) & \text{if } 1000 \le V_{OA} \end{cases}$$

$S_O := S_O(V_{OA})$ $\qquad S_O = 71.30$ mi/h

C. Average Speed for Off-Ramp Junction

$$Speed := \frac{V_{12} + V_{OA}\cdot N_o}{\left(\frac{V_{12}}{S_R}\right) + \left(\frac{V_{OA}\cdot N_o}{S_O}\right)} \qquad Speed = 57.43 \text{ mi/h}$$

Step 5. Determine the Density and Level of Service

A. Density in Off-Ramp Influence Area

$$\text{Density}_R := 4.252 + 0.0086 \cdot V_{12} - 0.009 \cdot L_D \qquad \text{Density}_R = 27.4 \quad \text{pc/mi/ln}$$

B. Density in Outer Lanes

$$\text{Density}_O := \frac{V_{OA}}{S_O} \qquad \text{Density}_O = 7.5 \quad \text{pc/mi/ln}$$

C. Density of Entire Cross-Section

$$\text{Density} := \left| \begin{array}{l} \text{out} \leftarrow \text{Density}_R \quad \text{if} \quad \text{NumLanes} \le 2 \\ \text{out} \leftarrow \dfrac{\left[\text{Density}_R \cdot (2) + \text{Density}_O \cdot (\text{NumLanes} - 2)\right]}{\text{NumLanes}} \quad \text{if} \quad \text{NumLanes} > 2 \end{array} \right. \qquad \text{Density} = 20.8 \quad \text{pc/mi/ln}$$

D. Level of Service

$$\text{LOS}(\text{Density}) := \left| \begin{array}{l} \text{out} \leftarrow \text{"A"} \quad \text{if} \quad 0 \le \text{Density} \le 10 \\ \text{out} \leftarrow \text{"B"} \quad \text{if} \quad 10 < \text{Density} \le 20 \\ \text{out} \leftarrow \text{"C"} \quad \text{if} \quad 20 < \text{Density} \le 28 \\ \text{out} \leftarrow \text{"D"} \quad \text{if} \quad 28 < \text{Density} \le 35 \\ \text{out} \leftarrow \text{"E"} \quad \text{if} \quad 35 < \text{Density} \end{array} \right. \qquad \text{LOS}(\text{Density}) = \text{"C"}$$

Step 6. Determine Input Vol and %HV for Next Downstream Segment

$$\text{FwyVol}_{Cars} := \text{FwyVol} \cdot \left(1 - \frac{\%\text{Trucks}_F}{100}\right) = 3178.2$$

$$\text{RampVol}_{Cars} := \text{RampVol} \cdot \left(1 - \frac{\%\text{Trucks}_R}{100}\right) = 490$$

$$\text{FwyVol}_{CarsNew} := \text{FwyVol}_{Cars} - \text{RampVol}_{Cars} = 2688.2$$

$$\text{FwyVol}_{Trucks} := \text{FwyVol} \cdot \frac{\%\text{Trucks}_F}{100} = 157.799$$

$$\text{RampVol}_{Trucks} := \text{RampVol} \cdot \left(\frac{\%\text{Trucks}_R}{100}\right) = 10$$

$$\text{FwyVol}_{TrucksNew} := \text{FwyVol}_{Trucks} - \text{RampVol}_{Trucks} = 147.799$$

$$\text{FwyVolNew} := \text{FwyVol}_{CarsNew} + \text{FwyVol}_{TrucksNew} = 2836$$

$$\%\text{Trucks}_{FNew} := \frac{\text{FwyVol}_{TrucksNew}}{\text{FwyVolNew}} \cdot 100 = 5.2115$$

**FwyVolNew and %Trucks$_{FNew}$ are the input values for FwyVol and %Trucks$_F$ for the next downstream segment if there is one. If the next segment is a weave, then %Trucks$_{FNew}$ is the input value for %Trucks_FF and %Trucks_FR.*

Full Basic 10e

Input Values

Traffic

$FwyVol := 2836 \quad PHF := 0.95$

$f_p := 1.0 \quad FFS := 65$

$\%Trucks_F := 5.2115 \quad P_R := 0$

$P_T := \frac{\%Trucks_F}{100} = 0.0521$

**FwyVolNew and $\%Trucks_{FNew}$ from the previous upstream segment are the input values for FwyVol and $\%Trucks_F$ (if there is a previous upstream segment).*

Roadway

$N := 3 \quad LaneWidth := 12 \quad LatClear := 6 \quad IntDens := 0.691085$

$Terrain := 1$ 1 = Level, 2 = Rolling, 3 = Mountainous

$AreaType := 2$ 1 = Rural, 2 = Urban

**FREEPLAN finds IntDens by counting parclos and diamond as 1 interchange each, full as 2, and on and off as 1/2 each and adds them. Then, it divides that total number of interchanges by the total length of the facility.*

Find f_{HV} (using Exhibit 23-8 and Eq. 23-3)

$$E_T(Terrain) := \begin{array}{|l} out \leftarrow 1.5 \text{ if } Terrain = 1 \\ out \leftarrow 2.5 \text{ if } Terrain = 2 \\ out \leftarrow 4.5 \text{ if } Terrain = 3 \\ out \end{array} \qquad E_R(Terrain) := \begin{array}{|l} out \leftarrow 1.2 \text{ if } Terrain = 1 \\ out \leftarrow 2.0 \text{ if } Terrain = 2 \\ out \leftarrow 4.0 \text{ if } Terrain = 3 \\ out \end{array}$$

$E_T(Terrain) = 1.5 \quad E_T := E_T(Terrain) \quad E_R(Terrain) = 1.2 \quad E_R := E_R(Terrain)$

$$f_{HV} := \frac{1}{1 + P_T \cdot (E_T - 1) + P_R \cdot (E_R - 1)} \qquad f_{HV} = 0.9746$$

Find v_p (using Eq. 23-2)

$$v_p := \frac{FwyVol}{PHF \cdot N \cdot f_{HV} \cdot f_p} \qquad v_p = 1021 \text{ pc/h/ln}$$

Determine S

$S_1 := FFS$

$$S_2 := FFS - \left[\left(FFS - \frac{160}{3}\right) \cdot \left(\frac{v_p + 30 \cdot FFS - 3400}{30 \cdot FFS - 1000}\right)^{2.6}\right]$$

$$S_3 := FFS - \left[\frac{1}{9} \cdot (7 \cdot FFS - 340) \cdot \left(\frac{v_p + 30 \cdot FFS - 3400}{40 \cdot FFS - 1700}\right)^{2.6}\right]$$

$S_{cont2} := \text{if}\left[(55 \le FFS \le 75) \wedge \left[v_p \le (3400 - 30 \cdot FFS)\right], S_1, \text{"Cannot Compute"}\right]$

$S_{cont1} := \text{if}\left[(55 \le FFS \le 70) \wedge \left[(3400 - 30 \cdot FFS) < v_p \le (1700 + 10 \cdot FFS)\right], S_3, S_{cont2}\right]$

$S := \text{if}\left[(70 < FFS \le 75) \wedge \left[(3400 - 30 \cdot FFS) < v_p \le 2400\right], S_2, S_{cont1}\right]$

$S = 65$

Density (using Eq. 23-4)

$D := \frac{v_p}{S}$ $D = 15.7$ pc/mi/ln

Determine level of service (using Exhibit 23-2)

$$LOS(D) := \left| \begin{array}{l} out \leftarrow \text{"F"} \text{ if } D > 45 \\ out \leftarrow \text{"E"} \text{ if } 45 \geq D > 35 \\ out \leftarrow \text{"D"} \text{ if } 35 \geq D > 26 \\ out \leftarrow \text{"C"} \text{ if } 26 \geq D > 18 \\ out \leftarrow \text{"B"} \text{ if } 18 \geq D > 11 \\ out \leftarrow \text{"A"} \text{ if } 11 \geq D \\ out \end{array} \right.$$

$LOS(D) = \text{"B"}$

Determine Input Vol and %HV for Next Downstream Segment

$FwyVolNew := FwyVol = 2836$

$\%Trucks_{FNew} := \%Trucks_F = 5.2115$

**FwyVolNew and %Trucks$_{FNew}$ are the input values for FwyVol and %Trucks$_F$ for the next downstream segment if there is one. If the next segment is a weave, then %Trucks$_{FNew}$ is the input value for %Trucks_FF and %Trucks_FR.*

Full On 10f

Step 1. Data Inputs and Volume Adjusments

**FwyVolNew and %Trucks$_{FNew}$ from the previous upstream segment are the input values for FwyVol and %Trucks$_F$ (if there is a previous upstream segment).*

A. Inputs

$FwyVol := 2836$ veh/h $RampVol := 700$ veh/h

$\%Trucks_F := 5.2115$ $\%RV_F := 0$ $PHF := 0.95$ $f_p := 1$ $FFS := 65$ mi/h

$\%Trucks_R := 2$ $\%RV_R := 0$

$NumLanes := 3$ Number of mainline freeway lanes $NRamp := 1$ Number of lanes on ramp roadway

$Terrain := 1$ 1 = Level, 2 = Rolling, 3 = Mountainous

$L_A := 1000$ ft Total length of Acceleration Lane

$S_{FR} := 40$ mi/h Freeflow speed of the ramp at the junction point

$AdjUp := 2$ $AdjDn := 1$ 0 = none, 1 = on-ramp, 2 = off-ramp for Adjacent Upstream/Downstream Ramps

$L_{up} := 1000$ ft $L_{down} := 6780$ ft

$VolumeUp := 500$ veh/h Volume on adjacent upstream ramp

$VolumeDown := 600$ veh/h Volume on adjacent downstream ramp

B. Heavy Vehicle Adjustments

Passenger Car Equivalents

$$E_T(Terrain) := \begin{array}{|l} out \leftarrow 1.5 \ \text{if} \ Terrain = 1 \\ out \leftarrow 2.5 \ \text{if} \ Terrain = 2 \\ out \leftarrow 4.5 \ \text{if} \ Terrain = 3 \end{array} \qquad E_R(Terrain) := \begin{array}{|l} out \leftarrow 1.2 \ \text{if} \ Terrain = 1 \\ out \leftarrow 2.0 \ \text{if} \ Terrain = 2 \\ out \leftarrow 4.0 \ \text{if} \ Terrain = 3 \end{array}$$

$E_T(Terrain) = 1.5$ $E_R(Terrain) = 1.2$

$E_T := E_T(Terrain)$ $E_T = 1.5$ $E_R := E_R(Terrain)$ $E_R = 1.2$

$$f\_HV_F := \frac{100}{100 + \%Trucks_F(E_T - 1) + \%RV_F(E_R - 1)} = 0.975 \qquad f\_HV_F = 0.975$$

$$f\_HV_R := \frac{100}{100 + \%Trucks_R(E_T - 1) + \%RV_R(E_R - 1)} \qquad f\_HV_R = 0.99$$

C. Demand Flow Rate

$$V_f := \frac{FwyVol}{PHF \cdot f\_HV_F \cdot f_p} \qquad V_f = 3063 \ \text{pc/h} \qquad V_r := \frac{RampVol}{PHF \cdot f\_HV_R \cdot f_p} \qquad V_r = 744 \ \text{pc/h}$$

$$V_u := \frac{VolumeUp}{PHF \cdot f\_HV_R \cdot f_p} \qquad V_u = 532 \ \text{pc/h} \qquad V_d := \frac{VolumeDown}{PHF \cdot f\_HV_R \cdot f_p} \qquad V_d = 638 \ \text{pc/h}$$

Step 2. Determine the Approaching Flow Rate in Lanes 1 and 2

A. Equilibrium Seperation Distance for Adjacent Off-Ramp on a Six Lane Freeway

$$L_{EQup} := 0.214(V_f + V_r) + 0.444 \cdot L_A + 53.32 \cdot S_{FR} - 2403 \qquad L_{EQup} = 989 \ \text{ft}$$

$$L_{EQdown} := \frac{V_d}{0.1096 + 0.000107 \cdot L_A} \qquad L_{EQdown} = 2945 \text{ ft}$$

B. Estimating Proportion of Freeway Vehicles Remaining in lanes 1 and 2

$$Eqn1 := 0.5775 + 0.000028 \cdot L_A \qquad Eqn1 = 0.606$$

$$Eqn2 := 0.7289 - 0.0000135 \cdot (V_f + V_r) - 0.003296 \cdot S_{FR} + 0.000063 \cdot L_{up} \qquad Eqn2 = 0.609$$

$$Eqn3 := 0.5487 + 0.2628 \cdot \frac{V_d}{L_{down}} \qquad Eqn3 = 0.573$$

$$P_{FM}(NumLanes) := \left| \begin{array}{l}
out \leftarrow 1.00 \quad \text{if} \quad NumLanes = 2 \\
out \leftarrow Eqn1 \quad \text{if} \quad AdjUp \neq 2 \wedge AdjDn \neq 2 \wedge NumLanes = 3 \\
out \leftarrow Eqn3 \quad \text{if} \quad AdjUp = 0 \wedge AdjDn = 2 \wedge L_{down} < L_{EQdown} \wedge NumLanes = 3 \\
out \leftarrow Eqn1 \quad \text{if} \quad AdjUp = 0 \wedge AdjDn = 2 \wedge L_{down} \geq L_{EQdown} \wedge NumLanes = 3 \\
out \leftarrow Eqn2 \quad \text{if} \quad AdjUp = 2 \wedge AdjDn = 0 \wedge L_{up} < L_{EQup} \wedge NumLanes = 3 \\
out \leftarrow Eqn1 \quad \text{if} \quad AdjUp = 2 \wedge AdjDn = 0 \wedge L_{up} \geq L_{EQup} \wedge NumLanes = 3 \\
out \leftarrow Eqn1 \quad \text{if} \quad AdjUp = 1 \wedge AdjDn = 1 \wedge NumLanes = 3 \\
out \leftarrow Eqn3 \quad \text{if} \quad AdjUp = 1 \wedge AdjDn = 2 \wedge L_{down} < L_{EQdown} \wedge NumLanes = 3 \\
out \leftarrow Eqn1 \quad \text{if} \quad AdjUp = 1 \wedge AdjDn = 2 \wedge L_{down} \geq L_{EQdown} \wedge NumLanes = 3 \\
out \leftarrow Eqn2 \quad \text{if} \quad AdjUp = 2 \wedge AdjDn = 1 \wedge L_{up} < L_{EQup} \wedge NumLanes = 3 \\
out \leftarrow Eqn1 \quad \text{if} \quad AdjUp = 2 \wedge AdjDn = 1 \wedge L_{up} \geq L_{EQup} \wedge NumLanes = 3 \\
out \leftarrow \max(Eqn1, Eqn2) \quad \text{if} \quad AdjUp = 2 \wedge AdjDn = 2 \wedge L_{up} < L_{EQup} \wedge L_{down} \geq L_{EQdown} \wedge NumLanes = 3 \\
out \leftarrow \max(Eqn3, Eqn2) \quad \text{if} \quad AdjUp = 2 \wedge AdjDn = 2 \wedge L_{up} < L_{EQup} \wedge L_{down} < L_{EQdown} \wedge NumLanes = 3 \\
out \leftarrow Eqn1 \quad \text{if} \quad AdjUp = 2 \wedge AdjDn = 2 \wedge L_{up} \geq L_{EQup} \wedge L_{down} \geq L_{EQdown} \wedge NumLanes = 3 \\
out \leftarrow \max(Eqn1, Eqn3) \quad \text{if} \quad AdjUp = 2 \wedge AdjDn = 2 \wedge L_{up} \geq L_{EQup} \wedge L_{down} < L_{EQdown} \wedge NumLanes = 3 \\
out \leftarrow 0.2178 - 0.0000125 \cdot V_r + -0.0115 \cdot \frac{L_A}{S_{FR}} \quad \text{if} \quad \left(\frac{V_f}{S_{FR}} \leq 72\right) \wedge (NumLanes = 4) \\
out \leftarrow 0.2178 - 0.0000125 \cdot V_r \quad \text{if} \quad \left(\frac{V_f}{S_{FR}} > 72\right) \wedge (NumLanes = 4)
\end{array} \right.$$

$$P_{FM} := P_{FM}(NumLanes) \qquad P_{FM} = 0.606$$

C. Estimating Flow in Lanes 1 and 2

$$V_{12} := V_f \cdot P_{FM} \qquad V_{12} = 1855 \text{ pc/h}$$

D. Checking the Reasonableness of the Lane Distribution Prediction

Six Lane Freeways

$$V_3 := V_f - V_{12} \qquad V_3 = 1208 \text{ pc/h}$$

Eight Lane Freeways

$$V_{av34} := \frac{V_f - V_{12}}{2} \qquad V_{av34} = 604 \text{ pc/h}$$

$$\text{V12a}(\text{NumLanes}) := \left| \begin{array}{l} \text{out} \leftarrow V_{12} \;\; \text{if} \;\; \text{NumLanes} = 2 \\ \text{out} \leftarrow V_f - 2700 \;\; \text{if} \;\; V_3 > 2700 \wedge V_3 \le 1.5 \cdot \frac{V_{12}}{2} \vee \text{NumLanes} = 3 \\ \text{out} \leftarrow \frac{V_f}{1.75} \;\; \text{if} \;\; V_3 \le 2700 \wedge V_3 > 1.5 \cdot \frac{V_{12}}{2} \wedge \text{NumLanes} = 3 \\ \text{out} \leftarrow \max\left(V_f - 2700, \frac{V_f}{1.75}\right) \;\; \text{if} \;\; V_3 > 2700 \wedge V_3 > 1.5 \cdot \frac{V_{12}}{2} \wedge \text{NumLanes} = 3 \\ \text{out} \leftarrow V_{12} \;\; \text{if} \;\; V_3 \le 2700 \wedge V_3 \le 1.5 \cdot \frac{V_{12}}{2} \wedge \text{NumLanes} = 3 \\ \text{out} \leftarrow V_f - 5400 \;\; \text{if} \;\; V_{av34} > 2700 \wedge V_{av34} \le 1.5 \cdot \frac{V_{12}}{2} \wedge \text{NumLanes} = 4 \\ \text{out} \leftarrow \frac{V_f}{2.50} \;\; \text{if} \;\; V_{av34} \le 2700 \wedge V_{av34} > 1.5 \cdot \frac{V_{12}}{2} \wedge \text{NumLanes} = 4 \\ \text{out} \leftarrow \max\left(V_f - 5400, \frac{V_f}{2.50}\right) \;\; \text{if} \;\; V_{av34} > 2700 \wedge V_{av34} > 1.5 \cdot \frac{V_{12}}{2} \wedge \text{NumLanes} = 4 \\ \text{out} \leftarrow V_{12} \;\; \text{if} \;\; V_{av34} \le 2700 \wedge V_{av34} \le 1.5 \cdot \frac{V_{12}}{2} \wedge \text{NumLanes} = 4 \end{array} \right.$$

C. Final Flow in Lanes 1 and 2

$V_{12} := \text{V12a}(\text{NumLanes})$ $\qquad V_{12} = 1855$ pc/h

Step 3. Determine Capacity of Ramp-Freeway Junction

$V_{R12} := V_{12} + V_r$ $\qquad V_{R12} = 2599$ pc/h $\qquad$ Flow entering the ramp influence area

$$\text{CapUpFreewaySegment}(\text{NumLanes}, \text{FFS}) := \left| \begin{array}{l} \text{out} \leftarrow 4800 \;\; \text{if} \;\; \text{FFS} \ge 70 \wedge \text{NumLanes} = 2 \\ \text{out} \leftarrow 4700 \;\; \text{if} \;\; \text{FFS} = 65 \wedge \text{NumLanes} = 2 \\ \text{out} \leftarrow 4600 \;\; \text{if} \;\; \text{FFS} = 60 \wedge \text{NumLanes} = 2 \\ \text{out} \leftarrow 4600 \;\; \text{if} \;\; \text{FFS} = 55 \wedge \text{NumLanes} = 2 \\ \text{out} \leftarrow 7200 \;\; \text{if} \;\; \text{FFS} = 70 \wedge \text{NumLanes} = 3 \\ \text{out} \leftarrow 7050 \;\; \text{if} \;\; \text{FFS} = 65 \wedge \text{NumLanes} = 3 \\ \text{out} \leftarrow 6900 \;\; \text{if} \;\; \text{FFS} = 60 \wedge \text{NumLanes} = 3 \\ \text{out} \leftarrow 6750 \;\; \text{if} \;\; \text{FFS} = 55 \wedge \text{NumLanes} = 3 \\ \text{out} \leftarrow 9600 \;\; \text{if} \;\; \text{FFS} = 70 \wedge \text{NumLanes} = 4 \\ \text{out} \leftarrow 9400 \;\; \text{if} \;\; \text{FFS} = 65 \wedge \text{NumLanes} = 4 \\ \text{out} \leftarrow 9200 \;\; \text{if} \;\; \text{FFS} = 60 \wedge \text{NumLanes} = 4 \\ \text{out} \leftarrow 9000 \;\; \text{if} \;\; \text{FFS} = 55 \wedge \text{NumLanes} = 4 \\ \text{out} \leftarrow 2400 \cdot \text{NumLanes} \;\; \text{if} \;\; \text{FFS} = 70 \wedge \text{NumLanes} > 4 \\ \text{out} \leftarrow 2350 \cdot \text{NumLanes} \;\; \text{if} \;\; \text{FFS} = 65 \wedge \text{NumLanes} > 4 \\ \text{out} \leftarrow 2300 \cdot \text{NumLanes} \;\; \text{if} \;\; \text{FFS} = 60 \wedge \text{NumLanes} > 4 \\ \text{out} \leftarrow 2250 \cdot \text{NumLanes} \;\; \text{if} \;\; \text{FFS} = 55 \wedge \text{NumLanes} > 4 \end{array} \right.$$

$CapUpFreewaySegment(NumLanes, FFS) = 7050$ Capacity of Ramp Freeway Junction

MaxV12 = 4600 Maximum Desirable Flow Rate Entering Merge Influence Area

$$CapacityRampRoadway := \begin{array}{|l} out \leftarrow 2200 \;\text{ if }\; (NRamp = 1) \wedge (S_{FR} > 50) \\ out \leftarrow 2100 \;\text{ if }\; (NRamp = 1) \wedge (40 < S_{FR} \le 50) \\ out \leftarrow 2000 \;\text{ if }\; (NRamp = 1) \wedge (30 < S_{FR} \le 40) \\ out \leftarrow 1900 \;\text{ if }\; (NRamp = 1) \wedge (20 \le S_{FR} \le 30) \\ out \leftarrow 1800 \;\text{ if }\; (NRamp = 1) \wedge (20 > S_{FR}) \\ out \leftarrow 4400 \;\text{ if }\; (NRamp = 2) \wedge (S_{FR} > 50) \\ out \leftarrow 4200 \;\text{ if }\; (NRamp = 2) \wedge (40 < S_{FR} \le 50) \\ out \leftarrow 4000 \;\text{ if }\; (NRamp = 2) \wedge (30 < S_{FR} \le 40) \\ out \leftarrow 3800 \;\text{ if }\; (NRamp = 2) \wedge (20 \le S_{FR} \le 30) \\ out \leftarrow 3600 \;\text{ if }\; (NRamp = 2) \wedge (20 > S_{FR}) \end{array}$$

$CapacityRampRoadway = 2000$

$V_{FO} := V_f + V_r$ $V_{FO} = 3807$ pc/h Volume immediatley downstream of on-ramp influence area

Ramp Freeway Junction Checkpoint

Volume immediatley downstream of on-ramp influence area is chekced against freeway capacity. Failure of ramp freeway junction checkpoint (i.e. demand exceeds capacity) results in LOS F

Ramp Roadway Capacity Checkpoint

Capacity or ramp roadway should always be checked against the demand flow rate on the ramp. It is rarely a problem for the on-ramp

Maximum Desirable Flow Entering Ramp Influence Area Checkpoint

While the V_{R12} values is checked against the maximum desirable, failure does not result in assignment of LOS F. Failing this checkpoint generally means that there will be more turbulance in influence area than predicted by this methodology. Thus, predicted densities are most likely lower than those that will exist, and predicted speeds are most likely to be predicted as higher than those that will actually occur.

Step 4. Determine Speeds in the Vicinity of Ramp-Freeway Junction

A. Average Speed in the Ramp Influence Area

$$S_R := FFS - (FFS - 42) \cdot \left[0.321 + 0.0039\,\exp\left(\frac{V_{R12}}{1000}\right) - 0.002 \cdot \left(L_A \frac{S_{FR}}{1000}\right)\right]$$

$S_R = 58.25$ mi/h

B. Average Speed in the Outer Lanes of Freeway

Average Flow in Outer Lanes

$$No := \begin{array}{|l} out \leftarrow 1 \quad \text{if} \quad NumLanes = 3 \\ out \leftarrow 2 \quad \text{if} \quad NumLanes = 4 \\ out \leftarrow \infty \quad \text{if} \quad NumLanes = 2 \end{array}$$

$$V_{OA} := \frac{V_f - V_{12}}{No}$$

$V_{OA} = 1208$

$$S_O(V_{OA}) := \begin{array}{|l} out \leftarrow FFS \quad \text{if} \quad V_{OA} < 500 \\ out \leftarrow FFS - 0.0036 \cdot (V_{OA} - 500) \quad \text{if} \quad 500 \le V_{OA} \le 2300 \\ out \leftarrow FFS - 6.53 - 0.006 \cdot (V_{OA} - 2300) \quad \text{if} \quad V_{OA} > 2300 \end{array}$$

$S_O := S_O(V_{OA})$ $\qquad$ $S_O = 62.45$ mi/h

C. Average Speed for On-Ramp Junction

$$Speed := \frac{V_{R12} + V_{OA} \cdot No}{\left(\frac{V_{R12}}{S_R}\right) + \left(\frac{V_{OA} \cdot No}{S_O}\right)}$$

$Speed = 59.52$ mi/h

Step 5. Determine the Density and Level of Service

A. Density in On-Ramp Influence Area

$$Density_R := 5.475 + 0.00734 \cdot V_r + 0.0078 \cdot V_{12} - 0.00627 \cdot L_A$$

$Density_R = 19.1$ pc/mi/ln

B. Density in Outer Lanes

$$Density_O := \frac{V_{OA}}{S_O}$$

$Density_O = 19.3$ pc/mi/ln

C. Density of Entire Cross-Section

$$Density := \begin{array}{|l} out \leftarrow Density_R \quad \text{if} \quad NumLanes \le 2 \\ out \leftarrow \frac{\left[Density_R \cdot (2) + Density_O \cdot (NumLanes - 2)\right]}{NumLanes} \quad \text{if} \quad NumLanes > 2 \end{array}$$

$Density = 19.2$ pc/mi/ln

D. Level of Service

$$LOS(Density) := \begin{array}{|l} out \leftarrow \text{"A"} \quad \text{if} \quad 0 \le Density \le 10 \\ out \leftarrow \text{"B"} \quad \text{if} \quad 10 < Density \le 20 \\ out \leftarrow \text{"C"} \quad \text{if} \quad 20 < Density \le 28 \\ out \leftarrow \text{"D"} \quad \text{if} \quad 28 < Density \le 35 \\ out \leftarrow \text{"E"} \quad \text{if} \quad 35 < Density \end{array}$$

$LOS(Density) = \text{"B"}$

Step 6. Determine Input Vol and %HV for Next Downstream Segment

$$FwyVol_{Cars} := FwyVol \cdot \left(1 - \frac{\%Trucks_F}{100}\right) = 2688.2$$

$$RampVol_{Cars} := RampVol \cdot \left(1 - \frac{\%Trucks_R}{100}\right) = 686$$

$$FwyVol_{CarsNew} := FwyVol_{Cars} + RampVol_{Cars} = 3374.2$$

$$FwyVol_{Trucks} := FwyVol \cdot \frac{\%Trucks_F}{100} = 147.798$$

$$RampVol_{Trucks} := RampVol \cdot \left(\frac{\%Trucks_R}{100}\right) = 14$$

$$FwyVol_{TrucksNew} := FwyVol_{Trucks} + RampVol_{Trucks} = 161.798$$

$$FwyVolNew := FwyVol_{CarsNew} + FwyVol_{TrucksNew} = 3536$$

$$\%Trucks_{FNew} := \frac{FwyVol_{TrucksNew}}{FwyVolNew} \cdot 100 = 4.5757$$

**FwyVolNew and $\%Trucks_{FNew}$ are the input values for FwyVol and $\%Trucks_F$ for the next downstream segment if there is one. If the next segment is a weave, then $\%Trucks_{FNew}$ is the input value for %Trucks_FF and %Trucks_FR.*

Basic 11

Input Values

**FwyVolNew and %Trucks$_{FNew}$ from the previous upstream segment are the input values for FwyVol and %Trucks$_F$ (if there is a previous upstream segment).*

Traffic

$FwyVol := 3536 \quad PHF := 0.95$

$f_p := 1.0 \quad FFS := 65$

$\%Trucks_F := 4.5757 \quad P_R := 0$

$P_T := \frac{\%Trucks_F}{100} = 0.0458$

Roadway

$N := 3 \quad LaneWidth := 12 \quad LatClear := 6 \quad IntDens := 0.691085$

$Terrain := 1$ 1 = Level, 2 = Rolling, 3 = Mountainous

$AreaType := 2$ 1 = Rural, 2 = Urban

**FREEPLAN finds IntDens by counting parclos and diamond as 1 interchange each, full as 2, and on and off as 1/2 each and adds them. Then, it divides that total number of interchanges by the total length of the facility.*

Find f_{HV} (using Exhibit 23-8 and Eq. 23-3)

$$E_T(Terrain) := \left| \begin{array}{l} out \leftarrow 1.5 \ \text{ if } Terrain = 1 \\ out \leftarrow 2.5 \ \text{ if } Terrain = 2 \\ out \leftarrow 4.5 \ \text{ if } Terrain = 3 \\ out \end{array} \right. \qquad E_R(Terrain) := \left| \begin{array}{l} out \leftarrow 1.2 \ \text{ if } Terrain = 1 \\ out \leftarrow 2.0 \ \text{ if } Terrain = 2 \\ out \leftarrow 4.0 \ \text{ if } Terrain = 3 \\ out \end{array} \right.$$

$E_T(Terrain) = 1.5 \qquad E_T := E_T(Terrain) \qquad E_R(Terrain) = 1.2 \qquad E_R := E_R(Terrain)$

$$f_{HV} := \frac{1}{1 + P_T \cdot (E_T - 1) + P_R \cdot (E_R - 1)} \qquad f_{HV} = 0.9776$$

Find v_p (using Eq. 23-2)

$$v_p := \frac{FwyVol}{PHF \cdot N \cdot f_{HV} \cdot f_p} \qquad v_p = 1269.1 \ \text{pc/h/ln}$$

Determine S

$S_1 := FFS$

$$S_2 := FFS - \left[\left(FFS - \frac{160}{3} \right) \cdot \left(\frac{v_p + 30 \cdot FFS - 3400}{30 \cdot FFS - 1000} \right)^{2.6} \right]$$

$$S_3 := FFS - \left[\frac{1}{9} \cdot (7 \cdot FFS - 340) \cdot \left(\frac{v_p + 30 \cdot FFS - 3400}{40 \cdot FFS - 1700} \right)^{2.6} \right]$$

$S_{cont2} := \text{if}\left[(55 \le FFS \le 75) \wedge \left[v_p \le (3400 - 30 \cdot FFS) \right], S_1, \text{"Cannot Compute"} \right]$

$S_{cont1} := \text{if}\left[(55 \le FFS \le 70) \wedge \left[(3400 - 30 \cdot FFS) < v_p \le (1700 + 10 \cdot FFS) \right], S_3, S_{cont2} \right]$

$S := \text{if}\left[(70 < FFS \le 75) \wedge \left[(3400 - 30 \cdot FFS) < v_p \le 2400 \right], S_2, S_{cont1} \right]$

$S = 65$

Density (using Eq. 23-4)

$D := \frac{v_p}{S}$ $D = 19.5$ pc/mi/ln

Determine level of service (using Exhibit 23-2)

$$\text{LOS}(D) := \left| \begin{array}{l} out \leftarrow \text{"F"} \quad \text{if } D > 45 \\ out \leftarrow \text{"E"} \quad \text{if } 45 \geq D > 35 \\ out \leftarrow \text{"D"} \quad \text{if } 35 \geq D > 26 \\ out \leftarrow \text{"C"} \quad \text{if } 26 \geq D > 18 \\ out \leftarrow \text{"B"} \quad \text{if } 18 \geq D > 11 \\ out \leftarrow \text{"A"} \quad \text{if } 11 \geq D \\ out \end{array} \right.$$

$\text{LOS}(D) = \text{"C"}$

Determine Input Vol and %HV for Next Downstream Segment

$FwyVolNew := FwyVol = 3536$

$\%Trucks_{FNew} := \%Trucks_F = 4.5757$

**FwyVolNew and %Trucks$_{FNew}$ are the input values for FwyVol and %Trucks$_F$ for the next downstream segment if there is one. If the next segment is a weave, then %Trucks$_{FNew}$ is the input value for %Trucks_FF and %Trucks_FR.*

Weave (On 12, Basic 13, and Full Off 14a)

**FwyVolNew and %Trucks$_{FNew}$ from the previous upstream segment are the input values for SegInputVol and SegInput%HV if there is a previous upstream segment.*

Step 1. Data Inputs

OnRampVol := 600 OffRampVol := 455 SegInputVol := 3536 Int_Density := 0.87 int/mi

OnRamp%HV := 2 OffRamp%HV := 2 SegInput%HV := 4.5757

**FREEPLAN finds Int_Density by counting parclos and diamond as 1 interchange each, full as 2, and on and off as 1/2 each and adds them. Then, it divides that total number of interchanges by the total length of the facility.*

L_B := 4500 ft FFS := 65 mi/h PHF := .95 fp := 1.00

Terrain := 1 1 = Level, 2 = Rolling, 3 = Mountainous

Config := 1 1 = one-sided weaving segment, 2 = two-sided weaving segment

NumLanes := 4 Number of lanes in weaving section

C_IFL := 2350 pc/h/ln Capacity of basic freeway segment with same FFS as the weaving segment under equivalent ideal conditions

N_WL := 2 Number of lanes from which weaving maneuvers may be made with one lane change or no lane change. 2 or 3 for one sided and 0 for two sided weaving configuration

LC_RF := 1 Minimum number of lane changes that must be made by a single weaving vehicle from the on-ramp to freeway

LC_FR := 1 Minimum number of lane changes that must be made by a single weaving vehicle from freeway to the off-ramp

LC_RR := 0 Minimum number of lane changes that must be made by one ramp-to-ramp to complete a weaving maneuver

Step 2. Volume Adjustment

A. Heavy Vehicle and Volume Adjustments

Passenger Car Equivalents

$$\text{E\_T}(\text{Terrain}) := \begin{array}{|l} \text{out} \leftarrow 1.5 \ \text{if} \ \text{Terrain} = 1 \\ \text{out} \leftarrow 2.5 \ \text{if} \ \text{Terrain} = 2 \\ \text{out} \leftarrow 4.5 \ \text{if} \ \text{Terrain} = 3 \end{array}$$

$$\text{E\_T} := \text{E\_T}(\text{Terrain}) \qquad \text{E\_T} = 1.5$$

**FREEPLAN assumes trucks make up all of the heavy vehicles. Therefore, RV calculations have been left out.*

$$\text{f\_HV\_FF} := \frac{100}{100 + \text{SegInput\%HV}(\text{E\_T} - 1)} \qquad \text{f\_HV\_FR} := \frac{100}{100 + \text{OffRamp\%HV}(\text{E\_T} - 1)}$$

$$\text{f\_HV\_RF} := \frac{100}{100 + \text{OnRamp\%HV}(\text{E\_T} - 1)} \qquad \text{f\_HV\_RR} := \frac{100}{100 + \text{OnRamp\%HV}(\text{E\_T} - 1)}$$

$$\text{SegInputVolAdj} := \frac{\text{SegInputVol}}{\text{PHF} \cdot \text{f\_HV\_FF} \cdot \text{fp}} = 3807.261 \qquad \text{OffRampVolAdj} := \frac{\text{OffRampVol}}{\text{PHF} \cdot \text{f\_HV\_FR} \cdot \text{fp}} = 483.737$$

$$\text{OnRampVolAdj} := \frac{\text{OnRampVol}}{\text{PHF} \cdot \text{f\_HV\_RF} \cdot \text{fp}} = 637.895$$

**Freeplan assumes the Freeway to Ramp Volume will have the same %HV as the Off Ramp and that the Freeway to Freeway Volume will have the same %HV as the Segment Input Volume*

$$\text{f\_HV} := \frac{(\text{f\_HV\_FF} + \text{f\_HV\_FR} + \text{f\_HV\_RF} + \text{f\_HV\_RR})}{4} \qquad \text{f\_HV} = 0.987$$

B. Volumes for Weaving Segments

$v\_RR := .05 \cdot OnRampVolAdj = 31.895$ veh/h ** Freeplan assumes the v_RR is 5% of the total On-Ramp volume.*

$v\_FR := OffRampVolAdj - v\_RR = 451.842$ veh/h

$v\_RF := .95 \cdot OnRampVolAdj = 606$ veh/h

$v\_FF := SegInputVolAdj - v\_FR = 3355.42$ veh/h

$v\_Total := v\_FF + v\_RF + v\_FR + v\_RR = 4.445 \times 10^{3}$ veh/h

C. Weaving Demand Flow Rate

$$WeavingDemand(N\_WL) := \begin{vmatrix} out \leftarrow v\_RF + v\_FR \quad \text{if} \quad N\_WL \neq 0 \\ out \leftarrow v\_RR \quad \text{if} \quad N\_WL = 0 \end{vmatrix}$$

$WeavingFlowRate := WeavingDemand(N\_WL)$

$\boxed{WeavingFlowRate = 1058}$ pc/h

D. Non-Weaving Demand Flow Rate

$$NonWeavingDemand(N\_WL) := \begin{vmatrix} out \leftarrow v\_FF + v\_RR \quad \text{if} \quad N\_WL \neq 0 \\ out \leftarrow v\_FF + v\_FR + v\_RF \quad \text{if} \quad N\_WL = 0 \end{vmatrix}$$

$NonWeavingFlowRate := NonWeavingDemand(N\_WL)$

$\boxed{NonWeavingFlowRate = 3387}$ pc/h

E. Total Demand Flow Rate

$TotalFlowRate := WeavingFlowRate + NonWeavingFlowRate$

$\boxed{TotalFlowRate = 4445}$ pc/h

F. Volume Ratio

$VR := \frac{WeavingFlowRate}{TotalFlowRate}$ $\boxed{VR = 0.238}$

Step 3. Determine the Maximum Weaving Length

$MaximumLength := \left[5728(1 + VR)^{1.6}\right] - 1566 \cdot N\_WL$

$\boxed{MaximumLength = 4928}$ ft $Ls := L_B \cdot .77 = 3465$

If Maximum Length < Ls, then STOP
Analyze ramp junctions separately

Step 4. Determine the Capacity of Weaving Segment

A. Weaving segment capacity determined by density

$$C\_IWL := C\_IFL - \left[438.2\cdot(1 + VR)^{1.6}\right] + (0.0765\cdot Ls) + (119.8\cdot N\_WL)$$

$C\_IWL = 2238$ pc/h/ln C_IWL is the capacity per lane under equivalent ideal conditions

$$Cw1 := C\_IWL\cdot NumLanes\cdot f\_HV\cdot fp$$

$Cw1 = 8836$ veh/h Cw1 is the density based capacity of weaving segment under prevailing conditions

B. Weaving segment capacity determined by weaving demand flows

$$C\_IW(N\_WL) := \left| \begin{array}{l} out \leftarrow \dfrac{2400}{VR} \quad \text{if} \quad N\_WL = 2 \\ out \leftarrow \dfrac{3500}{VR} \quad \text{if} \quad N\_WL = 3 \\ out \leftarrow \dfrac{Cw1}{f\_HV\cdot fp} \quad \text{if} \quad N\_WL = 0 \end{array} \right.$$

For two sided segments, no limiting value on flow rate is proposed and thus capacity based on density only is estimated for the segment. Therefore same capacity value is used here to get the final as capacity determined by density for two sided segments.

$C\_IW := C\_IW(N\_WL)$ $C\_IW = 10085$ pc/h C_IW is the capacity of the weaving segment under ideal conditions

$$Cw2 := C\_IW\cdot f\_HV\cdot fp$$

$Cw2 = 9954$ veh/h Cw2 is the flow based capacity of weaving segment under prevailing conditions

C. Final Capacity of Weaving Segment

$$WeavingCapacity := \text{if}(Cw1 > Cw2, Cw2, Cw1)$$

$\boxed{WeavingCapacity = 8836}$ veh/h

D. Volume to Capacity (v/c) Ratio

$$VolumeToCapacity := \frac{TotalFlowRate\cdot f\_HV\cdot fp}{WeavingCapacity}$$

$\boxed{VolumeToCapacity = 0.497}$

If v/c ratio >1 then LOS is F
Terminate

Step 5. Determine Configuration Characteristics

$$LC\_MIN(Config) := \left| \begin{array}{l} out \leftarrow (LC\_RF\cdot v\_RF) + (LC\_FR\cdot v\_FR) \quad \text{if} \quad Config = 1 \\ out \leftarrow (LC\_RR\cdot v\_RR) \quad \text{if} \quad Config = 2 \end{array} \right.$$

$$LC\_MIN := LC\_MIN(Config)$$

$\boxed{LC\_MIN = 1058}$ lc/h Minimum Lane Changes

Step 6. Determine Lane-Changing Rates

A. Lane-Changing Rate for Weaving Vehicles

$$LC\_W(Ls) := \left| \begin{array}{l} out \leftarrow LC\_MIN + 0.39 \cdot \left[(Ls - 300)^{0.5} \cdot NumLanes^{2} \cdot (1 + Int\_Density)^{0.8} \right] \quad \text{if} \quad Ls \geq 300 \\ out \leftarrow LC\_MIN \quad \text{if} \quad Ls < 300 \end{array} \right.$$

$$LaneChangingWeaving := LC\_W(Ls)$$

$$\boxed{LaneChangingWeaving = 1637} \quad \text{lc/h}$$

B. Lane-Changing Rate for Non-Weaving Vehicles

$$I\_NW := \frac{Ls \cdot Int\_Density \cdot NonWeavingFlowRate}{10000} \qquad I\_NW = 1021$$

Non Weaving Vehicle Index

$$LC\_NW1 := (0.206 \cdot NonWeavingFlowRate) + (0.542 \cdot Ls) - (192.6 \cdot NumLanes)$$

$$LC\_NW2 := 2135 + 0.233 \cdot (NonWeavingFlowRate - 2000)$$

$$LC\_NW3 := LC\_NW1 + (LC\_NW2 - LC\_NW1) \cdot \frac{(I\_NW - 1300)}{650}$$

$$LC\_NW(I\_NW) := \left| \begin{array}{lll} out \leftarrow LC\_NW1 & \text{if} & I\_NW < 1300 \\ out \leftarrow LC\_NW2 & \text{if} & I\_NW \geq 1950 \\ out \leftarrow LC\_NW3 & \text{if} & 1300 < I\_NW < 1950 \\ out \leftarrow LC\_NW2 & \text{if} & LC\_NW1 \geq LC\_NW2 \end{array} \right.$$

$$LaneChangingNonWeaving := LC\_NW(I\_NW)$$

$$\boxed{LaneChangingNonWeaving = 1805} \quad \text{lc/h}$$

C. Total Lane-Changing Rate

$$TotalLaneChanging := LaneChangingWeaving + LaneChangingNonWeaving$$

$$\boxed{TotalLaneChanging = 3442} \quad \text{lc/h}$$

Step 7. Determine Average Speed of Weaving and Non-Weaving Vehicles

A. Average Speed of Weaving Vehicles

$$WeavingIntensityFactor := 0.226 \left(\frac{TotalLaneChanging}{Ls} \right)^{0.789}$$

$$WeavingIntensityFactor = 0.225$$

$$AverageWeavingSpeed := 15 + \left(\frac{FFS - 15}{1 + WeavingIntensityFactor} \right)$$

$$\boxed{AverageWeavingSpeed = 55.82} \quad \text{mi/h}$$

B. Average Speed of Non-Weaving Vehicles

$$AverageNonWeavingSpeed := FFS - (0.0072 \cdot LC\_MIN) - \left(0.0048 \cdot \frac{TotalFlowRate}{NumLanes}\right)$$

$\boxed{AverageNonWeavingSpeed = 52.05}$ mi/h

C. Average Speed of All Vehicles

$$AverageSpeed := \frac{WeavingFlowRate + NonWeavingFlowRate}{\left(\frac{WeavingFlowRate}{AverageWeavingSpeed}\right) + \left(\frac{NonWeavingFlowRate}{AverageNonWeavingSpeed}\right)}$$

$\boxed{AverageSpeed = 52.9}$ mi/h

Step 8. Determine the Level of Service

$$Density := \frac{\left(\frac{TotalFlowRate}{NumLanes}\right)}{AverageSpeed}$$

$\boxed{Density = 21}$ pc/mi/ln

$$LOS(Density) := \left| \begin{array}{lll} out \leftarrow \text{"A"} & \text{if} & 0 \le Density \le 10 \\ out \leftarrow \text{"B"} & \text{if} & 10 < Density \le 20 \\ out \leftarrow \text{"C"} & \text{if} & 20 < Density \le 28 \\ out \leftarrow \text{"D"} & \text{if} & 28 < Density \le 35 \\ out \leftarrow \text{"E"} & \text{if} & 35 < Density \\ out \leftarrow \text{"F"} & \text{if} & VolumeToCapacity > 1 \end{array} \right.$$

$\boxed{LOS(Density) = \text{"C"}}$

Step 9. Determine the Input Vol and %HV for the Next Downstream Segment

$$FwyVolNew := SegInputVol + (OnRampVol - v\_RR) - (OffRampVol - v\_RR) = 3681$$

$$\%Trucks_{FNew} := \frac{SegInputVol \cdot SegInput\%HV + (OnRampVol - v\_RR) \cdot OnRamp\%HV - (OffRampVol - v\_RR) \cdot OffRamp\%HV}{FwyVolNew}$$

$\%Trucks_{FNew} = 4.474$ **FwyVolNew and %Trucks$_{FNew}$ are the input values for FwyVol and %Trucks$_F$ for the next downstream segment if there is one. If the next segment is a weave, then %Trucks$_{FNew}$ is the input value for SegInput%HV and FwyVolNew is the input value for SegInputVol.*

Full Basic 14b

Input Values

**FwyVolNew and %Trucks$_{FNew}$ from the previous upstream segment are the input values for FwyVol and %Trucks$_F$ (if there is a previous upstream segment).*

Traffic

$FwyVol := 3681 \quad PHF := 0.95$

$f_p := 1.0 \quad FFS := 65$

$\%Trucks_F := 4.4742 \quad P_R := 0$

$$P_T := \frac{\%Trucks_F}{100} = 0.0447$$

Roadway

$N := 3 \quad LaneWidth := 12 \quad LatClear := 6 \quad IntDens := 0.861$

$Terrain := 1$ 1 = Level, 2 = Rolling, 3 = Mountainous

$AreaType := 2$ 1 = Rural, 2 = Urban

**FREEPLAN finds IntDens by counting parclos and diamond as 1 interchange each, full as 2, and on and off as 1/2 each and adds them. Then, it divides that total number of interchanges by the total length of the facility.*

Find f_{HV} (using Exhibit 23-8 and Eq. 23-3)

$$E_T(Terrain) := \left| \begin{array}{l} out \leftarrow 1.5 \ \text{ if } Terrain = 1 \\ out \leftarrow 2.5 \ \text{ if } Terrain = 2 \\ out \leftarrow 4.5 \ \text{ if } Terrain = 3 \\ out \end{array} \right. \qquad E_R(Terrain) := \left| \begin{array}{l} out \leftarrow 1.2 \ \text{ if } Terrain = 1 \\ out \leftarrow 2.0 \ \text{ if } Terrain = 2 \\ out \leftarrow 4.0 \ \text{ if } Terrain = 3 \\ out \end{array} \right.$$

$E_T(Terrain) = 1.5 \quad E_T := E_T(Terrain) \quad E_R(Terrain) = 1.2 \quad E_R := E_R(Terrain)$

$$f_{HV} := \frac{1}{1 + P_T \cdot (E_T - 1) + P_R \cdot (E_R - 1)} \qquad f_{HV} = 0.9781$$

Find v_p (using Eq. 23-2)

$$v_p := \frac{FwyVol}{PHF \cdot N \cdot f_{HV} \cdot f_p} \qquad v_p = 1320.5 \ \text{pc/h/ln}$$

Determine S

$S_1 := FFS$

$$S_2 := FFS - \left[\left(FFS - \frac{160}{3} \right) \cdot \left(\frac{v_p + 30 \cdot FFS - 3400}{30 \cdot FFS - 1000} \right)^{2.6} \right]$$

$$S_3 := FFS - \left[\frac{1}{9} \cdot (7 \cdot FFS - 340) \cdot \left(\frac{v_p + 30 \cdot FFS - 3400}{40 \cdot FFS - 1700} \right)^{2.6} \right]$$

$$S_{cont2} := if\left[(55 \le FFS \le 75) \wedge \left[v_p \le (3400 - 30 \cdot FFS) \right], S_1, \text{"Cannot Compute"} \right]$$

$$S_{cont1} := if\left[(55 \le FFS \le 70) \wedge \left[(3400 - 30 \cdot FFS) < v_p \le (1700 + 10 \cdot FFS) \right], S_3, S_{cont2} \right]$$

$$S := if\left[(70 < FFS \le 75) \wedge \left[(3400 - 30 \cdot FFS) < v_p \le 2400 \right], S_2, S_{cont1} \right]$$

$S = 65$

Density (using Eq. 23-4)

$$D := \frac{v_p}{S} \qquad D = 20.3 \quad \text{pc/mi/ln}$$

Determine level of service (using Exhibit 23-2)

$$LOS(D) := \left| \begin{array}{l} out \leftarrow \text{"F"} \quad \text{if } D > 45 \\ out \leftarrow \text{"E"} \quad \text{if } 45 \geq D > 35 \\ out \leftarrow \text{"D"} \quad \text{if } 35 \geq D > 26 \\ out \leftarrow \text{"C"} \quad \text{if } 26 \geq D > 18 \\ out \leftarrow \text{"B"} \quad \text{if } 18 \geq D > 11 \\ out \leftarrow \text{"A"} \quad \text{if } 11 \geq D \\ out \end{array} \right.$$

$LOS(D) = \text{"C"}$

Determine Input Vol and %HV for Next Downstream Segment

$FwyVolNew := FwyVol = 3681$

$\%Trucks_{FNew} := \%Trucks_F = 4.4742$

**FwyVolNew and %Trucks$_{FNew}$ are the input values for FwyVol and %Trucks$_F$ for the next downstream segment if there is one. If the next segment is a weave, then %Trucks$_{FNew}$ is the input value for %Trucks_FF and %Trucks_FR.*

Full Cloverleaf Weave (14c)

**FwyVolNew and %Truck$_{SFNew}$ from the previous upstream segment are the input values for SegInputVol and SegInput%HV if there is a previous upstream segment.*

Step 1. Data Inputs

OnRampVol := 455 OffRampVol := 455 SegInputVol := 3681 Int_Density := 0.861 int/mi

OnRamp%HV := 2 OffRamp%HV := 2 SegInput%HV := 4.4742

L_B := 2000 ft FFS := 65 mi/h PHF := .95 fp := 1

Terrain := 1 1 = Level, 2 = Rolling, 3 = Mountainous

**FREEPLAN finds Int_Density by counting parclos and diamond as 1 interchange each, full as 2, and on and off as 1/2 each and adds them. Then, it divides that total number of interchanges by the total length of the facility.*

Config := 1 1 = one-sided weaving segment, 2 = two-sided weaving segment

NumLanes := 4 Number of lanes in weaving section

C_IFL := 2350 pc/h/ln Capacity of basic freeway segment with same FFS as the weaving segment under equivalent ideal conditions

N_WL := 2 Number of lanes from which weaving maneuvers may be made with one lane change or no lane change. 2 or 3 for one sided and 0 for two sided weaving configuration

LC_RF := 1 Minimum number of lane changes that must be made by a single weaving vehicle from the on-ramp to freeway

LC_FR := 1 Minimum number of lane changes that must be made by a single weaving vehicle from freeway to the off-ramp

LC_RR := 0 Minimum number of lane changes that must be made by one ramp-to-ramp to complete a weaving maneuver

Step 2. Volume Adjustment

A. Heavy Vehicle and Volume Adjustments

Passenger Car Equivalents

$$\text{E\_T(Terrain)} := \left| \begin{array}{lll} \text{out} \leftarrow 1.5 & \text{if} & \text{Terrain} = 1 \\ \text{out} \leftarrow 2.5 & \text{if} & \text{Terrain} = 2 \\ \text{out} \leftarrow 4.5 & \text{if} & \text{Terrain} = 3 \end{array} \right.$$

$$\text{E\_T} := \text{E\_T(Terrain)}$$

$$\text{E\_T} = 1.5$$

**FREEPLAN assumes trucks make up all of the heavy vehicles. Therefore, RV calculations have been left out.*

$$\text{f\_HV\_FF} := \frac{100}{100 + \text{SegInput\%HV}(\text{E\_T} - 1)}$$

$$\text{f\_HV\_FR} := \frac{100}{100 + \text{OffRamp\%HV}(\text{E\_T} - 1)}$$

$$\text{f\_HV\_RF} := \frac{100}{100 + \text{OnRamp\%HV}(\text{E\_T} - 1)}$$

$$\text{f\_HV\_RR} := \frac{100}{100 + \text{OnRamp\%HV}(\text{E\_T} - 1)}$$

$$\text{SegInputVolAdj} := \frac{\text{SegInputVol}}{\text{PHF} \cdot \text{f\_HV\_FF} \cdot \text{fp}} = 3961.419$$

$$\text{OffRampVolAdj} := \frac{\text{OffRampVol}}{\text{PHF} \cdot \text{f\_HV\_FR} \cdot \text{fp}} = 483.7368$$

$$\text{OnRampVolAdj} := \frac{\text{OnRampVol}}{\text{PHF} \cdot \text{f\_HV\_RF} \cdot \text{fp}} = 483.7368$$

**Freeplan assumes the Freeway to Ramp Volume will have the same %HV as the Off Ramp and that the Freeway to Freeway Volume will have the same %HV as the Segment Input Volume*

$$\text{f\_HV} := \frac{(\text{f\_HV\_FF} + \text{f\_HV\_FR} + \text{f\_HV\_RF} + \text{f\_HV\_RR})}{4}$$

$$\text{f\_HV} = 0.9871$$

B. Volumes for Weaving Segments

$v\_RR := .05 \cdot OnRampVolAdj = 24.1868$ veh/h   ** Freeplan assumes the v_RR is 5% of the total On-Ramp volume.*

$v\_FR := OffRampVolAdj - v\_RR = 459.55$ veh/h

$v\_RF := .95 \cdot OnRampVolAdj = 459.55$ veh/h

$v\_FF := SegInputVolAdj - v\_FR = 3501.87$ veh/h

$v\_Total := v\_FF + v\_RF + v\_FR + v\_RR = 4.4452 \times 10^{3}$ veh/h

C. Weaving Demand Flow Rate

$$WeavingDemand(N\_WL) := \left| \begin{array}{l} out \leftarrow v\_RF + v\_FR \quad \text{if} \quad N\_WL \neq 0 \\ out \leftarrow v\_RR \quad \text{if} \quad N\_WL = 0 \end{array} \right.$$

$WeavingFlowRate := WeavingDemand(N\_WL)$

$\boxed{WeavingFlowRate = 919}$ pc/h

D. Non-Weaving Demand Flow Rate

$$NonWeavingDemand(N\_WL) := \left| \begin{array}{l} out \leftarrow v\_FF + v\_RR \quad \text{if} \quad N\_WL \neq 0 \\ out \leftarrow v\_FF + v\_FR + v\_RF \quad \text{if} \quad N\_WL = 0 \end{array} \right.$$

$NonWeavingFlowRate := NonWeavingDemand(N\_WL)$

$\boxed{NonWeavingFlowRate = 3526}$ pc/h

E. Total Demand Flow Rate

$TotalFlowRate := WeavingFlowRate + NonWeavingFlowRate$

$\boxed{TotalFlowRate = 4445}$ pc/h

F. Volume Ratio

$VR := \dfrac{WeavingFlowRate}{TotalFlowRate}$ $\boxed{VR = 0.2068}$

Step 3. Determine the Maximum Weaving Length

$MaximumLength := \left[5728(1 + VR)^{1.6}\right] - 1566 \cdot N\_WL$

$\boxed{MaximumLength = 4605}$ ft $Ls := L_B \cdot .77 = 1540$

If Maximum Length < Ls, then STOP
Analyze ramp junctions separately

Step 4. Determine the Capacity of Weaving Segment

A. Weaving segment capacity determined by density

$$C\_IWL := C\_IFL - \left[438.2 \cdot (1 + VR)^{1.6}\right] + (0.0765 \cdot Ls) + (119.8 \cdot N\_WL)$$

$C\_IWL = 2115$ pc/h/ln   C_IWL is the capacity per lane under equivalent ideal conditions

$$Cw1 := C\_IWL \cdot NumLanes \cdot f\_HV \cdot fp$$

$Cw1 = 8353$ veh/h   Cw1 is the density based capacity of weaving segment under prevailing conditions

B. Weaving segment capacity determined by weaving demand flows

$$C\_IW(N\_WL) := \left| \begin{array}{ll} out \leftarrow \dfrac{2400}{VR} & \text{if } N\_WL = 2 \\ out \leftarrow \dfrac{3500}{VR} & \text{if } N\_WL = 3 \\ out \leftarrow \dfrac{Cw1}{f\_HV \cdot fp} & \text{if } N\_WL = 0 \end{array} \right.$$

For two sided segments, no limiting value on flow rate is proposed and thus capacity based on density only is estimated for the segment. Therefore same capacity value is used here to get the final as capacity determined by density for two sided segments.

$C\_IW := C\_IW(N\_WL)$ $C\_IW = 11607$ pc/h   C_IW is the capacity of the weaving segment under ideal conditions

$$Cw2 := C\_IW \cdot f\_HV \cdot fp$$

$Cw2 = 11458$ veh/h   Cw2 is the flow based capacity of weaving segment under prevailing conditions

C. Final Capacity of Weaving Segment

$$WeavingCapacity := if(Cw1 > Cw2, Cw2, Cw1)$$

$\boxed{WeavingCapacity = 8353}$ veh/h

D. Volume to Capacity (v/c) Ratio

$$VolumeToCapacity := \frac{TotalFlowRate \cdot f\_HV \cdot fp}{WeavingCapacity}$$

$\boxed{VolumeToCapacity = 0.5253}$

If v/c ratio >1 then LOS is F
Terminate

Step 5. Determine Configuration Characteristics

$$LC\_MIN(Config) := \left| \begin{array}{ll} out \leftarrow (LC\_RF \cdot v\_RF) + (LC\_FR \cdot v\_FR) & \text{if } Config = 1 \\ out \leftarrow (LC\_RR \cdot v\_RR) & \text{if } Config = 2 \end{array} \right.$$

$$LC\_MIN := LC\_MIN(Config)$$

$\boxed{LC\_MIN = 919}$ lc/h   Minimum Lane Changes

Step 6. Determine Lane-Changing Rates

A. Lane-Changing Rate for Weaving Vehicles

$$LC\_W(Ls) := \begin{array}{|l} out \leftarrow LC\_MIN + 0.39 \cdot \left[(Ls - 300)^{0.5} \cdot NumLanes^2 \cdot (1 + Int\_Density)^{0.8}\right] \quad \text{if} \quad Ls \geq 300 \\ out \leftarrow LC\_MIN \quad \text{if} \quad Ls < 300 \end{array}$$

$LaneChangingWeaving := LC\_W(Ls)$

$\boxed{LaneChangingWeaving = 1280}$ lc/h

B. Lane-Changing Rate for Non-Weaving Vehicles

$I\_NW := \dfrac{Ls \cdot Int\_Density \cdot NonWeavingFlowRate}{10000}$ $I\_NW = 468$ Non Weaving Vehicle Index

$LC\_NW1 := (0.206 \cdot NonWeavingFlowRate) + (0.542 \cdot Ls) - (192.6 \cdot NumLanes)$

$LC\_NW2 := 2135 + 0.233 \cdot (NonWeavingFlowRate - 2000)$

$LC\_NW3 := LC\_NW1 + (LC\_NW2 - LC\_NW1) \cdot \dfrac{(I\_NW - 1300)}{650}$

$$LC\_NW(I\_NW) := \begin{array}{|l} out \leftarrow LC\_NW1 \quad \text{if} \quad I\_NW < 1300 \\ out \leftarrow LC\_NW2 \quad \text{if} \quad I\_NW \geq 1950 \\ out \leftarrow LC\_NW3 \quad \text{if} \quad 1300 < I\_NW < 1950 \\ out \leftarrow LC\_NW2 \quad \text{if} \quad LC\_NW1 \geq LC\_NW2 \end{array}$$

$LaneChangingNonWeaving := LC\_NW(I\_NW)$

$\boxed{LaneChangingNonWeaving = 791}$ lc/h

C. Total Lane-Changing Rate

$TotalLaneChanging := LaneChangingWeaving + LaneChangingNonWeaving$

$\boxed{TotalLaneChanging = 2071}$ lc/h

Step 7. Determine Average Speed of Weaving and Non-Weaving Vehicles

A. Average Speed of Weaving Vehicles

$$WeavingIntensityFactor := 0.226 \left(\frac{TotalLaneChanging}{Ls}\right)^{0.789}$$

$WeavingIntensityFactor = 0.2855$

$$AverageWeavingSpeed := 15 + \left(\frac{FFS - 15}{1 + WeavingIntensityFactor}\right)$$

$\boxed{AverageWeavingSpeed = 53.9}$ mi/h

B. Average Speed of Non-Weaving Vehicles

$$AverageNonWeavingSpeed := FFS - (0.0072 \cdot LC\_MIN) - \left(0.0048 \cdot \frac{TotalFlowRate}{NumLanes}\right)$$

$\boxed{AverageNonWeavingSpeed = 53.05}$ mi/h

C. Average Speed of All Vehicles

$$AverageSpeed := \frac{WeavingFlowRate + NonWeavingFlowRate}{\left(\frac{WeavingFlowRate}{AverageWeavingSpeed}\right) + \left(\frac{NonWeavingFlowRate}{AverageNonWeavingSpeed}\right)}$$

$\boxed{AverageSpeed = 53.22}$ mi/h

Step 8. Determine the Level of Service

$$Density := \frac{\left(\frac{TotalFlowRate}{NumLanes}\right)}{AverageSpeed}$$

$\boxed{Density = 20.9}$ pc/mi/ln

$$LOS(Density) := \left| \begin{array}{lll} out \leftarrow \text{"A"} & \text{if} & 0 \le Density \le 10 \\ out \leftarrow \text{"B"} & \text{if} & 10 < Density \le 20 \\ out \leftarrow \text{"C"} & \text{if} & 20 < Density \le 28 \\ out \leftarrow \text{"D"} & \text{if} & 28 < Density \le 35 \\ out \leftarrow \text{"E"} & \text{if} & 35 < Density \\ out \leftarrow \text{"F"} & \text{if} & VolumeToCapacity > 1 \end{array} \right.$$

$\boxed{LOS(Density) = \text{"C"}}$

Step 9. Determine the Input Vol and %HV for the Next Downstream Segment

$$FwyVolNew := SegInputVol + (OnRampVol - v\_RR) - (OffRampVol - v\_RR) = 3681$$

$$\%Trucks_{FNew} := \frac{SegInputVol \cdot SegInput\%HV + (OnRampVol - v\_RR) \cdot OnRamp\%HV - (OffRampVol - v\_RR) \cdot OffRamp\%HV}{FwyVolNew}$$

$\%Trucks_{FNew} = 4.474$

**FwyVolNew and %Trucks$_{FNew}$ are the input values for FwyVol and %Trucks$_F$ for the next downstream segment if there is one. If the next segment is a weave, then %Trucks$_{FNew}$ is the input value for SegInput%HV and FwyVolNew is the input value for SegInputVol.*

Full Clover Basic (14d)

Input Values

**FwyVolNew and %Trucks$_{FNew}$ from the previous upstream segment are the input values for FwyVol and %Trucks$_F$ (if there is a previous upstream segment).*

Traffic

$\text{FwyVol} := 3681 \qquad \text{PHF} := 0.95$

$f_p := 1.0 \qquad \text{FFS} := 65$

$\%\text{Trucks}_F := 4.4742 \qquad P_R := 0$

$P_T := \dfrac{\%\text{Trucks}_F}{100} = 0.0447$

Roadway

$N := 3 \qquad \text{LaneWidth} := 12 \qquad \text{LatClear} := 6 \qquad \text{IntDens} := 0.861$

$\text{Terrain} := 1$ 1 = Level, 2 = Rolling, 3 = Mountainous

$\text{AreaType} := 2$ 1 = Rural, 2 = Urban

**FREEPLAN finds IntDens by counting parclos and diamond as 1 interchange each, full as 2, and on and off as 1/2 each and adds them. Then, it divides that total number of interchanges by the total length of the facility.*

Find f_{HV} (using Exhibit 23-8 and Eq. 23-3)

$$E_T(\text{Terrain}) := \left| \begin{array}{l} \text{out} \leftarrow 1.5 \ \text{ if Terrain} = 1 \\ \text{out} \leftarrow 2.5 \ \text{ if Terrain} = 2 \\ \text{out} \leftarrow 4.5 \ \text{ if Terrain} = 3 \\ \text{out} \end{array} \right. \qquad E_R(\text{Terrain}) := \left| \begin{array}{l} \text{out} \leftarrow 1.2 \ \text{ if Terrain} = 1 \\ \text{out} \leftarrow 2.0 \ \text{ if Terrain} = 2 \\ \text{out} \leftarrow 4.0 \ \text{ if Terrain} = 3 \\ \text{out} \end{array} \right.$$

$E_T(\text{Terrain}) = 1.5 \qquad E_T := E_T(\text{Terrain}) \qquad E_R(\text{Terrain}) = 1.2 \qquad E_R := E_R(\text{Terrain})$

$$f_{HV} := \frac{1}{1 + P_T \cdot (E_T - 1) + P_R \cdot (E_R - 1)} \qquad f_{HV} = 0.9781$$

Find v_p (using Eq. 23-2)

$$v_p := \frac{\text{FwyVol}}{\text{PHF} \cdot N \cdot f_{HV} \cdot f_p} \qquad v_p = 1320.5 \ \text{pc/h/ln}$$

Determine S

$S_1 := \text{FFS}$

$$S_2 := \text{FFS} - \left[\left(\text{FFS} - \frac{160}{3} \right) \cdot \left(\frac{v_p + 30 \cdot \text{FFS} - 3400}{30 \cdot \text{FFS} - 1000} \right)^{2.6} \right]$$

$$S_3 := \text{FFS} - \left[\frac{1}{9} \cdot (7 \cdot \text{FFS} - 340) \cdot \left(\frac{v_p + 30 \cdot \text{FFS} - 3400}{40 \cdot \text{FFS} - 1700} \right)^{2.6} \right]$$

$S_{cont2} := \text{if}\left[(55 \le \text{FFS} \le 75) \wedge \left[v_p \le (3400 - 30 \cdot \text{FFS}) \right], S_1, \text{"Cannot Compute"} \right]$

$S_{cont1} := \text{if}\left[(55 \le \text{FFS} \le 70) \wedge \left[(3400 - 30 \cdot \text{FFS}) < v_p \le (1700 + 10 \cdot \text{FFS}) \right], S_3, S_{cont2} \right]$

$S := \text{if}\left[(70 < \text{FFS} \le 75) \wedge \left[(3400 - 30 \cdot \text{FFS}) < v_p \le 2400 \right], S_2, S_{cont1} \right]$

$S = 65$ mi/h

Density (using Eq. 23-4)

$$D := \frac{v_p}{S} \qquad D = 20.3 \quad \text{pc/mi/ln}$$

Determine level of service (using Exhibit 23-2)

$$\mathrm{LOS}(D) := \left| \begin{array}{l} \text{out} \leftarrow \text{"F"} \;\; \text{if } D > 45 \\ \text{out} \leftarrow \text{"E"} \;\; \text{if } 45 \geq D > 35 \\ \text{out} \leftarrow \text{"D"} \;\; \text{if } 35 \geq D > 26 \\ \text{out} \leftarrow \text{"C"} \;\; \text{if } 26 \geq D > 18 \\ \text{out} \leftarrow \text{"B"} \;\; \text{if } 18 \geq D > 11 \\ \text{out} \leftarrow \text{"A"} \;\; \text{if } 11 \geq D \\ \text{out} \end{array} \right.$$

$\mathrm{LOS}(D) = \text{"C"}$

Determine Input Vol and %HV for Next Downstream Segment

$FwyVolNew := FwyVol = 3681$

$\%Trucks_{FNew} := \%Trucks_F = 4.4742$

**FwyVolNew and %Trucks$_{FNew}$ are the input values for FwyVol and %Trucks$_F$ for the next downstream segment if there is one. If the next segment is a weave, then %Trucks$_{FNew}$ is the input value for %Trucks_FF and %Trucks_FR.*

Full Clover on (14e)

Step 1. Data Inputs and Volume Adjusments

**FwyVolNew and %Truck$_{SFNew}$ from the previous upstream segment are the input values for FwyVol and %Truck$_{SF}$ (if there is a previous upstream segment).*

A. Inputs

$FwyVol := 3681$ veh/h $RampVol := 455$ veh/h

$\%Trucks_F := 4.4742$ $\%RV_F := 0$ $PHF := 0.95$ $f_p := 1$ $FFS := 65$ mi/h

$\%Trucks_R := 2$ $\%RV_R := 0$

$NumLanes := 3$ Number of mainline freeway lanes $NRamp := 1$ Number of lanes on ramp roadway

$Terrain := 1$ 1 = Level, 2 = Rolling, 3 = Mountainous

$L_A := 1000$ ft Total length of Acceleration Lane

$S_{FR} := 40$ mi/h Freeflow speed of the ramp at the junction point

$AdjUp := 2$ $AdjDn := 0$ 0 = none, 1 = on-ramp, 2 = off-ramp for Adjacent Upstream/Downstream Ramps

$L_{up} := 1140$ ft $L_{down} := 6000$ ft

$VolumeUp := 455$ veh/h Volume on adjacent upstream ramp

$VolumeDown := 455$ veh/h Volume on adjacent downstream ramp

B. Heavy Vehicle Adjustments

Passenger Car Equivalents

$$E_T(Terrain) := \left| \begin{array}{lll} out \leftarrow 1.5 & \text{if} & Terrain = 1 \\ out \leftarrow 2.5 & \text{if} & Terrain = 2 \\ out \leftarrow 4.5 & \text{if} & Terrain = 3 \end{array} \right. \qquad E_R(Terrain) := \left| \begin{array}{lll} out \leftarrow 1.2 & \text{if} & Terrain = 1 \\ out \leftarrow 2.0 & \text{if} & Terrain = 2 \\ out \leftarrow 4.0 & \text{if} & Terrain = 3 \end{array} \right.$$

$E_T(Terrain) = 1.5$ $E_R(Terrain) = 1.2$

$E_T := E_T(Terrain)$ $E_T = 1.5$ $E_R := E_R(Terrain)$ $E_R = 1.2$

$$f\_HV_F := \frac{100}{100 + \%Trucks_F(E_T - 1) + \%RV_F(E_R - 1)} = 0.978 \qquad f\_HV_F = 0.978$$

$$f\_HV_R := \frac{100}{100 + \%Trucks_R(E_T - 1) + \%RV_R(E_R - 1)} \qquad f\_HV_R = 0.99$$

C. Demand Flow Rate

$$V_f := \frac{FwyVol}{PHF \cdot f\_HV_F \cdot f_p} \qquad V_f = 3961 \text{ pc/h} \qquad V_r := \frac{RampVol}{PHF \cdot f\_HV_R \cdot f_p} \qquad V_r = 484 \text{ pc/h}$$

$$V_u := \frac{VolumeUp}{PHF \cdot f\_HV_R \cdot f_p} \qquad V_u = 484 \text{ pc/h} \qquad V_d := \frac{VolumeDown}{PHF \cdot f\_HV_R \cdot f_p} \qquad V_d = 484 \text{ pc/h}$$

Step 2. Determine the Approaching Flow Rate in Lanes 1 and 2

A. Equilibrium Seperation Distance for Adjacent Off-Ramp on a Six Lane Freeway

$$L_{EQup} := 0.214(V_f + V_r) + 0.444 \cdot L_A + 53.32 \cdot S_{FR} - 2403 \qquad L_{EQup} = 1125 \text{ ft}$$

$$L_{EQdown} := \frac{V_d}{0.1096 + 0.000107 \cdot L_A} \qquad L_{EQdown} = 2233 \quad \text{ft}$$

B. Estimating Proportion of Freeway Vehicles Remaining in lanes 1 and 2

$$Eqn1 := 0.5775 + 0.000028 \cdot L_A \qquad Eqn1 = 0.606$$

$$Eqn2 := 0.7289 - 0.0000135 \cdot (V_f + V_r) - 0.003296 \cdot S_{FR} + 0.000063 \cdot L_{up} \qquad Eqn2 = 0.609$$

$$Eqn3 := 0.5487 + 0.2628 \cdot \frac{V_d}{L_{down}} \qquad Eqn3 = 0.57$$

$$P_{FM}(NumLanes) := \left| \begin{array}{l}
out \leftarrow 1.00 \quad \text{if} \quad NumLanes = 2 \\
out \leftarrow Eqn1 \quad \text{if} \quad AdjUp \neq 2 \wedge AdjDn \neq 2 \wedge NumLanes = 3 \\
out \leftarrow Eqn3 \quad \text{if} \quad AdjUp = 0 \wedge AdjDn = 2 \wedge L_{down} < L_{EQdown} \wedge NumLanes = 3 \\
out \leftarrow Eqn1 \quad \text{if} \quad AdjUp = 0 \wedge AdjDn = 2 \wedge L_{down} \geq L_{EQdown} \wedge NumLanes = 3 \\
out \leftarrow Eqn2 \quad \text{if} \quad AdjUp = 2 \wedge AdjDn = 0 \wedge L_{up} < L_{EQup} \wedge NumLanes = 3 \\
out \leftarrow Eqn1 \quad \text{if} \quad AdjUp = 2 \wedge AdjDn = 0 \wedge L_{up} \geq L_{EQup} \wedge NumLanes = 3 \\
out \leftarrow Eqn1 \quad \text{if} \quad AdjUp = 1 \wedge AdjDn = 1 \wedge NumLanes = 3 \\
out \leftarrow Eqn3 \quad \text{if} \quad AdjUp = 1 \wedge AdjDn = 2 \wedge L_{down} < L_{EQdown} \wedge NumLanes = 3 \\
out \leftarrow Eqn1 \quad \text{if} \quad AdjUp = 1 \wedge AdjDn = 2 \wedge L_{down} \geq L_{EQdown} \wedge NumLanes = 3 \\
out \leftarrow Eqn2 \quad \text{if} \quad AdjUp = 2 \wedge AdjDn = 1 \wedge L_{up} < L_{EQup} \wedge NumLanes = 3 \\
out \leftarrow Eqn1 \quad \text{if} \quad AdjUp = 2 \wedge AdjDn = 1 \wedge L_{up} \geq L_{EQup} \wedge NumLanes = 3 \\
out \leftarrow \max(Eqn1, Eqn2) \quad \text{if} \quad AdjUp = 2 \wedge AdjDn = 2 \wedge L_{up} < L_{EQup} \wedge L_{down} \geq L_{EQdown} \wedge NumLanes = 3 \\
out \leftarrow \max(Eqn3, Eqn2) \quad \text{if} \quad AdjUp = 2 \wedge AdjDn = 2 \wedge L_{up} < L_{EQup} \wedge L_{down} < L_{EQdown} \wedge NumLanes = 3 \\
out \leftarrow Eqn1 \quad \text{if} \quad AdjUp = 2 \wedge AdjDn = 2 \wedge L_{up} \geq L_{EQup} \wedge L_{down} \geq L_{EQdown} \wedge NumLanes = 3 \\
out \leftarrow \max(Eqn1, Eqn3) \quad \text{if} \quad AdjUp = 2 \wedge AdjDn = 2 \wedge L_{up} \geq L_{EQup} \wedge L_{down} < L_{EQdown} \wedge NumLanes = 3 \\
out \leftarrow 0.2178 - 0.0000125 \cdot V_r + -0.0115 \cdot \frac{L_A}{S_{FR}} \quad \text{if} \quad \left(\frac{V_f}{S_{FR}} \leq 72\right) \wedge (NumLanes = 4) \\
out \leftarrow 0.2178 - 0.0000125 \cdot V_r \quad \text{if} \quad \left(\frac{V_f}{S_{FR}} > 72\right) \wedge (NumLanes = 4)
\end{array} \right.$$

$$P_{FM} := P_{FM}(NumLanes) \qquad P_{FM} = 0.606$$

C. Estimating Flow in Lanes 1 and 2

$$V_{12} := V_f \cdot P_{FM} \qquad V_{12} = 2399 \quad \text{pc/h}$$

D. Checking the Reasonableness of the Lane Distribution Prediction

Six Lane Freeways

$$V_3 := V_f - V_{12} \qquad V_3 = 1563 \quad \text{pc/h}$$

Eight Lane Freeways

$$V_{av34} := \frac{V_f - V_{12}}{2} \qquad V_{av34} = 781 \quad \text{pc/h}$$

$$\mathrm{V12a}(\mathrm{NumLanes}) := \left|\begin{array}{l}
\mathrm{out} \leftarrow V_{12} \quad \text{if} \quad \mathrm{NumLanes} = 2 \\
\mathrm{out} \leftarrow V_f - 2700 \quad \text{if} \quad V_3 > 2700 \wedge V_3 \le 1.5 \cdot \dfrac{V_{12}}{2} \vee \mathrm{NumLanes} = 3 \\
\mathrm{out} \leftarrow \dfrac{V_f}{1.75} \quad \text{if} \quad V_3 \le 2700 \wedge V_3 > 1.5 \cdot \dfrac{V_{12}}{2} \wedge \mathrm{NumLanes} = 3 \\
\mathrm{out} \leftarrow \max\left(V_f - 2700, \dfrac{V_f}{1.75}\right) \quad \text{if} \quad V_3 > 2700 \wedge V_3 > 1.5 \cdot \dfrac{V_{12}}{2} \wedge \mathrm{NumLanes} = 3 \\
\mathrm{out} \leftarrow V_{12} \quad \text{if} \quad V_3 \le 2700 \wedge V_3 \le 1.5 \cdot \dfrac{V_{12}}{2} \wedge \mathrm{NumLanes} = 3 \\
\mathrm{out} \leftarrow V_f - 5400 \quad \text{if} \quad V_{av34} > 2700 \wedge V_{av34} \le 1.5 \cdot \dfrac{V_{12}}{2} \wedge \mathrm{NumLanes} = 4 \\
\mathrm{out} \leftarrow \dfrac{V_f}{2.50} \quad \text{if} \quad V_{av34} \le 2700 \wedge V_{av34} > 1.5 \cdot \dfrac{V_{12}}{2} \wedge \mathrm{NumLanes} = 4 \\
\mathrm{out} \leftarrow \max\left(V_f - 5400, \dfrac{V_f}{2.50}\right) \quad \text{if} \quad V_{av34} > 2700 \wedge V_{av34} > 1.5 \cdot \dfrac{V_{12}}{2} \wedge \mathrm{NumLanes} = 4 \\
\mathrm{out} \leftarrow V_{12} \quad \text{if} \quad V_{av34} \le 2700 \wedge V_{av34} \le 1.5 \cdot \dfrac{V_{12}}{2} \wedge \mathrm{NumLanes} = 4
\end{array}\right.$$

C. Final Flow in Lanes 1 and 2

$V_{12} := \mathrm{V12a}(\mathrm{NumLanes})$ $\qquad V_{12} = 2399$ pc/h

Step 3. Determine Capacity of Ramp-Freeway Junction

$V_{R12} := V_{12} + V_r$ $\qquad V_{R12} = 2882$ pc/h $\qquad$ Flow entering the ramp influence area

$$\mathrm{CapUpFreewaySegment}(\mathrm{NumLanes}, \mathrm{FFS}) := \left|\begin{array}{l}
\mathrm{out} \leftarrow 4800 \quad \text{if} \quad \mathrm{FFS} \ge 70 \wedge \mathrm{NumLanes} = 2 \\
\mathrm{out} \leftarrow 4700 \quad \text{if} \quad \mathrm{FFS} = 65 \wedge \mathrm{NumLanes} = 2 \\
\mathrm{out} \leftarrow 4600 \quad \text{if} \quad \mathrm{FFS} = 60 \wedge \mathrm{NumLanes} = 2 \\
\mathrm{out} \leftarrow 4600 \quad \text{if} \quad \mathrm{FFS} = 55 \wedge \mathrm{NumLanes} = 2 \\
\mathrm{out} \leftarrow 7200 \quad \text{if} \quad \mathrm{FFS} = 70 \wedge \mathrm{NumLanes} = 3 \\
\mathrm{out} \leftarrow 7050 \quad \text{if} \quad \mathrm{FFS} = 65 \wedge \mathrm{NumLanes} = 3 \\
\mathrm{out} \leftarrow 6900 \quad \text{if} \quad \mathrm{FFS} = 60 \wedge \mathrm{NumLanes} = 3 \\
\mathrm{out} \leftarrow 6750 \quad \text{if} \quad \mathrm{FFS} = 55 \wedge \mathrm{NumLanes} = 3 \\
\mathrm{out} \leftarrow 9600 \quad \text{if} \quad \mathrm{FFS} = 70 \wedge \mathrm{NumLanes} = 4 \\
\mathrm{out} \leftarrow 9400 \quad \text{if} \quad \mathrm{FFS} = 65 \wedge \mathrm{NumLanes} = 4 \\
\mathrm{out} \leftarrow 9200 \quad \text{if} \quad \mathrm{FFS} = 60 \wedge \mathrm{NumLanes} = 4 \\
\mathrm{out} \leftarrow 9000 \quad \text{if} \quad \mathrm{FFS} = 55 \wedge \mathrm{NumLanes} = 4 \\
\mathrm{out} \leftarrow 2400 \cdot \mathrm{NumLanes} \quad \text{if} \quad \mathrm{FFS} = 70 \wedge \mathrm{NumLanes} > 4 \\
\mathrm{out} \leftarrow 2350 \cdot \mathrm{NumLanes} \quad \text{if} \quad \mathrm{FFS} = 65 \wedge \mathrm{NumLanes} > 4 \\
\mathrm{out} \leftarrow 2300 \cdot \mathrm{NumLanes} \quad \text{if} \quad \mathrm{FFS} = 60 \wedge \mathrm{NumLanes} > 4 \\
\mathrm{out} \leftarrow 2250 \cdot \mathrm{NumLanes} \quad \text{if} \quad \mathrm{FFS} = 55 \wedge \mathrm{NumLanes} > 4
\end{array}\right.$$

$\text{CapUpFreewaySegment}(\text{NumLanes}, \text{FFS}) = 7050$ Capacity of Ramp Freeway Junction

$\text{MaxV12} = 4600$ Maximum Desirable Flow Rate Entering Merge Influence Area

$$\text{CapacityRampRoadway} := \left| \begin{array}{l} \text{out} \leftarrow 2200 \quad \text{if} \quad (\text{NRamp} = 1) \wedge (S_{FR} > 50) \\ \text{out} \leftarrow 2100 \quad \text{if} \quad (\text{NRamp} = 1) \wedge (40 < S_{FR} \le 50) \\ \text{out} \leftarrow 2000 \quad \text{if} \quad (\text{NRamp} = 1) \wedge (30 < S_{FR} \le 40) \\ \text{out} \leftarrow 1900 \quad \text{if} \quad (\text{NRamp} = 1) \wedge (20 \le S_{FR} \le 30) \\ \text{out} \leftarrow 1800 \quad \text{if} \quad (\text{NRamp} = 1) \wedge (20 > S_{FR}) \\ \text{out} \leftarrow 4400 \quad \text{if} \quad (\text{NRamp} = 2) \wedge (S_{FR} > 50) \\ \text{out} \leftarrow 4200 \quad \text{if} \quad (\text{NRamp} = 2) \wedge (40 < S_{FR} \le 50) \\ \text{out} \leftarrow 4000 \quad \text{if} \quad (\text{NRamp} = 2) \wedge (30 < S_{FR} \le 40) \\ \text{out} \leftarrow 3800 \quad \text{if} \quad (\text{NRamp} = 2) \wedge (20 \le S_{FR} \le 30) \\ \text{out} \leftarrow 3600 \quad \text{if} \quad (\text{NRamp} = 2) \wedge (20 > S_{FR}) \end{array} \right.$$

$\text{CapacityRampRoadway} = 2000$

$V_{FO} := V_f + V_r$ $\quad V_{FO} = 4445$ pc/h Volume immediatley downstream of on-ramp influence area

Ramp Freeway Junction Checkpoint

Volume immediatley downstream of on-ramp influence area is chekced against freeway capacity. Failure of ramp freeway junction checkpoint (i.e. demand exceeds capacity) results in LOS F

Ramp Roadway Capacity Checkpoint

Capacity or ramp roadway should always be checked against the demand flow rate on the ramp. It is rarely a problem for the on-ramp

Maximum Desirable Flow Entering Ramp Influence Area Checkpoint

While the V_{R12} values is checked against the maximum desirable, failure does not result in assignment of LOS F. Failing this checkpoint generally means that there will be more turbulance in influence area than predicted by this methodology. Thus, predicted densities are most likely lower than those that will exist, and predicted speeds are most likely to be predicted as higher than those that will actually occur.

Step 4. Determine Speeds in the Vicinity of Ramp-Freeway Junction

A. Average Speed in the Ramp Influence Area

$$S_R := FFS - (FFS - 42)\cdot\left[0.321 + 0.0039\exp\left(\frac{V_{R12}}{1000}\right) - 0.002\cdot\left(L_A\frac{S_{FR}}{1000}\right)\right] \qquad S_R = 57.86 \quad \text{mi/h}$$

B. Average Speed in the Outer Lanes of Freeway

Average Flow in Outer Lanes

$$No := \begin{cases} out \leftarrow 1 & \text{if } NumLanes = 3 \\ out \leftarrow 2 & \text{if } NumLanes = 4 \\ out \leftarrow \infty & \text{if } NumLanes = 2 \end{cases} \qquad V_{OA} := \frac{V_f - V_{12}}{No} \qquad V_{OA} = 1563$$

$$S_O(V_{OA}) := \begin{cases} out \leftarrow FFS & \text{if } V_{OA} < 500 \\ out \leftarrow FFS - 0.0036\cdot(V_{OA} - 500) & \text{if } 500 \le V_{OA} \le 2300 \\ out \leftarrow FFS - 6.53 - 0.006\cdot(V_{OA} - 2300) & \text{if } V_{OA} > 2300 \end{cases}$$

$$S_O := S_O(V_{OA}) \qquad S_O = 61.17 \quad \text{mi/h}$$

C. Average Speed for On-Ramp Junction

$$Speed := \frac{V_{R12} + V_{OA}\cdot No}{\left(\frac{V_{R12}}{S_R}\right) + \left(\frac{V_{OA}\cdot No}{S_O}\right)} \qquad Speed = 58.98 \quad \text{mi/h}$$

Step 5. Determine the Density and Level of Service

A. Density in On-Ramp Influence Area

$$Density_R := 5.475 + 0.00734\cdot V_r + 0.0078\cdot V_{12} - 0.00627\cdot L_A \qquad Density_R = 21.5 \quad \text{pc/mi/ln}$$

B. Density in Outer Lanes

$$Density_O := \frac{V_{OA}}{S_O} \qquad Density_O = 25.5 \quad \text{pc/mi/ln}$$

C. Density of Entire Cross-Section

$$Density := \begin{cases} out \leftarrow Density_R & \text{if } NumLanes \le 2 \\ out \leftarrow \frac{\left[Density_R\cdot(2) + Density_O\cdot(NumLanes - 2)\right]}{NumLanes} & \text{if } NumLanes > 2 \end{cases} \qquad Density = 22.8 \quad \text{pc/mi/ln}$$

D. Level of Service

$$LOS(Density) := \begin{cases} out \leftarrow \text{"A"} & \text{if } 0 \le Density \le 10 \\ out \leftarrow \text{"B"} & \text{if } 10 < Density \le 20 \\ out \leftarrow \text{"C"} & \text{if } 20 < Density \le 28 \\ out \leftarrow \text{"D"} & \text{if } 28 < Density \le 35 \\ out \leftarrow \text{"E"} & \text{if } 35 < Density \end{cases} \qquad LOS(Density) = \text{"C"}$$

Step 6. Determine Input Vol and %HV for Next Downstream Segment

$$FwyVol_{Cars} := FwyVol \cdot \left(1 - \frac{\%Trucks_F}{100}\right) = 3516.3$$

$$RampVol_{Cars} := RampVol \cdot \left(1 - \frac{\%Trucks_R}{100}\right) = 445.9$$

$$FwyVol_{CarsNew} := FwyVol_{Cars} + RampVol_{Cars} = 3962.2$$

$$FwyVol_{Trucks} := FwyVol \cdot \frac{\%Trucks_F}{100} = 164.695$$

$$RampVol_{Trucks} := RampVol \cdot \left(\frac{\%Trucks_R}{100}\right) = 9.1$$

$$FwyVol_{TrucksNew} := FwyVol_{Trucks} + RampVol_{Trucks} = 173.795$$

$$FwyVolNew := FwyVol_{CarsNew} + FwyVol_{TrucksNew} = 4136$$

$$\%Trucks_{FNew} := \frac{FwyVol_{TrucksNew}}{FwyVolNew} \cdot 100 = 4.2020$$

**FwyVolNew and %Trucks$_{FNew}$ are the input values for FwyVol and %Trucks$_F$ for the next downstream segment if there is one. If the next segment is a weave, then %Trucks$_{FNew}$ is the input value for %Trucks_FF and %Trucks_FR.*