Ramps and Ramps Junctions Worksheet

General Information

Analyst: Analyst
Agency or Company: Agency or Company
Date Performed: Date Performed
Analyst Time Period: Analyst Time Period

Site Information

Freeway/Direction of Travel: Freeway/Direction of Travel
Junction: Junction
Jurisdiction: Jurisdiction
Analysis Year: Analysis Year

☑ Operational (LOS) ☐ Design (LA, LD or N) ☐ Planning (LOS) ☐ Planning (LA, LD or N)

Definition of new units

In this case, the units of meters (m) are used to define new units, but any other could be used.

$$veh := \frac{m}{m}$$

$$pc := \frac{m}{m}$$

$$ln := \frac{m}{m}$$

Inputs

Upstream Adjacent Ramp

○ Yes ○ On
◉ No ○ Off

$L_{up} := 0ft$

$V_U := 0\frac{veh}{hr}$

Terrain: Level

Number of lanes on freeway segment (one direction): $N_F := 2$

Number of lanes on ramp: $N_R := 1$

Acceleration lane length (outer): $L_{Ao} := 0ft$

Acceleration lane length (inner)*: $L_{Ai} := 750ft$

Deceleration lane length (outer): $L_{Do} := 0ft$

Deceleration lane length (inner)*: $L_{Di} := 0ft$

Side of ramp: ◉ Right-hand ○ Left-hand

Area Type: ◉ Merge Areas ○ Diverge Areas

$S_{FF} := 60mph$ $S_{FR} := 45mph$

Downstream Adjacent Ramp

○ Yes ○ On
◉ No ○ Off

$L_{down} := 0ft$

$V_D := 0\frac{veh}{hr}$

* For single-lane ramps, enter the length of the acceleration or deceleration lane on the "inner" option.

Conversion to pc/h Under Base Conditions

(pc/h)	AADT (veh/day)	K	D	V (veh/h)	PHF	%HV	f_p
v_F	0	0	0	2500	0.9	10	1
v_R	0	0	0	550	0.9	5	1
v_U	0	0	0	0	0	0	0
v_D	0	0	0	0	0	0	0

Variables used in this section and not defined in HCM

Data: input table of the Conversion to pc/h Under Base Conditions section
Terrain: defines de type of terrain, 1 for Level, 2 for Rolling and 3 for Mountainous

Renaming parameters

$AADT := Data^{\langle 0 \rangle}$

$K := Data^{\langle 1 \rangle}$

$D := Data^{\langle 2 \rangle}$

$Vol := Data^{\langle 3 \rangle}$

$PHF := Data^{\langle 4 \rangle}$

$P_T := Data^{\langle 5 \rangle}$

$f_p := Data^{\langle 6 \rangle}$

Passenger-Car equivalents on extended freeway segments (*see Exhibit 23-8*)

Create a vector of ET values, using the first row of Exhibit 23-8

$$E_T := \begin{pmatrix} 1.5 \\ 2.5 \\ 4.5 \end{pmatrix}$$

Heavy-vehicle adjustment factor (*see Equation 23-3*)

The term of Equation 23-3 related to P_R and E_R is not used in the computation because the %RVs is not entered in the input table.
The equation is computed only if a volume is defined for the given case $(Vol_i \neq 0)$.

$$f_{HV} := \left| \begin{array}{l} f_3 \leftarrow 0 \\ \text{for } i \in 0..3 \\ \quad f_i \leftarrow \dfrac{1}{1 + \dfrac{P_{T_i}}{100} \cdot \left(E_{T_{Terrain-1}} - 1\right)} \text{ if } Vol_i \neq 0 \\ f \end{array} \right.$$

Volume

If AADT is not entered $(Data_{i,0} = 0)$, the volume used in the computations is the one entered in the fourth column of the input table. Otherwise the volume is computed as AADT*K*D)

$$V := \left| \begin{array}{l} \text{for } i \in 0..3 \\ \quad \left| \begin{array}{l} V_i \leftarrow Vol_i \text{ if } AADT_i = 0 \\ V_i \leftarrow AADT_i \cdot K_i \cdot D_i \text{ otherwise} \end{array} \right. \\ V \end{array} \right.$$

Flow rate under base conditions during peak 15 min of hour (*see Equation 25-1*)

The flow rates values are rounded to the nearest integer.

$i := 0..\,3$

$$v_i := \text{round}\left(\frac{V_i}{PHF_i \cdot f_{HV_i} \cdot f_{p_i}}\right)$$

Results table

$\text{Results} := \text{augment}(f_{HV}, v)$

(pc/h)	f_{HV}	v (pc/h)
v_F	0.952	2917
v_R	0.976	626
v_U	0	0
v_D	0	0

Results =

Note: f_{HV} and v cannot be displayed in the same table along with the rest of the parameters (as in the HCM worksheet), because f_{HV} and v depend on those parameters.

Variables used in this section and not defined in HCM

Area: defines type of area, 1 for Merge Areas and 2 for Diverge Areas
Case: defines the equation for P_{FM} for six-lane freeways
Downstream: defines whether a downstream adjacent ramp exists or not, 1 if yes and 2 if no
L_{Ao}: outer acceleration lane length
L_{Ai}: inner acceleration lane length
N_F: number of lanes on freeway segment in one direction
N_R: number of lanes on ramp
OnOffDownstream: 1 if the downstream adjacent ramp is On or 2 if it is Off
OnOffUpstream: 1 if the upstream adjacent ramp is On or 2 if it is Off
Side: defines the side of ramp, 1 if its is right-hand or 2 if left-hand
Upstream: defines whether a upstream adjacent ramp exists or not, 1 if yes and 2 if no

Flow rates

The values of the flow rates vector computed above, are used to create 4 new variables. This is done to facilitate the readability of the following equations.

$v_F := v_0$

$v_R := v_1$

$v_U := v_2$

$v_D := v_3$

MERGE AREAS

Estimation of v_{12}

Selecting equations for P_{FM} for six-lane freeways (*see Exhibit 25-6*)

A case number is assigned to each of the rows of Exhibit 25-6. The first row is Case 1 and the last row is Case 9. The case number is used to select the equation to compute P_{FM}.

$$
\text{Case} := \begin{cases}
1 & \text{if } \text{Upstream} = 2 \wedge \text{Downstream} = 2 \\
2 & \text{if } \text{Upstream} = 2 \wedge (\text{Downstream} = 1 \wedge \text{OnOffDownstream} = 1) \\
3 & \text{if } \text{Upstream} = 2 \wedge (\text{Downstream} = 1 \wedge \text{OnOffDownstream} = 2) \\
4 & \text{if } (\text{Upstream} = 1 \wedge \text{OnOffUpstream} = 1) \wedge \text{Downstream} = 2 \\
5 & \text{if } (\text{Upstream} = 1 \wedge \text{OnOffUpstream} = 2) \wedge \text{Downstream} = 2 \\
6 & \text{if } (\text{Upstream} = 1 \wedge \text{OnOffUpstream} = 1) \wedge (\text{Downstream} = 1 \wedge \text{OnOffDownstream} = 1) \\
7 & \text{if } (\text{Upstream} = 1 \wedge \text{OnOffUpstream} = 1) \wedge (\text{Downstream} = 1 \wedge \text{OnOffDownstream} = 2) \\
8 & \text{if } (\text{Upstream} = 1 \wedge \text{OnOffUpstream} = 2) \wedge (\text{Downstream} = 1 \wedge \text{OnOffDownstream} = 1) \\
9 & \text{if } (\text{Upstream} = 1 \wedge \text{OnOffUpstream} = 2) \wedge (\text{Downstream} = 1 \wedge \text{OnOffDownstream} = 2)
\end{cases}
$$

Effective length of the acceleration lane (*see Equation 25-6*)

If the ramp has 2 lanes ($N_R = 2$), the L_{Aeff} is computed with the Equation 25-6, otherwise L_{Aeff} is the inner acceleration lane length (L_{Ai}).

L_{A2} of Equation 25-6 is computed as $L_{Ai} - L_{Ao}$. The units are removed from the final values of L_{Aeff}

$$
L_A := \begin{cases}
\dfrac{2 \cdot L_{Ao} + \left(L_{Ai} - L_{Ao}\right)}{1\text{ft}} & \text{if } N_R = 2 \\
\dfrac{L_{Ai}}{1\text{ft}} & \text{otherwise}
\end{cases}
$$

Equilibrium distance (*see Equations 25-2 and 25-3*)

Remove units of S_{FR}

$$S_{FR} := \frac{S_{FR}}{1\text{mph}}$$

This L_{EQm} is computed only for Merge Areas ($\text{Area} = 1$) and if the number of lanes on freeway segment in one direction is 3 ($N_F = 3$) (see Exhibit 25-5). For any other case L_{EQm} is 0.

If the equations to consider are Equations 2 and 1 (see Exhibit 25-5 and 25-6), $\text{Case} = 5 \vee \text{Case} = 8$, L_{EQm} is computed using the Equation 25-2.

If the equations to consider are Equations 3 and 1 (see Exhibit 25-5 and 25-6), $\text{Case} = 3 \vee \text{Case} = 7$, L_{EQm} is computed using the Equation 25-3.

The final values of L_{EQm} are rounded to the nearest integer.

$$L_{EQm} := \begin{cases} \text{if } Area = 1 \\ \quad \begin{cases} \text{if } N_F = 3 \\ \quad \begin{cases} \text{round}\left[0.214\cdot(v_F + v_R) + 0.444\cdot L_A + 52.32\cdot S_{FR} - 2403\right] & \text{if } Case = 5 \lor Case = 8 \\ \text{round}\left(\dfrac{v_D}{0.1096 + 0.000107\cdot L_A}\right) & \text{if } Case = 3 \lor Case = 7 \\ 0 & \text{otherwise} \end{cases} \\ 0 \quad \text{otherwise} \end{cases} \\ 0 \quad \text{otherwise} \end{cases}$$

Proportion of approaching freeway flow remaining in Lanes 1 and 2 immediately upstream of merge (*see Exhibit 25-5 and Page 25-9 for Special Case*)

Remove units of L_{up} and L_{down}

$$L_{up} := \frac{L_{up}}{1ft}$$

$$L_{down} := \frac{L_{down}}{1ft}$$

This following procedure returns the value P_{FM} and the number of equation used to compute it. This procedure is computed only for Merge Areas ($Area = 1$).
If the number of lanes on ramp is 1 ($N_R = 1$), the Exhibit 25-5 is used to compute P_{FM}. If the number of lanes in ramp is 2 ($N_R = 2$), the procedure for special case, presented on Page 25-9, is used.

```
PFM_Equation := | if Area = 1
                |   if N_R = 1
                |     if N_F = 2
                |       P_FM ← 1
                |       Equation ← 0
                |     if N_F = 3
                |       if Case = 1 ∨ Case = 2 ∨ Case = 4 ∨ Case = 6
                |         P_FM ← 0.5775 + 0.000028·L_A
                |         Equation ← 1
                |       if Case = 5 ∨ Case = 8
                |         if L_up ≥ L_EQm
                |           P_FM ← 0.5775 + 0.000028·L_A
                |           Equation ← 1
                |         if L_up < L_EQm
                |           P_FM ← 0.7289 − 0.0000135·(v_F + v_R) − 0.003296 + 0.000063·L_up
                |           Equation ← 2
                |       if Case = 3 ∨ Case = 7
                |         if L_down ≥ L_EQm
```

$$\text{down} \quad \text{EQm}$$

$$P_{FM} \leftarrow 0.5775 + 0.000028 \cdot L_A$$

$$\text{Equation} \leftarrow 1$$

$$\text{if } L_{down} < L_{EQm}$$

$$P_{FM} \leftarrow 0.5487 + 0.2628 \cdot \frac{v_D}{L_{down}}$$

$$\text{Equation} \leftarrow 3$$

$$\text{if Case} = 9$$

$$P_{FM1} \leftarrow 0.5775 + 0.000028 \cdot L_A$$

$$P_{FM2} \leftarrow 0.7289 - 0.0000135 \cdot (v_F + v_R) - 0.003296 + 0.000063 \cdot L_{up}$$

$$P_{FM3} \leftarrow 0.5487 + 0.2628 \cdot \frac{v_D}{L_{down}}$$

$$P_{FM} \leftarrow \max(P_{FM1}, P_{FM2}, P_{FM3})$$

$$\text{Equation} \leftarrow 1 \text{ if } P_{FM} = P_{FM1}$$

$$\text{Equation} \leftarrow 2 \text{ if } P_{FM} = P_{FM2}$$

$$\text{Equation} \leftarrow 3 \text{ if } P_{FM} = P_{FM3}$$

$$\text{if } N_F \geq 4$$

$$P_{FM} \leftarrow 0.2178 - 0.000125 \cdot v_R + 0.01115 \cdot \frac{L_A}{S_{FR}}$$

$$\text{Equation} \leftarrow 4$$

$$\text{if } N_R = 2$$

$$P_{FM} \leftarrow 1.000 \text{ if } N_F = 2$$

$$P_{FM} \leftarrow 0.555 \text{ if } N_F = 3$$

$$P_{FM} \leftarrow 0.209 \text{ if } N_F = 4$$

$$\text{Equation} \leftarrow \text{"SC"}$$

$$\text{otherwise}$$

$$P_{FM} \leftarrow 0$$

$$\text{Equation} \leftarrow 0$$

$$\begin{pmatrix} P_{FM} \\ \text{Equation} \end{pmatrix}$$

Extract the value of P_{FM} from the procedure computed above

$$P_{FM} := \text{PFM\_Equation}_0$$

Extract the number of equation used to compute P_{FM} in the procedure computed above. The subscript *m* is used to refer to Merge Areas.

$$\text{Equation}_m := \text{PFM\_Equation}_1$$

Specials cases: On-ramps on ten-lane freeways (five lanes in one direction) (*see Exhibit 25-11 and Equation 25-7*)

This procedure is computed only for Merge Areas ($Area = 1$) and if the number of lanes on the freeway segment is 5 ($N_F = 5$) and the number of lanes on the ramp is 1 ($N_R = 1$). Otherwise the values of v_F and N_F are not modified.

The approaching freeway flow in lane 5 (v_5) is computed using the Exhibit 25-11 and then the effective approaching freeway flow in four-lane freeway segment (v_{F4eff}) is computed with the Equation 25-7. The number of lanes on the freeway segment is changed to 4 ($N \leftarrow 4$).

$$SC_1 := \begin{array}{|l} \text{if } Area = 1 \\ \quad \begin{array}{|l} \text{if } N_F = 5 \wedge N_R = 1 \\ \quad \begin{array}{|l} N \leftarrow 4 \\ v_5 \leftarrow 2500 \ \text{ if } v_F \geq 8500 \\ v_5 \leftarrow 0.285 v_F \ \text{ if } 7500 \leq v_F < 8500 \\ v_5 \leftarrow 0.270 v_F \ \text{ if } 6500 \leq v_F < 7500 \\ v_5 \leftarrow 0.240 v_F \ \text{ if } 5500 \leq v_F < 6500 \\ v_5 \leftarrow 0.220 v_F \ \text{ if } v_F < 5500 \\ v_{F4eff} \leftarrow v_F - v_5 \\ \begin{pmatrix} v_{F4eff} \\ N \end{pmatrix} \end{array} \\ \begin{pmatrix} v_F \\ N_F \end{pmatrix} \ \text{otherwise} \end{array} \\ \begin{pmatrix} v_F \\ N_F \end{pmatrix} \ \text{otherwise} \end{array}$$

Extract the value of v_F from the procedure computed above

$$v_F := {SC_1}_0$$

Extract the number of lanes on the freeway segment from the procedure computed above.

$$N_F := {SC_1}_1$$

Flow rate in lanes 1 and 2 of freeway immediately upstream of merge (*see Exhibit 25-5*)

This equation is computed only for Merge Areas ($Area = 1$)

$$v_{12} := \begin{array}{|l} v_F \cdot P_{FM} \ \text{ if } Area = 1 \\ 0 \ \text{ otherwise} \end{array}$$

Units are added to v_{12}. The subscript *m* is used to refer to Merge Areas.

$$v_{12m} := v_{12} \cdot \frac{pc}{hr}$$

Special cases: Left-hand on-ramps (*see Page 25-11*)

This procedure is computed only for Merge Areas $(Area = 1)$ and if the ramp is on left-hand side $(Side = 2)$. The v_{12} is modified depending on the number of lanes on the freeway segment.

$$SC_2 := \begin{cases} \text{if } Area = 1 & \begin{cases} v_{12} \text{ if } Side = 1 \\ \text{if } Side = 2 & \begin{cases} v_{12} \text{ if } N_F = 2 \\ 1.12 \cdot v_{12} \text{ if } N_F = 3 \\ 1.20 \cdot v_{12} \text{ if } N_F = 4 \end{cases} \end{cases} \\ v_{12} \text{ otherwise} \end{cases}$$

Extract the value of v_F from the procedure computed above

$$v_{12} := SC_2$$

If the number of lanes on the freeway segment is 3 $(N_F = 3)$, v_{23} takes the value of v_{12} from the procedure for special case computed above. Units are added to the final value, even if it is 0. The subscript *m* is used to refer to Merge Areas.

$$v_{23m} := \begin{cases} \text{if } Area = 1 \wedge Side = 2 & \begin{cases} SC_2 \cdot \frac{pc}{hr} \text{ if } N_F = 3 \\ 0 \frac{pc}{hr} \text{ otherwise} \end{cases} \\ 0 \frac{pc}{hr} \text{ otherwise} \end{cases}$$

If the number of lanes on the freeway segment is 4 $(N_F = 4)$, v_{34} takes the value of v_{12} from the procedure for special case computed above. Units are added to the final value, even if it is 0. The subscript *m* is used to refer to Merge Areas.

$$v_{34m} := \begin{cases} \text{if } Area = 1 \wedge Side = 2 & \begin{cases} SC_2 \cdot \frac{pc}{hr} \text{ if } N_F = 4 \\ 0 \cdot \frac{pc}{hr} \text{ otherwise} \end{cases} \\ 0 \cdot \frac{pc}{hr} \text{ otherwise} \end{cases}$$

Capacity checks

Maximum downstream freeway flow (*see Exhibit 25-7*)

A matrix is created with the values of maximum downstream freeway flow given in Exhibit 25-7.

$$MaxV := \begin{pmatrix} 4800 & 7200 & 9600 & 2400 \\ 4700 & 7050 & 9400 & 2350 \\ 4600 & 6900 & 9200 & 2300 \\ 4500 & 6750 & 9000 & 2250 \end{pmatrix}$$

Total downstream freeway flow (*see Page 25-7*)

This equation is computed only for Merge Areas ($Area = 1$)

$$v_{FOm} := \begin{vmatrix} v_F + v_R & \text{if } Area = 1 \\ 0 & \text{otherwise} \end{vmatrix}$$

Total flow entering the ramp influence area (*see Equation 25-4*)

This equation is computed only for Merge Areas ($Area = 1$)

$$v_{R12} := \begin{vmatrix} v_{12} + v_R & \text{if } Area = 1 \\ 0 & \text{otherwise} \end{vmatrix}$$

Maximum v_{FO} (*see Exhibit 25-7*)

Remove the units of S_{FF}

$$S_{FF} := \frac{S_{FF}}{1mph}$$

This procedure is computed only for Merge Areas ($Area = 1$). The maximum downstream freeway flow is taken from Exhibit 25-7 ($MaxV$), based on the freeway free-flow speed (S_{FF}) and the number of lanes in one direction (N_F).

The expression $\frac{|S_{FF} - 70|}{5}$ defines which row of the exhibit must be used. The expression gives values of 0, 1, 2 and 3 for values of S_{FF} of 70, 65, 60 and 55, respectively.

If N_F is greater than 4, the value in the fourth column of the exhibit is multiplied by N_F to get the maximum v_{FO}.
If S_{FF} is greater than 70, the first row of the exhibit is used.

$$Max_{VFO} := \begin{vmatrix} \text{if } Area = 1 \\ \quad \begin{vmatrix} \text{if } N_F \le 4 \\ \quad \begin{vmatrix} MaxV_{\frac{|S_{FF}-70|}{5}, N_F-2} & \text{if } S_{FF} \le 70 \\ MaxV_{0, N_F-2} & \text{otherwise} \end{vmatrix} \end{vmatrix} \end{vmatrix}$$

$$\begin{array}{l} \text{otherwise} \\ \quad \begin{array}{ll} MaxV_{\frac{|S_{FF}-70|}{5},3} \cdot N_F & \text{if } S_{FF} \le 70 \\ MaxV_{0,3} \cdot N_F & \text{otherwise} \end{array} \\ 0 \quad \text{otherwise} \end{array}$$

LOS F?

Check whether the LOS is F or not.

If the actual value of v_{FO} is greater than the maximum, a LOS of F is assigned

$$LOS_{VFO} := \begin{array}{|l} \text{if } Area = 1 \\ \quad \begin{array}{|ll} \text{"Yes"} & \text{if } v_{FOm} > Max_{VFO} \\ \text{"No"} & \text{otherwise} \end{array} \\ 0 \quad \text{otherwise} \end{array}$$

LOS of F is assigned to v_{R12} only if v_{FO} exceeds its maximum (LOS F). Otherwise the LOS is determined using the density (see below) (see Page 25-8).

$$LOS_{VR12} := \begin{array}{|l} \text{if } Area = 1 \\ \quad \begin{array}{|ll} \text{"Yes"} & \text{if } LOS_{VFO} = \text{"Yes"} \\ \text{"No"} & \text{otherwise} \end{array} \\ 0 \quad \text{otherwise} \end{array}$$

Results table

The limit of v_{R12} is always 4600, but it is only displayed for Merged Areas $(\text{if}(Area = 1, 4600, 0))$.

$$CapacityChecks_m := \begin{pmatrix} v_{FOm} & Max_{VFO} & LOS_{VFO} \\ v_{R12} & \text{if}(Area = 1, 4600, 0) & LOS_{VR12} \end{pmatrix}$$

Level of service determination

Density of merge influence area (*see Equation 25-5*)

This equation is computed only for Merge Areas $(Area = 1)$ and if the LOS of v_{FO} is different than F. Otherwise the density is 0. The final value of the density is rounded to one decimal place.

$$D_R := \begin{array}{|l} \text{if } Area = 1 \\ \quad \begin{array}{|ll} \text{round}\left(5.475 + 0.00734v_R + 0.0078 \cdot v_{12} - 0.00627L_A, 1\right) & \text{if } LOS_{VFO} \ne \text{"Yes"} \\ 0 & \text{otherwise} \end{array} \\ 0 \quad \text{otherwise} \end{array}$$

Function to evaluate LOS for merge and diverge areas (*see Exhibit 25-4*)

$$LOS(x) := \begin{cases} \text{"A"} & \text{if } x \le 10 \\ \text{"B"} & \text{if } 10 < x \le 20 \\ \text{"C"} & \text{if } 20 < x \le 28 \\ \text{"D"} & \text{if } 28 < x \le 35 \\ \text{"E"} & \text{if } x > 35 \end{cases}$$

Level of service (*see Exhibit 25-4*)

Determine LOS only if v_{FO} does not exceed its limit ($LOS_{VFO} \ne \text{"Yes"}$), otherwise the LOS is F.

$$LOS_m := \begin{cases} \text{if } Area = 1 \\ \quad \begin{cases} LOS(D_R) & \text{if } LOS_{VFO} \ne \text{"Yes"} \\ \text{"F"} & \text{otherwise} \end{cases} \\ 0 \quad \text{otherwise} \end{cases}$$

Output D_R

Add units to the density value.

$$D_{Rm} := D_R \cdot \frac{pc}{mi \cdot ln}$$

Speed estimation

Intermediate speed determination variable for merge area (*see Exhibit 25-19*)

This equation is computed only for Merge Areas ($Area = 1$)

$$M_S := \begin{cases} 0.321 + 0.0039 \cdot e^{\frac{v_{R12}}{1000}} - 0.002 \cdot \frac{L_A \cdot S_{FR}}{1000} & \text{if } Area = 1 \\ 0 & \text{otherwise} \end{cases}$$

Space mean speed of vehicles within ramp influence area (*see Exhibit 25-19*)

This equation is computed only for Merge Areas ($Area = 1$)

$$S_R := \begin{cases} S_{FF} - (S_{FF} - 42) \cdot M_S & \text{if } Area = 1 \\ 0 & \text{otherwise} \end{cases}$$

Average per-lane flow rate in outer lanes (*see Equation 25-13*)

Compute the number of outside lanes in one direction (not including acceleration or deceleration lanes or Lanes 1 and 2)

$$N_O := \begin{cases} N_F - 2 & \text{if } N_F > 2 \\ 0 & \text{otherwise} \end{cases}$$

Compute V_{OA} if N_O is greater than 0.

$$v_{OA} := \begin{cases} \dfrac{v_F - v_{12}}{N_O} & \text{if } N_O > 0 \\ 0 & \text{otherwise} \end{cases}$$

Space mean speed of vehicles traveling in outer lanes (*see Exhibit 25-19*)

Compute S_O only for Merge Areas $(Area = 1)$ and if N_O is greater than 0. Otherwise S_O is 0.

$$S_O := \begin{cases} \text{if } Area = 1 \\ \quad \begin{cases} \text{if } N_O > 0 \\ \quad \begin{cases} S_{FF} & \text{if } v_{OA} < 500 \\ S_{FF} - 0.0036 \cdot (v_{OA} - 500) & \text{if } 500 \le v_{OA} \le 2300 \\ S_{FF} - 6.53 - 0.006 \cdot (v_{OA} - 2300) & \text{if } v_{OA} > 2300 \end{cases} \\ 0 \quad \text{otherwise} \end{cases} \\ 0 \quad \text{otherwise} \end{cases}$$

Space mean speed for all vehicles (*see Equation 25-14*)

This equation is computed only for Merge Areas $(Area = 1)$

$$S := \begin{cases} \dfrac{v_{R12} + v_{OA} \cdot N_O}{\dfrac{v_{R12}}{S_R} + \dfrac{v_{OA} \cdot N_O}{S_O}} & \text{if } Area = 1 \\ 0 & \text{otherwise} \end{cases}$$

Output values

The speed values are rounded to one decimal place and units are added to the final values.

$$S_{Rm} := \text{round}(S_R, 1) \cdot mph$$

$$S_{Om} := \text{round}(S_O, 1) \cdot mph$$

$$S_m := \text{round}(S, 1) \cdot mph$$

DIVERGE AREAS

Estimation of v_{12}

Selecting equations for P_{FD} for six-lane freeways (*see Exhibit 25-13*)

A case number is assigned to each of the rows of Exhibit 25-13. The first row is Case 1 and the last row is Case 9. The case number is used to select the equation to compute P_{FD}.

$$
\text{Case} := \begin{cases}
1 & \text{if } \text{Upstream} = 2 \wedge \text{Downstream} = 2 \\
2 & \text{if } \text{Upstream} = 2 \wedge (\text{Downstream} = 1 \wedge \text{OnOffDownstream} = 1) \\
3 & \text{if } \text{Upstream} = 2 \wedge (\text{Downstream} = 1 \wedge \text{OnOffDownstream} = 2) \\
4 & \text{if } (\text{Upstream} = 1 \wedge \text{OnOffUpstream} = 1) \wedge \text{Downstream} = 2 \\
5 & \text{if } (\text{Upstream} = 1 \wedge \text{OnOffUpstream} = 2) \wedge \text{Downstream} = 2 \\
6 & \text{if } (\text{Upstream} = 1 \wedge \text{OnOffUpstream} = 1) \wedge (\text{Downstream} = 1 \wedge \text{OnOffDownstream} = 1) \\
7 & \text{if } (\text{Upstream} = 1 \wedge \text{OnOffUpstream} = 1) \wedge (\text{Downstream} = 1 \wedge \text{OnOffDownstream} = 2) \\
8 & \text{if } (\text{Upstream} = 1 \wedge \text{OnOffUpstream} = 2) \wedge (\text{Downstream} = 1 \wedge \text{OnOffDownstream} = 1) \\
9 & \text{if } (\text{Upstream} = 1 \wedge \text{OnOffUpstream} = 2) \wedge (\text{Downstream} = 1 \wedge \text{OnOffDownstream} = 2)
\end{cases}
$$

Equilibrium distance (*see Equations 25-8 and 25-9*)

This L_{EQd} is computed only for Diverge Areas ($\text{Area} = 2$) and if the number of lanes on freeway segment in one direction is 3 ($N_F = 3$) (see Exhibit 25-12). For any other case L_{EQd} is 0. The subscript *d* is used to refer to Diverge Areas.
If the equations to consider are Equations 6 and 5 (see Exhibit 25-12 and 25-13), $\text{Case} = 4 \vee \text{Case} = 6$, L_{EQm} is computed using the Equation 25-8.
If the equations to consider are Equations 7 and 5 (see Exhibit 25-12 and 25-13), $\text{Case} = 3 \vee \text{Case} = 9$, L_{EQm} is computed using the Equation 25-9.
The final values of L_{EQm} are rounded to the nearest integer.

$$
L_{EQd} := \begin{cases}
\text{if } \text{Area} = 2 \\
\quad \begin{cases}
\text{if } N_F = 3 \\
\quad \begin{cases}
\text{round}\left(\dfrac{v_U}{0.071 + 0.000023 v_F - 0.000076 v_R}\right) & \text{if } \text{Case} = 4 \vee \text{Case} = 6 \\
\text{round}\left(\dfrac{v_D}{1.15 - 0.000032 v_F - 0.000369 v_R}\right) & \text{if } \text{Case} = 3 \vee \text{Case} = 9 \\
0 & \text{otherwise}
\end{cases} \\
0 \quad \text{otherwise}
\end{cases} \\
0 \quad \text{otherwise}
\end{cases}
$$

Proportion of through freeway flow remaining in Lanes 1 and 2 immediately upstream of diverge (*see Exhibit 25-12 and Page 25-15 for Special Case*)

This following procedure returns the value P_{FD} and the number of equation used to compute it. This procedure is computed only for Diverge Areas ($\text{Area} = 2$).
If the number of lanes on ramp is 1 ($N_R = 1$), the Exhibit 25-12 is used to compute P_{FM}. If the number of lanes in ramp is 2 ($N_R = 2$), the procedure for special case, presented on Page 25-15, is used.

$$
\text{PFD\_Equation} := \begin{cases}
\text{if } \text{Area} = 2 \\
\quad \begin{cases}
\text{if } N_R = 1 \\
\quad \begin{cases}
\text{if } N_F = 2 \\
\quad \begin{cases}
P_{FD} \leftarrow 1 \\
\text{Equation} \leftarrow 0
\end{cases}
\end{cases}
\end{cases}
\end{cases}
$$

$Equation \leftarrow 0$

if $N_F = 3$

if $Case = 1 \vee Case = 2 \vee Case = 5 \vee Case = 8$

$P_{FD} \leftarrow 0.760 - 0.000025 \cdot v_F - 0.000046 \cdot v_R$

$Equation \leftarrow 5$

if $Case = 4 \vee Case = 6$

if $L_{up} \geq L_{EQd}$

$P_{FD} \leftarrow 0.760 - 0.000025 \cdot v_F - 0.000046 \cdot v_R$

$Equation \leftarrow 5$

if $L_{up} < L_{EQd}$

$$P_{FD} \leftarrow 0.717 - 0.000039 \cdot v_F + 0.604 \cdot \frac{v_U}{L_{up}}$$

$Equation \leftarrow 6$

if $Case = 3 \vee Case = 9$

if $L_{down} \geq L_{EQd}$

$P_{FD} \leftarrow 0.760 - 0.000025 \cdot v_F - 0.000046 \cdot v_R$

$Equation \leftarrow 5$

if $L_{down} < L_{EQd}$

$$P_{FD} \leftarrow 0.616 - 0.000021 \cdot v_F + 0.1248 \cdot \frac{v_D}{L_{down}}$$

$Equation \leftarrow 7$

if $Case = 7$

$P_{FD1} \leftarrow 0.760 - 0.000025 \cdot v_F - 0.000046 \cdot v_R$

$$P_{FD2} \leftarrow 0.717 - 0.000039 \cdot v_F + 0.604 \cdot \frac{v_U}{L_{up}}$$

$$P_{FD3} \leftarrow 0.616 - 0.000021 \cdot v_F + 0.1248 \cdot \frac{v_D}{L_{down}}$$

$P_{FD} \leftarrow \max(P_{FD1}, P_{FD2}, P_{FD3})$

$Equation \leftarrow 5$ if $P_{FD} = P_{FD1}$

$Equation \leftarrow 6$ if $P_{FD} = P_{FD2}$

$Equation \leftarrow 7$ if $P_{FD} = P_{FD3}$

if $N_F \geq 4$

$P_{FD} \leftarrow 0.436$

$Equation \leftarrow 8$

if $N_R = 2$

$P_{FM} \leftarrow 1.000$ if $N_F = 2$

$P_{FM} \leftarrow 0.450$ if $N_F = 3$

$P_{FM} \leftarrow 0.260 \text{ if } N_F = 4$
Equation ← "SC"

otherwise

$P_{FD} \leftarrow 0$
Equation ← 0

$\begin{pmatrix} P_{FD} \\ \text{Equation} \end{pmatrix}$

Extract the value of P_{FD} from the procedure computed above

$P_{FD} := \text{PFD\_Equation}_0$

Extract the number of equation used to compute P_{FD} in the procedure computed above. The subscript *d* is used to refer to Diverge Areas.

$\text{Equation}_d := \text{PFD\_Equation}_1$

Specials cases: Off-ramps on ten-lane freeways (five lanes in one direction) (*see Exhibit 25-18 and Equation 25-7*)

This procedure is computed only for Diverge Areas ($\text{Area} = 2$) and if the number of lanes on the freeway segment is 5 ($N_F = 5$) and the number of lanes on the ramp is 1 ($N_R = 1$). Otherwise the values of v_F and N_F are not modified.

The approaching freeway flow in lane 5 (v_5) is computed using the Exhibit 25-18 and then the effective approaching freeway flow in four-lane freeway segment (v_{F4eff}) is computed with the Equation 25-7. The number of lanes on the freeway segment is changed to 4 ($N \leftarrow 4$).

$SC_1 :=$ if $\text{Area} = 2$

if $N_F = 5 \wedge N_R = 1$

$N \leftarrow 4$

$v_5 \leftarrow 0.2 v_F \text{ if } v_F \geq 7000$

$v_5 \leftarrow 0.15 v_F \text{ if } 5500 \leq v_F < 7000$

$v_5 \leftarrow 0.10 v_F \text{ if } 4000 \leq v_F < 5500$

$v_5 \leftarrow 0 \text{ if } v_F < 4000$

$v_{F4eff} \leftarrow v_F - v_5$

$\begin{pmatrix} v_{F4eff} \\ N \end{pmatrix}$

$\begin{pmatrix} v_F \\ N_F \end{pmatrix}$ otherwise

$\begin{pmatrix} v_F \\ N_F \end{pmatrix}$ otherwise

Extract the value of v_F from the procedure computed above

$$v_F := SC1_0$$

Extract the number of lanes on the freeway segment from the procedure computed above.

$$N_F := SC1_1$$

Flow rate in lanes 1 and 2 of freeway immediately upstream of diverge (*see Exhibit 25-12*)

This equation is computed only for Diverge Areas $(Area = 2)$

$$v_{12} := \begin{cases} v_R + (v_F - v_R) \cdot P_{FD} & \text{if } Area = 2 \\ 0 & \text{otherwise} \end{cases}$$

Units are added to v_{12}. The subscript *d* is used to refer to Diverge Areas.

$$v_{12d} := v_{12} \cdot \frac{pc}{hr}$$

Special cases: Left-hand off-ramps (*see Page 25-17*)

This procedure is computed only for Diverge Areas $(Area = 2)$ and if the ramp is on left-hand side $(Side = 2)$. The v_{12} is modified depending on the number of lanes on the freeway segment.

$$SC_2 := \begin{cases} \text{if } Area = 2 & \begin{cases} v_{12} & \text{if } Side = 1 \\ \text{if } Side = 2 & \begin{cases} v_{12} & \text{if } N_F = 2 \\ 1.05 \cdot v_{12} & \text{if } N_F = 3 \\ 1.10 \cdot v_{12} & \text{if } N_F = 4 \end{cases} \end{cases} \\ v_{12} & \text{otherwise} \end{cases}$$

Extract the value of v_F from the procedure computed above

$$v_{12} := SC_2$$

If the number of lanes on the freeway segment is 3 $(N_F = 3)$, v_{23} takes the value of v_{12} from the procedure for special case computed above. Units are added to the final value, even if it is 0. The subscript *d* is used to refer to Diverge Areas.

$$v_{23d} := \begin{cases} \text{if } Area = 2 \land Side = 2 & \begin{cases} SC_2 \cdot \frac{pc}{hr} & \text{if } N_F = 3 \\ 0 \frac{pc}{hr} & \text{otherwise} \end{cases} \\ 0 \frac{pc}{hr} & \text{otherwise} \end{cases}$$

If the number of lanes on the freeway segment is 4 ($N_F = 4$), v_{34} takes the value of v_{12} from the procedure for special case computed above. Units are added to the final value, even if it is 0. The subscript *d* is used to refer to Diverge Areas.

$$v_{34d} := \begin{cases} \begin{cases} SC_2 \cdot \frac{pc}{hr} & \text{if } N_F = 4 \\ 0 \cdot \frac{pc}{hr} & \text{otherwise} \end{cases} & \text{if } Area = 2 \wedge Side = 2 \\ 0 \cdot \frac{pc}{hr} & \text{otherwise} \end{cases}$$

Capacity checks

Capacity of ramp roadways (*see Exhibit 25-3*)

A matrix is created with the values of the approximate capacity of ramp roadways given in Exhibit 25-3. The first column correspond to single-lane ramps and the second column to two-lane ramps

$$MaxVR := \begin{pmatrix} 2200 & 4400 \\ 2100 & 4100 \\ 2000 & 3800 \\ 1900 & 3500 \\ 1800 & 3200 \end{pmatrix}$$

Maximum upstream or downstream freeway flow (*see Exhibit 25-14*)

A matrix is created with the values of maximum upstream or downstream freeway flow given in Exhibit 25-14.

$$MaxV := \begin{pmatrix} 4800 & 7200 & 9600 & 2400 \\ 4700 & 7050 & 9400 & 2350 \\ 4600 & 6900 & 9200 & 2300 \\ 4500 & 6750 & 9000 & 2250 \end{pmatrix}$$

Maximum upstream freeway flow (*see HCM Worksheet*)

$$v_{FI} := \begin{cases} v_F & \text{if } Area = 2 \\ 0 & \text{otherwise} \end{cases}$$

Total downstream freeway flow (*see HCM Worksheet*)

$$v_{FOd} := \begin{cases} v_F - v_R & \text{if } Area = 2 \\ 0 & \text{otherwise} \end{cases}$$

Maximum v_{FI} and v_{FO} (*see Exhibit 25-14*)

This procedure is computed only for Diverge Areas ($Area = 2$). The maximum upstream or downstream freeway flow is taken from Exhibit 25-14 ($MaxV$), based on the freeway free-flow speed (S_{FF}) and the number of lanes in one direction (N_F).

The expression $\frac{|S_{FF} - 70|}{5}$ defines which row of the exhibit must be used. The expression gives values of 0, 1, 2 and 3 for values of S_{FF} of 70, 65, 60 and 55, respectively.

If N_F is greater than 4, the value in the fourth column of the exhibit is multiplied by N_F to get the maximum v_{FO}.

If S_{FF} is greater than 70, the first row of the exhibit is used.

$$Max_{VFOI} := \begin{cases} \begin{cases} \begin{cases} MaxV_{\frac{|S_{FF}-70|}{5}, N_F-2} & \text{if } S_{FF} \le 70 \\ MaxV_{0, N_F-2} & \text{otherwise} \end{cases} & \text{if } N_F \le 4 \\ \begin{cases} MaxV_{\frac{|S_{FF}-70|}{5}, 3} \cdot N_F & \text{if } S_{FF} \le 70 \\ MaxV_{0,3} \cdot N_F & \text{otherwise} \end{cases} & \text{otherwise} \end{cases} & \text{if } Area = 2 \\ 0 & \text{otherwise} \end{cases}$$

Maximum v_R (*see Exhibit 25-3*)

The free-flow speed of ramp (S_{FR}) defines which row of Exhibit 25-3 must be used and the number of lanes on ramp (N_R) defines the column.

$$Max_{VR} := \begin{cases} \begin{array}{l} j \leftarrow 0 \text{ if } S_{FR} \ge 50 \\ j \leftarrow 1 \text{ if } 40 \le S_{FR} < 50 \\ j \leftarrow 2 \text{ if } 30 \le S_{FR} < 40 \\ j \leftarrow 3 \text{ if } 20 \le S_{FR} < 30 \\ j \leftarrow 4 \text{ if } S_{FR} < 20 \\ MaxVR_{j, N_R-1} \end{array} & \text{if } Area = 2 \\ 0 & \text{otherwise} \end{cases}$$

LOS F?

Check whether the LOS is F or not.

If the actual value of v_{FI} is greater than the maximum, a LOS of F is assigned

$$LOS_{VFI} := \begin{cases} \text{if } Area = 2 \\ \quad \begin{cases} \text{"Yes"} & \text{if } v_{FI} > Max_{VFOI} \\ \text{"No"} & \text{otherwise} \end{cases} \\ 0 \quad \text{otherwise} \end{cases}$$

If the actual value of v_{12} is greater than the maximum (4400), a LOS of F is assigned

$$LOS_{V12} := \begin{cases} \text{if } Area = 2 \\ \quad \begin{cases} \text{"Yes"} & \text{if } v_{12} > 4400 \\ \text{"No"} & \text{otherwise} \end{cases} \\ 0 \quad \text{otherwise} \end{cases}$$

If the actual value of v_{FO} is greater than the maximum, a LOS of F is assigned

$$LOS_{VFO} := \begin{cases} \text{if } Area = 2 \\ \quad \begin{cases} \text{"Yes"} & \text{if } v_{FOd} > Max_{VFOI} \\ \text{"No"} & \text{otherwise} \end{cases} \\ 0 \quad \text{otherwise} \end{cases}$$

If the actual value of v_R is greater than the maximum, a LOS of F is assigned

$$LOS_{VR} := \begin{cases} \text{if } Area = 2 \\ \quad \begin{cases} \text{"Yes"} & \text{if } v_R > Max_{VR} \\ \text{"No"} & \text{otherwise} \end{cases} \\ 0 \quad \text{otherwise} \end{cases}$$

Results table

The limit of v_{12} is always 4400, but it is only displayed for Diverge Areas ($\text{if}(Area = 2, 4400, 0)$).
v_R is only displayed for Diverge Areas ($\text{if}(Area = 2, v_R, 0)$).

$$CapacityChecks_d := \begin{pmatrix} v_{FI} & Max_{VFOI} & LOS_{VFI} \\ v_{12} & \text{if}(Area = 2, 4400, 0) & LOS_{V12} \\ v_{FOd} & Max_{VFOI} & LOS_{VFO} \\ \text{if}(Area = 2, v_R, 0) & Max_{VR} & LOS_{VR} \end{pmatrix}$$

Level of service determination

Effective length of the deceleration lane (*see Equation 25-11*)

If the ramp has 2 lanes ($N_R = 2$), the L_{Deff} is computed with the Equation 25-11, otherwise L_{Deff} is the inner deceleration lane length (L_{Di}).

L_{D2} of Equation 25-11 is computed as $L_{Di} - L_{Do}$. The units are removed from the final values of L_{Aeff}

$$L_D := \begin{cases} \dfrac{2 \cdot L_{Do} + \left(L_{Di} - L_{Do}\right)}{1ft} & \text{if } N_R = 2 \\ \dfrac{L_{Di}}{1ft} & \text{otherwise} \end{cases}$$

Density of merge influence area (*see Equation 25-10*)

This equation is computed only for Diverge Areas ($Area = 2$) and if all of the capacity checks performed above give a LOS different than F. Otherwise the density is 0. The final value of the density is rounded to one decimal place.

$$D_R := \begin{cases} \text{if } Area = 2 \\ \quad \begin{cases} \text{round}\left(4.252 + 0.0086 \cdot v_{12} - 0.009 L_D, 1\right) & \text{if } LOS_{VFI} \neq \text{"Yes"} \wedge LOS_{VFO} \neq \text{"Yes"} \wedge LOS_{VR} \neq \text{"Yes"} \\ 0 & \text{otherwise} \end{cases} \\ 0 \quad \text{otherwise} \end{cases}$$

Level of service (*see Exhibit 25-4*)

Determine LOS only if all of the capacity checks performed above give a LOS different than F, otherwise the LOS is F. The LOS is evaluated using the function defined in the Merge Areas section (see above).

$$LOS_d := \begin{cases} \text{if } Area = 2 \\ \quad \begin{cases} LOS\left(D_R\right) & \text{if } LOS_{VFI} \neq \text{"Yes"} \wedge LOS_{VFO} \neq \text{"Yes"} \wedge LOS_{VR} \neq \text{"Yes"} \\ \text{"F"} & \text{otherwise} \end{cases} \\ 0 \quad \text{otherwise} \end{cases}$$

Output D_R

Add units to the density value.

$$D_{Rd} := D_R \cdot \frac{pc}{mi \cdot ln}$$

Speed estimation

Intermediate speed determination variable for diverge area (*see Exhibit 25-19*)

This equation is computed only for Diverge Areas ($Area = 2$)

$$D_S := \begin{cases} 0.883 + 0.00009 \cdot v_R - 0.013 S_{FR} & \text{if } Area = 2 \\ 0 & \text{otherwise} \end{cases}$$

Space mean speed of vehicles within ramp influence area (*see Exhibit 25-19*)

This equation is computed only for Diverge Areas $(\text{Area} = 2)$

$$S_R := \begin{cases} S_{FF} - (S_{FF} - 42) \cdot D_S & \text{if Area} = 2 \\ 0 & \text{otherwise} \end{cases}$$

Average per-lane flow rate in outer lanes (*see Equation 25-13*)

Compute the number of outside lanes in one direction (not including acceleration or deceleration lanes or Lanes 1 and 2)

$$N_O := \begin{cases} N_F - 2 & \text{if } N_F > 2 \\ 0 & \text{otherwise} \end{cases}$$

Compute V_{OA} if N_O is greater than 0.

$$v_{OA} := \begin{cases} \dfrac{v_F - v_{12}}{N_O} & \text{if } N_O > 0 \\ 0 & \text{otherwise} \end{cases}$$

Space mean speed of vehicles traveling in outer lanes (*see Exhibit 25-19*)

Compute S_O only for Diverge Areas $(\text{Area} = 2)$ and if N_O is greater than 0. Otherwise S_O is 0.

$$S_O := \begin{cases} \text{if Area} = 2 \\ \quad \begin{cases} \text{if } N_O > 0 \\ \quad \begin{cases} 1.097 S_{FF} & \text{if } v_{OA} < 1000 \\ 1.097 S_{FF} - 0.0039 \cdot (v_{OA} - 1000) & \text{if } v_{OA} \ge 1000 \end{cases} \\ 0 \quad \text{otherwise} \end{cases} \\ 0 \quad \text{otherwise} \end{cases}$$

Space mean speed for all vehicles (*see Equation 25-15*)

This equation is computed only for Diverge Areas $(\text{Area} = 2)$

$$S := \begin{cases} \dfrac{v_{12} + v_{OA} \cdot N_O}{\dfrac{v_{12}}{S_R} + \dfrac{v_{OA} \cdot N_O}{S_O}} & \text{if Area} = 2 \\ 0 & \text{otherwise} \end{cases}$$

Output values

The speed values are rounded to one decimal place and units are added to the final values.

$$S_{Rd} := \text{round}(S_R, 1) \cdot \text{mph}$$

$$S_{Od} := \text{round}(S_O, 1) \cdot \text{mph}$$

$$S_d := \text{round}(S, 1) \cdot \text{mph}$$

Merge Areas

Estimation of v_{12}

$$v_{12} = v_F \cdot P_{FM}$$

$L_{EQm} = 0$ (Equation 25-2 or 25-3)

$P_{FM} = 1$ using $Equation_m = 0$ (Exhibit 25-5)

$v_{12m} = 2917 \frac{pc}{hr}$

$v_{23m} = 0 \frac{pc}{hr}$

$v_{34m} = 0 \frac{pc}{hr}$

Diverge Areas

Estimation of v_{12}

$$v_{12} = v_R + (v_F - v_R) \cdot P_{FD}$$

$L_{EQd} = 0$ (Equation 25-8 or 25-9)

$P_{FD} = 0$ using $Equation_d = 0$ (Exhibit 25-12)

$v_{12d} = 0 \frac{pc}{hr}$

$v_{23d} = 0 \frac{pc}{hr}$

$v_{34d} = 0 \frac{pc}{hr}$

Note: the display of v_{23} and v_{34} is additional to the HCM worksheet

Capacity Checks (Merge)

	Actual	Maximum	LOS F?
V_{FO}	3543	4600	"No"
V_{R12}	3543	4600	"No"

$CapacityChecks_m =$

Capacity Checks (Diverge)

	Actual	Maximum	LOS F?
V_{FI}	0	0	0
V_{12}	0	0	0
V_{FO}	0	0	0
V_{R12}	0	0	0

$CapacityChecks_d =$

Level-of-Service Determination (if not F) (Merge)

$$D_R = 5.475 + 0.00734 v_R + 0.0078 v_{12} - 0.00627 L_A$$

$D_{Rm} = 28.1 \frac{pc}{mi \cdot ln}$

$LOS_m = "D"$ (Exhibit 25-4)

Level-of-Service Determination (if not F) (Diverge)

$$D_R = 4.252 + 0.0086 v_{12} - 0.009 L_D$$

$D_{Rd} = 0 \frac{pc}{mi \cdot ln}$

$LOS_d = 0$ (Exhibit 25-4)

Speed Estimation (Merge)

$M_S = 0.388$ (Exhibit 25-19)

$S_{Rm} = 53 mph$ (Exhibit 25-19)

$S_{Om} = 0 mph$ (Exhibit 25-19)

$S_m = 53 mph$ (Exhibit 25-14)

Speed Estimation (Diverge)

$D_S = 0$ (Exhibit 25-19)

$S_{Rd} = 0 mph$ (Exhibit 25-19)

$S_{Od} = 0 mph$ (Exhibit 25-19)

$S_d = 0 mph$ (Exhibit 25-15)