Appendix H: HCS Reports

Traffic Analysis Process		Existing Baseline						Future Baseline						Near-Term Improvement Screening					
Direction	Ramp Junctions / Weaving Segments	2009 Base Conditions						2035 No Improvements *						Ridge Road Improvements (2009)					
		AM			PM			AM			PM			AM			PM		
		Density (pc/mi/ln)	LOS	Speed (mph)	Density (pc/mi/ln)	LOS	Speed (mph)	Density (pc/mi/ln)	LOS	Speed (mph)	Density (pc/mi/ln)	LOS	Speed (mph)	Density (pc/mi/ln)	LOS	Speed (mph)	Density (pc/mi/ln)	LOS	Speed (mph)
EB I-440	I-440 EB off-ramp to Ridge Rd	21.5	C	--	25.8	C	--	35.3	E	--	49.3	F	--	21.5	C	--	25.8	C	--
	I-440 EB on-ramp from CVA extension	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	I-440 EB on-ramp from Glenwood WB	13.5	B		15.2	B		26.5	C	--	29.9	F	--	14.9	B	--	14.9	B	--
	I-440 EB weaving Ridge Rd on to Glenwood off	22.5	C	46.17	32.6	D	38.94	49.0	F	37.01	69.0	F	32.16	--	--	--	--	--	--
	I-440 EB weaving Glenwood EB on to Glenwood off	--	--	--	--	--	--	--	--	--	--	--	--	26.9	C	49.8	35.1	E	46.28
WB I-440	I-440 WB off-ramp to Glenwood EB	--	--	--	--	--	--	--	--	--	--	--	--	27.5	C	--	19.3	B	--
	I-440 WB off-ramp to Glenwood WB	16.3	B	--	14.1	A	--	28.5 *	D *	--	24.6 *	C *	--	16.3	B	--	14.1	B	--
	I-440 WB off-ramp to Glenwood / CVA	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	I-440 WB on-ramp from CVA extension	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	I-440 WB on-ramp from Glenwood EB	32.6	D	--	27.1	C	--	64.7	F	--	46.6	F	--	33.0	D	--	27.5	C	--
	I-440 WB weaving Glenwood WB on to Glenwood EB off	31.4	D	47.09	20.4	C	50.37	68.4	F	37.79	43.3	F	41.44	--	--	--	--	--	--

Traffic Analysis Process		Long-Term Improvement Alternative Screening																					
Direction	Ramp Junctions / Weaving Segments	2035 Creedmoor Rd Interchange (without U-Turns on Glenwood Ave)						2035 Lead Mine Flyover						2035 Crabtree Valley Ave (CVA) Extensions						2035 CVA Extension to I-440 (with an at-grade intersection at CVA and Blue Ridge Rd)					
		AM			PM			AM			PM			AM			PM			AM			PM		
		Density (pc/mi/ln)	LOS	Speed (mph)	Density (pc/mi/ln)	LOS	Speed (mph)	Density (pc/mi/ln)	LOS	Speed (mph)	Density (pc/mi/ln)	LOS	Speed (mph)	Density (pc/mi/ln)	LOS	Speed (mph)	Density (pc/mi/ln)	LOS	Speed (mph)	Density (pc/mi/ln)	LOS	Speed (mph)	Density (pc/mi/ln)	LOS	Speed (mph)
EB I-440	I-440 EB off-ramp to Ridge Rd	35.3	E	--	49.3	F	--	35.3	E	--	49.3	F	--	24.6	C	--	38.7	F	--	24.6	C	--	38.7	F	--
	I-440 EB on-ramp from CVA extension	--	--	--	--	--	--	--	--	--	--	--	--	23.2	C	--	29.5	D	--	26.2	C	--	31.5	D	--
	I-440 EB on-ramp from Glenwood WB	26.5	C	--	29.9	F	--	26.5	C	--	29.9	F	--	28.9	D	--	32.4	F	--	28.9	D	--	32.3	F	--
	I-440 EB weaving Ridge Rd on to Glenwood off	49.0	F	37.01	69.0	F	32.16	49.0	F	37.01	69.0	F	32.16	--	--	--	--	--	--	--	--	--	--	--	--
	I-440 EB weaving Glenwood EB on to Glenwood off	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
WB I-440	I-440 WB off-ramp to Glenwood EB	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	I-440 WB off-ramp to Glenwood WB	28.5 *	D *	--	24.6 *	C *	--	28.5 *	D *	--	24.6 *	C *	--	--	--	--	--	--	--	--	--	--	--	--	--
	I-440 WB off-ramp to Glenwood / CVA	--	--	--	--	--	--	--	--	--	--	--	--	28.5 *	D *	--	24.6 *	C *	--	28.5 *	D *	--	24.6 *	C *	--
	I-440 WB on-ramp from CVA extension	--	--	--	--	--	--	--	--	--	--	--	--	38.3	F	--	33.9	D	--	37.3	F	--	31.2	D	--
	I-440 WB on-ramp from Glenwood EB	64.7	F	--	46.6	F	--	64.7	F	--	46.6	F	--	--	--	--	--	--	--	35.0	F	--	28.0	C	--
	I-440 WB weaving Glenwood WB on to Glenwood EB off	68.4	F	37.79	43.3	F	41.44	68.4	F	37.79	43.3	F	41.44	--	--	--	--	--	--	30.8	C	34.87	28.8	C	35.73

Traffic Analysis Process		Long-Term Improvement Phase I						Long-Term Improvement Phase II												Long-Term Improvement Phase III					
								Not Recommended						Recommended											
Direction	Ramp Junctions / Weaving Segments	2035 CVA Extension to I-440 (with a grade separation at CVA and Blue Ridge Rd)						2035 CVA Extension to I-440 and Creedmoor Rd SPUI						2035 CVA Extension to I-440 and WB Glenwood Ave Overpass						2035 CVA Extension to I-440, WB Glenwood Ave Overpass, and Creedmoor Rd SPUI					
		AM			PM			AM			PM			AM			PM			AM			PM		
		Density (pc/mi/ln)	LOS	Speed (mph)	Density (pc/mi/ln)	LOS	Speed (mph)	Density (pc/mi/ln)	LOS	Speed (mph)	Density (pc/mi/ln)	LOS	Speed (mph)	Density (pc/mi/ln)	LOS	Speed (mph)	Density (pc/mi/ln)	LOS	Speed (mph)	Density (pc/mi/ln)	LOS	Speed (mph)	Density (pc/mi/ln)	LOS	Speed (mph)
EB I-440	I-440 EB off-ramp to Ridge Rd	24.6	C	--	38.7	F	--	24.6	C	--	38.7	F	--	24.6	C	--	38.7	F	--	24.6	C	--	38.7	F	--
	I-440 EB on-ramp from CVA extension	26.2	C	--	31.5	D	--	26.2	C	--	31.5	D	--	26.2	C	--	31.5	D	--	26.2	C	--	31.5	D	--
	I-440 EB on-ramp from Glenwood WB	28.9	D	--	32.3	F	--	28.9	D	--	32.3	F	--	28.9	D	--	32.3	F	--	28.9	D	--	32.3	F	--
	I-440 EB weaving Ridge Rd on to Glenwood off	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	I-440 EB weaving Glenwood EB on to Glenwood off	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
WB I-440	I-440 WB off-ramp to Glenwood EB	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	I-440 WB off-ramp to Glenwood WB	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	I-440 WB off-ramp to Glenwood / CVA	28.5 *	D *	--	24.6 *	C *	--	28.5 *	D *	--	24.6 *	C *	--	28.5 *	D *	--	24.6 *	C *	--	28.5 *	D *	--	24.6 *	C *	--
	I-440 WB on-ramp from CVA extension	37.3	F	--	31.2	D	--	37.3	F	--	31.2	D	--	37.3	F	--	31.2	D	--	37.3	F	--	31.2	D	--
	I-440 WB on-ramp from Glenwood EB	35.0	F	--	28.0	C	--	35.0	F	--	28.0	C	--	35.0	F	--	28.0	C	--	35.0	F	--	28.0	C	--
	I-440 WB weaving Glenwood WB on to Glenwood EB off	30.8	C	34.87	28.8	C	35.73	30.8	C	34.87	28.8	C	35.73	36.0	D	33.3	38.0	F	33.3	36.0	D	33.3	41.9 **	F **	32.7 **

* While the average densities are within acceptable ranges, the freeway through traffic demand, when separated from the off-ramp traffic, will exceed the capacity.

* *An additional lane (third lane) on the WB C/D road may reduce the weaving segment density to 32.0 pc/mi/ln (LOS D) with an average speed of 28.57 mph.

2009 Base Conditions

RAMPS AND RAMP JUNCTIONS WORKSHEET

General Information / Site Information

Analyst	Caroline Kone	Freeway/Dir of Travel	EB I-440
Agency or Company	WSP SELLS	Junction	Off-ramp to Ridge Rd
Date Performed	6/16/2010	Jurisdiction	Raleigh/NCDOT/FHWA
Analysis Time Period	AM Existing	Analysis Year	2009

Project Description Crabtree Valley

Inputs

Upstream Adj Ramp
☐ Yes ☐ On
☑ No ☐ Off
L_{up} = ft
V_u = veh/h

Terrain: Level

S_{FF} = 65.0 mph S_{FR} = 65.0 mph

Sketch (show lanes, L_A, L_D, V_R, V_f)

Downstream Adj Ramp
☑ Yes ☑ On
☐ No ☐ Off
L_{down} = 830 ft
V_D = 303 veh/h

Conversion to pc/h Under Base Conditions

(pc/h)	V (Veh/hr)	PHF	Terrain	%Truck	%Rv	f_{HV}	f_p	v = V/PHF x f_{HV} x f_p
Freeway	3606	0.92	Level	3	0	0.985	1.00	3978
Ramp	144	0.92	Level	2	0	0.990	1.00	158
UpStream								
DownStream	303	0.92	Level	2	0	0.990	1.00	333

Merge Areas

Estimation of v_{12}

$V_{12} = V_F (P_{FM})$

L_{EQ} = (Equation 25-2 or 25-3)
P_{FM} = using Equation (Exhibit 25-5)
V_{12} = pc/h
V_3 or V_{av34} pc/h (Equation 25-4 or 25-5)
Is V_3 or V_{av34} > 2,700 pc/h? ☐ Yes ☐ No
Is V_3 or V_{av34} > 1.5 * V_{12}/2 ☐ Yes ☐ No
If Yes, V_{12a} = pc/h (Equation 25-8)

Capacity Checks

	Actual	Capacity		LOS F?
V_{FO}		Exhibit 25-7		

Flow Entering Merge Influence Area

	Actual	Max Desirable		Violation?
V_{R12}		Exhibit 25-7		

Level of Service Determination (if not F)

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

D_R = (pc/mi/ln)
LOS = (Exhibit 25-4)

Speed Determination

M_S = (Exibit 25-19)
S_R = mph (Exhibit 25-19)
S_0 = mph (Exhibit 25-19)
S = mph (Exhibit 25-14)

Diverge Areas

Estimation of v_{12}

$V_{12} = V_R + (V_F - V_R)P_{FD}$

L_{EQ} = (Equation 25-8 or 25-9)
P_{FD} = 0.653 using Equation (Exhibit 25-12)
V_{12} = 2654 pc/h
V_3 or V_{av34} 1324 pc/h (Equation 25-15 or 25-16)
Is V_3 or V_{av34} > 2,700 pc/h? ☐ Yes ☑ No
Is V_3 or V_{av34} > 1.5 * V_{12}/2 ☐ Yes ☑ No
If Yes, V_{12a} = pc/h (Equation 25-18)

Capacity Checks

	Actual	Capacity		LOS F?
V_F	3978	Exhibit 25-14	7050	No
$V_{FO} = V_F - V_R$	3820	Exhibit 25-14	7050	No
V_R	158	Exhibit 25-3	2200	No

Flow Entering Diverge Influence Area

	Actual	Max Desirable		Violation?
V_{12}	2654	Exhibit 25-14	4400:All	No

Level of Service Determination (if not F)

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

D_R = 21.5 (pc/mi/ln)
LOS = C (Exhibit 25-4)

Speed Determination

D_s = 0.052 (Exhibit 25-19)
S_R = 63.8 mph (Exhibit 25-19)
S_0 = 70.0 mph (Exhibit 25-19)
S = 65.7 mph (Exhibit 25-15)

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RAMPS AND RAMP JUNCTIONS WORKSHEET

General Information / Site Information

Analyst	Caroline Kone	Freeway/Dir of Travel	I-440 EB
Agency or Company	WSP SELLS	Junction	Glenwood Ave WB on-ramp
Date Performed	6/16/2010	Jurisdiction	Raleigh/NCDOT/FHWA
Analysis Time Period	AM Existing	Analysis Year	2009

Project Description Crabtree Valley

Inputs

Upstream Adj Ramp
☑ Yes ☑ On
☐ No ☐ Off
L_{up} = 1300 ft
V_u = 1397 veh/h

Terrain: Level

S_{FF} = 65.0 mph S_{FR} = 45.0 mph
Sketch (show lanes, L_A, L_D, V_R, V_f)

Downstream Adj Ramp
☐ Yes ☐ On
☑ No ☐ Off
L_{down} = ft
V_D = veh/h

Conversion to pc/h Under Base Conditions

(pc/h)	V (Veh/hr)	PHF	Terrain	%Truck	%Rv	f_{HV}	f_p	$v = V/PHF \times f_{HV} \times f_p$
Freeway	4344	0.92	Level	3	0	0.985	1.00	4793
Ramp	309	0.92	Level	2	0	0.990	1.00	339
UpStream	1397	0.92	Level	2	0	0.990	1.00	1534
DownStream								

Merge Areas

Estimation of v_{12}

$V_{12} = V_F (P_{FM})$
L_{EQ} = (Equation 25-2 or 25-3)
P_{FM} = 0.175 using Equation (Exhibit 25-5)
V_{12} = 841 pc/h
V_3 or V_{av34} 1976 pc/h (Equation 25-4 or 25-5)
Is V_3 or V_{av34} > 2,700 pc/h? ☐ Yes ☑ No
Is V_3 or V_{av34} > 1.5 * V_{12}/2 ☑ Yes ☐ No
If Yes, V_{12a} = 1917 pc/h (Equation 25-8)

Capacity Checks

	Actual	Capacity		LOS F?
V_{FO}	5132	Exhibit 25-7		No

Flow Entering Merge Influence Area

	Actual	Max Desirable		Violation?
V_{R12}	2256	Exhibit 25-7	4600:All	No

Level of Service Determination (if not F)

$D_R = 5.475 + 0.00734\, v_R + 0.0078\, V_{12} - 0.00627\, L_A$
D_R = 13.5 (pc/mi/ln)
LOS = B (Exhibit 25-4)

Speed Determination

M_S = 0.223 (Exibit 25-19)
S_R = 59.9 mph (Exhibit 25-19)
S_0 = 61.6 mph (Exhibit 25-19)
S = 60.8 mph (Exhibit 25-14)

Diverge Areas

Estimation of v_{12}

$V_{12} = V_R + (V_F - V_R) P_{FD}$
L_{EQ} = (Equation 25-8 or 25-9)
P_{FD} = using Equation (Exhibit 25-12)
V_{12} = pc/h
V_3 or V_{av34} pc/h (Equation 25-15 or 25-16)
Is V_3 or V_{av34} > 2,700 pc/h? ☐ Yes ☐ No
Is V_3 or V_{av34} > 1.5 * V_{12}/2 ☐ Yes ☐ No
If Yes, V_{12a} = pc/h (Equation 25-18)

Capacity Checks

	Actual	Capacity		LOS F?
V_F		Exhibit 25-14		
$V_{FO} = V_F - V_R$		Exhibit 25-14		
V_R		Exhibit 25-3		

Flow Entering Diverge Influence Area

	Actual	Max Desirable		Violation?
V_{12}		Exhibit 25-14		

Level of Service Determination (if not F)

$D_R = 4.252 + 0.0086\, V_{12} - 0.009\, L_D$
D_R = (pc/mi/ln)
LOS = (Exhibit 25-4)

Speed Determination

D_s = (Exhibit 25-19)
S_R = mph (Exhibit 25-19)
S_0 = mph (Exhibit 25-19)
S = mph (Exhibit 25-15)

FREEWAY WEAVING WORKSHEET

General Information

Analyst	Caroline Kone
Agency/Company	WSP SELLS
Date Performed	6/16/2010
Analysis Time Period	AM existing

Site Information

Freeway/Dir of Travel	I-440 EB
Weaving Seg Location	Ridge Rd on to Glenwood off
Jurisdiction	Raleigh/NCDOT/FHWA
Analysis Year	2009

Inputs

Freeway free-flow speed, S_{FF} (mi/h)	65	Weaving type	A
Weaving number of lanes, N	4	Volume ratio, VR	0.30
Weaving seg length, L (ft)	700	Weaving ratio, R	0.27
Terrain	Level		

Conversions to pc/h Under Base Conditions

(pc/h)	V	PHF	Truck %	RV %	E_T	E_R	f_{HV}	fp	v
V_{o1}	2644	0.92	3	0	1.5	1.2	0.985	1.00	2917
V_{o2}	0	0.92	2	0	1.5	1.2	0.990	1.00	0
V_{w1}	818	0.92	2	0	1.5	1.2	0.990	1.00	898
V_{w2}	303	0.92	2	0	1.5	1.2	0.990	1.00	332
V_w				1230	V_{nw}				2917
V									4147

Weaving and Non-Weaving Speeds

	Unconstrained		Constrained	
	Weaving (i = w)	Non-Weaving (i = nw)	Weaving (i = w)	Non-Weaving (= nw)
a (Exhibit 24-6)	0.15	0.0035		
b (Exhibit 24-6)	2.20	4.00		
c (Exhibit 24-6)	0.97	1.30		
d (Exhibit 24-6)	0.80	0.75		
Weaving Intensity factor, Wi	1.18	0.61		
Weaving and non-weaving speeds, Si (mi/h)	40.18	49.27		

Number of lanes required for unconstrained operation, Nw 1.36
Maximum number of lanes, Nw (max) 1.40

☑ If Nw < Nw(max) unconstrained operation ☐ If Nw > Nw (max) constrained operation

Weaving Segment Speed, Density, Level of Service, and Capacity

Weaving segment speed, S (mi/h)	46.17
Weaving segment density, D (pc/mi/ln)	22.46
Level of service, LOS	C
Capacity of base condition, c_b (pc/h)	6517
Capacity as a 15-minute flow rate, c (veh/h)	6421
Capacity as a full-hour volume, c_h (veh/h)	5907

Notes

a. Weaving segments longer than 2500 ft. are treated as isolated merge and diverge areas using the procedures of Chapter 25, "Ramps and Ramp Junctions".
b. Capacity constrained by basic freeway capacity.
c. Capacity occurs under constrained operating conditions.
d. Three-lane Type A segments do not operate well at volume ratios greater than 0.45. Poor operations and some local queuing are expected in such cases.
e. Four-lane Type A segments do not operate well at volume ratios greater than 0.35. Poor operations and some local queuing are expected in such cases.
f. Capacity constrained by maximum allowable weaving flow rate: 2,800 pc/h (Type A), 4,000 (Type B), 3,500 (Type C).
g. Five-lane Type A segments do not operate well at volume ratios greater than 0.20. Poor operations and some local queuing are expected in such cases.
h. Type B weaving segments do not operate well at volume ratios greater than 0.80. Poor operations and some local queuing are expected in such cases.
i. Type C weaving segments do not operate well at volume ratios greater than 0.50. Poor operations and some local queuing are expected in such cases.

RAMPS AND RAMP JUNCTIONS WORKSHEET

General Information / Site Information

Analyst	Caroline Kone	Freeway/Dir of Travel	I-440 WB
Agency or Company	WSP SELLS	Junction	off-ramp to Glenwood WB
Date Performed	6/16/2010	Jurisdiction	Raleigh/NCDOT/FHWA
Analysis Time Period	AM Existing	Analysis Year	2009

Project Description Crbatree Valley

Inputs

Upstream Adj Ramp
☐ Yes ☐ On
☑ No ☐ Off
L_{up} = ft
V_u = veh/h

Terrain: Level

S_{FF} = 65.0 mph S_{FR} = 45.0 mph

Sketch (show lanes, L_A, L_D, V_R, V_f)

Downstream Adj Ramp
☐ Yes ☐ On
☑ No ☐ Off
L_{down} = ft
V_D = veh/h

Conversion to pc/h Under Base Conditions

(pc/h)	V (Veh/hr)	PHF	Terrain	%Truck	%Rv	f_{HV}	f_p	$v = V/PHF \times f_{HV} \times f_p$
Freeway	6786	0.92	Level	3	0	0.985	1.00	7487
Ramp	0	0.92	Level	2	0	0.990	1.00	0
UpStream								
DownStream								

Merge Areas

Estimation of v_{12}

$V_{12} = V_F (P_{FM})$

L_{EQ} = (Equation 25-2 or 25-3)

P_{FM} = using Equation (Exhibit 25-5)

V_{12} = pc/h

V_3 or V_{av34} pc/h (Equation 25-4 or 25-5)

Is V_3 or V_{av34} > 2,700 pc/h? ☐ Yes ☐ No

Is V_3 or V_{av34} > 1.5 * V_{12}/2 ☐ Yes ☐ No

If Yes, V_{12a} = pc/h (Equation 25-8)

Capacity Checks

	Actual	Capacity		LOS F?
V_{FO}		Exhibit 25-7		

Flow Entering Merge Influence Area

	Actual	Max Desirable		Violation?
V_{R12}		Exhibit 25-7		

Level of Service Determination (if not F)

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

D_R = (pc/mi/ln)

LOS = (Exhibit 25-4)

Speed Determination

M_S = (Exibit 25-19)

S_R = mph (Exhibit 25-19)

S_0 = mph (Exhibit 25-19)

S = mph (Exhibit 25-14)

Diverge Areas

Estimation of v_{12}

$V_{12} = V_R + (V_F - V_R)P_{FD}$

L_{EQ} = (Equation 25-8 or 25-9)

P_{FD} = 0.260 using Equation (Exhibit 25-12)

V_{12} = 1557 pc/h

V_3 or V_{av34} 2216 pc/h (Equation 25-15 or 25-16)

Is V_3 or V_{av34} > 2,700 pc/h? ☐ Yes ☑ No

Is V_3 or V_{av34} > 1.5 * V_{12}/2 ☑ Yes ☐ No

If Yes, V_{12a} = 2396 pc/h (Equation 25-18)

Capacity Checks

	Actual	Capacity		LOS F?
V_F	5990	Exhibit 25-14	9400	No
$V_{FO} = V_F - V_R$	5990	Exhibit 25-14	9400	No
V_R	0	Exhibit 25-3	4100	No

Flow Entering Diverge Influence Area

	Actual	Max Desirable		Violation?
V_{12}	1557	Exhibit 25-14	4400:All	No

Level of Service Determination (if not F)

$D_R = 4.252 + 0.0086\ V_{12} - 0.009\ 1_D \quad 0.0109\ V_F$ (N)

D_R = 11.4 (pc/mi/ln) 16.32

LOS = B (Exhibit 25-4)

Speed Determination

D_s = 0.298 (Exhibit 25-19)

S_R = 58.1 mph (Exhibit 25-19)

S_0 = 68.2 mph (Exhibit 25-19)

S = 63.8 mph (Exhibit 25-15)

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RAMPS AND RAMP JUNCTIONS WORKSHEET

General Information / Site Information

Analyst	Caroline Kone	Freeway/Dir of Travel	I-440 WB
Agency or Company	WSP SELLS	Junction	on-ramp from Glenwood EB
Date Performed	6/16/2010	Jurisdiction	Raleigh/NCDOT/FHWA
Analysis Time Period	AM Existing	Analysis Year	2009

Project Description Crabtree Valley

Inputs

Upstream Adj Ramp
☑ Yes ☐ On
☐ No ☑ Off
L_{up} = 1500 ft
V_u = 651 veh/h

Terrain: Level
S_{FF} = 65.0 mph S_{FR} = 45.0 mph
Sketch (show lanes, L_A, L_D, V_R, V_f)

Downstream Adj Ramp
☐ Yes ☐ On
☑ No ☐ Off
L_{down} = ft
V_D = veh/h

Conversion to pc/h Under Base Conditions

(pc/h)	V (Veh/hr)	PHF	Terrain	%Truck	%Rv	f_{HV}	f_p	v = V/PHF x f_{HV} x f_p
Freeway	4712	0.92	Level	3	0	0.985	1.00	5199
Ramp	1043	0.92	Level	2	0	0.990	1.00	1145
UpStream	651	0.92	Level	2	0	0.990	1.00	715
DownStream								

Merge Areas

Estimation of v_{12}

$V_{12} = V_F (P_{FM})$

L_{EQ} = 1673.10 (Equation 25-2 or 25-3)
P_{FM} = 0.589 using Equation (Exhibit 25-5)
V_{12} = 3064 pc/h
V_3 or V_{av34} 2135 pc/h (Equation 25-4 or 25-5)
Is V_3 or V_{av34} > 2,700 pc/h? ☐ Yes ☑ No
Is V_3 or V_{av34} > 1.5 * V_{12}/2 ☐ Yes ☑ No
If Yes, V_{12a} = pc/h (Equation 25-8)

Capacity Checks

	Actual	Capacity		LOS F?
V_{FO}	6344	Exhibit 25-7		No

Flow Entering Merge Influence Area

	Actual	Max Desirable		Violation?
V_{R12}	4209	Exhibit 25-7	4600:All	No

Level of Service Determination (if not F)

$D_R = 5.475 + 0.00734\, v_R + 0.0078\, V_{12} - 0.00627\, L_A$

D_R = 32.6 (pc/mi/ln)
LOS = D (Exhibit 25-4)

Speed Determination

M_S = 0.510 (Exibit 25-19)
S_R = 53.3 mph (Exhibit 25-19)
S_0 = 59.1 mph (Exhibit 25-19)
S = 55.1 mph (Exhibit 25-14)

Diverge Areas

Estimation of v_{12}

$V_{12} = V_R + (V_F - V_R)P_{FD}$

L_{EQ} = (Equation 25-8 or 25-9)
P_{FD} = using Equation (Exhibit 25-12)
V_{12} = pc/h
V_3 or V_{av34} pc/h (Equation 25-15 or 25-16)
Is V_3 or V_{av34} > 2,700 pc/h? ☐ Yes ☐ No
Is V_3 or V_{av34} > 1.5 * V_{12}/2 ☐ Yes ☐ No
If Yes, V_{12a} = pc/h (Equation 25-18)

Capacity Checks

	Actual	Capacity		LOS F?
V_F		Exhibit 25-14		
$V_{FO} = V_F - V_R$		Exhibit 25-14		
V_R		Exhibit 25-3		

Flow Entering Diverge Influence Area

	Actual	Max Desirable		Violation?
V_{12}		Exhibit 25-14		

Level of Service Determination (if not F)

$D_R = 4.252 + 0.0086\, V_{12} - 0.009\, L_D$

D_R = (pc/mi/ln)
LOS = (Exhibit 25-4)

Speed Determination

D_s = (Exhibit 25-19)
S_R = mph (Exhibit 25-19)
S_0 = mph (Exhibit 25-19)
S = mph (Exhibit 25-15)

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FREEWAY WEAVING WORKSHEET

General Information

Analyst	Caroline Kone
Agency/Company	WSP SELLS
Date Performed	6/16/2010
Analysis Time Period	AM Existing

Site Information

Freeway/Dir of Travel	I-440 WB
Weaving Seg Location	Glenwood WB to Glenwood EB
Jurisdiction	Raleigh/NCDOT/FHWA
Analysis Year	2009

Inputs

Freeway free-flow speed, S_{FF} (mi/h)	65	Weaving type	A
Weaving number of lanes, N	4	Volume ratio, VR	0.14
Weaving seg length, L (ft)	630	Weaving ratio, R	0.14
Terrain	Level		

Conversions to pc/h Under Base Conditions

(pc/h)	V	PHF	Truck %	RV %	E_T	E_R	f_{HV}	fp	v
V_{o1}	4608	0.92	3	0	1.5	1.2	0.985	1.00	5083
V_{o2}	0	0.92	2	0	1.5	1.2	0.990	1.00	0
V_{w1}	651	0.92	2	0	1.5	1.2	0.990	1.00	714
V_{w2}	104	0.92	2	0	1.5	1.2	0.990	1.00	114
V_w				828	V_{nw}				5083
V									5911

Weaving and Non-Weaving Speeds

	Unconstrained		Constrained	
	Weaving (i = w)	Non-Weaving (i = nw)	Weaving (i = w)	Non-Weaving (= nw)
a (Exhibit 24-6)	0.15	0.0035		
b (Exhibit 24-6)	2.20	4.00		
c (Exhibit 24-6)	0.97	1.30		
d (Exhibit 24-6)	0.80	0.75		
Weaving intensity factor, Wi	1.37	0.62		
Weaving and non-weaving speeds, Si (mi/h)	38.22	48.94		

Number of lanes required for unconstrained operation, Nw 0.88
Maximum number of lanes, Nw (max) 1.40

☑ If Nw < Nw(max) unconstrained operation ☐ if Nw > Nw (max) constrained operation

Weaving Segment Speed, Density, Level of Service, and Capacity

Weaving segment speed, S (mi/h)	47.09
Weaving segment density, D (pc/mi/ln)	31.38
Level of service, LOS	D
Capacity of base condition, c_b (pc/h)	7392
Capacity as a 15-minute flow rate, c (veh/h)	7283
Capacity as a full-hour volume, c_h (veh/h)	6700

Notes

a. Weaving segments longer than 2500 ft. are treated as isolated merge and diverge areas using the procedures of Chapter 25, "Ramps and Ramp Junctions".
b. Capacity constrained by basic freeway capacity.
c. Capacity occurs under constrained operating conditions.
d. Three-lane Type A segments do not operate well at volume ratios greater than 0.45. Poor operations and some local queuing are expected in such cases.
e. Four-lane Type A segments do not operate well at volume ratios greater than 0.35. Poor operations and some local queuing are expected in such cases.
f. Capacity constrained by maximum allowable weaving flow rate: 2,800 pc/h (Type A), 4,000 (Type B), 3,500 (Type C).
g. Five-lane Type A segments do not operate well at volume ratios greater than 0.20. Poor operations and some local queuing are expected in such cases.
h. Type B weaving segments do not operate well at volume ratios greater than 0.80. Poor operations and some local queuing are expected in such cases.
i. Type C weaving segments do not operate well at volume ratios greater than 0.50. Poor operations and some local queuing are expected in such cases.

RAMPS AND RAMP JUNCTIONS WORKSHEET

General Information / Site Information

Analyst	Caroline Kone	Freeway/Dir of Travel	I-440 EB
Agency or Company	WSP SELLS	Junction	off-ramp to Ridge Rd
Date Performed	6/16/2010	Jurisdiction	Raleigh/NCDOT/FHWA
Analysis Time Period	PM Existing	Analysis Year	2009

Project Description Crabtree Valley

Inputs

Upstream Adj Ramp
☐ Yes ☐ On
☑ No ☐ Off
L_{up} = ft
V_u = veh/h

Terrain: Level

S_{FF} = 65.0 mph S_{FR} = 45.0 mph
Sketch (show lanes, L_A, L_D, V_R, V_I)

Downstream Adj Ramp
☑ Yes ☑ On
☐ No ☐ Off
L_{down} = 830 ft
V_D = 298 veh/h

Conversion to pc/h Under Base Conditions

(pc/h)	V (Veh/hr)	PHF	Terrain	%Truck	%Rv	f_{HV}	f_p	v = V/PHF x f_{HV} x f_p
Freeway	4455	0.92	Level	3	0	0.985	1.00	4915
Ramp	143	0.92	Level	2	0	0.990	1.00	157
UpStream								
DownStream	298	0.92	Level	2	0	0.990	1.00	327

Merge Areas

Estimation of v_{12}

$V_{12} = V_F (P_{FM})$
L_{EQ} = (Equation 25-2 or 25-3)
P_{FM} = using Equation (Exhibit 25-5)
V_{12} = pc/h
V_3 or V_{av34} pc/h (Equation 25-4 or 25-5)
Is V_3 or V_{av34} > 2,700 pc/h? ☐ Yes ☐ No
Is V_3 or V_{av34} > 1.5 * V_{12}/2 ☐ Yes ☐ No
If Yes, V_{12a} = pc/h (Equation 25-8)

Capacity Checks

	Actual	Capacity		LOS F?
V_{FO}		Exhibit 25-7		

Flow Entering Merge Influence Area

	Actual	Max Desirable		Violation?
V_{R12}		Exhibit 25-7		

Level of Service Determination (if not F)

$D_R = 5.475 + 0.00734\ v_R + 0.0078\ V_{12} - 0.00627\ L_A$
D_R = (pc/mi/ln)
LOS = (Exhibit 25-4)

Speed Determination

M_S = (Exibit 25-19)
S_R = mph (Exhibit 25-19)
S_0 = mph (Exhibit 25-19)
S = mph (Exhibit 25-14)

Diverge Areas

Estimation of v_{12}

$V_{12} = V_R + (V_F - V_R)P_{FD}$
L_{EQ} = (Equation 25-8 or 25-9)
P_{FD} = 0.630 using Equation (Exhibit 25-12)
V_{12} = 3154 pc/h
V_3 or V_{av34} 1761 pc/h (Equation 25-15 or 25-16)
Is V_3 or V_{av34} > 2,700 pc/h? ☐ Yes ☑ No
Is V_3 or V_{av34} > 1.5 * V_{12}/2 ☐ Yes ☑ No
If Yes, V_{12a} = pc/h (Equation 25-18)

Capacity Checks

	Actual	Capacity		LOS F?
V_F	4915	Exhibit 25-14	7050	No
$V_{FO} = V_F - V_R$	4758	Exhibit 25-14	7050	No
V_R	157	Exhibit 25-3	2100	No

Flow Entering Diverge Influence Area

	Actual	Max Desirable		Violation?
V_{12}	3154	Exhibit 25-14	4400:All	No

Level of Service Determination (if not F)

$D_R = 4.252 + 0.0086\ V_{12} - 0.009\ L_D$
D_R = 25.8 (pc/mi/ln)
LOS = C (Exhibit 25-4)

Speed Determination

D_s = 0.312 (Exhibit 25-19)
S_R = 57.8 mph (Exhibit 25-19)
S_0 = 68.3 mph (Exhibit 25-19)
S = 61.2 mph (Exhibit 25-15)

RAMPS AND RAMP JUNCTIONS WORKSHEET

General Information / Site Information

Analyst	Caroline Kone	Freeway/Dir of Travel	I-440 EB
Agency or Company	WSP SELLS	Junction	on-ramp from Glenwood WB
Date Performed	6/16/2010	Jurisdiction	Raleigh/NCDOT/FHWA
Analysis Time Period	PM Existing	Analysis Year	2009

Project Description Crabtree Valley

Inputs

Upstream Adj Ramp: ☑ Yes ☑ On ☐ No ☐ Off

L_{up} = 1300 ft

V_u = 1598 veh/h

Terrain: Level

S_{FF} = 65.0 mph S_{FR} = 45.0 mph

Sketch (show lanes, L_A, L_D, V_R, V_f)

Downstream Adj Ramp: ☐ Yes ☐ On ☑ No ☐ Off

L_{down} = ft

V_D = veh/h

Conversion to pc/h Under Base Conditions

(pc/h)	V (Veh/hr)	PHF	Terrain	%Truck	%Rv	f_{HV}	f_p	$v = V/PHF \times f_{HV} \times f_p$
Freeway	4907	0.92	Level	3	0	0.985	1.00	5414
Ramp	276	0.92	Level	2	0	0.990	1.00	303
UpStream	1598	0.92	Level	2	0	0.990	1.00	1754
DownStream								

Merge Areas

Estimation of v_{12}

$V_{12} = V_F (P_{FM})$

L_{EQ} = (Equation 25-2 or 25-3)

P_{FM} = 0.180 using Equation (Exhibit 25-5)

V_{12} = 974 pc/h

V_3 or V_{av34} 2220 pc/h (Equation 25-4 or 25-5)

Is V_3 or V_{av34} > 2,700 pc/h? ☐ Yes ☑ No

Is V_3 or V_{av34} > 1.5 * V_{12}/2 ☑ Yes ☐ No

If Yes, V_{12a} = 2165 pc/h (Equation 25-8)

Capacity Checks

	Actual	Capacity		LOS F?
V_{FO}	5717	Exhibit 25-7		No

Flow Entering Merge Influence Area

	Actual	Max Desirable		Violation?
V_{R12}	2468	Exhibit 25-7	4600:All	No

Level of Service Determination (if not F)

$D_R = 5.475 + 0.00734\, v_R + 0.0078\, V_{12} - 0.00627\, L_A$

D_R = 15.2 (pc/mi/ln)

LOS = B (Exhibit 25-4)

Speed Determination

M_S = 0.232 (Exibit 25-19)

S_R = 59.7 mph (Exhibit 25-19)

S_0 = 61.0 mph (Exhibit 25-19)

S = 60.4 mph (Exhibit 25-14)

Diverge Areas

Estimation of v_{12}

$V_{12} = V_R + (V_F - V_R) P_{FD}$

L_{EQ} = (Equation 25-8 or 25-9)

P_{FD} = using Equation (Exhibit 25-12)

V_{12} = pc/h

V_3 or V_{av34} pc/h (Equation 25-15 or 25-16)

Is V_3 or V_{av34} > 2,700 pc/h? ☐ Yes ☐ No

Is V_3 or V_{av34} > 1.5 * V_{12}/2 ☐ Yes ☐ No

If Yes, V_{12a} = pc/h (Equation 25-18)

Capacity Checks

	Actual	Capacity		LOS F?
V_F		Exhibit 25-14		
$V_{FO} = V_F - V_R$		Exhibit 25-14		
V_R		Exhibit 25-3		

Flow Entering Diverge Influence Area

	Actual	Max Desirable		Violation?
V_{12}		Exhibit 25-14		

Level of Service Determination (if not F)

$D_R = 4.252 + 0.0086\, V_{12} - 0.009\, L_D$

D_R = (pc/mi/ln)

LOS = (Exhibit 25-4)

Speed Determination

D_s = (Exhibit 25-19)

S_R = mph (Exhibit 25-19)

S_0 = mph (Exhibit 25-19)

S = mph (Exhibit 25-15)

FREEWAY WEAVING WORKSHEET

General Information

Analyst	Caroline Kone
Agency/Company	WSP SELLS
Date Performed	6/16/2010
Analysis Time Period	PM Existing

Site Information

Freeway/Dir of Travel	I-440 EB
Weaving Seg Location	Ridge Rd on to Glenwood off
Jurisdiction	Raleigh/NCDOT/FHWA
Analysis Year	2009

Inputs

Freeway free-flow speed, S_{FF} (mi/h)	65	Weaving type	A
Weaving number of lanes, N	4	Volume ratio, VR	0.35
Weaving seg length, L (ft)	700	Weaving ratio, R	0.19
Terrain	Level		

Conversions to pc/h Under Base Conditions

(pc/h)	V	PHF	Truck %	RV %	E_T	E_R	f_{HV}	fp	v
V_{o1}	3011	0.92	3	0	1.5	1.2	0.985	1.00	3321
V_{o2}	0	0.92	2	0	1.5	1.2	0.990	1.00	0
V_{w1}	1301	0.92	2	0	1.5	1.2	0.990	1.00	1428
V_{w2}	298	0.92	2	0	1.5	1.2	0.990	1.00	327
V_w				1755	V_{nw}				3321
V									5076

Weaving and Non-Weaving Speeds

	Unconstrained		Constrained	
	Weaving (i = w)	Non-Weaving (i = nw)	Weaving (i = w)	Non-Weaving (= nw)
a (Exhibit 24-6)			0.35	0.0020
b (Exhibit 24-6)			2.20	4.00
c (Exhibit 24-6)			0.97	1.30
d (Exhibit 24-6)			0.80	0.75
Weaving intensity factor, Wi			3.65	0.52
Weaving and non-weaving speeds, Si (mi/h)			26.83	51.14

Number of lanes required for unconstrained operation, Nw 1.55
Maximum number of lanes, Nw (max) 1.40

☐ If Nw < Nw(max) unconstrained operation ☑ If Nw > Nw (max) constrained operation

Weaving Segment Speed, Density, Level of Service, and Capacity

Weaving segment speed, S (mi/h)	38.94
Weaving segment density, D (pc/mi/ln)	32.59
Level of service, LOS	D
Capacity of base condition, c_b (pc/h)	6198
Capacity as a 15-minute flow rate, c (veh/h)	6106
Capacity as a full-hour volume, c_h (veh/h)	5618

Notes

a. Weaving segments longer than 2500 ft. are treated as isolated merge and diverge areas using the procedures of Chapter 25, "Ramps and Ramp Junctions".
b. Capacity constrained by basic freeway capacity.
c. Capacity occurs under constrained operating conditions.
d. Three-lane Type A segments do not operate well at volume ratios greater than 0.45. Poor operations and some local queuing are expected in such cases.
e. Four-lane Type A segments do not operate well at volume ratios greater than 0.35. Poor operations and some local queuing are expected in such cases.
f. Capacity constrained by maximum allowable weaving flow rate: 2,800 pc/h (Type A), 4,000 (Type B), 3,500 (Type C).
g. Five-lane Type A segments do not operate well at volume ratios greater than 0.20. Poor operations and some local queuing are expected in such cases.
h. Type B weaving segments do not operate well at volume ratios greater than 0.80. Poor operations and some local queuing are expected in such cases.
i. Type C weaving segments do not operate well at volume ratios greater than 0.50. Poor operations and some local queuing are expected in such cases.

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RAMPS AND RAMP JUNCTIONS WORKSHEET

General Information / Site Information

Analyst	G Teng	Freeway/Dir of Travel	I-440 WB
Agency or Company	WSP SELLS	Junction	off-ramp to Glenwood WB
Date Performed	6/16/2010	Jurisdiction	Raleigh/NCDOT/FHWA
Analysis Time Period	PM Existing	Analysis Year	2009

Project Description Crabtree Valley

Inputs

Upstream Adj Ramp
☐ Yes ☐ On
☑ No ☐ Off
L_{up} = ft
V_u = veh/h

Terrain: Level

S_{FF} = 65.0 mph S_{FR} = 45.0 mph

Sketch (show lanes, L_A, L_D, V_R, V_f)

Downstream Adj Ramp
☐ Yes ☐ On
☑ No ☐ Off
L_{down} = ft
V_D = veh/h

Conversion to pc/h Under Base Conditions

(pc/h)	V (Veh/hr)	PHF	Terrain	%Truck	%Rv	f_{HV}	f_p	v = V/PHF x f_{HV} x f_p
Freeway	5850	0.92	Level	3	0	0.985	1.00	6454
Ramp	0	0.92	Level	2	0	0.990	1.00	0
UpStream								
DownStream								

Merge Areas

Estimation of v_{12}

$V_{12} = V_F (P_{FM})$

L_{EQ} = (Equation 25-2 or 25-3)
P_{FM} = using Equation (Exhibit 25-5)
V_{12} = pc/h
V_3 or V_{av34} pc/h (Equation 25-4 or 25-5)
Is V_3 or V_{av34} > 2,700 pc/h? ☐ Yes ☐ No
Is V_3 or V_{av34} > 1.5 * V_{12}/2 ☐ Yes ☐ No
If Yes, V_{12a} = pc/h (Equation 25-8)

Capacity Checks

	Actual	Capacity		LOS F?
V_{FO}		Exhibit 25-7		

Flow Entering Merge Influence Area

	Actual	Max Desirable		Violation?
V_{R12}		Exhibit 25-7		

Level of Service Determination (if not F)

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

D_R = (pc/mi/ln)
LOS = (Exhibit 25-4)

Speed Determination

M_S = (Exibit 25-19)
S_R = mph (Exhibit 25-19)
S_0 = mph (Exhibit 25-19)
S = mph (Exhibit 25-14)

Diverge Areas

Estimation of v_{12}

$V_{12} = V_R + (V_F - V_R)P_{FD}$

L_{EQ} = (Equation 25-8 or 25-9)
P_{FD} = 0.260 using Equation (Exhibit 25-12)
V_{12} = 1426 pc/h
V_3 or V_{av34} 2030 pc/h (Equation 25-15 or 25-16)
Is V_3 or V_{av34} > 2,700 pc/h? ☐ Yes ☑ No
Is V_3 or V_{av34} > 1.5 * V_{12}/2 ☑ Yes ☐ No
If Yes, V_{12a} = 2194 pc/h (Equation 25-18)

Capacity Checks

	Actual	Capacity		LOS F?
V_F	5486	Exhibit 25-14	9400	No
$V_{FO} = V_F - V_R$	5486	Exhibit 25-14	9400	No
V_R	0	Exhibit 25-3	4100	No

Flow Entering Diverge Influence Area

	Actual	Max Desirable		Violation?
V_{12}	1426	Exhibit 25-14	4400:All	No

Level of Service Determination (if not F)

D_R = ~~4.252 + 0.0086 V_{12} - 0.009 L_D~~ 0.0109 V_F

D_R = ~~9.6~~ (pc/mi/ln) 14.07

LOS = A (Exhibit 25-4)

Speed Determination

D_s = 0.298 (Exhibit 25-19)
S_R = 58.1 mph (Exhibit 25-19)
S_0 = 68.8 mph (Exhibit 25-19)
S = 64.1 mph (Exhibit 25-15)

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RAMPS AND RAMP JUNCTIONS WORKSHEET

General Information / Site Information

Analyst	Caroline Kone	Freeway/Dir of Travel	I-440 WB
Agency or Company	WSP SELLS	Junction	on-ramp from Glenwood EB
Date Performed	6/16/2010	Jurisdiction	Raleigh/NCDOT/FHWA
Analysis Time Period	PM Existing	Analysis Year	2009

Project Description Crabtree Valley

Inputs

Upstream Adj Ramp
☑ Yes ☐ On
☐ No ☑ Off
L_{up} = 1500 ft
V_u = 556 veh/h

Terrain: Level

S_{FF} = 65.0 mph S_{FR} = 45.0 mph

Sketch (show lanes, L_A, L_D, V_R, V_f)

Downstream Adj Ramp
☐ Yes ☐ On
☑ No ☐ Off
L_{down} = ft
V_D = veh/h

Conversion to pc/h Under Base Conditions

(pc/h)	V (Veh/hr)	PHF	Terrain	%Truck	%Rv	f_{HV}	f_p	$v = V/PHF \times f_{HV} \times f_p$
Freeway	3167	0.92	Level	3	0	0.985	1.00	3494
Ramp	1289	0.92	Level	2	0	0.990	1.00	1415
UpStream	556	0.92	Level	2	0	0.990	1.00	610
DownStream								

Merge Areas

Estimation of v_{12}

$V_{12} = V_F (P_{FM})$

L_{EQ} = 1366.01 (Equation 25-2 or 25-3)
P_{FM} = 0.600 using Equation (Exhibit 25-5)
V_{12} = 2098 pc/h
V_3 or V_{av34} 1396 pc/h (Equation 25-4 or 25-5)
Is V_3 or V_{av34} > 2,700 pc/h? ☐ Yes ☑ No
Is V_3 or V_{av34} > 1.5 * V_{12}/2 ☐ Yes ☑ No
If Yes, V_{12a} = pc/h (Equation 25-8)

Capacity Checks

	Actual	Capacity		LOS F?
V_{FO}	4909	Exhibit 25-7		No

Flow Entering Merge Influence Area

	Actual	Max Desirable		Violation?
V_{R12}	3513	Exhibit 25-7	4600:All	No

Level of Service Determination (if not F)

$D_R = 5.475 + 0.00734\, v_R + 0.0078\, V_{12} - 0.00627\, L_A$

D_R = 27.1 (pc/mi/ln)
LOS = C (Exhibit 25-4)

Speed Determination

M_S = 0.378 (Exibit 25-19)
S_R = 56.3 mph (Exhibit 25-19)
S_0 = 61.8 mph (Exhibit 25-19)
S = 57.8 mph (Exhibit 25-14)

Diverge Areas

Estimation of v_{12}

$V_{12} = V_R + (V_F - V_R)P_{FD}$

L_{EQ} = (Equation 25-8 or 25-9)
P_{FD} = using Equation (Exhibit 25-12)
V_{12} = pc/h
V_3 or V_{av34} pc/h (Equation 25-15 or 25-16)
Is V_3 or V_{av34} > 2,700 pc/h? ☐ Yes ☐ No
Is V_3 or V_{av34} > 1.5 * V_{12}/2 ☐ Yes ☐ No
If Yes, V_{12a} = pc/h (Equation 25-18)

Capacity Checks

	Actual	Capacity		LOS F?
V_F		Exhibit 25-14		
$V_{FO} = V_F - V_R$		Exhibit 25-14		
V_R		Exhibit 25-3		

Flow Entering Diverge Influence Area

	Actual	Max Desirable		Violation?
V_{12}		Exhibit 25-14		

Level of Service Determination (if not F)

$D_R = 4.252 + 0.0086\, V_{12} - 0.009\, L_D$

D_R = (pc/mi/ln)
LOS = (Exhibit 25-4)

Speed Determination

D_s = (Exhibit 25-19)
S_R = mph (Exhibit 25-19)
S_0 = mph (Exhibit 25-19)
S = mph (Exhibit 25-15)

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FREEWAY WEAVING WORKSHEET

General Information

Analyst	Caroline Kone
Agency/Company	WSP SELLS
Date Performed	6/16/2010
Analysis Time Period	PM Existing

Site Information

Freeway/Dir of Travel	I-440 WB
Weaving Seg Location	Glenwood WB to Glenwood EB
Jurisdiction	Raleigh/NCDOT/FHWA
Analysis Year	2009

Inputs

Freeway free-flow speed, S_{FF} (mi/h)	65	Weaving type	A
Weaving number of lanes, N	4	Volume ratio, VR	0.19
Weaving seg length, L (ft)	630	Weaving ratio, R	0.20
Terrain	Level		

Conversions to pc/h Under Base Conditions

(pc/h)	V	PHF	Truck %	RV %	E_T	E_R	f_{HV}	f_p	v
V_{o1}	3024	0.92	3	0	1.5	1.2	0.985	1.00	3336
V_{o2}	0	0.92	2	0	1.5	1.2	0.990	1.00	0
V_{w1}	556	0.92	2	0	1.5	1.2	0.990	1.00	610
V_{w2}	143	0.92	2	0	1.5	1.2	0.990	1.00	156
V_w				766	V_{nw}				3336
V									4102

Weaving and Non-Weaving Speeds

	Unconstrained		Constrained	
	Weaving (i = w)	Non-Weaving (i = nw)	Weaving (i = w)	Non-Weaving (= nw)
a (Exhibit 24-6)	0.15	0.0035		
b (Exhibit 24-6)	2.20	4.00		
c (Exhibit 24-6)	0.97	1.30		
d (Exhibit 24-6)	0.80	0.75		
Weaving intensity factor, Wi	1.05	0.45		
Weaving and non-weaving speeds, Si (mi/h)	41.84	52.85		

Number of lanes required for unconstrained operation, Nw 1.00
Maximum number of lanes, Nw (max) 1.40

☑ If Nw < Nw(max) unconstrained operation ☐ if Nw > Nw (max) constrained operation

Weaving Segment Speed, Density, Level of Service, and Capacity

Weaving segment speed, S (mi/h)	50.37
Weaving segment density, D (pc/mi/ln)	20.36
Level of service, LOS	C
Capacity of base condition, c_b (pc/h)	7082
Capacity as a 15-minute flow rate, c (veh/h)	6977
Capacity as a full-hour volume, c_h (veh/h)	6419

Notes

a. Weaving segments longer than 2500 ft. are treated as isolated merge and diverge areas using the procedures of Chapter 25, "Ramps and Ramp Junctions".
b. Capacity constrained by basic freeway capacity.
c. Capacity occurs under constrained operating conditions.
d. Three-lane Type A segments do not operate well at volume ratios greater than 0.45. Poor operations and some local queuing are expected in such cases.
e. Four-lane Type A segments do not operate well at volume ratios greater than 0.35. Poor operations and some local queuing are expected in such cases.
f. Capacity constrained by maximum allowable weaving flow rate: 2,800 pc/h (Type A), 4,000 (Type B), 3,500 (Type C).
g. Five-lane Type A segments do not operate well at volume ratios greater than 0.20. Poor operations and some local queuing are expected in such cases.
h. Type B weaving segments do not operate well at volume ratios greater than 0.80. Poor operations and some local queuing are expected in such cases.
i. Type C weaving segments do not operate well at volume ratios greater than 0.50. Poor operations and some local queuing are expected in such cases.

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2035 No Improvements

RAMPS AND RAMP JUNCTIONS WORKSHEET

General Information / Site Information

Analyst	Caroline Kone	Freeway/Dir of Travel	I-440 EB
Agency or Company	WSP SELLS	Junction	off-ramp to Ridge Rd
Date Performed	6/17/2010	Jurisdiction	Raleigh/NCDOT/FHWA
Analysis Time Period	AM No-Build	Analysis Year	2035

Project Description Crabtree Valley

Inputs

Upstream Adj Ramp
☐ Yes ☐ On
☑ No ☐ Off
L_{up} = ft
V_u = veh/h

Terrain: Level

S_{FF} = 65.0 mph S_{FR} = 45.0 mph

Sketch (show lanes, L_A, L_D, V_R, V_f)

Downstream Adj Ramp
☑ Yes ☑ On
☐ No ☐ Off
L_{down} = 830 ft
V_D = 576 veh/h

Conversion to pc/h Under Base Conditions

(pc/h)	V (Veh/hr)	PHF	Terrain	%Truck	%Rv	f_{HV}	f_p	$v = V/PHF \times f_{HV} \times f_p$
Freeway	6851	1.00	Level	3	0	0.985	1.00	6954
Ramp	274	1.00	Level	2	0	0.990	1.00	277
UpStream								
DownStream	576	1.00	Level	2	0	0.990	1.00	582

Merge Areas

Estimation of v_{12}

$V_{12} = V_F (P_{FM})$

L_{EQ} = (Equation 25-2 or 25-3)
P_{FM} = using Equation (Exhibit 25-5)
V_{12} = pc/h
V_3 or V_{av34} pc/h (Equation 25-4 or 25-5)
Is V_3 or V_{av34} > 2,700 pc/h? ☐ Yes ☐ No
Is V_3 or V_{av34} > 1.5 * V_{12}/2 ☐ Yes ☐ No
If Yes, V_{12a} = pc/h (Equation 25-8)

Capacity Checks

	Actual	Capacity		LOS F?
V_{FO}		Exhibit 25-7		

Flow Entering Merge Influence Area

	Actual	Max Desirable		Violation?
V_{R12}		Exhibit 25-7		

Level of Service Determination (if not F)

$D_R = 5.475 + 0.00734\, v_R + 0.0078\, V_{12} - 0.00627\, L_A$

D_R = (pc/mi/ln)
LOS = (Exhibit 25-4)

Speed Determination

M_S = (Exibit 25-19)
S_R = mph (Exhibit 25-19)
S_0 = mph (Exhibit 25-19)
S = mph (Exhibit 25-14)

Diverge Areas

Estimation of v_{12}

$V_{12} = V_R + (V_F - V_R)P_{FD}$

L_{EQ} = (Equation 25-8 or 25-9)
P_{FD} = 0.573 using Equation (Exhibit 25-12)
V_{12} = 4106 pc/h
V_3 or V_{av34} 2848 pc/h (Equation 25-15 or 25-16)
Is V_3 or V_{av34} > 2,700 pc/h? ☑ Yes ☐ No
Is V_3 or V_{av34} > 1.5 * V_{12}/2 ☐ Yes ☑ No
If Yes, V_{12a} = 4254 pc/h (Equation 25-18)

Capacity Checks

	Actual	Capacity		LOS F?
V_F	6954	Exhibit 25-14	7050	No
$V_{FO} = V_F - V_R$	6677	Exhibit 25-14	7050	No
V_R	277	Exhibit 25-3	2100	No

Flow Entering Diverge Influence Area

	Actual	Max Desirable		Violation?
V_{12}	4106	Exhibit 25-14	4400:All	No

Level of Service Determination (if not F)

$D_R = 4.252 + 0.0086\, V_{12} - 0.009\, L_D$

D_R = 35.3 (pc/mi/ln)
LOS = E (Exhibit 25-4)

Speed Determination

D_s = 0.323 (Exhibit 25-19)
S_R = 57.6 mph (Exhibit 25-19)
S_0 = 64.7 mph (Exhibit 25-19)
S = 60.1 mph (Exhibit 25-15)

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RAMPS AND RAMP JUNCTIONS WORKSHEET

General Information / Site Information

Analyst	Caroline Kone	Freeway/Dir of Travel	I-440 EB
Agency or Company	WSP SELLS	Junction	on-ramp from Glenwood WB
Date Performed	6/17/2010	Jurisdiction	Raleigh/NCDOT/FHWA
Analysis Time Period	AM No-Build	Analysis Year	2035

Project Description Crabtree Valley

Inputs

Upstream Adj Ramp
☑ Yes ☑ On
☐ No ☐ Off
L_{up} = 1300 ft
V_u = 2634 veh/h

Terrain: Level
S_{FF} = 65.0 mph S_{FR} = 45.0 mph
Sketch (show lanes, L_A, L_D, V_R, V_f)

Downstream Adj Ramp
☐ Yes ☐ On
☑ No ☐ Off
L_{down} = ft
V_D = veh/h

Conversion to pc/h Under Base Conditions

(pc/h)	V (Veh/hr)	PHF	Terrain	%Truck	%Rv	f_{HV}	f_p	v = V/PHF x f_{HV} x f_p
Freeway	8232	1.00	Level	3	0	0.985	1.00	8355
Ramp	587	1.00	Level	2	0	0.990	1.00	593
UpStream	2634	1.00	Level	2	0	0.990	1.00	2660
DownStream								

Merge Areas

Estimation of v_{12}

$V_{12} = V_F (P_{FM})$
L_{EQ} = (Equation 25-2 or 25-3)
P_{FM} = 0.144 using Equation (Exhibit 25-5)
V_{12} = 1200 pc/h
V_3 or V_{av34} 3577 pc/h (Equation 25-4 or 25-5)
Is V_3 or V_{av34} > 2,700 pc/h? ☑ Yes ☐ No
Is V_3 or V_{av34} > 1.5 * V_{12}/2 ☑ Yes ☐ No
If Yes, V_{12a} = 3342 pc/h (Equation 25-8)

Capacity Checks

	Actual	Capacity		LOS F?
V_{FO}	8948	Exhibit 25-7		No

Flow Entering Merge Influence Area

	Actual	Max Desirable		Violation?
V_{R12}	3935	Exhibit 25-7	4600:All	No

Level of Service Determination (if not F)

$D_R = 5.475 + 0.00734\ v_R + 0.0078\ V_{12} - 0.00627\ L_A$
D_R = 26.5 (pc/mi/ln)
LOS = C (Exhibit 25-4)

Speed Determination

M_S = 0.386 (Exibit 25-19)
S_R = 56.1 mph (Exhibit 25-19)
S_0 = 57.2 mph (Exhibit 25-19)
S = 56.7 mph (Exhibit 25-14)

Diverge Areas

Estimation of v_{12}

$V_{12} = V_R + (V_F - V_R)P_{FD}$
L_{EQ} = (Equation 25-8 or 25-9)
P_{FD} = using Equation (Exhibit 25-12)
V_{12} = pc/h
V_3 or V_{av34} pc/h (Equation 25-15 or 25-16)
Is V_3 or V_{av34} > 2,700 pc/h? ☐ Yes ☐ No
Is V_3 or V_{av34} > 1.5 * V_{12}/2 ☐ Yes ☐ No
If Yes, V_{12a} = pc/h (Equation 25-18)

Capacity Checks

	Actual	Capacity		LOS F?
V_F		Exhibit 25-14		
$V_{FO} = V_F - V_R$		Exhibit 25-14		
V_R		Exhibit 25-3		

Flow Entering Diverge Influence Area

	Actual	Max Desirable		Violation?
V_{12}		Exhibit 25-14		

Level of Service Determination (if not F)

$D_R = 4.252 + 0.0086\ V_{12} - 0.009\ L_D$
D_R = (pc/mi/ln)
LOS = (Exhibit 25-4)

Speed Determination

D_s = (Exhibit 25-19)
S_R = mph (Exhibit 25-19)
S_0 = mph (Exhibit 25-19)
S = mph (Exhibit 25-15)

FREEWAY WEAVING WORKSHEET

General Information

Analyst	
Agency/Company	WSP SELLS
Date Performed	6/17/2010
Analysis Time Period	AM No-Build

Site Information

Freeway/Dir of Travel	I-440 EB
Weaving Seg Location	Ridge Rd on to Glenwood off
Jurisdiction	Raleigh/NCDOT/FHWA
Analysis Year	2035

Inputs

Freeway free-flow speed, S_{FF} (mi/h)	65	Weaving type	A
Weaving number of lanes, N	4	Volume ratio, VR	0.30
Weaving seg length, L (ft)	700	Weaving ratio, R	0.27
Terrain	Level		

Conversions to pc/h Under Base Conditions

(pc/h)	V	PHF	Truck %	RV %	E_T	E_R	f_{HV}	fp	v
V_{o1}	5022	1.00	3	0	1.5	1.2	0.985	1.00	5097
V_{o2}	0	1.00	2	0	1.5	1.2	0.990	1.00	0
V_{w1}	1555	1.00	2	0	1.5	1.2	0.990	1.00	1570
V_{w2}	576	1.00	2	0	1.5	1.2	0.990	1.00	581
V_w				2151	V_{nw}				5097
V									7248

Weaving and Non-Weaving Speeds

	Unconstrained		Constrained	
	Weaving (i = w)	Non-Weaving (i = nw)	Weaving (i = w)	Non-Weaving (= nw)
a (Exhibit 24-6)			0.35	0.0020
b (Exhibit 24-6)			2.20	4.00
c (Exhibit 24-6)			0.97	1.30
d (Exhibit 24-6)			0.80	0.75
Weaving intensity factor, Wi			4.75	0.71
Weaving and non-weaving speeds, Si (mi/h)			24.57	47.07

Number of lanes required for unconstrained operation, Nw 1.48
Maximum number of lanes, Nw (max) 1.40

☐ If Nw < Nw(max) unconstrained operation ☑ if Nw > Nw (max) constrained operation

Weaving Segment Speed, Density, Level of Service, and Capacity

Weaving segment speed, S (mi/h)	37.01
Weaving segment density, D (pc/mi/ln)	48.96
Level of service, LOS	F
Capacity of base condition, c_b (pc/h)	6516
Capacity as a 15-minute flow rate, c (veh/h)	6420
Capacity as a full-hour volume, c_h (veh/h)	6420

Notes

a. Weaving segments longer than 2500 ft. are treated as isolated merge and diverge areas using the procedures of Chapter 25, "Ramps and Ramp Junctions".
b. Capacity constrained by basic freeway capacity.
c. Capacity occurs under constrained operating conditions.
d. Three-lane Type A segments do not operate well at volume ratios greater than 0.45. Poor operations and some local queuing are expected in such cases.
e. Four-lane Type A segments do not operate well at volume ratios greater than 0.35. Poor operations and some local queuing are expected in such cases.
f. Capacity constrained by maximum allowable weaving flow rate: 2,800 pc/h (Type A), 4,000 (Type B), 3,500 (Type C).
g. Five-lane Type A segments do not operate well at volume ratios greater than 0.20. Poor operations and some local queuing are expected in such cases.
h. Type B weaving segments do not operate well at volume ratios greater than 0.80. Poor operations and some local queuing are expected in such cases.
i. Type C weaving segments do not operate well at volume ratios greater than 0.50. Poor operations and some local queuing are expected in such cases.

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RAMPS AND RAMP JUNCTIONS WORKSHEET

General Information / Site Information

Analyst	Caroline Kone	Freeway/Dir of Travel	I-440 WB
Agency or Company	WSP SELLS	Junction	off-ramp to Glenwood WB
Date Performed	6/17/2010	Jurisdiction	Raleigh/NCDOT/FHWA
Analysis Time Period	AM No-Build	Analysis Year	2035

Project Description: Crabtree Valley

Inputs

Upstream Adj Ramp	Terrain: Level	Downstream Adj Ramp
☐ Yes ☐ On		☐ Yes ☐ On
☑ No ☐ Off		☑ No ☐ Off
L_{up} = ft		L_{down} = ft
V_u = veh/h	S_{FF} = 65.0 mph S_{FR} = 45.0 mph Sketch (show lanes, L_A, L_D, V_R, V_f)	V_D = veh/h

Conversion to pc/h Under Base Conditions

(pc/h)	V (Veh/hr)	PHF	Terrain	%Truck	%Rv	f_{HV}	f_p	v = V/PHF x f_{HV} x f_p
Freeway	12893	1.00	Level	3	0	0.985	1.00	13086
Ramp	0	1.00	Level	2	0	0.990	1.00	0
UpStream								
DownStream								

Merge Areas

Estimation of v_{12}

$V_{12} = V_F (P_{FM})$

L_{EQ} = (Equation 25-2 or 25-3)

P_{FM} = using Equation (Exhibit 25-5)

V_{12} = pc/h

V_3 or V_{av34} pc/h (Equation 25-4 or 25-5)

Is V_3 or V_{av34} > 2,700 pc/h? ☐ Yes ☐ No

Is V_3 or V_{av34} > 1.5 * V_{12}/2 ☐ Yes ☐ No

If Yes, V_{12a} = pc/h (Equation 25-8)

Capacity Checks

	Actual	Capacity		LOS F?
V_{FO}		Exhibit 25-7		

Flow Entering Merge Influence Area

	Actual	Max Desirable		Violation?
V_{R12}		Exhibit 25-7		

Level of Service Determination (if not F)

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

D_R = (pc/mi/ln)

LOS = (Exhibit 25-4)

Speed Determination

M_S = (Exibit 25-19)

S_R = mph (Exhibit 25-19)

S_0 = mph (Exhibit 25-19)

S = mph (Exhibit 25-14)

Diverge Areas

Estimation of v_{12}

$V_{12} = V_R + (V_F - V_R)P_{FD}$

L_{EQ} = (Equation 25-8 or 25-9)

P_{FD} = 0.260 using Equation (Exhibit 25-12)

V_{12} = 2722 pc/h

V_3 or V_{av34} 3873 pc/h (Equation 25-15 or 25-16)

Is V_3 or V_{av34} > 2,700 pc/h? ☑ Yes ☐ No

Is V_3 or V_{av34} > 1.5 * V_{12}/2 ☑ Yes ☐ No

If Yes, V_{12a} = 4187 pc/h (Equation 25-18)

Capacity Checks

	Actual	Capacity		LOS F?
V_F	10469	Exhibit 25-14	9400	Yes
$V_{FO} = V_F - V_R$	10469	Exhibit 25-14	9400	Yes
V_R	0	Exhibit 25-3	4100	No

Flow Entering Diverge Influence Area

	Actual	Max Desirable		Violation?
V_{12}	2722	Exhibit 25-14	4400:All	No

Level of Service Determination (if not F)

D_R = ~~4.252 + 0.0086 V_{12} - 0.009 L_D~~ $0.0109 \frac{V_f}{N}$

D_R = ~~26.8~~ (pc/mi/ln) 28.53

LOS = ~~F~~ (Exhibit 25-4) D

Speed Determination

D_s = 0.298 (Exhibit 25-19)

S_R = 58.1 mph (Exhibit 25-19)

S_0 = 63.0 mph (Exhibit 25-19)

S = 60.9 mph (Exhibit 25-15)

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RAMPS AND RAMP JUNCTIONS WORKSHEET

General Information / Site Information

Analyst	Caroline Kone	Freeway/Dir of Travel	I-440 WB
Agency or Company	WSP SELLS	Junction	on-ramp from Glenwood EB
Date Performed	6/17/2010	Jurisdiction	Raleigh/NCDOT/FHWA
Analysis Time Period	AM No-Build	Analysis Year	2035

Project Description Crabtree Valley

Inputs

Upstream Adj Ramp
☑ Yes ☐ On
☐ No ☑ Off
L_{up} = 1500 ft
V_u = 1238 veh/h

Terrain: Level
S_{FF} = 65.0 mph S_{FR} = 45.0 mph
Sketch (show lanes, L_A, L_D, V_R, V_f)

Downstream Adj Ramp
☐ Yes ☐ On
☑ No ☐ Off
L_{down} = ft
V_D = veh/h

Conversion to pc/h Under Base Conditions

(pc/h)	V (Veh/hr)	PHF	Terrain	%Truck	%Rv	f_{HV}	f_p	$v = V/PHF \times f_{HV} \times f_p$
Freeway	8951	1.00	Level	3	0	0.985	1.00	9085
Ramp	1966	1.00	Level	2	0	0.990	1.00	1986
UpStream	1238	1.00	Level	2	0	0.990	1.00	1250
DownStream								

Merge Areas

Estimation of v_{12}

$V_{12} = V_F (P_{FM})$

L_{EQ} = 2684.67 (Equation 25-2 or 25-3)
P_{FM} = 0.526 using Equation (Exhibit 25-5)
V_{12} = 4775 pc/h
V_3 or V_{av34} 4310 pc/h (Equation 25-4 or 25-5)
Is V_3 or V_{av34} > 2,700 pc/h? ☑ Yes ☐ No
Is V_3 or V_{av34} > 1.5 * V_{12}/2 ☐ Yes ☑ No
If Yes, V_{12a} = 6385 pc/h (Equation 25-8)

Capacity Checks

	Actual	Capacity		LOS F?
V_{FO}	11071	Exhibit 25-7		Yes

Flow Entering Merge Influence Area

	Actual	Max Desirable		Violation?
V_{R12}	8371	Exhibit 25-7	4600:All	Yes

Level of Service Determination (if not F)

$D_R = 5.475 + 0.00734\, v_R + 0.0078\, V_{12} - 0.00627\, L_A$

D_R = 64.7 (pc/mi/ln)
LOS = F (Exhibit 25-4)

Speed Determination

M_S = 17.095 (Exibit 25-19)
S_R = -328.2 mph (Exhibit 25-19)
S_0 = 56.1 mph (Exhibit 25-19)
S = 488.8 mph (Exhibit 25-14)

Diverge Areas

Estimation of v_{12}

$V_{12} = V_R + (V_F - V_R)P_{FD}$

L_{EQ} = (Equation 25-8 or 25-9)
P_{FD} = using Equation (Exhibit 25-12)
V_{12} = pc/h
V_3 or V_{av34} pc/h (Equation 25-15 or 25-16)
Is V_3 or V_{av34} > 2,700 pc/h? ☐ Yes ☐ No
Is V_3 or V_{av34} > 1.5 * V_{12}/2 ☐ Yes ☐ No
If Yes, V_{12a} = pc/h (Equation 25-18)

Capacity Checks

	Actual	Capacity		LOS F?
V_F		Exhibit 25-14		
$V_{FO} = V_F - V_R$		Exhibit 25-14		
V_R		Exhibit 25-3		

Flow Entering Diverge Influence Area

	Actual	Max Desirable		Violation?
V_{12}		Exhibit 25-14		

Level of Service Determination (if not F)

$D_R = 4.252 + 0.0086\, V_{12} - 0.009\, L_D$

D_R = (pc/mi/ln)
LOS = (Exhibit 25-4)

Speed Determination

D_s = (Exhibit 25-19)
S_R = mph (Exhibit 25-19)
S_0 = mph (Exhibit 25-19)
S = mph (Exhibit 25-15)

FREEWAY WEAVING WORKSHEET

General Information

Analyst	Caroline Kone
Agency/Company	WSP SELLS
Date Performed	6/17/2010
Analysis Time Period	AM No-Build

Site Information

Freeway/Dir of Travel	I-440 WB
Weaving Seg Location	Glen. WB on to Glen. EB off
Jurisdiction	Raleigh/NCDOT/FHWA
Analysis Year	2035

Inputs

Freeway free-flow speed, S_{FF} (mi/h)	65	Weaving type	A
Weaving number of lanes, N	4	Volume ratio, VR	0.14
Weaving seg length, L (ft)	630	Weaving ratio, R	0.14
Terrain	Level		

Conversions to pc/h Under Base Conditions

(pc/h)	V	PHF	Truck %	RV %	E_T	E_R	f_{HV}	f_p	v
V_{o1}	8754	1.00	3	0	1.5	1.2	0.985	1.00	8885
V_{o2}	0	1.00	2	0	1.5	1.2	0.990	1.00	0
V_{w1}	1238	1.00	2	0	1.5	1.2	0.990	1.00	1250
V_{w2}	197	1.00	2	0	1.5	1.2	0.990	1.00	198
V_w				1448	V_{nw}				8885
V									10333

Weaving and Non-Weaving Speeds

	Unconstrained		Constrained	
	Weaving (i = w)	Non-Weaving (i = nw)	Weaving (i = w)	Non-Weaving (= nw)
a (Exhibit 24-6)	0.15	0.0035		
b (Exhibit 24-6)	2.20	4.00		
c (Exhibit 24-6)	0.97	1.30		
d (Exhibit 24-6)	0.80	0.75		
Weaving intensity factor, Wi	2.35	1.28		
Weaving and non-weaving speeds, Si (mi/h)	31.40	39.09		

Number of lanes required for unconstrained operation, Nw 0.96
Maximum number of lanes, Nw (max) 1.40

☑ If Nw < Nw(max) unconstrained operation ☐ If Nw > Nw (max) constrained operation

Weaving Segment Speed, Density, Level of Service, and Capacity

Weaving segment speed, S (mi/h)	37.79
Weaving segment density, D (pc/mi/ln)	68.35
Level of service, LOS	F
Capacity of base condition, c_b (pc/h)	7392
Capacity as a 15-minute flow rate, c (veh/h)	7283
Capacity as a full-hour volume, c_h (veh/h)	7283

Notes

a. Weaving segments longer than 2500 ft. are treated as isolated merge and diverge areas using the procedures of Chapter 25, "Ramps and Ramp Junctions".
b. Capacity constrained by basic freeway capacity.
c. Capacity occurs under constrained operating conditions.
d. Three-lane Type A segments do not operate well at volume ratios greater than 0.45. Poor operations and some local queuing are expected in such cases.
e. Four-lane Type A segments do not operate well at volume ratios greater than 0.35. Poor operations and some local queuing are expected in such cases.
f. Capacity constrained by maximum allowable weaving flow rate: 2,800 pc/h (Type A), 4,000 (Type B), 3,500 (Type C).
g. Five-lane Type A segments do not operate well at volume ratios greater than 0.20. Poor operations and some local queuing are expected in such cases.
h. Type B weaving segments do not operate well at volume ratios greater than 0.80. Poor operations and some local queuing are expected in such cases.
i. Type C weaving segments do not operate well at volume ratios greater than 0.50. Poor operations and some local queuing are expected in such cases.

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RAMPS AND RAMP JUNCTIONS WORKSHEET

General Information / Site Information

Analyst	Caroline Kone	Freeway/Dir of Travel	I-440 EB
Agency or Company	WSP SELLS	Junction	off-ramp to Ridge Rd
Date Performed	6/17/2010	Jurisdiction	Raleigh/NCDOT/FHWA
Analysis Time Period	PM No-Build	Analysis Year	2035

Project Description Crabtree Valley

Inputs

Upstream Adj Ramp	Terrain: Level	Downstream Adj Ramp
☐ Yes ☐ On		☑ Yes ☑ On
☑ No ☐ Off		☐ No ☐ Off
L_{up} = ft		L_{down} = 830 ft
V_u = veh/h	S_{FF} = 65.0 mph S_{FR} = 45.0 mph Sketch (show lanes, L_A, L_D, V_R, V_f)	V_D = 566 veh/h

Conversion to pc/h Under Base Conditions

(pc/h)	V (Veh/hr)	PHF	Terrain	%Truck	%Rv	f_{HV}	f_p	v = V/PHF x f_{HV} x f_p
Freeway	8463	1.00	Level	3	0	0.985	1.00	8590
Ramp	271	1.00	Level	2	0	0.990	1.00	274
UpStream								
DownStream	566	1.00	Level	2	0	0.990	1.00	572

Merge Areas

Estimation of v_{12}

$V_{12} = V_F (P_{FM})$

L_{EQ} = (Equation 25-2 or 25-3)

P_{FM} = using Equation (Exhibit 25-5)

V_{12} = pc/h

V_3 or V_{av34} pc/h (Equation 25-4 or 25-5)

Is V_3 or V_{av34} > 2,700 pc/h? ☐ Yes ☐ No

Is V_3 or V_{av34} > 1.5 * V_{12}/2 ☐ Yes ☐ No

If Yes, V_{12a} = pc/h (Equation 25-8)

Capacity Checks

	Actual	Capacity		LOS F?
V_{FO}		Exhibit 25-7		

Flow Entering Merge Influence Area

	Actual	Max Desirable		Violation?
V_{R12}		Exhibit 25-7		

Level of Service Determination (if not F)

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

D_R = (pc/mi/ln)

LOS = (Exhibit 25-4)

Speed Determination

M_S = (Exibit 25-19)

S_R = mph (Exhibit 25-19)

S_0 = mph (Exhibit 25-19)

S = mph (Exhibit 25-14)

Diverge Areas

Estimation of v_{12}

$V_{12} = V_R + (V_F - V_R)P_{FD}$

L_{EQ} = (Equation 25-8 or 25-9)

P_{FD} = 0.533 using Equation (Exhibit 25-12)

V_{12} = 4703 pc/h

V_3 or V_{av34} 3887 pc/h (Equation 25-15 or 25-16)

Is V_3 or V_{av34} > 2,700 pc/h? ☑ Yes ☐ No

Is V_3 or V_{av34} > 1.5 * V_{12}/2 ☐ Yes ☑ No

If Yes, V_{12a} = 5890 pc/h (Equation 25-18)

Capacity Checks

	Actual	Capacity		LOS F?
V_F	8590	Exhibit 25-14	7050	Yes
$V_{FO} = V_F - V_R$	8316	Exhibit 25-14	7050	Yes
V_R	274	Exhibit 25-3	2100	No

Flow Entering Diverge Influence Area

	Actual	Max Desirable		Violation?
V_{12}	4703	Exhibit 25-14	4400:All	Yes

Level of Service Determination (if not F)

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

D_R = 49.3 (pc/mi/ln)

LOS = F (Exhibit 25-4)

Speed Determination

D_s = 0.323 (Exhibit 25-19)

S_R = 57.6 mph (Exhibit 25-19)

S_0 = 64.7 mph (Exhibit 25-19)

S = 59.6 mph (Exhibit 25-15)

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RAMPS AND RAMP JUNCTIONS WORKSHEET

General Information / Site Information

Analyst	Caroline Kone	Freeway/Dir of Travel	I-440 EB
Agency or Company	WSP SELLS	Junction	on-ramp from Glenwood WB
Date Performed	6/17/2010	Jurisdiction	Raleigh/NCDOT/FHWA
Analysis Time Period	PM No-Build	Analysis Year	2035

Project Description Crabtree Valley

Inputs

Upstream Adj Ramp
☑ Yes ☑ On
☐ No ☐ Off
L_{up} = 1300 ft
V_u = 3181 veh/h

Terrain: Level

S_{FF} = 65.0 mph S_{FR} = 45.0 mph
Sketch (show lanes, L_A, L_D, V_R, V_f)

Downstream Adj Ramp
☐ Yes ☐ On
☑ No ☐ Off
L_{down} = ft
V_D = veh/h

Conversion to pc/h Under Base Conditions

(pc/h)	V (Veh/hr)	PHF	Terrain	%Truck	%Rv	f_{HV}	f_p	$v = V/PHF \times f_{HV} \times f_p$
Freeway	9468	1.00	Level	3	0	0.985	1.00	9610
Ramp	524	1.00	Level	2	0	0.990	1.00	529
UpStream	3181	1.00	Level	2	0	0.990	1.00	3213
DownStream								

Merge Areas

Estimation of v_{12}

$V_{12} = V_F (P_{FM})$

L_{EQ} = (Equation 25-2 or 25-3)
P_{FM} = 0.152 using Equation (Exhibit 25-5)
V_{12} = 1458 pc/h
V_3 or V_{av34} 4076 pc/h (Equation 25-4 or 25-5)
Is V_3 or V_{av34} > 2,700 pc/h? ☑ Yes ☐ No
Is V_3 or V_{av34} > 1.5 * V_{12}/2 ☑ Yes ☐ No
If Yes, V_{12a} = 3844 pc/h (Equation 25-8)

Capacity Checks

	Actual	Capacity		LOS F?
V_{FO}	10139	Exhibit 25-7		Yes

Flow Entering Merge Influence Area

	Actual	Max Desirable		Violation?
V_{R12}	4373	Exhibit 25-7	4600:All	No

Level of Service Determination (if not F)

$D_R = 5.475 + 0.00734\, v_R + 0.0078\, V_{12} - 0.00627\, L_A$

D_R = 29.9 (pc/mi/ln)
LOS = F (Exhibit 25-4)

Speed Determination

M_S = 0.495 (Exibit 25-19)
S_R = 53.6 mph (Exhibit 25-19)
S_0 = 55.0 mph (Exhibit 25-19)
S = 54.4 mph (Exhibit 25-14)

Diverge Areas

Estimation of v_{12}

$V_{12} = V_R + (V_F - V_R) P_{FD}$

L_{EQ} = (Equation 25-8 or 25-9)
P_{FD} = using Equation (Exhibit 25-12)
V_{12} = pc/h
V_3 or V_{av34} pc/h (Equation 25-15 or 25-16)
Is V_3 or V_{av34} > 2,700 pc/h? ☐ Yes ☐ No
Is V_3 or V_{av34} > 1.5 * V_{12}/2 ☐ Yes ☐ No
If Yes, V_{12a} = pc/h (Equation 25-18)

Capacity Checks

	Actual	Capacity		LOS F?
V_F		Exhibit 25-14		
$V_{FO} = V_F - V_R$		Exhibit 25-14		
V_R		Exhibit 25-3		

Flow Entering Diverge Influence Area

	Actual	Max Desirable		Violation?
V_{12}		Exhibit 25-14		

Level of Service Determination (if not F)

$D_R = 4.252 + 0.0086\, V_{12} - 0.009\, L_D$

D_R = (pc/mi/ln)
LOS = (Exhibit 25-4)

Speed Determination

D_s = (Exhibit 25-19)
S_R = mph (Exhibit 25-19)
S_0 = mph (Exhibit 25-19)
S = mph (Exhibit 25-15)

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FREEWAY WEAVING WORKSHEET

General Information

Analyst	G Teng
Agency/Company	WSP SELLS
Date Performed	6/17/2010
Analysis Time Period	PM No-Build

Site Information

Freeway/Dir of Travel	I-440 EB
Weaving Seg Location	Ridge Rd on to Glenwood off
Jurisdiction	Raleigh/NCDOT/FHWA
Analysis Year	2035

Inputs

Freeway free-flow speed, S_{FF} (mi/h)	65	Weaving type	A
Weaving number of lanes, N	4	Volume ratio, VR	0.35
Weaving seg length, L (ft)	700	Weaving ratio, R	0.19
Terrain	Level		

Conversions to pc/h Under Base Conditions

(pc/h)	V	PHF	Truck %	RV %	E_T	E_R	f_{HV}	fp	v
V_{o1}	5721	1.00	3	0	1.5	1.2	0.985	1.00	5806
V_{o2}	0	1.00	2	0	1.5	1.2	0.990	1.00	0
V_{w1}	2471	1.00	2	0	1.5	1.2	0.990	1.00	2495
V_{w2}	566	1.00	2	0	1.5	1.2	0.990	1.00	571
V_w				3066	V_{nw}				5806
V									8872

Weaving and Non-Weaving Speeds

	Unconstrained		Constrained	
	Weaving (i = w)	Non-Weaving (i = nw)	Weaving (i = w)	Non-Weaving (= nw)
a (Exhibit 24-6)			0.35	0.0020
b (Exhibit 24-6)			2.20	4.00
c (Exhibit 24-6)			0.97	1.30
d (Exhibit 24-6)			0.80	0.75
Weaving intensity factor, Wi			6.27	1.08
Weaving and non-weaving speeds, Si (mi/h)			22.57	41.47

Number of lanes required for unconstrained operation, Nw 1.69
Maximum number of lanes, Nw (max) 1.40

☐ If Nw < Nw(max) unconstrained operation ☑ if Nw > Nw (max) constrained operation

Weaving Segment Speed, Density, Level of Service, and Capacity

Weaving segment speed, S (mi/h)	32.16
Weaving segment density, D (pc/mi/ln)	68.97
Level of service, LOS	F
Capacity of base condition, c_b (pc/h)	6199
Capacity as a 15-minute flow rate, c (veh/h)	6107
Capacity as a full-hour volume, c_h (veh/h)	6107

Notes

a. Weaving segments longer than 2500 ft. are treated as isolated merge and diverge areas using the procedures of Chapter 25, "Ramps and Ramp Junctions".
b. Capacity constrained by basic freeway capacity.
c. Capacity occurs under constrained operating conditions.
d. Three-lane Type A segments do not operate well at volume ratios greater than 0.45. Poor operations and some local queuing are expected in such cases.
e. Four-lane Type A segments do not operate well at volume ratios greater than 0.35. Poor operations and some local queuing are expected in such cases.
f. Capacity constrained by maximum allowable weaving flow rate: 2,800 pc/h (Type A), 4,000 (Type B), 3,500 (Type C).
g. Five-lane Type A segments do not operate well at volume ratios greater than 0.20. Poor operations and some local queuing are expected in such cases.
h. Type B weaving segments do not operate well at volume ratios greater than 0.80. Poor operations and some local queuing are expected in such cases.
i. Type C weaving segments do not operate well at volume ratios greater than 0.50. Poor operations and some local queuing are expected in such cases.

RAMPS AND RAMP JUNCTIONS WORKSHEET

General Information / Site Information

Analyst	Caroline Kone	Freeway/Dir of Travel	I-440 WB
Agency or Company	WSP SELLS	Junction	off-ramp to Glenwood WB
Date Performed	6/17/2010	Jurisdiction	Raleigh/NCDOT/FHWA
Analysis Time Period	PM No-Build	Analysis Year	2035

Project Description Crabtree Valley

Inputs

Upstream Adj Ramp: ☐ Yes ☐ On ☑ No ☐ Off

L_{up} = ft

V_u = veh/h

Terrain: Level

S_{FF} = 65.0 mph S_{FR} = 45.0 mph

Sketch (show lanes, L_A, L_D, V_R, V_f)

Downstream Adj Ramp: ☐ Yes ☐ On ☑ No ☐ Off

L_{down} = ft

V_D = veh/h

Conversion to pc/h Under Base Conditions

(pc/h)	V (Veh/hr)	PHF	Terrain	%Truck	%Rv	f_{HV}	f_p	$v = V/PHF \times f_{HV} \times f_p$
Freeway	11115	1.00	Level	3	0	0.985	1.00	11282
Ramp	0	1.00	Level	2	0	0.990	1.00	0
UpStream								
DownStream								

Merge Areas

Estimation of v_{12}

$V_{12} = V_F (P_{FM})$

L_{EQ} = (Equation 25-2 or 25-3)

P_{FM} = using Equation (Exhibit 25-5)

V_{12} = pc/h

V_3 or V_{av34} pc/h (Equation 25-4 or 25-5)

Is V_3 or V_{av34} > 2,700 pc/h? ☐ Yes ☐ No

Is V_3 or V_{av34} > 1.5 * V_{12}/2 ☐ Yes ☐ No

If Yes, V_{12a} = pc/h (Equation 25-8)

Capacity Checks

	Actual	Capacity		LOS F?
V_{FO}		Exhibit 25-7		

Flow Entering Merge Influence Area

	Actual	Max Desirable		Violation?
V_{R12}		Exhibit 25-7		

Level of Service Determination (if not F)

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

D_R = (pc/mi/ln)

LOS = (Exhibit 25-4)

Speed Determination

M_S = (Exibit 25-19)

S_R = mph (Exhibit 25-19)

S_0 = mph (Exhibit 25-19)

S = mph (Exhibit 25-14)

Diverge Areas

Estimation of v_{12}

$V_{12} = V_R + (V_F - V_R) P_{FD}$

L_{EQ} = (Equation 25-8 or 25-9)

P_{FD} = 0.260 using Equation (Exhibit 25-12)

V_{12} = 2347 pc/h

V_3 or V_{av34} 3339 pc/h (Equation 25-15 or 25-16)

Is V_3 or V_{av34} > 2,700 pc/h? ☑ Yes ☐ No

Is V_3 or V_{av34} > 1.5 * V_{12}/2 ☑ Yes ☐ No

If Yes, V_{12a} = 3610 pc/h (Equation 25-18)

Capacity Checks

	Actual	Capacity		LOS F?
V_F	9026	Exhibit 25-14	9400	No
$V_{FO} = V_F - V_R$	9026	Exhibit 25-14	9400	No
V_R	0	Exhibit 25-3	4100	No

Flow Entering Diverge Influence Area

	Actual	Max Desirable		Violation?
V_{12}	2347	Exhibit 25-14	4400:All	No

Level of Service Determination (if not F)

D_R = ~~4.252 + 0.0086 V_{12} - 0.009 L_D~~ $0.0109\ V_F / N$

D_R = ~~21.8~~ (pc/mi/ln) 24.59

LOS = C (Exhibit 25-4)

Speed Determination

D_s = 0.298 (Exhibit 25-19)

S_R = 58.1 mph (Exhibit 25-19)

S_0 = 64.6 mph (Exhibit 25-19)

S = 61.9 mph (Exhibit 25-15)

RAMPS AND RAMP JUNCTIONS WORKSHEET

General Information / Site Information

Analyst	Caroline Kone	Freeway/Dir of Travel	I-440 Wb
Agency or Company	WSP SELLS	Junction	on-ramp from Glenwood EB
Date Performed	6/17/2010	Jurisdiction	Raleigh/NCDOT/FHWA
Analysis Time Period	PM No-Build	Analysis Year	2035

Project Description: Crabtree Valley

Inputs

Upstream Adj Ramp: ☑ Yes ☐ On; ☐ No ☑ Off

L_{up} = 1500 ft

V_u = 1056 veh/h

Terrain: Level

S_{FF} = 65.0 mph S_{FR} = 45.0 mph

Sketch (show lanes, L_A, L_D, V_R, V_f)

Downstream Adj Ramp: ☐ Yes ☐ On; ☑ No ☐ Off

L_{down} = ft

V_D = veh/h

Conversion to pc/h Under Base Conditions

(pc/h)	V (Veh/hr)	PHF	Terrain	%Truck	%Rv	f_{HV}	f_p	$v = V/PHF \times f_{HV} \times f_p$
Freeway	6017	1.00	Level	3	0	0.985	1.00	6107
Ramp	2566	1.00	Level	2	0	0.990	1.00	2592
UpStream	1056	1.00	Level	2	0	0.990	1.00	1067
DownStream								

Merge Areas

Estimation of v_{12}

$V_{12} = V_F (P_{FM})$

L_{EQ} = 2177.07 (Equation 25-2 or 25-3)

P_{FM} = 0.558 using Equation (Exhibit 25-5)

V_{12} = 3406 pc/h

V_3 or V_{av34} 2701 pc/h (Equation 25-4 or 25-5)

Is V_3 or V_{av34} > 2,700 pc/h? ☑ Yes ☐ No

Is V_3 or V_{av34} > 1.5 * V_{12}/2 ☑ Yes ☐ No

If Yes, V_{12a} = 3489 pc/h (Equation 25-8)

Capacity Checks

	Actual	Capacity		LOS F?
V_{FO}	8699	Exhibit 25-7		Yes

Flow Entering Merge Influence Area

	Actual	Max Desirable		Violation?
V_{R12}	6081	Exhibit 25-7	4600:All	Yes

Level of Service Determination (if not F)

$D_R = 5.475 + 0.00734\, v_R + 0.0078\, V_{12} - 0.00627\, L_A$

D_R = 46.6 (pc/mi/ln)

LOS = F (Exhibit 25-4)

Speed Determination

M_S = 1.953 (Exibit 25-19)

S_R = 20.1 mph (Exhibit 25-19)

S_0 = 56.6 mph (Exhibit 25-19)

S = 24.9 mph (Exhibit 25-14)

Diverge Areas

Estimation of v_{12}

$V_{12} = V_R + (V_F - V_R)P_{FD}$

L_{EQ} = (Equation 25-8 or 25-9)

P_{FD} = using Equation (Exhibit 25-12)

V_{12} = pc/h

V_3 or V_{av34} pc/h (Equation 25-15 or 25-16)

Is V_3 or V_{av34} > 2,700 pc/h? ☐ Yes ☐ No

Is V_3 or V_{av34} > 1.5 * V_{12}/2 ☐ Yes ☐ No

If Yes, V_{12a} = pc/h (Equation 25-18)

Capacity Checks

	Actual	Capacity		LOS F?
V_F		Exhibit 25-14		
$V_{FO} = V_F - V_R$		Exhibit 25-14		
V_R		Exhibit 25-3		

Flow Entering Diverge Influence Area

	Actual	Max Desirable		Violation?
V_{12}		Exhibit 25-14		

Level of Service Determination (if not F)

$D_R = 4.252 + 0.0086\, V_{12} - 0.009\, L_D$

D_R = (pc/mi/ln)

LOS = (Exhibit 25-4)

Speed Determination

D_s = (Exhibit 25-19)

S_R = mph (Exhibit 25-19)

S_0 = mph (Exhibit 25-19)

S = mph (Exhibit 25-15)

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FREEWAY WEAVING WORKSHEET

General Information

Analyst	
Agency/Company	WSP SELLS
Date Performed	6/17/2010
Analysis Time Period	PM No-Build

Site Information

Freeway/Dir of Travel	I-440 WB
Weaving Seg Location	Glen. WB on to Glen. EB off
Jurisdiction	Raleigh/NCDOT/FHWA
Analysis Year	2035

Inputs

Freeway free-flow speed, S_{FF} (mi/h)	65	Weaving type	A
Weaving number of lanes, N	4	Volume ratio, VR	0.19
Weaving seg length, L (ft)	630	Weaving ratio, R	0.20
Terrain	Level		

Conversions to pc/h Under Base Conditions

(pc/h)	V	PHF	Truck %	RV %	E_T	E_R	f_{HV}	fp	v
V_{o1}	5746	1.00	3	0	1.5	1.2	0.985	1.00	5832
V_{o2}	0	1.00	2	0	1.5	1.2	0.990	1.00	0
V_{w1}	1056	1.00	2	0	1.5	1.2	0.990	1.00	1066
V_{w2}	271	1.00	2	0	1.5	1.2	0.990	1.00	273
V_w				1339	V_{nw}				5832
V									7171

Weaving and Non-Weaving Speeds

	Unconstrained		Constrained	
	Weaving (i = w)	Non-Weaving (i = nw)	Weaving (i = w)	Non-Weaving (= nw)
a (Exhibit 24-6)	0.15	0.0035		
b (Exhibit 24-6)	2.20	4.00		
c (Exhibit 24-6)	0.97	1.30		
d (Exhibit 24-6)	0.80	0.75		
Weaving intensity factor, Wi	1.80	0.94		
Weaving and non-weaving speeds, Si (mi/h)	34.62	43.40		

Number of lanes required for unconstrained operation, Nw 1.09
Maximum number of lanes, Nw (max) 1.40

☑ If Nw < Nw(max) unconstrained operation ☐ If Nw > Nw (max) constrained operation

Weaving Segment Speed, Density, Level of Service, and Capacity

Weaving segment speed, S (mi/h)	41.44
Weaving segment density, D (pc/mi/ln)	43.26
Level of service, LOS	F
Capacity of base condition, c_b (pc/h)	7082
Capacity as a 15-minute flow rate, c (veh/h)	6977
Capacity as a full-hour volume, c_h (veh/h)	6977

Notes

a. Weaving segments longer than 2500 ft. are treated as isolated merge and diverge areas using the procedures of Chapter 25, "Ramps and Ramp Junctions".
b. Capacity constrained by basic freeway capacity.
c. Capacity occurs under constrained operating conditions.
d. Three-lane Type A segments do not operate well at volume ratios greater than 0.45. Poor operations and some local queuing are expected in such cases.
e. Four-lane Type A segments do not operate well at volume ratios greater than 0.35. Poor operations and some local queuing are expected in such cases.
f. Capacity constrained by maximum allowable weaving flow rate: 2,800 pc/h (Type A), 4,000 (Type B), 3,500 (Type C).
g. Five-lane Type A segments do not operate well at volume ratios greater than 0.20. Poor operations and some local queuing are expected in such cases.
h. Type B weaving segments do not operate well at volume ratios greater than 0.80. Poor operations and some local queuing are expected in such cases.
i. Type C weaving segments do not operate well at volume ratios greater than 0.50. Poor operations and some local queuing are expected in such cases.

Ridge Road Improvements (2009)

RAMPS AND RAMP JUNCTIONS WORKSHEET

General Information / Site Information

Analyst	Caroline Kone	Freeway/Dir of Travel	I-440 EB
Agency or Company	WSPSELLS	Junction	off-ramp to Ridge Rd
Date Performed	6/16/2010	Jurisdiction	Raleigh?NCDOT/FHWA
Analysis Time Period	AM CVA_Ridge Improve	Analysis Year	2009

Project Description Crabtree Valley

Inputs

Upstream Adj Ramp
☐ Yes ☐ On
☑ No ☐ Off
L_{up} = ft
V_u = veh/h

Terrain: Level

S_{FF} = 65.0 mph S_{FR} = 45.0 mph
Sketch (show lanes, L_A, L_D,V_R,V_f)

Downstream Adj Ramp
☑ Yes ☑ On
☐ No ☐ Off
L_{down} = 600 ft
V_D = 1397 veh/h

Conversion to pc/h Under Base Conditions

(pc/h)	V (Veh/hr)	PHF	Terrain	%Truck	%Rv	f_{HV}	f_p	v = V/PHF x f_{HV} x f_p
Freeway	3606	0.92	Level	3	0	0.985	1.00	3978
Ramp	144	0.92	Level	2	0	0.990	1.00	158
UpStream								
DownStream	1397	0.92	Level	2	0	0.990	1.00	1534

Merge Areas

Estimation of v_{12}

$V_{12} = V_F (P_{FM})$
L_{EQ} = (Equation 25-2 or 25-3)
P_{FM} = using Equation (Exhibit 25-5)
V_{12} = pc/h
V_3 or V_{av34} pc/h (Equation 25-4 or 25-5)
Is V_3 or V_{av34} > 2,700 pc/h? ☐ Yes ☐ No
Is V_3 or V_{av34} > 1.5 * V_{12}/2 ☐ Yes ☐ No
If Yes,V_{12a} = pc/h (Equation 25-8)

Capacity Checks

	Actual	Capacity		LOS F?
V_{FO}		Exhibit 25-7		

Flow Entering Merge Influence Area

	Actual	Max Desirable		Violation?
V_{R12}		Exhibit 25-7		

Level of Service Determination (if not F)

$D_R = 5.475 + 0.00734\ v_R + 0.0078\ V_{12} - 0.00627\ L_A$
D_R = (pc/mi/ln)
LOS = (Exhibit 25-4)

Speed Determination

M_S = (Exibit 25-19)
S_R = mph (Exhibit 25-19)
S_0 = mph (Exhibit 25-19)
S = mph (Exhibit 25-14)

Diverge Areas

Estimation of v_{12}

$V_{12} = V_R + (V_F - V_R)P_{FD}$
L_{EQ} = (Equation 25-8 or 25-9)
P_{FD} = 0.653 using Equation (Exhibit 25-12)
V_{12} = 2654 pc/h
V_3 or V_{av34} 1324 pc/h (Equation 25-15 or 25-16)
Is V_3 or V_{av34} > 2,700 pc/h? ☐ Yes ☑ No
Is V_3 or V_{av34} > 1.5 * V_{12}/2 ☐ Yes ☑ No
If Yes,V_{12a} = pc/h (Equation 25-18)

Capacity Checks

	Actual	Capacity		LOS F?
V_F	3978	Exhibit 25-14	7050	No
$V_{FO} = V_F - V_R$	3820	Exhibit 25-14	7050	No
V_R	158	Exhibit 25-3	2100	No

Flow Entering Diverge Influence Area

	Actual	Max Desirable		Violation?
V_{12}	2654	Exhibit 25-14	4400:All	No

Level of Service Determination (if not F)

$D_R = 4.252 + 0.0086\ V_{12} - 0.009\ L_D$
D_R = 21.5 (pc/mi/ln)
LOS = C (Exhibit 25-4)

Speed Determination

D_s = 0.312 (Exhibit 25-19)
S_R = 57.8 mph (Exhibit 25-19)
S_0 = 70.0 mph (Exhibit 25-19)
S = 61.4 mph (Exhibit 25-15)

RAMPS AND RAMP JUNCTIONS WORKSHEET

General Information / Site Information

Analyst	Caroline Kone	Freeway/Dir of Travel	I-440 EB
Agency or Company	WSP SELLS	Junction	on-ramp from Glenwood WB
Date Performed	6/16/2010	Jurisdiction	Raleigh/NCDOT/FHWA
Analysis Time Period	AM CVA_Ridge Improve	Analysis Year	2009

Project Description Crabtree Valley

Inputs

Upstream Adj Ramp
☑ Yes ☐ On
☐ No ☑ Off
L_{up} = 630 ft
V_u = 818 veh/h

Terrain: Level
S_{FF} = 65.0 mph S_{FR} = 45.0 mph
Sketch (show lanes, L_A, L_D,V_R,V_f)

Downstream Adj Ramp
☐ Yes ☐ On
☑ No ☐ Off
L_{down} = ft
V_D = veh/h

Conversion to pc/h Under Base Conditions

(pc/h)	V (Veh/hr)	PHF	Terrain	%Truck	%Rv	f_{HV}	f_p	$v = V/PHF \times f_{HV} \times f_p$
Freeway	4041	0.92	Level	3	0	0.985	1.00	4458
Ramp	612	0.92	Level	2	0	0.990	1.00	672
UpStream	818	0.92	Level	2	0	0.990	1.00	898
DownStream								

Merge Areas

Estimation of v_{12}

$V_{12} = V_F (P_{FM})$

L_{EQ} = (Equation 25-2 or 25-3)
P_{FM} = 0.134 using Equation (Exhibit 25-5)
V_{12} = 596 pc/h
V_3 or V_{av34} 1931 pc/h (Equation 25-4 or 25-5)
Is V_3 or V_{av34} > 2,700 pc/h? ☐ Yes ☑ No
Is V_3 or V_{av34} > 1.5 * V_{12}/2 ☑ Yes ☐ No
If Yes,V_{12a} = 1783 pc/h (Equation 25-8)

Capacity Checks

	Actual	Capacity		LOS F?
V_{FO}	5130	Exhibit 25-7		No

Flow Entering Merge Influence Area

	Actual	Max Desirable		Violation?
V_{R12}	2455	Exhibit 25-7	4600:All	No

Level of Service Determination (if not F)

$D_R = 5.475 + 0.00734\, v_R + 0.0078\, V_{12} - 0.00627\, L_A$

D_R = 14.9 (pc/mi/ln)
LOS = B (Exhibit 25-4)

Speed Determination

M_S = 0.231 (Exibit 25-19)
S_R = 59.7 mph (Exhibit 25-19)
S_0 = 62.0 mph (Exhibit 25-19)
S = 60.9 mph (Exhibit 25-14)

Diverge Areas

Estimation of v_{12}

$V_{12} = V_R + (V_F - V_R)P_{FD}$

L_{EQ} = (Equation 25-8 or 25-9)
P_{FD} = using Equation (Exhibit 25-12)
V_{12} = pc/h
V_3 or V_{av34} pc/h (Equation 25-15 or 25-16)
Is V_3 or V_{av34} > 2,700 pc/h? ☐ Yes ☐ No
Is V_3 or V_{av34} > 1.5 * V_{12}/2 ☐ Yes ☐ No
If Yes,V_{12a} = pc/h (Equation 25-18)

Capacity Checks

	Actual	Capacity		LOS F?
V_F		Exhibit 25-14		
$V_{FO} = V_F - V_R$		Exhibit 25-14		
V_R		Exhibit 25-3		

Flow Entering Diverge Influence Area

	Actual	Max Desirable		Violation?
V_{12}		Exhibit 25-14		

Level of Service Determination (if not F)

$D_R = 4.252 + 0.0086\, V_{12} - 0.009\, L_D$

D_R = (pc/mi/ln)
LOS = (Exhibit 25-4)

Speed Determination

D_s = (Exhibit 25-19)
S_R = mph (Exhibit 25-19)
S_0 = mph (Exhibit 25-19)
S = mph (Exhibit 25-15)

FREEWAY WEAVING WORKSHEET

General Information

Analyst	G Teng
Agency/Company	WSP SELLS
Date Performed	7/15/2010
Analysis Time Period	Weekday AM Peak Hour

Site Information

Freeway/Dir of Travel	EB I-440 _Ridge Rd Improvement
Weaving Seg Location	Ridge Rd to Glenwood Ave
Jurisdiction	City of Raleigh/NCDOT/FHWA
Analysis Year	2009

Inputs

Freeway free-flow speed, S_{FF} (mi/h)	65	Weaving type	B
Weaving number of lanes, N	4	Volume ratio, VR	0.45
Weaving seg length, L (ft)	2100	Weaving ratio, R	0.37
Terrain	Level		

Conversions to pc/h Under Base Conditions

(pc/h)	V	PHF	Truck %	RV %	E_T	E_R	f_{HV}	f_p	v
V_{o1}	2644	0.92	3	0	1.5	1.2	0.985	1.00	2917
V_{o2}	0	0.92	2	0	1.5	1.2	0.990	1.00	0
V_{w1}	1397	0.92	2	0	1.5	1.2	0.990	1.00	1533
V_{w2}	818	0.92	2	0	1.5	1.2	0.990	1.00	898
V_w				2431	V_{nw}				2917
V									5348

Weaving and Non-Weaving Speeds

	Unconstrained		Constrained	
	Weaving (i = w)	Non-Weaving (i = nw)	Weaving (i = w)	Non-Weaving (= nw)
a (Exhibit 24-6)	0.08	0.0020		
b (Exhibit 24-6)	2.20	6.00		
c (Exhibit 24-6)	0.70	1.00		
d (Exhibit 24-6)	0.50	0.50		
Weaving intensity factor, Wi	0.61	0.55		
Weaving and non-weaving speeds, Si (mi/h)	49.07	50.42		

Number of lanes required for unconstrained operation, Nw 1.97
Maximum number of lanes, Nw (max) 3.50

☑ If Nw < Nw(max) unconstrained operation ☐ if Nw > Nw (max) constrained operation

Weaving Segment Speed, Density, Level of Service, and Capacity

Weaving segment speed, S (mi/h)	49.80
Weaving segment density, D (pc/mi/ln)	26.85
Level of service, LOS	C
Capacity of base condition, c_b (pc/h)	7831
Capacity as a 15-minute flow rate, c (veh/h)	7715
Capacity as a full-hour volume, c_h (veh/h)	7098

Notes

a. Weaving segments longer than 2500 ft. are treated as isolated merge and diverge areas using the procedures of Chapter 25, "Ramps and Ramp Junctions".
b. Capacity constrained by basic freeway capacity.
c. Capacity occurs under constrained operating conditions.
d. Three-lane Type A segments do not operate well at volume ratios greater than 0.45. Poor operations and some local queuing are expected in such cases.
e. Four-lane Type A segments do not operate well at volume ratios greater than 0.35. Poor operations and some local queuing are expected in such cases.
f. Capacity constrained by maximum allowable weaving flow rate: 2,800 pc/h (Type A), 4,000 (Type B), 3,500 (Type C).
g. Five-lane Type A segments do not operate well at volume ratios greater than 0.20. Poor operations and some local queuing are expected in such cases.
h. Type B weaving segments do not operate well at volume ratios greater than 0.80. Poor operations and some local queuing are expected in such cases.
i. Type C weaving segments do not operate well at volume ratios greater than 0.50. Poor operations and some local queuing are expected in such cases.

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RAMPS AND RAMP JUNCTIONS WORKSHEET

General Information / Site Information

Analyst	Caroline Kone	Freeway/Dir of Travel	I-440 WB
Agency or Company	WSP SELLS	Junction	off-ramp to Glenwood EB
Date Performed	6/16/2010	Jurisdiction	Raleigh/NCDOT/FHWA
Analysis Time Period	AM CVA_Ridge Improve	Analysis Year	2009

Project Description Crabtree Valley

Inputs

Upstream Adj Ramp
☑ Yes ☐ On
☐ No ☑ Off
L_{up} = 1350 ft
V_u = 1527 veh/h

Terrain: Level
S_{FF} = 65.0 mph S_{FR} = 45.0 mph
Sketch (show lanes, L_A, L_D,V_R,V_f)

Downstream Adj Ramp
☐ Yes ☐ On
☑ No ☐ Off
L_{down} = ft
V_D = veh/h

Conversion to pc/h Under Base Conditions

(pc/h)	V (Veh/hr)	PHF	Terrain	%Truck	%Rv	f_{HV}	f_p	v = V/PHF x f_{HV} x f_p
Freeway	4608	0.92	Level	3	0	0.985	1.00	5084
Ramp	651	0.92	Level	2	0	0.990	1.00	715
UpStream	1527	0.92	Level	2	0	0.990	1.00	1676
DownStream								

Merge Areas

Estimation of v_{12}

$V_{12} = V_F (P_{FM})$
L_{EQ} = (Equation 25-2 or 25-3)
P_{FM} = using Equation (Exhibit 25-5)
V_{12} = pc/h
V_3 or V_{av34} pc/h (Equation 25-4 or 25-5)
Is V_3 or V_{av34} > 2,700 pc/h? ☐ Yes ☐ No
Is V_3 or V_{av34} > 1.5 * V_{12}/2 ☐ Yes ☐ No
If Yes,V_{12a} = pc/h (Equation 25-8)

Capacity Checks

	Actual	Capacity		LOS F?
V_{FO}		Exhibit 25-7		

Flow Entering Merge Influence Area

	Actual	Max Desirable		Violation?
V_{R12}		Exhibit 25-7		

Level of Service Determination (If not F)

$D_R = 5.475 + 0.00734\ v_R + 0.0078\ V_{12} - 0.00627\ L_A$
D_R = (pc/mi/ln)
LOS = (Exhibit 25-4)

Speed Determination

M_S = (Exibit 25-19)
S_R = mph (Exhibit 25-19)
S_0 = mph (Exhibit 25-19)
S = mph (Exhibit 25-14)

Diverge Areas

Estimation of v_{12}

$V_{12} = V_R + (V_F - V_R)P_{FD}$
L_{EQ} = (Equation 25-8 or 25-9)
P_{FD} = 0.600 using Equation (Exhibit 25-12)
V_{12} = 3336 pc/h
V_3 or V_{av34} 1748 pc/h (Equation 25-15 or 25-16)
Is V_3 or V_{av34} > 2,700 pc/h? ☐ Yes ☑ No
Is V_3 or V_{av34} > 1.5 * V_{12}/2 ☐ Yes ☑ No
If Yes,V_{12a} = pc/h (Equation 25-18)

Capacity Checks

	Actual	Capacity		LOS F?
V_F	5084	Exhibit 25-14	7050	No
$V_{FO} = V_F - V_R$	4369	Exhibit 25-14	7050	No
V_R	715	Exhibit 25-3	2100	No

Flow Entering Diverge Influence Area

	Actual	Max Desirable		Violation?
V_{12}	3336	Exhibit 25-14	4400:All	No

Level of Service Determination (If not F)

$D_R = 4.252 + 0.0086\ V_{12} - 0.009\ L_D$
D_R = 27.5 (pc/mi/ln)
LOS = C (Exhibit 25-4)

Speed Determination

D_s = 0.362 (Exhibit 25-19)
S_R = 56.7 mph (Exhibit 25-19)
S_0 = 68.4 mph (Exhibit 25-19)
S = 60.2 mph (Exhibit 25-15)

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RAMPS AND RAMP JUNCTIONS WORKSHEET

General Information / Site Information

Analyst	Caroline Kone	Freeway/Dir of Travel	I-440 WB
Agency or Company	WSP SELLS	Junction	Off-ramp to Glenwood WB
Date Performed	6/16/2010	Jurisdiction	Raleigh/NCDOT/FHWA
Analysis Time Period	AM CVA_Ridge Improve	Analysis Year	2009

Project Description Crabtree Valley

Inputs

Upstream Adj Ramp
☐ Yes ☐ On
☑ No ☐ Off
L_{up} = ft
V_u = veh/h

Terrain: Level

S_{FF} = 65.0 mph S_{FR} = 45.0 mph

Sketch (show lanes, L_A, L_D, V_R, V_f)

Downstream Adj Ramp
☐ Yes ☐ On
☑ No ☐ Off
L_{down} = ft
V_D = veh/h

Conversion to pc/h Under Base Conditions

(pc/h)	V (Veh/hr)	PHF	Terrain	%Truck	%Rv	f_{HV}	f_p	v = V/PHF x f_{HV} x f_p
Freeway	6786	0.92	Level	3	0	0.985	1.00	7487
Ramp	0	0.92	Level	2	0	0.990	1.00	0
UpStream								
DownStream								

Merge Areas

Estimation of v_{12}

$V_{12} = V_F (P_{FM})$

L_{EQ} = (Equation 25-2 or 25-3)
P_{FM} = using Equation (Exhibit 25-5)
V_{12} = pc/h
V_3 or V_{av34} pc/h (Equation 25-4 or 25-5)
Is V_3 or V_{av34} > 2,700 pc/h? ☐ Yes ☐ No
Is V_3 or V_{av34} > 1.5 * V_{12}/2 ☐ Yes ☐ No
If Yes, V_{12a} = pc/h (Equation 25-8)

Capacity Checks

	Actual	Capacity		LOS F?
V_{FO}		Exhibit 25-7		

Flow Entering Merge Influence Area

	Actual	Max Desirable		Violation?
V_{R12}		Exhibit 25-7		

Level of Service Determination (if not F)

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

D_R = (pc/mi/ln)
LOS = (Exhibit 25-4)

Speed Determination

M_S = (Exibit 25-19)
S_R = mph (Exhibit 25-19)
S_0 = mph (Exhibit 25-19)
S = mph (Exhibit 25-14)

Diverge Areas

Estimation of v_{12}

$V_{12} = V_R + (V_F - V_R)P_{FD}$

L_{EQ} = (Equation 25-8 or 25-9)
P_{FD} = 0.450 using Equation (Exhibit 25-12)
V_{12} = 3369 pc/h
V_3 or V_{av34} 4118 pc/h (Equation 25-15 or 25-16)
Is V_3 or V_{av34} > 2,700 pc/h? ☑ Yes ☐ No
Is V_3 or V_{av34} > 1.5 * V_{12}/2 ☑ Yes ☐ No
If Yes, V_{12a} = 4278 pc/h (Equation 25-18)

Capacity Checks

	Actual	Capacity		LOS F?
V_F	7487	Exhibit 25-14	7050	Yes
$V_{FO} = V_F - V_R$	7487	Exhibit 25-14	7050	Yes
V_R	0	Exhibit 25-3	4100	No

Flow Entering Diverge Influence Area

	Actual	Max Desirable		Violation?
V_{12}	3369	Exhibit 25-14	4400:All	No

Level of Service Determination (if not F)

$D_R = \cancel{4.252 + 0.0086\ V_{12} - 0.009\ L_D}\ 0.0109 V_F / N$

D_R = ~~32.0~~ (pc/mi/ln) 16.32
LOS = F (Exhibit 25-4) B

Speed Determination

D_s = 0.298 (Exhibit 25-19)
S_R = 58.1 mph (Exhibit 25-19)
S_0 = 62.7 mph (Exhibit 25-19)
S = 60.0 mph (Exhibit 25-15)

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RAMPS AND RAMP JUNCTIONS WORKSHEET

General Information / Site Information

Analyst	Caroline Kone	Freeway/Dir of Travel	I-440 WB
Agency or Company	WSP SELLS	Junction	on-ramp from Glenwood EB
Date Performed	6/16/2010	Jurisdiction	Raleigh/NCDOT/FHWA
Analysis Time Period	AM CVA_Ridge Improve	Analysis Year	2009

Project Description Crabtree Valley

Inputs

Upstream Adj Ramp
☑ Yes ☐ On
☐ No ☑ Off
L_{up} = 1500 ft
V_u = 651 veh/h

Terrain: Level

S_{FF} = 65.0 mph S_{FR} = 45.0 mph
Sketch (show lanes, L_A, L_D, V_R, V_f)

Downstream Adj Ramp
☐ Yes ☐ On
☑ No ☐ Off
L_{down} = ft
V_D = veh/h

Conversion to pc/h Under Base Conditions

(pc/h)	V (Veh/hr)	PHF	Terrain	%Truck	%Rv	f_{HV}	f_p	$v = V/PHF \times f_{HV} \times f_p$
Freeway	4608	0.92	Level	3	0	0.985	1.00	5084
Ramp	1147	0.92	Level	2	0	0.990	1.00	1259
UpStream	651	0.92	Level	2	0	0.990	1.00	715
DownStream								

Merge Areas

Estimation of v_{12}

$V_{12} = V_F (P_{FM})$

L_{EQ} = 1672.88 (Equation 25-2 or 25-3)
P_{FM} = 0.589 using Equation (Exhibit 25-5)
V_{12} = 2997 pc/h
V_3 or V_{av34} 2087 pc/h (Equation 25-4 or 25-5)
Is V_3 or V_{av34} > 2,700 pc/h? ☐ Yes ☑ No
Is V_3 or V_{av34} > 1.5 * V_{12}/2 ☐ Yes ☑ No
If Yes, V_{12a} = pc/h (Equation 25-8)

Capacity Checks

	Actual	Capacity		LOS F?
V_{FO}	6343	Exhibit 25-7		No

Flow Entering Merge Influence Area

	Actual	Max Desirable		Violation?
V_{R12}	4256	Exhibit 25-7	4600:All	No

Level of Service Determination (if not F)

$D_R = 5.475 + 0.00734\, v_R + 0.0078\, V_{12} - 0.00627\, L_A$

D_R = 33.0 (pc/mi/ln)
LOS = D (Exhibit 25-4)

Speed Determination

M_S = 0.522 (Exibit 25-19)
S_R = 53.0 mph (Exhibit 25-19)
S_0 = 59.3 mph (Exhibit 25-19)
S = 54.9 mph (Exhibit 25-14)

Diverge Areas

Estimation of v_{12}

$V_{12} = V_R + (V_F - V_R)P_{FD}$

L_{EQ} = (Equation 25-8 or 25-9)
P_{FD} = using Equation (Exhibit 25-12)
V_{12} = pc/h
V_3 or V_{av34} pc/h (Equation 25-15 or 25-16)
Is V_3 or V_{av34} > 2,700 pc/h? ☐ Yes ☐ No
Is V_3 or V_{av34} > 1.5 * V_{12}/2 ☐ Yes ☐ No
If Yes, V_{12a} = pc/h (Equation 25-18)

Capacity Checks

	Actual	Capacity		LOS F?
V_F		Exhibit 25-14		
$V_{FO} = V_F - V_R$		Exhibit 25-14		
V_R		Exhibit 25-3		

Flow Entering Diverge Influence Area

	Actual	Max Desirable		Violation?
V_{12}		Exhibit 25-14		

Level of Service Determination (if not F)

$D_R = 4.252 + 0.0086\, V_{12} - 0.009\, L_D$

D_R = (pc/mi/ln)
LOS = (Exhibit 25-4)

Speed Determination

D_s = (Exhibit 25-19)
S_R = mph (Exhibit 25-19)
S_0 = mph (Exhibit 25-19)
S = mph (Exhibit 25-15)

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RAMPS AND RAMP JUNCTIONS WORKSHEET

General Information / Site Information

Analyst	Caroline Kone	Freeway/Dir of Travel	I-440 EB
Agency or Company	WSP SELLS	Junction	off-ramp to Ridge Rd
Date Performed	6/16/2010	Jurisdiction	Raleigh/NCDOT/FHWA
Analysis Time Period	PM CVA_Ridge Improve	Analysis Year	2009

Project Description Crabtree Valley

Inputs

Upstream Adj Ramp
☐ Yes ☐ On
☑ No ☐ Off
L_{up} = ft
V_u = veh/h

Terrain: Level

S_{FF} = 65.0 mph S_{FR} = 45.0 mph
Sketch (show lanes, L_A, L_D, V_R, V_f)

Downstream Adj Ramp
☑ Yes ☑ On
☐ No ☐ Off
L_{down} = 830 ft
V_D = 1598 veh/h

Conversion to pc/h Under Base Conditions

(pc/h)	V (Veh/hr)	PHF	Terrain	%Truck	%Rv	f_{HV}	f_p	v = V/PHF x f_{HV} x f_p
Freeway	4455	0.92	Level	3	0	0.985	1.00	4915
Ramp	143	0.92	Level	2	0	0.990	1.00	157
UpStream								
DownStream	1598	0.92	Level	2	0	0.990	1.00	1754

Merge Areas

Estimation of v_{12}

$V_{12} = V_F (P_{FM})$

L_{EQ} = (Equation 25-2 or 25-3)
P_{FM} = using Equation (Exhibit 25-5)
V_{12} = pc/h
V_3 or V_{av34} pc/h (Equation 25-4 or 25-5)
Is V_3 or V_{av34} > 2,700 pc/h? ☐ Yes ☐ No
Is V_3 or V_{av34} > 1.5 * V_{12}/2 ☐ Yes ☐ No
If Yes, V_{12a} = pc/h (Equation 25-8)

Capacity Checks

	Actual	Capacity		LOS F?
V_{FO}		Exhibit 25-7		

Flow Entering Merge Influence Area

	Actual	Max Desirable		Violation?
V_{R12}		Exhibit 25-7		

Level of Service Determination (if not F)

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

D_R = (pc/mi/ln)
LOS = (Exhibit 25-4)

Speed Determination

M_S = (Exibit 25-19)
S_R = mph (Exhibit 25-19)
S_0 = mph (Exhibit 25-19)
S = mph (Exhibit 25-14)

Diverge Areas

Estimation of v_{12}

$V_{12} = V_R + (V_F - V_R)P_{FD}$

L_{EQ} = (Equation 25-8 or 25-9)
P_{FD} = 0.630 using Equation (Exhibit 25-12)
V_{12} = 3154 pc/h
V_3 or V_{av34} 1761 pc/h (Equation 25-15 or 25-16)
Is V_3 or V_{av34} > 2,700 pc/h? ☐ Yes ☑ No
Is V_3 or V_{av34} > 1.5 * V_{12}/2 ☐ Yes ☑ No
If Yes, V_{12a} = pc/h (Equation 25-18)

Capacity Checks

	Actual	Capacity		LOS F?
V_F	4915	Exhibit 25-14	7050	No
$V_{FO} = V_F - V_R$	4758	Exhibit 25-14	7050	No
V_R	157	Exhibit 25-3	2100	No

Flow Entering Diverge Influence Area

	Actual	Max Desirable		Violation?
V_{12}	3154	Exhibit 25-14	4400:All	No

Level of Service Determination (if not F)

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

D_R = 25.8 (pc/mi/ln)
LOS = C (Exhibit 25-4)

Speed Determination

D_s = 0.312 (Exhibit 25-19)
S_R = 57.8 mph (Exhibit 25-19)
S_0 = 68.3 mph (Exhibit 25-19)
S = 61.2 mph (Exhibit 25-15)

RAMPS AND RAMP JUNCTIONS WORKSHEET

General Information / Site Information

Analyst	Caroline Kone	Freeway/Dir of Travel	I-440 EB
Agency or Company	WSP SELLS	Junction	on-ramp from Glenwood WB
Date Performed	6/16/2010	Jurisdiction	Raleigh/NCDOT/FHWA
Analysis Time Period	AM CVA_Ridge Improve	Analysis Year	2009

Project Description Crabtree Valley

Inputs

Upstream Adj Ramp
☑ Yes ☐ On
☐ No ☑ Off
L_{up} = 630 ft
V_u = 818 veh/h

Terrain: Level

S_{FF} = 65.0 mph S_{FR} = 45.0 mph
Sketch (show lanes, L_A, L_D,V_R,V_f)

Downstream Adj Ramp
☐ Yes ☐ On
☑ No ☐ Off
L_{down} = ft
V_D = veh/h

Conversion to pc/h Under Base Conditions

(pc/h)	V (Veh/hr)	PHF	Terrain	%Truck	%Rv	f_{HV}	f_p	$v = V/PHF \times f_{HV} \times f_p$
Freeway	4041	0.92	Level	3	0	0.985	1.00	4458
Ramp	612	0.92	Level	2	0	0.990	1.00	672
UpStream	818	0.92	Level	2	0	0.990	1.00	898
DownStream								

Merge Areas

Estimation of v_{12}

$V_{12} = V_F(P_{FM})$

L_{EQ} = (Equation 25-2 or 25-3)
P_{FM} = 0.134 using Equation (Exhibit 25-5)
V_{12} = 596 pc/h
V_3 or V_{av34} 1931 pc/h (Equation 25-4 or 25-5)
Is V_3 or V_{av34} > 2,700 pc/h? ☐ Yes ☑ No
Is V_3 or V_{av34} > 1.5 * V_{12}/2 ☑ Yes ☐ No
If Yes,V_{12a} = 1783 pc/h (Equation 25-8)

Capacity Checks

	Actual	Capacity		LOS F?
V_{FO}	5130	Exhibit 25-7		No

Flow Entering Merge Influence Area

	Actual	Max Desirable		Violation?
V_{R12}	2455	Exhibit 25-7	4600:All	No

Level of Service Determination (if not F)

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

D_R = 14.9 (pc/mi/ln)
LOS = B (Exhibit 25-4)

Speed Determination

M_S = 0.231 (Exibit 25-19)
S_R = 59.7 mph (Exhibit 25-19)
S_0 = 62.0 mph (Exhibit 25-19)
S = 60.9 mph (Exhibit 25-14)

Diverge Areas

Estimation of v_{12}

$V_{12} = V_R + (V_F - V_R)P_{FD}$

L_{EQ} = (Equation 25-8 or 25-9)
P_{FD} = using Equation (Exhibit 25-12)
V_{12} = pc/h
V_3 or V_{av34} pc/h (Equation 25-15 or 25-16)
Is V_3 or V_{av34} > 2,700 pc/h? ☐ Yes ☐ No
Is V_3 or V_{av34} > 1.5 * V_{12}/2 ☐ Yes ☐ No
If Yes,V_{12a} = pc/h (Equation 25-18)

Capacity Checks

	Actual	Capacity		LOS F?
V_F		Exhibit 25-14		
$V_{FO} = V_F - V_R$		Exhibit 25-14		
V_R		Exhibit 25-3		

Flow Entering Diverge Influence Area

	Actual	Max Desirable		Violation?
V_{12}		Exhibit 25-14		

Level of Service Determination (if not F)

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

D_R = (pc/mi/ln)
LOS = (Exhibit 25-4)

Speed Determination

D_s = (Exhibit 25-19)
S_R = mph (Exhibit 25-19)
S_0 = mph (Exhibit 25-19)
S = mph (Exhibit 25-15)

FREEWAY WEAVING WORKSHEET

General Information

Analyst	G Teng
Agency/Company	WSP SELLS
Date Performed	7/15/2010
Analysis Time Period	Weekday PM Peak Hour

Site Information

Freeway/Dir of Travel	EB I-440 _Ridge Rd Improvement
Weaving Seg Location	Ridge Rd to Glenwood Ave
Jurisdiction	City of Raleigh/NCDOT/FHWA
Analysis Year	2009

Inputs

Freeway free-flow speed, S_{FF} (mi/h)	65	Weaving type	B
Weaving number of lanes, N	4	Volume ratio, VR	0.49
Weaving seg length, L (ft)	2100	Weaving ratio, R	0.45
Terrain	Level		

Conversions to pc/h Under Base Conditions

(pc/h)	V	PHF	Truck %	RV %	E_T	E_R	f_{HV}	fp	v
V_{o1}	3011	0.92	3	0	1.5	1.2	0.985	1.00	3321
V_{o2}	0	0.92	2	0	1.5	1.2	0.990	1.00	0
V_{w1}	1598	0.92	2	0	1.5	1.2	0.990	1.00	1754
V_{w2}	1301	0.92	2	0	1.5	1.2	0.990	1.00	1428
V_w				3182	V_{nw}				3321
V									6503

Weaving and Non-Weaving Speeds

	Unconstrained		Constrained	
	Weaving (i = w)	Non-Weaving (i = nw)	Weaving (i = w)	Non-Weaving (= nw)
a (Exhibit 24-6)	0.08	0.0020		
b (Exhibit 24-6)	2.20	6.00		
c (Exhibit 24-6)	0.70	1.00		
d (Exhibit 24-6)	0.50	0.50		
Weaving intensity factor, Wi	0.74	0.77		
Weaving and non-weaving speeds, Si (mi/h)	46.58	46.00		

Number of lanes required for unconstrained operation, Nw 2.20
Maximum number of lanes, Nw (max) 3.50

☑ If Nw < Nw(max) unconstrained operation ☐ if Nw > Nw (max) constrained operation

Weaving Segment Speed, Density, Level of Service, and Capacity

Weaving segment speed, S (mi/h)	46.28
Weaving segment density, D (pc/mi/ln)	35.13
Level of service, LOS	E
Capacity of base condition, c_0 (pc/h)	7639
Capacity as a 15-minute flow rate, c (veh/h)	7526
Capacity as a full-hour volume, c_h (veh/h)	6924

Notes

a. Weaving segments longer than 2500 ft. are treated as isolated merge and diverge areas using the procedures of Chapter 25, "Ramps and Ramp Junctions".
b. Capacity constrained by basic freeway capacity.
c. Capacity occurs under constrained operating conditions.
d. Three-lane Type A segments do not operate well at volume ratios greater than 0.45. Poor operations and some local queuing are expected in such cases.
e. Four-lane Type A segments do not operate well at volume ratios greater than 0.35. Poor operations and some local queuing are expected in such cases.
f. Capacity constrained by maximum allowable weaving flow rate: 2,800 pc/h (Type A), 4,000 (Type B), 3,500 (Type C).
g. Five-lane Type A segments do not operate well at volume ratios greater than 0.20. Poor operations and some local queuing are expected in such cases.
h. Type B weaving segments do not operate well at volume ratios greater than 0.80. Poor operations and some local queuing are expected in such cases.
i. Type C weaving segments do not operate well at volume ratios greater than 0.50. Poor operations and some local queuing are expected in such cases.

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RAMPS AND RAMP JUNCTIONS WORKSHEET

General Information / Site Information

Analyst	Caroline Kone	Freeway/Dir of Travel	I-440 Wb
Agency or Company	WSP SELLS	Junction	off-ramp to Glenwood EB
Date Performed	6/16/2010	Jurisdiction	Raleigh/NCDOT/FHWA
Analysis Time Period	PM CVA_Ridge Improve	Analysis Year	2009

Project Description Crabtree valley

Inputs

Upstream Adj Ramp
☑ Yes ☐ On
☐ No ☑ Off
L_{up} = 1350 ft
V_u = 2270 veh/h

Terrain: Level
S_{FF} = 65.0 mph S_{FR} = 45.0 mph
Sketch (show lanes, L_A, L_D,V_R,V_f)

Downstream Adj Ramp
☐ Yes ☐ On
☑ No ☐ Off
L_{down} = ft
V_D = veh/h

Conversion to pc/h Under Base Conditions

(pc/h)	V (Veh/hr)	PHF	Terrain	%Truck	%Rv	f_{HV}	f_p	v = V/PHF x f_{HV} x f_p
Freeway	3024	0.92	Level	3	0	0.985	1.00	3336
Ramp	556	0.92	Level	2	0	0.990	1.00	610
UpStream	2270	0.92	Level	2	0	0.990	1.00	2492
DownStream								

Merge Areas

Estimation of v_{12}

$V_{12} = V_F (P_{FM})$
L_{EQ} = (Equation 25-2 or 25-3)
P_{FM} = using Equation (Exhibit 25-5)
V_{12} = pc/h
V_3 or V_{av34} pc/h (Equation 25-4 or 25-5)
Is V_3 or V_{av34} > 2,700 pc/h? ☐ Yes ☐ No
Is V_3 or V_{av34} > 1.5 * V_{12}/2 ☐ Yes ☐ No
If Yes,V_{12a} = pc/h (Equation 25-8)

Capacity Checks

	Actual	Capacity		LOS F?
V_{FO}		Exhibit 25-7		

Flow Entering Merge Influence Area

	Actual	Max Desirable		Violation?
V_{R12}		Exhibit 25-7		

Level of Service Determination (if not F)

$D_R = 5.475 + 0.00734\ v_R + 0.0078\ V_{12} - 0.00627\ L_A$
D_R = (pc/mi/ln)
LOS = (Exhibit 25-4)

Speed Determination

M_S = (Exibit 25-19)
S_R = mph (Exhibit 25-19)
S_0 = mph (Exhibit 25-19)
S = mph (Exhibit 25-14)

Diverge Areas

Estimation of v_{12}

$V_{12} = V_R + (V_F - V_R)P_{FD}$
L_{EQ} = (Equation 25-8 or 25-9)
P_{FD} = 0.649 using Equation (Exhibit 25-12)
V_{12} = 2378 pc/h
V_3 or V_{av34} 958 pc/h (Equation 25-15 or 25-16)
Is V_3 or V_{av34} > 2,700 pc/h? ☐ Yes ☑ No
Is V_3 or V_{av34} > 1.5 * V_{12}/2 ☐ Yes ☑ No
If Yes,V_{12a} = pc/h (Equation 25-18)

Capacity Checks

	Actual	Capacity		LOS F?
V_F	3336	Exhibit 25-14	7050	No
$V_{FO} = V_F - V_R$	2726	Exhibit 25-14	7050	No
V_R	610	Exhibit 25-3	2100	No

Flow Entering Diverge Influence Area

	Actual	Max Desirable		Violation?
V_{12}	2378	Exhibit 25-14	4400:All	No

Level of Service Determination (if not F)

$D_R = 4.252 + 0.0086\ V_{12} - 0.009\ L_D$
D_R = 19.3 (pc/mi/ln)
LOS = B (Exhibit 25-4)

Speed Determination

D_s = 0.353 (Exhibit 25-19)
S_R = 56.9 mph (Exhibit 25-19)
S_0 = 71.3 mph (Exhibit 25-19)
S = 60.4 mph (Exhibit 25-15)

RAMPS AND RAMP JUNCTIONS WORKSHEET

General Information / Site Information

Analyst	Caroline Kone	Freeway/Dir of Travel	I-440 WB
Agency or Company	WSP SELLS	Junction	off-ramp to Glenwood WB
Date Performed	6/16/2010	Jurisdiction	Raleigh/NCDOT/FHWA
Analysis Time Period	PM CVA_Ridge Improve	Analysis Year	2009

Project Description Crabtree Valley

Inputs

Upstream Adj Ramp: ☐ Yes ☐ On ☑ No ☐ Off

L_{up} = ft

V_u = veh/h

Terrain: Level

S_{FF} = 65.0 mph S_{FR} = 45.0 mph

Sketch (show lanes, L_A, L_D, V_R, V_f)

Downstream Adj Ramp: ☐ Yes ☐ On ☑ No ☐ Off

L_{down} = ft

V_D = veh/h

Conversion to pc/h Under Base Conditions

(pc/h)	V (Veh/hr)	PHF	Terrain	%Truck	%Rv	f_{HV}	f_p	$v = V/PHF \times f_{HV} \times f_p$
Freeway	5850	0.92	Level	3	0	0.985	1.00	6454
Ramp	0	0.92	Level	2	0	0.990	1.00	0
UpStream								
DownStream								

Merge Areas

Estimation of v_{12}

$V_{12} = V_F(P_{FM})$

L_{EQ} = (Equation 25-2 or 25-3)

P_{FM} = using Equation (Exhibit 25-5)

V_{12} = pc/h

V_3 or V_{av34} pc/h (Equation 25-4 or 25-5)

Is V_3 or V_{av34} > 2,700 pc/h? ☐ Yes ☐ No

Is V_3 or V_{av34} > 1.5 * V_{12}/2 ☐ Yes ☐ No

If Yes, V_{12a} = pc/h (Equation 25-8)

Capacity Checks

	Actual	Capacity		LOS F?
V_{FO}		Exhibit 25-7		

Flow Entering Merge Influence Area

	Actual	Max Desirable		Violation?
V_{R12}		Exhibit 25-7		

Level of Service Determination (if not F)

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

D_R = (pc/mi/ln)

LOS = (Exhibit 25-4)

Speed Determination

M_S = (Exibit 25-19)

S_R = mph (Exhibit 25-19)

S_0 = mph (Exhibit 25-19)

S = mph (Exhibit 25-14)

Diverge Areas

Estimation of v_{12}

$V_{12} = V_R + (V_F - V_R)P_{FD}$

L_{EQ} = (Equation 25-8 or 25-9)

P_{FD} = 0.460 using Equation (Exhibit 25-12)

V_{12} = 2904 pc/h

V_3 or V_{av34} 3550 pc/h (Equation 25-15 or 25-16)

Is V_3 or V_{av34} > 2,700 pc/h? ☑ Yes ☐ No

Is V_3 or V_{av34} > 1.5 * V_{12}/2 ☑ Yes ☐ No

If Yes, V_{12a} = 3688 pc/h (Equation 25-18)

Capacity Checks

	Actual	Capacity		LOS F?
V_F	6454	Exhibit 25-14	7050	No
$V_{FO} = V_F - V_R$	6454	Exhibit 25-14	7050	No
V_R	0	Exhibit 25-3	4100	No

Flow Entering Diverge Influence Area

	Actual	Max Desirable		Violation?
V_{12}	2904	Exhibit 25-14	4400:All	No

Level of Service Determination (if not F)

D_R = ~~4.252 + 0.0086 V_{12} - 0.009 L_D~~ $0.0109 V_f$

D_R = ~~4.6~~ (pc/mi/ln) 14.07

LOS = ~~A~~ (Exhibit 25-4) B

Speed Determination

D_s = 0.298 (Exhibit 25-19)

S_R = 58.1 mph (Exhibit 25-19)

S_0 = 64.4 mph (Exhibit 25-19)

S = 60.7 mph (Exhibit 25-15)

RAMPS AND RAMP JUNCTIONS WORKSHEET

General Information / Site Information

Analyst	Caroline Kone	Freeway/Dir of Travel	I-440 WB
Agency or Company	WSP SELLS	Junction	on-ramp from Glenwood EB
Date Performed	6/16/2010	Jurisdiction	Raleigh/NCDOT/FHWA
Analysis Time Period	PM CVA_Ridge Improve	Analysis Year	2009

Project Description Crabtree Valley

Inputs

Upstream Adj Ramp
☑ Yes ☐ On
☐ No ☑ Off
L_{up} = 1500 ft
V_u = 556 veh/h

Terrain: Level

S_{FF} = 65.0 mph S_{FR} = 45.0 mph
Sketch (show lanes, L_A, L_D, V_R, V_f)

Downstream Adj Ramp
☐ Yes ☐ On
☑ No ☐ Off
L_{down} = ft
V_D = veh/h

Conversion to pc/h Under Base Conditions

(pc/h)	V (Veh/hr)	PHF	Terrain	%Truck	%Rv	f_{HV}	f_p	$v = V/PHF \times f_{HV} \times f_p$
Freeway	3024	0.92	Level	3	0	0.985	1.00	3336
Ramp	1432	0.92	Level	2	0	0.990	1.00	1572
UpStream	556	0.92	Level	2	0	0.990	1.00	610
DownStream								

Merge Areas

Estimation of v_{12}

$V_{12} = V_F (P_{FM})$

L_{EQ} = 1365.79 (Equation 25-2 or 25-3)
P_{FM} = 0.600 using Equation (Exhibit 25-5)
V_{12} = 2003 pc/h
V_3 or V_{av34} 1333 pc/h (Equation 25-4 or 25-5)
Is V_3 or V_{av34} > 2,700 pc/h? ☐ Yes ☑ No
Is V_3 or V_{av34} > 1.5 * V_{12}/2 ☐ Yes ☑ No
If Yes, V_{12a} = pc/h (Equation 25-8)

Capacity Checks

	Actual	Capacity		LOS F?
V_{FO}	4908	Exhibit 25-7		No

Flow Entering Merge Influence Area

	Actual	Max Desirable		Violation?
V_{R12}	3575	Exhibit 25-7	4600:All	No

Level of Service Determination (if not F)

$D_R = 5.475 + 0.00734\, v_R + 0.0078\, V_{12} - 0.00627\, L_A$

D_R = 27.5 (pc/mi/ln)
LOS = C (Exhibit 25-4)

Speed Determination

M_S = 0.386 (Exibit 25-19)
S_R = 56.1 mph (Exhibit 25-19)
S_0 = 62.0 mph (Exhibit 25-19)
S = 57.6 mph (Exhibit 25-14)

Diverge Areas

Estimation of v_{12}

$V_{12} = V_R + (V_F - V_R) P_{FD}$

L_{EQ} = (Equation 25-8 or 25-9)
P_{FD} = using Equation (Exhibit 25-12)
V_{12} = pc/h
V_3 or V_{av34} pc/h (Equation 25-15 or 25-16)
Is V_3 or V_{av34} > 2,700 pc/h? ☐ Yes ☐ No
Is V_3 or V_{av34} > 1.5 * V_{12}/2 ☐ Yes ☐ No
If Yes, V_{12a} = pc/h (Equation 25-18)

Capacity Checks

	Actual	Capacity		LOS F?
V_F		Exhibit 25-14		
$V_{FO} = V_F - V_R$		Exhibit 25-14		
V_R		Exhibit 25-3		

Flow Entering Diverge Influence Area

	Actual	Max Desirable		Violation?
V_{12}		Exhibit 25-14		

Level of Service Determination (If not F)

$D_R = 4.252 + 0.0086\, V_{12} - 0.009\, L_D$

D_R = (pc/mi/ln)
LOS = (Exhibit 25-4)

Speed Determination

D_s = (Exhibit 25-19)
S_R = mph (Exhibit 25-19)
S_0 = mph (Exhibit 25-19)
S = mph (Exhibit 25-15)

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2035 Crabtree Valley Ave (CVA) Extensions

RAMPS AND RAMP JUNCTIONS WORKSHEET

General Information / Site Information

Analyst	APATEL	Freeway/Dir of Travel	I-440 EB
Agency or Company	WSP SELLS	Junction	off-ramp to Ridge Rd/Glenwood
Date Performed	6/17/2010	Jurisdiction	Raleigh/NCDOT/FHWA
Analysis Time Period	AM Crabtree Extensions	Analysis Year	2035

Project Description Crabtree Valley

Inputs

Upstream Adj Ramp
☐ Yes ☐ On
☑ No ☐ Off
L_{up} = ft
V_u = veh/h

Terrain: Level

S_{FF} = 65.0 mph S_{FR} = 45.0 mph
Sketch (show lanes, L_A, L_D, V_R, V_f)

Downstream Adj Ramp
☑ Yes ☑ On
☐ No ☐ Off
L_{down} = 900 ft
V_D = 332 veh/h

Conversion to pc/h Under Base Conditions

(pc/h)	V (Veh/hr)	PHF	Terrain	%Truck	%Rv	f_{HV}	f_p	v = V/PHF x f_{HV} x f_p
Freeway	6851	1.00	Level	3	0	0.985	1.00	6954
Ramp	1829	1.00	Level	2	0	0.990	1.00	1847
UpStream								
DownStream	332	1.00	Level	2	0	0.990	1.00	335

Merge Areas

Estimation of v_{12}

$V_{12} = V_F (P_{FM})$
L_{EQ} = (Equation 25-2 or 25-3)
P_{FM} = using Equation (Exhibit 25-5)
V_{12} = pc/h
V_3 or V_{av34} pc/h (Equation 25-4 or 25-5)
Is V_3 or V_{av34} > 2,700 pc/h? ☐ Yes ☐ No
Is V_3 or V_{av34} > 1.5 * V_{12}/2 ☐ Yes ☐ No
If Yes, V_{12a} = pc/h (Equation 25-8)

Capacity Checks

	Actual	Capacity		LOS F?
V_{FO}		Exhibit 25-7		

Flow Entering Merge Influence Area

	Actual	Max Desirable		Violation?
V_{R12}		Exhibit 25-7		

Level of Service Determination (if not F)

$D_R = 5.475 + 0.00734\ v_R + 0.0078\ V_{12} - 0.00627\ L_A$
D_R = (pc/mi/ln)
LOS = (Exhibit 25-4)

Speed Determination

M_S = (Exibit 25-19)
S_R = mph (Exhibit 25-19)
S_0 = mph (Exhibit 25-19)
S = mph (Exhibit 25-14)

Diverge Areas

Estimation of v_{12}

$V_{12} = V_R + (V_F - V_R)P_{FD}$
L_{EQ} = (Equation 25-8 or 25-9)
P_{FD} = 0.450 using Equation (Exhibit 25-12)
V_{12} = 4145 pc/h
V_3 or V_{av34} 2809 pc/h (Equation 25-15 or 25-16)
Is V_3 or V_{av34} > 2,700 pc/h? ☑ Yes ☐ No
Is V_3 or V_{av34} > 1.5 * V_{12}/2 ☐ Yes ☑ No
If Yes, V_{12a} = 4254 pc/h (Equation 25-18)

Capacity Checks

	Actual	Capacity		LOS F?
V_F	6954	Exhibit 25-14	7050	No
$V_{FO} = V_F - V_R$	5107	Exhibit 25-14	7050	No
V_R	1847	Exhibit 25-3	4100	No

Flow Entering Diverge Influence Area

	Actual	Max Desirable		Violation?
V_{12}	4145	Exhibit 25-14	4400:All	No

Level of Service Determination (if not F)

$D_R = 4.252 + 0.0086\ V_{12} - 0.009\ L_D$
D_R = 24.6 (pc/mi/ln)
LOS = C (Exhibit 25-4)

Speed Determination

D_s = 0.464 (Exhibit 25-19)
S_R = 54.3 mph (Exhibit 25-19)
S_0 = 64.7 mph (Exhibit 25-19)
S = 57.9 mph (Exhibit 25-15)

RAMPS AND RAMP JUNCTIONS WORKSHEET

General Information / Site Information

Analyst	Caroline Kone	Freeway/Dir of Travel	I-440 EB
Agency or Company	WSP SELLS	Junction	on-ramp from Crab. Valley Ave
Date Performed	6/17/2010	Jurisdiction	Raleigh/NCDOT/FHWA
Analysis Time Period	AM Crabtree Extensions	Analysis Year	2035

Project Description Crabtree Valley

Inputs

Upstream Adj Ramp
☐ Yes ☐ On
☑ No ☐ Off
L_{up} = ft
V_u = veh/h

Terrain: Level

S_{FF} = 65.0 mph S_{FR} = 45.0 mph
Sketch (show lanes, L_A, L_D, V_R, V_f)

Downstream Adj Ramp
☑ Yes ☑ On
☐ No ☐ Off
L_{down} = 1500 ft
V_D = 2302 veh/h

Conversion to pc/h Under Base Conditions

(pc/h)	V (Veh/hr)	PHF	Terrain	%Truck	%Rv	f_{HV}	f_p	v = V/PHF x f_{HV} x f_p
Freeway	5022	1.00	Level	3	0	0.985	1.00	5097
Ramp	332	1.00	Level	2	0	0.990	1.00	335
UpStream								
DownStream	2302	1.00	Level	2	0	0.990	1.00	2325

Merge Areas

Estimation of v_{12}

$V_{12} = V_F (P_{FM})$

L_{EQ} = (Equation 25-2 or 25-3)
P_{FM} = 0.619 using Equation (Exhibit 25-5)
V_{12} = 3158 pc/h
V_3 or V_{av34} 1939 pc/h (Equation 25-4 or 25-5)
Is V_3 or V_{av34} > 2,700 pc/h? ☐ Yes ☑ No
Is V_3 or V_{av34} > 1.5 * V_{12}/2 ☐ Yes ☑ No
If Yes, V_{12a} = pc/h (Equation 25-8)

Capacity Checks

	Actual	Capacity		LOS F?
V_{FO}	5432	Exhibit 25-7		No

Flow Entering Merge Influence Area

	Actual	Max Desirable		Violation?
V_{R12}	3493	Exhibit 25-7	4600:All	No

Level of Service Determination (if not F)

$D_R = 5.475 + 0.00734\, v_R + 0.0078\, V_{12} - 0.00627\, L_A$

D_R = 23.2 (pc/mi/ln)
LOS = C (Exhibit 25-4)

Speed Determination

M_S = 0.314 (Exibit 25-19)
S_R = 57.8 mph (Exhibit 25-19)
S_0 = 59.8 mph (Exhibit 25-19)
S = 58.5 mph (Exhibit 25-14)

Diverge Areas

Estimation of v_{12}

$V_{12} = V_R + (V_F - V_R)P_{FD}$

L_{EQ} = (Equation 25-8 or 25-9)
P_{FD} = using Equation (Exhibit 25-12)
V_{12} = pc/h
V_3 or V_{av34} pc/h (Equation 25-15 or 25-16)
Is V_3 or V_{av34} > 2,700 pc/h? ☐ Yes ☐ No
Is V_3 or V_{av34} > 1.5 * V_{12}/2 ☐ Yes ☐ No
If Yes, V_{12a} = pc/h (Equation 25-18)

Capacity Checks

	Actual	Capacity		LOS F?
V_F		Exhibit 25-14		
$V_{FO} = V_F - V_R$		Exhibit 25-14		
V_R		Exhibit 25-3		

Flow Entering Diverge Influence Area

	Actual	Max Desirable		Violation?
V_{12}		Exhibit 25-14		

Level of Service Determination (if not F)

$D_R = 4.252 + 0.0086\, V_{12} - 0.009\, L_D$

D_R = (pc/mi/ln)
LOS = (Exhibit 25-4)

Speed Determination

D_s = (Exhibit 25-19)
S_R = mph (Exhibit 25-19)
S_0 = mph (Exhibit 25-19)
S = mph (Exhibit 25-15)

RAMPS AND RAMP JUNCTIONS WORKSHEET

General Information / Site Information

Analyst	G Teng	Freeway/Dir of Travel	I-440 EB
Agency or Company	WSP SELLS	Junction	on-ramp from Glenwood WB
Date Performed	6/16/2010	Jurisdiction	Raleigh/NCDOT/FHWA
Analysis Time Period	AM Crabtree Extensions	Analysis Year	2035

Project Description Crabtree Valley

Inputs

Upstream Adj Ramp
☑ Yes ☑ On
☐ No ☐ Off
L_{up} = 1200 ft
V_u = 2302 veh/h

Terrain: Level
S_{FF} = 65.0 mph S_{FR} = 45.0 mph
Sketch (show lanes, L_A, L_D, V_R, V_f)

Downstream Adj Ramp
☐ Yes ☐ On
☑ No ☐ Off
L_{down} = ft
V_D = veh/h

Conversion to pc/h Under Base Conditions

(pc/h)	V (Veh/hr)	PHF	Terrain	%Truck	%Rv	f_{HV}	f_p	v = V/PHF x f_{HV} x f_p
Freeway	7656	1.00	Level	3	0	0.985	1.00	7771
Ramp	1163	1.00	Level	2	0	0.990	1.00	1175
UpStream	2302	1.00	Level	2	0	0.990	1.00	2325
DownStream								

Merge Areas

Estimation of v_{12}

$V_{12} = V_F (P_{FM})$

L_{EQ} = (Equation 25-2 or 25-3)
P_{FM} = 0.071 using Equation (Exhibit 25-5)
V_{12} = 551 pc/h
V_3 or V_{av34} = 3610 pc/h (Equation 25-4 or 25-5)
Is V_3 or V_{av34} > 2,700 pc/h? ☑ Yes ☐ No
Is V_3 or V_{av34} > 1.5 * V_{12}/2 ☑ Yes ☐ No
If Yes, V_{12a} = 3108 pc/h (Equation 25-8)

Capacity Checks

	Actual	Capacity		LOS F?
V_{FO}	8946	Exhibit 25-7		No

Flow Entering Merge Influence Area

	Actual	Max Desirable		Violation?
V_{R12}	4283	Exhibit 25-7	4600:All	No

Level of Service Determination (if not F)

$D_R = 5.475 + 0.00734\, v_R + 0.0078\, V_{12} - 0.00627\, L_A$

D_R = 28.9 (pc/mi/ln)
LOS = D (Exhibit 25-4)

Speed Determination

M_S = 0.469 (Exibit 25-19)
S_R = 54.2 mph (Exhibit 25-19)
S_0 = 58.3 mph (Exhibit 25-19)
S = 56.3 mph (Exhibit 25-14)

Diverge Areas

Estimation of v_{12}

$V_{12} = V_R + (V_F - V_R) P_{FD}$

L_{EQ} = (Equation 25-8 or 25-9)
P_{FD} = using Equation (Exhibit 25-12)
V_{12} = pc/h
V_3 or V_{av34} = pc/h (Equation 25-15 or 25-16)
Is V_3 or V_{av34} > 2,700 pc/h? ☐ Yes ☐ No
Is V_3 or V_{av34} > 1.5 * V_{12}/2 ☐ Yes ☐ No
If Yes, V_{12a} = pc/h (Equation 25-18)

Capacity Checks

	Actual	Capacity		LOS F?
V_F		Exhibit 25-14		
$V_{FO} = V_F - V_R$		Exhibit 25-14		
V_R		Exhibit 25-3		

Flow Entering Diverge Influence Area

	Actual	Max Desirable		Violation?
V_{12}		Exhibit 25-14		

Level of Service Determination (if not F)

$D_R = 4.252 + 0.0086\, V_{12} - 0.009\, L_D$

D_R = (pc/mi/ln)
LOS = (Exhibit 25-4)

Speed Determination

D_s = (Exhibit 25-19)
S_R = mph (Exhibit 25-19)
S_0 = mph (Exhibit 25-19)
S = mph (Exhibit 25-15)

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RAMPS AND RAMP JUNCTIONS WORKSHEET

General Information / Site Information

Analyst	Caroline Kone	Freeway/Dir of Travel	I-440 WB
Agency or Company	WSP SELLS	Junction	off-ramp to Glenwood/CVA
Date Performed	6/17/2010	Jurisdiction	Raleigh/NCDOT/FHWA
Analysis Time Period	AM Crabtree Extensions	Analysis Year	2035

Project Description Crabtree Valley

Inputs

Upstream Adj Ramp
☐ Yes ☐ On
☑ No ☐ Off
L_{up} = ft
V_u = veh/h

Terrain: Level

S_{FF} = 65.0 mph S_{FR} = 45.0 mph

Sketch (show lanes, L_A, L_D, V_R, V_f)

Downstream Adj Ramp
☐ Yes ☐ On
☑ No ☐ Off
L_{down} = ft
V_D = veh/h

Conversion to pc/h Under Base Conditions

(pc/h)	V (Veh/hr)	PHF	Terrain	%Truck	%Rv	f_{HV}	f_p	v = V/PHF x f_{HV} x f_p
Freeway	12893	1.00	Level	3	0	0.985	1.00	13086
Ramp	0	1.00	Level	2	0	0.990	1.00	0
UpStream								
DownStream								

Merge Areas

Estimation of v_{12}

$V_{12} = V_F (P_{FM})$

L_{EQ} = (Equation 25-2 or 25-3)
P_{FM} = using Equation (Exhibit 25-5)
V_{12} = pc/h
V_3 or V_{av34} pc/h (Equation 25-4 or 25-5)
Is V_3 or V_{av34} > 2,700 pc/h? ☐ Yes ☐ No
Is V_3 or V_{av34} > 1.5 * V_{12}/2 ☐ Yes ☐ No
If Yes, V_{12a} = pc/h (Equation 25-8)

Capacity Checks

	Actual	Capacity		LOS F?
V_{FO}		Exhibit 25-7		

Flow Entering Merge Influence Area

	Actual	Max Desirable		Violation?
V_{R12}		Exhibit 25-7		

Level of Service Determination (if not F)

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

D_R = (pc/mi/ln)
LOS = (Exhibit 25-4)

Speed Determination

M_S = (Exibit 25-19)
S_R = mph (Exhibit 25-19)
S_0 = mph (Exhibit 25-19)
S = mph (Exhibit 25-14)

Diverge Areas

Estimation of v_{12}

$V_{12} = V_R + (V_F - V_R)P_{FD}$

L_{EQ} = (Equation 25-8 or 25-9)
P_{FD} = 0.260 using Equation (Exhibit 25-12)
V_{12} = 2722 pc/h
V_3 or V_{av34} 3873 pc/h (Equation 25-15 or 25-16)
Is V_3 or V_{av34} > 2,700 pc/h? ☑ Yes ☐ No
Is V_3 or V_{av34} > 1.5 * V_{12}/2 ☑ Yes ☐ No
If Yes, V_{12a} = 4187 pc/h (Equation 25-18)

Capacity Checks

	Actual	Capacity		LOS F?
V_F	10469	Exhibit 25-14	9400	Yes
$V_{FO} = V_F - V_R$	10469	Exhibit 25-14	9400	Yes
V_R	0	Exhibit 25-3	4100	No

Flow Entering Diverge Influence Area

	Actual	Max Desirable		Violation?
V_{12}	2722	Exhibit 25-14	4400:All	No

Level of Service Determination (if not F)

D_R = ~~4.252 + 0.0086 V_{12} - 0.009 L_D~~ 0.0109 V_F N

D_R = ~~35.8~~ (pc/mi/ln) 28.53
LOS = ~~F~~ (Exhibit 25-4) D

Speed Determination

D_s = 0.298 (Exhibit 25-19)
S_R = 58.1 mph (Exhibit 25-19)
S_0 = 63.0 mph (Exhibit 25-19)
S = 60.9 mph (Exhibit 25-15)

RAMPS AND RAMP JUNCTIONS WORKSHEET

General Information / Site Information

Analyst	Caroline Kone	Freeway/Dir of Travel	I-440 WB
Agency or Company	WSP SELLS	Junction	on-ramp from Crab. Valley Ave
Date Performed	6/17/2010	Jurisdiction	Raleigh/NCDOT/FHWA
Analysis Time Period	AM Crabtree Extensions	Analysis Year	2035

Project Description Crabtree Valley

Inputs

Upstream Adj Ramp
☑ Yes ☑ On
☐ No ☐ Off
L_{up} = 375 ft
V_u = 1310 veh/h

Terrain: Level
S_{FF} = 65.0 mph S_{FR} = 45.0 mph
Sketch (show lanes, L_A, L_D, V_R, V_f)

Downstream Adj Ramp
☐ Yes ☐ On
☑ No ☐ Off
L_{down} = ft
V_D = veh/h

Conversion to pc/h Under Base Conditions

(pc/h)	V (Veh/hr)	PHF	Terrain	%Truck	%Rv	f_{HV}	f_p	v = V/PHF x f_{HV} x f_p
Freeway	10064	1.00	Level	3	0	0.985	1.00	10215
Ramp	853	1.00	Level	2	0	0.990	1.00	862
UpStream	1310	1.00	Level	0	0	1.000	1.00	1310
DownStream								

Merge Areas

Estimation of v_{12}

$V_{12} = V_F (P_{FM})$
L_{EQ} = (Equation 25-2 or 25-3)
P_{FM} = 0.110 using Equation (Exhibit 25-5)
V_{12} = 1124 pc/h
V_3 or V_{av34} 4545 pc/h (Equation 25-4 or 25-5)
Is V_3 or V_{av34} > 2,700 pc/h? ☑ Yes ☐ No
Is V_3 or V_{av34} > 1.5 * V_{12}/2 ☑ Yes ☐ No
If Yes, V_{12a} = 4086 pc/h (Equation 25-8)

Capacity Checks

	Actual	Capacity		LOS F?
V_{FO}	11077	Exhibit 25-7		Yes

Flow Entering Merge Influence Area

	Actual	Max Desirable		Violation?
V_{R12}	4948	Exhibit 25-7	4600:All	Yes

Level of Service Determination (if not F)

$D_R = 5.475 + 0.00734 v_R + 0.0078 V_{12} - 0.00627 L_A$
D_R = 38.3 (pc/mi/ln)
LOS = F (Exhibit 25-4)

Speed Determination

M_S = 0.794 (Exibit 25-19)
S_R = 46.7 mph (Exhibit 25-19)
S_0 = 53.9 mph (Exhibit 25-19)
S = 50.4 mph (Exhibit 25-14)

Diverge Areas

Estimation of v_{12}

$V_{12} = V_R + (V_F - V_R)P_{FD}$
L_{EQ} = (Equation 25-8 or 25-9)
P_{FD} = using Equation (Exhibit 25-12)
V_{12} = pc/h
V_3 or V_{av34} pc/h (Equation 25-15 or 25-16)
Is V_3 or V_{av34} > 2,700 pc/h? ☐ Yes ☐ No
Is V_3 or V_{av34} > 1.5 * V_{12}/2 ☐ Yes ☐ No
If Yes, V_{12a} = pc/h (Equation 25-18)

Capacity Checks

	Actual	Capacity		LOS F?
V_F		Exhibit 25-14		
$V_{FO} = V_F - V_R$		Exhibit 25-14		
V_R		Exhibit 25-3		

Flow Entering Diverge Influence Area

	Actual	Max Desirable		Violation?
V_{12}		Exhibit 25-14		

Level of Service Determination (if not F)

$D_R = 4.252 + 0.0086 V_{12} - 0.009 L_D$
D_R = (pc/mi/ln)
LOS = (Exhibit 25-4)

Speed Determination

D_s = (Exhibit 25-19)
S_R = mph (Exhibit 25-19)
S_0 = mph (Exhibit 25-19)
S = mph (Exhibit 25-15)

RAMPS AND RAMP JUNCTIONS WORKSHEET

General Information / Site Information

Analyst	Caroline Kone	Freeway/Dir of Travel	I-440 EB
Agency or Company	WSP SELLS	Junction	off-ramp to Ridge Rd-Glenwood
Date Performed	6/17/2010	Jurisdiction	Raleigh/NCDOT/FHWA
Analysis Time Period	PM Crabtree Extensions	Analysis Year	2035

Project Description Crabtree Valley

Inputs

Upstream Adj Ramp
☐ Yes ☐ On
☑ No ☐ Off
L_{up} = ft
V_u = veh/h

Terrain: Level

S_{FF} = 65.0 mph S_{FR} = 45.0 mph
Sketch (show lanes, L_A, L_D, V_R, V_f)

Downstream Adj Ramp
☑ Yes ☑ On
☐ No ☐ Off
L_{down} = 900 ft
V_D = 721 veh/h

Conversion to pc/h Under Base Conditions

(pc/h)	V (Veh/hr)	PHF	Terrain	%Truck	%Rv	f_{HV}	f_p	v = V/PHF x f_{HV} x f_p
Freeway	8463	1.00	Level	3	0	0.985	1.00	8590
Ramp	2742	1.00	Level	2	0	0.990	1.00	2769
UpStream								
DownStream	721	1.00	Level	2	0	0.990	1.00	728

Merge Areas

Estimation of v_{12}

$V_{12} = V_F (P_{FM})$
L_{EQ} = (Equation 25-2 or 25-3)
P_{FM} = using Equation (Exhibit 25-5)
V_{12} = pc/h
V_3 or V_{av34} pc/h (Equation 25-4 or 25-5)
Is V_3 or V_{av34} > 2,700 pc/h? ☐ Yes ☐ No
Is V_3 or V_{av34} > 1.5 * V_{12}/2 ☐ Yes ☐ No
If Yes, V_{12a} = pc/h (Equation 25-8)

Capacity Checks

	Actual	Capacity		LOS F?
V_{FO}		Exhibit 25-7		

Flow Entering Merge Influence Area

	Actual	Max Desirable		Violation?
V_{R12}		Exhibit 25-7		

Level of Service Determination (if not F)

$D_R = 5.475 + 0.00734\ v_R + 0.0078\ V_{12} - 0.00627\ L_A$
D_R = (pc/mi/ln)
LOS = (Exhibit 25-4)

Speed Determination

M_S = (Exibit 25-19)
S_R = mph (Exhibit 25-19)
S_0 = mph (Exhibit 25-19)
S = mph (Exhibit 25-14)

Diverge Areas

Estimation of v_{12}

$V_{12} = V_R + (V_F - V_R)P_{FD}$
L_{EQ} = (Equation 25-8 or 25-9)
P_{FD} = 0.450 using Equation (Exhibit 25-12)
V_{12} = 5388 pc/h
V_3 or V_{av34} 3202 pc/h (Equation 25-15 or 25-16)
Is V_3 or V_{av34} > 2,700 pc/h? ☑ Yes ☐ No
Is V_3 or V_{av34} > 1.5 * V_{12}/2 ☐ Yes ☑ No
If Yes, V_{12a} = 5890 pc/h (Equation 25-18)

Capacity Checks

	Actual	Capacity		LOS F?
V_F	8590	Exhibit 25-14	7050	Yes
$V_{FO} = V_F - V_R$	5821	Exhibit 25-14	7050	No
V_R	2769	Exhibit 25-3	4100	No

Flow Entering Diverge Influence Area

	Actual	Max Desirable		Violation?
V_{12}	5388	Exhibit 25-14	4400:All	Yes

Level of Service Determination (if not F)

$D_R = 4.252 + 0.0086\ V_{12} - 0.009\ L_D$
D_R = 38.7 (pc/mi/ln)
LOS = F (Exhibit 25-4)

Speed Determination

D_s = 0.547 (Exhibit 25-19)
S_R = 52.4 mph (Exhibit 25-19)
S_0 = 64.7 mph (Exhibit 25-19)
S = 55.7 mph (Exhibit 25-15)

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RAMPS AND RAMP JUNCTIONS WORKSHEET

General Information / Site Information

Analyst	Caroline Kone	Freeway/Dir of Travel	I-440 EB
Agency or Company	WSP SELLS	Junction	on-ramp from Crab. Valley Ave
Date Performed	6/17/2010	Jurisdiction	Raleigh/NCDOT/FHWA
Analysis Time Period	PM Crabtree Extensions	Analysis Year	2035

Project Description Crabtree Valley

Inputs

Upstream Adj Ramp
☐ Yes ☐ On
☑ No ☐ Off
L_{up} = ft
V_u = veh/h

Terrain: Level

S_{FF} = 65.0 mph S_{FR} = 45.0 mph

Sketch (show lanes, L_A, L_D, V_R, V_f)

Downstream Adj Ramp
☑ Yes ☑ On
☐ No ☐ Off
L_{down} = 1500 ft
V_D = 2465 veh/h

Conversion to pc/h Under Base Conditions

(pc/h)	V (Veh/hr)	PHF	Terrain	%Truck	%Rv	f_{HV}	f_p	v = V/PHF x f_{HV} x f_p
Freeway	5721	1.00	Level	3	0	0.985	1.00	5807
Ramp	721	1.00	Level	2	0	0.990	1.00	728
UpStream								
DownStream	2465	1.00	Level	2	0	0.990	1.00	2490

Merge Areas

Estimation of v_{12}

$V_{12} = V_F (P_{FM})$

L_{EQ} = (Equation 25-2 or 25-3)
P_{FM} = 0.619 using Equation (Exhibit 25-5)
V_{12} = 3597 pc/h
V_3 or V_{av34} 2210 pc/h (Equation 25-4 or 25-5)
Is V_3 or V_{av34} > 2,700 pc/h? ☐ Yes ☑ No
Is V_3 or V_{av34} > 1.5 * V_{12}/2 ☐ Yes ☑ No
If Yes, V_{12a} = pc/h (Equation 25-8)

Capacity Checks

	Actual	Capacity		LOS F?
V_{FO}	6535	Exhibit 25-7		No

Flow Entering Merge Influence Area

	Actual	Max Desirable		Violation?
V_{R12}	4325	Exhibit 25-7	4600:All	No

Level of Service Determination (if not F)

$D_R = 5.475 + 0.00734\, v_R + 0.0078\, V_{12} - 0.00627\, L_A$

D_R = 29.5 (pc/mi/ln)
LOS = D (Exhibit 25-4)

Speed Determination

M_S = 0.481 (Exibit 25-19)
S_R = 53.9 mph (Exhibit 25-19)
S_0 = 58.8 mph (Exhibit 25-19)
S = 55.5 mph (Exhibit 25-14)

Diverge Areas

Estimation of v_{12}

$V_{12} = V_R + (V_F - V_R) P_{FD}$

L_{EQ} = (Equation 25-8 or 25-9)
P_{FD} = using Equation (Exhibit 25-12)
V_{12} = pc/h
V_3 or V_{av34} pc/h (Equation 25-15 or 25-16)
Is V_3 or V_{av34} > 2,700 pc/h? ☐ Yes ☐ No
Is V_3 or V_{av34} > 1.5 * V_{12}/2 ☐ Yes ☐ No
If Yes, V_{12a} = pc/h (Equation 25-18)

Capacity Checks

	Actual	Capacity		LOS F?
V_F		Exhibit 25-14		
$V_{FO} = V_F - V_R$		Exhibit 25-14		
V_R		Exhibit 25-3		

Flow Entering Diverge Influence Area

	Actual	Max Desirable		Violation?
V_{12}		Exhibit 25-14		

Level of Service Determination (if not F)

$D_R = 4.252 + 0.0086\, V_{12} - 0.009\, L_D$

D_R = (pc/mi/ln)
LOS = (Exhibit 25-4)

Speed Determination

D_s = (Exhibit 25-19)
S_R = mph (Exhibit 25-19)
S_0 = mph (Exhibit 25-19)
S = mph (Exhibit 25-15)

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RAMPS AND RAMP JUNCTIONS WORKSHEET

General Information / Site Information

Analyst	G Teng	Freeway/Dir of Travel	I-440 EB
Agency or Company	WSP SELLS	Junction	on-ramp from Glenwood WB
Date Performed	6/16/2010	Jurisdiction	Raleigh/NCDOT/FHWA
Analysis Time Period	PM Crabtree Extensions	Analysis Year	2035

Project Description Crabtree Valley

Inputs

Upstream Adj Ramp
☑ Yes ☑ On
☐ No ☐ Off
L_{up} = 1200 ft
V_u = 2465 veh/h

Terrain: Level
S_{FF} = 65.0 mph S_{FR} = 45.0 mph
Sketch (show lanes, L_A, L_D, V_R, V_f)

Downstream Adj Ramp
☐ Yes ☐ On
☑ No ☐ Off
L_{down} = ft
V_D = veh/h

Conversion to pc/h Under Base Conditions

(pc/h)	V (Veh/hr)	PHF	Terrain	%Truck	%Rv	f_{HV}	f_p	v = V/PHF x f_{HV} x f_p
Freeway	8907	1.00	Level	3	0	0.985	1.00	9041
Ramp	1090	1.00	Level	2	0	0.990	1.00	1101
UpStream	2465	1.00	Level	2	0	0.990	1.00	2490
DownStream								

Merge Areas

Estimation of v_{12}

$V_{12} = V_F (P_{FM})$

L_{EQ} = (Equation 25-2 or 25-3)
P_{FM} = 0.080 using Equation (Exhibit 25-5)
V_{12} = 725 pc/h
V_3 or V_{av34} = 4158 pc/h (Equation 25-4 or 25-5)
Is V_3 or V_{av34} > 2,700 pc/h? ☑ Yes ☐ No
Is V_3 or V_{av34} > 1.5 * V_{12}/2 ☑ Yes ☐ No
If Yes, V_{12a} = 3616 pc/h (Equation 25-8)

Capacity Checks

	Actual	Capacity		LOS F?
V_{FO}	10142	Exhibit 25-7		Yes

Flow Entering Merge Influence Area

	Actual	Max Desirable		Violation?
V_{R12}	4717	Exhibit 25-7	4600:All	Yes

Level of Service Determination (if not F)

$D_R = 5.475 + 0.00734\, v_R + 0.0078\, V_{12} - 0.00627\, L_A$

D_R = 32.4 (pc/mi/ln)
LOS = F (Exhibit 25-4)

Speed Determination

M_S = 0.622 (Exibit 25-19)
S_R = 50.7 mph (Exhibit 25-19)
S_0 = 56.0 mph (Exhibit 25-19)
S = 53.4 mph (Exhibit 25-14)

Diverge Areas

Estimation of v_{12}

$V_{12} = V_R + (V_F - V_R)P_{FD}$

L_{EQ} = (Equation 25-8 or 25-9)
P_{FD} = using Equation (Exhibit 25-12)
V_{12} = pc/h
V_3 or V_{av34} = pc/h (Equation 25-15 or 25-16)
Is V_3 or V_{av34} > 2,700 pc/h? ☐ Yes ☐ No
Is V_3 or V_{av34} > 1.5 * V_{12}/2 ☐ Yes ☐ No
If Yes, V_{12a} = pc/h (Equation 25-18)

Capacity Checks

	Actual	Capacity		LOS F?
V_F		Exhibit 25-14		
$V_{FO} = V_F - V_R$		Exhibit 25-14		
V_R		Exhibit 25-3		

Flow Entering Diverge Influence Area

	Actual	Max Desirable		Violation?
V_{12}		Exhibit 25-14		

Level of Service Determination (if not F)

$D_R = 4.252 + 0.0086\, V_{12} - 0.009\, L_D$

D_R = (pc/mi/ln)
LOS = (Exhibit 25-4)

Speed Determination

D_s = (Exhibit 25-19)
S_R = mph (Exhibit 25-19)
S_0 = mph (Exhibit 25-19)
S = mph (Exhibit 25-15)

RAMPS AND RAMP JUNCTIONS WORKSHEET

General Information / Site Information

Analyst	Caroline Kone	Freeway/Dir of Travel	I-440 WB
Agency or Company	WSP SELLS	Junction	off-ramp to Glenwood/CVA
Date Performed	6/17/2010	Jurisdiction	Raleigh/NCDOT/FHWA
Analysis Time Period	PM Crabtree Extensions	Analysis Year	2035

Project Description Crabtree Valley

Inputs

Upstream Adj Ramp
☐ Yes ☐ On
☑ No ☐ Off
L_{up} = ft
V_u = veh/h

Terrain: Level

S_{FF} = 65.0 mph S_{FR} = 45.0 mph

Sketch (show lanes, L_A, L_D, V_R, V_f)

Downstream Adj Ramp
☐ Yes ☐ On
☑ No ☐ Off
L_{down} = ft
V_D = veh/h

Conversion to pc/h Under Base Conditions

(pc/h)	V (Veh/hr)	PHF	Terrain	%Truck	%Rv	f_{HV}	f_p	v = V/PHF x f_{HV} x f_p
Freeway	11115	1.00	Level	3	0	0.985	1.00	11282
Ramp	0	1.00	Level	2	0	0.990	1.00	0
UpStream								
DownStream								

Merge Areas

Estimation of v_{12}

$V_{12} = V_F (P_{FM})$

L_{EQ} = (Equation 25-2 or 25-3)
P_{FM} = using Equation (Exhibit 25-5)
V_{12} = pc/h
V_3 or V_{av34} pc/h (Equation 25-4 or 25-5)
Is V_3 or V_{av34} > 2,700 pc/h? ☐ Yes ☐ No
Is V_3 or V_{av34} > 1.5 * V_{12}/2 ☐ Yes ☐ No
If Yes, V_{12a} = pc/h (Equation 25-8)

Capacity Checks

	Actual	Capacity		LOS F?
V_{FO}		Exhibit 25-7		

Flow Entering Merge Influence Area

	Actual	Max Desirable	Violation?
V_{R12}		Exhibit 25-7	

Level of Service Determination (if not F)

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

D_R = (pc/mi/ln)
LOS = (Exhibit 25-4)

Speed Determination

M_S = (Exibit 25-19)
S_R = mph (Exhibit 25-19)
S_0 = mph (Exhibit 25-19)
S = mph (Exhibit 25-14)

Diverge Areas

Estimation of v_{12}

$V_{12} = V_R + (V_F - V_R)P_{FD}$

L_{EQ} = (Equation 25-8 or 25-9)
P_{FD} = 0.260 using Equation (Exhibit 25-12)
V_{12} = 2347 pc/h
V_3 or V_{av34} 3339 pc/h (Equation 25-15 or 25-16)
Is V_3 or V_{av34} > 2,700 pc/h? ☑ Yes ☐ No
Is V_3 or V_{av34} > 1.5 * V_{12}/2 ☑ Yes ☐ No
If Yes, V_{12a} = 3610 pc/h (Equation 25-18)

Capacity Checks

	Actual	Capacity		LOS F?
V_F	9026	Exhibit 25-14	9400	No
$V_{FO} = V_F - V_R$	9026	Exhibit 25-14	9400	No
V_R	0	Exhibit 25-3	4100	No

Flow Entering Diverge Influence Area

	Actual	Max Desirable		Violation?
V_{12}	2347	Exhibit 25-14	4400:All	No

Level of Service Determination (if not F)

D_R = ~~4.252 + 0.0086 V_{12} - 0.0091 L_D~~ $0.0109 v_F$ / N

D_R = ~~30.0~~ (pc/mi/ln) 24.59
LOS = ~~D~~ (Exhibit 25-4) C

Speed Determination

D_s = 0.298 (Exhibit 25-19)
S_R = 58.1 mph (Exhibit 25-19)
S_0 = 64.6 mph (Exhibit 25-19)
S = 61.9 mph (Exhibit 25-15)

RAMPS AND RAMP JUNCTIONS WORKSHEET

General Information / Site Information

Analyst	Caroline Kone	Freeway/Dir of Travel	I-440 WB
Agency or Company	WSP SELLS	Junction	on-ramp from Crab. Valley Ave
Date Performed	6/17/2010	Jurisdiction	Raleigh/NCDOT/FHWA
Analysis Time Period	PM Crabtree Extensions	Analysis Year	2035

Project Description Crabtree Valley

Inputs

Upstream Adj Ramp: ☑ Yes ☑ On / ☐ No ☐ Off

L_{up} = 375 ft

V_u = 1339 veh/h

Terrain: Level

S_{FF} = 65.0 mph S_{FR} = 45.0 mph

Sketch (show lanes, L_A, L_D, V_R, V_f)

Downstream Adj Ramp: ☐ Yes ☐ On / ☑ No ☐ Off

L_{down} = ft

V_D = veh/h

Conversion to pc/h Under Base Conditions

(pc/h)	V (Veh/hr)	PHF	Terrain	%Truck	%Rv	f_{HV}	f_p	v = V/PHF x f_{HV} x f_p
Freeway	7085	1.00	Level	3	0	0.985	1.00	7191
Ramp	1524	1.00	Level	2	0	0.990	1.00	1539
UpStream	1339	1.00	Level	0	0	1.000	1.00	1339
DownStream								

Merge Areas

Estimation of v_{12}

$V_{12} = V_F (P_{FM})$

L_{EQ} = (Equation 25-2 or 25-3)

P_{FM} = 0.025 using Equation (Exhibit 25-5)

V_{12} = 183 pc/h

V_3 or V_{av34} 3504 pc/h (Equation 25-4 or 25-5)

Is V_3 or V_{av34} > 2,700 pc/h? ☑ Yes ☐ No

Is V_3 or V_{av34} > 1.5 * V_{12}/2 ☑ Yes ☐ No

If Yes, V_{12a} = 2876 pc/h (Equation 25-8)

Capacity Checks

	Actual	Capacity		LOS F?
V_{FO}	8730	Exhibit 25-7		No

Flow Entering Merge Influence Area

	Actual	Max Desirable		Violation?
V_{R12}	4415	Exhibit 25-7	4600:All	No

Level of Service Determination (if not F)

$D_R = 5.475 + 0.00734\, v_R + 0.0078\, V_{12} - 0.00627\, L_A$

D_R = 33.9 (pc/mi/ln)

LOS = D (Exhibit 25-4)

Speed Determination

M_S = 0.567 (Exibit 25-19)

S_R = 52.0 mph (Exhibit 25-19)

S_0 = 59.0 mph (Exhibit 25-19)

S = 55.2 mph (Exhibit 25-14)

Diverge Areas

Estimation of v_{12}

$V_{12} = V_R + (V_F - V_R)P_{FD}$

L_{EQ} = (Equation 25-8 or 25-9)

P_{FD} = using Equation (Exhibit 25-12)

V_{12} = pc/h

V_3 or V_{av34} pc/h (Equation 25-15 or 25-16)

Is V_3 or V_{av34} > 2,700 pc/h? ☐ Yes ☐ No

Is V_3 or V_{av34} > 1.5 * V_{12}/2 ☐ Yes ☐ No

If Yes, V_{12a} = pc/h (Equation 25-18)

Capacity Checks

	Actual	Capacity		LOS F?
V_F		Exhibit 25-14		
$V_{FO} = V_F - V_R$		Exhibit 25-14		
V_R		Exhibit 25-3		

Flow Entering Diverge Influence Area

	Actual	Max Desirable		Violation?
V_{12}		Exhibit 25-14		

Level of Service Determination (if not F)

$D_R = 4.252 + 0.0086\, V_{12} - 0.009\, L_D$

D_R = (pc/mi/ln)

LOS = (Exhibit 25-4)

Speed Determination

D_s = (Exhibit 25-19)

S_R = mph (Exhibit 25-19)

S_0 = mph (Exhibit 25-19)

S = mph (Exhibit 25-15)

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2035 CVA Extension to I-440

RAMPS AND RAMP JUNCTIONS WORKSHEET

General Information / Site Information

Analyst	APATEL	Freeway/Dir of Travel	I-440 EB
Agency or Company	WSP SELLS	Junction	off-ramp to Ridge Rd
Date Performed	6/17/2010	Jurisdiction	Raleigh/NCDOT/FHWA
Analysis Time Period	AM CVA Ext. to I-440	Analysis Year	2035

Project Description Crabtree Valley

Inputs

Upstream Adj Ramp
☐ Yes ☐ On
☑ No ☐ Off
L_{up} = ft
V_u = veh/h

Terrain: Level

S_{FF} = 65.0 mph S_{FR} = 45.0 mph
Sketch (show lanes, L_A, L_D, V_R, V_f)

Downstream Adj Ramp
☑ Yes ☑ On
☐ No ☐ Off
L_{down} = 900 ft
V_D = 744 veh/h

Conversion to pc/h Under Base Conditions

(pc/h)	V (Veh/hr)	PHF	Terrain	%Truck	%Rv	f_{HV}	f_p	v = V/PHF x f_{HV} x f_p
Freeway	6851	1.00	Level	3	0	0.985	1.00	6954
Ramp	1829	1.00	Level	2	0	0.990	1.00	1847
UpStream								
DownStream	744	1.00	Level	2	0	0.990	1.00	751

Merge Areas

Estimation of v_{12}

$V_{12} = V_F (P_{FM})$
L_{EQ} = (Equation 25-2 or 25-3)
P_{FM} = using Equation (Exhibit 25-5)
V_{12} = pc/h
V_3 or V_{av34} pc/h (Equation 25-4 or 25-5)
Is V_3 or V_{av34} > 2,700 pc/h? ☐ Yes ☐ No
Is V_3 or V_{av34} > 1.5 * V_{12}/2 ☐ Yes ☐ No
If Yes, V_{12a} = pc/h (Equation 25-8)

Capacity Checks

	Actual	Capacity		LOS F?
V_{FO}		Exhibit 25-7		

Flow Entering Merge Influence Area

	Actual	Max Desirable		Violation?
V_{R12}		Exhibit 25-7		

Level of Service Determination (if not F)

$D_R = 5.475 + 0.00734\ v_R + 0.0078\ V_{12} - 0.00627\ L_A$
D_R = (pc/mi/ln)
LOS = (Exhibit 25-4)

Speed Determination

M_S = (Exibit 25-19)
S_R = mph (Exhibit 25-19)
S_0 = mph (Exhibit 25-19)
S = mph (Exhibit 25-14)

Diverge Areas

Estimation of v_{12}

$V_{12} = V_R + (V_F - V_R)P_{FD}$
L_{EQ} = (Equation 25-8 or 25-9)
P_{FD} = 0.450 using Equation (Exhibit 25-12)
V_{12} = 4145 pc/h
V_3 or V_{av34} 2809 pc/h (Equation 25-15 or 25-16)
Is V_3 or V_{av34} > 2,700 pc/h? ☑ Yes ☐ No
Is V_3 or V_{av34} > 1.5 * V_{12}/2 ☐ Yes ☑ No
If Yes, V_{12a} = 4254 pc/h (Equation 25-18)

Capacity Checks

	Actual	Capacity		LOS F?
V_F	6954	Exhibit 25-14	7050	No
$V_{FO} = V_F - V_R$	5107	Exhibit 25-14	7050	No
V_R	1847	Exhibit 25-3	4100	No

Flow Entering Diverge Influence Area

	Actual	Max Desirable		Violation?
V_{12}	4145	Exhibit 25-14	4400:All	No

Level of Service Determination (if not F)

$D_R = 4.252 + 0.0086\ V_{12} - 0.009\ L_D$
D_R = 24.6 (pc/mi/ln)
LOS = C (Exhibit 25-4)

Speed Determination

D_s = 0.464 (Exhibit 25-19)
S_R = 54.3 mph (Exhibit 25-19)
S_0 = 64.7 mph (Exhibit 25-19)
S = 57.9 mph (Exhibit 25-15)

RAMPS AND RAMP JUNCTIONS WORKSHEET

General Information / Site Information

Analyst	APATEL	Freeway/Dir of Travel	I-440 EB
Agency or Company	WSP SELLS	Junction	on-ramp from Crab/ Valley Ave
Date Performed	6/17/2010	Jurisdiction	Raleigh/NCDOT/FHWA
Analysis Time Period	AM CVA extension to I-440	Analysis Year	2035

Project Description Crabtree Valley

Inputs

Upstream Adj Ramp
☐ Yes ☐ On
☑ No ☐ Off
L_{up} = ft
V_u = veh/h

Terrain: Level

S_{FF} = 65.0 mph S_{FR} = 45.0 mph

Sketch (show lanes, L_A, L_D, V_R, V_f)

Downstream Adj Ramp
☑ Yes ☑ On
☐ No ☐ Off
L_{down} = 1500 ft
V_D = 1890 veh/h

Conversion to pc/h Under Base Conditions

(pc/h)	V (Veh/hr)	PHF	Terrain	%Truck	%Rv	f_{HV}	f_p	$v = V/PHF \times f_{HV} \times f_p$
Freeway	5022	1.00	Level	3	0	0.985	1.00	5097
Ramp	744	1.00	Level	2	0	0.990	1.00	751
UpStream								
DownStream	1890	1.00	Level	2	0	0.990	1.00	1909

Merge Areas

Estimation of v_{12}

$V_{12} = V_F (P_{FM})$

L_{EQ} = (Equation 25-2 or 25-3)
P_{FM} = 0.619 using Equation (Exhibit 25-5)
V_{12} = 3158 pc/h
V_3 or V_{av34} 1939 pc/h (Equation 25-4 or 25-5)
Is V_3 or V_{av34} > 2,700 pc/h? ☐ Yes ☑ No
Is V_3 or V_{av34} > 1.5 * V_{12}/2 ☐ Yes ☑ No
If Yes, V_{12a} = pc/h (Equation 25-8)

Capacity Checks

	Actual	Capacity		LOS F?
V_{FO}	5848	Exhibit 25-7		No

Flow Entering Merge Influence Area

	Actual	Max Desirable		Violation?
V_{R12}	3909	Exhibit 25-7	4600:All	No

Level of Service Determination (if not F)

$D_R = 5.475 + 0.00734\, v_R + 0.0078\, V_{12} - 0.00627\, L_A$

D_R = 26.2 (pc/mi/ln)
LOS = C (Exhibit 25-4)

Speed Determination

M_S = 0.380 (Exibit 25-19)
S_R = 56.3 mph (Exhibit 25-19)
S_0 = 59.8 mph (Exhibit 25-19)
S = 57.4 mph (Exhibit 25-14)

Diverge Areas

Estimation of v_{12}

$V_{12} = V_R + (V_F - V_R)P_{FD}$

L_{EQ} = (Equation 25-8 or 25-9)
P_{FD} = using Equation (Exhibit 25-12)
V_{12} = pc/h
V_3 or V_{av34} pc/h (Equation 25-15 or 25-16)
Is V_3 or V_{av34} > 2,700 pc/h? ☐ Yes ☐ No
Is V_3 or V_{av34} > 1.5 * V_{12}/2 ☐ Yes ☐ No
If Yes, V_{12a} = pc/h (Equation 25-18)

Capacity Checks

	Actual	Capacity		LOS F?
V_F		Exhibit 25-14		
$V_{FO} = V_F - V_R$		Exhibit 25-14		
V_R		Exhibit 25-3		

Flow Entering Diverge Influence Area

	Actual	Max Desirable		Violation?
V_{12}		Exhibit 25-14		

Level of Service Determination (if not F)

$D_R = 4.252 + 0.0086\, V_{12} - 0.009\, L_D$

D_R = (pc/mi/ln)
LOS = (Exhibit 25-4)

Speed Determination

D_s = (Exhibit 25-19)
S_R = mph (Exhibit 25-19)
S_0 = mph (Exhibit 25-19)
S = mph (Exhibit 25-15)

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RAMPS AND RAMP JUNCTIONS WORKSHEET

General Information / Site Information

Analyst	APATEL	Freeway/Dir of Travel	I-440 EB
Agency or Company	WSP SELLS	Junction	on-ramp from Glenwood WB
Date Performed	6/17/2010	Jurisdiction	Raleigh/NCDOT/FHWA
Analysis Time Period	AM CVA extension to I-440	Analysis Year	2035

Project Description Crabtree Valley

Inputs

Upstream Adj Ramp
☑ Yes ☑ On
☐ No ☐ Off
L_{up} = 1200 ft
V_u = 1890 veh/h

Terrain: Level
S_{FF} = 65.0 mph S_{FR} = 45.0 mph
Sketch (show lanes, L_A, L_D, V_R, V_f)

Downstream Adj Ramp
☐ Yes ☐ On
☑ No ☐ Off
L_{down} = ft
V_D = veh/h

Conversion to pc/h Under Base Conditions

(pc/h)	V (Veh/hr)	PHF	Terrain	%Truck	%Rv	f_{HV}	f_p	v = V/PHF x f_{HV} x f_p
Freeway	7656	1.00	Level	3	0	0.985	1.00	7771
Ramp	1163	1.00	Level	2	0	0.990	1.00	1175
UpStream	1890	1.00	Level	0	0	1.000	1.00	1890
DownStream								

Merge Areas

Estimation of v_{12}

$V_{12} = V_F (P_{FM})$
L_{EQ} = (Equation 25-2 or 25-3)
P_{FM} = 0.071 using Equation (Exhibit 25-5)
V_{12} = 551 pc/h
V_3 or V_{av34} 3610 pc/h (Equation 25-4 or 25-5)
Is V_3 or V_{av34} > 2,700 pc/h? ☑ Yes ☐ No
Is V_3 or V_{av34} > 1.5 * V_{12}/2 ☑ Yes ☐ No
If Yes, V_{12a} = 3108 pc/h (Equation 25-8)

Capacity Checks

	Actual	Capacity		LOS F?
V_{FO}	8946	Exhibit 25-7		No

Flow Entering Merge Influence Area

	Actual	Max Desirable		Violation?
V_{R12}	4283	Exhibit 25-7	4600:All	No

Level of Service Determination (if not F)

$D_R = 5.475 + 0.00734\, v_R + 0.0078\, V_{12} - 0.00627\, L_A$
D_R = 28.9 (pc/mi/ln)
LOS = D (Exhibit 25-4)

Speed Determination

M_S = 0.469 (Exibit 25-19)
S_R = 54.2 mph (Exhibit 25-19)
S_0 = 58.3 mph (Exhibit 25-19)
S = 56.3 mph (Exhibit 25-14)

Diverge Areas

Estimation of v_{12}

$V_{12} = V_R + (V_F - V_R)P_{FD}$
L_{EQ} = (Equation 25-8 or 25-9)
P_{FD} = using Equation (Exhibit 25-12)
V_{12} = pc/h
V_3 or V_{av34} pc/h (Equation 25-15 or 25-16)
Is V_3 or V_{av34} > 2,700 pc/h? ☐ Yes ☐ No
Is V_3 or V_{av34} > 1.5 * V_{12}/2 ☐ Yes ☐ No
If Yes, V_{12a} = pc/h (Equation 25-18)

Capacity Checks

	Actual	Capacity		LOS F?
V_F		Exhibit 25-14		
$V_{FO} = V_F - V_R$		Exhibit 25-14		
V_R		Exhibit 25-3		

Flow Entering Diverge Influence Area

	Actual	Max Desirable		Violation?
V_{12}		Exhibit 25-14		

Level of Service Determination (if not F)

$D_R = 4.252 + 0.0086\, V_{12} - 0.009\, L_D$
D_R = (pc/mi/ln)
LOS = (Exhibit 25-4)

Speed Determination

D_s = (Exhibit 25-19)
S_R = mph (Exhibit 25-19)
S_0 = mph (Exhibit 25-19)
S = mph (Exhibit 25-15)

RAMPS AND RAMP JUNCTIONS WORKSHEET

General Information / Site Information

Analyst	Caroline Kone	Freeway/Dir of Travel	I-440 WB
Agency or Company	WSP SELLS	Junction	off-ramp to Glenwood & CVA
Date Performed	6/17/2010	Jurisdiction	Raleigh/NVDOT/FHWA
Analysis Time Period	AM CVA extension to I-440	Analysis Year	2035
Project Description	Crabtree valley		

Inputs

Upstream Adj Ramp
☐ Yes ☐ On
☑ No ☐ Off
L_{up} = ft
V_u = veh/h

Terrain: Level

S_{FF} = 65.0 mph S_{FR} = 45.0 mph

Sketch (show lanes, L_A, L_D, V_R, V_f)

Downstream Adj Ramp
☐ Yes ☐ On
☑ No ☐ Off
L_{down} = ft
V_D = veh/h

Conversion to pc/h Under Base Conditions

(pc/h)	V (Veh/hr)	PHF	Terrain	%Truck	%Rv	f_{HV}	f_p	v = V/PHF x f_{HV} x f_p
Freeway	12893	1.00	Level	3	0	0.985	1.00	13086
Ramp	0	1.00	Level	2	0	0.990	1.00	0
UpStream								
DownStream								

Merge Areas

Estimation of v_{12}

$V_{12} = V_F (P_{FM})$

L_{EQ} = (Equation 25-2 or 25-3)
P_{FM} = using Equation (Exhibit 25-5)
V_{12} = pc/h
V_3 or V_{av34} pc/h (Equation 25-4 or 25-5)
Is V_3 or V_{av34} > 2,700 pc/h? ☐ Yes ☐ No
Is V_3 or V_{av34} > 1.5 * V_{12}/2 ☐ Yes ☐ No
If Yes, V_{12a} = pc/h (Equation 25-8)

Capacity Checks

	Actual	Capacity		LOS F?
V_{FO}		Exhibit 25-7		

Flow Entering Merge Influence Area

	Actual	Max Desirable		Violation?
V_{R12}		Exhibit 25-7		

Level of Service Determination (if not F)

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

D_R = (pc/mi/ln)
LOS = (Exhibit 25-4)

Speed Determination

M_S = (Exibit 25-19)
S_R = mph (Exhibit 25-19)
S_0 = mph (Exhibit 25-19)
S = mph (Exhibit 25-14)

Diverge Areas

Estimation of v_{12}

$V_{12} = V_R + (V_F - V_R)P_{FD}$

L_{EQ} = (Equation 25-8 or 25-9)
P_{FD} = 0.260 using Equation (Exhibit 25-12)
V_{12} = 2722 pc/h
V_3 or V_{av34} 3873 pc/h (Equation 25-15 or 25-16)
Is V_3 or V_{av34} > 2,700 pc/h? ☑ Yes ☐ No
Is V_3 or V_{av34} > 1.5 * V_{12}/2 ☑ Yes ☐ No
If Yes, V_{12a} = 4187 pc/h (Equation 25-18)

Capacity Checks

	Actual	Capacity		LOS F?
V_F	10469	Exhibit 25-14	9400	Yes
$V_{FO} = V_F - V_R$	10469	Exhibit 25-14	9400	Yes
V_R	0	Exhibit 25-3	4100	No

Flow Entering Diverge Influence Area

	Actual	Max Desirable		Violation?
V_{12}	2722	Exhibit 25-14	4400:All	No

Level of Service Determination (if not F)

$D_R = 4.252 + 0.0086\ V_{12} - 0.009\ L_D$ ~~0.0109~~ $\frac{V_f}{N}$

D_R = ~~8.8~~ (pc/mi/ln) 28.53
LOS = ~~F~~ (Exhibit 25-4) D

Speed Determination

D_s = 0.298 (Exhibit 25-19)
S_R = 58.1 mph (Exhibit 25-19)
S_0 = 63.0 mph (Exhibit 25-19)
S = 60.9 mph (Exhibit 25-15)

RAMPS AND RAMP JUNCTIONS WORKSHEET

General Information / Site Information

Analyst	Caroline Kone	Freeway/Dir of Travel	I-440 WB
Agency or Company	WSP SELLS	Junction	on-ramp from CVA extension
Date Performed	6/17/2010	Jurisdiction	Raleigh/NCDOT/FHWA
Analysis Time Period	AM CVA extension to I-440	Analysis Year	2035

Project Description Crabtree Valley

Inputs

Upstream Adj Ramp
☑ Yes ☑ On
☐ No ☐ Off
L_{up} = 300 ft
V_u = 1349 veh/h

Terrain: Level
S_{FF} = 65.0 mph S_{FR} = 45.0 mph
Sketch (show lanes, L_A, L_D, V_R, V_f)

Downstream Adj Ramp
☐ Yes ☐ On
☑ No ☐ Off
L_{down} = ft
V_D = veh/h

Conversion to pc/h Under Base Conditions

(pc/h)	V (Veh/hr)	PHF	Terrain	%Truck	%Rv	f_{HV}	f_p	v = V/PHF x f_{HV} x f_p
Freeway	10300	1.00	Level	3	0	0.985	1.00	10454
Ramp	617	1.00	Level	2	0	0.990	1.00	623
UpStream	1349	1.00	Level	2	0	0.990	1.00	1362
DownStream								

Merge Areas

Estimation of v_{12}

$V_{12} = V_F (P_{FM})$
L_{EQ} = (Equation 25-2 or 25-3)
P_{FM} = 0.140 using Equation (Exhibit 25-5)
V_{12} = 1463 pc/h
V_3 or V_{av34} 4495 pc/h (Equation 25-4 or 25-5)
Is V_3 or V_{av34} > 2,700 pc/h? ☑ Yes ☐ No
Is V_3 or V_{av34} > 1.5 * V_{12}/2 ☑ Yes ☐ No
If Yes, V_{12a} = 4181 pc/h (Equation 25-8)

Capacity Checks

	Actual	Capacity		LOS F?
V_{FO}	11077	Exhibit 25-7		Yes

Flow Entering Merge Influence Area

	Actual	Max Desirable		Violation?
V_{R12}	4804	Exhibit 25-7	4600:All	Yes

Level of Service Determination (if not F)

$D_R = 5.475 + 0.00734\, v_R + 0.0078\, V_{12} - 0.00627\, L_A$
D_R = 37.3 (pc/mi/ln)
LOS = F (Exhibit 25-4)

Speed Determination

M_S = 0.720 (Exibit 25-19)
S_R = 48.4 mph (Exhibit 25-19)
S_0 = 53.5 mph (Exhibit 25-19)
S = 51.2 mph (Exhibit 25-14)

Diverge Areas

Estimation of v_{12}

$V_{12} = V_R + (V_F - V_R)P_{FD}$
L_{EQ} = (Equation 25-8 or 25-9)
P_{FD} = using Equation (Exhibit 25-12)
V_{12} = pc/h
V_3 or V_{av34} pc/h (Equation 25-15 or 25-16)
Is V_3 or V_{av34} > 2,700 pc/h? ☐ Yes ☐ No
Is V_3 or V_{av34} > 1.5 * V_{12}/2 ☐ Yes ☐ No
If Yes, V_{12a} = pc/h (Equation 25-18)

Capacity Checks

	Actual	Capacity		LOS F?
V_F		Exhibit 25-14		
$V_{FO} = V_F - V_R$		Exhibit 25-14		
V_R		Exhibit 25-3		

Flow Entering Diverge Influence Area

	Actual	Max Desirable		Violation?
V_{12}		Exhibit 25-14		

Level of Service Determination (if not F)

$D_R = 4.252 + 0.0086\, V_{12} - 0.009\, L_D$
D_R = (pc/mi/ln)
LOS = (Exhibit 25-4)

Speed Determination

D_s = (Exhibit 25-19)
S_R = mph (Exhibit 25-19)
S_0 = mph (Exhibit 25-19)
S = mph (Exhibit 25-15)

RAMPS AND RAMP JUNCTIONS WORKSHEET

General Information / Site Information

Analyst	Caroline Kone	Freeway/Dir of Travel	I-440 WB
Agency or Company	WSP SELLS	Junction	on-ramp from Glen. EB
Date Performed	6/17/2010	Jurisdiction	Raleigh/NCDOT/FHWA
Analysis Time Period	AM CVA extensionto I-440	Analysis Year	2035

Project Description Crabtree Valley

Inputs

Upstream Adj Ramp	Terrain: Level	Downstream Adj Ramp
☐ Yes ☐ On		☑ Yes ☑ On
☑ No ☐ Off		☐ No ☐ Off
L_{up} = ft		L_{down} = 300 ft
V_u = veh/h	S_{FF} = 65.0 mph S_{FR} = 45.0 mph Sketch (show lanes, L_A, L_D,V_R,V_f)	V_D = 617 veh/h

Conversion to pc/h Under Base Conditions

(pc/h)	V (Veh/hr)	PHF	Terrain	%Truck	%Rv	f_{HV}	f_p	v = V/PHF x f_{HV} x f_p
Freeway	8951	1.00	Level	3	0	0.985	1.00	9085
Ramp	1349	1.00	Level	2	0	0.990	1.00	1362
UpStream								
DownStream	617	1.00	Level	2	0	0.990	1.00	623

Merge Areas

Estimation of v_{12}

$V_{12} = V_F (P_{FM})$

L_{EQ} = (Equation 25-2 or 25-3)

P_{FM} = 0.048 using Equation (Exhibit 25-5)

V_{12} = 432 pc/h

V_3 or V_{av34} = 4326 pc/h (Equation 25-4 or 25-5)

Is V_3 or V_{av34} > 2,700 pc/h? ☑ Yes ☐ No

Is V_3 or V_{av34} > 1.5 * V_{12}/2 ☑ Yes ☐ No

If Yes,V_{12a} = 3634 pc/h (Equation 25-8)

Capacity Checks

	Actual	Capacity		LOS F?
V_{FO}	10447	Exhibit 25-7		Yes

Flow Entering Merge Influence Area

	Actual	Max Desirable		Violation?
V_{R12}	4996	Exhibit 25-7	4600:All	Yes

Level of Service Determination (if not F)

$D_R = 5.475 + 0.00734\, v_R + 0.0078\, V_{12} - 0.00627\, L_A$

D_R = 35.0 (pc/mi/ln)

LOS = F (Exhibit 25-4)

Speed Determination

M_S = 0.772 (Exibit 25-19)

S_R = 47.3 mph (Exhibit 25-19)

S_0 = 55.9 mph (Exhibit 25-19)

S = 51.4 mph (Exhibit 25-14)

Diverge Areas

Estimation of v_{12}

$V_{12} = V_R + (V_F - V_R)P_{FD}$

L_{EQ} = (Equation 25-8 or 25-9)

P_{FD} = using Equation (Exhibit 25-12)

V_{12} = pc/h

V_3 or V_{av34} = pc/h (Equation 25-15 or 25-16)

Is V_3 or V_{av34} > 2,700 pc/h? ☐ Yes ☐ No

Is V_3 or V_{av34} > 1.5 * V_{12}/2 ☐ Yes ☐ No

If Yes,V_{12a} = pc/h (Equation 25-18)

Capacity Checks

	Actual	Capacity		LOS F?
V_F		Exhibit 25-14		
$V_{FO} = V_F - V_R$		Exhibit 25-14		
V_R		Exhibit 25-3		

Flow Entering Diverge Influence Area

	Actual	Max Desirable		Violation?
V_{12}		Exhibit 25-14		

Level of Service Determination (if not F)

$D_R = 4.252 + 0.0086\, V_{12} - 0.009\, L_D$

D_R = (pc/mi/ln)

LOS = (Exhibit 25-4)

Speed Determination

D_s = (Exhibit 25-19)

S_R = mph (Exhibit 25-19)

S_0 = mph (Exhibit 25-19)

S = mph (Exhibit 25-15)

FREEWAY WEAVING WORKSHEET

General Information

Analyst	G Teng
Agency/Company	WSP SELLS
Date Performed	7/19/2010
Analysis Time Period	AM CVA extension to I-440

Site Information

Freeway/Dir of Travel	I-440 WB
Weaving Seg Location	Glen. WB on to Glen. EB off
Jurisdiction	Raleigh/NCDOT/FHWA
Analysis Year	2035

Inputs

Freeway free-flow speed, S_{FF} (mi/h)	55	Weaving type	B
Weaving number of lanes, N	2	Volume ratio, VR	0.67
Weaving seg length, L (ft)	870	Weaving ratio, R	0.14
Terrain	Level		

Conversions to pc/h Under Base Conditions

(pc/h)	V	PHF	Truck %	RV %	E_T	E_R	f_{HV}	f_p	v
V_{o1}	691	1.00	3	0	1.5	1.2	0.985	1.00	701
V_{o2}	0	1.00	0	0	1.5	1.2	1.000	1.00	0
V_{w1}	1238	1.00	2	0	1.5	1.2	0.990	1.00	1250
V_{w2}	197	1.00	2	0	1.5	1.2	0.990	1.00	198
V_w				1448	V_{nw}				701
V									2149

Weaving and Non-Weaving Speeds

	Unconstrained		Constrained	
	Weaving (i = w)	Non-Weaving (i = nw)	Weaving (i = w)	Non-Weaving (= nw)
a (Exhibit 24-6)	0.08	0.0020		
b (Exhibit 24-6)	2.20	6.00		
c (Exhibit 24-6)	0.70	1.00		
d (Exhibit 24-6)	0.50	0.50		
Weaving intensity factor, Wi	1.12	1.60		
Weaving and non-weaving speeds, Si (mi/h)	36.28	32.29		

Number of lanes required for unconstrained operation, Nw 1.80
Maximum number of lanes, Nw (max) 3.50

☑ If Nw < Nw(max) unconstrained operation ☐ if Nw > Nw (max) constrained operation

Weaving Segment Speed, Density, Level of Service, and Capacity

Weaving segment speed, S (mi/h)	34.87
Weaving segment density, D (pc/mi/ln)	30.81
Level of service, LOS	C
Capacity of base condition, c_0 (pc/h)	
Capacity as a 15-minute flow rate, c (veh/h)	
Capacity as a full-hour volume, c_h (veh/h)	

Notes

a. Weaving segments longer than 2500 ft. are treated as isolated merge and diverge areas using the procedures of Chapter 25, "Ramps and Ramp Junctions".
b. Capacity constrained by basic freeway capacity.
c. Capacity occurs under constrained operating conditions.
d. Three-lane Type A segments do not operate well at volume ratios greater than 0.45. Poor operations and some local queuing are expected in such cases.
e. Four-lane Type A segments do not operate well at volume ratios greater than 0.35. Poor operations and some local queuing are expected in such cases.
f. Capacity constrained by maximum allowable weaving flow rate: 2,800 pc/h (Type A), 4,000 (Type B), 3,500 (Type C).
g. Five-lane Type A segments do not operate well at volume ratios greater than 0.20. Poor operations and some local queuing are expected in such cases.
h. Type B weaving segments do not operate well at volume ratios greater than 0.80. Poor operations and some local queuing are expected in such cases.
i. Type C weaving segments do not operate well at volume ratios greater than 0.50. Poor operations and some local queuing are expected in such cases.

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RAMPS AND RAMP JUNCTIONS WORKSHEET

General Information / Site Information

Analyst	APATEL	Freeway/Dir of Travel	I-440 EB
Agency or Company	WSP SELLS	Junction	off-ramp to Ridge Rd
Date Performed	6/17/2010	Jurisdiction	Raleigh/NCDOT/FHWA
Analysis Time Period	PM CVA Ext. to I-440	Analysis Year	2035

Project Description: Crabtree Valley

Inputs

Upstream Adj Ramp: ☐ Yes ☐ On ☑ No ☐ Off

L_{up} = ft

V_u = veh/h

Terrain: Level

S_{FF} = 65.0 mph S_{FR} = 45.0 mph

Sketch (show lanes, L_A, L_D, V_R, V_f)

Downstream Adj Ramp: ☑ Yes ☑ On ☐ No ☐ Off

L_{down} = 900 ft

V_D = 989 veh/h

Conversion to pc/h Under Base Conditions

(pc/h)	V (Veh/hr)	PHF	Terrain	%Truck	%Rv	f_{HV}	f_p	v = V/PHF x f_{HV} x f_p
Freeway	8463	1.00	Level	3	0	0.985	1.00	8590
Ramp	2742	1.00	Level	2	0	0.990	1.00	2769
UpStream								
DownStream	989	1.00	Level	2	0	0.990	1.00	999

Merge Areas

Estimation of v_{12}

$V_{12} = V_F (P_{FM})$

L_{EQ} = (Equation 25-2 or 25-3)

P_{FM} = using Equation (Exhibit 25-5)

V_{12} = pc/h

V_3 or V_{av34} pc/h (Equation 25-4 or 25-5)

Is V_3 or V_{av34} > 2,700 pc/h? ☐ Yes ☐ No

Is V_3 or V_{av34} > 1.5 * V_{12}/2 ☐ Yes ☐ No

If Yes, V_{12a} = pc/h (Equation 25-8)

Capacity Checks

	Actual	Capacity		LOS F?
V_{FO}		Exhibit 25-7		

Flow Entering Merge Influence Area

	Actual	Max Desirable		Violation?
V_{R12}		Exhibit 25-7		

Level of Service Determination (if not F)

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

D_R = (pc/mi/ln)

LOS = (Exhibit 25-4)

Speed Determination

M_S = (Exibit 25-19)

S_R = mph (Exhibit 25-19)

S_0 = mph (Exhibit 25-19)

S = mph (Exhibit 25-14)

Diverge Areas

Estimation of v_{12}

$V_{12} = V_R + (V_F - V_R)P_{FD}$

L_{EQ} = (Equation 25-8 or 25-9)

P_{FD} = 0.450 using Equation (Exhibit 25-12)

V_{12} = 5388 pc/h

V_3 or V_{av34} 3202 pc/h (Equation 25-15 or 25-16)

Is V_3 or V_{av34} > 2,700 pc/h? ☑ Yes ☐ No

Is V_3 or V_{av34} > 1.5 * V_{12}/2 ☐ Yes ☑ No

If Yes, V_{12a} = 5890 pc/h (Equation 25-18)

Capacity Checks

	Actual	Capacity		LOS F?
V_F	8590	Exhibit 25-14	7050	Yes
$V_{FO} = V_F - V_R$	5821	Exhibit 25-14	7050	No
V_R	2769	Exhibit 25-3	4100	No

Flow Entering Diverge Influence Area

	Actual	Max Desirable		Violation?
V_{12}	5388	Exhibit 25-14	4400:All	Yes

Level of Service Determination (if not F)

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

D_R = 38.7 (pc/mi/ln)

LOS = F (Exhibit 25-4)

Speed Determination

D_s = 0.547 (Exhibit 25-19)

S_R = 52.4 mph (Exhibit 25-19)

S_0 = 64.7 mph (Exhibit 25-19)

S = 55.7 mph (Exhibit 25-15)

RAMPS AND RAMP JUNCTIONS WORKSHEET

General Information / Site Information

Analyst	APATEL	Freeway/Dir of Travel	I-440 EB
Agency or Company	WSP SELLS	Junction	on-ramp from Crab/ Valley Ave
Date Performed	6/17/2010	Jurisdiction	Raleigh/NCDOT/FHWA
Analysis Time Period	PM CVA extension to I-440	Analysis Year	2035

Project Description Crabtree Valley

Inputs

Upstream Adj Ramp
☐ Yes ☐ On
☑ No ☐ Off
L_{up} = ft
V_u = veh/h

Terrain: Level

S_{FF} = 65.0 mph S_{FR} = 45.0 mph

Sketch (show lanes, L_A, L_D, V_R, V_f)

Downstream Adj Ramp
☑ Yes ☑ On
☐ No ☐ Off
L_{down} = 1500 ft
V_D = 2192 veh/h

Conversion to pc/h Under Base Conditions

(pc/h)	V (Veh/hr)	PHF	Terrain	%Truck	%Rv	f_{HV}	f_p	$v = V/PHF \times f_{HV} \times f_p$
Freeway	5721	1.00	Level	3	0	0.985	1.00	5807
Ramp	989	1.00	Level	2	0	0.990	1.00	999
UpStream								
DownStream	2192	1.00	Level	2	0	0.990	1.00	2214

Merge Areas

Estimation of v_{12}

$V_{12} = V_F (P_{FM})$

L_{EQ} = (Equation 25-2 or 25-3)
P_{FM} = 0.619 using Equation (Exhibit 25-5)
V_{12} = 3597 pc/h
V_3 or V_{av34} 2210 pc/h (Equation 25-4 or 25-5)
Is V_3 or V_{av34} > 2,700 pc/h? ☐ Yes ☑ No
Is V_3 or V_{av34} > 1.5 * V_{12}/2 ☐ Yes ☑ No
If Yes, V_{12a} = pc/h (Equation 25-8)

Capacity Checks

	Actual	Capacity		LOS F?
V_{FO}	6806	Exhibit 25-7		No

Flow Entering Merge Influence Area

	Actual	Max Desirable		Violation?
V_{R12}	4596	Exhibit 25-7	4600:All	No

Level of Service Determination (if not F)

$D_R = 5.475 + 0.00734\, v_R + 0.0078\, V_{12} - 0.00627\, L_A$

D_R = 31.5 (pc/mi/ln)
LOS = D (Exhibit 25-4)

Speed Determination

M_S = 0.572 (Exibit 25-19)
S_R = 51.8 mph (Exhibit 25-19)
S_0 = 58.8 mph (Exhibit 25-19)
S = 53.9 mph (Exhibit 25-14)

Diverge Areas

Estimation of v_{12}

$V_{12} = V_R + (V_F - V_R)P_{FD}$

L_{EQ} = (Equation 25-8 or 25-9)
P_{FD} = using Equation (Exhibit 25-12)
V_{12} = pc/h
V_3 or V_{av34} pc/h (Equation 25-15 or 25-16)
Is V_3 or V_{av34} > 2,700 pc/h? ☐ Yes ☐ No
Is V_3 or V_{av34} > 1.5 * V_{12}/2 ☐ Yes ☐ No
If Yes, V_{12a} = pc/h (Equation 25-18)

Capacity Checks

	Actual	Capacity		LOS F?
V_F		Exhibit 25-14		
$V_{FO} = V_F - V_R$		Exhibit 25-14		
V_R		Exhibit 25-3		

Flow Entering Diverge Influence Area

	Actual	Max Desirable		Violation?
V_{12}		Exhibit 25-14		

Level of Service Determination (if not F)

$D_R = 4.252 + 0.0086\, V_{12} - 0.009\, L_D$

D_R = (pc/mi/ln)
LOS = (Exhibit 25-4)

Speed Determination

D_s = (Exhibit 25-19)
S_R = mph (Exhibit 25-19)
S_0 = mph (Exhibit 25-19)
S = mph (Exhibit 25-15)

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RAMPS AND RAMP JUNCTIONS WORKSHEET

General Information / Site Information

Analyst	APATEL	Freeway/Dir of Travel	I-440 EB
Agency or Company	WSP SELLS	Junction	on-ramp from Glenwood WB
Date Performed	6/17/2010	Jurisdiction	Raleigh/NCDOT/FHWA
Analysis Time Period	PM CVA extension to I-440	Analysis Year	2035

Project Description Crabtree Valley

Inputs

Upstream Adj Ramp
☑ Yes ☑ On
☐ No ☐ Off
L_{up} = 1200 ft
V_u = 2192 veh/h

Terrain: Level

S_{FF} = 65.0 mph S_{FR} = 45.0 mph

Sketch (show lanes, L_A, L_D, V_R, V_f)

Downstream Adj Ramp
☐ Yes ☐ On
☑ No ☐ Off
L_{down} = ft
V_D = veh/h

Conversion to pc/h Under Base Conditions

(pc/h)	V (Veh/hr)	PHF	Terrain	%Truck	%Rv	f_{HV}	f_p	v = V/PHF x f_{HV} x f_p
Freeway	8902	1.00	Level	3	0	0.985	1.00	9036
Ramp	1090	1.00	Level	2	0	0.990	1.00	1101
UpStream	2192	1.00	Level	0	0	1.000	1.00	2192
DownStream								

Merge Areas

Estimation of v_{12}

$V_{12} = V_F (P_{FM})$

L_{EQ} = (Equation 25-2 or 25-3)
P_{FM} = 0.080 using Equation (Exhibit 25-5)
V_{12} = 724 pc/h
V_3 or V_{av34} 4156 pc/h (Equation 25-4 or 25-5)
Is V_3 or V_{av34} > 2,700 pc/h? ☑ Yes ☐ No
Is V_3 or V_{av34} > 1.5 * V_{12}/2 ☑ Yes ☐ No
If Yes, V_{12a} = 3614 pc/h (Equation 25-8)

Capacity Checks

	Actual	Capacity		LOS F?
V_{FO}	10137	Exhibit 25-7		Yes

Flow Entering Merge Influence Area

	Actual	Max Desirable		Violation?
V_{R12}	4715	Exhibit 25-7	4600:All	Yes

Level of Service Determination (if not F)

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

D_R = 32.3 (pc/mi/ln)
LOS = F (Exhibit 25-4)

Speed Determination

M_S = 0.621 (Exibit 25-19)
S_R = 50.7 mph (Exhibit 25-19)
S_0 = 56.0 mph (Exhibit 25-19)
S = 53.4 mph (Exhibit 25-14)

Diverge Areas

Estimation of v_{12}

$V_{12} = V_R + (V_F - V_R)P_{FD}$

L_{EQ} = (Equation 25-8 or 25-9)
P_{FD} = using Equation (Exhibit 25-12)
V_{12} = pc/h
V_3 or V_{av34} pc/h (Equation 25-15 or 25-16)
Is V_3 or V_{av34} > 2,700 pc/h? ☐ Yes ☐ No
Is V_3 or V_{av34} > 1.5 * V_{12}/2 ☐ Yes ☐ No
If Yes, V_{12a} = pc/h (Equation 25-18)

Capacity Checks

	Actual	Capacity		LOS F?
V_F		Exhibit 25-14		
$V_{FO} = V_F - V_R$		Exhibit 25-14		
V_R		Exhibit 25-3		

Flow Entering Diverge Influence Area

	Actual	Max Desirable		Violation?
V_{12}		Exhibit 25-14		

Level of Service Determination (if not F)

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

D_R = (pc/mi/ln)
LOS = (Exhibit 25-4)

Speed Determination

D_s = (Exhibit 25-19)
S_R = mph (Exhibit 25-19)
S_0 = mph (Exhibit 25-19)
S = mph (Exhibit 25-15)

RAMPS AND RAMP JUNCTIONS WORKSHEET

General Information / Site Information

Analyst	APATEL	Freeway/Dir of Travel	I-440 WB
Agency or Company	WSP SELLS	Junction	off-ramp to Glenwood/CVA
Date Performed	6/17/2010	Jurisdiction	Raleigh/NCDOT/FHWA
Analysis Time Period	PM CVA extension to I-440	Analysis Year	2035

Project Description: Crabtree valley

Inputs

Upstream Adj Ramp: ☐ Yes ☐ On ☑ No ☐ Off
L_{up} = ft
V_u = veh/h

Terrain: Level

S_{FF} = 65.0 mph S_{FR} = 45.0 mph

Sketch (show lanes, L_A, L_D, V_R, V_f)

Downstream Adj Ramp: ☑ Yes ☐ On ☐ No ☑ Off
L_{down} = 500 ft
V_D = 1761 veh/h

Conversion to pc/h Under Base Conditions

(pc/h)	V (Veh/hr)	PHF	Terrain	%Truck	%Rv	f_{HV}	f_p	v = V/PHF x f_{HV} x f_p
Freeway	11115	1.00	Level	3	0	0.985	1.00	11282
Ramp	0	1.00	Level	2	0	0.990	1.00	0
UpStream								
DownStream	1761	1.00	Level	2	0	0.990	1.00	1779

Merge Areas

Estimation of v_{12}

$V_{12} = V_F (P_{FM})$

L_{EQ} = (Equation 25-2 or 25-3)
P_{FM} = using Equation (Exhibit 25-5)
V_{12} = pc/h
V_3 or V_{av34} pc/h (Equation 25-4 or 25-5)
Is V_3 or V_{av34} > 2,700 pc/h? ☐ Yes ☐ No
Is V_3 or V_{av34} > 1.5 * V_{12}/2 ☐ Yes ☐ No
If Yes, V_{12a} = pc/h (Equation 25-8)

Capacity Checks

	Actual	Capacity		LOS F?
V_{FO}		Exhibit 25-7		

Flow Entering Merge Influence Area

	Actual	Max Desirable		Violation?
V_{R12}		Exhibit 25-7		

Level of Service Determination (if not F)

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

D_R = (pc/mi/ln)
LOS = (Exhibit 25-4)

Speed Determination

M_S = (Exibit 25-19)
S_R = mph (Exhibit 25-19)
S_0 = mph (Exhibit 25-19)
S = mph (Exhibit 25-14)

Diverge Areas

Estimation of v_{12}

$V_{12} = V_R + (V_F - V_R)P_{FD}$

L_{EQ} = (Equation 25-8 or 25-9)
P_{FD} = 0.260 using Equation (Exhibit 25-12)
V_{12} = 2347 pc/h
V_3 or V_{av34} 3339 pc/h (Equation 25-15 or 25-16)
Is V_3 or V_{av34} > 2,700 pc/h? ☑ Yes ☐ No
Is V_3 or V_{av34} > 1.5 * V_{12}/2 ☑ Yes ☐ No
If Yes, V_{12a} = 3610 pc/h (Equation 25-18)

Capacity Checks

	Actual	Capacity		LOS F?
V_F	9026	Exhibit 25-14	9400	No
$V_{FO} = V_F - V_R$	9026	Exhibit 25-14	9400	No
V_R	0	Exhibit 25-3	4100	No

Flow Entering Diverge Influence Area

	Actual	Max Desirable		Violation?
V_{12}	2347	Exhibit 25-14	4400:All	No

Level of Service Determination (if not F)

D_R = ~~4.252 + 0.0086 V_{12} - 0.009 L_D~~ 0.0109 V_F → N

D_R = ~~21.8~~ (pc/mi/ln) 24.59
LOS = C (Exhibit 25-4)

Speed Determination

D_s = 0.298 (Exhibit 25-19)
S_R = 58.1 mph (Exhibit 25-19)
S_0 = 64.6 mph (Exhibit 25-19)
S = 61.9 mph (Exhibit 25-15)

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RAMPS AND RAMP JUNCTIONS WORKSHEET

General Information / Site Information

Analyst	Caroline Kone	Freeway/Dir of Travel	I-440 WB
Agency or Company	WSP SELLS	Junction	on-ramp from CVA extension
Date Performed	6/17/2010	Jurisdiction	Raleigh/NCDOT/FHWA
Analysis Time Period	PM CVA extension to I-440	Analysis Year	2035

Project Description Crabtree Valley

Inputs

Upstream Adj Ramp
☑ Yes ☑ On
☐ No ☐ Off
L_{up} = 300 ft
V_u = 1651 veh/h

Terrain: Level

S_{FF} = 65.0 mph S_{FR} = 45.0 mph

Sketch (show lanes, L_A, L_D, V_R, V_f)

Downstream Adj Ramp
☐ Yes ☐ On
☑ No ☐ Off
L_{down} = ft
V_D = veh/h

Conversion to pc/h Under Base Conditions

(pc/h)	V (Veh/hr)	PHF	Terrain	%Truck	%Rv	f_{HV}	f_p	v = V/PHF x f_{HV} x f_p
Freeway	7668	1.00	Level	3	0	0.985	1.00	7783
Ramp	915	1.00	Level	2	0	0.990	1.00	924
UpStream	1651	1.00	Level	2	0	0.990	1.00	1668
DownStream								

Merge Areas

Estimation of v_{12}

$V_{12} = V_F (P_{FM})$

L_{EQ} = (Equation 25-2 or 25-3)
P_{FM} = 0.102 using Equation (Exhibit 25-5)
V_{12} = 796 pc/h
V_3 or V_{av34} = 3493 pc/h (Equation 25-4 or 25-5)
Is V_3 or V_{av34} > 2,700 pc/h? ☑ Yes ☐ No
Is V_3 or V_{av34} > 1.5 * V_{12}/2 ☑ Yes ☐ No
If Yes, V_{12a} = 3113 pc/h (Equation 25-8)

Capacity Checks

	Actual	Capacity		LOS F?
V_{FO}	8707	Exhibit 25-7		No

Flow Entering Merge Influence Area

	Actual	Max Desirable		Violation?
V_{R12}	4037	Exhibit 25-7	4600:All	No

Level of Service Determination (if not F)

$D_R = 5.475 + 0.00734\, v_R + 0.0078\, V_{12} - 0.00627\, L_A$

D_R = 31.2 (pc/mi/ln)
LOS = D (Exhibit 25-4)

Speed Determination

M_S = 0.465 (Exibit 25-19)
S_R = 54.3 mph (Exhibit 25-19)
S_0 = 58.3 mph (Exhibit 25-19)
S = 56.4 mph (Exhibit 25-14)

Diverge Areas

Estimation of v_{12}

$V_{12} = V_R + (V_F - V_R)P_{FD}$

L_{EQ} = (Equation 25-8 or 25-9)
P_{FD} = using Equation (Exhibit 25-12)
V_{12} = pc/h
V_3 or V_{av34} = pc/h (Equation 25-15 or 25-16)
Is V_3 or V_{av34} > 2,700 pc/h? ☐ Yes ☐ No
Is V_3 or V_{av34} > 1.5 * V_{12}/2 ☐ Yes ☐ No
If Yes, V_{12a} = pc/h (Equation 25-18)

Capacity Checks

	Actual	Capacity		LOS F?
V_F		Exhibit 25-14		
$V_{FO} = V_F - V_R$		Exhibit 25-14		
V_R		Exhibit 25-3		

Flow Entering Diverge Influence Area

	Actual	Max Desirable		Violation?
V_{12}		Exhibit 25-14		

Level of Service Determination (if not F)

$D_R = 4.252 + 0.0086\, V_{12} - 0.009\, L_D$

D_R = (pc/mi/ln)
LOS = (Exhibit 25-4)

Speed Determination

D_s = (Exhibit 25-19)
S_R = mph (Exhibit 25-19)
S_0 = mph (Exhibit 25-19)
S = mph (Exhibit 25-15)

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RAMPS AND RAMP JUNCTIONS WORKSHEET

General Information / Site Information

Analyst	Caroline Kone	Freeway/Dir of Travel	I-440 WB
Agency or Company	WSP SELLS	Junction	on-ramp from Glen. EB
Date Performed	6/17/2010	Jurisdiction	Raleigh/NCDOT/FHWA
Analysis Time Period	PM CVA extensionto I-440	Analysis Year	2035

Project Description Crabtree Valley

Inputs

Upstream Adj Ramp
☐ Yes ☐ On
☑ No ☐ Off
L_{up} = ft
V_u = veh/h

Terrain: Level

S_{FF} = 65.0 mph S_{FR} = 45.0 mph
Sketch (show lanes, L_A, L_D, V_R, V_f)

Downstream Adj Ramp
☑ Yes ☑ On
☐ No ☐ Off
L_{down} = 300 ft
V_D = 915 veh/h

Conversion to pc/h Under Base Conditions

(pc/h)	V (Veh/hr)	PHF	Terrain	%Truck	%Rv	f_{HV}	f_p	v = V/PHF x f_{HV} x f_p
Freeway	6017	1.00	Level	3	0	0.985	1.00	6107
Ramp	1651	1.00	Level	2	0	0.990	1.00	1668
UpStream								
DownStream	915	1.00	Level	2	0	0.990	1.00	924

Merge Areas

Estimation of v_{12}

$V_{12} = V_F (P_{FM})$
L_{EQ} = (Equation 25-2 or 25-3)
P_{FM} = 0.009 using Equation (Exhibit 25-5)
V_{12} = 57 pc/h
V_3 or V_{av34} = 3025 pc/h (Equation 25-4 or 25-5)
Is V_3 or V_{av34} > 2,700 pc/h? ☑ Yes ☐ No
Is V_3 or V_{av34} > 1.5 * V_{12}/2 ☑ Yes ☐ No
If Yes, V_{12a} = 2442 pc/h (Equation 25-8)

Capacity Checks

	Actual	Capacity		LOS F?
V_{FO}	7775	Exhibit 25-7		No

Flow Entering Merge Influence Area

	Actual	Max Desirable		Violation?
V_{R12}	4110	Exhibit 25-7	4600:All	No

Level of Service Determination (if not F)

$D_R = 5.475 + 0.00734\, v_R + 0.0078\, V_{12} - 0.00627\, L_A$
D_R = 28.0 (pc/mi/ln)
LOS = C (Exhibit 25-4)

Speed Determination

M_S = 0.433 (Exibit 25-19)
S_R = 55.0 mph (Exhibit 25-19)
S_0 = 60.2 mph (Exhibit 25-19)
S = 57.4 mph (Exhibit 25-14)

Diverge Areas

Estimation of v_{12}

$V_{12} = V_R + (V_F - V_R)P_{FD}$
L_{EQ} = (Equation 25-8 or 25-9)
P_{FD} = using Equation (Exhibit 25-12)
V_{12} = pc/h
V_3 or V_{av34} = pc/h (Equation 25-15 or 25-16)
Is V_3 or V_{av34} > 2,700 pc/h? ☐ Yes ☐ No
Is V_3 or V_{av34} > 1.5 * V_{12}/2 ☐ Yes ☐ No
If Yes, V_{12a} = pc/h (Equation 25-18)

Capacity Checks

	Actual	Capacity		LOS F?
V_F		Exhibit 25-14		
$V_{FO} = V_F - V_R$		Exhibit 25-14		
V_R		Exhibit 25-3		

Flow Entering Diverge Influence Area

	Actual	Max Desirable		Violation?
V_{12}		Exhibit 25-14		

Level of Service Determination (if not F)

$D_R = 4.252 + 0.0086\, V_{12} - 0.009\, L_D$
D_R = (pc/mi/ln)
LOS = (Exhibit 25-4)

Speed Determination

D_s = (Exhibit 25-19)
S_R = mph (Exhibit 25-19)
S_0 = mph (Exhibit 25-19)
S = mph (Exhibit 25-15)

FREEWAY WEAVING WORKSHEET

General Information

Analyst	
Agency/Company	WSP SELLS
Date Performed	7/19/2010
Analysis Time Period	PM CVA Extension to I-440

Site Information

Freeway/Dir of Travel	I-440 WB
Weaving Seg Location	Glen. WB on to Glen. EB off
Jurisdiction	Rlaeigh/NCDOT/FHWA
Analysis Year	2035

Inputs

Freeway free-flow speed, S_{FF} (mi/h)	55	Weaving type	B
Weaving number of lanes, N	2	Volume ratio, VR	0.65
Weaving seg length, L (ft)	870	Weaving ratio, R	0.20
Terrain	Level		

Conversions to pc/h Under Base Conditions

(pc/h)	V	PHF	Truck %	RV %	E_T	E_R	f_{HV}	f_p	v
V_{o1}	705	1.00	3	0	1.5	1.2	0.985	1.00	715
V_{o2}	0	1.00	2	0	1.5	1.2	0.990	1.00	0
V_{w1}	1056	1.00	2	0	1.5	1.2	0.990	1.00	1066
V_{w2}	271	1.00	2	0	1.5	1.2	0.990	1.00	273
V_w				1339	V_{nw}				715
V									2054

Weaving and Non-Weaving Speeds

	Unconstrained		Constrained	
	Weaving (i = w)	Non-Weaving (i = nw)	Weaving (i = w)	Non-Weaving (= nw)
a (Exhibit 24-6)	0.08	0.0020		
b (Exhibit 24-6)	2.20	6.00		
c (Exhibit 24-6)	0.70	1.00		
d (Exhibit 24-6)	0.50	0.50		
Weaving intensity factor, Wi	1.05	1.41		
Weaving and non-weaving speeds, Si (mi/h)	36.96	33.63		

Number of lanes required for unconstrained operation, Nw 1.75
Maximum number of lanes, Nw (max) 3.50

☑ If Nw < Nw(max) unconstrained operation ☐ if Nw > Nw (max) constrained operation

Weaving Segment Speed, Density, Level of Service, and Capacity

Weaving segment speed, S (mi/h)	35.73
Weaving segment density, D (pc/mi/ln)	28.75
Level of service, LOS	C
Capacity of base condition, c_b (pc/h)	
Capacity as a 15-minute flow rate, c (veh/h)	
Capacity as a full-hour volume, c_h (veh/h)	

Notes

a. Weaving segments longer than 2500 ft. are treated as isolated merge and diverge areas using the procedures of Chapter 25, "Ramps and Ramp Junctions".
b. Capacity constrained by basic freeway capacity.
c. Capacity occurs under constrained operating conditions.
d. Three-lane Type A segments do not operate well at volume ratios greater than 0.45. Poor operations and some local queuing are expected in such cases.
e. Four-lane Type A segments do not operate well at volume ratios greater than 0.35. Poor operations and some local queuing are expected in such cases.
f. Capacity constrained by maximum allowable weaving flow rate: 2,800 pc/h (Type A), 4,000 (Type B), 3,500 (Type C).
g. Five-lane Type A segments do not operate well at volume ratios greater than 0.20. Poor operations and some local queuing are expected in such cases.
h. Type B weaving segments do not operate well at volume ratios greater than 0.80. Poor operations and some local queuing are expected in such cases.
i. Type C weaving segments do not operate well at volume ratios greater than 0.50. Poor operations and some local queuing are expected in such cases.

2035 CVA Extension to I-440 and WB Glenwood Ave Overpass

RAMPS AND RAMP JUNCTIONS WORKSHEET

General Information / Site Information

Analyst	APATEL	Freeway/Dir of Travel	I-440 EB
Agency or Company	WSP SELLS	Junction	off-ramp to Ridge Rd
Date Performed	7/16/2010	Jurisdiction	Raleigh/NCDOT/FHWA
Analysis Time Period	AM Glenwood Overpass ONLY	Analysis Year	2035

Project Description Crabtree Valley

Inputs

Upstream Adj Ramp
☐ Yes ☐ On
☑ No ☐ Off
L_{up} = ft
V_u = veh/h

Terrain: Level

S_{FF} = 65.0 mph S_{FR} = 45.0 mph

Sketch (show lanes, L_A, L_D, V_R, V_f)

Downstream Adj Ramp
☑ Yes ☑ On
☐ No ☐ Off
L_{down} = 900 ft
V_D = 744 veh/h

Conversion to pc/h Under Base Conditions

(pc/h)	V (Veh/hr)	PHF	Terrain	%Truck	%Rv	f_{HV}	f_p	v = V/PHF x f_{HV} x f_p
Freeway	6851	1.00	Level	3	0	0.985	1.00	6954
Ramp	1829	1.00	Level	2	0	0.990	1.00	1847
UpStream								
DownStream	744	1.00	Level	2	0	0.990	1.00	751

Merge Areas

Estimation of v_{12}

$V_{12} = V_F (P_{FM})$

L_{EQ} = (Equation 25-2 or 25-3)
P_{FM} = using Equation (Exhibit 25-5)
V_{12} = pc/h
V_3 or V_{av34} pc/h (Equation 25-4 or 25-5)
Is V_3 or V_{av34} > 2,700 pc/h? ☐ Yes ☐ No
Is V_3 or V_{av34} > 1.5 * V_{12}/2 ☐ Yes ☐ No
If Yes, V_{12a} = pc/h (Equation 25-8)

Capacity Checks

	Actual	Capacity		LOS F?
V_{FO}		Exhibit 25-7		

Flow Entering Merge Influence Area

	Actual	Max Desirable		Violation?
V_{R12}		Exhibit 25-7		

Level of Service Determination (if not F)

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

D_R = (pc/mi/ln)
LOS = (Exhibit 25-4)

Speed Determination

M_S = (Exibit 25-19)
S_R = mph (Exhibit 25-19)
S_0 = mph (Exhibit 25-19)
S = mph (Exhibit 25-14)

Diverge Areas

Estimation of v_{12}

$V_{12} = V_R + (V_F - V_R)P_{FD}$

L_{EQ} = (Equation 25-8 or 25-9)
P_{FD} = 0.450 using Equation (Exhibit 25-12)
V_{12} = 4145 pc/h
V_3 or V_{av34} 2809 pc/h (Equation 25-15 or 25-16)
Is V_3 or V_{av34} > 2,700 pc/h? ☑ Yes ☐ No
Is V_3 or V_{av34} > 1.5 * V_{12}/2 ☐ Yes ☑ No
If Yes, V_{12a} = 4254 pc/h (Equation 25-18)

Capacity Checks

	Actual	Capacity		LOS F?
V_F	6954	Exhibit 25-14	7050	No
$V_{FO} = V_F - V_R$	5107	Exhibit 25-14	7050	No
V_R	1847	Exhibit 25-3	4100	No

Flow Entering Diverge Influence Area

	Actual	Max Desirable		Violation?
V_{12}	4145	Exhibit 25-14	4400:All	No

Level of Service Determination (if not F)

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

D_R = 24.6 (pc/mi/ln)
LOS = C (Exhibit 25-4)

Speed Determination

D_s = 0.464 (Exhibit 25-19)
S_R = 54.3 mph (Exhibit 25-19)
S_0 = 64.7 mph (Exhibit 25-19)
S = 57.9 mph (Exhibit 25-15)

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RAMPS AND RAMP JUNCTIONS WORKSHEET

General Information / Site Information

Analyst	APATEL	Freeway/Dir of Travel	I-440 EB
Agency or Company	WSP SELLS	Junction	on-ramp from CVA extension
Date Performed	7/16/2010	Jurisdiction	Raleigh/NCDOT/FHWA
Analysis Time Period	AM Glenwood Overpass ONLY	Analysis Year	2035

Project Description Crabtree Valley

Inputs

Upstream Adj Ramp
☐ Yes ☐ On
☑ No ☐ Off
L_{up} = ft
V_u = veh/h

Terrain: Level

S_{FF} = 65.0 mph S_{FR} = 45.0 mph
Sketch (show lanes, L_A, L_D,V_R,V_f)

Downstream Adj Ramp
☑ Yes ☑ On
☐ No ☐ Off
L_{down} = 1500 ft
V_D = 1890 veh/h

Conversion to pc/h Under Base Conditions

(pc/h)	V (Veh/hr)	PHF	Terrain	%Truck	%Rv	f_{HV}	f_p	v = V/PHF x f_{HV} x f_p
Freeway	5022	1.00	Level	3	0	0.985	1.00	5097
Ramp	744	1.00	Level	2	0	0.990	1.00	751
UpStream								
DownStream	1890	1.00	Level	2	0	0.990	1.00	1909

Merge Areas

Estimation of v_{12}

$V_{12} = V_F (P_{FM})$
L_{EQ} = (Equation 25-2 or 25-3)
P_{FM} = 0.619 using Equation (Exhibit 25-5)
V_{12} = 3158 pc/h
V_3 or V_{av34} 1939 pc/h (Equation 25-4 or 25-5)
Is V_3 or V_{av34} > 2,700 pc/h? ☐ Yes ☑ No
Is V_3 or V_{av34} > 1.5 * V_{12}/2 ☐ Yes ☑ No
If Yes,V_{12a} = pc/h (Equation 25-8)

Capacity Checks

	Actual	Capacity		LOS F?
V_{FO}	5848	Exhibit 25-7		No

Flow Entering Merge Influence Area

	Actual	Max Desirable		Violation?
V_{R12}	3909	Exhibit 25-7	4600:All	No

Level of Service Determination (if not F)

$D_R = 5.475 + 0.00734\ v_R + 0.0078\ V_{12} - 0.00627\ L_A$
D_R = 26.2 (pc/mi/ln)
LOS = C (Exhibit 25-4)

Speed Determination

M_S = 0.380 (Exibit 25-19)
S_R= 56.3 mph (Exhibit 25-19)
S_0= 59.8 mph (Exhibit 25-19)
S = 57.4 mph (Exhibit 25-14)

Diverge Areas

Estimation of v_{12}

$V_{12} = V_R + (V_F - V_R)P_{FD}$
L_{EQ} = (Equation 25-8 or 25-9)
P_{FD} = using Equation (Exhibit 25-12)
V_{12} = pc/h
V_3 or V_{av34} pc/h (Equation 25-15 or 25-16)
Is V_3 or V_{av34} > 2,700 pc/h? ☐ Yes ☐ No
Is V_3 or V_{av34} > 1.5 * V_{12}/2 ☐ Yes ☐ No
If Yes,V_{12a} = pc/h (Equation 25-18)

Capacity Checks

	Actual	Capacity		LOS F?
V_F		Exhibit 25-14		
$V_{FO} = V_F - V_R$		Exhibit 25-14		
V_R		Exhibit 25-3		

Flow Entering Diverge Influence Area

	Actual	Max Desirable		Violation?
V_{12}		Exhibit 25-14		

Level of Service Determination (if not F)

$D_R = 4.252 + 0.0086\ V_{12} - 0.009\ L_D$
D_R = (pc/mi/ln)
LOS = (Exhibit 25-4)

Speed Determination

D_s = (Exhibit 25-19)
S_R= mph (Exhibit 25-19)
S_0= mph (Exhibit 25-19)
S = mph (Exhibit 25-15)

RAMPS AND RAMP JUNCTIONS WORKSHEET

General Information / Site Information

Analyst	APATEL	Freeway/Dir of Travel	I-440 EB
Agency or Company	WSP SELLS	Junction	on-ramp from Glenwood WB
Date Performed	7/16/2010	Jurisdiction	Raleigh/NCDOT/FHWA
Analysis Time Period	AM Glenwood Overpass ONLY	Analysis Year	2035

Project Description Crabtree Valley

Inputs

Upstream Adj Ramp
☑ Yes ☑ On
☐ No ☐ Off
L_{up} = 1200 ft
V_u = 1890 veh/h

Terrain: Level

S_{FF} = 65.0 mph S_{FR} = 45.0 mph

Sketch (show lanes, L_A, L_D, V_R, V_f)

Downstream Adj Ramp
☐ Yes ☐ On
☑ No ☐ Off
L_{down} = ft
V_D = veh/h

Conversion to pc/h Under Base Conditions

(pc/h)	V (Veh/hr)	PHF	Terrain	%Truck	%Rv	f_{HV}	f_p	$v = V/PHF \times f_{HV} \times f_p$
Freeway	7656	1.00	Level	3	0	0.985	1.00	7771
Ramp	1163	1.00	Level	2	0	0.990	1.00	1175
UpStream	1890	1.00	Level	0	0	1.000	1.00	1890
DownStream								

Merge Areas

Estimation of v_{12}

$V_{12} = V_F (P_{FM})$

L_{EQ} = (Equation 25-2 or 25-3)

P_{FM} = 0.071 using Equation (Exhibit 25-5)

V_{12} = 551 pc/h

V_3 or V_{av34} 3610 pc/h (Equation 25-4 or 25-5)

Is V_3 or V_{av34} > 2,700 pc/h? ☑ Yes ☐ No

Is V_3 or V_{av34} > 1.5 * V_{12}/2 ☑ Yes ☐ No

If Yes, V_{12a} = 3108 pc/h (Equation 25-8)

Capacity Checks

	Actual	Capacity		LOS F?
V_{FO}	8946	Exhibit 25-7		No

Flow Entering Merge Influence Area

	Actual	Max Desirable		Violation?
V_{R12}	4283	Exhibit 25-7	4600:All	No

Level of Service Determination (if not F)

$D_R = 5.475 + 0.00734\, v_R + 0.0078\, V_{12} - 0.00627\, L_A$

D_R = 28.9 (pc/mi/ln)

LOS = D (Exhibit 25-4)

Speed Determination

M_S = 0.469 (Exibit 25-19)

S_R = 54.2 mph (Exhibit 25-19)

S_0 = 58.3 mph (Exhibit 25-19)

S = 56.3 mph (Exhibit 25-14)

Diverge Areas

Estimation of v_{12}

$V_{12} = V_R + (V_F - V_R)P_{FD}$

L_{EQ} = (Equation 25-8 or 25-9)

P_{FD} = using Equation (Exhibit 25-12)

V_{12} = pc/h

V_3 or V_{av34} pc/h (Equation 25-15 or 25-16)

Is V_3 or V_{av34} > 2,700 pc/h? ☐ Yes ☐ No

Is V_3 or V_{av34} > 1.5 * V_{12}/2 ☐ Yes ☐ No

If Yes, V_{12a} = pc/h (Equation 25-18)

Capacity Checks

	Actual	Capacity		LOS F?
V_F		Exhibit 25-14		
$V_{FO} = V_F - V_R$		Exhibit 25-14		
V_R		Exhibit 25-3		

Flow Entering Diverge Influence Area

	Actual	Max Desirable		Violation?
V_{12}		Exhibit 25-14		

Level of Service Determination (if not F)

$D_R = 4.252 + 0.0086\, V_{12} - 0.009\, L_D$

D_R = (pc/mi/ln)

LOS = (Exhibit 25-4)

Speed Determination

D_s = (Exhibit 25-19)

S_R = mph (Exhibit 25-19)

S_0 = mph (Exhibit 25-19)

S = mph (Exhibit 25-15)

RAMPS AND RAMP JUNCTIONS WORKSHEET

General Information / Site Information

Analyst	APATEL	Freeway/Dir of Travel	I-440 WB
Agency or Company	WSP SELLS	Junction	off-ramp to Glenwood/CVA
Date Performed	7/15/2010	Jurisdiction	Raleigh/NCDOT/FHWA
Analysis Time Period	AM Glenwood Overpass ONLY	Analysis Year	2035

Project Description Crabtree Valley

Inputs

Upstream Adj Ramp
☐ Yes ☐ On
☑ No ☐ Off
L_{up} = ft
V_u = veh/h

Terrain: Level

S_{FF} = 65.0 mph S_{FR} = 45.0 mph
Sketch (show lanes, L_A, L_D, V_R, V_f)

Downstream Adj Ramp
☐ Yes ☐ On
☑ No ☐ Off
L_{down} = ft
V_D = veh/h

Conversion to pc/h Under Base Conditions

(pc/h)	V (Veh/hr)	PHF	Terrain	%Truck	%Rv	f_{HV}	f_p	v = V/PHF x f_{HV} x f_p
Freeway	12893	1.00	Level	3	0	0.985	1.00	13086
Ramp	0	1.00	Level	2	0	0.990	1.00	0
UpStream								
DownStream								

Merge Areas

Estimation of v_{12}

$V_{12} = V_F (P_{FM})$
L_{EQ} = (Equation 25-2 or 25-3)
P_{FM} = using Equation (Exhibit 25-5)
V_{12} = pc/h
V_3 or V_{av34} pc/h (Equation 25-4 or 25-5)
Is V_3 or V_{av34} > 2,700 pc/h? ☐ Yes ☐ No
Is V_3 or V_{av34} > 1.5 * V_{12}/2 ☐ Yes ☐ No
If Yes, V_{12a} = pc/h (Equation 25-8)

Capacity Checks

	Actual	Capacity		LOS F?
V_{FO}		Exhibit 25-7		

Flow Entering Merge Influence Area

	Actual	Max Desirable		Violation?
V_{R12}		Exhibit 25-7		

Level of Service Determination (if not F)

$D_R = 5.475 + 0.00734\ v_R + 0.0078\ V_{12} - 0.00627\ L_A$
D_R = (pc/mi/ln)
LOS = (Exhibit 25-4)

Speed Determination

M_S = (Exibit 25-19)
S_R = mph (Exhibit 25-19)
S_0 = mph (Exhibit 25-19)
S = mph (Exhibit 25-14)

Diverge Areas

Estimation of v_{12}

$V_{12} = V_R + (V_F - V_R)P_{FD}$
L_{EQ} = (Equation 25-8 or 25-9)
P_{FD} = 0.260 using Equation (Exhibit 25-12)
V_{12} = 2722 pc/h
V_3 or V_{av34} 3873 pc/h (Equation 25-15 or 25-16)
Is V_3 or V_{av34} > 2,700 pc/h? ☑ Yes ☐ No
Is V_3 or V_{av34} > 1.5 * V_{12}/2 ☑ Yes ☐ No
If Yes, V_{12a} = 4187 pc/h (Equation 25-18)

Capacity Checks

	Actual	Capacity		LOS F?
V_F	10469	Exhibit 25-14	9400	Yes
$V_{FO} = V_F - V_R$	10469	Exhibit 25-14	9400	Yes
V_R	0	Exhibit 25-3	4100	No

Flow Entering Diverge Influence Area

	Actual	Max Desirable		Violation?
V_{12}	2722	Exhibit 25-14	4400:All	No

Level of Service Determination (if not F)

D_R = ~~4.252 + 0.0086 V_{12} - 0.009 L_D~~ 0.0109 $\frac{V_F}{N}$
D_R = ~~8.9~~ (pc/mi/ln) 28.53
LOS = ~~F~~ (Exhibit 25-4) D

Speed Determination

D_s = 0.298 (Exhibit 25-19)
S_R = 58.1 mph (Exhibit 25-19)
S_0 = 63.0 mph (Exhibit 25-19)
S = 60.9 mph (Exhibit 25-15)

RAMPS AND RAMP JUNCTIONS WORKSHEET

General Information / Site Information

Analyst	APATEL	Freeway/Dir of Travel	I-440 WB
Agency or Company	WSP SELLS	Junction	on-ramp from CVA extension
Date Performed	7/19/2010	Jurisdiction	Raleigh/NCDOT/FHWA
Analysis Time Period	AM Glenwood Overpass ONLY	Analysis Year	2035

Project Description Crabtree Valley

Inputs

Upstream Adj Ramp: ☑ Yes ☑ On ☐ No ☐ Off

L_{up} = 300 ft

V_u = 1349 veh/h

Terrain: Level

S_{FF} = 65.0 mph S_{FR} = 45.0 mph

Sketch (show lanes, L_A, L_D, V_R, V_f)

Downstream Adj Ramp: ☐ Yes ☐ On ☑ No ☐ Off

L_{down} = ft

V_D = veh/h

Conversion to pc/h Under Base Conditions

(pc/h)	V (Veh/hr)	PHF	Terrain	%Truck	%Rv	f_{HV}	f_p	v = V/PHF x f_{HV} x f_p
Freeway	10300	1.00	Level	3	0	0.985	1.00	10454
Ramp	617	1.00	Level	2	0	0.990	1.00	623
UpStream	1349	1.00	Level	2	0	0.990	1.00	1362
DownStream								

Merge Areas

Estimation of v_{12}

$V_{12} = V_F (P_{FM})$

L_{EQ} = (Equation 25-2 or 25-3)

P_{FM} = 0.140 using Equation (Exhibit 25-5)

V_{12} = 1463 pc/h

V_3 or V_{av34} 4495 pc/h (Equation 25-4 or 25-5)

Is V_3 or V_{av34} > 2,700 pc/h? ☑ Yes ☐ No

Is V_3 or V_{av34} > 1.5 * V_{12}/2 ☑ Yes ☐ No

If Yes, V_{12a} = 4181 pc/h (Equation 25-8)

Capacity Checks

	Actual	Capacity		LOS F?
V_{FO}	11077	Exhibit 25-7		Yes

Flow Entering Merge Influence Area

	Actual	Max Desirable		Violation?
V_{R12}	4804	Exhibit 25-7	4600:All	Yes

Level of Service Determination (if not F)

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

D_R = 37.3 (pc/mi/ln)

LOS = F (Exhibit 25-4)

Speed Determination

M_S = 0.720 (Exibit 25-19)

S_R = 48.4 mph (Exhibit 25-19)

S_0 = 53.5 mph (Exhibit 25-19)

S = 51.2 mph (Exhibit 25-14)

Diverge Areas

Estimation of v_{12}

$V_{12} = V_R + (V_F - V_R)P_{FD}$

L_{EQ} = (Equation 25-8 or 25-9)

P_{FD} = using Equation (Exhibit 25-12)

V_{12} = pc/h

V_3 or V_{av34} pc/h (Equation 25-15 or 25-16)

Is V_3 or V_{av34} > 2,700 pc/h? ☐ Yes ☐ No

Is V_3 or V_{av34} > 1.5 * V_{12}/2 ☐ Yes ☐ No

If Yes, V_{12a} = pc/h (Equation 25-18)

Capacity Checks

	Actual	Capacity		LOS F?
V_F		Exhibit 25-14		
$V_{FO} = V_F - V_R$		Exhibit 25-14		
V_R		Exhibit 25-3		

Flow Entering Diverge Influence Area

	Actual	Max Desirable		Violation?
V_{12}		Exhibit 25-14		

Level of Service Determination (if not F)

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

D_R = (pc/mi/ln)

LOS = (Exhibit 25-4)

Speed Determination

D_s = (Exhibit 25-19)

S_R = mph (Exhibit 25-19)

S_0 = mph (Exhibit 25-19)

S = mph (Exhibit 25-15)

RAMPS AND RAMP JUNCTIONS WORKSHEET

General Information / Site Information

Analyst	APATEL	Freeway/Dir of Travel	I-440 WB
Agency or Company	WSP SELLS	Junction	on-ramp from Glen. EB
Date Performed	7/19/2010	Jurisdiction	Raleigh/NCDOT/FHWA
Analysis Time Period	AM Glenwood Overpass ONLY	Analysis Year	2035

Project Description Crabtree Valley

Inputs

Upstream Adj Ramp
☐ Yes ☐ On
☑ No ☐ Off
L_{up} = ft
V_u = veh/h

Terrain: Level

S_{FF} = 65.0 mph S_{FR} = 45.0 mph
Sketch (show lanes, L_A, L_D, V_R, V_f)

Downstream Adj Ramp
☑ Yes ☑ On
☐ No ☐ Off
L_{down} = 300 ft
V_D = 617 veh/h

Conversion to pc/h Under Base Conditions

(pc/h)	V (Veh/hr)	PHF	Terrain	%Truck	%Rv	f_{HV}	f_p	v = V/PHF x f_{HV} x f_p
Freeway	8951	1.00	Level	3	0	0.985	1.00	9085
Ramp	1349	1.00	Level	2	0	0.990	1.00	1362
UpStream								
DownStream	617	1.00	Level	2	0	0.990	1.00	623

Merge Areas

Estimation of v_{12}

$V_{12} = V_F (P_{FM})$
L_{EQ} = (Equation 25-2 or 25-3)
P_{FM} = 0.048 using Equation (Exhibit 25-5)
V_{12} = 432 pc/h
V_3 or V_{av34} = 4326 pc/h (Equation 25-4 or 25-5)
Is V_3 or V_{av34} > 2,700 pc/h? ☑ Yes ☐ No
Is V_3 or V_{av34} > 1.5 * V_{12}/2 ☑ Yes ☐ No
If Yes, V_{12a} = 3634 pc/h (Equation 25-8)

Capacity Checks

	Actual	Capacity		LOS F?
V_{FO}	10447	Exhibit 25-7		Yes

Flow Entering Merge Influence Area

	Actual	Max Desirable		Violation?
V_{R12}	4996	Exhibit 25-7	4600:All	Yes

Level of Service Determination (if not F)

$D_R = 5.475 + 0.00734\, v_R + 0.0078\, V_{12} - 0.00627\, L_A$
D_R = 35.0 (pc/mi/ln)
LOS = F (Exhibit 25-4)

Speed Determination

M_S = 0.772 (Exibit 25-19)
S_R = 47.3 mph (Exhibit 25-19)
S_0 = 55.9 mph (Exhibit 25-19)
S = 51.4 mph (Exhibit 25-14)

Diverge Areas

Estimation of v_{12}

$V_{12} = V_R + (V_F - V_R)P_{FD}$
L_{EQ} = (Equation 25-8 or 25-9)
P_{FD} = using Equation (Exhibit 25-12)
V_{12} = pc/h
V_3 or V_{av34} pc/h (Equation 25-15 or 25-16)
Is V_3 or V_{av34} > 2,700 pc/h? ☐ Yes ☐ No
Is V_3 or V_{av34} > 1.5 * V_{12}/2 ☐ Yes ☐ No
If Yes, V_{12a} = pc/h (Equation 25-18)

Capacity Checks

	Actual	Capacity		LOS F?
V_F		Exhibit 25-14		
$V_{FO} = V_F - V_R$		Exhibit 25-14		
V_R		Exhibit 25-3		

Flow Entering Diverge Influence Area

	Actual	Max Desirable		Violation?
V_{12}		Exhibit 25-14		

Level of Service Determination (if not F)

$D_R = 4.252 + 0.0086\, V_{12} - 0.009\, L_D$
D_R = (pc/mi/ln)
LOS = (Exhibit 25-4)

Speed Determination

D_s = (Exhibit 25-19)
S_R = mph (Exhibit 25-19)
S_0 = mph (Exhibit 25-19)
S = mph (Exhibit 25-15)

FREEWAY WEAVING WORKSHEET

General Information

Analyst	APATEL
Agency/Company	WSP SELLS
Date Performed	7/19/2010
Analysis Time Period	AM Glenwood Overpass ONLY

Site Information

Freeway/Dir of Travel	I-440 WB
Weaving Seg Location	Glen WB onto Glen EB off
Jurisdiction	Raleigh/NCDOT/FHWA
Analysis Year	2035

Inputs

Freeway free-flow speed, S_{FF} (mi/h)	55
Weaving number of lanes, N	2
Weaving seg length, L (ft)	870
Terrain	Level

Weaving type	B
Volume ratio, VR	0.71
Weaving ratio, R	0.26

Conversions to pc/h Under Base Conditions

(pc/h)	V	PHF	Truck %	RV %	E_T	E_R	f_{HV}	f_p	v
V_{o1}	691	1.00	3	0	1.5	1.2	0.985	1.00	701
V_{o2}	0	1.00	0	0	1.5	1.2	1.000	1.00	0
V_{w1}	1238	1.00	2	0	1.5	1.2	0.990	1.00	1250
V_{w2}	442	1.00	2	0	1.5	1.2	0.990	1.00	446
V_w				1696	V_{nw}				701
V									2397

Weaving and Non-Weaving Speeds

	Unconstrained		Constrained	
	Weaving (i = w)	Non-Weaving (i = nw)	Weaving (i = w)	Non-Weaving (= nw)
a (Exhibit 24-6)	0.08	0.0020		
b (Exhibit 24-6)	2.20	6.00		
c (Exhibit 24-6)	0.70	1.00		
d (Exhibit 24-6)	0.50	0.50		
Weaving Intensity factor, Wi	1.26	2.01		
Weaving and non-weaving speeds, Si (mi/h)	34.93	29.93		

Number of lanes required for unconstrained operation, Nw 1.88
Maximum number of lanes, Nw (max) 3.50

☑ If Nw < Nw(max) unconstrained operation ☐ If Nw > Nw (max) constrained operation

Weaving Segment Speed, Density, Level of Service, and Capacity

Weaving segment speed, S (mi/h)	33.30
Weaving segment density, D (pc/mi/ln)	35.99
Level of service, LOS	D
Capacity of base condition, c_b (pc/h)	
Capacity as a 15-minute flow rate, c (veh/h)	
Capacity as a full-hour volume, c_h (veh/h)	

Notes

a. Weaving segments longer than 2500 ft. are treated as isolated merge and diverge areas using the procedures of Chapter 25, "Ramps and Ramp Junctions".
b. Capacity constrained by basic freeway capacity.
c. Capacity occurs under constrained operating conditions.
d. Three-lane Type A segments do not operate well at volume ratios greater than 0.45. Poor operations and some local queuing are expected in such cases.
e. Four-lane Type A segments do not operate well at volume ratios greater than 0.35. Poor operations and some local queuing are expected in such cases.
f. Capacity constrained by maximum allowable weaving flow rate: 2,800 pc/h (Type A), 4,000 (Type B), 3,500 (Type C).
g. Five-lane Type A segments do not operate well at volume ratios greater than 0.20. Poor operations and some local queuing are expected in such cases.
h. Type B weaving segments do not operate well at volume ratios greater than 0.80. Poor operations and some local queuing are expected in such cases.
i. Type C weaving segments do not operate well at volume ratios greater than 0.50. Poor operations and some local queuing are expected in such cases.

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RAMPS AND RAMP JUNCTIONS WORKSHEET

General Information / Site Information

Analyst	APATEL	Freeway/Dir of Travel	I-440 EB
Agency or Company	WSP SELLS	Junction	off-ramp to Ridge Rd
Date Performed	7/19/2010	Jurisdiction	Raleigh/NCDOT/FHWA
Analysis Time Period	PM Glenwood Overpass ONLY	Analysis Year	2035

Project Description Crabtree Valley

Inputs

Upstream Adj Ramp
☐ Yes ☐ On
☑ No ☐ Off
L_{up} = ft
V_u = veh/h

Terrain: Level

S_{FF} = 65.0 mph S_{FR} = 45.0 mph
Sketch (show lanes, L_A, L_D, V_R, V_f)

Downstream Adj Ramp
☑ Yes ☑ On
☐ No ☐ Off
L_{down} = 900 ft
V_D = 989 veh/h

Conversion to pc/h Under Base Conditions

(pc/h)	V (Veh/hr)	PHF	Terrain	%Truck	%Rv	f_{HV}	f_p	$v = V/PHF \times f_{HV} \times f_p$
Freeway	8463	1.00	Level	3	0	0.985	1.00	8590
Ramp	2742	1.00	Level	2	0	0.990	1.00	2769
UpStream								
DownStream	989	1.00	Level	2	0	0.990	1.00	999

Merge Areas

Estimation of v_{12}

$V_{12} = V_F (P_{FM})$

L_{EQ} = (Equation 25-2 or 25-3)
P_{FM} = using Equation (Exhibit 25-5)
V_{12} = pc/h
V_3 or V_{av34} pc/h (Equation 25-4 or 25-5)
Is V_3 or V_{av34} > 2,700 pc/h? ☐ Yes ☐ No
Is V_3 or V_{av34} > 1.5 * V_{12}/2 ☐ Yes ☐ No
If Yes, V_{12a} = pc/h (Equation 25-8)

Capacity Checks

	Actual	Capacity		LOS F?
V_{FO}		Exhibit 25-7		

Flow Entering Merge Influence Area

	Actual	Max Desirable		Violation?
V_{R12}		Exhibit 25-7		

Level of Service Determination (if not F)

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

D_R = (pc/mi/ln)
LOS = (Exhibit 25-4)

Speed Determination

M_S = (Exibit 25-19)
S_R = mph (Exhibit 25-19)
S_0 = mph (Exhibit 25-19)
S = mph (Exhibit 25-14)

Diverge Areas

Estimation of v_{12}

$V_{12} = V_R + (V_F - V_R)P_{FD}$

L_{EQ} = (Equation 25-8 or 25-9)
P_{FD} = 0.450 using Equation (Exhibit 25-12)
V_{12} = 5388 pc/h
V_3 or V_{av34} 3202 pc/h (Equation 25-15 or 25-16)
Is V_3 or V_{av34} > 2,700 pc/h? ☑ Yes ☐ No
Is V_3 or V_{av34} > 1.5 * V_{12}/2 ☐ Yes ☑ No
If Yes, V_{12a} = 5890 pc/h (Equation 25-18)

Capacity Checks

	Actual	Capacity		LOS F?
V_F	8590	Exhibit 25-14	7050	Yes
$V_{FO} = V_F - V_R$	5821	Exhibit 25-14	7050	No
V_R	2769	Exhibit 25-3	4100	No

Flow Entering Diverge Influence Area

	Actual	Max Desirable		Violation?
V_{12}	5388	Exhibit 25-14	4400:All	Yes

Level of Service Determination (if not F)

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

D_R = 38.7 (pc/mi/ln)
LOS = F (Exhibit 25-4)

Speed Determination

D_s = 0.547 (Exhibit 25-19)
S_R = 52.4 mph (Exhibit 25-19)
S_0 = 64.7 mph (Exhibit 25-19)
S = 55.7 mph (Exhibit 25-15)

RAMPS AND RAMP JUNCTIONS WORKSHEET

General Information / Site Information

Analyst	APATEL	Freeway/Dir of Travel	I-440 EB
Agency or Company	WSP SELLS	Junction	on-ramp from CVA extension
Date Performed	7/19/2010	Jurisdiction	Raleigh/NCDOT/FHWA
Analysis Time Period	PM Glenwood Overpass ONLY	Analysis Year	2035

Project Description Crabtree Valley

Inputs

Upstream Adj Ramp
☐ Yes ☐ On
☑ No ☐ Off
L_{up} = ft
V_u = veh/h

Terrain: Level

S_{FF} = 65.0 mph S_{FR} = 45.0 mph
Sketch (show lanes, L_A, L_D, V_R, V_f)

Downstream Adj Ramp
☑ Yes ☑ On
☐ No ☐ Off
L_{down} = 1500 ft
V_D = 2192 veh/h

Conversion to pc/h Under Base Conditions

(pc/h)	V (Veh/hr)	PHF	Terrain	%Truck	%Rv	f_{HV}	f_p	v = V/PHF x f_{HV} x f_p
Freeway	5721	1.00	Level	3	0	0.985	1.00	5807
Ramp	989	1.00	Level	2	0	0.990	1.00	999
UpStream								
DownStream	2192	1.00	Level	2	0	0.990	1.00	2214

Merge Areas

Estimation of v_{12}

$V_{12} = V_F (P_{FM})$
L_{EQ} = (Equation 25-2 or 25-3)
P_{FM} = 0.619 using Equation (Exhibit 25-5)
V_{12} = 3597 pc/h
V_3 or V_{av34} 2210 pc/h (Equation 25-4 or 25-5)
Is V_3 or V_{av34} > 2,700 pc/h? ☐ Yes ☑ No
Is V_3 or V_{av34} > 1.5 * V_{12}/2 ☐ Yes ☑ No
If Yes, V_{12a} = pc/h (Equation 25-8)

Capacity Checks

	Actual	Capacity		LOS F?
V_{FO}	6806	Exhibit 25-7		No

Flow Entering Merge Influence Area

	Actual	Max Desirable		Violation?
V_{R12}	4596	Exhibit 25-7	4600:All	No

Level of Service Determination (if not F)

$D_R = 5.475 + 0.00734\, v_R + 0.0078\, V_{12} - 0.00627\, L_A$
D_R = 31.5 (pc/mi/ln)
LOS = D (Exhibit 25-4)

Speed Determination

M_S = 0.572 (Exibit 25-19)
S_R = 51.8 mph (Exhibit 25-19)
S_0 = 58.8 mph (Exhibit 25-19)
S = 53.9 mph (Exhibit 25-14)

Diverge Areas

Estimation of v_{12}

$V_{12} = V_R + (V_F - V_R)P_{FD}$
L_{EQ} = (Equation 25-8 or 25-9)
P_{FD} = using Equation (Exhibit 25-12)
V_{12} = pc/h
V_3 or V_{av34} pc/h (Equation 25-15 or 25-16)
Is V_3 or V_{av34} > 2,700 pc/h? ☐ Yes ☐ No
Is V_3 or V_{av34} > 1.5 * V_{12}/2 ☐ Yes ☐ No
If Yes, V_{12a} = pc/h (Equation 25-18)

Capacity Checks

	Actual	Capacity		LOS F?
V_F		Exhibit 25-14		
$V_{FO} = V_F - V_R$		Exhibit 25-14		
V_R		Exhibit 25-3		

Flow Entering Diverge Influence Area

	Actual	Max Desirable		Violation?
V_{12}		Exhibit 25-14		

Level of Service Determination (if not F)

$D_R = 4.252 + 0.0086\, V_{12} - 0.009\, L_D$
D_R = (pc/mi/ln)
LOS = (Exhibit 25-4)

Speed Determination

D_s = (Exhibit 25-19)
S_R = mph (Exhibit 25-19)
S_0 = mph (Exhibit 25-19)
S = mph (Exhibit 25-15)

RAMPS AND RAMP JUNCTIONS WORKSHEET

General Information / Site Information

Analyst	APATEL	Freeway/Dir of Travel	I-440 EB
Agency or Company	WSP SELLS	Junction	on-ramp from Glenwood WB
Date Performed	6/21/2010	Jurisdiction	Raleigh/NCDOT/FHWA
Analysis Time Period	PM Glenwood Overpass ONLY	Analysis Year	2035

Project Description Crabtree Valley

Inputs

Upstream Adj Ramp
☑ Yes ☑ On
☐ No ☐ Off
L_{up} = 1200 ft
V_u = 2192 veh/h

Terrain: Level
S_{FF} = 65.0 mph S_{FR} = 45.0 mph
Sketch (show lanes, L_A, L_D, V_R, V_f)

Downstream Adj Ramp
☐ Yes ☐ On
☑ No ☐ Off
L_{down} = ft
V_D = veh/h

Conversion to pc/h Under Base Conditions

(pc/h)	V (Veh/hr)	PHF	Terrain	%Truck	%Rv	f_{HV}	f_p	v = V/PHF x f_{HV} x f_p
Freeway	8902	1.00	Level	3	0	0.985	1.00	9036
Ramp	1090	1.00	Level	2	0	0.990	1.00	1101
UpStream	2192	1.00	Level	0	0	1.000	1.00	2192
DownStream								

Merge Areas

Estimation of v_{12}

$V_{12} = V_F (P_{FM})$
L_{EQ} = (Equation 25-2 or 25-3)
P_{FM} = 0.080 using Equation (Exhibit 25-5)
V_{12} = 724 pc/h
V_3 or V_{av34} 4156 pc/h (Equation 25-4 or 25-5)
Is V_3 or V_{av34} > 2,700 pc/h? ☑ Yes ☐ No
Is V_3 or V_{av34} > 1.5 * V_{12}/2 ☑ Yes ☐ No
If Yes, V_{12a} = 3614 pc/h (Equation 25-8)

Capacity Checks

	Actual	Capacity		LOS F?
V_{FO}	10137	Exhibit 25-7		Yes

Flow Entering Merge Influence Area

	Actual	Max Desirable		Violation?
V_{R12}	4715	Exhibit 25-7	4600:All	Yes

Level of Service Determination (if not F)

$D_R = 5.475 + 0.00734\ v_R + 0.0078\ V_{12} - 0.00627\ L_A$
D_R = 32.3 (pc/mi/ln)
LOS = F (Exhibit 25-4)

Speed Determination

M_S = 0.621 (Exibit 25-19)
S_R = 50.7 mph (Exhibit 25-19)
S_0 = 56.0 mph (Exhibit 25-19)
S = 53.4 mph (Exhibit 25-14)

Diverge Areas

Estimation of v_{12}

$V_{12} = V_R + (V_F - V_R)P_{FD}$
L_{EQ} = (Equation 25-8 or 25-9)
P_{FD} = using Equation (Exhibit 25-12)
V_{12} = pc/h
V_3 or V_{av34} pc/h (Equation 25-15 or 25-16)
Is V_3 or V_{av34} > 2,700 pc/h? ☐ Yes ☐ No
Is V_3 or V_{av34} > 1.5 * V_{12}/2 ☐ Yes ☐ No
If Yes, V_{12a} = pc/h (Equation 25-18)

Capacity Checks

	Actual	Capacity		LOS F?
V_F		Exhibit 25-14		
$V_{FO} = V_F - V_R$		Exhibit 25-14		
V_R		Exhibit 25-3		

Flow Entering Diverge Influence Area

	Actual	Max Desirable		Violation?
V_{12}		Exhibit 25-14		

Level of Service Determination (if not F)

$D_R = 4.252 + 0.0086\ V_{12} - 0.009\ L_D$
D_R = (pc/mi/ln)
LOS = (Exhibit 25-4)

Speed Determination

D_s = (Exhibit 25-19)
S_R = mph (Exhibit 25-19)
S_0 = mph (Exhibit 25-19)
S = mph (Exhibit 25-15)

RAMPS AND RAMP JUNCTIONS WORKSHEET

General Information / Site Information

Analyst	Caroline Kone	Freeway/Dir of Travel	I-440 WB
Agency or Company	WSP SELLS	Junction	off-ramp to Glenwood/CVA
Date Performed	6/21/2010	Jurisdiction	Raleigh/NCDOT/FHWA
Analysis Time Period	PM Glenwood Overpass ONLY	Analysis Year	2035

Project Description: Crabtree Valley

Inputs

Upstream Adj Ramp	Terrain: Level	Downstream Adj Ramp
☐ Yes ☐ On		☐ Yes ☐ On
☑ No ☐ Off		☑ No ☐ Off
L_{up} = ft		L_{down} = ft
V_u = veh/h	S_{FF} = 65.0 mph S_{FR} = 45.0 mph Sketch (show lanes, L_A, L_D, V_R, V_f)	V_D = veh/h

Conversion to pc/h Under Base Conditions

(pc/h)	V (Veh/hr)	PHF	Terrain	%Truck	%Rv	f_{HV}	f_p	v = V/PHF x f_{HV} x f_p
Freeway	11115	1.00	Level	3	0	0.985	1.00	11282
Ramp	0	1.00	Level	2	0	0.990	1.00	0
UpStream								
DownStream								

Merge Areas

Estimation of v_{12}

$V_{12} = V_F (P_{FM})$

L_{EQ} = (Equation 25-2 or 25-3)

P_{FM} = using Equation (Exhibit 25-5)

V_{12} = pc/h

V_3 or V_{av34} pc/h (Equation 25-4 or 25-5)

Is V_3 or V_{av34} > 2,700 pc/h? ☐ Yes ☐ No

Is V_3 or V_{av34} > 1.5 * V_{12}/2 ☐ Yes ☐ No

If Yes, V_{12a} = pc/h (Equation 25-8)

Capacity Checks

	Actual	Capacity		LOS F?
V_{FO}		Exhibit 25-7		

Flow Entering Merge Influence Area

	Actual	Max Desirable		Violation?
V_{R12}		Exhibit 25-7		

Level of Service Determination (if not F)

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

D_R = (pc/mi/ln)

LOS = (Exhibit 25-4)

Speed Determination

M_S = (Exibit 25-19)

S_R = mph (Exhibit 25-19)

S_0 = mph (Exhibit 25-19)

S = mph (Exhibit 25-14)

Diverge Areas

Estimation of v_{12}

$V_{12} = V_R + (V_F - V_R)P_{FD}$

L_{EQ} = (Equation 25-8 or 25-9)

P_{FD} = 0.260 using Equation (Exhibit 25-12)

V_{12} = 2347 pc/h

V_3 or V_{av34} 3339 pc/h (Equation 25-15 or 25-16)

Is V_3 or V_{av34} > 2,700 pc/h? ☑ Yes ☐ No

Is V_3 or V_{av34} > 1.5 * V_{12}/2 ☑ Yes ☐ No

If Yes, V_{12a} = 3610 pc/h (Equation 25-18)

Capacity Checks

	Actual	Capacity		LOS F?
V_F	9026	Exhibit 25-14	9400	No
$V_{FO} = V_F - V_R$	9026	Exhibit 25-14	9400	No
V_R	0	Exhibit 25-3	4100	No

Flow Entering Diverge Influence Area

	Actual	Max Desirable		Violation?
V_{12}	2347	Exhibit 25-14	4400:All	No

Level of Service Determination (if not F)

D_R = ~~4.252 + 0.0086 V_{12} - 0.009 L_D~~ $0.0109\ \frac{V_F}{N}$

D_R = ~~5.8~~ (pc/mi/ln) 24.59

LOS = ~~A~~ (Exhibit 25-4) C

Speed Determination

D_s = 0.298 (Exhibit 25-19)

S_R = 58.1 mph (Exhibit 25-19)

S_0 = 64.6 mph (Exhibit 25-19)

S = 61.9 mph (Exhibit 25-15)

RAMPS AND RAMP JUNCTIONS WORKSHEET

General Information / Site Information

Analyst	APATEL	Freeway/Dir of Travel	I-440 WB
Agency or Company	WSP SELLS	Junction	on-ramp from CVA extension
Date Performed	7/19/2010	Jurisdiction	Raleigh/NCDOT/FHWA
Analysis Time Period	PM Glenwood Overpass ONLY	Analysis Year	2035

Project Description Crabtree Valley

Inputs

Upstream Adj Ramp
☑ Yes ☑ On
☐ No ☐ Off
L_{up} = 300 ft
V_u = 1651 veh/h

Terrain: Level
S_{FF} = 65.0 mph S_{FR} = 45.0 mph
Sketch (show lanes, L_A, L_D, V_R, V_f)

Downstream Adj Ramp
☐ Yes ☐ On
☑ No ☐ Off
L_{down} = ft
V_D = veh/h

Conversion to pc/h Under Base Conditions

(pc/h)	V (Veh/hr)	PHF	Terrain	%Truck	%Rv	f_{HV}	f_p	v = V/PHF x f_{HV} x f_p
Freeway	7668	1.00	Level	3	0	0.985	1.00	7783
Ramp	915	1.00	Level	2	0	0.990	1.00	924
UpStream	1651	1.00	Level	2	0	0.990	1.00	1668
DownStream								

Merge Areas

Estimation of v_{12}

$V_{12} = V_F (P_{FM})$
L_{EQ} = (Equation 25-2 or 25-3)
P_{FM} = 0.102 using Equation (Exhibit 25-5)
V_{12} = 796 pc/h
V_3 or V_{av34} = 3493 pc/h (Equation 25-4 or 25-5)
Is V_3 or V_{av34} > 2,700 pc/h? ☑ Yes ☐ No
Is V_3 or V_{av34} > 1.5 * V_{12}/2 ☑ Yes ☐ No
If Yes, V_{12a} = 3113 pc/h (Equation 25-8)

Capacity Checks

	Actual	Capacity		LOS F?
V_{FO}	8707	Exhibit 25-7		No

Flow Entering Merge Influence Area

	Actual	Max Desirable		Violation?
V_{R12}	4037	Exhibit 25-7	4600:All	No

Level of Service Determination (if not F)

$D_R = 5.475 + 0.00734\, v_R + 0.0078\, V_{12} - 0.00627\, L_A$
D_R = 31.2 (pc/mi/ln)
LOS = D (Exhibit 25-4)

Speed Determination

M_S = 0.465 (Exibit 25-19)
S_R = 54.3 mph (Exhibit 25-19)
S_0 = 58.3 mph (Exhibit 25-19)
S = 56.4 mph (Exhibit 25-14)

Diverge Areas

Estimation of v_{12}

$V_{12} = V_R + (V_F - V_R) P_{FD}$
L_{EQ} = (Equation 25-8 or 25-9)
P_{FD} = using Equation (Exhibit 25-12)
V_{12} = pc/h
V_3 or V_{av34} = pc/h (Equation 25-15 or 25-16)
Is V_3 or V_{av34} > 2,700 pc/h? ☐ Yes ☐ No
Is V_3 or V_{av34} > 1.5 * V_{12}/2 ☐ Yes ☐ No
If Yes, V_{12a} = pc/h (Equation 25-18)

Capacity Checks

	Actual	Capacity		LOS F?
V_F		Exhibit 25-14		
$V_{FO} = V_F - V_R$		Exhibit 25-14		
V_R		Exhibit 25-3		

Flow Entering Diverge Influence Area

	Actual	Max Desirable		Violation?
V_{12}		Exhibit 25-14		

Level of Service Determination (if not F)

$D_R = 4.252 + 0.0086\, V_{12} - 0.009\, L_D$
D_R = (pc/mi/ln)
LOS = (Exhibit 25-4)

Speed Determination

D_s = (Exhibit 25-19)
S_R = mph (Exhibit 25-19)
S_0 = mph (Exhibit 25-19)
S = mph (Exhibit 25-15)

RAMPS AND RAMP JUNCTIONS WORKSHEET

General Information / Site Information

Analyst	APATEL	Freeway/Dir of Travel	I-440 WB
Agency or Company	WSP SELLS	Junction	on-ramp from Glen. EB
Date Performed	7/15/2010	Jurisdiction	Raleigh/NCDOT/FHWA
Analysis Time Period	PM Glenwood Overpass Only	Analysis Year	2035

Project Description Crabtree Valley

Inputs

Upstream Adj Ramp
☐ Yes ☐ On
☑ No ☐ Off
L_{up} = ft
V_u = veh/h

Terrain: Level

S_{FF} = 65.0 mph S_{FR} = 45.0 mph
Sketch (show lanes, L_A, L_D, V_R, V_f)

Downstream Adj Ramp
☑ Yes ☑ On
☐ No ☐ Off
L_{down} = 300 ft
V_D = 915 veh/h

Conversion to pc/h Under Base Conditions

(pc/h)	V (Veh/hr)	PHF	Terrain	%Truck	%Rv	f_{HV}	f_p	v = V/PHF x f_{HV} x f_p
Freeway	6017	1.00	Level	3	0	0.985	1.00	6107
Ramp	1651	1.00	Level	2	0	0.990	1.00	1668
UpStream								
DownStream	915	1.00	Level	2	0	0.990	1.00	924

Merge Areas

Estimation of v_{12}

$V_{12} = V_F (P_{FM})$
L_{EQ} = (Equation 25-2 or 25-3)
P_{FM} = 0.009 using Equation (Exhibit 25-5)
V_{12} = 57 pc/h
V_3 or V_{av34} 3025 pc/h (Equation 25-4 or 25-5)
Is V_3 or V_{av34} > 2,700 pc/h? ☑ Yes ☐ No
Is V_3 or V_{av34} > 1.5 * V_{12}/2 ☑ Yes ☐ No
If Yes, V_{12a} = 2442 pc/h (Equation 25-8)

Capacity Checks

	Actual	Capacity		LOS F?
V_{FO}	7775	Exhibit 25-7		No

Flow Entering Merge Influence Area

	Actual	Max Desirable		Violation?
V_{R12}	4110	Exhibit 25-7	4600:All	No

Level of Service Determination (if not F)

$D_R = 5.475 + 0.00734\ v_R + 0.0078\ V_{12} - 0.00627\ L_A$
D_R = 28.0 (pc/mi/ln)
LOS = C (Exhibit 25-4)

Speed Determination

M_S = 0.433 (Exibit 25-19)
S_R = 55.0 mph (Exhibit 25-19)
S_0 = 60.2 mph (Exhibit 25-19)
S = 57.4 mph (Exhibit 25-14)

Diverge Areas

Estimation of v_{12}

$V_{12} = V_R + (V_F - V_R)P_{FD}$
L_{EQ} = (Equation 25-8 or 25-9)
P_{FD} = using Equation (Exhibit 25-12)
V_{12} = pc/h
V_3 or V_{av34} pc/h (Equation 25-15 or 25-16)
Is V_3 or V_{av34} > 2,700 pc/h? ☐ Yes ☐ No
Is V_3 or V_{av34} > 1.5 * V_{12}/2 ☐ Yes ☐ No
If Yes, V_{12a} = pc/h (Equation 25-18)

Capacity Checks

	Actual	Capacity		LOS F?
V_F		Exhibit 25-14		
$V_{FO} = V_F - V_R$		Exhibit 25-14		
V_R		Exhibit 25-3		

Flow Entering Diverge Influence Area

	Actual	Max Desirable		Violation?
V_{12}		Exhibit 25-14		

Level of Service Determination (if not F)

$D_R = 4.252 + 0.0086\ V_{12} - 0.009\ L_D$
D_R = (pc/mi/ln)
LOS = (Exhibit 25-4)

Speed Determination

D_s = (Exhibit 25-19)
S_R = mph (Exhibit 25-19)
S_0 = mph (Exhibit 25-19)
S = mph (Exhibit 25-15)

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FREEWAY WEAVING WORKSHEET

General Information

Analyst	
Agency/Company	WSP SELLS
Date Performed	7/19/2010
Analysis Time Period	PM Glenwood Overpass ONLY

Site Information

Freeway/Dir of Travel	I-440 WB
Weaving Seg Location	Glen. WB on to Glen. EB off
Jurisdiction	Raleigh/NCDOT/FHWA
Analysis Year	2035

Inputs

Freeway free-flow speed, S_{FF} (mi/h)	55	Weaving type	B
Weaving number of lanes, N	2	Volume ratio, VR	0.68
Weaving seg length, L (ft)	870	Weaving ratio, R	0.38
Terrain	Level		

Conversions to pc/h Under Base Conditions

(pc/h)	V	PHF	Truck %	RV %	E_T	E_R	f_{HV}	f_p	v
V_{o1}	796	1.00	3	0	1.5	1.2	0.985	1.00	807
V_{o2}	0	1.00	2	0	1.5	1.2	0.990	1.00	0
V_{w1}	1056	1.00	2	0	1.5	1.2	0.990	1.00	1066
V_{w2}	651	1.00	2	0	1.5	1.2	0.990	1.00	657
V_w				1723	V_{nw}				807
V									2530

Weaving and Non-Weaving Speeds

	Unconstrained		Constrained	
	Weaving (i = w)	Non-Weaving (i = nw)	Weaving (i = w)	Non-Weaving (= nw)
a (Exhibit 24-6)	0.08	0.0020		
b (Exhibit 24-6)	2.20	6.00		
c (Exhibit 24-6)	0.70	1.00		
d (Exhibit 24-6)	0.50	0.50		
Weaving intensity factor, Wi	1.26	1.94		
Weaving and non-weaving speeds, Si (mi/h)	34.89	30.33		

Number of lanes required for unconstrained operation, Nw 1.83
Maximum number of lanes, Nw (max) 3.50

☑ If Nw < Nw(max) unconstrained operation ☐ if Nw > Nw (max) constrained operation

Weaving Segment Speed, Density, Level of Service, and Capacity

Weaving segment speed, S (mi/h)	33.30
Weaving segment density, D (pc/mi/ln)	37.99
Level of service, LOS	E
Capacity of base condition, c_0 (pc/h)	
Capacity as a 15-minute flow rate, c (veh/h)	
Capacity as a full-hour volume, c_h (veh/h)	

Notes

a. Weaving segments longer than 2500 ft. are treated as isolated merge and diverge areas using the procedures of Chapter 25, "Ramps and Ramp Junctions".
b. Capacity constrained by basic freeway capacity.
c. Capacity occurs under constrained operating conditions.
d. Three-lane Type A segments do not operate well at volume ratios greater than 0.45. Poor operations and some local queuing are expected in such cases.
e. Four-lane Type A segments do not operate well at volume ratios greater than 0.35. Poor operations and some local queuing are expected in such cases.
f. Capacity constrained by maximum allowable weaving flow rate: 2,800 pc/h (Type A), 4,000 (Type B), 3,500 (Type C).
g. Five-lane Type A segments do not operate well at volume ratios greater than 0.20. Poor operations and some local queuing are expected in such cases.
h. Type B weaving segments do not operate well at volume ratios greater than 0.80. Poor operations and some local queuing are expected in such cases.
i. Type C weaving segments do not operate well at volume ratios greater than 0.50. Poor operations and some local queuing are expected in such cases.

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2035 CVA Extension to I-440, WB Glenwood Ave Overpass and Creedmoor Road SPUI

RAMPS AND RAMP JUNCTIONS WORKSHEET

General Information / Site Information

Analyst	APATEL	Freeway/Dir of Travel	I-440 EB
Agency or Company	WSP SELLS	Junction	off-ramp to Ridge Rd
Date Performed	7/14/2010	Jurisdiction	Raleigh/NCDOT/FHWA
Analysis Time Period	AM Glenwood WB Overpass	Analysis Year	2035

Project Description Crabtree Valley

Inputs

Upstream Adj Ramp
☐ Yes ☐ On
☑ No ☐ Off
L_{up} = ft
V_u = veh/h

Terrain: Level

S_{FF} = 65.0 mph S_{FR} = 45.0 mph
Sketch (show lanes, L_A, L_D, V_R, V_f)

Downstream Adj Ramp
☑ Yes ☑ On
☐ No ☐ Off
L_{down} = 900 ft
V_D = 744 veh/h

Conversion to pc/h Under Base Conditions

(pc/h)	V (Veh/hr)	PHF	Terrain	%Truck	%Rv	f_{HV}	f_p	v = V/PHF x f_{HV} x f_p
Freeway	6851	1.00	Level	3	0	0.985	1.00	6954
Ramp	1829	1.00	Level	2	0	0.990	1.00	1847
UpStream								
DownStream	744	1.00	Level	2	0	0.990	1.00	751

Merge Areas

Estimation of v_{12}

$V_{12} = V_F (P_{FM})$
L_{EQ} = (Equation 25-2 or 25-3)
P_{FM} = using Equation (Exhibit 25-5)
V_{12} = pc/h
V_3 or V_{av34} pc/h (Equation 25-4 or 25-5)
Is V_3 or V_{av34} > 2,700 pc/h? ☐ Yes ☐ No
Is V_3 or V_{av34} > 1.5 * V_{12}/2 ☐ Yes ☐ No
If Yes, V_{12a} = pc/h (Equation 25-8)

Capacity Checks

	Actual	Capacity		LOS F?
V_{FO}		Exhibit 25-7		

Flow Entering Merge Influence Area

	Actual	Max Desirable		Violation?
V_{R12}		Exhibit 25-7		

Level of Service Determination (if not F)

$D_R = 5.475 + 0.00734\ v_R + 0.0078\ V_{12} - 0.00627\ L_A$
D_R = (pc/mi/ln)
LOS = (Exhibit 25-4)

Speed Determination

M_S = (Exibit 25-19)
S_R = mph (Exhibit 25-19)
S_0 = mph (Exhibit 25-19)
S = mph (Exhibit 25-14)

Diverge Areas

Estimation of v_{12}

$V_{12} = V_R + (V_F - V_R)P_{FD}$
L_{EQ} = (Equation 25-8 or 25-9)
P_{FD} = 0.450 using Equation (Exhibit 25-12)
V_{12} = 4145 pc/h
V_3 or V_{av34} 2809 pc/h (Equation 25-15 or 25-16)
Is V_3 or V_{av34} > 2,700 pc/h? ☑ Yes ☐ No
Is V_3 or V_{av34} > 1.5 * V_{12}/2 ☐ Yes ☑ No
If Yes, V_{12a} = 4254 pc/h (Equation 25-18)

Capacity Checks

	Actual	Capacity		LOS F?
V_F	6954	Exhibit 25-14	7050	No
$V_{FO} = V_F - V_R$	5107	Exhibit 25-14	7050	No
V_R	1847	Exhibit 25-3	4100	No

Flow Entering Diverge Influence Area

	Actual	Max Desirable		Violation?
V_{12}	4145	Exhibit 25-14	4400:All	No

Level of Service Determination (if not F)

$D_R = 4.252 + 0.0086\ V_{12} - 0.009\ L_D$
D_R = 24.6 (pc/mi/ln)
LOS = C (Exhibit 25-4)

Speed Determination

D_s = 0.464 (Exhibit 25-19)
S_R = 54.3 mph (Exhibit 25-19)
S_0 = 64.7 mph (Exhibit 25-19)
S = 57.9 mph (Exhibit 25-15)

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RAMPS AND RAMP JUNCTIONS WORKSHEET

General Information / Site Information

Analyst	APATEL	Freeway/Dir of Travel	I-440 EB
Agency or Company	WSP SELLS	Junction	on-ramp from CVA extension
Date Performed	7/15/2010	Jurisdiction	Raleigh/NCDOT/FHWA
Analysis Time Period	AM Glenwood Overpass	Analysis Year	2035

Project Description Crabtree Valley

Inputs

Upstream Adj Ramp
☐ Yes ☐ On
☑ No ☐ Off
L_{up} = ft
V_u = veh/h

Terrain: Level

S_{FF} = 65.0 mph S_{FR} = 45.0 mph
Sketch (show lanes, L_A, L_D, V_R, V_f)

Downstream Adj Ramp
☑ Yes ☑ On
☐ No ☐ Off
L_{down} = 1500 ft
V_D = 1890 veh/h

Conversion to pc/h Under Base Conditions

(pc/h)	V (Veh/hr)	PHF	Terrain	%Truck	%Rv	f_{HV}	f_p	v = V/PHF x f_{HV} x f_p
Freeway	5022	1.00	Level	3	0	0.985	1.00	5097
Ramp	744	1.00	Level	2	0	0.990	1.00	751
UpStream								
DownStream	1890	1.00	Level	2	0	0.990	1.00	1909

Merge Areas

Estimation of v_{12}

$V_{12} = V_F (P_{FM})$

L_{EQ} = (Equation 25-2 or 25-3)
P_{FM} = 0.619 using Equation (Exhibit 25-5)
V_{12} = 3158 pc/h
V_3 or V_{av34} 1939 pc/h (Equation 25-4 or 25-5)
Is V_3 or V_{av34} > 2,700 pc/h? ☐ Yes ☑ No
Is V_3 or V_{av34} > 1.5 * V_{12}/2 ☐ Yes ☑ No
If Yes, V_{12a} = pc/h (Equation 25-8)

Capacity Checks

	Actual	Capacity		LOS F?
V_{FO}	5848	Exhibit 25-7		No

Flow Entering Merge Influence Area

	Actual	Max Desirable		Violation?
V_{R12}	3909	Exhibit 25-7	4600:All	No

Level of Service Determination (if not F)

$D_R = 5.475 + 0.00734\, v_R + 0.0078\, V_{12} - 0.00627\, L_A$

D_R = 26.2 (pc/mi/ln)
LOS = C (Exhibit 25-4)

Speed Determination

M_S = 0.380 (Exibit 25-19)
S_R = 56.3 mph (Exhibit 25-19)
S_0 = 59.8 mph (Exhibit 25-19)
S = 57.4 mph (Exhibit 25-14)

Diverge Areas

Estimation of v_{12}

$V_{12} = V_R + (V_F - V_R) P_{FD}$

L_{EQ} = (Equation 25-8 or 25-9)
P_{FD} = using Equation (Exhibit 25-12)
V_{12} = pc/h
V_3 or V_{av34} pc/h (Equation 25-15 or 25-16)
Is V_3 or V_{av34} > 2,700 pc/h? ☐ Yes ☐ No
Is V_3 or V_{av34} > 1.5 * V_{12}/2 ☐ Yes ☐ No
If Yes, V_{12a} = pc/h (Equation 25-18)

Capacity Checks

	Actual	Capacity		LOS F?
V_F		Exhibit 25-14		
$V_{FO} = V_F - V_R$		Exhibit 25-14		
V_R		Exhibit 25-3		

Flow Entering Diverge Influence Area

	Actual	Max Desirable		Violation?
V_{12}		Exhibit 25-14		

Level of Service Determination (if not F)

$D_R = 4.252 + 0.0086\, V_{12} - 0.009\, L_D$

D_R = (pc/mi/ln)
LOS = (Exhibit 25-4)

Speed Determination

D_s = (Exhibit 25-19)
S_R = mph (Exhibit 25-19)
S_0 = mph (Exhibit 25-19)
S = mph (Exhibit 25-15)

RAMPS AND RAMP JUNCTIONS WORKSHEET

General Information / Site Information

Analyst	APATEL	Freeway/Dir of Travel	I-440 EB
Agency or Company	WSP SELLS	Junction	on-ramp from Glenwood WB
Date Performed	7/15/2010	Jurisdiction	Raleigh/NCDOT/FHWA
Analysis Time Period	AM Glenwood Overpass	Analysis Year	2035

Project Description Crabtree Valley

Inputs

Upstream Adj Ramp
☑ Yes ☑ On
☐ No ☐ Off
L_{up} = 1200 ft
V_u = 1890 veh/h

Terrain: Level

S_{FF} = 65.0 mph S_{FR} = 45.0 mph
Sketch (show lanes, L_A, L_D, V_R, V_f)

Downstream Adj Ramp
☐ Yes ☐ On
☑ No ☐ Off
L_{down} = ft
V_D = veh/h

Conversion to pc/h Under Base Conditions

(pc/h)	V (Veh/hr)	PHF	Terrain	%Truck	%Rv	f_{HV}	f_p	v = V/PHF x f_{HV} x f_p
Freeway	7656	1.00	Level	3	0	0.985	1.00	7771
Ramp	1163	1.00	Level	2	0	0.990	1.00	1175
UpStream	1890	1.00	Level	2	0	0.990	1.00	1909
DownStream								

Merge Areas

Estimation of v_{12}

$V_{12} = V_F (P_{FM})$
L_{EQ} = (Equation 25-2 or 25-3)
P_{FM} = 0.071 using Equation (Exhibit 25-5)
V_{12} = 551 pc/h
V_3 or V_{av34} 3610 pc/h (Equation 25-4 or 25-5)
Is V_3 or V_{av34} > 2,700 pc/h? ☑ Yes ☐ No
Is V_3 or V_{av34} > 1.5 * V_{12}/2 ☑ Yes ☐ No
If Yes, V_{12a} = 3108 pc/h (Equation 25-8)

Capacity Checks

	Actual	Capacity		LOS F?
V_{FO}	8946	Exhibit 25-7		No

Flow Entering Merge Influence Area

	Actual	Max Desirable		Violation?
V_{R12}	4283	Exhibit 25-7	4600:All	No

Level of Service Determination (if not F)

$D_R = 5.475 + 0.00734 v_R + 0.0078 V_{12} - 0.00627 L_A$
D_R = 28.9 (pc/mi/ln)
LOS = D (Exhibit 25-4)

Speed Determination

M_S = 0.469 (Exibit 25-19)
S_R = 54.2 mph (Exhibit 25-19)
S_0 = 58.3 mph (Exhibit 25-19)
S = 56.3 mph (Exhibit 25-14)

Diverge Areas

Estimation of v_{12}

$V_{12} = V_R + (V_F - V_R)P_{FD}$
L_{EQ} = (Equation 25-8 or 25-9)
P_{FD} = using Equation (Exhibit 25-12)
V_{12} = pc/h
V_3 or V_{av34} pc/h (Equation 25-15 or 25-16)
Is V_3 or V_{av34} > 2,700 pc/h? ☐ Yes ☐ No
Is V_3 or V_{av34} > 1.5 * V_{12}/2 ☐ Yes ☐ No
If Yes, V_{12a} = pc/h (Equation 25-18)

Capacity Checks

	Actual	Capacity		LOS F?
V_F		Exhibit 25-14		
$V_{FO} = V_F - V_R$		Exhibit 25-14		
V_R		Exhibit 25-3		

Flow Entering Diverge Influence Area

	Actual	Max Desirable		Violation?
V_{12}		Exhibit 25-14		

Level of Service Determination (if not F)

$D_R = 4.252 + 0.0086 V_{12} - 0.009 L_D$
D_R = (pc/mi/ln)
LOS = (Exhibit 25-4)

Speed Determination

D_s = (Exhibit 25-19)
S_R = mph (Exhibit 25-19)
S_0 = mph (Exhibit 25-19)
S = mph (Exhibit 25-15)

RAMPS AND RAMP JUNCTIONS WORKSHEET

General Information / Site Information

Analyst	APATEL	Freeway/Dir of Travel	I-440 WB
Agency or Company	WSP SELLS	Junction	off-ramp to Glenwood/ CVA
Date Performed	7/15/2010	Jurisdiction	Raleigh/NCDOT/FHWA
Analysis Time Period	AM Glenwood Overpass	Analysis Year	2035

Project Description: Crabtree Valley

Inputs

Upstream Adj Ramp: ☐ Yes ☐ On ☑ No ☐ Off
L_{up} = ft
V_u = veh/h

Terrain: Level

S_{FF} = 65.0 mph S_{FR} = 45.0 mph
Sketch (show lanes, L_A, L_D, V_R, V_f)

Downstream Adj Ramp: ☐ Yes ☐ On ☑ No ☐ Off
L_{down} = ft
V_D = veh/h

Conversion to pc/h Under Base Conditions

(pc/h)	V (Veh/hr)	PHF	Terrain	%Truck	%Rv	f_{HV}	f_p	$v = V/PHF \times f_{HV} \times f_p$
Freeway	12893	1.00	Level	3	0	0.985	1.00	13086
Ramp	0	1.00	Level	2	0	0.990	1.00	0
UpStream								
DownStream								

Merge Areas

Estimation of v_{12}

$V_{12} = V_F (P_{FM})$
L_{EQ} = (Equation 25-2 or 25-3)
P_{FM} = using Equation (Exhibit 25-5)
V_{12} = pc/h
V_3 or V_{av34} pc/h (Equation 25-4 or 25-5)
Is V_3 or V_{av34} > 2,700 pc/h? ☐ Yes ☐ No
Is V_3 or V_{av34} > 1.5 * V_{12}/2 ☐ Yes ☐ No
If Yes, V_{12a} = pc/h (Equation 25-8)

Capacity Checks

	Actual	Capacity		LOS F?
V_{FO}		Exhibit 25-7		

Flow Entering Merge Influence Area

	Actual	Max Desirable		Violation?
V_{R12}		Exhibit 25-7		

Level of Service Determination (If not F)

$D_R = 5.475 + 0.00734\ v_R + 0.0078\ V_{12} - 0.00627\ L_A$
D_R = (pc/mi/ln)
LOS = (Exhibit 25-4)

Speed Determination

M_S = (Exibit 25-19)
S_R = mph (Exhibit 25-19)
S_0 = mph (Exhibit 25-19)
S = mph (Exhibit 25-14)

Diverge Areas

Estimation of v_{12}

$V_{12} = V_R + (V_F - V_R)P_{FD}$
L_{EQ} = (Equation 25-8 or 25-9)
P_{FD} = 0.260 using Equation (Exhibit 25-12)
V_{12} = 2722 pc/h
V_3 or V_{av34} 3873 pc/h (Equation 25-15 or 25-16)
Is V_3 or V_{av34} > 2,700 pc/h? ☑ Yes ☐ No
Is V_3 or V_{av34} > 1.5 * V_{12}/2 ☑ Yes ☐ No
If Yes, V_{12a} = 4187 pc/h (Equation 25-18)

Capacity Checks

	Actual	Capacity		LOS F?
V_F	10469	Exhibit 25-14	9400	Yes
$V_{FO} = V_F - V_R$	10469	Exhibit 25-14	9400	Yes
V_R	0	Exhibit 25-3	4100	No

Flow Entering Diverge Influence Area

	Actual	Max Desirable		Violation?
V_{12}	2722	Exhibit 25-14	4400:All	No

Level of Service Determination (If not F)

$D_R = 4.252 + 0.0086\ V_{12} - 0.009\ L_D$ $0.0109 \frac{V_F}{N}$
D_R = 35.8 (pc/mi/ln) 28.53
LOS = F (Exhibit 25-4) D

Speed Determination

D_s = 0.298 (Exhibit 25-19)
S_R = 58.1 mph (Exhibit 25-19)
S_0 = 63.0 mph (Exhibit 25-19)
S = 60.9 mph (Exhibit 25-15)

RAMPS AND RAMP JUNCTIONS WORKSHEET

General Information / Site Information

Analyst	APATEL	Freeway/Dir of Travel	I-440 WB
Agency or Company	WSP SELLS	Junction	on-ramp from CVA extension
Date Performed	7/15/2010	Jurisdiction	Raleigh/NCDOT/FHWA
Analysis Time Period	AM Glenwood Overpass	Analysis Year	2035

Project Description: Crabtree Valley

Inputs

Upstream Adj Ramp: ☑ Yes ☑ On ☐ No ☐ Off

L_{up} = 300 ft

V_u = 1349 veh/h

Terrain: Level

S_{FF} = 65.0 mph S_{FR} = 45.0 mph

Sketch (show lanes, L_A, L_D, V_R, V_f)

Downstream Adj Ramp: ☐ Yes ☐ On ☑ No ☐ Off

L_{down} = ft

V_D = veh/h

Conversion to pc/h Under Base Conditions

	V (Veh/hr)	PHF	Terrain	%Truck	%Rv	f_{HV}	f_p	v = V/PHF x f_{HV} x f_p
Freeway	10300	1.00	Level	3	0	0.985	1.00	10454
Ramp	617	1.00	Level	2	0	0.990	1.00	623
UpStream	1349	1.00	Level	2	0	0.990	1.00	1362
DownStream								

Merge Areas

Estimation of v_{12}

$V_{12} = V_F (P_{FM})$

L_{EQ} = (Equation 25-2 or 25-3)

P_{FM} = 0.140 using Equation (Exhibit 25-5)

V_{12} = 1463 pc/h

V_3 or V_{av34} = 4495 pc/h (Equation 25-4 or 25-5)

Is V_3 or V_{av34} > 2,700 pc/h? ☑ Yes ☐ No

Is V_3 or V_{av34} > 1.5 * V_{12}/2 ☑ Yes ☐ No

If Yes, V_{12a} = 4181 pc/h (Equation 25-8)

Capacity Checks

	Actual	Capacity		LOS F?
V_{FO}	11077	Exhibit 25-7		Yes

Flow Entering Merge Influence Area

	Actual	Max Desirable		Violation?
V_{R12}	4804	Exhibit 25-7	4600:All	Yes

Level of Service Determination (if not F)

$D_R = 5.475 + 0.00734\, v_R + 0.0078\, V_{12} - 0.00627\, L_A$

D_R = 37.3 (pc/mi/ln)

LOS = F (Exhibit 25-4)

Speed Determination

M_S = 0.720 (Exibit 25-19)

S_R = 48.4 mph (Exhibit 25-19)

S_0 = 53.5 mph (Exhibit 25-19)

S = 51.2 mph (Exhibit 25-14)

Diverge Areas

Estimation of v_{12}

$V_{12} = V_R + (V_F - V_R)P_{FD}$

L_{EQ} = (Equation 25-8 or 25-9)

P_{FD} = using Equation (Exhibit 25-12)

V_{12} = pc/h

V_3 or V_{av34} pc/h (Equation 25-15 or 25-16)

Is V_3 or V_{av34} > 2,700 pc/h? ☐ Yes ☐ No

Is V_3 or V_{av34} > 1.5 * V_{12}/2 ☐ Yes ☐ No

If Yes, V_{12a} = pc/h (Equation 25-18)

Capacity Checks

	Actual	Capacity		LOS F?
V_F		Exhibit 25-14		
$V_{FO} = V_F - V_R$		Exhibit 25-14		
V_R		Exhibit 25-3		

Flow Entering Diverge Influence Area

	Actual	Max Desirable		Violation?
V_{12}		Exhibit 25-14		

Level of Service Determination (if not F)

$D_R = 4.252 + 0.0086\, V_{12} - 0.009\, L_D$

D_R = (pc/mi/ln)

LOS = (Exhibit 25-4)

Speed Determination

D_s = (Exhibit 25-19)

S_R = mph (Exhibit 25-19)

S_0 = mph (Exhibit 25-19)

S = mph (Exhibit 25-15)

RAMPS AND RAMP JUNCTIONS WORKSHEET

General Information / Site Information

Analyst	APATEL	Freeway/Dir of Travel	I-440 WB
Agency or Company	WSP SELLS	Junction	on-ramp from Glen. EB
Date Performed	7/15/2010	Jurisdiction	Raleigh/NCDOT/FHWA
Analysis Time Period	AM Glenwood Overpass	Analysis Year	2035

Project Description: Crabtree Valley

Inputs

Upstream Adj Ramp: ☐ Yes ☐ On ☑ No ☐ Off

L_{up} = ft

V_u = veh/h

Terrain: Level

S_{FF} = 65.0 mph S_{FR} = 45.0 mph

Sketch (show lanes, L_A, L_D, V_R, V_f)

Downstream Adj Ramp: ☑ Yes ☑ On ☐ No ☐ Off

L_{down} = 300 ft

V_D = 617 veh/h

Conversion to pc/h Under Base Conditions

(pc/h)	V (Veh/hr)	PHF	Terrain	%Truck	%Rv	f_{HV}	f_p	v = V/PHF x f_{HV} x f_p
Freeway	8951	1.00	Level	3	0	0.985	1.00	9085
Ramp	1349	1.00	Level	2	0	0.990	1.00	1362
UpStream								
DownStream	617	1.00	Level	2	0	0.990	1.00	623

Merge Areas

Estimation of v_{12}

$V_{12} = V_F (P_{FM})$

L_{EQ} = (Equation 25-2 or 25-3)

P_{FM} = 0.048 using Equation (Exhibit 25-5)

V_{12} = 432 pc/h

V_3 or V_{av34} = 4326 pc/h (Equation 25-4 or 25-5)

Is V_3 or V_{av34} > 2,700 pc/h? ☑ Yes ☐ No

Is V_3 or V_{av34} > 1.5 * V_{12}/2 ☑ Yes ☐ No

If Yes, V_{12a} = 3634 pc/h (Equation 25-8)

Capacity Checks

	Actual	Capacity		LOS F?
V_{FO}	10447	Exhibit 25-7		Yes

Flow Entering Merge Influence Area

	Actual	Max Desirable		Violation?
V_{R12}	4996	Exhibit 25-7	4600:All	Yes

Level of Service Determination (if not F)

$D_R = 5.475 + 0.00734\, v_R + 0.0078\, V_{12} - 0.00627\, L_A$

D_R = 35.0 (pc/mi/ln)

LOS = F (Exhibit 25-4)

Speed Determination

M_S = 0.772 (Exibit 25-19)

S_R = 47.3 mph (Exhibit 25-19)

S_0 = 55.9 mph (Exhibit 25-19)

S = 51.4 mph (Exhibit 25-14)

Diverge Areas

Estimation of v_{12}

$V_{12} = V_R + (V_F - V_R)P_{FD}$

L_{EQ} = (Equation 25-8 or 25-9)

P_{FD} = using Equation (Exhibit 25-12)

V_{12} = pc/h

V_3 or V_{av34} pc/h (Equation 25-15 or 25-16)

Is V_3 or V_{av34} > 2,700 pc/h? ☐ Yes ☐ No

Is V_3 or V_{av34} > 1.5 * V_{12}/2 ☐ Yes ☐ No

If Yes, V_{12a} = pc/h (Equation 25-18)

Capacity Checks

	Actual	Capacity		LOS F?
V_F		Exhibit 25-14		
$V_{FO} = V_F - V_R$		Exhibit 25-14		
V_R		Exhibit 25-3		

Flow Entering Diverge Influence Area

	Actual	Max Desirable		Violation?
V_{12}		Exhibit 25-14		

Level of Service Determination (if not F)

$D_R = 4.252 + 0.0086\, V_{12} - 0.009\, L_D$

D_R = (pc/mi/ln)

LOS = (Exhibit 25-4)

Speed Determination

D_s = (Exhibit 25-19)

S_R = mph (Exhibit 25-19)

S_0 = mph (Exhibit 25-19)

S = mph (Exhibit 25-15)

FREEWAY WEAVING WORKSHEET

General Information

Analyst	APATEL
Agency/Company	WSP SELLS
Date Performed	7/15/2010
Analysis Time Period	AM Glenwood Overpass

Site Information

Freeway/Dir of Travel	I-440 WB
Weaving Seg Location	Glen WB onto Glen EB off
Jurisdiction	Raleigh/NCDOT/FHWA
Analysis Year	2035

Inputs

Freeway free-flow speed, S_{FF} (mi/h)	55	Weaving type	B
Weaving number of lanes, N	2	Volume ratio, VR	0.71
Weaving seg length, L (ft)	870	Weaving ratio, R	0.26
Terrain	Level		

Conversions to pc/h Under Base Conditions

(pc/h)	V	PHF	Truck %	RV %	E_T	E_R	f_{HV}	f_p	v
V_{o1}	691	1.00	3	0	1.5	1.2	0.985	1.00	701
V_{o2}	0	1.00	0	0	1.5	1.2	1.000	1.00	0
V_{w1}	1238	1.00	2	0	1.5	1.2	0.990	1.00	1250
V_{w2}	442	1.00	2	0	1.5	1.2	0.990	1.00	446
V_w				1696	V_{nw}				701
V									2397

Weaving and Non-Weaving Speeds

	Unconstrained		Constrained	
	Weaving (i = w)	Non-Weaving (i = nw)	Weaving (i = w)	Non-Weaving (= nw)
a (Exhibit 24-6)	0.08	0.0020		
b (Exhibit 24-6)	2.20	6.00		
c (Exhibit 24-6)	0.70	1.00		
d (Exhibit 24-6)	0.50	0.50		
Weaving intensity factor, Wi	1.26	2.01		
Weaving and non-weaving speeds, Si (mi/h)	34.93	29.93		

Number of lanes required for unconstrained operation, Nw 1.88
Maximum number of lanes, Nw (max) 3.50

☑ If Nw < Nw(max) unconstrained operation ☐ If Nw > Nw (max) constrained operation

Weaving Segment Speed, Density, Level of Service, and Capacity

Weaving segment speed, S (mi/h)	33.30
Weaving segment density, D (pc/mi/ln)	35.99
Level of service, LOS	D
Capacity of base condition, c_b (pc/h)	
Capacity as a 15-minute flow rate, c (veh/h)	
Capacity as a full-hour volume, c_h (veh/h)	

Notes

a. Weaving segments longer than 2500 ft. are treated as isolated merge and diverge areas using the procedures of Chapter 25, "Ramps and Ramp Junctions".
b. Capacity constrained by basic freeway capacity.
c. Capacity occurs under constrained operating conditions.
d. Three-lane Type A segments do not operate well at volume ratios greater than 0.45. Poor operations and some local queuing are expected in such cases.
e. Four-lane Type A segments do not operate well at volume ratios greater than 0.35. Poor operations and some local queuing are expected in such cases.
f. Capacity constrained by maximum allowable weaving flow rate: 2,800 pc/h (Type A), 4,000 (Type B), 3,500 (Type C).
g. Five-lane Type A segments do not operate well at volume ratios greater than 0.20. Poor operations and some local queuing are expected in such cases.
h. Type B weaving segments do not operate well at volume ratios greater than 0.80. Poor operations and some local queuing are expected in such cases.
i. Type C weaving segments do not operate well at volume ratios greater than 0.50. Poor operations and some local queuing are expected in such cases.

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FREEWAY WEAVING WORKSHEET

General Information

Analyst	Caroline Kone
Agency/Company	WSP SELLS
Date Performed	6/21/2010
Analysis Time Period	AM Glenwood Overpass

Site Information

Freeway/Dir of Travel	I-440 WB 3-Lane C/D Rd
Weaving Seg Location	Glen. WB on to Glen. EB off
Jurisdiction	Raleigh/NCDOT/FHWA
Analysis Year	2035

Inputs

Freeway free-flow speed, S_{FF} (mi/h)	55	Weaving type	A
Weaving number of lanes, N	3	Volume ratio, VR	0.71
Weaving seg length, L (ft)	870	Weaving ratio, R	0.26
Terrain	Level		

Conversions to pc/h Under Base Conditions

(pc/h)	V	PHF	Truck %	RV %	E_T	E_R	f_{HV}	f_p	v
V_{o1}	691	1.00	3	0	1.5	1.2	0.985	1.00	701
V_{o2}	0	1.00	2	0	1.5	1.2	0.990	1.00	0
V_{w1}	1238	1.00	2	0	1.5	1.2	0.990	1.00	1250
V_{w2}	442	1.00	2	0	1.5	1.2	0.990	1.00	446
V_w				1696	V_{nw}				701
V									2397

Weaving and Non-Weaving Speeds

	Unconstrained		Constrained	
	Weaving (i = w)	Non-Weaving (i = nw)	Weaving (i = w)	Non-Weaving (= nw)
a (Exhibit 24-6)			0.35	0.0020
b (Exhibit 24-6)			2.20	4.00
c (Exhibit 24-6)			0.97	1.30
d (Exhibit 24-6)			0.80	0.75
Weaving Intensity factor, Wi			3.30	0.63
Weaving and non-weaving speeds, Si (mi/h)			25.45	42.61

Number of lanes required for unconstrained operation, Nw 1.90
Maximum number of lanes, Nw (max) 1.40

☐ If Nw < Nw(max) unconstrained operation ☑ if Nw > Nw (max) constrained operation

Weaving Segment Speed, Density, Level of Service, and Capacity

Weaving segment speed, S (mi/h)	28.85
Weaving segment density, D (pc/mi/ln)	27.69
Level of service, LOS	C
Capacity of base condition, c_b (pc/h)	4102
Capacity as a 15-minute flow rate, c (veh/h)	4041
Capacity as a full-hour volume, c_h (veh/h)	4041

Notes

a. Weaving segments longer than 2500 ft. are treated as isolated merge and diverge areas using the procedures of Chapter 25, "Ramps and Ramp Junctions".
b. Capacity constrained by basic freeway capacity.
c. Capacity occurs under constrained operating conditions.
d. Three-lane Type A segments do not operate well at volume ratios greater than 0.45. Poor operations and some local queuing are expected in such cases.
e. Four-lane Type A segments do not operate well at volume ratios greater than 0.35. Poor operations and some local queuing are expected in such cases.
f. Capacity constrained by maximum allowable weaving flow rate: 2,800 pc/h (Type A), 4,000 (Type B), 3,500 (Type C).
g. Five-lane Type A segments do not operate well at volume ratios greater than 0.20. Poor operations and some local queuing are expected in such cases.
h. Type B weaving segments do not operate well at volume ratios greater than 0.80. Poor operations and some local queuing are expected in such cases.
i. Type C weaving segments do not operate well at volume ratios greater than 0.50. Poor operations and some local queuing are expected in such cases.

RAMPS AND RAMP JUNCTIONS WORKSHEET

General Information / Site Information

Analyst	APATEL	Freeway/Dir of Travel	I-440 EB
Agency or Company	WSP SELLS	Junction	off-ramp to Ridge Rd
Date Performed	7/15/2010	Jurisdiction	Raleigh/NCDOT/FHWA
Analysis Time Period	PM Glenwood WB Overpass	Analysis Year	2035

Project Description Crabtree Valley

Inputs

Upstream Adj Ramp
☐ Yes ☐ On
☑ No ☐ Off
L_{up} = ft
V_u = veh/h

Terrain: Level

S_{FF} = 65.0 mph S_{FR} = 45.0 mph
Sketch (show lanes, L_A, L_D, V_R, V_f)

Downstream Adj Ramp
☑ Yes ☑ On
☐ No ☐ Off
L_{down} = 900 ft
V_D = 989 veh/h

Conversion to pc/h Under Base Conditions

(pc/h)	V (Veh/hr)	PHF	Terrain	%Truck	%Rv	f_{HV}	f_p	$v = V/PHF \times f_{HV} \times f_p$
Freeway	8463	1.00	Level	3	0	0.985	1.00	8590
Ramp	2742	1.00	Level	2	0	0.990	1.00	2769
UpStream								
DownStream	989	1.00	Level	2	0	0.990	1.00	999

Merge Areas

Estimation of v_{12}

$V_{12} = V_F (P_{FM})$
L_{EQ} = (Equation 25-2 or 25-3)
P_{FM} = using Equation (Exhibit 25-5)
V_{12} = pc/h
V_3 or V_{av34} pc/h (Equation 25-4 or 25-5)
Is V_3 or V_{av34} > 2,700 pc/h? ☐ Yes ☐ No
Is V_3 or V_{av34} > 1.5 * V_{12}/2 ☐ Yes ☐ No
If Yes, V_{12a} = pc/h (Equation 25-8)

Capacity Checks

	Actual	Capacity		LOS F?
V_{FO}		Exhibit 25-7		

Flow Entering Merge Influence Area

	Actual	Max Desirable		Violation?
V_{R12}		Exhibit 25-7		

Level of Service Determination (if not F)

$D_R = 5.475 + 0.00734\ v_R + 0.0078\ V_{12} - 0.00627\ L_A$
D_R = (pc/mi/ln)
LOS = (Exhibit 25-4)

Speed Determination

M_S = (Exibit 25-19)
S_R = mph (Exhibit 25-19)
S_0 = mph (Exhibit 25-19)
S = mph (Exhibit 25-14)

Diverge Areas

Estimation of v_{12}

$V_{12} = V_R + (V_F - V_R)P_{FD}$
L_{EQ} = (Equation 25-8 or 25-9)
P_{FD} = 0.450 using Equation (Exhibit 25-12)
V_{12} = 5388 pc/h
V_3 or V_{av34} 3202 pc/h (Equation 25-15 or 25-16)
Is V_3 or V_{av34} > 2,700 pc/h? ☑ Yes ☐ No
Is V_3 or V_{av34} > 1.5 * V_{12}/2 ☐ Yes ☑ No
If Yes, V_{12a} = 5890 pc/h (Equation 25-18)

Capacity Checks

	Actual	Capacity		LOS F?
V_F	8590	Exhibit 25-14	7050	Yes
$V_{FO} = V_F - V_R$	5821	Exhibit 25-14	7050	No
V_R	2769	Exhibit 25-3	4100	No

Flow Entering Diverge Influence Area

	Actual	Max Desirable		Violation?
V_{12}	5388	Exhibit 25-14	4400:All	Yes

Level of Service Determination (if not F)

$D_R = 4.252 + 0.0086\ V_{12} - 0.009\ L_D$
D_R = 38.7 (pc/mi/ln)
LOS = F (Exhibit 25-4)

Speed Determination

D_s = 0.547 (Exhibit 25-19)
S_R = 52.4 mph (Exhibit 25-19)
S_0 = 64.7 mph (Exhibit 25-19)
S = 55.7 mph (Exhibit 25-15)

RAMPS AND RAMP JUNCTIONS WORKSHEET

General Information / Site Information

Analyst	APATEL	Freeway/Dir of Travel	I-440 EB
Agency or Company	WSP SELLS	Junction	on-ramp from CVA extension
Date Performed	7/15/2010	Jurisdiction	Raleigh/NCDOT/FHWA
Analysis Time Period	PM Glenwood Overpass	Analysis Year	2035

Project Description Crabtree Valley

Inputs

Upstream Adj Ramp
☐ Yes ☐ On
☑ No ☐ Off
L_{up} = ft
V_u = veh/h

Terrain: Level

S_{FF} = 65.0 mph S_{FR} = 45.0 mph
Sketch (show lanes, L_A, L_D, V_R, V_f)

Downstream Adj Ramp
☑ Yes ☑ On
☐ No ☐ Off
L_{down} = 1500 ft
V_D = 2192 veh/h

Conversion to pc/h Under Base Conditions

(pc/h)	V (Veh/hr)	PHF	Terrain	%Truck	%Rv	f_{HV}	f_p	v = V/PHF x f_{HV} x f_p
Freeway	5721	1.00	Level	3	0	0.985	1.00	5807
Ramp	989	1.00	Level	2	0	0.990	1.00	999
UpStream								
DownStream	2192	1.00	Level	2	0	0.990	1.00	2214

Merge Areas

Estimation of v_{12}

$V_{12} = V_F (P_{FM})$
L_{EQ} = (Equation 25-2 or 25-3)
P_{FM} = 0.619 using Equation (Exhibit 25-5)
V_{12} = 3597 pc/h
V_3 or V_{av34} 2210 pc/h (Equation 25-4 or 25-5)
Is V_3 or V_{av34} > 2,700 pc/h? ☐ Yes ☑ No
Is V_3 or V_{av34} > 1.5 * V_{12}/2 ☐ Yes ☑ No
If Yes, V_{12a} = pc/h (Equation 25-8)

Capacity Checks

	Actual	Capacity		LOS F?
V_{FO}	6806	Exhibit 25-7		No

Flow Entering Merge Influence Area

	Actual	Max Desirable		Violation?
V_{R12}	4596	Exhibit 25-7	4600:All	No

Level of Service Determination (if not F)

$D_R = 5.475 + 0.00734\, v_R + 0.0078\, V_{12} - 0.00627\, L_A$
D_R = 31.5 (pc/mi/ln)
LOS = D (Exhibit 25-4)

Speed Determination

M_S = 0.572 (Exibit 25-19)
S_R = 51.8 mph (Exhibit 25-19)
S_0 = 58.8 mph (Exhibit 25-19)
S = 53.9 mph (Exhibit 25-14)

Diverge Areas

Estimation of v_{12}

$V_{12} = V_R + (V_F - V_R)P_{FD}$
L_{EQ} = (Equation 25-8 or 25-9)
P_{FD} = using Equation (Exhibit 25-12)
V_{12} = pc/h
V_3 or V_{av34} pc/h (Equation 25-15 or 25-16)
Is V_3 or V_{av34} > 2,700 pc/h? ☐ Yes ☐ No
Is V_3 or V_{av34} > 1.5 * V_{12}/2 ☐ Yes ☐ No
If Yes, V_{12a} = pc/h (Equation 25-18)

Capacity Checks

	Actual	Capacity		LOS F?
V_F		Exhibit 25-14		
$V_{FO} = V_F - V_R$		Exhibit 25-14		
V_R		Exhibit 25-3		

Flow Entering Diverge Influence Area

	Actual	Max Desirable		Violation?
V_{12}		Exhibit 25-14		

Level of Service Determination (if not F)

$D_R = 4.252 + 0.0086\, V_{12} - 0.009\, L_D$
D_R = (pc/mi/ln)
LOS = (Exhibit 25-4)

Speed Determination

D_s = (Exhibit 25-19)
S_R = mph (Exhibit 25-19)
S_0 = mph (Exhibit 25-19)
S = mph (Exhibit 25-15)

RAMPS AND RAMP JUNCTIONS WORKSHEET

General Information / Site Information

Analyst	APATEL	Freeway/Dir of Travel	I-440 EB
Agency or Company	WSP SELLS	Junction	on-ramp from Glenwood WB
Date Performed	7/15/2010	Jurisdiction	Raleigh/NCDOT/FHWA
Analysis Time Period	PM Glenwood Overpass	Analysis Year	2035

Project Description Crabtree Valley

Inputs

Upstream Adj Ramp: ☑ Yes ☑ On ☐ No ☐ Off; L_{up} = 1200 ft; V_u = 2192 veh/h

Terrain: Level

S_{FF} = 65.0 mph S_{FR} = 45.0 mph

Sketch (show lanes, L_A, L_D, V_R, V_f)

Downstream Adj Ramp: ☐ Yes ☐ On ☑ No ☐ Off; L_{down} = ft; V_D = veh/h

Conversion to pc/h Under Base Conditions

(pc/h)	V (Veh/hr)	PHF	Terrain	%Truck	%Rv	f_{HV}	f_p	$v = V/PHF \times f_{HV} \times f_p$
Freeway	8902	1.00	Level	3	0	0.985	1.00	9036
Ramp	1090	1.00	Level	2	0	0.990	1.00	1101
UpStream	2192	1.00	Level	2	0	0.990	1.00	2214
DownStream								

Merge Areas

Estimation of v_{12}

$V_{12} = V_F (P_{FM})$

L_{EQ} = (Equation 25-2 or 25-3)

P_{FM} = 0.080 using Equation (Exhibit 25-5)

V_{12} = 724 pc/h

V_3 or V_{av34} 4156 pc/h (Equation 25-4 or 25-5)

Is V_3 or V_{av34} > 2,700 pc/h? ☑ Yes ☐ No

Is V_3 or V_{av34} > 1.5 * V_{12}/2 ☑ Yes ☐ No

If Yes, V_{12a} = 3614 pc/h (Equation 25-8)

Capacity Checks

	Actual	Capacity		LOS F?
V_{FO}	10137	Exhibit 25-7		Yes

Flow Entering Merge Influence Area

	Actual	Max Desirable		Violation?
V_{R12}	4715	Exhibit 25-7	4600:All	Yes

Level of Service Determination (if not F)

$D_R = 5.475 + 0.00734\, v_R + 0.0078\, V_{12} - 0.00627\, L_A$

D_R = 32.3 (pc/mi/ln)

LOS = F (Exhibit 25-4)

Speed Determination

M_S = 0.621 (Exibit 25-19)

S_R = 50.7 mph (Exhibit 25-19)

S_0 = 56.0 mph (Exhibit 25-19)

S = 53.4 mph (Exhibit 25-14)

Diverge Areas

Estimation of v_{12}

$V_{12} = V_R + (V_F - V_R) P_{FD}$

L_{EQ} = (Equation 25-8 or 25-9)

P_{FD} = using Equation (Exhibit 25-12)

V_{12} = pc/h

V_3 or V_{av34} pc/h (Equation 25-15 or 25-16)

Is V_3 or V_{av34} > 2,700 pc/h? ☐ Yes ☐ No

Is V_3 or V_{av34} > 1.5 * V_{12}/2 ☐ Yes ☐ No

If Yes, V_{12a} = pc/h (Equation 25-18)

Capacity Checks

	Actual	Capacity		LOS F?
V_F		Exhibit 25-14		
$V_{FO} = V_F - V_R$		Exhibit 25-14		
V_R		Exhibit 25-3		

Flow Entering Diverge Influence Area

	Actual	Max Desirable		Violation?
V_{12}		Exhibit 25-14		

Level of Service Determination (if not F)

$D_R = 4.252 + 0.0086\, V_{12} - 0.009\, L_D$

D_R = (pc/mi/ln)

LOS = (Exhibit 25-4)

Speed Determination

D_s = (Exhibit 25-19)

S_R = mph (Exhibit 25-19)

S_0 = mph (Exhibit 25-19)

S = mph (Exhibit 25-15)

RAMPS AND RAMP JUNCTIONS WORKSHEET

General Information / Site Information

Analyst	APATEL	Freeway/Dir of Travel	I-440 WB
Agency or Company	WSP SELLS	Junction	off-ramp to Glenwood/CVA
Date Performed	7/15/2010	Jurisdiction	Raleigh/NCDOT/FHWA
Analysis Time Period	PM Glenwood Overpass	Analysis Year	2035

Project Description Crabtree Valley

Inputs

Upstream Adj Ramp
☐ Yes ☐ On
☑ No ☐ Off
L_{up} = ft
V_u = veh/h

Terrain: Level

S_{FF} = 65.0 mph S_{FR} = 45.0 mph

Sketch (show lanes, L_A, L_D, V_R, V_f)

Downstream Adj Ramp
☐ Yes ☐ On
☑ No ☐ Off
L_{down} = ft
V_D = veh/h

Conversion to pc/h Under Base Conditions

(pc/h)	V (Veh/hr)	PHF	Terrain	%Truck	%Rv	f_{HV}	f_p	v = V/PHF x f_{HV} x f_p
Freeway	11115	1.00	Level	3	0	0.985	1.00	11282
Ramp	0	1.00	Level	2	0	0.990	1.00	0
UpStream								
DownStream								

Merge Areas

Estimation of v_{12}

$V_{12} = V_F (P_{FM})$

L_{EQ} = (Equation 25-2 or 25-3)
P_{FM} = using Equation (Exhibit 25-5)
V_{12} = pc/h
V_3 or V_{av34} pc/h (Equation 25-4 or 25-5)
Is V_3 or V_{av34} > 2,700 pc/h? ☐ Yes ☐ No
Is V_3 or V_{av34} > 1.5 * V_{12}/2 ☐ Yes ☐ No
If Yes, V_{12a} = pc/h (Equation 25-8)

Capacity Checks

	Actual	Capacity		LOS F?
V_{FO}		Exhibit 25-7		

Flow Entering Merge Influence Area

	Actual	Max Desirable		Violation?
V_{R12}		Exhibit 25-7		

Level of Service Determination (if not F)

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

D_R = (pc/mi/ln)
LOS = (Exhibit 25-4)

Speed Determination

M_S = (Exibit 25-19)
S_R = mph (Exhibit 25-19)
S_0 = mph (Exhibit 25-19)
S = mph (Exhibit 25-14)

Diverge Areas

Estimation of v_{12}

$V_{12} = V_R + (V_F - V_R)P_{FD}$

L_{EQ} = (Equation 25-8 or 25-9)
P_{FD} = 0.260 using Equation (Exhibit 25-12)
V_{12} = 2347 pc/h
V_3 or V_{av34} 3339 pc/h (Equation 25-15 or 25-16)
Is V_3 or V_{av34} > 2,700 pc/h? ☑ Yes ☐ No
Is V_3 or V_{av34} > 1.5 * V_{12}/2 ☑ Yes ☐ No
If Yes, V_{12a} = 3610 pc/h (Equation 25-18)

Capacity Checks

	Actual	Capacity		LOS F?
V_F	9026	Exhibit 25-14	9400	No
$V_{FO} = V_F - V_R$	9026	Exhibit 25-14	9400	No
V_R	0	Exhibit 25-3	4100	No

Flow Entering Diverge Influence Area

	Actual	Max Desirable		Violation?
V_{12}	2347	Exhibit 25-14	4400:All	No

Level of Service Determination (if not F)

~~$D_R = 4.252 + 0.0086\ V_{12} - 0.009\ L_D$~~ $0.0109\ V_F$ N

D_R = ~~4.0~~ (pc/mi/ln) 24.59
LOS = ~~A~~ (Exhibit 25-4) C

Speed Determination

D_s = 0.298 (Exhibit 25-19)
S_R = 58.1 mph (Exhibit 25-19)
S_0 = 64.6 mph (Exhibit 25-19)
S = 61.9 mph (Exhibit 25-15)

RAMPS AND RAMP JUNCTIONS WORKSHEET

General Information / Site Information

Analyst	APATEL	Freeway/Dir of Travel	I-440 WB
Agency or Company	WSP SELLS	Junction	on-ramp from CVA extension
Date Performed	7/15/2010	Jurisdiction	Raleigh/NCDOT/FHWA
Analysis Time Period	PM Glenwood Overpass	Analysis Year	2035

Project Description Crabtree Valley

Inputs

Upstream Adj Ramp
☑ Yes ☑ On
☐ No ☐ Off
L_{up} = 300 ft
V_u = 1651 veh/h

Terrain: Level
S_{FF} = 65.0 mph S_{FR} = 45.0 mph
Sketch (show lanes, L_A, L_D, V_R, V_f)

Downstream Adj Ramp
☐ Yes ☐ On
☑ No ☐ Off
L_{down} = ft
V_D = veh/h

Conversion to pc/h Under Base Conditions

(pc/h)	V (Veh/hr)	PHF	Terrain	%Truck	%Rv	f_{HV}	f_p	v = V/PHF x f_{HV} x f_p
Freeway	7668	1.00	Level	3	0	0.985	1.00	7783
Ramp	915	1.00	Level	2	0	0.990	1.00	924
UpStream	1651	1.00	Level	2	0	0.990	1.00	1668
DownStream								

Merge Areas

Estimation of v_{12}

$V_{12} = V_F (P_{FM})$
L_{EQ} = (Equation 25-2 or 25-3)
P_{FM} = 0.102 using Equation (Exhibit 25-5)
V_{12} = 796 pc/h
V_3 or V_{av34} = 3493 pc/h (Equation 25-4 or 25-5)
Is V_3 or V_{av34} > 2,700 pc/h? ☑ Yes ☐ No
Is V_3 or V_{av34} > 1.5 * V_{12}/2 ☑ Yes ☐ No
If Yes, V_{12a} = 3113 pc/h (Equation 25-8)

Capacity Checks

	Actual	Capacity		LOS F?
V_{FO}	8707	Exhibit 25-7		No

Flow Entering Merge Influence Area

	Actual	Max Desirable		Violation?
V_{R12}	4037	Exhibit 25-7	4600:All	No

Level of Service Determination (if not F)

$D_R = 5.475 + 0.00734\, v_R + 0.0078\, V_{12} - 0.00627\, L_A$
D_R = 31.2 (pc/mi/ln)
LOS = D (Exhibit 25-4)

Speed Determination

M_S = 0.465 (Exibit 25-19)
S_R = 54.3 mph (Exhibit 25-19)
S_0 = 58.3 mph (Exhibit 25-19)
S = 56.4 mph (Exhibit 25-14)

Diverge Areas

Estimation of v_{12}

$V_{12} = V_R + (V_F - V_R) P_{FD}$
L_{EQ} = (Equation 25-8 or 25-9)
P_{FD} = using Equation (Exhibit 25-12)
V_{12} = pc/h
V_3 or V_{av34} = pc/h (Equation 25-15 or 25-16)
Is V_3 or V_{av34} > 2,700 pc/h? ☐ Yes ☐ No
Is V_3 or V_{av34} > 1.5 * V_{12}/2 ☐ Yes ☐ No
If Yes, V_{12a} = pc/h (Equation 25-18)

Capacity Checks

	Actual	Capacity		LOS F?
V_F		Exhibit 25-14		
$V_{FO} = V_F - V_R$		Exhibit 25-14		
V_R		Exhibit 25-3		

Flow Entering Diverge Influence Area

	Actual	Max Desirable		Violation?
V_{12}		Exhibit 25-14		

Level of Service Determination (if not F)

$D_R = 4.252 + 0.0086\, V_{12} - 0.009\, L_D$
D_R = (pc/mi/ln)
LOS = (Exhibit 25-4)

Speed Determination

D_s = (Exhibit 25-19)
S_R = mph (Exhibit 25-19)
S_0 = mph (Exhibit 25-19)
S = mph (Exhibit 25-15)

RAMPS AND RAMP JUNCTIONS WORKSHEET

General Information / Site Information

Analyst	APATEL	Freeway/Dir of Travel	I-440 WB
Agency or Company	WSP SELLS	Junction	on-ramp from Glen. EB
Date Performed	7/15/2010	Jurisdiction	Raleigh/NCDOT/FHWA
Analysis Time Period	PM Glenwood Overpass	Analysis Year	2035

Project Description Crabtree Valley

Inputs

Upstream Adj Ramp
☐ Yes ☐ On
☑ No ☐ Off
L_{up} = ft
V_u = veh/h

Terrain: Level

S_{FF} = 65.0 mph S_{FR} = 45.0 mph
Sketch (show lanes, L_A, L_D, V_R, V_f)

Downstream Adj Ramp
☑ Yes ☑ On
☐ No ☐ Off
L_{down} = 300 ft
V_D = 915 veh/h

Conversion to pc/h Under Base Conditions

(pc/h)	V (Veh/hr)	PHF	Terrain	%Truck	%Rv	f_{HV}	f_p	v = V/PHF x f_{HV} x f_p
Freeway	6017	1.00	Level	3	0	0.985	1.00	6107
Ramp	1651	1.00	Level	2	0	0.990	1.00	1668
UpStream								
DownStream	915	1.00	Level	2	0	0.990	1.00	924

Merge Areas

Estimation of v_{12}

$V_{12} = V_F (P_{FM})$
L_{EQ} = (Equation 25-2 or 25-3)
P_{FM} = 0.009 using Equation (Exhibit 25-5)
V_{12} = 57 pc/h
V_3 or V_{av34} 3025 pc/h (Equation 25-4 or 25-5)
Is V_3 or V_{av34} > 2,700 pc/h? ☑ Yes ☐ No
Is V_3 or V_{av34} > 1.5 * V_{12}/2 ☑ Yes ☐ No
If Yes, V_{12a} = 2442 pc/h (Equation 25-8)

Capacity Checks

	Actual	Capacity		LOS F?
V_{FO}	7775	Exhibit 25-7		No

Flow Entering Merge Influence Area

	Actual	Max Desirable		Violation?
V_{R12}	4110	Exhibit 25-7	4600:All	No

Level of Service Determination (if not F)

$D_R = 5.475 + 0.00734\ v_R + 0.0078\ V_{12} - 0.00627\ L_A$
D_R = 28.0 (pc/mi/ln)
LOS = C (Exhibit 25-4)

Speed Determination

M_S = 0.433 (Exibit 25-19)
S_R = 55.0 mph (Exhibit 25-19)
S_0 = 60.2 mph (Exhibit 25-19)
S = 57.4 mph (Exhibit 25-14)

Diverge Areas

Estimation of v_{12}

$V_{12} = V_R + (V_F - V_R)P_{FD}$
L_{EQ} = (Equation 25-8 or 25-9)
P_{FD} = using Equation (Exhibit 25-12)
V_{12} = pc/h
V_3 or V_{av34} pc/h (Equation 25-15 or 25-16)
Is V_3 or V_{av34} > 2,700 pc/h? ☐ Yes ☐ No
Is V_3 or V_{av34} > 1.5 * V_{12}/2 ☐ Yes ☐ No
If Yes, V_{12a} = pc/h (Equation 25-18)

Capacity Checks

	Actual	Capacity		LOS F?
V_F		Exhibit 25-14		
$V_{FO} = V_F - V_R$		Exhibit 25-14		
V_R		Exhibit 25-3		

Flow Entering Diverge Influence Area

	Actual	Max Desirable		Violation?
V_{12}		Exhibit 25-14		

Level of Service Determination (if not F)

$D_R = 4.252 + 0.0086\ V_{12} - 0.009\ L_D$
D_R = (pc/mi/ln)
LOS = (Exhibit 25-4)

Speed Determination

D_s = (Exhibit 25-19)
S_R = mph (Exhibit 25-19)
S_0 = mph (Exhibit 25-19)
S = mph (Exhibit 25-15)

FREEWAY WEAVING WORKSHEET

General Information

Analyst	
Agency/Company	WSP SELLS
Date Performed	7/15/2010
Analysis Time Period	PM Glenwood Overpass

Site Information

Freeway/Dir of Travel	I-440 WB
Weaving Seg Location	Glen WB onto Glen EB off
Jurisdiction	Raleigh/NCDOT/FHWA
Analysis Year	2035

Inputs

Freeway free-flow speed, S_{FF} (mi/h)	55	Weaving type	B
Weaving number of lanes, N	2	Volume ratio, VR	0.67
Weaving seg length, L (ft)	870	Weaving ratio, R	0.42
Terrain	Level		

Conversions to pc/h Under Base Conditions

(pc/h)	V	PHF	Truck %	RV %	E_T	E_R	f_{HV}	f_p	v
V_{o1}	887	1.00	3	0	1.5	1.2	0.985	1.00	900
V_{o2}	0	1.00	0	0	1.5	1.2	1.000	1.00	0
V_{w1}	1056	1.00	2	0	1.5	1.2	0.990	1.00	1066
V_{w2}	773	1.00	2	0	1.5	1.2	0.990	1.00	780
V_w				1846	V_{nw}				900
V									2746

Weaving and Non-Weaving Speeds

	Unconstrained		Constrained	
	Weaving (i = w)	Non-Weaving (i = nw)	Weaving (i = w)	Non-Weaving (= nw)
a (Exhibit 24-6)	0.08	0.0020		
b (Exhibit 24-6)	2.20	6.00		
c (Exhibit 24-6)	0.70	1.00		
d (Exhibit 24-6)	0.50	0.50		
Weaving intensity factor, Wi	1.32	2.04		
Weaving and non-weaving speeds, Si (mi/h)	34.39	29.82		

Number of lanes required for unconstrained operation, Nw 1.82
Maximum number of lanes, Nw (max) 3.50

☑ If Nw < Nw(max) unconstrained operation ☐ if Nw > Nw (max) constrained operation

Weaving Segment Speed, Density, Level of Service, and Capacity

Weaving segment speed, S (mi/h)	32.74
Weaving segment density, D (pc/mi/ln)	41.93
Level of service, LOS	F
Capacity of base condition, c_b (pc/h)	
Capacity as a 15-minute flow rate, c (veh/h)	
Capacity as a full-hour volume, c_h (veh/h)	

Notes

a. Weaving segments longer than 2500 ft. are treated as isolated merge and diverge areas using the procedures of Chapter 25, "Ramps and Ramp Junctions".
b. Capacity constrained by basic freeway capacity.
c. Capacity occurs under constrained operating conditions.
d. Three-lane Type A segments do not operate well at volume ratios greater than 0.45. Poor operations and some local queuing are expected in such cases.
e. Four-lane Type A segments do not operate well at volume ratios greater than 0.35. Poor operations and some local queuing are expected in such cases.
f. Capacity constrained by maximum allowable weaving flow rate: 2,800 pc/h (Type A), 4,000 (Type B), 3,500 (Type C).
g. Five-lane Type A segments do not operate well at volume ratios greater than 0.20. Poor operations and some local queuing are expected in such cases.
h. Type B weaving segments do not operate well at volume ratios greater than 0.80. Poor operations and some local queuing are expected in such cases.
i. Type C weaving segments do not operate well at volume ratios greater than 0.50. Poor operations and some local queuing are expected in such cases.

FREEWAY WEAVING WORKSHEET

General Information

Analyst	
Agency/Company	WSP SELLS
Date Performed	6/21/2010
Analysis Time Period	PM Glenwood Overpass

Site Information

Freeway/Dir of Travel	I-440 WB 3-Lane C/D Rd
Weaving Seg Location	Glen. WB on to Glen. EB off
Jurisdiction	Raleigh/NCDOT/FHWA
Analysis Year	2035

Inputs

Freeway free-flow speed, S_{FF} (mi/h)	55	Weaving type	A
Weaving number of lanes, N	3	Volume ratio, VR	0.67
Weaving seg length, L (ft)	870	Weaving ratio, R	0.42
Terrain	Level		

Conversions to pc/h Under Base Conditions

(pc/h)	V	PHF	Truck %	RV %	E_T	E_R	f_{HV}	f_p	v
V_{o1}	887	1.00	3	0	1.5	1.2	0.985	1.00	900
V_{o2}	0	1.00	2	0	1.5	1.2	0.990	1.00	0
V_{w1}	1056	1.00	2	0	1.5	1.2	0.990	1.00	1066
V_{w2}	773	1.00	2	0	1.5	1.2	0.990	1.00	780
V_w				1846	V_{nw}				900
V									2746

Weaving and Non-Weaving Speeds

	Unconstrained		Constrained	
	Weaving (i = w)	Non-Weaving (i = nw)	Weaving (i = w)	Non-Weaving (= nw)
a (Exhibit 24-6)			0.35	0.0020
b (Exhibit 24-6)			2.20	4.00
c (Exhibit 24-6)			0.97	1.30
d (Exhibit 24-6)			0.80	0.75
Weaving Intensity factor, Wi			3.60	0.69
Weaving and non-weaving speeds, Si (mi/h)			24.78	41.61

Number of lanes required for unconstrained operation, Nw 1.87
Maximum number of lanes, Nw (max) 1.40

☐ If Nw < Nw(max) unconstrained operation ☑ If Nw > Nw (max) constrained operation

Weaving Segment Speed, Density, Level of Service, and Capacity

Weaving segment speed, S (mi/h)	28.57
Weaving segment density, D (pc/mi/ln)	32.04
Level of service, LOS	D
Capacity of base condition, c_b (pc/h)	4102
Capacity as a 15-minute flow rate, c (veh/h)	4041
Capacity as a full-hour volume, c_h (veh/h)	4041

Notes

a. Weaving segments longer than 2500 ft. are treated as isolated merge and diverge areas using the procedures of Chapter 25, "Ramps and Ramp Junctions".
b. Capacity constrained by basic freeway capacity.
c. Capacity occurs under constrained operating conditions.
d. Three-lane Type A segments do not operate well at volume ratios greater than 0.45. Poor operations and some local queuing are expected in such cases.
e. Four-lane Type A segments do not operate well at volume ratios greater than 0.35. Poor operations and some local queuing are expected in such cases.
f. Capacity constrained by maximum allowable weaving flow rate: 2,800 pc/h (Type A), 4,000 (Type B), 3,500 (Type C).
g. Five-lane Type A segments do not operate well at volume ratios greater than 0.20. Poor operations and some local queuing are expected in such cases.
h. Type B weaving segments do not operate well at volume ratios greater than 0.80. Poor operations and some local queuing are expected in such cases.
i. Type C weaving segments do not operate well at volume ratios greater than 0.50. Poor operations and some local queuing are expected in such cases.