ARTPLAN 2009

Computational Methodology Documentation

Revised 12/18/2009

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Inputs

Project Properties

Roadway Variables:

$AreaType := 1$ 1 = Large Urbanized, 2 = Other Urbanized, 3 = Transitioning/Urban, 4 = Rural Developed

$Class := 2$

Intersection

Facility-Wide Values:

$BaseSatFlowRate := 1950$ $Sig := 2$ 0 = Pretimed, 1 = Semi Actuated, 2 = Fully Actuated

Intersection Data:

Int_1	Int_2	Int_3	Int_4
No Inputs Required	$Cycle_1 := 120$	$Cycle_2 := 150$	$Cycle_3 := 150$
	$gC_1 := 0.50$	$gC_2 := 0.40$	$gC_3 := 0.45$
	$ArrivalType_1 := 4$	$ArrivalType_2 := 3$	$ArrivalType_3 := 5$
	$NumDirLanes_1 := 3$	$NumDirLanes_2 := 3$	$NumDirLanes_3 := 4$
	$\%LeftTurns_1 := 12$	$\%LeftTurns_2 := 7$	$\%LeftTurns_3 := 9$
	$\%RightTurns_1 := 8$	$\%RightTurns_2 := 5$	$\%RightTurns_3 := 4$
	$LeftTurnBay_1 := 1$	$LeftTurnBay_2 := 1$	$LeftTurnBay_3 := 1$
	$RightTurnBay_1 := 0$	$RightTurnBay_2 := 0$	$RightTurnBay_3 := 1$

*For left turn and right turn bays: 0 = No, 1 = Yes

Segment (Auto)

Facility-Wide Values:

$K := 0.095$ $D := 0.55$ $PHF := 0.95$ $\%HV := 2.5$

Segment Data:

Seg_1	Seg_2	Seg_3
$Length_1 := 2500$	$Length_2 := 1500$	$Length_3 := 1700$
$AADT_1 := 43250$	$AADT_2 := 43250$	$AADT_3 := 43250$
$HourlyDirVol_1 := round(AADT_1 \cdot K \cdot D)$	$HourlyDirVol_2 := round(AADT_2 \cdot K \cdot D)$	$HourlyDirVol_3 := round(AADT_3 \cdot K \cdot D)$
$HourlyDirVol_1 = 2260$	$HourlyDirVol_2 = 2260$	$HourlyDirVol_3 = 2260$
$SegNumLanes_1 := 3$	$SegNumLanes_2 := 3$	$SegNumLanes_3 := 4$
$FFS_1 := 50$	$FFS_2 := 50$	$FFS_3 := 50$
$MedianType_1 := 1$	$MedianType_2 := 2$	$MedianType_3 := 1$

*For MedianType: 0 = None, 1 = NonRestrictive, 2 = Restrictive

Segment (MM)

Seg_1	Seg_2	Seg_3	
$W_{outln_1} := 12$	$W_{outln_2} := 12$	$W_{outln_3} := 12$	feet
$PvtCond_1 := 1$	$PvtCond_2 := 1$	$PvtCond_3 := 1$	0 = Undes, 1 = Typ, 2 = Des
$ShoulderBikeLn_1 := 1$	$ShoulderBikeLn_2 := 1$	$ShoulderBikeLn_3 := 0$	0 = No, 1 = Yes
$Sidewalk_1 := 1$	$Sidewalk_2 := 1$	$Sidewalk_3 := 1$	0 = No, 1 = Yes
$SwRdwySep_1 := 1$	$SwRdwySep_2 := 1$	$SwRdwySep_3 := 1$	0 = Adj 1 = Typ, 2 = Wide
$SwRdwyBar_1 := 1$	$SwRdwyBar_2 := 1$	$SwRdwyBar_3 := 0$	0 = No, 1 = Yes
$BusStopObstacle_1 := 0$	$BusStopObstacle_2 := 0$	$BusStopObstacle_3 := 0$	0 = No, 1 = Yes
$BusFrequency_1 := 2$	$BusFrequency_2 := 2$	$BusFrequency_3 := 2$	buses/hour
$BusSpanService_1 := 15$	$BusSpanService_2 := 15$	$BusSpanService_3 := 15$	hours/day

*For W_{outln} : Typical = 12, Narrow = 10, Wide = 14, Custom = 8 through 16

Auto LOS Computational Steps

1. Calculate the Saturation Flow Rate Adjustment Factors

A. Calculate the population adjustment factor

$$\text{Population(AreaType)} := \begin{array}{|l} \text{out} \leftarrow 1.5 \;\text{ if }\; \text{AreaType} = 1 \\ \text{out} \leftarrow 0.4 \;\text{ if }\; \text{AreaType} = 2 \\ \text{out} \leftarrow 0.03 \;\text{ if }\; \text{AreaType} = 3 \\ \text{out} \leftarrow 0.003 \;\text{ if }\; \text{AreaType} = 4 \end{array}$$

$\text{Population(AreaType)} = 1.5$

$$\text{PopFact} := \frac{1}{\text{Population(AreaType)}^{-0.018}}$$

$\text{PopFact} = 1.007$

B. Calculate the number of lanes adjustment factor

$E_{CL} := 1.03$

$$\text{NumLnsFact(i)} := \frac{1}{1 + \frac{1}{\text{NumDirLanes}_i}\cdot\left(E_{CL} - 1\right)}$$

$\text{NumLnsFact}(1) = 0.99$

$\text{NumLnsFact}(2) = 0.99$

$\text{NumLnsFact}(3) = 0.993$

C. Calculate the posted speed adjustment factor

* FFS - 5 is equivalent to the posted speed entered in ARTPLAN

$$\text{PostedSpd(i)} := \min\left(\max\left(30, \text{FFS}_i - 5\right), 55\right)$$

$$\text{SpdFact(i)} := \frac{1}{1 - 0.0066(\text{PostedSpd(i)} - 50)}$$

$\text{SpdFact}(1) = 0.968$ $\text{SpdFact}(2) = 0.968$ $\text{SpdFact}(3) = 0.968$

D. Calculate the traffic pressure adjustment factor

$$\text{CalcPctTurns(\%LT, \%RT, i)} := \begin{array}{|l} \text{\%LT} \;\text{ if }\; \text{LeftTurnBay}_i = 1 \wedge \text{RightTurnBay}_i = 0 \\ \text{\%RT} \;\text{ if }\; \text{LeftTurnBay}_i = 0 \wedge \text{RightTurnBay}_i = 1 \\ \text{\%LT} + \text{\%RT} \;\text{ if }\; \text{LeftTurnBay}_i = 1 \wedge \text{RightTurnBay}_i = 1 \\ 0 \;\text{ otherwise} \end{array}$$

$\text{\%Turns}_1 := \text{CalcPctTurns}\left(\text{\%LeftTurns}_1, \text{\%RightTurns}_1, 1\right)$ $\text{\%Turns}_1 = 12$

$\text{\%Turns}_2 := \text{CalcPctTurns}\left(\text{\%LeftTurns}_2, \text{\%RightTurns}_2, 2\right)$ $\text{\%Turns}_2 = 7$

$\text{\%Turns}_3 := \text{CalcPctTurns}\left(\text{\%LeftTurns}_3, \text{\%RightTurns}_3, 3\right)$ $\text{\%Turns}_3 = 13$

$$\text{ThruMvmtFlowRate(i)} := \frac{\text{HourlyDirVol}_i}{\text{PHF}}\cdot\left[1 - \left(\frac{\text{\%Turns}_i}{100}\right)\right]$$

$\text{ThruMvmtFlowRate}(1) = 2093.5$

$\text{ThruMvmtFlowRate}(2) = 2212.4$

$\text{ThruMvmtFlowRate}(3) = 2069.7$

$$v(i) := \min\left(\frac{ThruMvmtFlowRate(i)\cdot Cycle_i}{NumDirLanes_i\cdot 3600}, 30\right)$$

$v(1) = 23.261$ $v(2) = 30$ $v(3) = 21.559$

$$TrafFact(i) := \frac{1}{1 - 0.0032(v(i) - 20)}$$

$TrafFact(1) = 1.011$ $TrafFact(2) = 1.033$ $TrafFact(3) = 1.005$

E. Calculate the lane width adjustment factor

$$W_{inln}(i) := \begin{cases} 12 & \text{if } W_{outln_i} \geq 12 \\ W_{outln_i} & \text{if } W_{outln_i} < 12 \end{cases}$$

$W_{inln}(1) = 12$
$W_{inln}(2) = 12$
$W_{inln}(3) = 12$

$$W_{avg}(i) := \frac{\left[W_{inln}(i)\cdot\left(NumDirLanes_i - 1\right)\right] + W_{outln_i}}{NumDirLanes_i}$$

$W_{avg}(1) = 12$
$W_{avg}(2) = 12$
$W_{avg}(3) = 12$

$$LnWidthFact(i) := 1 + \frac{W_{avg}(i) - 12}{30}$$

$LnWidthFact(1) = 1.00$
$LnWidthFact(2) = 1.00$
$LnWidthFact(3) = 1.00$

F. Determine the Median adjustment factor

$$MedianFact(i) := \begin{array}{|l} out \leftarrow 0.95 \ \text{ if } MedianType_i = 0 \\ out \leftarrow 1.0 \ \text{ if } MedianType_i = 1 \\ out \leftarrow 1.0 \ \text{ if } MedianType_i = 2 \\ out \end{array}$$

$MedianFact(1) = 1$
$MedianFact(2) = 1$
$MedianFact(3) = 1$

G. Determine the left turn bay adjustment factor

$$LTFact(i) := \begin{array}{|l} out \leftarrow 0.8 \ \text{ if } LeftTurnBay_i = 0 \wedge \%LeftTurns_i \neq 0 \\ out \leftarrow 1.0 \ \text{ if } LeftTurnBay_i = 1 \vee \%LeftTurns_i = 0 \\ out \end{array}$$

$LTFact(1) = 1.0$
$LTFact(2) = 1.0$
$LTFact(3) = 1.0$

H. Determine the right turn adjustment factor

$$E_{RT}(i) := \begin{array}{|l} out \leftarrow 1.07 \ \text{ if } RightTurnBay_i = 0 \\ out \leftarrow 1.0 \ \text{ if } RightTurnBay_i = 1 \\ out \end{array}$$

$E_{RT}(1) = 1.07$
$E_{RT}(2) = 1.07$
$E_{RT}(3) = 1$

$$RTFact(i) := \left[\frac{1}{1 + \frac{\%RightTurns_i}{100}\cdot\left(E_{RT}(i) - 1\right)}\right]$$

$RTFact(1) = 0.994$
$RTFact(2) = 0.997$
$RTFact(3) = 1$

I. Calculate the heavy vehicle adjustment factor

$E_T := 1.74$ (per Q/LOS Handbook)

$$f_{HV} := \frac{1}{1 + \left[\frac{\%HV}{100} \cdot (E_T - 1)\right]}$$

$f_{HV} = 0.982$

2. Calculate the Adjusted Saturation Flow Rate

$$\text{FactAdj}(i) := \text{LnWidthFact}(i) \cdot \text{MedianFact}(i) \cdot f_{HV} \cdot \text{PopFact} \cdot \text{TrafFact}(i) \cdot \text{NumLnsFact}(i) \cdot \text{SpdFact}(i) \cdot \text{LTFact}(i) \cdot \text{RTFact}(i)$$

$\text{FactAdj}(1) = 0.953$
$\text{FactAdj}(2) = 0.976$
$\text{FactAdj}(3) = 0.955$

$$\text{AdjSatFlowRate}(i) := \text{BaseSatFlowRate} \cdot \text{FactAdj}(i)$$

$\text{AdjSatFlowRate}(1) = 1857.598$
$\text{AdjSatFlowRate}(2) = 1902.956$
$\text{AdjSatFlowRate}(3) = 1862.388$

ARTPLAN reports (NumDirLanes)(AdjSatFlowRate)

$\text{AdjSatFlowRate}(1) \cdot \text{NumDirLanes}_1 = 5573$
$\text{AdjSatFlowRate}(2) \cdot \text{NumDirLanes}_2 = 5709$
$\text{AdjSatFlowRate}(3) \cdot \text{NumDirLanes}_3 = 7450$

3. Calculate signal delay

A. Calculate volume to capacity ratio (v/c)

$\text{ThruMvmtFlowRate}(1) = 2093.474$
$\text{ThruMvmtFlowRate}(2) = 2212.421$
$\text{ThruMvmtFlowRate}(3) = 2069.684$

$$c(i) := \text{AdjSatFlowRate}(i) \cdot \text{NumDirLanes}_i \cdot gC_i$$

$c(1) = 2786.397$
$c(2) = 2283.547$
$c(3) = 3352.298$

$$vc(i) := \frac{\text{ThruMvmtFlowRate}(i)}{c(i)}$$

$vc(1) = 0.751319$
$vc(2) = 0.969$
$vc(3) = 0.617393$

B. Calculate uniform delay (d_1)

$$d_1(i) := \frac{0.5 \cdot \text{Cycle}_i \cdot (1 - gC_i)^2}{1 - (vc(i) \cdot gC_i)}$$

Equation 15-2 HCM 2000

$d_1(1) = 24.03$

$d_1(2) = 44.08$

$d_1(3) = 31.42$

C. Calculate incremental delay (d_2)

1. Determine k, signal controller mode delay adjustment factor

If the intersection is operating under pretimed mode, k = 0.5.

From Exhibit 15-6 HCM 2000

$$\text{kfact}(i) := \left| \begin{array}{l} \text{return } .5 \ \text{ if } Sig = 0 \\ \text{return } .5 \ \text{ if } Sig = 1 \\ \text{if } Sig = 2 \\ \quad \left| \begin{array}{l} \text{return } .11 \ \text{ if } vc(i) < .5 \\ \text{return } [(1 - 2 \cdot .11) \cdot (vc(i) - .5) + .11] \ \text{ if } vc(i) \geq .5 \end{array} \right. \end{array} \right.$$

$k_1 := \text{kfact}(1) \quad k_2 := \text{kfact}(2) \quad k_3 := \text{kfact}(3)$

$k_1 = 0.306$
$k_2 = 0.476$
$k_3 = 0.202$

2. Determine I, the upstream filtering/metering adjustment factor

If the v/c ratio for the upstream signal is greater than 1, then I = 0.09.

When there is no upstream signal, use the v/c ratio for that intersection.

From Exhibit 15-7 HCM 2000

$$\text{Ifact}(i) := \left| \begin{array}{l} \text{return } 1.0 - 0.91 \cdot vc(i)^{2.68} \ \text{ if } vc(i) < 1 \wedge i = 1 \\ \text{return } 0.09 \ \text{ if } vc(i) \geq 1 \wedge i = 1 \\ \text{return } 1.0 - 0.91 \cdot vc(i-1)^{2.68} \ \text{ if } vc(i-1) < 1.0 \\ \text{return } 0.09 \ \text{ if } vc(i-1) \geq 1.0 \end{array} \right.$$

$I_1 := \text{Ifact}(1) \quad I_2 := \text{Ifact}(2) \quad I_3 := \text{Ifact}(3)$

$I_1 = 0.577$
$I_2 = 0.577$
$I_3 = 0.164$

$T := 0.25$ (ARTPLAN default)

Equation 15-3 HCM 2000

$$d_2(i) := 900 \cdot T \cdot \left[(vc(i) - 1) + \sqrt{(vc(i) - 1)^2 + \frac{8 \cdot k_i \cdot I_i \cdot vc(i)}{T \cdot c(i)}} \right]$$

$d_2(1) = 0.685$
$d_2(2) = 8.413$
$d_2(3) = 0.057$

D. Calculate progression adjustment factor (PF)

Determine f_{PA} and R_p based on Arrival Type.

1. Determine Platoon Ratio

From Exhibit 15-4HCM 2000

$$CalcR_p(i) := \left| \begin{array}{l} out \leftarrow 0.333 \text{ if } ArrivalType_i = 1 \\ out \leftarrow 0.667 \text{ if } ArrivalType_i = 2 \\ out \leftarrow 1.0 \text{ if } ArrivalType_i = 3 \\ out \leftarrow 1.333 \text{ if } ArrivalType_i = 4 \\ out \leftarrow 1.667 \text{ if } ArrivalType_i = 5 \\ out \leftarrow 2 \text{ otherwise} \\ out \end{array} \right.$$

$R_{p_1} := CalcR_p(1)$ $\quad R_{p_1} = 1.333$

$R_{p_2} := CalcR_p(2)$ $\quad R_{p_2} = 1$

$R_{p_3} := CalcR_p(3)$ $\quad R_{p_3} = 1.667$

2. Calculate supplemental adjustment factor for platoon arrival during the green

From Exhibit 15-5 HCM 2000

$$Calcf_{PA}(i) := \left| \begin{array}{l} out \leftarrow 1.0 \text{ if } ArrivalType_i = 1 \\ out \leftarrow 0.93 \text{ if } ArrivalType_i = 2 \\ out \leftarrow 1.0 \text{ if } ArrivalType_i = 3 \\ out \leftarrow 1.15 \text{ if } ArrivalType_i = 4 \\ out \leftarrow 1.0 \text{ if } ArrivalType_i = 5 \\ out \leftarrow 1 \text{ otherwise} \\ out \end{array} \right.$$

$f_{PA_1} := Calcf_{PA}(1)$ $\quad f_{PA_1} = 1.15$

$f_{PA_2} := Calcf_{PA}(2)$ $\quad f_{PA_2} = 1$

$f_{PA_3} := Calcf_{PA}(3)$ $\quad f_{PA_3} = 1$

3. Calculate the percent arrivals on green

Equation 15-4 HCM 2000

$$Calc\%Green(i) := \left| \begin{array}{l} out \leftarrow 1.0 \text{ if } \left(R_{p_i} \cdot gC_i\right) > 1.0 \\ out \leftarrow R_{p_i} \cdot gC_i \text{ otherwise} \\ out \end{array} \right.$$

$\%Green_1 := Calc\%Green(1)$ $\quad \%Green_1 = 0.667$

$\%Green_2 := Calc\%Green(2)$ $\quad \%Green_2 = 0.4$

$\%Green_3 := Calc\%Green(3)$ $\quad \%Green_3 = 0.75$

4. Calculate the Progression Adjustment Factor (PF)

Equation 15-5 HCM 2000

$$CalcPF(i) := \left| \begin{array}{l} out \leftarrow \dfrac{\left(1 - \%Green_i\right) \cdot f_{PA_i}}{1 - gC_i} \text{ if } gC_i \neq 1.0 \\ out \leftarrow 0 \text{ otherwise} \\ out \end{array} \right.$$

$PF_1 := CalcPF(1)$ $\quad PF_1 = 0.767$

$PF_2 := CalcPF(2)$ $\quad PF_2 = 1$

$PF_3 := CalcPF(3)$ $\quad PF_3 = 0.454$

E. Calculate the total signal delay

Equation 15-1 HCM 2000

$CalcCtrlDelay(i) := d_1(i) \cdot PF_i + d_2(i)$

$CtrlDelay_1 := CalcCtrlDelay(1)$ $CtrlDelay_1 = 19.114$

$CtrlDelay_2 := CalcCtrlDelay(2)$ $CtrlDelay_2 = 52.497$

$CtrlDelay_3 := CalcCtrlDelay(3)$ $CtrlDelay_3 = 14.329$

4. Calculate the Segment and Facility Running Time/Speed

A. Calculate the signal density

$$CalcSigs(i) := \min\left(\frac{5280}{Length_i}, 9\right)$$

$SigsPerMile_1 := CalcSigs(1)$ $SigsPerMile_1 = 2.112$

$SigsPerMile_2 := CalcSigs(2)$ $SigsPerMile_2 = 3.52$

$SigsPerMile_3 := CalcSigs(3)$ $SigsPerMile_3 = 3.106$

B. Calculate the peak per-lane hourly volume

$$Calcv\_temp(i) := \min\left(\frac{HourlyDirVol_i}{SegNumLanes_i \cdot PHF}, 1000\right)$$

$v\_temp_1 := Calcv\_temp(1)$ $v\_temp_1 = 792.982$ veh/h

$v\_temp_2 := Calcv\_temp(2)$ $v\_temp_2 = 792.982$ veh/h

$v\_temp_3 := Calcv\_temp(3)$ $v\_temp_3 = 594.737$ veh/h

C. Calculate the running speed with the regression equations

$$CalcRunSpeed(i) := \left| \begin{array}{l} out \leftarrow 61.31367 - 1.96278 \cdot SigsPerMile_i - 0.00597 \cdot v\_temp_i \;\text{ if }\; FFS_i = 60 \\ out \leftarrow 56.941 - 1.53944 \cdot SigsPerMile_i - 0.00721 \cdot v\_temp_i \;\text{ if }\; FFS_i = 55 \\ out \leftarrow 51.888 - 1.14222 \cdot SigsPerMile_i - 0.00795 \cdot v\_temp_i \;\text{ if }\; FFS_i = 50 \\ out \leftarrow 46.574 - 0.89222 \cdot SigsPerMile_i - 0.00604 \cdot v\_temp_i \;\text{ if }\; FFS_i = 45 \\ out \leftarrow 39.69506 - 0.10306 \cdot SigsPerMile_i - 0.00585 \cdot v\_temp_i \;\text{ if }\; FFS_i = 40 \\ out \leftarrow 35.23011 - 0.21722 \cdot SigsPerMile_i - 0.00517 \cdot v\_temp_i \;\text{ if }\; FFS_i = 35 \\ out \leftarrow 29.893 - 0.05611 \cdot SigsPerMile_i - 0.00398 \cdot v\_temp_i \;\text{ if }\; FFS_i = 30 \\ out \leftarrow 25.58418 - 0.00095 \cdot SigsPerMile_i - 0.00356 \cdot v\_temp_i \;\text{ if }\; FFS_i = 25 \\ out \end{array} \right.$$

$RunSpeed_1 := CalcRunSpeed(1)$ $RunSpeed_1 = 43.171$ mi/h

$RunSpeed_2 := CalcRunSpeed(2)$ $RunSpeed_2 = 41.563$ mi/h

$RunSpeed_3 := CalcRunSpeed(3)$ $RunSpeed_3 = 43.612$ mi/h

D. Calculate segment running time

$$CalcSegRunTime(i) := \frac{3600}{RunSpeed_i}$$

$SegRunTime_1 := CalcSegRunTime(1)$ $SegRunTime_1 = 83.388$ sec/mile

$SegRunTime_2 := CalcSegRunTime(2)$ $SegRunTime_2 = 86.615$ sec/mile

$SegRunTime_3 := CalcSegRunTime(3)$ $SegRunTime_3 = 82.546$ sec/mile

E. Calculate total segment travel time

$$CalcTotTT(i) := \frac{SegRunTime_i \cdot Length_i}{5280} + CtrlDelay_i$$

$TotTravTime_1 := CalcTotTT(1)$ $TotTravTime_1 = 58.6$ sec

$TotTravTime_2 := CalcTotTT(2)$ $TotTravTime_2 = 77.1$ sec

$TotTravTime_3 := CalcTotTT(3)$ $TotTravTime_3 = 40.91$ sec

F. Calculate the segment average speed

$$CalcS_A(i) := \frac{3600 \cdot \left(\frac{Length_i}{5280}\right)}{TotTravTime_i}$$

Equation 15-6 HCM 2000

$S_{A_1} := CalcS_A(1)$ $S_{A_1} = 29.09$ mi/h

$S_{A_2} := CalcS_A(2)$ $S_{A_2} = 13.26$ mi/h

$S_{A_3} := CalcS_A(3)$ $S_{A_3} = 28.34$ mi/h

G. Calculate the facility travel time and speed

$$FacTravTime := \left(\frac{Length_1}{5280\,S_{A_1}}\right) + \left(\frac{Length_2}{5280 \cdot S_{A_2}}\right) + \left(\frac{Length_3}{5280 \cdot S_{A_3}}\right)$$

$FacTravTime = 0.049$ hours

$$S_{A_4} := \frac{Length_1 + Length_2 + Length_3}{5280 \cdot FacTravTime}$$

$S_{A_4} = 22.01$ mi/h

5. Determine Segment LOS.

$SegLOS_1 := CalcLOS(Class, 1)$
$SegLOS_2 := CalcLOS(Class, 2)$
$SegLOS_3 := CalcLOS(Class, 3)$

$SegLOS_1 = "B"$

$SegLOS_2 = "E"$

$SegLOS_3 = "B"$

From Exhibit 15-2
HCM 2000

$$
\begin{aligned}
CalcLOS(Class, i) := \; & \text{if } Class = 1 \\
& \quad \begin{aligned}
& out \leftarrow \text{"A"} \;\; \text{if } S_{A_i} > 42 \\
& out \leftarrow \text{"B"} \;\; \text{if } 34 < S_{A_i} \le 42 \\
& out \leftarrow \text{"C"} \;\; \text{if } 27 < S_{A_i} \le 34 \\
& out \leftarrow \text{"D"} \;\; \text{if } 21 < S_{A_i} \le 27 \\
& out \leftarrow \text{"E"} \;\; \text{if } 16 < S_{A_i} \le 21 \\
& out \leftarrow \text{"F"} \;\; \text{if } S_{A_i} \le 16
\end{aligned} \\
& \text{if } Class = 2 \\
& \quad \begin{aligned}
& out \leftarrow \text{"A"} \;\; \text{if } S_{A_i} > 35 \\
& out \leftarrow \text{"B"} \;\; \text{if } 28 < S_{A_i} \le 35 \\
& out \leftarrow \text{"C"} \;\; \text{if } 22 < S_{A_i} \le 28 \\
& out \leftarrow \text{"D"} \;\; \text{if } 17 < S_{A_i} \le 22 \\
& out \leftarrow \text{"E"} \;\; \text{if } 13 < S_{A_i} \le 17 \\
& out \leftarrow \text{"F"} \;\; \text{if } S_{A_i} \le 13
\end{aligned} \\
& \text{if } Class = 3 \\
& \quad \begin{aligned}
& out \leftarrow \text{"A"} \;\; \text{if } S_{A_i} > 30 \\
& out \leftarrow \text{"B"} \;\; \text{if } 24 < S_{A_i} \le 30 \\
& out \leftarrow \text{"C"} \;\; \text{if } 18 < S_{A_i} \le 24 \\
& out \leftarrow \text{"D"} \;\; \text{if } 14 < S_{A_i} \le 18 \\
& out \leftarrow \text{"E"} \;\; \text{if } 10 < S_{A_i} \le 14 \\
& out \leftarrow \text{"F"} \;\; \text{if } S_{A_i} \le 10
\end{aligned} \\
& \text{if } Class = 4 \\
& \quad \begin{aligned}
& out \leftarrow \text{"A"} \;\; \text{if } S_{A_i} > 25 \\
& out \leftarrow \text{"B"} \;\; \text{if } 19 < S_{A_i} \le 25 \\
& out \leftarrow \text{"C"} \;\; \text{if } 13 < S_{A_i} \le 19 \\
& out \leftarrow \text{"D"} \;\; \text{if } 9 < S_{A_i} \le 13 \\
& out \leftarrow \text{"E"} \;\; \text{if } 7 < S_{A_i} \le 9 \\
& out \leftarrow \text{"F"} \;\; \text{if } S_{A_i} \le 7
\end{aligned} \\
& out
\end{aligned}
$$

6. Determine Facility LOS.

$FacAvgSpeed := S_{A_4}$

$FacAvgSpeed = 22.006$ mi/h

$FacLOS := CalcLOS(Class, 4)$

$FacLOS = "C"$

Bicycle LOS Computational Steps

1. Determine methodology inputs

A. Calculate peak 15-minute volume

$$v_{15}(i) := \frac{HourlyDirVol_i}{4 \cdot PHF}$$

$v_{15}(1) = 594.7$ veh/15-min
$v_{15}(2) = 594.7$ veh/15-min
$v_{15}(3) = 594.7$ veh/15-min

B. Calculate the pavement condition adjustment

$$PR(i) := \left| \begin{array}{l} \text{return } 4.5 \text{ if } PvtCond_i = 2 \\ \text{return } 3.5 \text{ if } PvtCond_i = 1 \\ \text{return } 2.5 \text{ if } PvtCond_i = 0 \end{array} \right.$$

$PR(1) = 3.5$
$PR(2) = 3.5$
$PR(3) = 3.5$

C. Calculate the effective buffer/separations widths

$$Wv(i) := \left| \begin{array}{l} out \leftarrow W_{outln_i} \text{ if } AADT_i > (4000 \cdot NumDirLanes_i) \\ out \leftarrow W_{outln_i} \cdot \left(2 - \frac{0.0005 \cdot AADT_i}{NumDirLanes_i \cdot 2}\right) \text{ otherwise} \end{array} \right.$$

$Wv(1) = 12$ ft
$Wv(2) = 12$ ft
$Wv(3) = 12$ ft

$$We(i) := \left| \begin{array}{l} out \leftarrow Wv(i) \text{ if } ShoulderBikeLn_i = 0 \\ out \leftarrow Wv(i) + 10 \text{ if } ShoulderBikeLn_i = 1 \end{array} \right.$$

$We(1) = 22$ ft
$We(2) = 22$ ft
$We(3) = 12$ ft

D. Calculate the SP

$$SP_{temp}(i) := 1.1199 \cdot \ln(RunSpeed_i - 20) + 0.8103$$

$SP_{temp}(1) = 4.33$
$SP_{temp}(2) = 4.249$
$SP_{temp}(3) = 4.351$

$$SP_t(i) := \left| \begin{array}{l} out \leftarrow 1.1199 \cdot \ln(RunSpeed_i - 20) + 0.8103 \text{ if } SP_{temp}(i) \geq 0 \\ out \leftarrow 0 \text{ otherwise} \end{array} \right.$$

$SP_t(1) = 4.33$
$SP_t(2) = 4.249$
$SP_t(3) = 4.351$

2. Determine Segment Bicycle LOS.

$$\text{BikeScore}(i) := 0.507 \cdot \ln\left(\frac{v_{15}(i)}{\text{NumDirLanes}_i}\right) + 0.199 \cdot SP_t(i) \cdot \left(1 + 10.38 \cdot \frac{\%HV}{100}\right)^2 + 7.066 \cdot \left(\frac{1}{PR(i)}\right)^2 - 0.005 \cdot We(i)^2 + 0.76$$

$$\text{BikeScore}(i) := \max(\text{BikeScore}(i), 0.5)$$

BikeScore(1) = 2.966

BikeScore(2) = 2.94

BikeScore(3) = 4.526

$$\text{BikeLOSGrade}(i) := \begin{array}{|l} \text{return "A" if BikeScore}(i) \le 1.5 \\ \text{return "B" if BikeScore}(i) \le 2.5 \\ \text{return "C" if BikeScore}(i) \le 3.5 \\ \text{return "D" if BikeScore}(i) \le 4.5 \\ \text{return "E" if BikeScore}(i) \le 5.5 \\ \text{return "F" if BikeScore}(i) > 5.5 \end{array}$$

BikeLOSGrade(1) = "C"

BikeLOSGrade(2) = "C"

BikeLOSGrade(3) = "E"

3. Determine Facility Bicycle LOS.

$$\text{FacilityBikeScore} := \frac{(\text{BikeScore}(1))^2 \text{Length}_1 + (\text{BikeScore}(2))^2 \text{Length}_2 + (\text{BikeScore}(3))^2 \text{Length}_3}{(\text{BikeScore}(1))\text{Length}_1 + (\text{BikeScore}(2))\text{Length}_2 + (\text{BikeScore}(3))\text{Length}_3}$$

FacilityBikeScore = 3.575

$$\text{FacilityBikeLOSGrade} := \begin{array}{|l} \text{return "A" if FacilityBikeScore} \le 1.5 \\ \text{return "B" if FacilityBikeScore} \le 2.5 \\ \text{return "C" if FacilityBikeScore} \le 3.5 \\ \text{return "D" if FacilityBikeScore} \le 4.5 \\ \text{return "E" if FacilityBikeScore} \le 5.5 \\ \text{return "F" if FacilityBikeScore} > 5.5 \end{array}$$

FacilityBikeLOSGrade = "D"

Pedestrian LOS Computational Steps

1. Determine methodology inputs

$OSP := 0$

A. Determine width of the shoulder/bike lane

$BkLnWid(i) := ShoulderBikeLn_i \cdot 5$

$BkLnWid(1) = 5$
$BkLnWid(2) = 5$
$BkLnWid(3) = 0$

B. Determine sidewalk properties based on roadway/sidewalk separation

$$Ws(i) := \left| \begin{array}{l} out \leftarrow 6 \;\text{ if }\; SwRdwySep_i = 0 \\ out \leftarrow 10 \;\text{ if }\; SwRdwySep_i = 1 \\ out \leftarrow 15 \;\text{ if }\; SwRdwySep_i = 2 \end{array} \right.$$

$Ws(1) = 10$
$Ws(2) = 10$
$Ws(3) = 10$

$$fsw(i) := \left| \begin{array}{l} out \leftarrow 4 \;\text{ if }\; SwRdwySep_i = 0 \\ out \leftarrow 3 \;\text{ if }\; SwRdwySep_i = 1 \\ out \leftarrow 2.5 \;\text{ if }\; SwRdwySep_i = 2 \end{array} \right.$$

$fsw(1) = 3$
$fsw(2) = 3$
$fsw(3) = 3$

C. Determine the roadway/sidewalk barrier factor

$$fb(i) := \left| \begin{array}{l} out \leftarrow 1 \;\text{ if }\; SwRdwyBar_i = 0 \\ out \leftarrow 1.5 \;\text{ if }\; SwRdwyBar_i = 1 \end{array} \right.$$

$fb(1) = 1.5$
$fb(2) = 1.5$
$fb(3) = 1$

D. Adjust for existence of sidewalk

$Ws(i) := Ws(i) \cdot Sidewalk_i$ $fsw(i) := fsw(i) \cdot Sidewalk_i$ $fb(i) := fb(i) \cdot Sidewalk_i$

$Ws(1) = 10$	$fsw(1) = 3$	$fb(1) = 1.5$
$Ws(2) = 10$	$fsw(2) = 3$	$fb(2) = 1.5$
$Ws(3) = 10$	$fsw(3) = 3$	$fb(3) = 1$

2. Determine Segment Pedestrian LOS.

$$PedScore(i) := -1.2276 \cdot \ln\left(W_{outln_i} + BkLnWid(i) + 0.2 \cdot OSP + fsw(i) \cdot Ws(i) \cdot fb(i)\right) + 0.0091 \cdot \left(\frac{v_{15}(i)}{NumDirLanes_i}\right) \ldots$$

$$+ 0.0004 \cdot \left(RunSpeed_i\right)^2 + 6.0468$$

$PedScore(1) = 3.53$ $PedScore(2) = 3.475$ $PedScore(3) = 3.572$

$$PedLOSGrade(i) := \left| \begin{array}{l} \text{return "A" if } PedScore(i) \le 1.5 \\ \text{return "B" if } PedScore(i) \le 2.5 \\ \text{return "C" if } PedScore(i) \le 3.5 \\ \text{return "D" if } PedScore(i) \le 4.5 \\ \text{return "E" if } PedScore(i) \le 5.5 \\ \text{return "F" if } PedScore(i) > 5.5 \end{array} \right.$$

$PedLOSGrade(1) = \text{"D"}$

$PedLOSGrade(2) = \text{"C"}$

$PedLOSGrade(3) = \text{"D"}$

3. Determine Facility Pedestrian LOS.

$$FacilityPedScore := \frac{(PedScore(1))^2 Length_1 + (PedScore(2))^2 Length_2 + (PedScore(3))^2 Length_3}{(PedScore(1))Length_1 + (PedScore(2))Length_2 + (PedScore(3))Length_3}$$

$FacilityPedScore = 3.529$

$$FacilityPedLOS := \left| \begin{array}{l} \text{return "A" if } FacilityPedScore \le 1.5 \\ \text{return "B" if } FacilityPedScore \le 2.5 \\ \text{return "C" if } FacilityPedScore \le 3.5 \\ \text{return "D" if } FacilityPedScore \le 4.5 \\ \text{return "E" if } FacilityPedScore \le 5.5 \\ \text{return "F" if } FacilityPedScore > 5.5 \end{array} \right.$$

$FacilityPedLOS = \text{"D"}$

Bus LOS Computational Steps

1. Determine adjustment factors

A. Calculate pedestrian LOS adjustment

$$\text{PedAdj}(i) := \left| \begin{array}{l} \text{return } 1.15 \text{ if PedLOSGrade}(i) = \text{"A"} \\ \text{return } 1.1 \text{ if PedLOSGrade}(i) = \text{"B"} \\ \text{return } 1.05 \text{ if PedLOSGrade}(i) = \text{"C"} \\ \text{return } 1.0 \text{ if PedLOSGrade}(i) = \text{"D"} \\ \text{return } 0.85 \text{ if PedLOSGrade}(i) = \text{"E"} \\ \text{return } 0.55 \text{ if PedLOSGrade}(i) = \text{"F"} \end{array} \right.$$

$\text{PedAdj}(1) = 1$

$\text{PedAdj}(2) = 1.05$

$\text{PedAdj}(3) = 1$

B. Calculate connectivity adjustment

$$\text{ConnectivityAdj}(i) := \left| \begin{array}{l} 1.0 \text{ if BusStopObstacle}_i = 0 \\ 0.9 \text{ if BusStopObstacle}_i = 1 \end{array} \right.$$

$\text{ConnectivityAdj}(1) = 1$

$\text{ConnectivityAdj}(2) = 1$

$\text{ConnectivityAdj}(3) = 1$

C. Calculate crossing adjustment

$$\text{SegLOSABC}(i) := \left| \begin{array}{l} \text{return } 1 \text{ if SegLOS}_i = \text{"A"} \vee \text{SegLOS}_i = \text{"B"} \vee \text{SegLOS}_i = \text{"C"} \\ \text{return } 0 \end{array} \right.$$

=1 if SegLOS is either A, B, or C

$\text{SegLOSABC}(1) = 1$ $\text{SegLOSABC}(2) = 0$ $\text{SegLOSABC}(3) = 1$

$$\text{SegLOSDEF}(i) := \left| \begin{array}{l} \text{return } 1 \text{ if SegLOS}_i = \text{"D"} \vee \text{SegLOS}_i = \text{"E"} \vee \text{SegLOS}_i = \text{"F"} \\ \text{return } 0 \end{array} \right.$$

=1 if SegLOS is either D, E, or F

$\text{SegLOSDEF}(1) = 0$ $\text{SegLOSDEF}(2) = 1$ $\text{SegLOSDEF}(3) = 0$

$$\text{CrossAdj}(i) := \left| \begin{array}{l} \text{return } 1.05 \text{ if Class} = 1 \wedge \text{NumDirLanes}_i = 1 \wedge (\text{SegLOS}_i = \text{"A"} \vee \text{SegLOS}_i = \text{"B"}) \\ \text{return } 1.05 \text{ if Class} = 2 \wedge \text{NumDirLanes}_i = 1 \wedge \text{SegLOSABC}(i) = 1 \\ \text{return } 1.05 \text{ if Class} = 3 \wedge \text{NumDirLanes}_i = 2 \wedge (\text{SegLOS}_i = \text{"A"} \vee \text{SegLOS}_i = \text{"B"}) \\ \text{return } 1.05 \text{ if Class} = 4 \wedge \text{NumDirLanes}_i = 2 \\ \text{return } 0.8 \text{ if Class} = 1 \wedge \text{NumDirLanes}_i \geq 2 \wedge \text{SegLOS}_i \neq \text{"A"} \wedge \text{MedianType} \neq 2 \\ \text{return } 0.8 \text{ if Class} = 1 \wedge \text{NumDirLanes}_i \geq 4 \wedge \text{MedianType}_i = 2 \\ \text{return } 0.8 \text{ if Class} = 2 \wedge \text{NumDirLanes}_i \geq 4 \wedge \text{MedianType}_i = 2 \\ \text{return } 0.8 \text{ if Class} = 2 \wedge \text{NumDirLanes}_i \geq 2 \wedge \text{SegLOS}_i \neq \text{"A"} \wedge \text{SegLOS}_i \neq \text{"B"} \wedge \text{MedianType}_i \neq 2 \\ \text{return } 0.8 \text{ if Class} = 3 \wedge \text{NumDirLanes}_i \geq 2 \wedge \text{SegLOSDEF}(i) = 1 \wedge \text{MedianType}_i \neq 2 \\ \text{return } 0.8 \text{ if Class} = 3 \wedge \text{NumDirLanes}_i \geq 4 \wedge \text{MedianType}_i = 2 \\ \text{return } 1.0 \end{array} \right.$$

$CrossAdj(1) = 1$
$CrossAdj(2) = 1$
$CrossAdj(3) = 1$

D. Calculate the span of service adjustment

$$BusSpanServiceAdj(i) := \begin{array}{|l} \text{return } 1.15 \text{ if } BusSpanService_i \geq 19 \\ \text{return } 1.05 \text{ if } 17 \leq BusSpanService_i < 19 \\ \text{return } 1 \text{ if } 14 \leq BusSpanService_i < 17 \\ \text{return } .9 \text{ if } 12 \leq BusSpanService_i < 14 \\ \text{return } .75 \text{ if } 4 \leq BusSpanService_i < 12 \\ \text{return } 0.55 \text{ if } BusSpanService_i < 4 \end{array}$$

$BusSpanServiceAdj(1) = 1$
$BusSpanServiceAdj(2) = 1$
$BusSpanServiceAdj(3) = 1$

2. Determine Segment Bus LOS.

$$BusPoints(i) := BusFrequency_i \cdot PedAdj(i) \cdot ConnectivityAdj(i) \cdot CrossAdj(i) \cdot BusSpanServiceAdj(i)$$

$BusPoints(1) = 2$ $BusPoints(2) = 2.1$ $BusPoints(3) = 2$

$$BusLOS(i) := \begin{array}{|l} out \leftarrow \text{"A"} \text{ if } BusPoints(i) > 6 \\ out \leftarrow \text{"B"} \text{ if } 4 < BusPoints(i) \leq 6 \\ out \leftarrow \text{"C"} \text{ if } 3 \leq BusPoints(i) \leq 4 \\ out \leftarrow \text{"D"} \text{ if } 2 \leq BusPoints(i) < 3 \\ out \leftarrow \text{"E"} \text{ if } 1 \leq BusPoints(i) < 2 \\ out \leftarrow \text{"F"} \text{ if } BusPoints(i) < 1 \end{array}$$

$BusLOS(1) = \text{"D"}$
$BusLOS(2) = \text{"D"}$
$BusLOS(3) = \text{"D"}$

3. Determine Facility Bus LOS.

$$FacilityBusPoints := \frac{BusPoints(1) \cdot Length_1 + BusPoints(2) \cdot Length_2 + BusPoints(3) \cdot Length_3}{Length_1 + Length_2 + Length_3}$$

$FacilityBusPoints = 2.026$

$$FacilityBusLOS := \begin{array}{|l} out \leftarrow \text{"A"} \text{ if } FacilityBusPoints > 6 \\ out \leftarrow \text{"B"} \text{ if } 4 < FacilityBusPoints \leq 6 \\ out \leftarrow \text{"C"} \text{ if } 3 \leq FacilityBusPoints \leq 4 \\ out \leftarrow \text{"D"} \text{ if } 2 \leq FacilityBusPoints < 3 \\ out \leftarrow \text{"E"} \text{ if } 1 \leq FacilityBusPoints < 2 \\ out \leftarrow \text{"F"} \text{ if } FacilityBusPoints < 1 \end{array}$$

$FacilityBusLOS = \text{"D"}$

Service Volumes Check

From Exhibit 15-2 HCM 2000, for a Class II Arterial, the average speed (S_A) threshold for LOS C is 22.0 mi/h.

Using the procedure documented above, the following results are obtained for the displayed 2260 veh/h peak direction service volume.

$$\text{InputAADT} := \text{Round}\left(\frac{2260}{K \cdot D}, 10\right) = 43250$$

* This AADT input must be the same for all segments

$$\text{SegRunTime} := 83.388 + 86.615 + 82.546 = 252.549$$ seconds/mile

$$\text{ControlDelay} := 19.114 + 52.497 + 14.329 = 85.94$$ seconds

$$\text{FacilityLength} := \frac{2500 + 1500 + 1700}{5280} = 1.08$$ miles

$$\text{TotalTravelTime} := \left(83.388 \cdot \frac{2500}{5280} + 19.114\right) + \left(86.615 \cdot \frac{1500}{5280} + 52.497\right) + \left(82.546 \cdot \frac{1700}{5280} + 14.329\right)$$

$$\text{TotalTravelTime} = 176.607$$ seconds

$$\text{FacilitySpeed} := \frac{\text{FacilityLength}}{\frac{\text{TotalTravelTime}}{3600}}$$

$$\text{FacilitySpeed} = 22.006$$ mi/h

Thus, the maximum service volume (AADT) for LOS C for the conditions in the example calculations file is ~43,250.

Service Volumes Upper Limit

Service Volumes are limited by the volume/capacity ratio of any given intersection along the arterial. That is, when the v/c ratio exceeds 1/PHF for any intersection, ARTPLAN will stop and report the service volume as the maximum non-failing (i.e., v/c <= 1/PHF) volume.

Multimodal Service Volumes are limited by an approximation of capacity of 1000 pc/hr/ln. Whenever the auto volume reaches this maximum, ARTPLAN will stop and report the service volume as the maximum non-failing (i.e., volume <= 1000 * # Lanes) volume.