ARTPLAN Computational Methodology

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General Facility Data Inputs

Roadway Variables:

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

$Class := 2$ $ThruLanes := 4$ both directions

$PostedSpeed := 45$ $MedianType := 2$ 0 = None, 1 = NonRestrictive, 2 = Restrictive

$InsideLaneWidth := 12$ $LeftTurnBay := 1$ 0 = No, 1 = Yes

$OutsideLaneWidth := 12$ $RightTurnBay := 0$ 0 = No, 1 = Yes

Traffic Variables:

$AADT := 30000$ $PHF := 0.925$ $\%LeftTurns := 12$ $BaseSatFlowRate := 1950$

$Kfactor := 0.095$ $\%HV := 2$ $\%RightTurns := 12$

$Dfactor := 0.55$

Intersection and Segment Data Inputs

Intersection Data:

Int_1 No Inputs Required

Int_2 $Cycle_1 := 120$ $gC_1 := 0.44$ $ArrivalType_1 := 4$ $\%LeftTurns_1 := 12$ $\%RightTurns_1 := 12$ $NumDirLanes_1 := 2$

Int_3 $Cycle_2 := 120$ $gC_2 := 0.44$ $ArrivalType_2 := 4$ $\%LeftTurns_2 := 12$ $\%RightTurns_2 := 12$ $NumDirLanes_2 := 2$

Segment Data:

Seg_1

$Length_1 := 1760$

$AADT_1 := 30000$

$HourlyDirVol_1 := AADT_1 \cdot Kfactor \cdot Dfactor$

$HourlyDirVol_1 = 1568$

$FFS_1 := 50$

Seg_2

$Length_2 := 1760$

$AADT_2 := 30000$

$HourlyDirVol_2 := AADT_2 \cdot Kfactor \cdot Dfactor$

$HourlyDirVol_2 = 1568$

$FFS_2 := 50$

Signal Data:

$Sig_1 := 0$ No Inputs Required

$Sig_2 := 1$ 0 = Pretimed, 1 = Semi Actuated, 2 = Fully Actuated

$Sig_3 := 1$ 0 = Pretimed, 1 = Semi Actuated, 2 = Fully Actuated

Computational Steps

1. Calculate the Saturation Flow Rate Adjustment Factors

A. Calculate the population adjustment factor

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

$$\text{Population}(\text{AreaType}) = 0.4$$

$$\text{PopFact} := \frac{1}{\text{Population}(\text{AreaType})^{-0.018}} \qquad \text{PopFact} = 0.984$$

B. Calculate the number of lanes adjustment factor

$$N := \frac{\text{ThruLanes}}{2} \qquad E_{CL} := 1.03$$

$$\text{NumLanesFact} := \frac{1}{1 + \frac{1}{N}\cdot\left(E_{CL} - 1\right)} \qquad \text{NumLanesFact} = 0.985$$

C. Calculate the posted speed adjustment factor

$$\text{SpeedFact} := \frac{1}{1 - 0.0066(\text{PostedSpeed} - 50)} \qquad \text{SpeedFact} = 0.968$$

D. Calculate the traffic pressure adjustment factor

$$\%\text{Turns}(\%\text{LT}, \%\text{RT}) := \left| \begin{array}{l} \%\text{LT} \ \text{ if } \ \text{LeftTurnBay} = 1 \wedge \text{RightTurnBay} = 0 \\ \%\text{RT} \ \text{ if } \ \text{LeftTurnBay} = 0 \wedge \text{RightTurnBay} = 1 \\ \%\text{LT} + \%\text{RT} \ \text{ if } \ \text{LeftTurnBay} = 1 \wedge \text{RightTurnBay} = 1 \\ 0 \ \text{ otherwise} \end{array} \right.$$

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

$$\text{ThruMvmtFlowRate}_1 := \frac{\text{HourlyDirVol}_1}{\text{PHF}}\cdot\left[1 - \left(\frac{\%\text{Turns}_1}{100}\right)\right] \qquad \text{ThruMvmtFlowRate}_1 = 1491.2$$

$Cycle_1 := 120$

$$v_1 := \frac{ThruMvmtFlowRate_1 \cdot Cycle_1}{N \cdot 3600} \qquad v_1 = 24.854$$

$$TrafFact := \frac{1}{1 - 0.0032(v_1 - 20)} \qquad TrafFact = 1.016$$

E. Calculate the lane width adjustment factor

$$AvgLaneWidth_1 := \frac{[InsideLaneWidth \cdot (NumDirLanes_2 - 1)] + OutsideLaneWidth}{NumDirLanes_2}$$

$$LaneWidthFact_1 := 1 + \frac{AvgLaneWidth_1 - 12}{30} \qquad LaneWidthFact_1 = 1.0$$

F. Determine the Median adjustment factor

$$MedianFact(Median) := \left| \begin{array}{l} out \leftarrow 0.95 \ \text{ if } \ Median = 0 \\ out \leftarrow 1.0 \ \text{ if } \ Median = 1 \\ out \leftarrow 1.0 \ \text{ if } \ Median = 2 \\ out \end{array} \right.$$

$MedianFact(MedianType) = 1$

$MedianFact_1 := MedianFact(MedianType)$ $\qquad MedianFact_1 = 1.0$

G. Determine the left turn bay adjustment factor

$$LeftTurnFact(LeftTurnBay) := \left| \begin{array}{l} out \leftarrow 0.8 \ \text{ if } \ LeftTurnBay = 0 \\ out \leftarrow 1.0 \ \text{ if } \ LeftTurnBay = 1 \\ out \end{array} \right.$$

$LeftTurnFact(LeftTurnBay) = 1$

$LeftTurnFact_1 := LeftTurnFact(LeftTurnBay)$ $\qquad LeftTurnFact_1 = 1.0$

H. Determine the right turn adjustment factor

$$E_{RT}(RightTurnBay) := \left| \begin{array}{l} out \leftarrow 1.07 \ \text{ if } \ RightTurnBay = 0 \\ out \leftarrow 1.0 \ \text{ if } \ RightTurnBay = 1 \\ out \end{array} \right.$$

$E_{RT}(\mathrm{RightTurnBay}) = 1.07$

$$\mathrm{RightTurnFact} := \left[\frac{1}{1 + \frac{\%\mathrm{RightTurns}_1}{100}\cdot\left(E_{RT}(\mathrm{RightTurnBay}) - 1\right)}\right] \qquad \mathrm{RightTurnFact} = 0.992$$

I. Calculate the heavy vehicle adjustment factor

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

$$f_{HV1} := \frac{1}{1 + \left[\frac{\%HV}{100}\cdot\left(E_T - 1\right)\right]} \qquad f_{HV1} = 0.985$$

2. Calculate the Adjusted Saturation Flow Rate

$$\mathrm{FactAdj} := \mathrm{LaneWidthFact}_1\cdot\mathrm{MedianFact}_1\cdot f_{HV1}\cdot\mathrm{PopFact}\cdot\mathrm{TrafFact}\cdot\mathrm{NumLanesFact}\cdot\mathrm{SpeedFact}\cdot\mathrm{LeftTurnFact}_1\cdot\mathrm{RightTurnFact}$$

$\mathrm{FactAdj} = 0.931$

$\mathrm{AdjSatFlowRate}_1 := \mathrm{BaseSatFlowRate}\cdot\mathrm{FactAdj} \qquad \mathrm{AdjSatFlowRate}_1 = 1816$

3. Calculate signal delay

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

Sig_1

$c := \mathrm{AdjSatFlowRate}_1\cdot gC_1 \qquad c = 799$

$$\mathrm{ThruMvmtFlowRate}_1 := \frac{\mathrm{HourlyDirVol}_1}{\mathrm{PHF}}\cdot\left[1 - \left(\frac{\%\mathrm{Turns}_1}{100}\right)\right] \qquad \mathrm{ThruMvmtFlowRate}_1 = 1491.2$$

$$vc_1 := \frac{\mathrm{ThruMvmtFlowRate}_1}{c\cdot\mathrm{NumDirLanes}_1} \qquad vc_1 = 0.933$$

Sig_2

$c := \mathrm{AdjSatFlowRate}_1\cdot gC_2 \qquad c = 799$

$\%\mathrm{Turns}_2 := \%\mathrm{Turns}\left(\%\mathrm{LeftTurns}_2, \%\mathrm{RightTurns}_2\right) \qquad \%\mathrm{Turns}_2 = 12$

$$\mathrm{ThruMvmtFlowRate}_2 := \frac{\mathrm{HourlyDirVol}_1}{\mathrm{PHF}}\cdot\left[1 - \left(\frac{\%\mathrm{Turns}_2}{100}\right)\right] \qquad \mathrm{ThruMvmtFlowRate}_2 = 1491.2$$

$$vc_2 := \frac{ThruMvmtFlowRate_2}{c \cdot NumDirLanes_2} \qquad vc_2 = 0.933$$

B. Calculate uniform delay (d_1)

$$d_{1\_1} := \frac{0.5 \cdot Cycle_2 \cdot \left(1 - gC_2\right)^2}{1 - \left(vc_2 \cdot gC_2\right)} \qquad d_{1\_1} = 31.92$$

Equation 15-2 HCM 2000

C. Calculate incremetal delay (d_2)

Determine k, signal controller mode delay adjustment factor

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

$$kfactor(Signal) := \left| \begin{array}{l} out \leftarrow 0.5 \ \text{ if } \ Signal = 0 \\ out \leftarrow 0.5 \ \text{ if } \ Signal = 1 \\ \text{if } \ Signal = 2 \\ \quad \left| \begin{array}{l} out \leftarrow 0.11 \ \text{ if } \ vc_2 < 0.5 \\ out \leftarrow (1 - 2 \cdot 0.11) \cdot \left(vc_2 - 0.5\right) + 0.11 \ \text{ otherwise} \end{array} \right. \\ out \end{array} \right.$$

From Exhibit 15-6 HCM 2000

$$kfactor\left(Sig_2\right) = 0.5 \qquad k_1 := kfactor\left(Sig_2\right) \qquad k_1 = 0.5$$

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.

$$Ifactor := \left| \begin{array}{l} out \leftarrow 0.09 \ \text{ if } \ vc_1 \ge 1.0 \\ out \leftarrow 1.0 - 0.91 \cdot vc_1^{\ 2.68} \ \text{ if } \ vc_1 < 1.0 \\ out \end{array} \right.$$

From Exhibit 15-7 HCM 2000

$$Ifactor = 0.244 \qquad I_1 := Ifactor \qquad I_1 = 0.244$$

<u>Calculation:</u>

$T := 0.25$ (ARTPLAN default)

$$d_{2\_1} := 900 \cdot T \cdot \left[\left(vc_2 - 1\right) + \sqrt{\left(vc_2 - 1\right)^2 + \frac{8 \cdot k_1 \cdot I_1 \cdot vc_2}{T \cdot c \cdot NumDirLanes_2}}\right]$$

Equation 15-3 HCM 2000

$d_{2\_1} = 3.444$

D. Calculate progression adjustment factor (PF)

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

Determine Platoon Ratio

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

From Exhibit 15-4
HCM 2000

$R_p(\text{ArrivalType}_2) = 1.333$ $\quad R_{p\_1} := R_p(\text{ArrivalType}_2)$ $\quad R_{p\_1} = 1.333$

Calculate supplemental adjustment factor for platoon arrival during the green

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

From Exhibit 15-5
HCM 2000

$f_{PA}(\text{ArrivalType}_2) = 1.15$ $\quad f_{PA\_1} := f_{PA}(\text{ArrivalType}_2)$ $\quad f_{PA\_1} = 1.15$

Calculate the percent arrivals on green

$$\%\text{Green}(gC_2) := \left| \begin{array}{l} \text{out} \leftarrow 1.0 \;\; \text{if } (R_{p\_1} \cdot gC_2) > 1.0 \\ \text{out} \leftarrow R_{p\_1} \cdot gC_2 \;\; \text{otherwise} \\ \text{out} \end{array} \right.$$

Equation 15-4
HCM 2000

$\%\text{Green}(gC_2) = 0.587$ $\quad \%\text{Green}_1 := \%\text{Green}(gC_2)$ $\quad \%\text{Green}_1 = 0.587$

Calculate the Progression Adjustment Factor (PF)

$$PF(gC_2) := \begin{array}{|l} out \leftarrow \dfrac{(1 - \%Green_1) \cdot f_{PA\_1}}{1 - gC_2} \quad \text{if } gC_2 \neq 1.0 \\ out \leftarrow 0 \quad \text{otherwise} \\ out \end{array}$$

Equation 15-5
HCM 2000

$PF(gC_2) = 0.849$ $\quad$ $PF_1 := PF(gC_2)$ $\quad$ $PF_1 = 0.849$

e. Calculate the total signal delay

$$CtrlDelay_1 := d_{1\_1} \cdot PF_1 + d_{2\_1}$$

Equation 15-1
HCM 2000

$CtrlDelay_1 = 30.55$

7. Calculate the Segment Running Time/Speed

Calculations:

$Sigs_1 := \dfrac{5280}{Length_1}$ $\quad$ $Sigs_1 = 3$ $\quad$ signals/mi

$v\_temp := \dfrac{HourlyDirVol_1}{NumDirLanes_1}$ $\quad$ $v\_temp = 783.75$ $\quad$ not adjusted by PHF

$$RunSpeed_1 := \begin{array}{|l} out \leftarrow 56.941 - 1.53944 \cdot Sigs_1 - 0.00721 \cdot v\_temp \quad \text{if } FFS_1 = 55 \\ out \leftarrow 51.888 - 1.14222 \cdot Sigs_1 - 0.00795 \cdot v\_temp \quad \text{if } FFS_1 = 50 \\ out \leftarrow 46.574 - 0.89222 \cdot Sigs_1 - 0.00604 \cdot v\_temp \quad \text{if } FFS_1 = 45 \\ out \leftarrow 39.69506 - 0.10306 \cdot Sigs_1 - 0.00585 \cdot v\_temp \quad \text{if } FFS_1 = 40 \\ out \leftarrow 35.23011 - 0.21722 \cdot Sigs_1 - 0.00517 \cdot v\_temp \quad \text{if } FFS_1 = 35 \\ out \leftarrow 29.893 - 0.05611 \cdot Sigs_1 - 0.00398 \cdot v\_temp \quad \text{if } FFS_1 = 30 \\ out \leftarrow 25.58418 - 0.00095 \cdot Sigs_1 - 0.00356 \cdot v\_temp \quad \text{if } FFS_1 = 25 \\ out \end{array}$$

Regression
Equations

ARTPLAN uses specific array values for running time, rather than the above regression equations, so results do not match.

$RunSpeed_1 = 42.2$ $\quad$ mi/h $\quad$ running time

$SegRunTime_1 := \dfrac{3600}{RunSpeed_1}$ $\quad$ $SegRunTime_1 = 85.2$ $\quad$ seconds/mile

$$L_1 := \frac{Length_1}{5280} \qquad L_1 = 0.333$$ miles

$$TotTravTime_1 := SegRunTime_1 \cdot L_1 + CtrlDelay_1 \qquad TotTravTime_1 = 59.0$$ seconds

$$S_{A1} := \frac{3600 \cdot L_1}{TotTravTime_1}$$

Equation 15-6
HCM 2000

$S_{A1} = 20.35$ mi/h segment running speed

8. Determine Segment LOS.

Calculations:

$$
\mathrm{LOS}(\mathrm{Class}, S_A) := \left|
\begin{array}{l}
\text{if Class} = 1 \\
\quad \left| \begin{array}{l}
\text{out} \leftarrow \text{"A"} \quad \text{if } S_A > 42 \\
\text{out} \leftarrow \text{"B"} \quad \text{if } 34 < S_A \le 42 \\
\text{out} \leftarrow \text{"C"} \quad \text{if } 27 < S_A \le 34 \\
\text{out} \leftarrow \text{"D"} \quad \text{if } 21 < S_A \le 27 \\
\text{out} \leftarrow \text{"E"} \quad \text{if } 16 < S_A \le 21 \\
\text{out} \leftarrow \text{"F"} \quad \text{if } S_A \le 16
\end{array} \right. \\
\text{if Class} = 2 \\
\quad \left| \begin{array}{l}
\text{out} \leftarrow \text{"A"} \quad \text{if } S_A > 35 \\
\text{out} \leftarrow \text{"B"} \quad \text{if } 28 < S_A \le 35 \\
\text{out} \leftarrow \text{"C"} \quad \text{if } 22 < S_A \le 28 \\
\text{out} \leftarrow \text{"D"} \quad \text{if } 17 < S_A \le 22 \\
\text{out} \leftarrow \text{"E"} \quad \text{if } 13 < S_A \le 17 \\
\text{out} \leftarrow \text{"F"} \quad \text{if } S_A \le 13
\end{array} \right. \\
\text{if Class} = 3 \\
\quad \left| \begin{array}{l}
\text{out} \leftarrow \text{"A"} \quad \text{if } S_A > 30 \\
\text{out} \leftarrow \text{"B"} \quad \text{if } 24 < S_A \le 30 \\
\text{out} \leftarrow \text{"C"} \quad \text{if } 18 < S_A \le 24 \\
\text{out} \leftarrow \text{"D"} \quad \text{if } 14 < S_A \le 18 \\
\text{out} \leftarrow \text{"E"} \quad \text{if } 10 < S_A \le 14 \\
\text{out} \leftarrow \text{"F"} \quad \text{if } S_A \le 10
\end{array} \right. \\
\text{if Class} = 4 \\
\quad \left| \begin{array}{l}
\text{out} \leftarrow \text{"A"} \quad \text{if } S_A > 25 \\
\text{out} \leftarrow \text{"B"} \quad \text{if } 19 < S_A \le 25 \\
\text{out} \leftarrow \text{"C"} \quad \text{if } 13 < S_A \le 19 \\
\text{out} \leftarrow \text{"D"} \quad \text{if } 9 < S_A \le 13 \\
\text{out} \leftarrow \text{"E"} \quad \text{if } 7 < S_A \le 9 \\
\text{out} \leftarrow \text{"F"} \quad \text{if } S_A \le 7
\end{array} \right. \\
\text{out}
\end{array} \right.
$$

$\mathrm{LOS}(\mathrm{Class}, S_{A1}) = \text{"D"}$

From Exhibit 15-2
HCM 2000