HIGHPLAN Computational Methodology

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Two-Lane Facility Analysis, Example 1

Inputs and Initial Computations.

1. Input Roadway and Traffic Data.

Roadway Data

$AnalysisType := 0$ 0 = segment, 1 = facility

$\%NPZ := 50$

$Median := 0$ 0 = no median, 1 = median

$PostedSpeed := 55$

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

$FFS := PostedSpeed + 5$

Peak Direction is EB

$L_{up} := 3$ mi $L_{down} := 4$ mi

$L_T := L_{up} + L_{down}$

Traffic Data

$AADT := 10000$ $K := 0.10$ $D := 0.6$ $PHF := 0.95$

$DDHV := AADT \cdot K \cdot D$ $DDHV = 600$ veh / hr

$LocalAdjustmentFactor := 1.0$ $LAF := LocalAdjustmentFactor$

$v_p := \dfrac{DDHV}{PHF \cdot LAF}$ $v_p = 631.6$ $v_o := \dfrac{AADT \cdot K \cdot (1 - D)}{PHF \cdot LAF}$ $v_o = 421.1$

$\%TruckBus := 3$ $\%RV := 2$ $P_T := \dfrac{\%TruckBus + \%RV}{100}$ $P_T = 0.05$

$\%HV_{EB} := 5$ $\%HV_{WB} := 5$ $\%HV_{NB} := 5$ $\%HV_{SB} := 5$

$v_{LT} := 50$ $v_{RT} := 50$ $\%LT := \dfrac{\dfrac{v_{LT}}{PHF}}{v_p} \cdot 100$ $\%LT = 8.333$

Signal Data

$GreenTime_{EW} := 54$ $GreenTime_{NS} := 26$ $YellowRedTime := 5$

$C := 90$ $g\_C := \frac{GreenTime_{EW}}{C}$ $g\_C = 0.6$

$LeftTurnLane := 1$ 0 = No, 1 = Yes

$BaseCapacity := 1700$

2. Determine segment lengths

Length of basic two-lane segment upstream of signal (L1)

$$L_{eff\_up} := 43.2463 + 4.2688 \cdot \left(\frac{v_p}{100}\right)^2 + 5.2178 \cdot C - 57.3041 \cdot \left(\frac{v_p}{100}\right) \cdot \frac{\%LT}{100} - 5.244 \cdot C \cdot g\_C$$

$L_{eff\_up} = 369.791$ (ft) $L_{eff\_up} := \frac{L_{eff\_up}}{5280}$ $L_{eff\_up} = 0.07$ (mi)

$L_1 := L_{up} - L_{eff\_up}$ $L_1 = 2.930$ (mi)

Length of signalized intersection influence area (L2)

$L_A := \frac{0.1655 \cdot FFS^{2.0917}}{5280}$ $L_A = 0.164$ (mi) Acceleration distance from stop at signal

$L_2 := L_{eff\_up} + L_A$ $L_2 = 0.234$ (mi)

Length of transition two-lane highway downstream of signalized intersection influence area (L3)

$L_{eff\_down} := 2.218584 - 0.122942 \cdot \left(\frac{v_p}{100}\right)$ $L_{eff\_down} = 1.442$ (mi)

$L_3 := L_{eff\_down} - L_A$ $L_3 = 1.278$ (mi)

Length of basic two-lane segment downstream of signal (L1)

$L_4 := L_T - (L_1 + L_2 + L_3)$ $L_4 = 2.558$ (mi)

3. Estimate the free-flow speed

$FFS := PostedSpeed + 5$ $FFS = 60$ mi/h

4. Calculate the average travel speed on the unaffected upstream segment

$ATS_1 := 49.6$ mi/h See ATS calculations section below

5. Calculate control delay at the signalized intersection influence area

$ControlDelay := 12.6$ sec/veh See signal delay calculations section below

6. Determine average travel speed on the unaffected downstream segment

$ATS_4 := 49.6$ mi/h

7. Determine average travel speed on the affected downstream segment

F = user defined Flow a = maximum Flow b = minimum Flow
x = maximum Value y = minimum Value

$$InterpolateFlow(F,a,x,b,y) := \left| \begin{array}{l} out \leftarrow y + \dfrac{x-y}{a-b}\cdot(F-b) \\ out \end{array} \right.$$

$f_{ATS} := InterpolateFlow(600, 660, 1.800, 440, 1.320)$ $f_{ATS} = 1.669$ need to adjust for PHF

$ATS_3 := ATS_4 - f_{ATS}$ $ATS_3 = 47.93$ mi/h

8. Determine the delay of every segment

$L_1 = 2.93$ $S_1 := ATS_1$ $S_1 = 49.6$ $FFS = 60$

$$D_1 := \left(\frac{L_1}{S_1} - \frac{L_1}{FFS}\right)\cdot 3600 \qquad D_1 = 36.861$$

$L_2 = 0.234$

$D_2 := ControlDelay$ $D_2 = 12.6$

$L_3 = 1.278$ $S_3 := ATS_3$ $S_3 = 47.931$ $FFS = 60$

$$D_3 := \left(\frac{L_3}{S_3} - \frac{L_3}{FFS}\right)\cdot 3600 \qquad D_3 = 19.306$$

$L_4 = 2.558$ $S_4 := ATS_4$ $S_4 = 49.6$ $FFS = 60$

$$D_4 := \left(\frac{L_4}{S_4} - \frac{L_4}{FFS}\right)\cdot 3600 \qquad D_4 = 32.18$$

9. Determine the percent time-delayed of the entire facility

1. The total length of the facility:

$L_t := L_1 + L_2 + L_3 + L_4$ $\qquad L_t = 7$ mi

2. The total delay of the facility:

$D_T := D_1 + D_2 + D_3 + D_4$ $\qquad D_T = 100.947$ sec/veh

3. Calculate the total travel time of the facility based on the free flow speed:

$T_{tFFS} := \left(\frac{L_t}{FFS}\right)\cdot 3600$ $\qquad T_{tFFS} = 420$ sec/veh

4. Calculate the percent time-delayed of the facility:

$PTD := \left(\frac{D_T}{T_{tFFS}}\right)\cdot 100$ $\qquad PTD = 24.03$ (%)

10. Determine the Level of Service

$$LOS(PTD) := \begin{array}{|l} los \leftarrow \text{"A"} \ \text{ if } \ PTD \le 7.5 \\ los \leftarrow \text{"B"} \ \text{ if } \ 7.5 < PTD \le 15 \\ los \leftarrow \text{"C"} \ \text{ if } \ 15 < PTD \le 25 \\ los \leftarrow \text{"D"} \ \text{ if } \ 25 < PTD \le 35 \\ los \leftarrow \text{"E"} \ \text{ if } \ 35 < PTD \le 45 \\ los \leftarrow \text{"F"} \ \text{ if } \ PTD > 45 \\ los \end{array}$$

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

Signal Delay Calculations

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

$E_T := 2.0$

$$f_{HV} := \frac{1}{1 + P_T\cdot(E_T - 1)} \qquad f_{HV} = 0.952$$

$$P_{RT} := \frac{\frac{v_{RT}}{PHF}}{v_p - \frac{v_{LT}}{PHF}} \qquad P_{RT} = 0.091$$

$$f_{RT} := 1.0 - 0.15 \cdot P_{RT} \qquad f_{RT} = 0.986$$

shared lane equation instead of single lane

$$BaseSatFlowRate := 1900$$

$$AdjSatFlowRate := BaseSatFlowRate \cdot f_{HV} \cdot f_{RT} \qquad AdjSatFlowRate = 1784.8$$

$$c := AdjSatFlowRate \cdot g\_C \qquad c = 1070.9$$

$$ThruMvmtFlowRate_1 := v_p \cdot \left[1 - \left(\frac{\%LT}{100}\right)\right] \qquad ThruMvmtFlowRate_1 = 578.9$$

$$vc_1 := \frac{ThruMvmtFlowRate_1}{c \cdot 1} \qquad vc_1 = 0.541$$

b. Calculate uniform delay (d_1)

$$d_{1\_1} := \frac{0.5 \cdot C \cdot (1 - g\_C)^2}{1 - (vc_1 \cdot g\_C)} \qquad d_{1\_1} = 10.7$$

Equation 15-2
HCM 2000

c. Calculate incremetal delay (d_2)

Determine k, signal controller mode delay adjustment factor

$k := 0.5$ pretimed mode

Determine I, the incremental delay adjustment factor

$I := 1.0$ random arrivals

Calculate incremetal delay (d_2)

Definition:

$T := 0.25$ (default)

Calculation:

$$d_{2\_1} := 900 \cdot T \cdot \left[(vc_1 - 1) + \sqrt{(vc_1 - 1)^2 + \frac{8 \cdot k \cdot I \cdot vc_1}{T \cdot c \cdot 1}} \right]$$

Equation 15-3
HCM 2000

$d_{2\_1} = 2.0$

d. Calculate the total delay

<u>Calculations:</u>

$PF := 1$

$TotDelay_1 := d_{1\_1} \cdot PF + d_{2\_1}$

Equation 15-1
HCM 2000

$TotDelay_1 = 12.6$

ATS Calculations

2. Calculate DDHV (Design Directional Hour Volume)

<u>Calculation:</u>

$DDHV := v_p \cdot PHF$ $\quad$ $DDHV = 600$

3. Determine adjustment for the presence of a median and/or left turn lanes.

Left Turn Lane Adjustment (LTadj) = -0.2 for left turn lanes NOT present, LTadj = 0 otherwise.

Median Adjustment (MedAdj) = 0.05 for median present, MadAdj = 0 otherwise.

<u>Calculations:</u>

Left Turn Lane:

$$LTadj(LeftTurnLane) := \left| \begin{array}{l} out \leftarrow -0.2 \text{ if } LeftTurnLane = 0 \\ out \leftarrow 0 \text{ if } LeftTurnLane = 1 \\ out \end{array} \right.$$

$LTadj(LeftTurnLane) = 0$ $\quad$ $LTadj := LTadj(LeftTurnLane)$ $\quad$ $LTadj = 0$

Median:

$$\text{MedAdj(Median)} := \left| \begin{array}{l} \text{out} \leftarrow 0 \quad \text{if Median} = 0 \\ \text{out} \leftarrow 0.05 \quad \text{if Median} = 1 \\ \text{out} \end{array} \right.$$

$\text{MedAdj(Median)} = 0$ $\quad$ $\text{MedAdj} := \text{MedAdj(Median)}$ $\quad$ $\text{MedAdj} = 0$

Final Adjustment Value for Left Turn Lane and Median:

$$\text{AdjMedLTL} := 1 + \text{LTadj} + \text{MedAdj}$$

$\text{AdjMedLTL} = 1$

4. Determine Facility Adjustment Factor (FacAdj).

FacAdj = 1.0 for Analysis Type = Segment

FacAdj = 0.9 for Analysis Type = Facility

<u>Calculation:</u>

$$\text{FacAdj(AnalysisType)} := \left| \begin{array}{l} \text{out} \leftarrow 1.0 \quad \text{if AnalysisType} = 0 \\ \text{out} \leftarrow 0.9 \quad \text{if AnalysisType} = 1 \\ \text{out} \end{array} \right.$$

$\text{FacAdj(AnalysisType)} = 1$ $\quad$ $\text{FacAdj} := \text{FacAdj(AnalysisType)}$ $\quad$ $\text{FacAdj} = 1$

5. Calculate Adjusted Volume (AdjVol).

<u>Calculation:</u>

$$\text{AdjVol} := \frac{\text{DDHV}}{\text{PHF} \cdot \text{LAF} \cdot \text{AdjMedLTL} \cdot \text{FacAdj}}$$

$\text{AdjVol} = 631.6$ veh/h $\quad$ $V := \text{AdjVol}$ $\quad$ $V = 631.6$ veh/h

6. Determine E_T (Truck passenger car equivalency factor).

<u>Calculation:</u>

$$
\text{PCEs}(\text{Terrain}, V) := \left|\begin{array}{l}
\text{if Terrain} = 1 \\
\quad \left|\begin{array}{l}
E_T \leftarrow 1.7 \quad \text{if } 0 \le V \le 300 \\
E_T \leftarrow 1.2 \quad \text{if } 300 < V \le 600 \\
E_T \leftarrow 1.1 \quad \text{if } V > 600 \\
E_R \leftarrow 1.0 \\
\text{out} \leftarrow \begin{pmatrix} E_T \\ E_R \end{pmatrix} \\
\text{out}
\end{array}\right. \\
\text{if Terrain} = 2 \\
\quad \left|\begin{array}{l}
E_T \leftarrow 2.5 \quad \text{if } 0 \le V \le 300 \\
E_T \leftarrow 1.9 \quad \text{if } 300 < V \le 600 \\
E_T \leftarrow 1.5 \quad \text{if } V > 600 \\
E_R \leftarrow 1.1 \\
\text{out} \leftarrow \begin{pmatrix} E_T \\ E_R \end{pmatrix} \\
\text{out}
\end{array}\right. \\
\text{out}
\end{array}\right.
$$

From Exhibit 20-9
HCM 2000

$$\text{PCEs}(\text{Terrain}, V) = \begin{pmatrix} 1.1 \\ 1.0 \end{pmatrix}$$

$E_T := \text{PCEs}(\text{Terrain}, V)_1$ $\quad E_T = 1.1$

$E_R := \text{PCEs}(\text{Terrain}, V)_2$ $\quad E_R = 1.0$

7. Calculate heavy vehicle factor (f_{HV}).

<u>Calculation:</u>

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

From Equation 20-4
HCM 2000

$f_{HV} = 0.995$

8. Determine grade adjustment factor (f_G).

<u>Calculation:</u>

$$f_G(\text{Terrain}, V) := \left| \begin{array}{l} \text{if Terrain} = 1 \\ \quad \left| \begin{array}{l} f_G \leftarrow 1.0 \\ \text{out} \leftarrow f_G \\ \text{out} \end{array} \right. \\ \text{if Terrain} = 2 \\ \quad \left| \begin{array}{l} f_G \leftarrow 0.71 \ \text{ if } 0 \le V \le 300 \\ f_G \leftarrow 0.93 \ \text{ if } 300 < V \le 600 \\ f_G \leftarrow 0.99 \ \text{ if } V > 600 \\ \text{out} \leftarrow f_G \\ \text{out} \end{array} \right. \\ \text{out} \end{array} \right.$$

From Exhibit 20-7
HCM 2000

$f_G(\text{Terrain}, V) = 1$ $\qquad f_G := f_G(\text{Terrain}, V)$ $\qquad f_G = 1$

9. Calculate forward direction volume (v_d).

Calculations:

$$v_d := \frac{V}{PHF \cdot f_G \cdot f_{HV}}$$

From Equation 20-12
HCM 2000

Since the PHF was already accounted for in Step 5, the following equation is used:

$$v_d := \frac{AdjVol}{f_G \cdot f_{HV}}$$

$v_d = 634.7$ pc/h

Check this value against flow range used for Exhbits 20-10 and 20-8, and repeat steps 6 through 9 as necessary.

10. Calculate opposing direction volume (v_o).

Calculations:

$$v_o := \frac{V_o}{PHF \cdot f_G \cdot f_{HV}}$$

From Equation 20-13
HCM 2000

The "equivalent" is performed by the following equation:

$$v_o := \frac{v_d \cdot (1 - D)}{D}$$

$v_o = 423.2$ pc/h

f_G and f_{HV} are not currently accounted for in the determination of v_o as they are in the HCM 2000 methodology. Additionally, the PHF is assumed to be the same in the off-peak direction.

11. Determine adjustment for % no-passing zones in analysis direction (f_{np}) for HCM Equation 20-15.

Look up value from HCM Exhibit 20-19 (linear interpolation if necessary, by both volume and percent no-passing zone).

Input:

$\text{PostedSpeed} = 55$ $\%NPZ = 50$ $v_o = 423.2$

$FFS := \text{PostedSpeed} + 5$

$FFS = 60$

Calculation:

This example calls for interpolation by %NPZ and volume

$$\text{Interp1} := 2.0 + (\%NPZ - 40) \cdot \left(\frac{2.5 - 2.0}{60 - 40}\right) \qquad \text{Interp1} = 2.25$$

$$\text{Interp2} := 1.3 + (\%NPZ - 40) \cdot \left(\frac{1.6 - 1.3}{60 - 40}\right) \qquad \text{Interp2} = 1.45$$

From Exhibit 20-19 HCM 2000

$$f_{np} := 2.25 - (v_o - 400) \cdot \left(\frac{\text{Interp1} - \text{Interp2}}{600 - 400}\right)$$

$f_{np} = 2.157$

12. Calculate average travel speed (ATS).

Input:

$FFS_d := FFS$	$FFS_d = 60$	from inputs
$v_d = 634.7$	from step 9	
$v_o = 423.2$	from step 10	
$f_{np} = 2.16$	from step 11	

Calculation:

$$ATS_d := FFS_d - 0.00776 \cdot \left(v_d + v_o\right) - f_{np}$$

From Equation 20-5
HCM 2000

$ATS_d = 49.6$ mi/h