HIGHPLAN Computational Methodology

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Dr. Scott Washburn
University of Florida
Transportation Research Center

Two-Lane Methodology

Inputs

Project Properties

Roadway Information:

$AreaType := 2$ 1 = Urbanized, 2 = Transitioning/Urban, 3 = Rural developed, 4 = Rural undeveloped

Highway Data

Roadway Variables:

$NumberofLanes := 2$

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

$PostedSpeed := 50$ mi/h

$SegLength := 4$ mi

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

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

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

$Spacing := 0$ mi

$\%NPZ := 60$

Traffic Variables:

$AADT := 14410$

$K := 0.096$

$D := 0.60$

$PHF := 0.91$

$P_T := 4\%$ Percent trucks

$BaseCapacity := 1700$

$LocalAdjustmentFactor := 1.0$

LOS Computational Steps

1. Calculate Peak and Off-Peak Hour Volumes

$PeakHrVol := AADT \cdot K \cdot D$ $PeakHrVol = 830.0$ veh/h

$OffPeakHrVol := AADT \cdot K \cdot (1 - D)$ $OffPeakHrVol = 553.3$

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

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

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

Left Turn Lane:

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

$\mathrm{LTadj(LeftTurnImpact)} = 0$ $\mathrm{LTadj} := \mathrm{LTadj(LeftTurnImpact)}$ $\mathrm{LTadj} = 0$

Median:

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

$\mathrm{MedAdj(Median)} = 0$ $\mathrm{MedAdj} := \mathrm{MedAdj(Median)}$ $\mathrm{MedAdj} = 0$

Final Adjustment Value for Left Turn Lane and Median:

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

3. Calculate Adjusted Volume (AdjVol)

Note: the PHF is assumed to be the same in the off-peak direction.

$\mathrm{AdjPeakVol} := \dfrac{\mathrm{PeakHrVol}}{\mathrm{PHF} \cdot \mathrm{AdjMedLTL}}$ $\mathrm{AdjPeakVol} = 912$ veh/h

$\mathrm{AdjOffPeakVol} := \dfrac{\mathrm{OffPeakHrVol}}{\mathrm{PHF} \cdot \mathrm{AdjMedLTL}}$ $\mathrm{AdjOffPeakVol} = 608$ veh/h

Calculations for Percent Time Spent Following (PTSF)

4. Determine E_T (Truck passenger car equivalency factor)

Note: '1' indicates analysis direction, '2' indicates opposing direction

$\mathrm{VolIndexLow} := 900$ $\mathrm{valueLow} := 1.0$

$\mathrm{VolIndexHigh} := 1000$ $\mathrm{valueHigh} := 1.0$

From Exhibit 15-18
HCM 2010

Interpolation:

$$E_{T1\_PTSF} := valueLow + (valueHigh - valueLow) \cdot \left(\frac{AdjPeakVol - VolIndexLow}{VolIndexHigh - VolIndexLow} \right)$$

$$E_{T1\_PTSF} = 1.00$$

$VolIndexLow := 600$ $valueLow := 1.2$

$VolIndexHigh := 700$ $valueHigh := 1.0$

Interpolation:

$$E_{T2\_PTSF} := valueLow + (valueHigh - valueLow) \cdot \left(\frac{AdjOffPeakVol - VolIndexLow}{VolIndexHigh - VolIndexLow} \right)$$

$$E_{T2\_PTSF} = 1.18$$

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

Note: All heavy vehicles are considered as trucks in HIGHPLAN

Equation 15-8 HCM 2010

$$f_{HV1\_PTSF} := \frac{1}{1 + P_T \cdot \left(E_{T1\_PTSF} - 1\right)} \qquad f_{HV1\_PTSF} = 1.00$$

$$f_{HV2\_PTSF} := \frac{1}{1 + P_T \cdot \left(E_{T2\_PTSF} - 1\right)} \qquad f_{HV2\_PTSF} = 0.99$$

6. Determine grade adjustment factor (f_G)

From Exhibit 15-16 HCM 2010

$VolIndexLow := 900$ $valueLow := 1.0$

$VolIndexHigh := 1000$ $valueHigh := 1.0$

Interpolation:

$$f_{G1\_PTSF} := valueLow + (valueHigh - valueLow) \cdot \left(\frac{AdjPeakVol - VolIndexLow}{VolIndexHigh - VolIndexLow} \right)$$

$$f_{G1\_PTSF} = 1.00$$

$VolIndexLow := 600$ $valueLow := 0.97$

$VolIndexHigh := 700$ $valueHigh := 0.99$

Interpolation:

$$f_{G2\_PTSF} := valueLow + (valueHigh - valueLow) \cdot \left(\frac{AdjOffPeakVol - VolIndexLow}{VolIndexHigh - VolIndexLow} \right)$$

$f_{G2\_PTSF} = 0.97$

7. Calculate analysis and opposing direction volumes

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

Equation 15-7
HCM 2010

$$v_{d\_PTSF} := \frac{AdjPeakVol}{f_{G1\_PTSF} \cdot f_{HV1\_PTSF}} \qquad v_{d\_PTSF} = 912.1 \quad \text{pc/h}$$

$$v_{o\_PTSF} := \frac{AdjOffPeakVol}{f_{G2\_PTSF} \cdot f_{HV2\_PTSF}} \qquad v_{o\_PTSF} = 630.4 \quad \text{pc/h}$$

8. Determine values of coefficients 'a' and 'b' for HCM Equation 15-10

Note: This table uses opposing demand flow rate (pc/h)

$VolIndexLow := 600 \qquad valueLow := -0.0033$

$VolIndexHigh := 800 \qquad valueHigh := -0.0045$

From Exhibit 15-20
HCM 2010

Interpolation:

$$a := valueLow + (valueHigh - valueLow) \cdot \left(\frac{v_{o\_PTSF} - VolIndexLow}{VolIndexHigh - VolIndexLow} \right)$$

$a = -0.0035$

$VolIndexLow := 600 \qquad valueLow := 0.870$

$VolIndexHigh := 800 \qquad valueHigh := 0.833$

Interpolation:

$$b := valueLow + (valueHigh - valueLow) \cdot \left(\frac{v_{o\_PTSF} - VolIndexLow}{VolIndexHigh - VolIndexLow} \right)$$

$b = 0.8644$

9. Calculate base percent time spent following (BPTSF)

$$BPTSF_d := 100 \cdot \left(1 - e^{a \cdot v_{d\_PTSF}^{\,b}} \right) \qquad BPTSF_d = 71.6$$

Equation 15-10
HCM 2010

10. Determine adjustment for % no-passing zones in analysis direction (f_{np}) for HCM Equation 20-16

$v_{TwoWay} := v_{d\_PTSF} + v_{o\_PTSF}$ $v_{TwoWay} = 1542.5$

$VolIndexLow := 1400$ $valueLow := 25.4$

$VolIndexHigh := 2000$ $valueHigh := 16.0$

From Exhibit 15-21
HCM 2010

Interpolation:

$$f_{np} := valueLow + (valueHigh - valueLow)\cdot\left(\frac{v_{TwoWay} - VolIndexLow}{VolIndexHigh - VolIndexLow}\right)$$

$f_{np} = 23.17$

11. Calculate percent time spent following (PTSF)

$$PTSF_d := BPTSF_d + f_{np}\cdot\left(\frac{v_{d\_PTSF}}{v_{TwoWay}}\right)$$

$PTSF_d = 85.3$

Equation 15-9
HCM 2010

Calculations for Average Travel Speed (ATS)

12. Determine E_T (Truck passenger car equivalency factor)

Note: '1' indicates analysis direction, '2' indicates opposing direction

$VolIndexLow := 900$ $valueLow := 1.3$

$VolIndexHigh := 1000$ $valueHigh := 1.3$

From Exhibit 15-11
HCM 2010

Interpolation:

$$E_{T1\_ATS} := valueLow + (valueHigh - valueLow)\cdot\left(\frac{AdjPeakVol - VolIndexLow}{VolIndexHigh - VolIndexLow}\right)$$

$E_{T1\_ATS} = 1.30$

$VolIndexLow := 600$ $valueLow := 1.7$

$VolIndexHigh := 700$ $valueHigh := 1.6$

Interpolation:

$$E_{T2\_ATS} := valueLow + (valueHigh - valueLow)\cdot\left(\frac{AdjOffPeakVol - VolIndexLow}{VolIndexHigh - VolIndexLow}\right)$$

$E_{T2\_ATS} = 1.69$

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

Note: All heavy vehicles are considered as trucks in HIGHPLAN

Equation 15-4
HCM 2010

$$f_{HV1\_ATS} := \frac{1}{1 + P_T \cdot (E_{T1\_ATS} - 1)} \qquad f_{HV1\_ATS} = 0.99$$

$$f_{HV2\_ATS} := \frac{1}{1 + P_T \cdot (E_{T2\_ATS} - 1)} \qquad f_{HV2\_ATS} = 0.97$$

14. Determine grade adjustment factor (f_G)

From Exhibit 15-9
HCM 2010

$VolIndexLow := 900 \qquad valueLow := 1.0$

$VolIndexHigh := 1000 \qquad valueHigh := 1.0$

Interpolation:

$$f_{G1\_ATS} := valueLow + (valueHigh - valueLow) \cdot \left(\frac{AdjPeakVol - VolIndexLow}{VolIndexHigh - VolIndexLow} \right)$$

$f_{G1\_ATS} = 1.00$

$VolIndexLow := 600 \qquad valueLow := 0.97$

$VolIndexHigh := 700 \qquad valueHigh := 0.98$

Interpolation:

$$f_{G2\_ATS} := valueLow + (valueHigh - valueLow) \cdot \left(\frac{AdjOffPeakVol - VolIndexLow}{VolIndexHigh - VolIndexLow} \right)$$

$f_{G2\_ATS} = 0.97$

15. Calculate analysis and opposing direction volumes

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

Equation 15-3
HCM 2010

$$v_{d\_ATS} := \frac{AdjPeakVol}{f_{G1\_ATS} \cdot f_{HV1\_ATS}} \qquad v_{d\_ATS} = 923.1 \quad \text{pc/h}$$

$$v_{o\_ATS} := \frac{AdjOffPeakVol}{f_{G2\_ATS} \cdot f_{HV2\_ATS}} \qquad v_{o\_ATS} = 643.7 \quad \text{pc/h}$$

16. Determine adjustment for % no-passing zones in analysis direction (f_{np}) for HCM Equation 15-6

$$FFS := PostedSpeed + 5 = 55$$

$VolIndexLow := 600$ $valueLow := 1.6$

$VolIndexHigh := 800$ $valueHigh := 1.1$

From Exhibit 15-15 HCM 2010

Interpolation:

$$f_{np} := valueLow + (valueHigh - valueLow)\cdot\left(\frac{v_{o\_ATS} - VolIndexLow}{VolIndexHigh - VolIndexLow}\right)$$

$$f_{np} = 1.49$$

17. Calculate average travel speed (ATS)

$$ATS_d := FFS - 0.00776\cdot\left(v_{d\_ATS} + v_{o\_ATS}\right) - f_{np}$$

$ATS_d = 41.4$ mi/h

Equation 15-6 HCM 2010

18. Calculate Percentage of Free-Flow Speed (%FFS)

$$\%FFS := \frac{ATS_d}{FFS}\cdot 100$$

$\%FFS = 75.2$

19. Calculate Free-Flow Delay

$$FFDelay := \left(\frac{SegLength}{ATS_d} - \frac{SegLength}{FFS}\right)\cdot 3600$$

$FFDelay = 86.4$ sec/veh

20. Calculate LOS Threshold Delay

$$LOSspeedthresh(AreaType) := \begin{array}{|l} \text{return } 37 \text{ if } AreaType = 1 \\ \text{return } 50 \text{ if } AreaType = 2 \vee AreaType = 3 \vee AreaType = 4 \end{array}$$

$$LOSspeedthresh(AreaType) = 50$$

$$LOSDelay := \left(\frac{SegLength}{ATS_d} - \frac{SegLength}{LOSspeedthresh(AreaType)}\right)\cdot 3600$$

$LOSDelay = 60.2$ sec/veh

21. Calculate v/c ratio

Use the higher volumes between PTSF and ATS, which is ATS in this case

Note: In the software, the v/c ratios are checked to make sure they are not greater than 1.0 before proceeding with the rest of the analysis. If one of the v/c ratios is greater than 1.0, the analysis stops and LOS is set to 'F'.

$$vcratioTwoWay := \frac{v_{d\_ATS} + v_{o\_ATS}}{BaseCapacity \cdot \left(\frac{3200}{1700}\right)} \qquad vcratioTwoWay = 0.49$$

$$vcratioOneWay := \frac{v_{d\_ATS}}{BaseCapacity} \qquad vcratioOneWay = 0.54$$

$$vcratio := \max(vcratioTwoWay, vcratioOneWay) \qquad vcratio = 0.54$$

22. Determine Class

$$ClassCalc(AreaType) := \left| \begin{array}{l} \text{return } 1 \text{ if } AreaType = 4 \\ \text{return } 3 \text{ if } AreaType = 1 \vee AreaType = 2 \vee AreaType = 3 \end{array} \right.$$

$$Class := ClassCalc(AreaType) \qquad Class = 3$$

23. Determine Level of Service

If Class = 1, the lower LOS governs

From Exhibit 15-3 HCM 2010

$$
\text{LosCalc}(\text{Class},\text{PTSF},\text{ATS},\text{FFS}) := \left|
\begin{array}{l}
\text{if Class} = 1 \\
\quad \left| \begin{array}{l}
out_1 \leftarrow \text{"A"} \;\; \text{if PTSF} \le 35 \\
out_1 \leftarrow \text{"B"} \;\; \text{if } 35 < \text{PTSF} \le 50 \\
out_1 \leftarrow \text{"C"} \;\; \text{if } 50 < \text{PTSF} \le 65 \\
out_1 \leftarrow \text{"D"} \;\; \text{if } 65 < \text{PTSF} \le 80 \\
out_1 \leftarrow \text{"E"} \;\; \text{if PTSF} > 80 \\
out_2 \leftarrow \text{"A"} \;\; \text{if ATS} > 55 \\
out_2 \leftarrow \text{"B"} \;\; \text{if } 50 < \text{ATS} \le 55 \\
out_2 \leftarrow \text{"C"} \;\; \text{if } 45 < \text{ATS} \le 50 \\
out_2 \leftarrow \text{"D"} \;\; \text{if } 40 < \text{ATS} \le 45 \\
out_2 \leftarrow \text{"E"} \;\; \text{if ATS} \le 40 \\
out \leftarrow \begin{pmatrix} out_1 \\ out_2 \end{pmatrix}
\end{array} \right. \\
\text{if Class} = 2 \\
\quad \left| \begin{array}{l}
out \leftarrow \text{"A"} \;\; \text{if PTSF} \le 40 \\
out \leftarrow \text{"B"} \;\; \text{if } 40 < \text{PTSF} \le 55 \\
out \leftarrow \text{"C"} \;\; \text{if } 55 < \text{PTSF} \le 70 \\
out \leftarrow \text{"D"} \;\; \text{if } 70 < \text{PTSF} \le 85 \\
out \leftarrow \text{"E"} \;\; \text{if PTSF} > 80 \\
out
\end{array} \right. \\
\text{if Class} = 3 \\
\quad \left| \begin{array}{l}
out \leftarrow \text{"A"} \;\; \text{if } \frac{\text{ATS}}{\text{FFS}} > 0.917 \\
out \leftarrow \text{"B"} \;\; \text{if } 0.833 < \frac{\text{ATS}}{\text{FFS}} \le 0.917 \\
out \leftarrow \text{"C"} \;\; \text{if } 0.750 < \frac{\text{ATS}}{\text{FFS}} \le 0.833 \\
out \leftarrow \text{"D"} \;\; \text{if } 0.667 < \frac{\text{ATS}}{\text{FFS}} \le 0.750 \\
out \leftarrow \text{"E"} \;\; \text{if } 0.583 < \frac{\text{ATS}}{\text{FFS}} \le 0.667 \\
out \leftarrow \text{"F"} \;\; \text{if } \frac{\text{ATS}}{\text{FFS}} \le 0.583 \\
out
\end{array} \right. \\
out
\end{array} \right.
$$

$$\text{LOS} := \max\left(\text{LosCalc}\left(\text{Class}, \text{PTSF}_d, \text{ATS}_d, \text{FFS}\right)\right)$$

$\text{LOS} = \text{"C"}$

Service Volumes Check

From Exhibit 15-3 HCM 2000, for a Class III highway the percent free flow speed (%FFS) threshold for LOS C is 0.75.

Using the procedure documented above, the following results are obtained for the displayed 830 veh/h peak direction service volume.

$$\text{InputAADT} := \text{Round}\left(\frac{830}{K \cdot D}, 10\right) = 14410$$

$ATS_d = 41.351$ mi/h

$FFS = 55$ mi/h

$$\frac{ATS_d}{FFS} = 0.752$$

Thus, the maximum service volume (AADT) for LOS C for the conditions in the example calculations file is ~14,410.

Passing Lane Improvement

If there is a passing lane in the analysis direction, the service volumes will be increased by the proportion of the length of the passing lane (assumed to be 1 mile) to the passing lane spacing, as illustrated below.

$\text{NoPassingSV} := 830$ veh/h

$\text{Spacing} := 2$ miles

$$\text{Improvement} := \frac{1}{\text{Spacing}} = 0.5$$

$$\text{PassingSV} := \text{NoPassingSV} \cdot (1 + \text{Improvement})$$

$\text{PassingSV} := \text{PassingSV} - \text{mod}(\text{PassingSV}, 10)$ * HIGHPLAN rounds down to multiples of 10

$\text{PassingSV} = 1240$ veh/h

Note that the improvement to the service volumes cannot exceed capacity. In other words, the service volume for any level of service is capped at the LOS E service volume for the no-passing lane condition.