11.1 Two-Lane Highways

Two-lane highway operations are characterized by passing maneuvers, formation of platoons within the traffic stream, and delay experienced by trailing vehicles while unable to pass lead vehicles. For increased passing demand, passing capacity decreases due to limited passing opportunities. Quality of service becomes unacceptable even for lower volume-to-capacity (v/c) ratios. Hence, use of volume-to-capacity ratio may not be a good performance measure for two-lane highway analysis. In addition, the v/c ratio calculation for two lane highways is very basic as it is just a flow rate divided by a fixed capacity value. This creates a misleading result as it does not reflect any of the driver behavior present (platooning, inability to maintain desired speed, etc.) on a two-lane highway.

The HCM 2010 manual uses Percent-Time Spent Following (PTSF), Average Travel Speed (ATS), and Percent Free-flow Speed (PFFS) as a measure to assess two-lane highways operations. In general, any segment that is two to three miles from the nearest signalized intersection on rural highways exhibits uninterrupted flow (HCM, 2010). Two-lane highways are classified into Class I, Class II and Class III highways based on wide range of functions. As per the HCM, arterials are considered to be Class I highways, and most collectors and local roads are considered to be Class II. Class III highways are a special case and may be any functional class. Definitions of the three classes are (HCM, 2010):

- **Class I two-lane highways** are highways where motorists expect to travel at relatively high speeds. Two-lane highways that are major intercity routes, primary connectors of major traffic generators, daily commuter routes, or major links in state or national highway networks are generally assigned to Class I. These facilities serve mostly long-distance trips or provide the connections between facilities that serve long-distance trips. Rural Principal Arterials (Functional Class 02 highways) mostly act as Class I highways. Coos Bay-Roseburg Highway-OR 42 (No. 35) is an example of a Class I highway.
- **Class II two-lane highways** are highways where motorists do not necessarily expect to travel at high speeds. Two-lane highways functioning as access routes to Class I facilities, serving as scenic or recreational routes (and not as primary arterials), or passing through rugged terrain (where high-speed operation would be impossible) are assigned to Class II. Class II facilities most often serve relatively short trips, the beginning or ending portions of longer trips, or trips for which sightseeing plays a significant role. Rural Minor Arterials (Functional Class 06 highways) and Rural Major Collectors (Functional Class 07) mostly act as Class II highways. For instance, West Diamond Lake Hwy- OR 230 (No. 233) that connects Crater Lake Hwy (OR 62) and Diamond Lake Hwy (OR 138) primarily serves recreational trips and passes through undeveloped, rugged terrain.
- **Class III two-lane highways** are special cases serving moderately developed areas. They may be portions of a Class I or Class II highway that pass through small towns, unincorporated communities, or developed recreational areas. On such segments, local traffic often mixes with through traffic, and the density of unsignalized roadside access points is noticeably higher than in a purely rural area. Class III highways may also be longer segments passing through more spread-out recreational areas, also with increased roadside densities. Such segments are often accompanied by reduced speed limits that reflect the higher activity level. Any signalized intersections in these areas convert the

section to an urban street and this method no longer applies. Some example sections:

- Gearhart to Warrenton section on Oregon Coast Hwy-US 101 (No. 9)
- Detroit city section on N Santiam Hwy-OR 22 (No. 162)
- Richland city section on Baker – Copperfield Highway-OR 86 (No. 12)

The rural US 101 section from Gearhart to Warrenton is a spread-out recreational area with substantial development along the highway. The Detroit and Richland sections of the highways pass through small towns having speed restrictions, significant road side developments and unsignalized access points.

ATS is a mobility indicator on two-lane highways. PTSF represents the freedom to maneuver and is defined as percent time spent following in platoon behind a slow moving vehicle while unable to pass. PFFS reflects the percent of travel at or near the posted speed limit. On Class I highways, both ATS and PTSF represents quality of service. While, PTSF defines LOS on Class II highways, PFFS is used to define LOS on Class III highways. LOS criteria for two-lane highways are summarized in Exhibit 11-1.

Exhibit 11-1 LOS for Two-Lane Highways

LOS	Class I Highways		Class II Highways	Class III Highways
	ATS (mi/h)	PTSF (%)	PTSF (%)	PFFS (%)
A	>55	≤35	≤40	>91.7
B	>50–55	>35–50	>40–55	>83.3–91.7
C	>45–50	>50–65	>55–70	>75.0–83.3
D	>40–45	>65–80	>70–85	>66.7–75.0
E	≤40	>80	>85	≤66.7

Source: HCM 2010, Exhibit 15-3

The HCM 2010 manual presents only directional segment analysis and that is considered acceptable on ODOT two-lane highway facilities. The capacity of two-lane highways under based conditions is 1,700 passenger cars per hour (pc/h), with a limit of 3,200 pc/h for both directions. For a complete description of the methodology, refer to Chapter 15 of the HCM 2010 Manual.

The PTSF performance measure used in the HCM 2010 manual is difficult to measure in the field. The HCM also recommends use of a surrogate measure, percent followers, defined as the percentage of vehicles in the traffic stream with time headways smaller than 3.0 seconds. However, development of alternative performance measure for two-lane operations has attracted increasing interest. For instance, average travel speed, percent followers, and follower densities are key alternative measures tested for two-lane highway operations.

11.1.1 Follower Density Models for Class I and Class II Highways

The Oregon Department of Transportation (ODOT) has conducted studies to develop alternative LOS criteria for two-lane highway analysis[1]. The studies were based on the framework adopted

[1] Modeling Follower Density on Two-Lane Rural Highways; and Modeling Performance Indicators on Two-Lane Rural Highways: The Oregon Experience

for empirical investigation of two-lane rural highway performance indicators in Montana[2]. The study uses follower density as a performance measure to describe two-lane highways operations. Follower density is the number of followers in a directional traffic stream over a unit length of a highway. Followers are vehicles travelling with headway less than 3.0 seconds (*HCM, 2010*). The argument behind using this performance indicator is that a road with low average daily traffic (ADT) and high PTSF should have a lower LOS than the same road with a higher ADT and equal PTSF[3]. Unlike other performance measures, follower density takes into consideration the effect of the traffic level on highway performance[2]. Generally, density measures are difficult to directly measure in the field, but it can be estimated at point locations from volume and speed measurements from permanent or temporary traffic count detectors.

Similar to the HCM 2010 methodology, the ODOT study developed LOS criteria for Class I and II two-lane highways. The study developed relationships between follower density (veh/mile/lane) and platooning variables for the best statistical significance. Exhibit 11-2 lists the follower density models.

The platooning variables included in the follower density models are:

- Traffic flow in the direction of travel (veh/h),
- Opposing traffic flow (veh/h),
- Percent heavy vehicles (%),
- Percent no-passing zones (%),
- Rolling Terrain[4] (1 = Rolling Terrain, 0 = Otherwise), and
- Mountainous Terrain[5] (1 = Mountainous Terrain, 0 = Otherwise).

Exhibit 11-2 Follower Density Models by Two-Lane Highway Class

Functional Class	Model Form	R^2
Class I Highways	Follower Density = -0.1917 + 0.005953 (Traffic Volume) + 0.0005167 (Opposing Volume) + 0.0006739 (% Heavy Vehicles) + 0.0002392 (% No Passing) + 0.05248 (Rolling Terrain)	0.81
Class II Highways	Follower Density = -0.1784 + 0.006189 (Traffic Volume) - 0.0001607 (Opposing Volume) + 0.0006163 (%Heavy Vehicles) + 0.0006055 (% No Passing) + 0.0168 (Rolling Terrain) + 0.03994 (Mountainous Terrain)	0.75

Follower density acts as a surrogate measure to assess operations of rural two-lane highways. Example 11-1 and 11-2 outlines the application of these procedures. Follower density is most significantly affected by traffic volume and opposing volume. Percent heavy vehicles, percent no-passing zones and terrain type have a much lesser effect. The effect of these variables on

---

[2] Al-Kaisy, A., and Karjala, S. (2008). Indicators of Performance on Two-Lane Rural Highways: Empirical Investigation, Transportation Research Record, No. 2071, pp. 87–97.

[3] Van As, C. (2003).The Development of an Analysis Method for the Determination of Level of Service on Two-Lane Undivided Highways in South Africa. South African National Roads Agency, Pretoria.

[4] Terrain is: Level for grades less than 3% ; Rolling for grades between 3 to 6%; and Mountainous for grades greater than 6 %

Class II highways is somewhat greater than on Class I highways. The overall effect of these variables will not affect the Level of Service unless near a boundary condition. Percent heavy vehicles and terrain type are readily available. Percent no-passing zone data is typically collected from videologs which may be somewhat time consuming, and could be defaulted to a rough estimate such as 25%, 50%, 75% etc. With the help of follower density models and PTSF LOS boundaries, follower density thresholds are established at each LOS category as listed in Exhibit 11-3:

Exhibit 11-3 LOS Criteria by Two-Lane Highway Class

LOS	Class I Highways	Class II Highways
	Follower Density (veh/mile/lane)	**Follower Density (veh/mile/lane)**
A	<= 2	<= 2.5
B	> 2 - 3.5	> 2.5 - 4.0
C	> 3.5 - 6.0	> 4.0 - 6.5
D	> 6.0 - 9.0	> 6.5 - 10.0
E	> 9.0	> 10.0

The HCM 2010 manual emphasized estimation of capacity conditions, especially, for evacuation planning, special event planning, and evaluation of the downstream impacts of incident bottlenecks once cleared. However, use the capacity estimation for judging events, not for a volume-capacity calculation. For a complete description of the capacity estimation, refer to Chapter 15 of the HCM 2010 Manual.

This LOS-based methodology should be used for the analysis of rural state two-lane highways and can be used for county and other jurisdiction roadways. This methodology can be used on a planning analysis basis for corridor plans using AADT, K30 and D30 factors from ATR's to develop 30th highest hour volumes as well as information from databases (i.e. Highway Economic Reporting System (HERS)). Using directional and classification tube counts, analysis can be created for more detailed refinement/facility plans and projects.

For the purposes of reporting, the volume-to-capacity measure should still be shown with the caveats noted in the introductory paragraph of this section for consistency with established mobility targets and design guidelines. This LOS-based measure should be used as a supplement, not as a replacement for v/c ratio. Both measures need to be reported but the follower-density based LOS measure is a better representation of highway performance.

The subject roadways need to be segmented by HCM roadway class, major intersections, passing/climbing lanes, and terrain type. Segments need to be at least two miles from any signalized intersection to avoid platooning effects. Class III segments need to be two lanes, so any two-way left turn lane segments are not included (need to use an urban street methodology for these).

Class I and II sections with resulting poor LOS may indicate that a slow-moving vehicle turnout, passing lane, climbing lane, or multilane section is needed. For passing and climbing lanes and the multilane sections follow the HCM normal procedures. Class III sections with resulting poor LOS may indicate that turn lanes or additional through lanes may be necessary.

Example 11-1 Class I Highway LOS

This example demonstrates the application of follower density based LOS criteria for Class I highway to find the expected LOS in each direction on the two-lane highway segment as described below:

Input Data

- Albany-Corvallis Highway (No. 31), MP 6.41
- Peak hour volume = 1833 veh/h (both directions; 2012 data)
- Directional split (during analysis period) = 63% EB and 37% WB
- PHF = 0.92
- 2 % trucks EB ; 2 % trucks WB
- 1-mile segment length
- 34% no-passing zones EB ; 50% no-passing zones WB
- Level terrain

LOS by Follower Density Model

This highway section is a rural principal arterial (Functional Class 02) which links two major cities (Albany and Corvallis) and is an important commuter corridor. Therefore, this segment is Class I as per the HCM 2010.

For a directional split of 63/37, analysis will be conducted for both 63 % direction of flow and 37 % direction of flow.

> *Follower density model*:
>
> Follower Density = -0.1917 + 0.005953 (Traffic Volume) + 0.0005167 (Opposing Volume) + 0.0006739 (% Heavy Vehicles) + 0.0002392 (% No Passing) + 0.05248 (Rolling Terrain)

LOS criteria:

LOS	Class I Highways
	Follower Density (veh/mile/lane)
A	<= 2.0
B	> 2.0 - 3.5
C	> 3.5 - 6.0
D	> 6.0 - 9.0
E	> 9.0

Analysis on 63 % direction of flow (EB)

Traffic flow rate = volume / PHF = (1833 x 0.63) / 0.92 = 1255 veh/hr

Opposing traffic flow rate = opposing volume / PHF = (1833 x 0.37) / 0.92 = 737 veh/hr

Percent Heavy Vehicles = 2 %

Percent No Passing zone = 34%

Rolling Terrain = 0 as terrain is considered "Level"

Follower Density = -0.1917 + 0.005953 (1255) + 0.0005167 (737) + 0.0006739 (2) + 0.0002392 (34) + 0.05248 (0)

= 7.3 veh/mile/lane

LOS is D for the analysis direction.

Analysis on 37 % direction of flow (WB)

Traffic flow rate = volume / PHF = (1833 x 0.37) / 0.92 = 737 veh/hr

Opposing traffic flow rate = opposing volume / PHF = (1833 x 0.63) / 0.92 = 1255 veh/hr

Percent Heavy Vehicles = 2 %

Percent No Passing zone = 50 %

Rolling Terrain = 0 as terrain is considered "Level"

Follower Density = -0.1917 + 0.005953 (737) + 0.0005167 (1255) + 0.0006739 (2) + 0.0002392 (50) + 0.05248 (0)

= 4.2 veh/mile/lane

LOS is C for the analysis direction.

Example 11-2 Class II Highway LOS

This example demonstrates the application of follower density based LOS criteria for a Class II highway to find the expected LOS in each direction on the two-lane highway segment.

Input Data

- West Diamond Lake Hwy (No. 233) at MP 5.86
- Peak hour volume = 109 veh/h (total in both directions; 2013 data)
- Directional split (during analysis period) = 69 % EB and 31 % WB
- PHF = 0.74
- 26 % trucks EB ; 27 % trucks WB
- 1-mile segment length
- 45% no-passing zones EB ;5% no-passing zones WB
- Rolling terrain

LOS by Follower Density Model

This highway section is a rural minor arterial which serves primarily scenic and recreational destinations (i.e. Crater Lake National Park), passes through rugged terrain, and high travel speeds are not expected in all places. This highway best fits into the HCM Class II designation.

For a directional split of 69/31, analysis will be conducted for both 69 % direction of flow and 31 % direction of flow.

Follower density model:

Follower Density = -0.1784 + 0.006189 (Traffic Volume) - 0.0001607 (Opposing Volume) + 0.0006163 (%Heavy Vehicles) + 0.0006055 (% No Passing) + 0.0168 (Rolling Terrain) + 0.03994 (Mountainous Terrain)

LOS criteria:

LOS	**Class II Highways**
	Follower Density (veh/mile/lane)
A	<= 2.5
B	> 2.5 - 4.0
C	> 4.0 - 6.5
D	> 6.5 - 10.0
E	> 10

Analysis on 69 % direction of flow (EB)

Traffic flow rate = volume / PHF = (109 x 0.69) / 0.74 = 102 veh/hr

Opposing traffic flow rate = opposing volume / PHF = (109 x 0.31) / 0.74 = 46 veh/hr

Percent Heavy Vehicles = 26 %

Percent No Passing zone = 45%

Rolling Terrain = 1 as terrain is considered “Rolling”

Mountainous Terrain = 0 as terrain is considered “Rolling” type

Follower Density = -0.1784 + 0.006189 (102) - 0.0001607 (46) + 0.0006163 (26)
+ 0.0006055 (45) + 0.0168 (1) + 0.03994 (0)
= 0.51 veh/mile/lane

LOS is A for the analysis direction.

Analysis on 31 % direction of flow (WB)

Traffic flow rate = volume / PHF = (109 x 0.31) / 0.74 = 46 veh/hr

Opposing traffic flow rate = opposing volume / PHF = (109 x 0.69) / 0.74 = 102 veh/hr

Percent Heavy Vehicles = 27 %

Percent No Passing zone = 5%

Rolling Terrain = 1 as terrain is considered "Rolling"

Mountainous Terrain = 0 as terrain is considered "Rolling"

Follower Density = -0.1784 + 0.006189 (46) - 0.0001607 (102) + 0.0006163 (27)
+ 0.0006055 (5) + 0.0168 (1) + 0.03994 (0)
= 0.13 veh/mile/lane

LOS is A for the analysis direction.

11.1.2 Class III Highways Methodology

Preliminary models developed for Class III highways were limited because of limited sample size. However, the percent free flow speed (PFFS) LOS measure suggested in the HCM can easily be obtained from field data. Until the Class III model is refined, users are advised to use the HCM 2010 methodology and LOS criteria for Class III highways. Motorists are expected to travel at or near the posted speed limit on these facilities. Neither higher speeds nor concerns about passing restrictions are expected. Instead, the ability to travel near the free flow speed (measured by PFFS) is a LOS measure. The PFFS is the ratio of average travel speed to free-flow speed. The LOS criteria for two-lane Class III highways are shown in Exhibit 11-1. For a complete description of the methodology, refer to Chapter 15 of the HCM 2010 Manual. However, the following steps provide a brief summary of Class III highways methodology.

Step 1: Estimation of FFS

After gathering input data, the first step in the analysis is to find the free flow speed (FFS). The HCM 2010 manual suggests three methodologies to estimated FFS.

- **Direct Field Measurement:** Mean speed of 100 random vehicle speeds at low traffic conditions (i.e., two-way flow rate is less than or equal to 200 veh/h) for each analysis direction.
- **Field Measurements at Higher Flow Rates:** If the observed total flow rate exceeds 200 veh/h, find the mean speed of a random sample of 100 vehicle speeds in each analysis direction. The measured mean speed is then adjusted as (Equation 15-1, HCM 2010):

$$FFS = S_{FM} + 0.00776\left(\frac{v}{f_{HV,ATS}}\right)$$

Where

FFS = free-flow speed (mi/h),

S_{FM} = mean speed of sample (v > 200 veh/h) (mi/h),

v = total demand flow rate (both directions), during period of speed measurements (veh/h),

$f_{HV,ATS}$ = heavy vehicle adjustment factor for ATS, from Equation 15-4 or Equation 15-5.

- **Estimating FFS:** If the field data is not available, FFS can be estimated as (Equation 15-2, HCM 2010):

$$FFS = BFFS - f_{LS} - f_A$$

Where

FFS	=	free-flow speed (mi/h),
$BFFS$	=	base free-flow speed (mi/h),
f_{LS}	=	adjustment for lane and shoulder width (mi/h) (Exhibit 15-7), and
f_A	=	adjustment for access-point density (mi/h) (Exhibit 15-8).

The BFFS is the speed that would be expected on the basis of the facility's horizontal and vertical alignment, if standard lane and shoulder widths were present and there were no roadside access points. A rough estimate of BFFS might be taken as the posted speed limit plus 10 mi/h (HCM, 2010).

Step 2: Demand Adjustment for ATS

Demand volumes in both directions (analysis direction and opposing direction) are converted to flow rates under equivalent base conditions as (Equation 15-3, HCM 2010):

$$v_{i,ATS} = \frac{V_i}{PHF \times f_{g,ATS} \times f_{HV,ATS}}$$

Where

$v_{i,ATS}$	=	demand flow rate i for ATS estimation (pc/h);
i	=	"d" (analysis direction) or "o" (opposing direction);
V_i	=	demand volume for direction i (veh/h);
$f_{g,ATS}$	=	grade adjustment factor, from Exhibit 15-9 or Exhibit 15-10 in HCM 2010
$f_{HV,ATS}$	=	heavy vehicle adjustment factor, from Equation 15-4 or Equation 15-5

Step 3: Estimate the ATS

Average Travel Speed (ATS) is estimated from the FFS, the demand flow rate, the opposing flow rate, and the percentage of no-passing zones in the analysis direction as (Equation 15-6, HCM 2010):

$$ATS_d = FFS - 0.00776\left(v_{d,ATS} + v_{o,ATS}\right) - f_{np,ATS}$$

Where

ATS_d	=	average travel speed in the analysis direction (mi/h);
FFS	=	free-flow speed (mi/h);

$v_{d,ATS}$ = demand flow rate for ATS determination in the analysis direction (pc/h);

$v_{o,ATS}$ = demand flow rate for ATS determination in the opposing direction (pc/h); and

$f_{np,ATS}$ = adjustment factor for ATS determination for the percentage of no-passing zones in the analysis direction, from Exhibit 15-5 in the HCM 2010 manual.

Step 4: Estimate the Percent Free-Flow Speed (PFFS)

PFFS is the ratio of Average Travel Speed (ATS) in the analysis direction and Free Flow Speed (FFS), Equation 15-11, HCM 2010.

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

Step 5: Capacity Estimation

Under base conditions, capacity of two-lane highways in one direction is 1,700 pc/h. However, capacity is limited to 3,200 pc/h for both directions, because of interaction between directional flows. It is important to note that two-lane highways quality of service deteriorates even at low volume-to-capacity ratios (HCM, 2010). For Class III highways, only the ATS-based capacity is computed (Equation 15-12, HCM 2010):

$$c_{dATS} = 1{,}700 f_{g,ATS} f_{HV,ATS}$$

Where

c_{dATS} = capacity in the analysis direction under prevailing conditions based on ATS (pc/h),

$f_{g,ATS}$ = grade adjustment factor, and

$f_{HV,ATS}$ = heavy vehicle adjustment factor.

The adjustment factors in the capacity estimation are based on a flow rate greater than 900 veh/h to avoid an iterative solution. Flow rates of less than 900 veh/h will require iteration. If the directional distribution is other than 50/50 (in level and rolling terrain), the two-way capacity may be more than the 3,200 pc/h limit. If the limit is exceeded, then the base capacity is restricted to 1,700 pc/h in the heaviest demand direction. Capacity in the opposing direction is found by using the directional distribution of opposing flow, with an upper limit of 1,500 pc/h. The capacity estimation is for judging potential bottlenecks caused by high travel periods or special events, not for a volume-to-capacity ratio calculation. Example 11-3 provides an example for assessing LOS on Class III Highways.

Example 11-3 Class III Highway LOS

This example demonstrates the application of follower density based LOS criteria for Class I highway to find the expected LOS in each direction on the two-lane highway segment as described below:

Input Data

- Baker – Copperfield Highway (No. 12), MP 42.27
- Peak hour volume = 104 veh/h (total in both directions; 2010 data)
- Directional split (during analysis period) = 53% EB and 47% EB
- PHF = 0.83
- 24 % trucks EB ; 24 % trucks WB
- 1-mile segment length
- 100% no-passing zones EB ; 100% no-passing zones WB
- Level terrain
- Field measured FFS = 35 mph

LOS by HCM Methodology

This highway segment is a rural major collector (Functional Class 07) and travels through the town of Richland. This will have local traffic mixing with the through traffic, have a higher amount of access points, no signalized intersections, and has reduced speed limits. Since there are no signalized intersections, the two-lane methodology still applies and would be a HCM Class III section.

Step 1: Estimation of FFS

Field measured FFS = 35 mph

Step 2: Demand Adjustment for ATS

Separate analysis is done for both directions. Demand volume is converted to flow rate under equivalent base conditions using (Equation 15-3 in HCM 2010):

$$v_{i,ATS} = \frac{V_i}{PHF \times f_{g,ATS} \times f_{HV,ATS}}$$

Total demand volume in both directions is:

$$V_{\mathrm{EB}} = (104 \times 0.53) = 55 \text{ veh/h}$$

$$V_{\mathrm{WB}} = (104 \times 0.47) = 49 \text{ veh/h}$$

Demand flow rate for both directions is:

$$v_{\mathrm{EB}} = (104 \times 0.53) / 0.83 = 67 \text{ veh/h}$$

$$v_{\mathrm{WB}} = (104 \times 0.47) / 0.83 = 59 \text{ veh/h}$$

Value of $f_{g,ATS}$, and E_T for both directions (see Exhibit 15-11 HCM 2010):

Value	EB	WB

$f_{g,ATS}$	1.00	1.00
E_T	1.9	1.9

Then, $f_{HV ATS}$ is calculated using (Equation 15-4 in HCM 2010) $f_{HV,ATS} = \dfrac{1}{1+P_T(E_T-1)+P_R(E_R-1)}$

$$f_{HV,ATS(EB)} = \frac{1}{1+0.24(1.9-1)} = 0.82$$

$$f_{HV,ATS(WB)} = \frac{1}{1+0.24(1.9-1)} = 0.82$$

Note that the recreational vehicle term P_R is not used since RVs are included in the truck percentage.

Demand adjusted flow rates are:

$$v_{EB,ATS} = \frac{(104\times0.53)}{0.83\times1.00\times0.82} = 81 \text{ pc/h}$$

$$v_{WB,ATS} = \frac{(104\times0.47)}{0.83\times1.00\times0.82} = 72 \text{ pc/h}$$

<u>Step 3: Estimate the ATS</u>

The ATS is estimated using (Equation 15-6 in HCM 2010)

$$ATS_d = FFS - 0.00776(v_{d,ATS} + v_{o,ATS}) - f_{np,ATS}$$

The $f_{np,ATS}$ adjustment factor for no-passing zones is taken from Exhibit 15-15 (HCM, 2010). The adjustment factor is based on a 35-mph FFS, opposing demand flow rate of 81 pc/h EB and 72 pc/h WB, and 100% no-passing zones.

$f_{np,ATS(\mathrm{EB})}$	=	2.4 mi/h
$f_{np,ATS(\mathrm{WB})}$	=	2.4 mi/h

The ATS in each direction of analysis is:

$$ATS_{\mathrm{EB}} = 35.0 - 0.00776(81+72) - 2.4 = 31.4 \text{ mi/h}$$

$$ATS_{\mathrm{WB}} = 35.0 - 0.00776\,(72+81) - 2.4 = 31.4 \text{ mi/h}$$

<u>Step 4: Estimate the Percent Free-Flow Speed (PFFS)</u>

The LOS for Class III facilities is based on PFFS achieved, or ATS/FFS. For this segment PFFS is as follows (Equation 15-11 HCM 2010):

$$PFFS_{\mathrm{EB}} = 31.4/35.0 = 89.7\%$$

$$PFFS_{\mathrm{WB}} = 31.4/35.0 = 89.7\%$$

From Exhibit 11-AA, the LOS for EB direction is B, while the LOS for WB direction is also B.

<u>Step 5: Capacity Estimation</u>

Capacity in the analysis direction under prevailing conditions is given by Equation 15-12 HCM 2010:

$$c_{dATS} = 1{,}700 f_{g,ATS} f_{HV,ATS}$$

The adjustment factors in the capacity estimation ($f_{g,ATS}$, $f_{HV\,ATS}$) are based on a flow rate greater than 900 veh/h. Capacity in either direction is as follows:

$$c_{\mathrm{EB},ATS} = 1{,}700 \times 1.00 \times 1.00 = 1{,}700 \text{ veh/h}$$
$$c_{\mathrm{WB},ATS} = 1{,}700 \times 1.00 \times 1.00 = 1{,}700 \text{ veh/h}$$

The implied values of capacity are

1,700/0.53 = 3,208 veh/h (EB) and

1,700/0.47 = 3,617 veh/h (WB).

As the capacity is limited to 3,200 pc/h, the prevailing capacity would be 3,200 × 1.00 × 1.00 = 3,200 veh/h.

With a 53/47 directional split,

EB capacity would be 3,200 × 0.53 = 1,696 veh/h and,

WB capacity would be 3,200 × 0.47 = 1,504 veh/h.