APPENDIX N

PROCEDURES FOR ESTIMATING HIGHWAY CAPACITY

HPMS SOFTWARE

The procedures used in the HPMS software for determining highway capacity conform to the Highway Capacity Manual 2000 (HCM 2000). The capacity calculations are based on service flow rates for level of service E and are for the peak direction. The capacity coded in HPMS is used for system planning analysis, not project level analysis. The number of peak lanes (number of through lanes used in the peak period in the peak direction) coded in HPMS (Item 87) is used in the procedures for determining capacity. The number of through lanes coded in HPMS (Item 34) is used in the procedures to determine the number of lanes on the facility. The equations for determining the volume/service flow ratio (V/SF) are shown at the end of this Appendix along with tables that contain the data items used in the capacity calculations and in the V/SF ratio.

All references to chapters, tables, etc., are to the HCM. All calculations and values in the Appendix are in English units; i.e., miles per hour (mph), feet, miles, etc. The assumptions made by FHWA for adjustment factors used in the procedures are consistent with the recommended values in the HCM. The reference to the data item value in the procedures indicates the way the data item is coded in the HPMS.

HIERARCHY OF APPLICATION FOR CAPACITY PROCEDURES

Figure 1 presents the decision rules for applying the methodologies of measuring capacity for highway sections. The logic is based on first identifying if the section is on a structure or is a rural unpaved road; and second if it is characterized by "interrupted flow;" that is, a section where traffic is influenced by traffic control devices (signals and stop signs).

If the traffic control device density is below the thresholds (0.5 signals or stop signs per mile), the facility is assumed to be an uninterrupted flow facility. For these, the following definitions apply.

Freeways (Urban and Rural)
For HPMS, the design characteristics, not the functional classification, determine if a section is a freeway ("freeway by design"). The characteristics of a freeway are:

- Four or more through lanes with two-way flow (Data Item 34 >= 4 and Data Item 27 = 2) **OR** two or more through lanes and one-way flow (Data Item 34 >= 2 and Data Item 27 = 1)

- Divided Cross-Section – for sections with two-way traffic flow, median width >= 4 feet (Data Item 57) or with a "positive" or "curbed" barrier (Data Item 56 = 1 or 2) (not applicable for one-way sections) and

- Full Control of Access (Data Item 55 = 1)

Multilane Highways (Urban and Rural)
The main characteristic distinguishing these facilities from freeways is the lack of access control. They

are defined by:

- Partial or no access control (Data Item 55 = 2 or 3) with a Divided Cross-Section (see above under "Freeways") **OR** Full Access Control and Undivided Cross-Section; and

- 4 or more through lanes and two-way operation (Data Item 34 >= 4 and Data Item 27 = 2) **OR** 2 or more through lanes and one-way operation (Data Item 34 = 2 or 3 and Data Item 27 = 1)

Rural Two-Lane Highways
All rural sections that have two through lanes of travel and two-way operation are covered by this method. Most of these sections will not have full access control, though this condition does exist in the HPMS data.

Rural One-Lane, One-Way Highways
This is a rare condition in HPMS, but it does exist.

Rural Three-Lane Highways
These are highways with two through lanes in one direction and one through lane in the opposite direction.

Urban One/Two/Three-Lane Highways
These are highway sections in urban areas that do not meet the traffic control device density requirement for either signals or stop signs. They can either have one-way or two-way traffic flow, as follows:

- One-Way, One-Lane Highways: Data Item 34 = 1 and Data Item 27 = 1;

- Two-Way, 2/3-Lane Highways: Data Item 34 = (2 or 3) and Data Item 27 = 2; and

- Two-Way, One-Lane Highways: Data Item 34 = 2 and Data Item 27 = 1. This is an unusual occurrence but some states code unstriped highways in this manner. For HPMS, it is assumed that these are in fact two-lane highways.
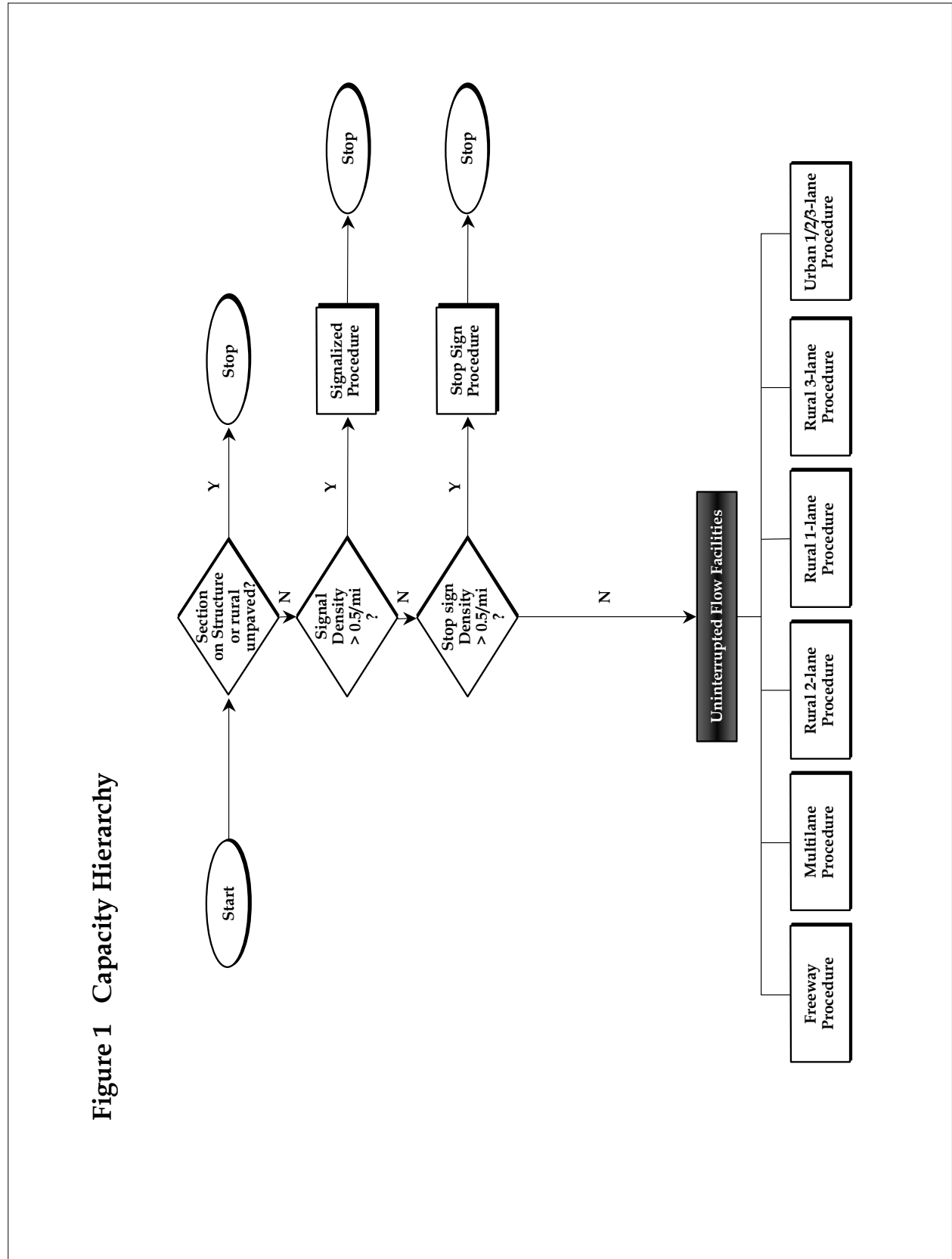
Figure 1. Capacity Hierarchy

FREEWAY CAPACITY

APPLICATION

All highways (rural and urban) that are "freeway by design" use the following procedures. These are facilities with:

- Four or more through lanes with two-way flow (Data Item 34 >= 4 and Data Item 27 = 2) **OR** two or more through lanes and one-way flow (Data Item 34 >= 2 and Data Item 27 = 1)

- Divided Highways – median width >= 4 feet (Data Item 57) or with a "positive" or "curbed" barrier (Data Item 56 = 1 or 2)

- Access-Controlled Highways (Data Item 55 = 1)

PROCEDURE

Step 1: Calculate Free Flow Speed (FFS)

The first step in the procedure is to estimate free flow speed (FFS) of the facility. *HCM* Equation 23-1 is applied directly:

$$FFS = BFFS - f_{LW} - f_{LC} - f_N - f_{ID} \tag{1}$$

Where:

$BFFS$ = base free flow speed
f_{LW} = adjustment factor for lane width
f_{LC} = adjustment factor for right shoulder lateral clearance
f_N = adjustment factor for number of lanes
f_{ID} = adjustment factor for interchange density

Base Free Flow Speed

BFFS is set at 70 mph for urban facilities and 75 mph for rural facilities.

Adjustment Factor for Lane Width (f_{LW})

The values from *HCM* Exhibit 23-4 are used and are directly based on the values of Data Item 54:

Lane Width	Reduction in FFS (mph; f_{LW})
12 ft.	0.0
11 ft.	1.9
<=10 ft.	6.6

Adjustment Factor for Right Shoulder Lateral Clearance (f_{LC})

The values from *HCM* Exhibit 23-5 (shown as Table 1 here) are used and based directly on the values of Data Item 59. The number of lanes in one direction are computed by halving Data Item 34 for two-way facilities or by using Data Item 34 directly for one-way facilities:

Table 1. Influence of Right Shoulder Widths on FFS

Right Shoulder Width	Reduction in FFS (mph; f_{LC})			
	LANES IN ONE DIRECTION			
	2	3	4	>=5
>=6	0.0	0.0	0.0	0.0
5	0.6	0.4	0.2	0.1
4	1.2	0.8	0.4	0.2
3	1.8	1.2	0.6	0.3
2	2.4	1.6	0.8	0.4
1	3.0	2.0	1.0	0.5
0	3.6	2.4	1.2	0.6

Adjustment Factor for Number of Lanes (f_N)

The values from *HCM* Exhibit 23-6 are used and based on the number of lanes in one direction. For two-way operation, the number of lanes in one direction is Data Item 34 divided by 2; for one-way facilities the value of Data Item 34 is used directly. The adjustment is made for urban freeways only; for rural facilities f_N is set to 0:

No. Lanes (One Direction; Urban Only)	Reduction in FFS (mph; f_N)
>= 5	0.0
4	1.5
3	3.0
2	4.5

Adjustment Factor for Interchange Density (f_{ID})

The number of interchanges is no longer available in HPMS. Therefore, an analysis of 1998 HPMS data was done to determine average interchange densities as a function of functional class and area size (Data Item 13, Rural/Urban Designation). For rural sections, interchange density is assumed not to influence free flow speed. The factor is based on the average interchange densities, as found in the 1998 HPMS data, and linear interpolation of the information in *HCM* Exhibit 23-7.

Table 2. Influence of Interchange Density on FFS

Functional Class	Area Size	Interchange Density	Interchange Adj. Factor, (f_{ID})
Urban Interstates	Small Urban	0.70	1.0
	Small Urbanized	0.76	1.3
	Large Urbanized	0.83	1.7
Other Urban Highways Qualifying as Freeways	Small Urban	0.83	1.7
	Small Urbanized	0.88	1.9
	Large Urbanized	0.91	2.1

Step 2: Calculate Base Capacity (*BaseCap*)

The Base Capacity (passenger cars per hour per lane; pcphpl) of a freeway facility is based on information found in *HCM* Exhibit 23-3. The following equations were developed based on this information:

$$BaseCap \quad = \quad 1{,}700 + 10FFS; \text{ for } FFS <= 70 \tag{2}$$

$$BaseCap \quad = \quad 2{,}400; \text{ for } FFS > 70$$

Step 3: Determine Peak Capacity (*PeakCap*)

The *HCM 2000* procedure does not make adjustments to the Base Capacity in order to calculate level of service and performance measures. Instead, adjustments are made to the hourly demand volume. However, for HPMS, the capacity of the segment, in terms of total vehicles per hour (vph), must be computed for a variety of analytic purposes. Therefore, the same factors used in the *HCM 2000* to adjust volume are used to adjust base capacity instead. Essentially, these adjustments convert the units from passenger cars to vehicles and lower capacity to account for the effect of heavy vehicles. The procedure is based on *HCM* Equation 23-2:

$$PeakCap \quad = \quad BaseCap * PHF * N * f_{HV} * f_p \tag{3}$$

Where:

PeakCap	=	HPMS Peak Capacity (Data Item 95), vehicles per hour (all lanes, one direction)
PHF	=	Peak Hour Factor
N	=	Number of lanes in one direction
	=	Number of Peak Lanes (Data Item 87)
f_{HV}	=	Adjustment factor for heavy vehicles
f_p	=	Adjustment factor for driver population

Peak Hour Factor (PHF)

The Peak Hour Factor is used to account for variations in flow within the peak hour. The *HCM 2000* recommends defaults of 0.92 for urban facilities and 0.88 for rural facilities (Chapter 13). It also states that congested facilities have larger values (0.95 is "typical") than uncongested (unsaturated) ones. Clearly, these factors can have a large impact on capacity. However, determining if an HPMS section is congested is in fact a function of first determining its capacity. Therefore, an iterative process is used:

- Set PHF in Equation 3 equal to 1.0; compute peak capacity
- Determine an initial volume-to-capacity ratio (V/C), where:
    - V = AADT * K-Factor * D-Factor (Data Items 33, 85, and 86, respectively, where the K- and D-factors are expressed as decimals)
    - C = Peak Capacity
- Assign a final PHF as follows:

Table 3. PHF Assignment

Area Type	V/C Ratio	PHF
Rural	< 0.7744	0.88
	0.7744<=V/C<=0.9025	Equation (4)
	> 0.9025	0.95
Urban	< 0.8100	0.90
	0.8100<=V/C<=0.9025	Equation (4)
	> 0.9025	0.95

Where: PHF = $(0.9025 * V/C)^{0.5}/0.95$ for special cases above   (4)

Adjustment Factor for Heavy Vehicles (f_{HV})

The adjustment factor for heavy vehicles is based on calculating passenger-car equivalents for trucks and buses. (Recreational vehicles are ignored.) *HCM* Equation 23-3 and Exhibit 23-8 are used:

$$f_{HV} = \frac{1}{1 + P_T(E_T - 1)} \qquad (5)$$

Where:

P_T	=	Proportion of trucks and buses in the traffic stream, expressed as a decimal (e.g., 0.15 for 15%)
	=	(Percent Peak Combination Trucks, Data Item 83 + Percent Peak Single Unit Trucks, Data Item 81)
E_T	=	Passenger-car equivalents
	=	1.5 for all urban freeways
	=	1.5 for rural freeways in level terrain (Data Item 70 = 1)
	=	2.5 for rural freeways in rolling terrain (Data Item 70 = 2)
	=	4.5 for rural freeways in mountainous terrain (Data Item 70 = 3)

Adjustment Factor for Driver Population (f_p)

For Urban Freeways, the driver population factor is set to 1.0 to indicate that drivers are familiar with roadway and traffic conditions (by virtue of the fact that most of the traffic is composed of commuters). On Rural Freeways, the factor is set to 0.975.

MULTILANE HIGHWAY CAPACITY

APPLICATION

The following procedures are applied to rural and urban multilane highways with the following characteristics:

- Partial or no access control (Data Item 55 = 2 or 3) with a Divided Cross-Section (see above under "Freeways") **OR** Full Access Control and Undivided Cross-Section; and

- 4 or more through lanes and two-way operation (Data Item 34 >= 4 and Data Item 27 = 2) **OR** 2-3 through lanes and one-way operation (Data Item 34 = 2 or 3 and Data Item 27 = 1.

PROCEDURE

Step 1: Calculate Free Flow Speed (FFS)

The first step in the procedure is to estimate free flow speed (FFS) of the facility. *HCM* Equation 21-1 is applied directly:

$$FFS \quad = \quad BFFS - f_{LW} - f_{LC} - f_M - f_A \tag{6}$$

Where:

$BFFS$ = base free flow speed

f_{LW} = adjustment factor for lane width

f_{LC} = adjustment factor for lateral clearance

f_M = adjustment factor for median type

f_A = adjustment factor for access points

Base Free Flow Speed

Base Free Flow Speed is based on the coded speed limit (Data Item 80) and guidance from the *HCM 2000*. To be consistent with the *HCM 2000* methodology, the BFFS is not allowed to go below 40 mph or above 70 mph. This conflicts with guidance in the *HCM 2000* which states that the methodology is valid for free flow speeds between 45 mph and 60 mph. However, the *HCM 2000* methodology is geared to estimating performance characteristics, not capacity; for the purpose of capacity, these restrictions were relaxed.

$$BFFS \quad = \quad 40 \text{ mph, for posted speed limits} < 40 \text{ mph} \tag{7}$$

$$= \quad SpeedLimit + 7, \text{ for posted speed limits 40-45 mph}$$

$$= \quad SpeedLimit + 5, \text{ for posted speed limits} >= 50 \text{ mph}$$

Where: *SpeedLimit* is the value for Data Item 80.

Adjustment Factor for Lane Width (f_{LW})

The values from *HCM* Exhibit 21-4 are used and directly based on the values of Data Item 54:

Lane Width	Reduction in *FFS* (mph; f_{LW})
12 ft.	0.0
11 ft.	1.9
<=10 ft.	6.6

Adjustment Factor for Lateral Clearance (f_{LC})

The values from *HCM* Exhibit 21-5 are used and based on computing Total Lateral Clearance (*TLC*) using right and left shoulder widths. Lateral Clearance Left (*LC$_L$*) is computed for divided highways only (Data Item 57 >= 4 or Data Item 56 = 1 or Data Item 56 = 2). In all other cases, such as if a continuous

two-way left turn lane exists (Data Item 88 = 2) or the facility is undivided, then LC_L is set to 6. (The median type adjustment factor accounts for the fact that the roadway is undivided.) Facilities with one-way traffic operation are considered divided highways since there is no opposing flow to interfere with traffic. For one-way facilities, left shoulder width is not coded. Therefore, a value of 6 is assumed for one-way facilities.

$$TLC \quad = \quad LC_R + LC_L \tag{8}$$

Where:

$$LC_R \quad = \quad \text{Data Item 59, maximum value of 6}$$

$$LC_L \quad = \quad \text{Data Item 60, maximum value of 6}$$

Once *TLC* is computed, the values in *HCM* Exhibit 21-5 are used. Linear interpolation is used for intermediate values:

Table 4. Adjustment for Lateral Clearance

4-Lane Two-Way Highways and 2-Lane One-way Highways		6+Lane Two-Way Highways and 3+Lane One-Way Highways	
TOTAL LATERAL CLEARANCE	REDUCTION IN *FFS*	TOTAL LATERAL CLEARANCE	REDUCTION IN *FFS*
12	0.0	12	0.0
10	0.4	10	0.4
8	0.9	8	0.9
6	1.3	6	1.3
4	1.8	4	1.7
2	3.6	2	2.8
0	5.4	0	3.9

Adjustment Factor for Median Type (f_M)

The values from *HCM* Exhibit 21-6 are used and based on whether the facility is divided or undivided. (See definition under Lateral Clearance Adjustment).

Highway Type	Reduction in FFS (mph; f_M)
Undivided	1.6
Divided (including TWLTLs[1])	0.0

Adjustment Factor for Access Points (f_A)

The number of access points per mile is based directly on the values of the number of at-grade intersections with no traffic control devices (Data Item 94) and section length (Data Item 30). In addition, default values for driveways per mile are also assumed. A linear equation was fit to the data in *HCM* Exhibit 21-7 and produces:

$$f_A \quad = \quad MIN((0.25*AccessPointDensity), 10) \tag{9}$$

Where:

AccessPointDensity $\quad = \quad$ (Data Item 94/Data Item 30) + *DrivewayDensity*

DrivewayDensity $\quad = \quad$ 2 for divided highways

$\quad = \quad$ 3 for undivided highways

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[1] Two-Way Left Turning Lanes.

Step 2: Calculate Base Capacity (BaseCap)

The Base Capacity (passenger cars per hour per lane; pcphpl) of a multilane facility is based on information found in *HCM* Exhibit 21-3. The following equations were developed based on this information:

$$BaseCap \quad = \quad 1{,}000 + 20FFS; \text{ for } FFS <= 60 \qquad\qquad (10)$$

$$BaseCap \quad = \quad 2{,}200; \text{ for } FFS > 60$$

Step 3: Determine Peak Capacity (PeakCap)

The *HCM 2000* procedure does not make adjustments to the Base Capacity in order to calculate level of service and performance measures. Instead, adjustments are made to the hourly demand volume. However, for HPMS, the capacity of the section, in terms of total vehicles per hour (vph), must be computed for a variety of analytic purposes. Therefore, the same factors used in the *HCM 2000* to adjust volume are used to adjust base capacity. Essentially, these adjustments convert the units from passenger cars to vehicles and lower capacity to account for the effect of heavy vehicles. The procedure is based on *HCM* Equation 21-3:

$$PeakCap \quad = \quad BaseCap * PHF * N * f_{HV} * f_p \qquad\qquad (11)$$

Where:

$PeakCap$ = HPMS Peak Capacity (Data Item 95), vehicles per hour (all lanes, one direction)

PHF = Peak Hour Factor

N = Number of lanes in one direction

= Number of Peak Lanes (Data Item 87)

f_{HV} = Adjustment factor for heavy vehicles

f_p = Adjustment factor for driver population

= 1.0 for HPMS

Peak Hour Factor (*PHF*)

The Peak Hour Factor is used to account for variations in flow within the peak hour. The *HCM 2000* recommends defaults of 0.92 for urban facilities and 0.88 for rural facilities (Chapter 13). It also states that congested facilities have larger values (0.95 is "typical") than uncongested (unsaturated) ones. Clearly, these factors can have a large impact on capacity. However, determining if an HPMS section is congested is in fact a function of first determining its capacity. Therefore, an iterative process is used:

- Set *PHF* in Equation 6 equal to 1.0; compute peak capacity
- Determine an initial volume-to-capacity ratio (V/C), where:
  - V = AADT * K-Factor * D-Factor (Data Items 33, 85, and 86, respectively)
  - C = Peak Capacity
- Assign a final *PHF* as follows:

Table 5. Final *PHF* Assignment

Area Type	V/C Ratio	PHF
Rural	< 0.7744	0.88
	0.7744<=V/C<=0.9025	Equation (12)
	> 0.9025	0.95
Urban	< 0.8100	0.90
	0.8100<=V/C<=0.9025	Equation (12)
	> 0.9025	0.95

Where: PHF = $(0.9025 * V/C)^{0.5}/0.95$ for special cases above   (12)

Adjustment Factor for Heavy Vehicles (f_{HV})

The adjustment factor for heavy vehicles is based on calculating passenger-car equivalents for trucks and buses. (Recreational vehicles are ignored.) *HCM* Equation 23-3 and Exhibit 23-8 are used:

$$f_{HV} = \frac{1}{1 + P_T(E_T - 1)}$$ (13)

Where:

P_T = Proportion of trucks and buses in the traffic stream, expressed as a decimal (e.g., 0.15 for 15%)

= (Percent Peak Combination Trucks {Data Item 83}) + (Percent Peak Single Unit Trucks {Data Item 81})

E_T = Passenger-car equivalents

= 1.5 for all urban highways

= 1.5 for rural highways in level terrain (Data Item 70 = 1)

= 2.5 for rural highways in rolling terrain (Data Item 70 = 2)

= 4.5 for rural highways in mountainous terrain (Data Item 70 = 3)

RURAL TWO-LANE CAPACITY

BASIC CONCEPTS AND APPROACH

In the *HCM 2000*, capacity is taken as a value that "… is nearly independent of the directional distribution of traffic on a facility, except that for extended lengths of a two-lane highway, the capacity will not exceed 3,200 pc/h for both directions of travel combined." The purpose of the *HCM 2000* procedure is to develop two primary performance measures: average travel speed (ATS) and percent time-spent-following. In computing the ATS, v/c ratio, or other performance measures, adjustments are made to volume while the capacity remains fixed at 3,200 passenger cars per hour (pch).

For HPMS, the procedure for estimating ATS is the better of the two for estimating capacity. Equation 20-5 in the *HCM 2000* relates ATS to FFS, adjusted flow rate, and the no passing zone factor:

$$ATS \quad = \quad FFS - 0.00776V_P - f_{np} \tag{14}$$

Where:

ATS = Average travel speed
V_P = passenger car equivalent flow rate for peak 15-minutes
f_{np} = no passing zone adjustment factor from Table 20-11

FFS is developed from a base (ideal) free flow speed and a flow speed adjusted for lane width, shoulder width, and access points. V_p is the two-way hourly volume adjusted for peak 15-minute flows, grades, and heavy vehicles. These concepts are different from previous versions of the *HCM* where adjustments were made to capacity. However, for use in HPMS and its applications, estimates of capacity are needed. Therefore, the procedure used here is based on adjusting the base capacity for the factors related to V_P and f_{np}. The adjustments for *FFS* are **not** applied to capacity. This avoids double counting when speed and delay methodologies other than those in the *HCM 2000* are applied. (These methods usually relate performance measures directly to volume and capacity.)

APPLICATION

All rural sections that have partial or no access control and two through lanes of travel and two-way operation are covered by this method.

PROCEDURE

For HPMS purposes estimates of capacity are still needed. Therefore, instead of adjusting flow rates, (volumes) capacity will be adjusted by most of the same factors:

$$Two\text{-}Way\ Capacity \quad = \quad (3,200\ pch * PHF * f_G * f_{HV}) - V_{NP} \tag{15}$$

Where:

PHF = Peak Hour Factor
  = 0.88
f_G = Adjustment factor for grades
f_{HV} = Adjustment factor for heavy vehicles
V_{NP} = Volume adjustment for no passing zones

Grade Adjustment Factor (f_G)

HCM Exhibit 20-7 offers values for f_G but only for level and rolling terrain; it is assumed that the steep grades associated with mountainous terrain will be analyzed individually. For HPMS, this is impractical since a section can have multiple grades: determining an average grade may underestimate the impact while selecting the most severe grade may overestimate the impact. As a compromise, f_G values for grades in the 5.5 – 6.5 percent range with a length of 0.5 miles are assumed for mountainous terrain and *HCM* Exhibit 20-13 is used. This results in the factors presented in Table 6. The two-way flow rates in Table 6 are based on adjusting the HPMS AADT value to peak passenger cars and is computed as:

Two-Way Flow Rate = $(AADT * K)/f_{HVD}$ (16)

Where:

$AADT$ = Data Item 33
K = Data Item 85, expressed as a decimal
f_{HVD} = Daily heavy vehicle adjustment factor
  = $1/(1 + 0.5P_T)$
P_T = Percentage of daily trucks
  = (Data Item 82 + Data Item 84) * 0.01

Table 6. Grade Adjustment Factors (f_G) for HPMS

Two-Way Flow Rates			
(PCH)	LEVEL	ROLLING	MOUNTAINOUS
0-600	1.00	0.71	0.57
>600-1,200	1.00	0.93	0.85
>1,200	1.00	0.99	0.99

Adjustment for Heavy Vehicles (f_{HV})

The *HCM 2000* presents two ways of computing passenger car equivalents (pce's) for heavy trucks: one for computing ATS and one for computing percent time-spent-following. For capacity purposes, ATS is considered to be more appropriate. (Percent time-spent-following is more descriptive of driver experience than of physical capacity.) As with grades, mountainous sections are excluded from the default values in the *HCM 2000*. Therefore, for default purposes, pce's for trucks (E_T) is also taken for grades of 5.5 – 6.5 percent and a length of 0.5 miles using *HCM* Exhibit 20-15. This results in the values in Table 7.

Table 7. Passenger Car Equivalents for Trucks (E_T)

Two-Way Flow Rates	Type of Terrain		
(PCH)	LEVEL	ROLLING	MOUNTAINOUS
0-600	1.7	2.5	7.2
>600-1,200	1.2	1.9	7.2
>1,200	1.1	1.5	7.2

Once E_T is found, the adjustment factor for heavy vehicles is computed as:

$$f_{HV} = \frac{1}{1 + P_T(E_T - 1)} \tag{17}$$

Where:

P_T = proportion of trucks (combinations plus single units) from HPMS, expressed as a decimal

= (Percent Peak Combination Trucks, Data Item 83 + Percent Peak Single Unit Trucks, Data Item 81)

E_T = Passenger car equivalents from Table 7.

Note that recreational vehicles are included with single unit trucks in HPMS.

Peak Hour Factor (*PHF*)

The *PHF* represents the variation in traffic flow within an hour. A default value of 0.88 should be used for rural two-lane highways.

Adjustment for Percentage of No-Passing Zones (V_{NP})

This adjustment is used in the *HCM 2000* procedure to compute ATS rather than adjusting flow rate. In Equation 1, f_{np} can be equilibrated to volume simply by dividing by 0.00776. For example, an f_{np} of 2.0 translates to 258 passenger cars. For HPMS, this adjustment can also be made to capacity since it too is in terms of passenger cars:

$$V_{NP} \quad = \quad f_{NP}/0.00776 \tag{18}$$

Where:

$$f_{NP} \quad = \quad \text{values from } HCM \text{ Exhibit 20-11 (given here as Table 8)}$$

HCM Exhibit 20-11 should be entered using values for Two-Way Flow Rate (Equation 18). *HCM* Exhibit 20-11 also requires "% No Passing Zones". This computes as:

$$\% \textit{ No Passing Zones} \quad = \quad 1 - (\text{Data Item 78} * 0.01) \tag{19}$$

Table 8. Adjustment (f_{np}) for Effect of No-Passing Zones on Average Travel Speed on Two-Way Segments

TWO-WAY DEMAND FLOW RATE, VP(PC/H)	Reduction in Average Travel Speed (mi/h) No-Passing Zones (%)										
	0	10	20	30	40	50	60	70	80	90	100
0-100	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
101-300	0.0	0.3	0.6	1.0	1.4	1.9	2.4	2.5	2.6	3.1	3.5
301-500	0.0	0.9	1.7	2.2	2.7	3.1	3.5	3.7	3.9	4.2	4.5
501-700	0.0	0.8	1.6	2.0	2.4	2.7	3.0	3.2	3.4	3.7	3.9
701-900	0.0	0.7	1.4	1.7	1.9	2.2	2.4	2.6	2.7	2.9	3.0
901-1,100	0.0	0.6	1.1	1.4	1.6	1.8	2.0	2.1	2.2	2.4	2.6
1,101-1,300	0.0	0.4	0.8	1.0	1.2	1.4	1.6	1.8	1.9	2.0	2.1
1,301-1,500	0.0	0.3	0.6	0.8	0.9	1.1	1.2	1.3	1.4	1.6	1.7
1,501-1,700	0.0	0.3	0.6	0.7	0.8	1.0	1.1	1.2	1.3	1.4	1.5
1,701-1,900	0.0	0.3	0.5	0.6	0.7	0.9	1.0	1.1	1.1	1.2	1.3
1,901-2,100	0.0	0.3	0.5	0.6	0.6	0.8	0.9	1.0	1.0	1.1	1.1
2,101-2,300	0.0	0.3	0.5	0.6	0.6	0.8	0.9	0.9	0.9	1.0	1.1
2,301-2,500	0.0	0.3	0.5	0.6	0.6	0.7	0.8	0.9	0.9	1.0	1.1
2,501-2,700	0.0	0.3	0.5	0.6	0.6	0.7	0.8	0.9	0.9	1.0	1.0
2,701-2,900	0.0	0.3	0.5	0.6	0.6	0.7	0.7	0.8	0.8	0.9	0.9
2,901-3,100	0.0	0.3	0.5	0.6	0.6	0.7	0.7	0.7	0.7	0.8	0.8
3,101-3,300	0.0	0.3	0.5	0.6	0.6	0.6	0.6	0.6	0.6	0.7	0.7
>3,300	0.0	0.3	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5

Adapted from *HCM* Exhibit 20-11.

RURAL ONE-LANE CAPACITY

APPLICATION

These highways, though rare, do exist in HPMS. They include facilities with both one-way and two-way operation.

PROCEDURE

One-Way Operation

The capacity of these sections should be computed using the procedure for Rural Two-Lane Highways, with the following changes:

- Change the base capacity from 3,200 pch to 1,600 pch

- Compute the one-way flow rate using the same equation as for two-way flow rate; enter all lookup tables and equations labeled for two-way flow rate with this value.

- Assume 100% no passing zones.

The resulting capacity is, by definition, a one-way value.

Two-Way Operation

One-lane highways open to both directions of traffic are extremely rare. For these cases, compute the capacity for one-way operation and divide by 2.

RURAL THREE-LANE HIGHWAY CAPACITY

APPLICATION

These highways have two through lanes in one direction and a single lane in the opposite direction. The through lanes are assumed to cover an extended length and are not auxiliary or truck climbing lanes. (This is consistent with the coding of HPMS data).

PROCEDURE

It is assumed that these highways operate as a multilane undivided facility in the two-lane direction and as a single direction of a rural two-lane facility in the one-lane direction. The two-way capacity (required by HPMS for these facilities) is then the sum of these two separate capacities.

The capacity for the two-lane direction is computed using the Multilane Highway capacity procedure assuming an undivided cross-section. The capacity for the one-lane direction is computed using the procedure for Rural One-Lane, One-Way Highways.

SIGNALIZED INTERSECTION CAPACITY

APPLICATION

Sections that meet the criteria in the hierarchy for signalized intersection density (> .5 /mile) are analyzed using this procedure. For both rural and urban section where Left Turning Lanes (Data Item 88) and Right Turning Lanes (Data Item 89) are missing, a simplified procedure is used (see page N-23). Data Items 88 and 89 are used to identify lane groups, a critical step in the signalized intersection capacity procedure.

Typical Percent Green Time (Data Item 91) and Peak Parking (Data Item 61) are considered optional for the coding of rural sections. However, default values for these data are provided so that if Data Items 88 and 89 are present, the urban procedure may be used.

URBAN PROCEDURE

Signalized Intersection Approach Capacity

For HPMS, the capacity of the entire approach is required, including all movements, primarily for consistency with the speed/delay procedures. Intersection approach capacity is based on *HCM* Equation 16-6:

$$C_A = \sum_i s_i \frac{g_i}{C} \qquad (20)$$

where:

$$C_A \quad = \quad \text{intersection approach capacity}$$

$$s_i \quad = \quad \text{saturation flow rate for lane group } i$$

$$\frac{g_i}{C} \quad = \quad \text{effective green ratio for lane group } i$$

This approach is based directly on the *HCM 2000* principles. When operational analysis is conducted using capacity computed in this way, the *HCM 2000* method takes into account the volumes assigned to each lane group. In HPMS, turning movement volumes are not available; only total intersection approach volume is computed from AADT. Therefore, the volume-to-service flow ratio for HPMS is computed using the total intersection approach capacity and volume, rather than considering the operational characteristics of each lane group individually. The HPMS method therefore assumes that traffic is distributed roughly proportionate to the available lane group capacity (i.e., lane groups are neither under-utilized nor over-utilized). While it is possible that this may result in an overestimation of capacity in some instances, there is currently no basis upon which a realistic adjustment can be made. Further, because lane groups are based on the existence of exclusive turning lanes, there is no reason to suspect some lane groups are underutilized at the expense of others; turning lanes are implemented to handle high turning volumes.

Determining Lane Groups

The *HCM 2000* methodology for signalized intersections is based on determining capacity for individual lane groups. Lane groups take into account intersection geometry and turning movements. Separate lane groups should be identified for:

- Continuous LT lane or 1 + exclusive LT lanes – LT only lane group

- Continuous RT lane or 1 + exclusive RT lanes – RT only lane group

In addition to possible exclusive turning lane groups, it is always assumed that through movements occur at the intersection. This assumption does not account for T-intersections, but no intersection geometry data exist in HPMS that would allow this determination. The maximum number of lane groups for HPMS purposes is three. Table 9 is used in developing lane groups, based on the coding of left and right turning lanes.

Table 9. Determining Lane Groups in HPMS

DATA ITEM 88	DATA ITEM 89	NO. PEAK LANES	LANE GROUPS	NO. LANES IN GROUP
1	1	N/A	Exclusive LT Exclusive Through Exclusive RT	2 N 2
	2, 3		Exclusive LT Exclusive Through Exclusive RT	2 N 1
	4	1, 2	Exclusive LT Shared Through/RT	2 N
		3+	Exclusive LT Exclusive Through Shared Through/RT	2 N- 1 1
	5	N/A	Exclusive LT Exclusive Through	2 N
2,3	1	N/A	Exclusive LT Exclusive Through Exclusive RT	1 N 2
	2, 3		Exclusive LT Exclusive Through Exclusive RT	1 N 1
	4	1, 2	Exclusive LT Shared Through/RT	1 N
		3+	Exclusive LT Exclusive Through Shared Through/RT	1 N- 1 1
	5	N/A	Exclusive LT Exclusive Through	1 N
4	1	1, 2	Shared LT/Through Exclusive RT	Data Item 87 2
		3+	Shared LT/Through Exclusive Through Exclusive RT	1 N– 1 2
	2, 3	1, 2	Shared LT/Through Exclusive RT	N 1
		3+	Shared LT/Through Exclusive Through Exclusive RT	1 N– 1 1
	4	1, 2	Shared LT/Through/RT	N
		3+	Shared LT/Through Exclusive Through Shared RT/Through	1 N– 2 1
	5	1, 2	Shared LT/Through	N
		3+	Shared LT/Through Exclusive Through	1 N– 1
5	1	N/A	Exclusive Through Exclusive RT	N 2
	2, 3	N/A	Exclusive Through Exclusive RT	N 1
	4	1, 2	Shared RT/Through	N
		3+	Shared RT/Through Exclusive Through	1 N– 1
	5	N/A	Exclusive Through	N

Where: N =   Data Item 87

Determining Saturation Flow Rate

A slightly modified version of *HCM* Equation 16-4 is used to determine saturation flow rate:

$$s = s_o N f_w f_{HV} f_g f_p f_{bb} f_a f_{LU} f_{LT} f_{RT} f_{Lpb} f_{Rpb} PHF \tag{21}$$

where:

$s =$ saturation flow rate for subject lane group, expressed as a total for all lanes in lane group (vph);

$s_o =$ base saturation flow rate per lane (pcphpl);

$N =$ number of lanes in lane group;

$f_w =$ adjustment factor for lane width;

$f_{HV} =$ adjustment factor for heavy vehicles in traffic stream;

$f_g =$ adjustment factor for approach grade;

$f_p =$ adjustment factor for existence of a parking lane and parking activity adjacent to lane group;

$f_{bb} =$ adjustment factor for blocking effect of local buses that stop within intersection area;

$f_a =$ adjustment factor for area type;

$f_{LU} =$ adjustment factor for lane utilization;

$f_{LT} =$ adjustment factor for left turns in lane group;

$f_{RT} =$ adjustment factor for right turns in lane group;

$f_{Lpb} =$ pedestrian-bicycle adjustment factor for left-turn movements;

$f_{Rpb} =$ pedestrian-bicycle adjustment factor for right-turn movements; and

$PHF =$ Peak Hour Factor.

Note that the Peak Hour Factor is included in the calculation of saturation flow rate. The *HCM 2000* adjusts volume with this factor, but for HPMS purposes, it is used to adjust saturation flow rate.

Base Saturation Flow Rate, S_O

The base saturation flow rate is set at 1,900 pcphpl.

Adjustment Factor for Lane Width, f_W

The lane width adjustment factor is based directly on the *HCM 2000* procedure:

$$f_W = 1 + \frac{(W - 12)}{30} \tag{22}$$

where:

$$W = \text{Lane Width (Data Item 54); minimum of 8, maximum of 16}$$

Adjustment for Heavy Vehicles, f_{HV}

The heavy vehicle adjustment factor is based directly on the *HCM 2000* procedure, assuming 2 passenger car equivalents for heavy vehicles:

$$f_{HV} = \frac{100}{100 + HV(E_T - 1)} \tag{23}$$

where:

HV	=	percent heavy vehicles
E_T	=	2.0 passenger car equivalents

The percent heavy vehicles factor is the sum of peak combination and single unit trucks (Data Items 81 and 83).

Adjustment for Grade, f_g

For HPMS purposes, f_g is set to 1.0 because of the lack of grade information on urban minor arterials and collectors.

Adjustment for Parking, f_p

The calculation of the parking adjustment factor is:

$$f_p = \frac{N - 0.1 - \dfrac{18 N_m}{3{,}600}}{N} \tag{24}$$

where:

f_p	=	parking adjustment factor
N	=	number of lanes in group
N_m	=	number of parking maneuvers per hour
	=	6 for two-way streets with parking one side
	=	12 for two-way streets with parking both sides or one-way streets with parking one side
	=	24 for one-way streets with parking on both sides (based on *HCM* Exhibit 10-20).

The parking factor is applied only to lane groups that are immediately adjacent to parking spaces. For two-way streets or one-way streets with parking on one side, this is assumed to occur in the right-most lane group; this will be either an exclusive right-turn lane or a lane with shared movements. For one-way streets with parking on both sides, the parking factor adjustment is made for the left-most **and** the right-most lane groups.

When parking is not allowed or unavailable (Data Item 61 = 3), f_p is set to 1.0. It is also set to 1.0 if Data Item 61 = 0.

Adjustment for Bus Blockage, f_{bb}

For HPMS, f_{bb} is set to 1.0. No data exist in HPMS as to the occurrence of bus routes. Further, the default values in the *HCM 2000* for bus maneuvers lead to adjustment factors close to 1.0.

Type of Area Adjustment, f_a

Area type is no longer coded in HPMS. An analysis of 1998 HPMS showed that 9 percent of urban signalized intersections were located in CBDs. The *HCM 2000* indicates that f_a should be 0.9 in CBDs, 1.0 elsewhere. Weighting these values with the findings from the 1998 HPMS data provides a value of 0.991 for f_a for urban conditions. A value of 1.0 is used for rural conditions.

Lane Utilization Adjustment, f_{LU}

The *HCM 2000* states that: "As demand approaches capacity, the analyst may use lane utilization factors [close] to 1.0, which would indicate a more uniform use of the available lanes and less opportunity for drivers to freely select their lane" (*HCM* page 10-26). Because the purpose of this factor in HPMS is to estimate capacity rather than perform an analysis of an individual intersection, a lane utilization adjustment factor of 1.0 is used. This will avoid underestimating capacity in investment analysis where demand volumes are forecast for a long time horizon (usually 20 years).

Adjustment for Left Turns, f_{LT}

Left turns are a major determinant of intersection approach capacity, yet only limited data are available in HPMS for conducting capacity analyses. The *HCM 2000* identifies six cases, as shown in Table 10. The adjustment factor for left turns is applied only if left turns are made from the lane group; this determination is made by checking the coding of Data Item 88, also as shown in Table 10.

Table 10. *HCM 2000* Left Turn Adjustment Cases as Applied to HPMS

LT Adjustment Case	Data Item 88	Functional Class	f_{LT}
1. Protected Phasing, Exclusive LT	1, 2, 3	All Arterials; Rural Major Collectors	$f_{LT} = 0.95$
2. Permitted Phasing, Exclusive LT	1, 2, 3	Rural Minor Collectors; Urban Collectors	(see below)
3. Protected/Permitted Phasing, Exclusive LT	N/A	N/A	N/A
4. Protected Phasing, Shared LT	4	Principal Arterials	$f_{LT} = \dfrac{1}{1.0 + 0.05 P_{LT}}$ $(P_{LT} = 0.10)$
5. Permitted Phasing, Shared LT	4	Minor Arterials; All Collectors	(see below)
6. Protected/Permitted Phasing, Shared LT	N/A	N/A	N/A

A major assumption here is that the phasing is determined by functional class; higher order facilities are

assumed to have protected phasing.

Note that Protected/Permitted Phasing is assumed to not exist because of lack of information on signal phasing in HPMS. For Case 4, P_{LT} is the proportion of left turns in the lane group. As recommended in the *HCM 2000*, a default value of 10 percent is used for HPMS (*HCM* page 10-19).

If left turns are not made from the lane group, the left turn adjustment factor is set to 1.0.

Special Procedure for Permissive Left Turns

The permissive left turn procedure in the *HCM 2000* is highly complex and dependent on many variables not present in the HPMS data (Appendix C, *HCM* Chapter 16). The new procedure is substantially more complex than those in previous versions of the *HCM*. For HPMS purposes, the procedure from the 1994 edition of the *HCM* is used because it is more compatible with the available data in HPMS:

$$f_{LT} = (1400-V_o)/[(1400-V_o)+(235+0.435*V_o)*P_{LT}] \text{ for } V_o <= 1,220 \text{ vph} \quad (25)$$

$$= 1/(1+(4.525*P_{LT})) \text{ for } V_o > 1,220 \text{ vph}$$

Where: V_o = AADT $* K * (1 – D)$; this is the opposing flow in the off peak direction

AADT = annual average daily traffic, (Data Item 33)

K = K-factor, (Data Item 85) expressed as a decimal

D = the directional factor for the peak direction, (Data Item 86) expressed as a decimal

P_{LT} = proportion of left turns; assume proportion of left turns is 10 percent

Adjustment for Right Turns, f_{RT}

The adjustment factor for right turns is applied only if right turns are made from the lane group. The right turn adjustment factor is based on the coding of HPMS Data Item 89 as follows:

$$f_{RT} = 0.85 \text{ (for Data Item 89 = 1, 2, or 3)} \quad (26)$$

$$= 1.0 – 0.15 P_{RT} \text{ (for Data Item 89 = 4)}$$

where:

$$P_{RT} = \text{proportion of right turns in the lane group}$$

$$= 0.10 \text{ (HCM, page 10 - 19)}$$

If right turns are not made from the lane group, the right turn adjustment factor is set to 1.0.

Adjustment for Pedestrian-Bicycle Blockage on Left Turns, f_{Lpb}

As with permissive left turns, calculation of the adjustment factor for pedestrians and bicycles is complex and requires extensive inputs, most of which are unavailable in HPMS. Further, pedestrian/bicycle blockage is likely to have a major impact only in densely developed areas and these conditions can no longer be determined from HPMS data. Therefore, for the purpose of HPMS, f_{Lpb} is set to 1.0.

Adjustment for Pedestrian-Bicycle Blockage on Right-Turns, f_{Rpb}

Based on the same conditions as for pedestrian-bicycle blockage on left turns, f_{Rpb} is set to 1.0.

Peak Hour Factor (*PHF*)

As discussed on *HCM* page 10-8, a default value of 0.92 is used for the PHF for urban sections. For rural sections, the PHF is set to 0.88.

Effective Green Ratios (*g*$_i$*/C*) for Lane Groups

The following values are used for the various types of lane groups. They are based on the coded value for HPMS Data Item 91 (Typical Peak Percent Green Time), which applies to the through movement only. For all lane groups except for exclusive left turn lane groups, the value for Data Item 91 is used for g_i/C. (This assumes that an exclusive signal phase for right turns coincides with the through movement phase.) For Exclusive Left Turn Lane Groups, the green ratio is a function of the green ratio for the through movement (Data Item 91). A distinction is made for low and high values for through green ratio:

For *g/C* <= 0.65

$$g_{LT}/C \quad = \quad 0.35*g/C \quad \text{for principal arterials} \tag{27}$$

$$= \quad 0.25*g/C \quad \text{for all other highway types}$$

For *g/C* > 0.65

$$g_{LT}/C \quad = \quad 0.5*(1 - g/C) \quad \text{(all highways)} \tag{28}$$

where: g/C =   green ratio for through movement (Data Item 91).

If Data Item 91 is missing, g/C default values of 0.45 for arterials and 0.40 for collectors are used (*NCHRP 387*, Table 9-3).

SIMPLIFIED PROCEDURE FOR RURAL SIGNALIZED INTERSECTION CAPACITY AND URBAN SECTIONS WITH MISSING DATA

APPLICATION

In the coding of HPMS data, several data items required for applying the urban signalized capacity analysis are either "optional" or not required for rural sections. The data items of interest for capacity calculations, since they are used to identify lane groups, are:

- Data Item 88: Left Turning Lanes
- Data Item 89: Right Turning Lanes.

PROCEDURE

Although some states do code these items for rural sections, a provision must be made to handle cases where the data are not present; this could also be true for some urban sections. In the cases where rural signalized sections have nonzero values coded for these data items, the signalized intersection capacity is used. When these data are coded as zero, the following procedure is used:

$$C_A \quad = \quad 1{,}900 * N * f_w * f_{HV} * PHF * g/C \tag{29}$$

where:

C_A =   intersection approach capacity

N	=	number of lanes on the segment (one direction)
	=	Data Item 87 (Number of Peak Lanes)
f_w	=	adjustment factor for lane width (use Equation 22)
f_{HV}	=	adjustment factor for heavy vehicles (use Equation 23)
PHF	=	Peak Hour Factor
	=	0.88 for rural conditions, 0.92 for urban conditions
g/C	=	effective green time-to-cycle length ratio
	=	0.55 for principal arterials
	=	0.45 for minor arterials
	=	0.40 for collectors

The g/C ratio default values given above attempt to account for, in a general way, the presence of exclusive turn lanes and phases. These values are higher than the default values listed in Table 9-3 of *NCHRP 387* (0.40-0.45) but those values consider only through movement capacity.

STOP SIGN-CONTROLLED HIGHWAY CAPACITY

APPLICATION

All highways that have at least one stop sign and meet the density requirement (> .5/mile) on the inventory route.

PROCEDURE

The *HCM 2000* procedure for stop sign-controlled intersections is complex and highly dependent on turning movements on all the approaches. Procedures also vary for two-way controlled intersections versus all-way controlled intersections. None of these data are present in HPMS. Therefore, a highly simplified method is recommended. It is based on the *HCM 2000* procedure for two-way controlled intersections. This is the simpler and less data intensive of the two methods.

The procedure is based on first calculating the potential capacity for each turning movement. (It is assumed that the potential capacity is equal to the "movement capacity", and none of the *HCM 2000* procedures for converting potential capacity to movement capacity are used.) Where shared lanes exist for turning movements, an extra calculation is required to derive the potential (movement) capacity of the shared lane. This step combines the potential capacities for two or three turning movements (depending on the lane configuration) into a single potential capacity. The final capacity of the stop sign-controlled approach is then the sum of all the potential capacities calculated for the turning movements.

Step 1: Calculate Potential Capacity of Each Turning Movement

The procedure starts with *HCM* Equation 17-3. It first calculates the potential capacity for each of the movements on the stop sign-controlled approach:

$$C_{p,x} = CV_{c,x} \frac{e^{-V_{c,x}t_{c,x}/3600}}{1-e^{-V_{c,x}t_{f,x}/3600}}$$

(30)

Where:

$C_{p,x}$	$=$	potential capacity of movement x (vph)
$CV_{c,x}$	$=$	conflicting flow rate for each movement x (vph); Table 12
$t_{c,x}$	$=$	critical gap (seconds) for each movement x
	$=$	$t_{c,base} + (P_{HV} * t_{c,HV})$
$t_{c,base}$	$=$	default values from Table 11
$t_{c,HV}$	$=$	1.0 for one or two-through lane roads (Data Item 34 <= 2)
	$=$	2.0 otherwise
P_{HV}	$=$	percent of heavy vehicles in traffic stream, peak period, expressed as a decimal
$t_{f,x}$	$=$	follow-up time (seconds) for each movement x
	$=$	$t_{f,base} + (P_{HV} * t_{f,HV})$
$t_{f,HV}$	$=$	0.9 for one or two-through lane roads (Data Item 34 <= 2)
	$=$	1.0 otherwise

Table 11. Default Values for Calculating Potential Capacities ($C_{p,x}$) of Stop Sign-Controlled Highways

Vehicle Movement (x)	Base Critical Gap, $t_{c,base}$	Follow-up Time, $t_{f,base}$
Right Turns	6.2	3.3
Through	6.5	4.0
Left Turns	7.1	3.5

Table 12. Default Values for Conflicting Flow Rates

Functional Class	Conflicting Flow Rate, $CV_{c,x}$
Rural Principal Arterials	100
Rural Minor Arterials	150
Other Rural	200
Urban Principal Arterials	250
Urban Minor Arterials	500
Other Urban	750

Clearly, the major assumption in this Step is that of the conflicting volumes. Basically, it is assumed that the intersection is composed of a higher class facility in one direction and a lower class facility in the other. Many stop sign-controlled intersections, particularly those with all-way control, are comprised of

similar class facilities intersecting. However, without detailed knowledge of such occurrences, the assumption is a reasonable default.

Step 2: Determine Approach Capacity

Several adjustments to potential capacity are defined in the *HCM 2000* in order to derive "movement capacity". Most of the adjustments are based on knowledge of turning movements on and the geometry of all approaches of the intersection. Since none of these data are available in HPMS, major assumptions would be required. ***As an alternative, the movement capacity is set equal to potential capacity for most cases, except for shared lanes.*** The adjustment for shared-lane capacity is essential for calculating intersection approach capacity. *HCM* Equation 17-15 is used in these cases:

$$C_{p,SH} = \frac{\sum_x V_x}{\sum_x \left(\dfrac{V_x}{C_{p,x}} \right)} \tag{31}$$

Where:

$C_{p,SH}$ =   potential capacity of the shared lane (vph)

V_x =   flow rate of the *x* movement in the shared lane (vph)

$C_{p,x}$ =   potential capacity of the *x* movement in the shared lane (vph) from Equation 1.

Volumes for the turning movements on the intersection approach in question must be made in order to apply Equation 30. It is assumed that 10 percent of the approach volume is composed of left-turning vehicles and 10 percent composed of right turning vehicles (recommended defaults from Chapter 10 of *HCM 2000*). Total approach volume is calculated as:

   Approach Volume =   AADT * (K * 0.01) * (D * 0.01)   (32)

Where:

   AADT   =   Data Item 33

      K   =   Data Item 85

      D   =   Data Item 86

            =   MIN(70, Data Item 86)

Values for V_x are then computed for left turns, through movements and right turns by applying the assumed turning percentages to the approach volume: 10%, 80%, and 10%, respectively.

The number of lanes handling turning movements on the approach are then determined. This is based on Data Items 88 and 89 (Left and Right Turning Lanes) for urban sections and for rural sections where these data are coded.   Table 3 shows how to handle each of the possible cases. The approach capacity is based on Equation 30 for nonshared lanes and Equation 31 for shared lanes. In some cases both terms are used. Note that C_A is adjusted to account for the number of lanes handling each movement. Where HPMS indicates "multiple" turning lanes, it is assumed that two such lanes exist. ***For rural sections – or for any sections where Data Items 88 and 89 are coded as zero – it is assumed that no exclusive left turn or right turn lanes exist.***

Table 13. Determining Stop Sign-Controlled Intersection Approach Capacity (C_A)

Left Turning Bay/Lanes Coding (Data Item 88)	Right Turning Bay/Lanes Coding (Data Item 89)	Approach Capacity Calculation, C_A (vph)
0, 4	0, 4	All movements made from a shared lane; $C_A = N_T C_{p,SH}$
	1, 2, 3	Shared LT + T lane; exclusive RT lane; $C_A = N_T C_{p,SH(LT+T)} + N_{RT} C_{p,RT}$
	5	Do not consider right turn volumes; $C_A = N_T C_{p,SH(LT+T)}$
1, 2, 3	0, 4	Shared RT + T lane; exclusive LT lane $C_A = N_T C_{p,SH(RT+T)} + N_{LT} C_{p,LT}$
	1, 2, 3	Exclusive lanes for all movements; $C_A = N_{LT} C_{p,LT} + N_T C_{p,T} + N_{RT} C_{p,RT}$
	5	Do not consider right turn volumes; $C_A = N_{LT} C_{p,LT} + N_T C_{p,T}$
5	0, 4	Do not consider left turn volumes $C_A = N_T C_{p,SH(RT+T)}$
	1, 2, 3	Do not consider left turn volumes $C_A = N_T C_{p,T} + N_{RT} C_{p,RT}$
	5	Consider only through volumes $C_A = N_T C_{p,T}$

Where:

N_T = Number of Peak Through Lanes

= 1 for rural highways with 2 through lanes

= 2 for rural highways with 3 through lanes

= Data Item 87 otherwise

N_{LT} = Number of Left Turn Lanes

= 2 if Data Item 88 = 1

= 1 if Data Item 88 = (2,3)

= 0 otherwise

N_{RT} = Number of Right Turn Lanes

= 2 if Data Item 89 = 1

= 1 if Data Item 89 = (2,3)

= 0 otherwise

$C_{p,SH}$ = potential capacity of the shared lane (vph) from Equation 31 (the terms in parentheses indicate which movements are being handled by the shared lane, e.g., "LT+T" means that left turns and through movements share the lanes

$C_{p,T}$ = potential capacity (assumed to be the movement capacity from Equation

30) for the through movement

$C_{p,RT}$	=	potential capacity (assumed to be the movement capacity from Equation 30) for the right turn movement
$C_{p,LT}$	=	potential capacity (assumed to be the movement capacity from Equation 30) for the left turn movement

Step 3: Set Peak Capacity to Approach Capacity

For HPMS, the Peak Capacity of the section is then based on the approach capacity of the stop sign-controlled intersection analyzed above. For urban sections, since the HPMS definition of urban capacity is one-way, the Peak Capacity is set equal to the approach capacity. For rural sections, it is based on the total number of through lanes (Data Item 34). This is done to account for the definition of capacity for 2- and 3-lane sections in HPMS, which is two-way capacity.

Rural 4+ through lanes

Peak Capacity = Approach Capacity

Rural 3-through lanes

Peak Capacity = Approach Capacity * 1.67 (assumes that the direction with two lanes is the inventory direction)

Rural 2-through lanes

Peak Capacity = Approach Capacity * 2

URBAN ONE/TWO/THREE LANE HIGHWAY CAPACITY

APPLICATION

These are used on highway sections in urban areas that do not meet the traffic control device density requirement for either signals or stop signs. They can either have one-way or two-way traffic flow, as follows:

- One-Way, One-Lane Highways: Data Item 34 = 1 and Data Item 27 = 1;

- Two-Way, 2/3-Lane Highways: Data Item 34 = (2 or 3) and Data Item 27 = 2; and

- Two-Way, One-Lane Highways: Data Item 34 = 2 and Data Item 27 = 1. This is an unusual occurrence but some states code unstriped highways in this manner. For HPMS, it is assumed that these are in fact two-lane highways. In these cases, lane width is determined as the larger of: (Data Item 54 divided by 2) or seven feet.

Many urban sections in HPMS with 1-3 lanes do not have traffic control devices present on the actual section. However, it is possible that these sections are influenced by traffic control devices upstream and downstream of the section. One approach to capacity estimation for these sections is to assume that the capacity is controlled by "off-section" traffic control devices, probably signals. This approach would use the simplified procedure for calculating signalized intersection capacity since the data required for the detailed procedure are lacking. The other approach is to assume that capacity is strictly a function of the section's characteristics, not off-section traffic control devices. Three reasons exist for using the latter

assumption. First, it is consistent with the HPMS philosophy of using the coded data to the maximum extent possible. Second, states can provide capacity estimates directly if off-section traffic control devices exert a major influence on the section's capacity. Third, even if off-section traffic control devices exist, the spacing of these may be large enough that they don't affect the section's capacity. For these reasons, it assumed that these sections are not under the influence of traffic control devices.

PROCEDURE

The recommended procedure is based on the adjusted saturation flow rate step from the Signalized Intersection procedure:

$$Capacity = s_o N f_w f_{HV} f_p f_a PHF \tag{33}$$

where:

s_o = base saturation flow rate per lane (pcphpl);

N = number of peak lanes (Data Item 87);

f_w = adjustment factor for lane width;

f_{HV} = adjustment factor for heavy vehicles in traffic stream;

f_p = adjustment factor for existence of parking activity;

f_a = adjustment factor for area type;

PFH = Peak Hour Factor.

Base Saturation Flow Rate, S_O

The base saturation flow rate is set at 1,900 pcphpl.

Adjustment Factor for Lane Width, f_W

The lane width adjustment factor is based directly on the *HCM 2000* procedure:

$$f_W = 1 + \frac{(W - 12)}{30} \tag{34}$$

where:

W = Lane Width (Data Item 54); minimum of 8, maximum of 16

Adjustment for Heavy Vehicles, f_{HV}

The heavy vehicle adjustment factor is based directly on the *HCM 2000* procedure, assuming 2 passenger car equivalents for heavy vehicles:

$$f_{HV} = \frac{100}{100 + HV (E_T - 1)} \tag{35}$$

where:

HV = percent heavy vehicles

E_T = 2.0 passenger car equivalents

The percent heavy vehicles factor is the sum of peak combination and single unit trucks (Data Items 81 and 83).

Adjustment for Parking, f_p

The calculation of the parking adjustment factor is:

$$f_p = \frac{N - 0.1 - \dfrac{18\,N_m}{3{,}600}}{N} \tag{36}$$

where:

f_p	=	parking adjustment factor
N	=	number of lanes in lane group
N_m	=	number of parking maneuvers per hour
	=	6 for two-way streets for parking on one side
	=	12 for two-way streets with parking on both sides or one-way streets with parking on one side
	=	24 for one-way streets with parking on both sides (based on *HCM* Exhibit 10 - 20)

When parking is not allowed or unavailable (Data Item 61 = 3), f_p is set to 1.0. It is also set to 1.0 if Data Item 61 = 0.

Adjustment for Area Type

Area type is no longer coded in HPMS. An analysis of 1998 HPMS showed that 9 percent of urban signalized intersections were located in CBDs. The *HCM 2000* indicates that f_a should be 0.9 in CBDs, 1.0 elsewhere. Weighting these values with the findings from the 1998 HPMS data provides a value of 0.991 for f_a for urban conditions.

Peak Hour Factor

As discussed on *HCM* page 10-8, a default value of 0.92 is used for the PHF for urban sections.

HPMS DATA ITEMS USED IN CAPACITY CALCULATIONS

Item Number	Description	Item Number	Description
17	Functional System	80	Speed Limit
27	Type of Facility	81	Percent Peak Single Unit Trucks
30	Section Length	82	Percent Average Daily Single Unit Trucks
33	AADT	83	Percent Peak Combination Trucks
34	Number of Through Lanes	84	Percent Average Daily Combination Trucks
54	Lane Width	85	K Factor
55	Access Control	86	Directional Factor
56	Median Type	87	Number of Peak Lanes
57	Median Width	88	Left Turning Lanes
59	Right Shoulder Width	89	Right Turning Lanes
60	Left Shoulder Width	91	Typical Peak Percent Green Time
61	Peak Parking	92	Number At-Grade Intersections - Signals
70	Type of Terrain	93	Number At-Grade Intersections - Stop Signs
78	Percent Passing Sight Distance - **Rural**	94	Number At-Grade Intersections - Other /No Control

VOLUME/SERVICE FLOW RATIO (V/SF)

The volume-to-service flow (capacity) ratio is determined for each paved rural sample section and all urban sample sections. It is used as a measurement for congestion. The equations to determine the volume-to-service flow ratio are by type of facility. V/SF is not calculated for a sample section that is entirely on a structure (HPMS, Item 27 = 3,4).

Rural two- or three-lane facility:
$$V/SF = (AADT \text{ (HPMS, Item 33)} \ * \ K\text{-factor (HPMS, Item 85))} \ / \ Peak \ Capacity$$
(HPMS, Item 95)

Rural Multilane and All Urban facilities:

$$V/SF = (AADT \text{ (HPMS, Item 33)} \ * \ K\text{-Factor (HPMS, Item 85)} \ * \ Directional \ Factor$$
(HPMS, Item 86)) / Peak Capacity (HPMS, Item 95)

HPMS DATA ITEMS USED IN V/SF RATIO

Item Number	Description
33	AADT
85	K-Factor
86	Directional Factor
95	Peak Capacity