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Traffic Data Computation Method

POCKET GUIDE

U.S. Department of Transportation
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NOTICE

QUALITY ASSURANCE STATEMENT

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Abbreviations

AACR	Annual Average Change Rate
AADT	Annual Average Daily Traffic
AADTT	Annual Average Daily Truck Traffic
AASHTO	American Association of State Highway and Transportation Officials
ACF	Axle Correction Factor
ADT	Average Daily Traffic
BS	Bus
CBD	Central Business District
CU	Combination Unit Truck
CTR	Centerline Turning Radius
CCS	Continuous Count Station
DDHV	Directional Design Hourly Volume
DH	Design Hour
DHV	Design Hour Volume
DOW	Day of Week
DSFL	Design Service Flow Rate
DVDT	Daily Vehicle Distance Traveled
DVMT	Daily Vehicle Miles Traveled
ESAL	Equivalent Single Axle Load
FFS	Free Flow Speed
FHWA	Federal Highway Administration
GVW	Gross Vehicle Weight
HCM	Highway Capacity Manual
HPMS	Highway Performance Monitoring System
HV	Heavy Vehicle
LOS	Level of Service
LR	Load Range
LT	Light Truck Over 102”
MADT	Monthly Average Daily Traffic
MADTT	Monthly Average Daily Truck Traffic
MADW	Monthly Average Day of the Week
MAWDT	Monthly Average Weekday Daily Traffic

MAWDTT	Monthly Average Weekday Daily Truck Traffic
MC	Motorcycle
MPH	Miles Per Hour
MPO	Metropolitan Planning Organization
NHS	National Highway System
PHF	Peak Hour Factor
PC	Passenger Car
PCE	Passenger Car Equivalent
PTR	Portable Traffic Recorder
PV	Passenger Vehicle Under 102”
SU	Single-Unit Vehicle
TAZ	Transportation Analysis Zone
THDF	Truck Hourly Distribution Factor
TMC	Transportation Management Center
TMG	Traffic Monitoring Guide
TOD	Time of Day
TT	Tractor Trailer
TVT	Traffic Volume Trend
VCD	Vehicle Class Distribution
V/C	Volume-to-Capacity
VMT	Vehicle Miles Traveled
WIM	Weigh-In-Motion

Preface

The Federal Highway Administration (FHWA), Office of Highway Policy Information, has developed this "Traffic Data Computation Method Pocket Guide." Traffic data items are performance indicators that are computed from raw and processed traffic information. They are used for operational assessment of transportation facilities, in designing and planning, investment prioritization, and policy decisions.

The objective of the pocket guide is to succinctly provide computational methods for selected traffic data items. The audience is anyone involved in the collection, processing, analysis, utilization, and reporting of traffic data.

Forty-eight traffic data items are covered in this guide. Individual data items are discussed in a two-page format. For each item, a brief description is first provided. This is followed by discussion and illustration of the data item. In the majority of the discussions, supplemental notes and tips useful for the data item computation are provided. Related data items and cross references are provided for further reading. For traffic data items that require large datasets, Excel-based worked examples are available for download from the FHWA website. Data items with a worked example are identified with this symbol. The data items are alphabetically ordered and the index provides easy access to any data item and key words.

In developing the guide, the following references were used.

1. FHWA Traffic Monitoring Guide (TMG) – 2016 edition.
2. American Association of State Highway and Transportation Officials (AASHTO) Guidelines for Traffic Data Programs – 2009 edition.
3. FHWA Highway Performance Monitoring System (HPMS) Field Manual – 2016 edition.
4. Transportation Research Board (TRB) Highway Capacity Manual (HCM) – 2016, 6^{th}, edition.
5. American Association of State Highway and Transportation Officials (AASHTO) A Policy on Geometric Design of Highways and Streets – 2011, 6^{th}, edition.

85th Percentile Speed

The speed below which 85 percent of vehicles in the traffic stream travel.

Discussion and Illustration. 85th percentile speed is used as a guide in setting or adjusting the posted speed limit of a facility. Also, it is used in the computation of base travel times for urban streets and signal timing plans. This speed is likely to be influenced by the traffic conditions, so it reflects the conditions during the analysis period.

In general, 85th percentile speed is computed from field-collected speed data. For freeways, speed detection sensors are usually placed 0.25 miles apart to ensure accurate depiction of speed patterns. For interrupted flow, the speed sensors are placed in the midway location of the intersection or 0.2 miles away from the intersection.

Figure 1. Speed distribution curve

As presented in Figure 1, the cumulative speed distribution curves break at 15 percent and 85 percent of the total travelers. The travelers observed in the 15th percentile or below are driving unreasonably slowly.

Similarly, travelers observed in upper 15% ($\geq$85 percent) are driving in excess of safe and reasonable speed.

A steep slope of speed distribution can be observed between 85 percent and 15 percent drivers, which indicates that posting a speed limit less than the critical 85^{th} percentile value would unfairly impact the driving behavior of those who would otherwise be driving at a safe and reasonable speed.

Example: A reduction of the maximum speed limit by 5 mph from the 85th percentile speed would unfairly impact 23% of the drivers in the traffic stream, as shown in Figure 1. Thus, the 85^{th} percentile speed value is considered to be the traffic speed that most closely conforms with the safe and reasonable speed.

To compute 85^{th} percentile speed, arrange all the collected speeds in an ascending order. Take the total sample size and multiply it by 0.85 to get the 85^{th} percentile vehicle. Determine the speed of the one vehicle representing the 85^{th} percentile vehicle, which will be the 85^{th} percentile speed.

Figure 1 shows that out of the 100-vehicle sample, the speed of the 85^{th} vehicle is 65 mph.

Additional Notes and Tips.

- Speed checks are necessary at regular intervals to ensure that the posted maximum speed limit matches the current traffic's 85^{th} percentile speed.

Related Traffic Data Items. Capacity.

Cross Reference. HCM Sec. 3-14 and 4-13.

Annual Average Daily Traffic (AADT)

AADT estimates, with as little bias as possible, the mean traffic volume across all days for a year for a given location along a roadway. AADT is different from ADT because it represents data for the entire year.

Various AADT estimation methods are in use. They include: 1) Simple average method, 2) AASHTO method (average of averages method), and 3) FHWA AADT method. FHWA AADT method is being adopted by State DOTs. Under the simple average method, AADT is estimated as the total traffic volume passing a point (or segment) of a road in both directions for a year divided by the number of days in the year. It requires volume for every day of the year. The AASHTO method incorporates 84 averages, i.e., 7 averages for the days of week for each of the 12 months. It requires daily volumes on at least one of each day of the week within each month. While the AASHTO method is currently the adopted practice by FHWA, FHWA recommends use of the FHWA AADT method due to the reduced bias.

Simple average method	$AADT = \frac{1}{n}\sum_{k=1}^{n} VOL_k$
AASHTO method	$AADT = \frac{1}{12}\sum_{m=1}^{12}\left[\frac{1}{7}\sum_{j=1}^{7}\left(\frac{1}{n_{jm}}\sum_{i=1}^{n_{jm}} VOL_{ijm}\right)\right]$

Where:

VOL_k = daily traffic on k^{th} day of the year

n = number of days in a year (365 or 366)

VOL_{ijm} = daily volume for i^{th} occurrence of the j^{th} day of week within the m^{th} month

i = occurrences of day j in month m for which traffic data are available

j = day of week (1 to 7)

m = month of year (1 to 12)

n_{jm} = number of occurrences of day j in month m for which traffic data are available.

Discussion and Illustration. AADT is a basic measurement that indicates vehicle traffic load on a road segment. It measures how busy a road is and is a critical input parameter in many transportation planning applications as well as for fund allocation to transportation agencies.

For the simple average to be accurate, it requires a complete traffic volume measured on every day of the year, which can be operationally challenging. The AASHTO method requires less total data but results can be low or high compared to true mean due to equally weighting each day of the week and month even though days of the week occur either 4 or 5 times in a particular month and days within a month vary from 28 to 31. The 2016 TMG contains the FHWA AADT method that eliminates these biases and allows for partial days data or data from other than daily volumes to be utilized.

Additional Notes and Tips.

- Multiplying AADT by the length of the road segment yields estimated daily vehicle miles traveled (DVMT).
- AADT can be converted to design volume and directional volumes by multiplying it with appropriate factors.
- The same AADT estimation methods can be applied to estimate average class-based daily volumes.
- AADT trends are used in traffic planning and forecasting.

Related Traffic Data Items. AADT, ADT, MADT, AADTT, DDHV, K-factor, D-factor, and DHV.

Cross Reference. TMG Sec. 1.2.7, 3.2.1., and 3.3.1; HPMS Field Manual Item 21; HCM Sec. 3.2.

Annual Average Daily Truck Traffic (AADTT)

The average daily volume of truck traffic on a road segment for a year. Trucks are defined as vehicles of classes 4 through 13 in the FHWA's 13-category vehicle classification system. The computation of AADTT follows that of AADT, except that only truck volumes are used. AADTT can be computed in two ways, i.e., the simple average and AASHTO methods.

Simple average method	$AADTT = \frac{1}{n}\sum_{k=1}^{n}(Truck\ VOL)_k$
AASHTO method	$AADTT = \frac{1}{12}\sum_{m=1}^{12}\left[\frac{1}{7}\sum_{j=1}^{7}\left(\frac{1}{n_{jm}}\sum_{i=1}^{n_{jm}}(Truck\ VOL)_{ijm}\right)\right]$

Where:

Truck VOL_k = daily truck volume on k^{th} day of year
n = number of days in a year (365 or 366)
Truck VOL_{ijm} = daily truck volume for i^{th} occurrence of the j^{th} day of week within the m^{th} month
i = occurrences of day j in month m for which truck traffic data are available
j = day of week (1 to 7)
m = month of year (1 to 12)
n_{jm} = number of occurrences of day j in month m for which truck traffic data are available

Discussion and Illustration. AADTT provides information on truck movements which is critical for design and analysis of pavements, freight, air quality, crash data, highway planning, and performance assessment. Vehicle Class Distribution (VCD) refers to the percentage distribution of AADTT in the population of FHWA vehicles of classes 4 through 13. Similarly, Truck Hourly Distribution Factors refer to distribution of AADTT over the 24 hours. Table 1 shows computations of VCD and Truck Hourly Distribution Factor (THDF).

Table 1. Computation of VCD and THDF (source: TMG).

Class	AADTT	VCD
4	235	2.0
5	654	5.5
6	961	8.1
7	1,620	13.6
8	1,240	10.4
9	654	5.5
10	598	5.0
11	103	0.9
12	1,245	10.4
13	4,621	38.7
Total	**11,931**	**100**

Hour	Hourly-AADTT	THDF
00-01	8	0.6
01-02	9	0.7
02-03	12	0.9
03-04	16	1.3
04-05	25	2.0
05-06	36	2.8
06-07	45	3.5
07-08	68	5.3
08-09	78	6.1
09-10	76	5.9
10-11	78	6.1
11-12	82	6.4
12-13	98	7.7
13-14	98	7.7
14-15	86	6.7
15-16	88	6.9
16-17	74	5.8
17-18	78	6.1
18-19	64	5.0
19-20	52	4.1
20-21	54	4.2
21-22	26	2.0
22-23	18	1.4
23-24	10	0.8
TOTAL	**1,279**	**100**

Related Traffic Data Items. AADT, Vehicle Weight, Vehicle Class, Class Factor, ACF, and Load Distribution Factor.

Cross Reference. TMG Sec. 3.2.3, 3.4, G6, G7, G8, and H4.

Average Daily Traffic (ADT)

The ADT, also referred to as mean daily traffic, is the average number of vehicles that travel through a specific point of a road over a short duration time period (often 7 days or less). It is estimated by dividing the total daily volumes during a specified time period by the number of days in the period.

$$ADT = \frac{1}{n}\sum_{i=1}^{n} VOL_i$$

Where:

VOL_i = daily volume in the i^{th} day and
n = the number of whole days.

Discussion and Illustration. ADT is the most basic unit used for traffic monitoring and forecasting. It provides an aggregated measure of traffic volume. In combination with other traffic data items, it is used for determining the dimensions or function of proposed roadways, particularly roads of low and moderate traffic volumes. ADT requires TOD, DOW, and MOY factors to properly annualize the values to AADT.

Example: A temporary traffic count station measures traffic volume for seven days as shown in Table 2. The ADT can be calculated as follows.

Table 2. Daily volume and ADT

Day	Daily Volume (veh/day)	Daily Factors	Weighted Volume
Day 1	4,410	0.11	4,410 x 0.11 = 490
Day 2	5,135	0.12	5,135 x 0.12 = 614
Day 3	5,270	0.13	5,270 x 0.13 = 676
Day 4	5,114	0.15	5,114 x 0.15 = 743
Day 5	5,980	0.16	5,980 x 0.16 = 971
Day 6	4,295	0.16	4,295 x 0.16 = 697
Day 7	2,890	0.17	2,890 x 0.17 = 494
		ADT (sum)	**4,686 (veh/day)**

Additional Notes and Tips

- ADT is representative only of the time period and type of traffic volumes included. Related measures like AADT and MADT are also averages but are normalized and more contextually relevant.
- Two-way design hour volume (DHV) is usually 8-12% of the ADT.
- The difference between ADT and AADT is the temporal coverage of the data used to compute them.
- ADT can be converted to AADT by applying monthly, day of week, axle factor, and change rate.

Related Traffic Data Items. AADT, MADT, AADTT, D-factor, K-factor, Monthly and Day of Week Factors.

Cross Reference. AASHTO Sec. 2.3.2.; HCM Sec. 3.2; TMG Sec. 1.2.7.

Axle Correction Factor (ACF)

ACFs are the ratio of number of vehicles divided by number of axles in each type of vehicle class. ACF are also known as axle factor.

$$ACF = \frac{\text{Total number of vehicles of Class X}}{Total\ Number\ of\ axles\ of\ class\ X\ vehicles}$$

Discussion and Illustration. Data collection equipment, like pneumatic tubes, collect axle counts when only one road tube is used. In such cases, ACFs are used to adjust axle counts into vehicle counts. ACFs can be measured at an individual point on a roadway for each vehicle classification or at the system level. To measure the ACF at a system level, a combination of vehicle classification counts will be averaged to represent vehicles traveling on an entire system of roads. By dividing these vehicle classification counts by their respective number of axles, axle factor groups are formed. However, this method involves a certain percentage of error in axle factor. In general, truck percentages on roadways vary (even on roads within the same functional class). Therefore, the TMG recommends calculation of ACFs that are specific to vehicle classification and roadway location. ACFs must be determined from per vehicle axle class or weight data.

Example: Table 3 shows daily vehicle and axle counts for vehicle of class A at two roadway locations. Axle factor for this vehicle class and road is computed by dividing the daily vehicle volume count (X) by daily axle count (Y).

Another method of adjusting axle counts to vehicle counts is by measuring average number of axles per vehicle, which is the inverse of axle factor.

Table 3. ACF and axles per vehicle computation from vehicle and axle counts

Roadway ID	Daily vehicle Volume count for vehicle Class A (X)	Daily Axle Count for vehicle Class A (Y)	ACF = X/Y	Average Number of Axles per vehicle = (Y/X)
R120A	50,000	125,000	0.40	2.50
R280K	48,000	123,000	0.39	2.56

Now that the ACFs for a roadway at a location of interest are available, vehicle counts for another location in the vicinity can be computed from axle counts or vice versa. In general, the day of week in both the cases should be the same. In Table 4, axle counts are multiplied by ACFs to compute the daily vehicle counts.

Table 4. Vehicle count adjustment using ACF

Roadway ID	Daily Axle Count for vehicle Class A (Y)	ACF	Average Number of Axles per vehicle	Daily vehicle Volume count for vehicle class A
R120A	143,000	0.40	2.50	57,200
R280A	129,000	0.39	2.56	50,390

Additional Notes and Tips.

- Because ACF is inversely proportional to the number of axles on a vehicle, for example, a lower ACF indicates a higher number of axles per vehicle, which reflects a higher percentage of multi-axle vehicular traffic. A typical range of ACF is 0.50 to 0.30.

Related Traffic Data Items. AADT and Daily Axle Counts.

Cross Reference. TMG Sec. 1.2.6.

Capacity

The maximum sustainable hourly flow rate at which vehicles reasonably can be expected to traverse a point or a lane on a roadway during a given time period, typically 15-minute intervals under prevailing roadway, traffic, and control conditions. It is expressed in vehicles per hour per lane.

Discussion and Illustration. Capacity is a key parameter that determines the ability of a transportation facility to meet the travel demand. It is used for level of service (LOS) analysis of a transportation facility, designing of signal timing plans, and identification of bottlenecks.

Capacity of a transportation facility is affected by many factors including number of lanes, width of lanes, traffic speed, proportion of heavy vehicles (HVs), conflicting or opposing traffic, roadway alignment, presence of merge and weave segments, weather, and both width and type of shoulder. Also, for signalized intersections, factors such as signal green time portion and pedestrian counts affect the capacity.

In addition to the factors mentioned above, daily, monthly, and seasonal variations in traffic demand must be taken into consideration before estimating the capacity. This ensures year-round accommodation of traffic demand.

In some instances, the capacity of a transportation facility may be greater than its hourly demand. However, when the traffic flow within a portion of the hour exceeds capacity, the impact created by excess demand takes a long time to dissipate. To mitigate this issue, both directions of a transportation facility must have adequate capacity to accommodate peak directional flow.

The Highway Capacity Manual (HCM) provides default values for capacities on basic freeway and multilane highway segments based on the factors mentioned above. The default capacity values, presented in HCM, assume ideal roadway geometry, good weather, and a traffic stream consisting entirely of passenger vehicles.

The capacity of basic freeway segment depends on the facility's free flow speed (FFS). The default capacity recommended by HCM for facilities with FFS of 75 to 70 mph is 2,400 veh/h/ln. For facilities with FFSs of 65 mph, 60 mph, and 55 mph, the default capacities are 2,350 veh/h/ln, 2300 veh/h/ln, and 2,250 veh/h/ln.

Additional Notes and Tips.

- When the traffic demand meets the capacity, critical density and critical speed occur.
- Capacity of segments with no weaving, near zero truck volumes, and constant speed near the FFSs can be up to 2,850 veh/h/ln.

Related Traffic Data Items. Volume, Saturation Flow, LOS, Signal Green Time, and Free Flow.

Cross Reference. HCM Sec. 1 through 8.

Change Rate

Change rate (also called growth factor) is an adjustment factor to reflect traffic change on a facility or in an area over a given time period. In general, change rate is calculated as a ratio of AADT of the most recent year to the AADT of a preceding year. It can be expressed as a ratio or percent.

$$Change\ Rate = (\mathrm{AADT}_{Current\ Year} / \mathrm{AADT}_{Preceding\ Year})$$

Discussion and Illustration. Change rate is a key parameter in designing the capacity of a transportation facility to meet the growing demand in the region. Change rate factors are applied for AADT values counted in prior years that need to be adjusted up to current year.

Typically, the segments in the subject area are grouped based on their change rates or assigned volume factor groups. In this way, multiple change rate groups with varying change rates will be identified. These groups include urbanized areas – central cities and older suburbs; urbanized areas – newer suburbs; rural and small urban interstate system; other rural; and other small urban.

In developing change rates, AADT values of the most current year along with its preceding year are required.

Example: Table 5 presents the AADT values of segments 1 through 5. For segment 1, the AADT value is 1,768 vehicles/day for the most current year; and 1,723 vehicles/day for the preceding year. The computed change rate for the first segment will be 1.026. A similar method can be used for calculating change rates for all segments.

After converting the ratio to a percent, an average change rate of 4.4% is observed in the region between the two years. The segments can be categorized into three groups based on their change rates. Segments 1 and 5 can be grouped with an average change rate of 2.5% (ratios = 1.024 and 1.026). Similarly, segments 2 and 4 can be grouped with an average change rate of 4.5% (ratios = 1.044 and 1.046). Segment 3 can be treated as the third group with change rates of 7.8% (1.078).

Table 5. Change Rate Development

Segment	Current AADT	Preceding AADT	Change Rate	Change Rate Group
1	1,768	1,723	1.026	1
2	1,985	1,901	1.044	2
3	3,120	2,895	1.078	3
4	2,285	2,184	1.046	2
5	2,349	2,294	1.024	1
Average Change Rate			**1.044**	

Additional Notes and Tips.

- Rural and urban areas have different change rates.
- The outlying parts of an urbanized area are likely to experience faster traffic change than the city center or older, established parts of suburbs.
- Traffic on the interstate system in the rural and small urban areas consists primarily of through traffic, so change rate on these roads are less affected by the local economy than on other roads.
- Large states experience regionally varying change rates in different rural and urbanized areas.

Related Traffic Data Items. AADT, Design Volume, Future AADT, and Short Term ADT to AADT Conversion.

Cross Reference. AASHTO Guidelines for Traffic Data Programs Sec. 5.2.3, Table 5-3.

Combination Unit Truck AADT

A Combination Unit (CU) Truck is any truck that meets the requirements established for the FHWA Truck Classification Method for Categories 8 through 13. AADT is expressed in vehicles per day units.

$$CU\ Truck\ AADT = \frac{1}{7}\sum_{i=1}^{7}\left[\frac{1}{12}\sum_{j=1}^{12}\left(\frac{1}{n}\sum_{k=1}^{n} ADT_{ijk8-13}\right)\right]$$

Where:

CU Truck AADT = AADT for CU Trucks

$ADT_{ijk8\text{-}13}$ = daily combination traffic for day k, of DOW i, and month j

i = DOW

j = month of the year

k = count of occurrence of that day of week in a month; 4 when it occurs four times in a month

n = the number of days of that day of the week during that month (for which you have data)

Discussion and Illustration. CU Truck AADT is used to estimate pavement deterioration, calculate operating speeds, and perform freight analysis for a transportation facility or segment. Depending on its functional class, each roadway segment experiences different volumes of truck traffic. To get accurate estimates, HPMS recommends actual traffic counts of the road segment. If the actual measured values are not available, the most credible method would be to use other site-specific measured values from sites located on the same route. Other methods may include: assigning site-specific measured values to other samples that are located on similar facilities with similar traffic characteristics in the same geographic area and in the same volume group; or assigning measured values from samples in the same functional system and in the same area type.

HPMS contains data for this traffic parameter for NHS and sample segments. Outside HPMS, states have access to traffic classification counts and data on the percentage of vehicles passing through a counting point.

Once the traffic classification counts are collected, average traffic counts on each day of week for each month are computed, e.g., the average CU Truck volume for Monday of every month and annual average can be computed. In this way, monthly and annual averages of counts for each day of week can be computed for all seven days. Averaging the annual averages of the seven day of week counts will yield the AADT of CU Trucks. Since this data is taking averages for all days, it is less prone to any bias issues created by any missing data due to malfunctions and maintenance of PTRs/CCSs. FHWA recommends at least the 6 vehicle types listed in the HPMS Vehicle summary table be collected, stored and factored to annualized data whenever a portable class count is taken. This then allows for the VMT weighting required in the HPMS vehicle summary table.

Additional Notes and Tips. CU truck AADTs are computed bidirectionally for two-way facilities and directionally for one-way roadways and ramps.

Related Traffic Data Items. AADT and SU Truck AADT.

Cross Reference. HPMS Sec. 4.3 - Item24; TMG Sec. 3.2.3 and Table 3-3.

Critical Speed

The traffic speed at which volume meets capacity of a segment is called critical speed or speed at capacity. It is expressed in Miles Per Hour (mph).

$$Critical\ Speed\ (mph) = \left(\frac{Maximum\ Flow\ rate\ \left(\frac{Veh}{H}\right)}{Critical\ Density\ \left(\frac{Veh}{Mile}\right)}\right)$$

Where:

Maximum flow rate = The capacity of a transportation facility

Critical Density = Traffic density when flow rate is maximum

Discussion and Illustration. Critical speed is a key parameter in understanding the prevailing traffic conditions for a transportation facility or corridor.

Flow-Speed-Density relationships are presented in Exhibit 4-2 in HCM 2016. In practical terms, the speed achieved by a single vehicle when there are no other vehicles in the corridor is called Free Flow Speed (FFS). As more traffic starts flowing through the transportation facility, the speed of the traffic stream drops and reaches the critical point known as the facility’s capacity.

Operation at critical speed is very unstable as there are no usable gaps in the traffic stream. As a result, any small disturbance created by an entering or lane changing vehicle might cause traffic flow breakdown. For this reason, traffic and transportation management center (TMC) engineers observe the dynamic shifts in the travel speeds and take necessary actions before the traffic speed reaches the critical speed.

The critical speed varies depending on the prevailing traffic, roadway conditions, and segment length. For uninterrupted flow, the default value for density at capacity is 45 pc/mi/ln. Using this default value along with the flow rate value, critical speed could be computed.

Example. If the maximum flow rate is 2,350 veh/h and critical density is 45 pc/mi/ln, then the critical speed will be 50 mph.

Additional Notes and Tips. The objective of an effective traffic management strategy is to keep traffic speed at or above the critical speed. This avoids traffic flow breakdown and capacity drop.

Related Traffic Data Items. Flow Rate, Critical Density, and Free Flow.

Cross Reference. HCM Sec. 4-8.

Design Hour

Design hour (DH) is an hour with a traffic volume that represents a location specific peak hour value for designing the geometric and control elements of a facility. This peak hour selected will allow the designed facility to accommodate traffic during most of the peak hours. In general, the design hour for a transportation facility depends upon its location (e.g. rural or urban) and type (e.g., freeway, arterial, collector, or ramp).

Discussion and Illustration. The design hour is a key characteristic in estimating the expected demand for a proposed transportation facility.

Typically, the hour corresponding to the 30th highest hourly volume of the year is considered as the design hour as stated by the Highway Performance Monitoring System (HPMS). However, local jurisdictions and metropolitan planning organizations (MPOs) may adjust the design hour based on their local facility-specific traffic conditions.

In rural settings, customary practice in the United States is to base highway design on the 30th highest hour of the year. The 30th hour is used because it falls in the range of subsequent highest hours that have similar volumes. Even though a considerable variance is observed between the peak (highest) and 30th highest hourly volumes of a year, designing for the peak hour would not be deemed economical and feasible in many regions.

In urban settings, the difference in demand between peak hour and 30th hour of the year is minimal. Similarly, the 50th and 100th highest hourly volumes of the year are closer together in urban than rural settings. This is true for urban areas because of the recurring morning and evening traffic patterns.

Example: Two highways, one each in an urban and rural setting, require estimation of design hour based on their annual hourly traffic volumes. The urban highway observed 3,992; 3,850; 3,735; and 3,355 vph as their 1st, 30th, 50th, and 100th peak hour volumes. Similarly, the rural highway observed 4,389; 3,782; 3,591; and 3,234 vph as their 1st, 30th, 50th, and 100th peak hour volumes.

For the urban highway, a minimal traffic variance of 4% was observed between the 1st and 30th peak hour. Similarly, 3% variance was observed between 30th and 50th hours. However, higher variances were observed when compared with the 100th hour. Therefore, a design hour within the range of the 30th and 50th hour can be selected for this highway.

Table 6. Design Hour Selection

Urban Settings		Rural Settings	
Peak Hours	**% Variance**	**Peak Hour**	**% Variance**
1st and 30th	4	1st and 30th	14
30th and 50th	3	30th and 50th	5
30th and 100th	13	30th and 100th	15
50th and 100th	10	50th and 100th	10

Additional Notes and Tips. The variance of traffic for the 1st and 30th hours on a rural highway was considerably higher at 14%. However, Traffic variation is stable around the 30th hour. Therefore, the 30th hour can be selected as the design hour.

Related Traffic Data Items. Design Volume, K-factor, D-factor, and DHV.

Cross Reference. HCM Sec. 3-11 and 7-3.

Design Vehicles

Given the large variety of vehicle types using roadway facilities, adapting standard physical and operating vehicle features is essential. Design vehicles are vehicles of representative size, weight, and operating performance specifications used to establish highway design controls by setting criteria to accommodate designated vehicle classes to optimize roadway functionality.

Discussion and Illustration. AASHTO has defined 20 design vehicles categorized under four general vehicle classes, i.e., passenger cars, buses, trucks, and recreational vehicles.

1. Passenger Car	11. Interstate Semitrailer 62 ft
2. Single-Unit Truck	12. Interstate Semitrailer 67 ft
3. Single-Unit Truck (3-axle)	13. Double-Bottom Semitrailer/Trailer
4. Intercity Bus	14. Double-Semitrailer/Trailer
5. Intercity Bus 45 ft	15. Triple-Semitrailer/Trailer
6. City Transit Bus	16. Turnpike Double-Semitrailer/Trailer
7. School Bus 65 pass.	17. Motor Home
8. Large School Bus 84 pass.	18. Car and Camper Trailer
9. Articulated Bus	19. Car and Boat Trailer
10. Intermediate Semitrailer 40 ft	20. Motor Home and Boat Trailer

The proportion of vehicle types and sizes that a facility is expected to accommodate determines the design vehicle to be used, i.e., roadway features are designed to allow safe and easy operations of the vehicles that are likely to use the facility.

Note that the design vehicle does not represent the average vehicle in its class; rather it has slightly larger physical dimensions and a larger minimum turning radius than most vehicles in its class. Therefore, a facility that is designed to accommodate the design vehicle will also accommodate most of the vehicles in its class and nearly all of the vehicles in the classes composed of smaller vehicles.

The choice of design vehicle is also influenced by the functional classification of a roadway. For example, a pickup truck and a large school bus can be considered as the design vehicles when designing parkway streets and low-volume county highway intersections, respectively. The entire facility, including specific sites like intersections, curves, ramps, turnouts, clearances, and grades, should accommodate the design vehicle considered.

Additional Notes and Tips.

- Critical features of design vehicles are length, wheelbase, acceleration, minimum turning radius, and rear tire path.
- Generally, the design of freeways should accommodate the largest of all the several design vehicles.
- A vehicle with larger wheelbase has restricted turning capability and calls for larger geometric design values.
- If a roadway permits bicycle use, the design procedure should consider a bicycle as an additional design vehicle.
- Because combination truck sizes and turning features vary widely, there are several combination truck design vehicles.
- In addition to accommodating the design vehicles, access to emergency vehicles is an essential roadway design criterion.

Related Traffic Data Items. Turning Radius, Vehicle Class, and Vehicle Weight.

Cross Reference. AASHTO Sec. 2.1.

Design Volume

This is the projected traffic volume for the design life of a transportation facility, usually 10 to 20 years in the future, during a specified design hour. Design volumes are estimated in the roadway planning process and are often expressed as the expected traffic volume during a specified design hour, i.e., the peak period.

Discussion and Illustration. Design volume is used in the roadway planning process for making design decisions during the design year. Such decisions include roadway structures, capacity, geometric layouts, and auxiliary services like size of parking areas. In addition, design volume is used for designing traffic control devices. To avoid inadequate or uneconomical roadway design, the 30^{th} highest hourly volume is usually used as the design volume.

Design volume and Design Service Flow Rate (DSFL) are two separate concepts. DSFL is the maximum hourly flow rate of traffic that a new facility can serve without the degree of congestion falling below a pre-selected level. A roadway should be designed using a design volume that is less than or equal to the DSFL.

A facility should be designed to accommodate the traffic volume that is likely to occur within its design life. This can be achieved in two ways. The first method is to use a well-validated travel demand forecasting model and estimate the design volume. The second method is to use the average daily traffic (ADT) or annual average daily traffic (AADT) values from a similar facility located in similar transportation settings and estimate design volume.

Among the two methods, use of design volume method is proven to be critical, as the traffic volume on the transportation facility can be significantly higher than the ADT or AADT on certain days. In design volume method, travel demand forecasting models consider the traffic settings, land uses, and change rate in the selected corridor to forecast the best estimate of design volume for the design life of the facility.

Based on the projected design volumes, AASHTO provides requirements for design speed, traveled way and shoulder width, clear roadway width, design loading, and roadway structural capacity.

Design volume considers directional split to understand the shifts in traffic volume and accommodate the peak direction. For example, a rural arterial has a forecasted design volume of 6,000 veh/h. If the directional split is 50-50, then two lanes in each direction will be sufficient to accommodate traffic in both directions, assuming a capacity of 1,500 veh/h/ln. However, if the split is 70-30 for the peak and off-peak directions, which means 70 percent of the design volume travels in one direction (e.g., northbound) and 30 percent in the opposite direction (e.g., southbound), then three lanes in each direction are required to accommodate the peak period traffic (4,200 veh/h).

Additional Notes and Tips.

- According to AASHTO, the design life of a transportation facility is a maximum of 15 to 24 years.
- Assuming higher design life can lead to higher operational and maintenance costs of the facility.

Related Traffic Data Items. Design Hour, DHV, Directional Design Hourly Volume (DDHV), K-factor, D-factor, AADT, and LOS.

Cross Reference. AASHTO Sec. 2.4.3, 5, 6 and 7; Table 5-1, 5-5, 5-7, 6-1, 6-5, 6-6, 6-7 and 7-3; HCM Sec. 3-11 and 7-3.

Directional Design-Hour Volume (DDHV)

Directional Design-Hour Volume (DDHV) is the proportion of AADT in the peak-hour (design hour) in the predominant direction of traffic flow. DDHV is determined from field measurements on the facility under consideration or on parallel and similar facilities. It is given by multiplying AADT by K-factor and D-factor.

$$DDHV = AADT \times K \times D$$

Where:

K = the proportion of AADT occurring in the peak hour, i.e., the K-factor.

D = peak-hour volume proportion in the major direction, i.e., the D-factor.

Discussion and Illustration. DDHV is an important parameter used for transportation planning and design of new highway construction or the reconstruction of an existing facility. The concept of DDHV is to guide planners in effectively estimating the needed capacity of a given facility operating under given LOS. Designing a facility with too much capacity will be uneconomical, and a facility with too little capacity will be inadequate.

Neither the AADT nor the ADT indicates the variations in traffic volumes that occur during the day, specifically high traffic volumes that occur during the peak hour of travel. Therefore, AADT or ADT should be adjusted for peak-hour volume and directionality, which is the purpose of calculating DDHV. DDHV is a critical design volume with a directional component.

Example 1: The projected AADT of a proposed facility is 33,000 veh/day. If the proportion of AADT in the design hour is 16 percent and the peak-hour directional distribution is 65:35, then DDHV will be:

DDHV = 33,000 × 0.16 × 0.65 = 3,430 vph.

Note that the higher directional distribution should be used, i.e., 65 should be used instead of 35.

A practical application of DDHV is in computing the number of lanes needed for a given LOS, as shown below.

$$N = \frac{DDHV}{PHF \times MSF_i \times f_{HV} \times f_p}$$

Where:

PHF = Peak hour factor
MSF_i = Maximum service flow rate for LOS i
f_{HV} = heavy vehicles adjustment factor
f_p = road user familiarity adjustment factor

Example 2: Assume that the PHF, fHV, and fp of the proposed facility are 0.91, 0.925, and 1.0, respectively, the maximum service flow rate for the facility to provide a LOS of C is 1,500 pc/h/ln. The number of lanes required will be:

$$\boldsymbol{N = \frac{3,430}{0.91 \times 1,500 \times 0.925 \times 1} = 2.3\ (use\ 3\ lanes)}$$

Additional Notes and Tips.

- DDHV is one-direction volume and its unit is vph.
- The number of lanes affects the facility's free flow speed, which in turn affects the number of lanes. This makes the design analysis of freeways an iterative process.

Related Traffic Data Items. DHV, AADT, K-factor, D-factor, PHF, and LOS.

Cross Reference. AASHTO Sec. 2.3.3., 8.2.2.; HCM Sec. 3.2., 15.III.

Directional Factor

Directional factor (D-factor) is the traffic volume proportion moving in the higher volume direction during the peak hour to the combined volume in both directions. It is usually expressed as a percentage. It represents the directional distribution of hourly traffic volumes. D-30 represents the traffic volume proportion in the 30th highest hourly volume of the year traveling in the peak direction. Similarly, D-100 represent the traffic proportion in the 100th highest hourly volumes of the year. Guidance in the HPMS Field manual suggests using the 30th highest hourly volume for a given year (typically used) for the purposes of calculating D-factor. D-30 is used in design capacity analysis, while D-100 is typically used in calculating the LOS of a facility.

$$D - factor = \frac{K^{th}\ highest\ volume\ in\ direction}{Volume\ in\ both\ directions} \times 100\%$$

Discussion and Illustration. D-factor is based on the fact that traffic volumes may not be evenly split in both travel directions during the design hour. A road located in an urban center often has equal traffic volumes in both directions, i.e., a D-factor of nearly 50%. On the other hand, a road in suburban areas carry imbalanced directional flows due to larger traffic traveling toward an urban area in the morning and away from an urban area in the evening, i.e., D-factor is always greater than 50%. Directional distribution of traffic may significantly affect the LOS of a facility. Therefore, D-factor plays an important role in highway design by considering the directional split of traffic, especially for two-lane rural highways. D factors for one way roadways is always 100%.

Example: Suppose the hourly volume in east- and west-bound directions of a highway are 1,300 and 2,200 vph during the peak hour, respectively. Note that the west-bound direction has the higher volume, therefore, it is the peak direction. The combined volume in both directions is 3,500 vph (i.e., 1,300 + 2,200). Hence, the D-factor will be:

$$\boldsymbol{D-factor} = \frac{\mathbf{2,200}}{\mathbf{3,500}} \times \mathbf{100\%} = \mathbf{63\%}$$

AADT can be multiplied by both the K-factor and the D-factor to convert it to an equivalent directional design hourly volume (DDHV) in the major direction.

$$DDHV = AADT * K * D$$

Example: The forecasted AADT of a highway is 48,000 vph. The expected K- and D-factors are 12% and 58%, respectively. The DDHV will be given by:

$$DDHV = 48{,}000 * 0.12 * 0.58 = 3{,}340 \text{ vph.}$$

Additional Notes and Tips

- In general, the value of D-factor for non-one way roadways range from 50% to 75%.
- D-factor is best measured at continuous monitoring sites.
- Land use pattern near a facility affects its D-factor value.
- The directional distributions of traffic change based on hour of the day, day of the week, and season.
- The same peak hour volume used to calculate K-factor should be used to calculate D-factor.
- In some urban areas, imbalanced directional distributions can be mitigated by using reversible lanes.
- The peak directional volume of two multilane highways with similar AADT may differ by as much as 60%.

Related Traffic Data Items. AADT, DDHV, and K-factor.

Cross Reference. HPMS Field Manual Item 27; TMG Sec. I Q-24 to Q-29; HCM Sec. 3.2.; AASHTO Sec. 2.3.3.

Directional Flow Rate and Ratio

Directional flow rate is the traffic flow rate in one direction of a transportation facility, where flow rate is the equivalent hourly rate at which vehicles pass over a given point or section of a lane or roadway during a given time interval of less than 1 h, usually 15 min. It is expressed in veh/h/ln.

$$Directional\ Flow\ Rate\ (V_i) = \left(\frac{V}{PHF * N}\right)$$

Directional flow ratio is the ratio of directional flow rate and saturation flow rate in a given direction.

$$Directional\ Flow\ Ratio = \left(\frac{V_i}{S_i}\right)$$

Where:

PHF = Peak Hour Factor

V= Hourly Directional volume

N= Number of directional lanes

V_i= Directional flow rate in direction i

S_i= Saturation flow rate in direction i

Discussion and Illustration. Directional flow rate and ratio are key parameters in critical lane group and critical signal phasing identification at an intersection as discussed below.

Directional flow rate for a transportation facility is computed by dividing the hourly directional volume with the peak hour factor and number of lanes in that direction.

Directional flow ratio at an intersection is computed by dividing the demand flow rate with the saturation flow rate for a given direction and lane group.

Example: Consider a two-lane (one lane per direction) arterial roadway. If the hourly directional volume is 750 veh/h and peak hour factor (PHF) is 0.83, then the directional flow rate is 900 veh/h/ln. For the same facility, if the saturation flow is 1,200 veh/h of green/ln, then the flow ratio of this facility is 0.75.

a= critical flow ratio

Figure 2. Determination of critical lane group and phasing from flow ratio

At signalized intersections, the lane group with highest flow ratio is considered as the critical lane group and the phase associated with that lane group is called critical phase. For example, Figure 2 presents the flow ratios of lane groups at a minor and major arterial street intersection. Phases 4 and 8 refer to minor street lane movements. Phases 1, 2, 5, and 6 refer to major street lane movements. Right turns are permitted on the minor streets during the major street's protected left turn phases. On the minor street, phase 4 is considered as the critical phase as it has a higher flow ratio when compared to phase 8. Similarly, the combination of phases 5 and 6 is considered as the critical phase on the major street (0.30+0.35=0.65), compared to the combination of phases 1 and 2 (0.40+0.20 =0.60).

Related Traffic Data Items. Saturation Flow, PHF, and Traffic Demand, D-factor, and K-factor.

Cross Reference. HCM Sec. 15-36, 19-4, 24-18.

Equivalent Single Axle Load (ESAL)

The equivalent number of 18,000 lbf (pound force) single-axle loads that are imposed by a mix of traffic having different axle loads, axle grouping configurations, and pavement characteristics that are predicted over the design life or analysis period of a pavement.

$$w_{18} = D_D * D_L * W_{18}$$

Where:

w_{18} = the ESAL for the design lane.

D_D = the directional factor for a two-way roadway.

D_L = a lane traffic splitting factor for a roadway having more than one lane in each direction.

W_{18} = cumulative two-way ESAL projected for a roadway segment.

Discussion and Illustration. ESAL is a key parameter in determining the expected loads experienced by a pavement in its lifetime. Traffic modeling and design traffic professionals project cumulative ESAL data from all vehicles for the entire pavement life expectancy.

The axle distribution by axle weight range can be easily converted into ESAL, the most common pavement design loading value currently used in the United States. Even though load spectra is more accurate than ESAL, it is less commonly used due to its complex calculation methodology. ESAL at a local level might be different from the ESAL of the entire state. ESAL distribution in an area is affected by land uses and connectivity to other regions.

Cumulative ESAL: AASHTO provides ESAL values for the gross weight of the axles. For calculating cumulative ESAL, consider four single axles on a roadway. The gross weights of the first two and last two axles are 20,000 lbs and 30,000 lbs each, respectively. AASHTO ESALs/axle values for these single axles are 1.371 (20,000 lbs) and 6.546 (30,000 lbs). Now, as all axles are of the same type (single axle), multiplying the number of axles with ESALs will give total ESALs (1.371*2 = 2.742; 6.546*2=13.092). Summation of these ESALs (15.834) will produce ESAL by axle type (single). Summation of this single axle ESAL with ESAL of other axle types (tandem, tridem, etc.,) will produce cumulative ESAL experienced by roadway.

Load Equivalency Factor tables from AASHTO guide are used to determine the ESALs applied by different axles based on their type and gross weight. The Load Equivalency table is developed by using high powered ESAL equation, which considers various factors including applied axle loads, curve slope factor, pavement structural number, serviceability index and useful life.

If the cumulative ESAL on a two-way road is 454 ESALs for all vehicle types, the NB directional split is 56% (0.56) and the traffic split on lane 1 and 2 is 0.6 and 0.4, then the expected ESAL on design life of lane 1 and 2 is 152.5 and 101.7 ESALs respectively.

Additional Notes and Tips.

- While ESAL has limitations as a measure of traffic loading for pavement design, it is still a very useful way of comparing the relative pavement damaging potential of different load spectra.
- ESAL can only be used for axle groups up to tridems.

Related Traffic Data Items. Load Spectra and Vehicle Class.

Cross Reference. TMG Sec. 3.2.4 and Appendix H.3.

Free Flow

A situation where traffic flow is unaffected by upstream or downstream conditions. It reflects vehicles' desired flow, unconstrained by other vehicles or traffic control. It is typically expressed in pc/h/ln.

Discussion and Illustration. Free flow is considered as a base parameter to calculate various other traffic parameters including but not limited to speed, capacity, travel time index, and planning time index. It also plays a key role in determining the capacity and LOS of a freeway section.

The speed at which free-flow traffic prevails is called free-flow speed. Free-flow speed is the speed at which vehicles' speeds are unaffected by surrounding conditions and other vehicles. Free-flow speed is the key parameter in estimation of freeway and multilane highway capacity.

It is usually calculated from pre-defined algorithms or field observations. However, since it is used mostly in the design phase of freeways, pre-defined algorithms are used in most cases. These free-flow speeds are estimated from base free-flow speeds, which are considered to be the speeds that are only affected by the horizontal and vertical alignments of a transportation facility.

Once the base free-flow speed is determined, it is adjusted for different factors. In addition to vertical and horizontal alignment, free-flow speed is also affected by various factors of the roadway including lane widths, lateral clearances, weaving, median type, and access points.

Example: Consider a passenger car traveling at 70 mph on a basic freeway segment. Assuming good weather and unconstrained driving conditions, the car's speed is expected to be unaffected until the flow on the lane exceeds 1300 pc/h/ln (approximately 1 pc per every 3 seconds or 22 cars per minute). Similarly, a car traveling at 65 mph would face a reduction in travel speed if the flow rate on the freeway exceeds 1,450 pc/h/ln. These observations can be found in Table 7 (see HCM 2016 Exhibit 12-7).

Table 7. Free-flow Speed and Flow Rate for Basic Freeway Segment

Free-Flow Speed (mph)	Flow Rate (pc/h/ln)
75	1,150
70	1,300
65	1,450
60	1,600
55	1,750

Source: HCM

Additional Notes and Tips.

- Free-flow traffic conditions are usually observed during off-peak hours. Early hours of the morning offer most favorable conditions for traffic free flow.

Related Traffic Data Items. Capacity, LOS, Critical Speed, Critical Density, and Saturation Flow.

Cross Reference. HCM Sec. 12-9 to 12-11.

Future AADT

AADT forecasted for a specific succeeding year of interest.

$$\mathrm{AADT}_{Future} = \mathrm{AADT}_{Current} * (1 + AACR)^n$$

Where:

$\mathrm{AADT}_{\mathrm{Future}}$ = Annual Average Daily Traffic for the forecasted year (veh/day)

$\mathrm{AADT}_{\mathrm{Current}}$ = Annual Average Daily Traffic for the current year (veh/day)

AACR = Annual Average Change Rate

n = number of forecasted years

Discussion and Illustration. Future AADT is used to estimate capabilities and deficiencies of a selected transportation facility and its future improvement needs. Based on these estimates, cost allocation for transportation facility pavement modeling is determined. Future AADT also helps traffic engineers evaluate the safety of the facility.

Data parameters required for calculation of future AADT include current year AADT, AACR, and number of years to be forecasted. Typically, a 20-year forecast AADT should be used, which covers 18 to 25 years from the time of data forecast.

AACR for a selected transportation facility is estimated based on the statewide modeling programs and inputs provided by metropolitan planning organizations (MPOs). In the absence of modeling programs, states can use the local population growth or gasoline tax growth rate to estimate the AACR of regional traffic conditions.

Example. Table 8 depicts information about AADT, AACR, and forecast years for three transportation facilities. If the current AADTs of transportation facilities are 24,000, 19,000, and 34,500 veh/day and the respective AACR are 3%, 2.8%, and 4.2%, respectively, then the forecasted AADT for 20 years will be 43,350, 33,009, and 78,555 veh/day, respectively. These values can be inputted in the HPMS submittal software for quality checks.

Table 8. Future AADT Computation

Route	$AADT_{Current}$ (veh/day)	1+AACR	n (years)	$AADT_{Future}$ (veh/day)
I-20	24,000	1.030	20	43,350
I-10	19,000	1.028	20	33,009
I-30	34,500	1.042	20	78,555

Additional Notes and Tips.

- The HPMS submittal software will perform a quality check and reports flag/concern if:
    - Future AADT is missing;
    - Future AADT less than current AADT; and
    - Future AADT greater than 300% of current AADT.

Related Traffic Data Items. AADT and Change Rate.

Cross Reference. HPMS Sec. 4.3 – Item 28.

Gross Vehicle Weight (GVW)

GVW refers to the sum of the axle loads exerted by the vehicle's chassis, body, engine, fluids, fuel, accessories, driver, passengers, and cargo due to gravity. Vehicle weight is transmitted to pavement surface through the tires in the wheel assembly, axle, and axle groups.

$$GVW = \sum (vehicle\ axle\ loads)$$

Discussion and Illustration. GVW and load spectra (axle load distribution by axle type) is a useful data item in the design, maintenance, and evaluation of pavements and bridges. Also, it is important for roads geometry, e.g., grade and curves. State DOTs are required to submit weigh in motion (WIM) data to FHWA. Such data are useful in weight law enforcement, economic analysis of freight movements, and others.

FHWA recommends that states submit weight data using the Traffic Monitoring Guide (2016 TMG) weight or per vehicle format, i.e., one record corresponds to one vehicle and describes its axle weights and spacings in English units.

Example: A three axle truck has axle weights of 12,000 lbs, 34,000 lbs, and 34,000 lbs. The front axle is single, while the middle and rear are tandem (see Figure 3). The total GVW is 80,000 lbs (12,000 + 34,000 + 34,000).

Vehicle axle loads and spacings can be measured by using weigh-in-motion (WIM) scales. WIM scales record vehicles' axle loads and spacing at roadway speeds without requiring them to come to a stop. The sum of the axle loads provides the measured GVW. WIM scales are calibrated to correctly identify the vehicle class, inter-axle spacing and its axle group(s), e.g., single, tandem, tridems, and larger axle groups. The WIM devices utilize sensor technologies such as piezo-electric and bending plate systems, load cells, strain gauges, and others.

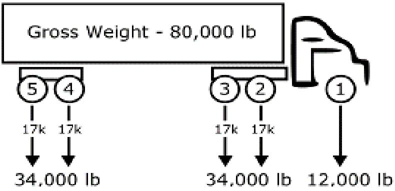

Figure 3. Vehicle axle loads and spacing (Source: FHWA).

Additional Notes and Tips.

- GVW data are collected as per vehicle records and are collected along with class of the vehicle.
- For pavement and bridge design procedures, vehicle axle loads have historically been converted to ESAL.
- Roads can be heavily, moderately, or lightly loaded depending on the allowable GVW they serve.
- Both road directions may not carry the same traffic load. Also, traffic load may not be equally shared by all lanes.
- Vehicle axle loads can shift due to vehicle drive axle and suspension arrangements, wind, grade, and cross slope.
- Average vehicle weights may differ according to day/night or weekdays/weekends.
- WIM measures the dynamic axle weights, which may be different from static weights due to vehicle dynamics.
- A vehicle's weight-to-power ratio, that determines the vehicle's acceleration rate, is calculated by dividing the GVW by the net engine power.

Related Traffic Data Items. ESAL, ACF, and Axle Spacing.

Cross Reference. TMG Sec. 3.2.4., and 7.6.

Headway

The time difference between successive vehicles as they pass a point on a roadway, measured from the same point on each vehicle (front bumper to front bumper or axle to axle).

For uninterrupted flow, headway in a lane is the reciprocal of the flow rate. Headway is expressed in seconds per vehicle.

$$Headway\ \left(\frac{sec}{veh}\right) = \left(\frac{Spacing\left(\frac{ft}{veh}\right)}{Speed\ \left(\frac{ft}{sec}\right)}\right)$$

Discussion and Illustration. Headway can be used to describe traffic operations on any transportation facility at a microscopic level. It is a key parameter in determining macroscopic traffic parameters like flow rate and average speed of the traffic stream.

Typically, headways could be collected for 5-minute or 15-minute intervals and can be categorized based on vehicle classification. Alternatively, headways could be calculated in two methods by using: i) flow rate for uninterrupted flow or ii) average spacing and average speed for interrupted flow.

In the first method, headway is the inverse of the flow rate expressed in vehicles per second, as shown in the formula below.

$$Headway\ \left(\frac{sec}{veh}\right) = \left(\frac{3600\ (\frac{sec}{h})}{Flow\ rate\ \left(\frac{Veh}{h}\right)}\right)$$

Example 1. Table 9 depicts information about traffic counts of two transportation facilities. If the flow rate values of the facilities are 1100 and 1400 veh/h, then the headway values will be 3.27 and 2.57 sec/veh, respectively.

Table 9. Average Headway calculations from Flow Rate

Flow Rate (veh/h)	Headway (sec/veh)
1100	3.27
1400	2.57

Example 2. Table 10 depicts information about average spacing and average speed of two transportation facilities. If the average spacings between vehicles in the facilities are 151 and 220 feet per vehicle, then the average headway values will be 2.96 and 3.01 seconds/vehicle respectively.

Table 10. Average Headway calculations from Average Spacing and Average Speed

Average Spacing (ft./veh)	Average Speed (ft./sec)	Average Headway (sec/veh)
151	51	2.96
220	73	3.01

Additional Notes and Tips.

- A higher percentage of heavy vehicles in the traffic stream increases the average headway.
- A higher traffic demand on roadways results in increased density and decreased headways.

Related Traffic Data Items. Flow rate, Speed, and Average Spacing.

Cross Reference. HCM Sec. 3-2, 4-2, 4-6, 4-12 to 4-16, 4-18,4-19, 4-23, 4-37, 4-45, 6-8, 6-24, 8-2, 8-3, and 8-8.

K-Factor

K-factor is the proportion of AADT occurring in the peak hour, i.e., the design hour volume (DHV). Depending on which hourly volume is used out of the 8,760 possible hours in a typical calendar year, K-factor can be expressed in different ways. K-30 is the 30th highest hourly volume of the year expressed as a percentage of the AADT. K-50 and K-100 use the 50th and 100th highest hourly volumes of the year, respectively. K-30 represents the reasonable design hour volume, but not always. Jurisdictions and local DOTs may use K-50 and K-100 for other purposes. K-factor is calculated as follows.

$$K - factor = \frac{K^{th}\ highest\ volume}{AADT} \times 100\%$$

Discussion and Illustration. K-factor is used in pavement design, geometric design (e.g., number of lanes needed), capacity analysis, estimation of volume-to-capacity ratios and levels of service, functional classification of roads, and analysis of traffic operations (e.g., effect of lane closures).

Example: If the AADT of a facility is 5,292 vehicles per day and the 30th, 50th, and 100th highest hourly volumes are 670, 652, and 621 vph, respectively, then:

K-30 factor = 670 / 5,292 * 100% = 12.7%
K-50 factor = 652 / 5,292 * 100% = 12.3%
K-100 factor = 621 / 5,292 * 100% = 11.7%

To calculate K-factor, one-year hourly volume data is required. Arrange the hourly volumes in decreasing order. The 30th entry in the ordered hourly volumes is the hourly volume to be used for K-30 calculation while the 50th and 100th entries correspond to K-50 and K-100, respectively.

Based on the hourly volume data, calculate the AADT. The ratio of the 30th, 50th, and 100th highest hourly volume and the AADT expressed as a percentage will be the K-30, K-50, and K-100 factors. Graphically, this can be represented as shown in Figure 4. Note that the values in Figure 4 does not serve as a reference for any site.

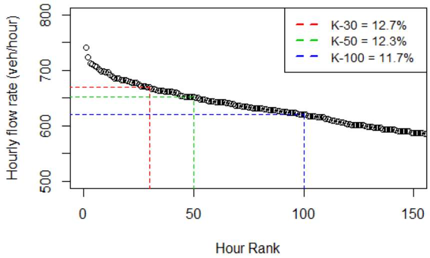

Figure 4. K-30, K-50, and K-100 factors.

Additional Notes and Tips.

- It ranges from 7% to 12% depending on whether a facility is in an urban, suburban, or rural area.
- Either one direction or combined directions can be used to determine the peak volumes and the AADT.
- It is best estimated from continuous count stations.
- As AADT increases, k-factor generally decreases.
- It is highest for recreational facilities, followed by rural facilities, and lowest for urban facilities.
- It depends on the analysis hour, traffic flow patterns, road geometry, and location.

Related Traffic Data Items. AADT, Design Hour Volume, and D-factor.

Cross Reference. HPMS Field Manual Item 26; TMG Sec. I Q-24 to Q-29; and HCM Sec. 3.2.

Lane Groups

A lane or set of lanes designated for separate analysis. On a given approach, separate lane groups can be assigned for each movement.

Discussion and Illustration. For signalized intersections, the design and layout of the intersection depends on the demand on lane group. The lane groups with highest flow rate commands higher green time than the other lane groups on the same approach. As the traffic demand does not reach its peak on all approaches, HCM model produces the capacity for each lane group rather than for the entire intersection. The capacity of an arterial lane group could be calculated using the formula below.

$$Capacity = (Saturation\ Flow) * \left(\frac{\text{Effective Green Time}}{Cycle\ Length}\right)$$

In general, for arterials, a lane group is established for

i. Each lane or combination of lanes that exclusively serves one movement. Examples of exclusive left, through, and right lane groups are depicted in Figure 5 (approach #3).

ii. Each lane shared by two or more movements. Fully shared lane group on first approach and through and right shared group on second approach are examples of shared lane groups.

For freeways,

- The lane groups concept was introduced to allow analysts to assign separate attributes to managed and general-purpose lanes, by retaining the ability to model interaction between two facilities.
- Adjacent lane groups are required to have the same segment length, but may have unique traffic

demand parameters and different geometric characteristics.

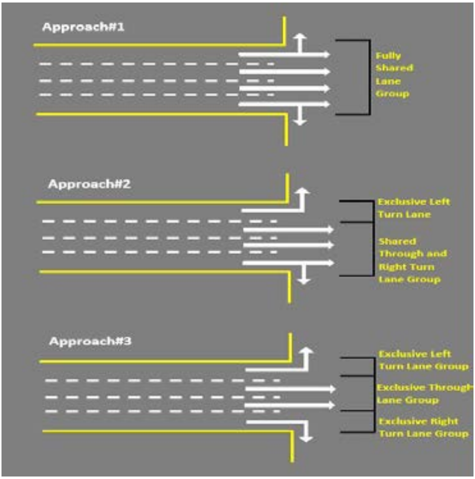

Figure 5. Example of different lane group types

Additional Notes and Tips.

- The lane groups that have the highest flow rates for a given signal phase are called critical lane groups.
- Varying signal timings throughout the day alters the capacities of lane groups.

Related Traffic Data Items. Capacity.

Cross Reference. HCM Sec. 3-14 and 4-13.

Load Spectra

The load spectra for a given vehicle class and axle group type consists of a set of counts of axles belonging to each of several load ranges. Load Spectra is utilized in mechanistic and empirical pavement designs.

Discussion and Illustration. Load spectra is the key parameter in determining the expected loads experienced by a pavement in its lifetime. Among the AASHTO recommended methods, the load spectra method provides a more accurate value of expected load than the Equivalent Single Axle Load (ESAL) method. First, the input axle weights for a candidate segment are usually calculated using weigh-in-motion (WIM) sensors. Later, the standard load range (LR) values, as shown in Table 11, are used to categorize the counts of axle groups based on their respective LR. For a complete table of standardized load ranges, refer to Table 5-1 in AASHTO Guidelines For Traffic Data Programs.

Table 11. Standard load ranges for load spectra sample

Upper Limit of Load Range (kips) by Type of Axle Group				
LR	**Single**	**Tandem**	**Tridem**	**Quad**
1	3	6	12	12
2	4	8	15	15
3	5	10	18	18

Example: Table 12 presents the loads of different axle types of vehicles of Class 7 including single, tandem and tridem axles. Each of these axle weights are categorized into a LR group and thereby the counts of each axle group with respect to its LR is determined. If vehicle 1 has a single axle with 2.5 kips of load and two tandem axles of 8 and 10 kips of loads, then the single axle falls in LR 1 and two tandem axles fall in load ranges 2 and 3 respectively. Load ranges for all the vehicles on the segment could be determined using the same method. Following the LR calculations, counts of each axle group with respect to their LRs are categorized, as shown in Table 13.

Table 12. Axle type loads and load ranges for vehicles of class 7

Vehicle No.	Axle Type Loads (kips) and LR					
	Single	LR	Tandem	LR	Tridem	LR
1	2.5	1	8,10	2,3	-	-
2	5	3	-	-	15.5	3
3	4.75	3	9.5	3	17.5	3

Table 13. Load Spectra example for Vehicle Class 7

LR	Single Axle	Tandem Axle	Tridem Axle
1	1	-	-
2	-	1	-
3	2	2	2

Additional Notes and Tips.

- TrafLoad software, available from NCHRP, can be used to estimate the load spectra.
- Although not covered in the AASHTO table listed, FHWA is finding penta and larger axle groups that contain significantly large load spectra loading patterns that should be considered when designing some roadways."
- The legal axle weight limits on roadways are 20,000 lbs. and 34,000 lbs. for single and tandem axles, respectively.

Related Traffic Data Items. ESAL and Vehicle Class.

Cross Reference. AASHTO Guidelines for Traffic Data Programs Sec. 3-14 and 4-13.

Month of Year and Day of Week Factors

Factors are used to properly annualize short duration traffic counts (usually 24-48 hours). Such factors are computed by using continuous count data, but they are applied to short duration counts. Seasonal or monthly, day of week, and time of day factors adjust counts to correct for the corresponding biases. Monthly and day of week factors are commonly used, and are computed as follows.

$$\boldsymbol{M_j = \frac{AADT}{MADT_j}} \qquad \text{and} \qquad \boldsymbol{D_i = \frac{AADT}{ADT_i}}$$

A daily volume can be converted to an AADT as follows.

AADT = VOL * M * D * A * G

Where:

M_j is the monthly factor for month j of the year.
D_i is the day of week factor for day i of the week.
VOL is the daily volume.
M, D, A, and G are the monthly, day of week, axle correction (where needed), and yearly change rates, respectively.

Discussion and Illustration. Factors provide an insight into how travel changes over time. Day of week factors can be developed for each day (seven factors) or for weekdays and weekends (two factors). The ratio of AADT to MAWDT captures monthly and daily variations in a single factor. Figure 6 shows an example of monthly factors.

Example: If volume on Tuesday May 24, 2016 is 9,200 veh/day, and the monthly and day of week factors for May and Tuesday are 0.93 and 1.01, respectively, the AADT (assuming that axle and change rates are both 1.0) will be:

AADT = 9,200 * 0.93 * 1.01 * 1 * 1 = 8,642 veh/day.

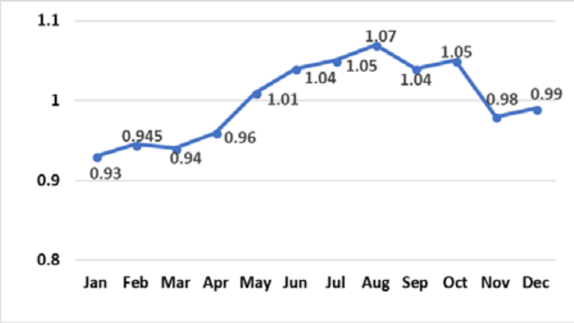

Figure 6. Monthly factors

Additional Notes and Tips.

- As the distance between the temporary and permanent traffic counter increases, factors' accuracy usually decreases.
- For day of week factors, a minimum of weekday and weekend factors should be developed.
- Factors for low volume roads can be unstable, as small changes may result in high-percentage changes.
- The sum of the seven daily and twelve monthly factors do not add up to 7 and 12, respectively.
- Months with higher MADT have lower monthly factors.
- Monthly and day of week factors cannot be derived from hourly volume data, but from daily volume data.
- Factors are not applicable for atypical traffic patterns.
- Change rates should be applied when estimating current AADT from short duration counts in previous years.

Related Traffic Data Items. AADT, ADT, MADT, ACF, and Class Factors.

Cross Reference. TMG Sec. 3.2.1. and 3.3.1.

Monthly Average Daily Traffic (MADT)

MADT estimates the average daily traffic volume over one month. It can be computed by the simple average method or the AASHTO method. In the simple average method, MADT is computed by summing the daily volumes during a given month and then dividing the sum by the number of days in the month. It requires volume for every day of the month. In the AASHTO method, MADT is computed by calculating the average daily volume for each of day of week in a month and then averaging the seven average daily volumes. It requires at least one day of volume data for each day of the week within a month.

Simple average method	$MADT_j = \frac{1}{n}\sum_{i=1}^{n} VOL_{ij}$
AASHTO method	$MADT_k = \frac{1}{7}\sum_{j=1}^{7}\left(\frac{1}{n_j}\sum_{i=1}^{n_j} VOL_{ijk}\right)$

Where:

VOL_{ij} = daily traffic on i^{th} day of the j^{th} month
n = number of days in j^{th} month
VOL_{ijk} = daily volume for i^{th} occurrence of j^{th} day of week within the k^{th} month
i = occurrence of a particular day of week in a month
j = day of week (1 to 7)
k = month of year
n_j = number of times day j occurs in a month for which traffic data is available

Discussion and Illustration. By using monthly traffic volume correction factors, MADT can be converted to AADT. MADT statistics for a particular roadway often exhibit a monthly pattern of higher and lower values compared to overall roadway AADT that is called seasonality. The seasonality pattern often repeats similarly from year to year for a roadway.

The AASHTO method may provide a biased MADT estimate compared to the simple average method due to equal weighting of each day of the week within a month even though all months (except February in non-leap years) have a mixture of four and five occurrences of each day of week. FHWA has developed a new MADT method for computing MADT that removes this bias and allows for smaller than daily volumes to be utilized – see the 2016 TMG for more details. FHWA recommends use of this method.

Additional Notes and Tips.

- Monthly correction factors are estimated by dividing AADT by the MADT of each month.
- MADT, in combination with other volume measures, is used in monitoring of traffic volume trends and grouping traffic patterns.

Related Traffic Data Items. ADT, AADT, MADTT, and Monthly Factors.

Cross Reference. TMG Sec. 1.2.7, 3.2.1.1, and 3.3.1.

Number of Intersections of Other Type

Number of at-grade intersections, where full sequence traffic signal or stop sign traffic control devices are not present, in the inventory direction. Continuously operating flashing yellow and roundabouts are considered as other at-grade type of traffic control devices.

Discussion and Illustration. The numbers of intersections that are not controlled by either signal or stop sign are used to calculate capacity and estimate delay for a roadway segment or geographic boundary. To estimate the number of other type intersections, the first rule is to choose a statewide direction for inventory purposes. The second rule is to either count the beginning at-grade intersection or the ending at-grade intersection, but never both. For divided roadways, continuous cross streets are to be counted as a single intersection the separation between cross streets is at least 50 feet. In the latter case, it shall be counted as two intersections. If the sample section does not begin or end with another type of intersection, then all the other type intersections in between would be reported, when using either the beginning rule or ending rule.

Access points to large traffic generators (e.g., shopping centers, malls, large work sites, office parks, apartment complexes, etc.) shall be included in the intersection counts.

Example: In the upper portion of Figure 7, 2 other type intersections would be reported, when using either the beginning rule or ending rule. In the bottom portion of Figure 7, 2 other type intersections would be reported, when using the beginning only rule; 1 other type intersection would be reported, when using ending only rule. Note that the inventory direction in Figure 7 goes from bottom to top.

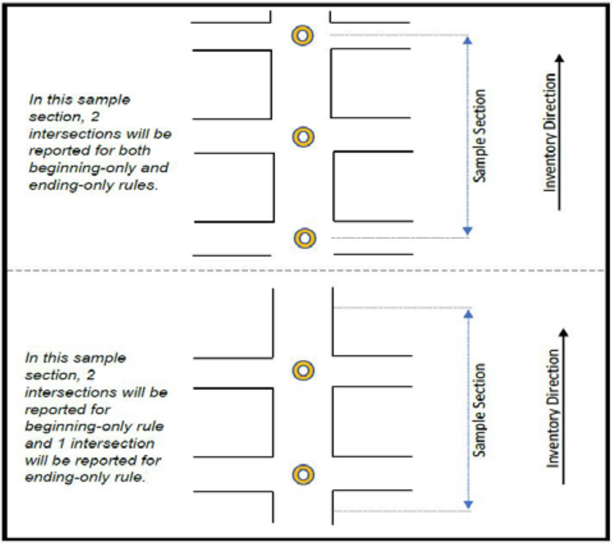

Figure 7. Example for no. of "at-grade/other" intersections count

Additional Notes and Tips.

- The number of intersections of other type in a sample section depends on the geographic boundaries and road functional class. This data item does not have a specific range.
- The summation of signalized, stop sign-controlled and at-grade/other intersections results in the total number of intersections in a given geographic boundary.

Related Traffic Data Items. Number of Signalized Intersections, Number of Stop Sign Intersections.

Cross Reference. HPMS Sec. 4.3–Item 33 Figure 4.45-4.46.

Number of Signalized Intersections

A count of at-grade intersections where traffic signals are present. Only signals that cycle through a complete sequence of signalization (i.e., red, yellow (amber), and green) for all or a portion of the day are counted.

Discussion and Illustration. Numbers of signalized intersections are used to calculate capacity and estimate delay for a roadway segment or the area within a geographic boundary. To estimate the number of signalized intersections, the first rule is to choose a statewide starting direction (e.g., south to north, west to east) for inventory purposes. The second rule is to either count the beginning at-grade intersection or the ending at-grade intersection of the defined segment, but never both. For divided roadways, continuous cross streets are to be counted as a single intersection unless the separation between cross streets is at least 50 feet. In the latter case, it is counted as two intersections. If the sample section does not begin or end with a signalized intersection, then all the signalized intersections in between would be reported, when using either the beginning rule or ending rule. Access points to large traffic generators (e.g., shopping centers, malls, large work sites, office parks, apartment complexes, etc.) should be counted as intersections if the access point is controlled by a traffic signal.

The number of signalized intersections and the distance between them plays a key role in determining the offset time between consecutive intersections while designing the signal cycle timings. In a coordinated signal system, a timely offset would ensure orderly progression of traffic.

Example: In the upper portion of Figure 8, 2 signalized intersections would be reported when using either the beginning rule or ending rule. In the bottom portion of Figure 8, 2 signalized intersections would be reported when using the beginning only rule; 1 signalized intersection would be reported when using the ending only rule. Note that the inventory direction in Figure 8 goes from bottom to top.

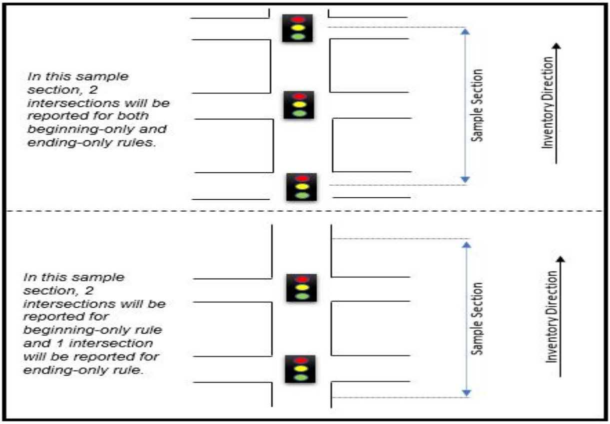

Figure 8. Signalized intersection count example

Additional Notes and Tips.

- The number of signalized intersections in a sample section depends on the geographic boundaries and road functional classification.
- A geographic area with high traffic demand requires more signalized intersections. This data item does not have a specific range.

Related Traffic Data Items. Number of Stop Sign Intersections and Number of Intersections.

Cross Reference. HPMS Sec. 4.3 – Item 31 and Figure 4.42.

Number of Stop Sign Intersections

The number of at-grade intersections where one or more stop signs are present.

Discussion and Illustration. Numbers of stop sign intersections are used to calculate capacity and estimate delay for a roadway segment or an area within a geographic boundary. To estimate the number of stop sign intersections, the first rule is to choose a statewide starting direction (e.g., north, east) for inventory purposes. The second rule is to either count the beginning at-grade intersection or the ending at-grade intersection, but never both. For divided roadways, continuous cross streets are to be counted as a single intersection the separation between cross streets is at least 50 feet. In the latter case, it is counted as two intersections. If the sample section does not begin or end with a signalized intersection, then all the stop sign intersections in between would be reported, when using either the beginning rule or ending rule.

Access points to large traffic generators (e.g., shopping centers, malls, large work sites, office parks, apartment complexes, etc.) should be counted as intersections if the access point is controlled by a stop sign. The stop signs on grade separated intersecting roadways should not be included in the total count.

Example: In the upper portion of Figure 9, 2 stop sign intersections would be reported, when using either the beginning rule or ending rule. In the bottom portion of Figure 9, 2 stop sign intersections would be reported when using the beginning only rule; 1 stop sign intersection would be reported when using the ending only rule. Note that the inventory direction in Figure 9 goes from bottom to top.

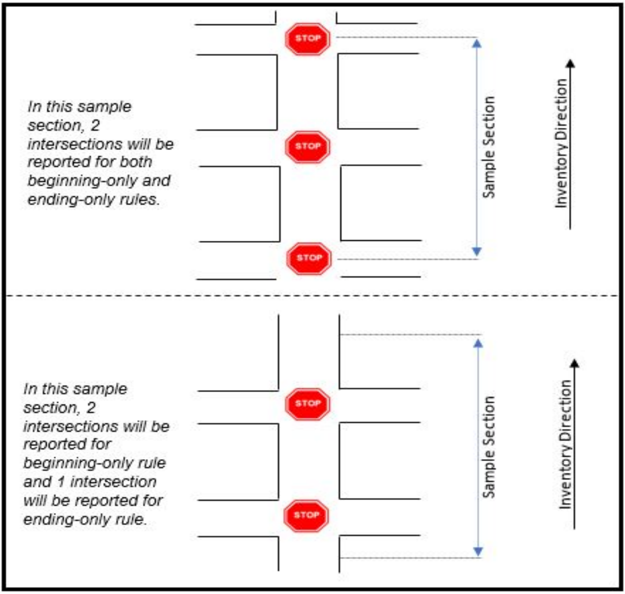

Figure 9. Example for no. of stop sign intersections count

Additional Notes and Tips.

- Number of stop sign intersections in a sample section depends on the geographic boundaries and road functional classification. This data item does not have a specific range.

Related Traffic Data Items. Number of Signalized Intersections and Number of Intersections.

Cross Reference. HPMS Sec. 4.3 – Item 32, Figure 4.43, and Figure 4.44.

Passenger Car Equivalent (PCE)

PCE is the number of passenger cars that will result in the same operational conditions as a single heavy vehicle of a particular type under identical roadway, traffic, and control conditions.

Discussion and Illustration. PCE factors are used to convert counts of heavy vehicles into counts of passenger cars such that a mixed flow of heavy and light vehicles is converted to an equivalent traffic stream consisting entirely of passenger cars.

Depending on the type and location of a facility, length and type of grade, and other factors, one heavy vehicle might occupy as much roadway space as two to twelve passenger cars. This variance in key operational characteristics of heavy vehicles and passenger cars is accounted in the design of roads by providing additional capacity as needed.

In general, heavy vehicles are classified into SU Trucks and Tractor Trailers (TTs). Recreational vehicles and buses are treated as SU Trucks. PCE values (E_T) for heavy vehicles on level and rolling terrain are provided in Table 14. However, at higher grades PCE values could range up to 11.81 (~12).

Table 14. PCEs of general terrain segments

Factor	Type of Terrain	
	Level	**Rolling**
E_T	2.0	3.0

Example: Table 15 depicts the information about traffic volume on a two-lane freeway, percentage share of heavy vehicles, and their PCE. The freeway has a 4.5% grade for a 1-mile segment length. The total volume on a transportation facility is 1500 veh/h, of which 14% are TTs and 6% are SU trucks. From the HCM PCE values, each TT and SU Truck displaces 2.85 passenger cars (E_{TT} & E_{SUT}). Here E_{TT} & E_{SUT} represent PCE values for TTs and SU Trucks.

The number of PCEs in the traffic stream is computed by multiplying the number of vehicles in each class by its respective PCE, noting that PCE for passenger cars is 1.0 by default. Computed values of TT and SU Truck passenger-car equivalent volumes are 599 and 257 pc/h, respectively. Thereby, the total equivalent passenger cars in the traffic stream summed up to 2056. Thus, the prevailing traffic stream of 1500 veh/h operates as if it contains 2056 pc/h.

Note that this is a 30% SU Truck and 70% TT mix. Exhibit 12-26 in HCM was used to compute the PCE values.

Table 15. PCE computation example

Vehicle Type	Total Volume (veh/h)	% Truck	Heavy Vehicle volume	ET	Passenger Car Equivalent Volume (pc/h)
Truck	1,500	14	210	2.85	599
RV and Bus		6	90	2.85	257

$$Volume_{PCE} = (1500 - 210 - 90) + \ (599 + 257)$$
$$= 2056\ \frac{pc}{hr}$$

Additional Notes and Tips.

- PCE values for various percentage mixes of SUTs and TTs with respect to the grade and length of roadway segment are provided in HCM.

Related Traffic Data Items. Volume, SU Truck & Bus AADT, Percent Peak SU Trucks & Buses, Combination Truck AADT, and Percent Peak Combination Trucks.

Cross Reference. HCM Sec. 7-31; Exhibits 12-26, 12-27, 12-28.

Peak Hour Factor (PHF)

Traffic demand varies; it changes even within the analysis hour. PHF is a measure of traffic demand variation within the analysis hour and describes the relationship between full hourly volume and the peak 15-min flow rate within the hour. It is given by dividing the hourly volume by the peak 15-min flow rate within the analysis hour. In estimating PHF, 15-min is used because it is considered as the minimum time period over which traffic flow is statistically stable.

$$PHF = \frac{V}{Maximum\ flow\ rate} = \frac{V}{4 \times V_{m15}}$$

Where: V = hourly volume in veh/h
V_{m15} = maximum volume during the peak 15-min of the analysis period (veh/15-min)

Conversely, the maximum flow rate within an hour can be estimated by dividing the hourly volume by the PHF.

Discussion and Illustration. PHF is an important variable for facility design and capacity analysis because the design should always seek to accommodate the traffic demand in most peak-hour periods of the year. The PHF is primarily used for planning purposes when DHV is known but peak 15-min analysis is sought. It is best estimated from local peak traffic trends.

Example 1: If the PHF during the design hour is predicted to be 0.85 and the design hourly volume is 6,000 veh/h, then the maximum flow rate will be:

$$\boldsymbol{V_{max} = \frac{6,000}{0.85} = 7,060\ veh/h}$$

Example 2: Given the data shown below, estimate the PHF.

<table>
<tr><th>Time interval</th><th>Vehicles count</th><td rowspan="5">Hourly volume = 1,150+1,275+1,210+1,130 = 4,765 veh/h
Maximum volume during the analysis hour, i.e., V_{m15}, is 1,275 veh/15-min
$$\boldsymbol{PHF = \frac{4,765}{4 \times 1,275} = 0.93}$$</td></tr>
<tr><td>4:00 pm</td><td>1,150</td></tr>
<tr><td>4:15 pm</td><td>1,275</td></tr>
<tr><td>4:30 pm</td><td>1,210</td></tr>
<tr><td>4:45 pm</td><td>1,130</td></tr>
</table>

The maximum and minimum PHF values are 1.00 and 0.25, respectively. A PHF of 1.00 indicates no variation in traffic flow within the analysis hour and a PHF of 0.25 indicates that the entire hourly volume occurred during the peak 15-min interval.

Additional Notes and Tips.

- The notion of PHF is that the flow rate observed in the peak 15-min is not sustained throughout the entire hour.
- PHF is unitless. It is applicable to directional volume only.
- High PHF indicates steady traffic.
- The use of hourly volume divided by a PHF is preferred when volumes are projected.
- On freeway segments, PHF ranges from 0.85 to 0.98 while on multilane highways it ranges from 0.75 to 0.95.
- A single average PHF is used for intersection analysis.
- Given the LOS, multiplying the service flow rate with the PHF gives the service volume over a full peak hour.
- PHF is applicable to any analysis hour, i.e., peak or off-peak.
- PHF affects the number of lanes needed for traffic to operate at desired LOS.

Related Traffic Data Items. DHV, DDHV, DH, capacity, and LOS.

Cross Reference. HCM Sec. 4.2.; AASHTO Sec. 2.4.4.

Percent Green Time

The percentage of green time allocated for through traffic at intersections is called percent green time. It is calculated using the green time for through movements and the total control signal cycle length.

$$Percent\ Green\ Time = \left(\frac{\text{Green Cycle Time for Through Movement}}{Total\ Signal\ Cycle\ Timing\ for\ the\ Approach}\right)$$

Discussion and Illustration. Percent green time is critical for the assessment of performance of traffic signals at any intersection. This provides an insight on the time allocated for the through traffic movement. It is used to calculate the capacity of a traffic signal and to perform congestion analysis.

Table 16. Percent green time computation for pre-timed control signals

Through Green Time (sec)	Amber or Yellow Time (sec)	Red Clear. Interval (sec)	Green for Turning Move. (sec)	Total Cycle Time (sec)	Percent Green Time (%)
40	3.5	1.5	12	57	70.2
24	3	1	8	36	66.7
11	3	1	-	15	73.3

Example. Table 16 depicts the information about signal timings on three different approaches. If the total green, amber and red times of the first approach are 40, 3.5, 1.5 seconds, then the percent green time for the approach is 70.2%. Note that green time for the turning movements are not included in the green time. In the case of actuated signals, several checks of peak period light cycles are performed to determine the typical or average green time. This typical green time is used to calculate the percent green time.

Example. Table 17 depicts the percent green time computation methodology for actuated control signals.

Table 17. Percent green time computation for actuated control signals

	Green Time (sec)	Amber or Yellow Time (sec)	Red Clearance Interval (sec)	Total Cycle Time (sec)	Percent Green Time (%)
Cycle 1	35	3.5	1.5	40	33.5 / 38 = 88.2
Cycle 2	28	3	1	32	
Cycle 3	40	3.5	1.5	45	
Cycle 4	31	3	1	35	
Average	**33.5**	**3.25**	**1.25**	**38**	

Additional Notes and Tips.

- An approach with high percentage green time indicates it serves higher through traffic.

Related Traffic Data Items. Traffic flow.

Cross Reference. HPMS Item 30.

Percent Peak Combination Unit Trucks

A Combination Unit (CU) truck is any truck in FHWA Categories 8 through 13. The Percent Peak CU Trucks value is the number of combination trucks during the hour with the highest total volume (i.e., the peak hour) divided by the AADT (i.e., the total daily traffic).

$$Percent\ Peak\ CU\ Trucks = \left(\frac{\text{Peak Hour CU Trucks}}{AADT} * 100\right)$$

Where:

AADT = Annual Average Daily Traffic (veh/day)

Peak Hour CU Trucks = Volume of CU trucks during the peak traffic hour

Note: This data item is based on the truck traffic during the peak traffic hour (for all vehicle classes) and not the hour with the most truck traffic.

Discussion and Illustration. Percent Peak CU Trucks is used to calculate capacity, peak volumes, ACFs, and pavement deterioration for a roadway segment or functional class or facility. Depending on its functional class, each roadway segment experiences different percentage of truck traffic. To get accurate estimates, HPMS recommends actual traffic counts of the road segment. If the actual measured values are not available, the most credible method would be to use other site-specific measured values from sites located on the same route. Other methods may include: assigning site-specific measured values to other samples that are located on similar facilities with similar traffic characteristics in the same geographic area and in the same volume group; or assigning measured values from samples in the same functional system and in the same area type.

States have access to traffic classification counts and data on the percentage of vehicles passing through a counting point. This information is used to estimate Percent Peak CU trucks for an entire roadway or city or county or state using weighted average method.

Example: Data parameters required to estimate % Peak CU Trucks are traffic counts of a road or facility or functional class and truck volume for the peak traffic hour. Table 18 depicts information about traffic counts and peak hour CU truck traffic counts of two roadways. If the AADT values of a facility are 165,000 and 7,000 per day and the respective peak hour truck traffic counts are 1,825 and 60, then the % Peak CU Trucks will be 1.106% and 0.857% respectively. HPMS rounds % peak CU trucks to the nearest thousandth.

Table 18. Computation of % peak CU trucks from AADT and peak hour CU truck volume

Roadway ID	AADT (veh/day)	Peak Hour CU Truck Volume (veh/h)	Percent Peak CU Trucks
R100A	165,000	1,825	1.106
R200B	7,000	60	0.857

Additional Notes and Tips. The HPMS submittal software will perform a quality check and reports error if:

$$\frac{\text{Percent Peak CU Truck}}{100} \times AADT > 30\%\ of\ CU\ Truck\ AADT$$

Related Traffic Data Items. AADT and Truck Volume

Cross Reference. HPMS Sec. 4.3 – Item 25; TMG Sec. 3.2.3 and Table 3-3.

Percent Peak Single Unit Trucks & Buses

A Single Unit (SU) truck is any truck in FHWA Categories 4 through 7, as defined above. Single Unit trucks include buses. The Percent Peak Single-Unit Trucks and Buses is the number of SU trucks and buses during the hour with the highest total volume (i.e., the peak hour) divided by the AADT (i.e. the total daily traffic).

$$Percent\ Peak\ SU\ Trucks = \left(\frac{(\text{Peak Hour SU Trucks})}{AADT} * 100\right)$$

Where:

AADT = Annual Average Daily Traffic (veh/day)

Peak Hour SU Trucks = Volume of SU trucks during the peak hour

<u>Note:</u> This data item is based on the truck traffic during the peak hour (for all vehicle classes) and not the hour with the most truck traffic.

Discussion and Illustration. Percent Peak SU Trucks is used to calculate capacity, peak volumes, ACFs, and pavement deterioration for a roadway segment or facility. Depending on its functional class, each roadway segment experiences a different percentage of truck traffic. To get accurate estimates, HPMS recommends actual classification traffic counts on the road segment. If the actual measured values are not available, the most credible method would be to use other site-specific measured values from sites located on the same route. Other methods may include: assigning site-specific measured values to other samples that are located on similar facilities with similar traffic characteristics in the same geographic area and in the same volume group; or assigning measured values from samples in the same functional system and in the same area type.

States have access to traffic classification counts and data on the percentage of vehicles passing through a counting point. This information is used to estimate Percent Peak SU Trucks for an entire roadway or region using weighted average method.

Example: Data parameters required to estimate Percent Peak SU Trucks are traffic counts of a road or facility or functional class and truck volume for the peak traffic hour. Table 19 depicts information about traffic counts and peak hour SU Truck traffic counts of two roadways. If the AADT values of facilities are 140,000 and 2,000 veh/day and the respective peak hour truck traffic counts are 1510 and 15 veh/h, then the Percent Peak SU Trucks will be 1.078% and 0.750%, respectively. HPMS rounds Percent Peak SU trucks to the nearest thousandth.

Table 19. Computation of % peak SU trucks from AADT and peak hour SU truck volume

Roadway ID	AADT (veh/day)	Peak Hour SU Truck Volume (veh/h)	Percent Peak SU Trucks
R100A	140,000	1,510	1.078
R200B	2,000	15	0.750

Additional Notes and Tips. The HPMS submittal software will perform a quality check and reports error if:

$$\frac{\text{Percent Peak SU Truck}}{100} \times AADT > 30\% \text{ of } SU\ Truck\ AADT$$

Related Traffic Data Items. AADT and Truck Volume.

Cross Reference. HPMS Sec. 4.3 – Item 23; TMG Sec. 3.2.3 and Table 3-3.

Roadway Occupancy

It can be defined in two ways, i.e., occupancy in space and in time. Occupancy in space refers to the proportion of the actual length of the roadway occupied by each vehicle to the total roadway length, while occupancy in time refers to the proportion of time a detector was occupied by vehicles in a defined period of time.

$$Occupancy = \frac{Length\ of\ roadway\ occupied\ by\ vehicles}{Total\ length\ of\ roadway}$$

$$Occupancy = \frac{Total\ time\ the\ detector\ is\ occupied}{Defined\ time\ period}$$

Where:

Total length of roadway = length of roadway defined for occupancy detection. Any length of roadway can be considered.

Defined time period = Total time period defined for occupancy detection. Typically, 5- or 15-minute time.

Discussion and Illustration. Roadway occupancies are often used in the calculations of traffic speed and density. Estimation of roadway occupancy is easy to collect in the field through the use of detectors. In traffic data collection, roadway occupancy is often considered as a surrogate for vehicle density. Similar to density, roadway occupancy is a key parameter in characterizing the quality of traffic operations on a transportation facility. Even though both traffic parameters indicate the amount of congestion on a roadway, occupancy is a percent of congestion in space or time, where density is a count of vehicles.

Example. In a 1-mile roadway segment, if 1,400 feet is occupied by vehicles, the occupancy is 0.265

$$Occupancy = \frac{1{,}400\ ft}{1 * 5280\ ft} = 0.265$$

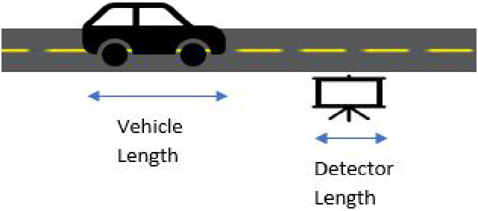

Figure 10. Vehicle length and detector length

Similarly, in a 15-minute time period, if the detector is occupied for 180 seconds, the occupancy for that time period is 0.200.

$$Occupancy = \frac{180\ seconds}{15 * 60\ seconds} = 0.200$$

Given the length of the average vehicle and field detector, density can be calculated from the occupancy values. For a detailed example, please refer to Density data item.

Additional Notes and Tips.

- Average vehicle length and sensitivity of sensors act as limiting factors for the accuracy of roadway occupancy estimation.
- A lane occupancy value of 0.350 or higher indicates congestion in traffic stream.

Related Traffic Data Items. Critical Speed, Critical Density, Capacity, and Density.

Cross Reference. HCM Sec. 4-6.

Saturation Flow

Saturation flow is used in the context of signalized intersections. It is the number of vehicles per hour per lane that could pass through a signalized intersection if a green signal was displayed for the full hour, the flow of vehicles never stopped, and there were no large headways. This parameter is expressed in vehicles per hour of green per lane.

$$S = \frac{3{,}600}{h}$$

Where:

S = Saturation Flow (veh/hg/ln)

h = Saturation Headway (sec/veh)

Discussion and Illustration. Saturation flow is a key parameter in analyzing intersection capacity. It represents the capacity of an intersection lane or lane group assuming that the light is always green.

Once the saturation flow rate is computed, the capacity of that lane can also be computed based on the effective green time. On-field video detectors are often used for estimation of saturation flow.

In reality, the saturation flow rate varies widely with a variety of prevailing conditions, including lane widths, heavy-vehicle presence, approach grades, parking conditions near the intersection, transit bus presence, vehicular and pedestrian flow rates, and other conditions.

To calculate saturation flow, the total number of seconds in an hour (3,600) should be divided by the saturation headway of the vehicles in the traffic stream. Total seconds in the hour are used, as it is assumed that the traffic signal at the intersection remains green throughout the hour. Because signal lights are not always green, mechanisms for dealing with starting and stopping movements in signal cycles must be developed.

Example: Table 20 depicts the saturation headways for three roadway sections. If their saturation headways are 3.8, 2.9, and 4.1 seconds, respectively, then their respective saturation flows will be 947, 1241, and 878 veh/hg/ln.

Table 20. Saturation flow computation example

Roadway ID	Saturation Headway (sec/veh)	Saturation Flow (veh/hg/ln)
R210A	3.8	947
R320H	2.9	1,241
R570K	4.1	878

These saturation flow values should be multiplied by the number of lanes in the respective roadway sections to get saturation flow for all lanes.

Additional Notes and Tips.

- A typical range of saturation flow is between 600 and 1,800 veh/hg/ln. Higher values of saturation flows indicate normal to good operating conditions.
- Similarly, lower values of saturation flows indicate congested operating conditions. Saturation flows in central business districts (CBDs) are significantly lower than those in less constrained and visually less intense areas.

Related Traffic Data Items. Saturation Headway and Capacity.

Cross Reference. HCM Sec. 4-14, 4-16, 4-17, 4-20, 4-21, 4-23, 4-25, 4-38, 6-20 and 7-4.

Saturation Headway

Saturation headway at intersections can have slightly different meanings depending on the intersection types being considered.

In signalized intersections, saturation headway is the average headway between vehicles occurring after the fourth vehicle in the queue and continuing until the last vehicle of the initial queue at the beginning of the traffic signal green time clears. It is expressed in seconds per vehicle, and it represents the average headway that can be achieved by a queue of vehicles, e.g., vehicles queuing at saturated intersection approaches.

$$Saturation\ Headway = \frac{h_4 + h_5 + h_6 + h_6 + \cdots + h_n}{n - 4}$$

Where:

h_4 to h_n = headways of vehicles 4 to vehicle n

In an all-way-stop-intersection, saturation headway is the time between departures of successive vehicles on a given approach, assuming continuous queue.

Discussion and Illustration. Saturation headway is a key parameter in analyzing intersection capacity. On-field video detectors are often used for estimation of saturation headway. As depicted in Figure 11, the first four vehicles are subject to a start-up lost time taken by the drivers to perceive the change in signal indicator from red to green and react to the signal change by accelerating. This phenomenon of start-up lost time is expected to dissipate with the fourth vehicle in the initial queue. For all-way-stop intersections, saturation headway on a subject approach increases with the degree of conflict between vehicles on other approaches. For example, vehicles on opposing approaches (oncoming traffic) will have less impact on increases in saturation headway compared to vehicles on conflicting approaches (perpendicular traffic).

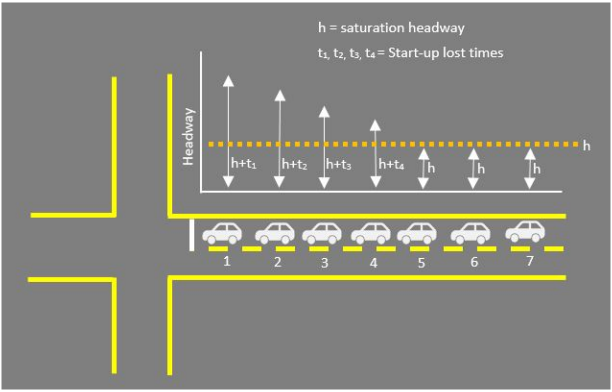

Figure 11. Saturation headway and start-up lost time at a signalized intersection

Additional Notes and Tips.

- Saturation headway ranges from 2 to 6 seconds.
- Lower saturation headways indicate normal to good operating conditions and vice versa.
- Saturation headways on Central Business Districts (CBDs) are significantly longer than those in less constrained and visually less intense areas.

Related Traffic Data Items. Saturation Flow, Headway, and Capacity.

Cross Reference. HCM Sec. 4-15 to 4-18.

Short Term Count ADT by Vehicle Class to AADT by Vehicle Class Conversion

A weighted average of short duration ADT count of a select vehicle class by considering its occurrence in day of the week and month of the year will result in AADT by vehicle class. Both ADT and AADT are expressed in vehicles per day units.

$$AADT_c = \frac{1}{7}\sum_{i=1}^{7}\left[\frac{1}{12}\sum_{j=1}^{12}\left(\frac{1}{n}\sum_{k=1}^{n} VOL_{ijkc}\right)\right]$$

Where:

i = day of the week

j = month of the year

$AADT_c$ = annual average daily traffic for vehicle class c

VOL_{ijkc} = daily truck traffic for class c, day k, of DOW i, and month j

k = 1 when the day is the first occurrence of that day of the week in a month, 4 when it is the fourth occurrence of that day of the week

n = the number of days of that day of the week during that month

Discussion and Illustration. The conversion of ADT into AADT by vehicle class is useful in areas without long term traffic counters. AADT by vehicle class for a transportation facility is a key parameter in the analysis of pavement conditions and design of transportation facilities with similar roadway and traffic settings. Portable Traffic Recorder (PTR) stations are deployed in these sites and traffic data is collected for a set of consecutive days.

The $AADT_c$ formula stated above computes an average DOW value for each month, and then computes an annual average value from those monthly averages, before finally computing a single annual average daily value. This process effectively removes most biases that result from missing days of data, especially when those missing days are unequally distributed across months or days of the week.

In this worked example, daily volume counts of passenger cars (pc) for 205 days out of 365 days were available. The $AADT_c$ formula was applied to this data to estimate the AADT for each day of week, month averages, and annual average. These AADTs are useful to understand and plan for the changing travel patterns throughout the year.

Additional Notes and Tips.

- TMG recommends collection of daily counts for 25 to 30% of the days in each year to calculate a reliable estimate of AADT.

Related Traffic Data Items. AADT, ADT, and Vehicle Class.

Cross Reference. TMG Sec. 3.4.5.

Short Term Count ADT to AADT Conversion

A short duration count of Average Daily Traffic (ADT) at a location can be converted to Annual Average Daily Traffic (AADT) by applying adjustment factors to month (MOY), DOW, HOD, ACF, and change rate computed from a continuous count station on a similar location. Both ADT and AADT are expressed in vehicles per day units.

$$AADT = (Short\ Term\ ADT * M_i * DOW_i * A_i * G_i)$$

Where:

Short Term ADT **=** Daily traffic volume computed for a short duration (veh/day)

M_i = the monthly factor for factor group i

DOW_i = the DOW factor for factor group i

A_i = the axle-correction factor for location i

G_i = the change rate for factor group i

Discussion and Illustration. The conversion of ADT to AADT is useful in areas without continuous count stations. Portable Traffic Recorder (PTR) stations are deployed in these sites and traffic data is typically collected for a set of consecutive days. In parallel, data on AADT, monthly average daily traffic (MADT), and daily traffic counts are exported from a similar transportation facility that is nearby or adjacent to the location. Based on the adjacent facility's counts, HOD, DOW and MOY factors are developed.

If the traffic counts at the select location are collected for a partial day, then each hours' count for that day needs to have a HOD factor to account for hourly variations in traffic. If the traffic counts at the select location are collected for less than seven consecutive days, then each day's count is multiplied with the DOW factor to account for daily variations in traffic. Similarly, a monthly factor is used to adjust the short-term ADT for the monthly variations. If the short-term ADT counts and the adjacent facility counts are for different years, then a change rate must be applied to account for the traffic change between years. If the detector counts the number of axles instead of the number of vehicles, then an appropriate ACF is applied.

Example: Consider that 9,100 vehicles were observed during a seven consecutive days count. Assuming the monthly factor is 1.14 and change rate is 1, then AADT can be estimated in the following way.

$$Short\ Term\ ADT = Total\ Volume/days = 9100/7$$
$$= 1300\ veh/day$$

Since the seven-day count includes all the days in a week, DOW factor is not necessary.

Now, the short-term ADT is multiplied with the monthly factor to obtain the AADT, which is 1,482 veh/day.

$$AADT = Short\ Term\ ADT * M_i = 1300 * 1.14$$
$$= 1482\ veh/day$$

Additional Notes and Tips.

- Misusing the monthly factor can lead to an overestimation of AADT by as much as 15%. For example, summer season experiences higher traffic than winter. A misuse of a summer month in place of a winter month could cause overestimation.

Related Traffic Data Items. AADT, ADT, Seasonal Factor, and Change Rate.

Cross Reference. TMG Sec. 3.3.1.

Signal Type

The predominant type of traffic signal system used on a sample section.

Discussion and Illustration. The type of signal installed at an intersection determines the mobility functioning of the corridor. Signal type is used in the calculations of intersection capacity and delay.

In general, four signal types are available based on the location of the intersection, expected traffic demand, and type of traffic operation.

I. Uncoordinated Fixed Time Signals: These traffic signals are observed in rural areas that do not have traffic signals in close proximity and thereby do not require coordination. The signal timings in these signals are pre-timed to suit the existing traffic demand. Timely revisions to signal timing plans will be performed when congestion is identified.

II. Uncoordinated Traffic Actuated Signals: These traffic signals are usually observed at a major and minor street intersections. In-pavement loop detectors are installed to detect the minor street traffic and thereby activate the minor street signal timing. These signals are beneficial in intersections with minimum minor street traffic, as major street traffic is not disturbed unless a minor street demand is observed.

III. Coordinated Progressive Signals: These traffic signals can be observed in urban areas with busy traffic conditions. Several intersection signals will be operated through coordination and hence a constant flow of traffic is maintained.

IV. Coordinated Traffic Adaptive Signals: These traffic signals are observed in streets with unpredictable traffic demand shifts. Actuated signals will identify the approaches with peak demand and adjust the signal timings accordingly. In addition, coordination of signals will help in active and dynamic management of traffic demand. A corridor level benefit in mobility performance could be achieved. However, on field identification of these signals is difficult and requires communication with local traffic personnel.

Criteria for selecting signal type: In general, pre-timed control signals are less expensive to install and maintain. Uncoordinated traffic signals are most suitable for intersections with simple and predictable traffic movements on all approaches. However, in areas with complex and unpredictable traffic conditions, actuated signals are proven to be more beneficial. Further, actuated signals have the flexibility of operating fully actuated, semi actuated, or pre-timed. The operation type may also change by time of day.

Coordinated and pre-timed signal types have proven to be more efficient than actuated signals. The pre-timed signals ensure consistent starting time and duration of intervals. This capability permits progressive traffic movements and maximizes efficiency.

Additional Notes and Tips.

- Actuated signals are interchangeable between manufacturers due to National Electrical Manufacturers Association or Type 170 standards.

Related Traffic Data Items. Flow and Capacity.

Cross Reference. HPMS Item 29; 4-61.

Single Unit Truck & Bus AADT

A Single Unit (SU) truck is any truck that meets the requirements established for the FHWA Truck Classification Scheme for Categories 4 through 7. Single Unit trucks include buses. SU truck AADT is expressed in vehicles per day units.

$$SU\ Truck\ AADT = \frac{1}{7}\sum_{i=1}^{7}\left[\frac{1}{12}\sum_{j=1}^{12}\left(\frac{1}{n}\sum_{k=1}^{n} ADT_{ijk4-7}\right)\right]$$

Where:

SU Truck AADT = AADT for SU Trucks

$ADT_{ijk4\text{-}7}$ = daily SU traffic for day k, of DOW i, and month j

i = day of the week (DOW)

j = month of the year

k = count of occurrence of that day of week in a month; 4 when it is fourth occurrence of that day of week

n = the number of days of that day of the week during that month (for which you have data)

Discussion and Illustration. SU Truck AADT is used to estimate pavement deterioration, calculate operating speeds, and perform freight analysis for a transportation facility. Depending on its functional class, each roadway segment experiences different volumes of truck traffic. To get accurate estimates, HPMS recommends actual traffic counts on the road segment. If measured values are not available, the most credible method would be to use values measured from other sites located on the same route. Alternatively, measured values from other sites that are located on similar facilities with similar traffic characteristics in the same geographic area and volume group can be assigned. The last option would be assigning measured values from sites in the same functional class with similar geographic area.

Once the traffic classification counts are collected, average SU truck counts on each day of week for each month are computed. For example, the average SU truck volume for Monday of every month and annual average can be computed. In this way, monthly and annual averages of counts for each day of week can be computed for all seven days of the week. Averaging the annual averages of the seven day of week counts will yield the AADT of SU trucks and buses. Since this data is taking averages for all days, it is less prone to any bias issues created by any missing data due to malfunctions and maintenance of continuous count stations (CCS).

Additional Notes and Tips.

- SU truck and bus AADTs are computed bidirectionally for two-way facilities and directionally for one-way roadways and ramps.

Related Traffic Data Items. AADT.

Cross Reference. HPMS Sec. 4.3 – Item 22; TMG Sec. 3.2.3 & Table 3-3.

Time of Day (TOD) Factor

Time of Day factor is the ratio of an hourly traffic average divided by sum of hourly averages for that day on a given roadway segment.

$$Time\ of\ Day\ Factor = \frac{Hourly\ Traffic\ Average}{Sum\ of\ Hourly\ Averages}$$

Discussion and Illustration. The Time-of-Day factors or ratios are only required if partial day classification counts are collected. Typically, these ratios are developed from automated classification counts collected during weekdays in urban areas for periods of at least 24 hours (and, preferably, at least 48 hours).

Separate TODs are collected for different groups of vehicle classes. AASHTO recommends grouping of vehicles classes 1 through 3 into personal-use vehicles and classes 4 through 13 into buses and trucks.

In addition, transportation agencies should establish factor groups to distinguish between roads based on amount of overnight truck activity relative to the amount during the mid-day period when manual classification counts are performed during the quarterly and annual mobility studies.

TOD factors can be developed based on the data from continuous classification counts or, more frequently, from short-duration weekday classification counts.

For continuous count locations, the 24 annual average weekday hour-of-the-day volumes are computed by using the Monthly Average Day of the Week (MADW) procedure.

For short-duration classification counts, the weekday counts obtained for each hour of the day are averaged to produce 24 weekday averages.

Once the average hourly counts are available for 24 hours, each of the hourly averages is divided by the sum of hourly averages to obtain the TOD factors for each of the 24 hours.

Finally, the 24 hourly traffic ratios for the vehicle class and factor group are obtained by averaging the corresponding traffic ratios produced for each of the sites in the factor group.

In the worked example, hourly truck counts from short-term classification counts collected for a 65-hour period were used. This data was collected in an urban area on four consecutive weekdays.

Additional Notes and Tips.

- Typically, at the sites that experience most of their truck volume during the business or daylight hours and minimal traffic during overnight hours, estimates of truck traffic developed from manual classification might lead to an overestimation of truck volumes.
- At such sites, application of TOD factors to manual truck counts avoids this overestimation.

Related Traffic Data Items. Month of Year and Day of Week Factors, ADT, and AADT.

Cross Reference. TMG Sec. 3.4.5.

Traffic Demand

The number of vehicles or other road users desiring to use a given roadway segment during a specific time period, typically, 1 h or 15 min. Also known as Travel Demand.

Discussion and Illustration. Traffic demand is the key parameter used by traffic engineers and transportation planners to assess the capacity requirements of a transportation facility. Typically, travel demand models are used to model and forecast the demand for a transportation facility. These models employ a four-step process:

1. **Trip generation.** This step determines the number of trips to be made by the travelers. The entire analysis area is categorized into Transportation Analysis Zones (TAZ). Several factors including number and size of households, vehicle ownership rate, land use, and density of development in each TAZ are considered to determine the trips generated by each TAZ. Most of the information used in trip generation will be gathered through surveys and travel diaries.
2. **Trip distribution.** This step determines the destinations of the trips generated in each TAZ. Each TAZ is weighted with an attractiveness factor based on the number of attractions present in that TAZ and its distance from other TAZs.
3. **Mode Choice.** This step determines the modes used by the travelers to travel from their origin to destination. Modes can include personal car, transit, carpooling, and others. Factors including the existing or forecasted transit and carpooling capacities are considered for this step.

4. **Route Assignment.** This step determines the route(s) taken by the travelers from their origin to destination. Generally, the model assumes that the traveler will choose the route with the least travel time to their destination.

Based on the location of the analysis area or transportation facility, various travel demand models including multi-county, countywide, sub-regional, regional, cross-state, and statewide models are available. In general, the travel demand is predicted for the model lifecycle span of the transportation facility (for example, 20 years). Typically, demands during the peak periods are used as the baseline for designing the capacity of transportation facilities.

To check the compliance of transportation facilities with dynamic changes in travel demand, travel demand analysis will usually be performed every 10 years. This analysis will compare the existing travel demand to the capacity of the transportation facility. If the travel demand exceeds the capacity, long queues at bottlenecks will be observed. Several alternatives can be modeled to improve the bottlenecks and thereby ensure smooth traffic operations.

Additional Notes and Tips.

- In most regions, the forecasted demand was observed by transportation facilities in shorter time ranges than originally forecast, due to dynamic shifts in development densities in the respective region.
- In cases where the demand exceeded the capacity, instead of expanding the transportation facility, alternative demand management strategies, like congestion pricing, can be employed.

Related Traffic Data Items. AADT and Future AADT.

Cross Reference. HCM Sec. 3-5, 4-2, 5-4, 6-1, 6-3, 6-7, 6-10, 6-27, 7-8, 7-11 to 7-14, 7-15, 7-26, 7-30, 7-31, and 7-32.

Turning Radius

Turning radius is the radius of the circular arc formed by the smallest turning path of the front outside tire of a vehicle. This is also referred to as curb-to-curb radius. It is expressed in feet throughout the U.S.

Discussion and Illustration. Turning radius is a principal characteristic dimension that affects horizontal roadway design. The principal dimensions affecting the design of turning radius are the minimum Centerline Turning Radius (CTR), the out-to-out track width, the wheelbase, and the path of the inner rear tire. Here, the minimum CTR refers to the turning radius of the centerline of the front axle of a vehicle with its steering wheels at the steering lock position. Based on the principal dimensions, each design vehicle requires roadways to have a specific minimum turning radius to make a turning maneuver. The effect of driver characteristics and slip angles on the design are minimized by assuming the maximum turning speed of the design vehicle to be less than 10 mph. AASHTO Green Book 2011 includes 20 design vehicles. For any design vehicle,

- Wheelbase is the distance between the centerline of the front axle and the centerline of the rear axle.
- Steering Angle is the average of the angles made by the left and right steering wheels with the longitudinal axis of the vehicle when the wheels are turned to their maximum angle.
- CTR is the turning radius of the centerline of the front axle of a vehicle with its steering wheel at the steering lock position.

Higher values of CTR, wheel base, and maximum steering angle lead to greater minimum turning radius. In addition to steering angle, all the combination units with an attached articulating part will have an articulating angle. This angle is measured between the longitudinal axes of the tractor and trailer (articulating part) as the vehicle turns. All the above mentioned turning characteristics are depicted in AASHTO 2011 Figure 2-10.

Additional Notes and Tips.

- Larger trucks with more articulating units require wider turning radius.

Related Traffic Data Items. Design Vehicles, Centerline Turning Radius.

Cross Reference. AASHTO Sec. 2.1.2 Table 2-2a and 2-2b; Figures 2-1 through 2-9 and 2-13 through 2-23.

Vehicle Class Factoring

Factors used for volume counts do not differentiate among different vehicle classes and therefore are not applicable for adjusting vehicle classification data. Vehicle class factors are specifically used to adjust short duration vehicle counts to estimate AADT by vehicle class. The monthly class factors, e.g., for trucks, are computed as a ratio of AADTT to MADTTs. Generally, monthly class factors are given by:

$$Monthly\ Factors_{Class,j} = \frac{AADT_{Class}}{MADT_{Class,j}}$$

Where:

Class represents a specific vehicle class.

j represents a specific month of the year.

Discussion and Illustration. FHWA adopts a 13-category vehicle classification system. However, for vehicle class factoring purposes, a minimum of six generalized vehicle classes are recommended, i.e., motorcycles (MC), passenger vehicles under 102” (PV), light trucks over 102” (LT), buses (BS), single-unit trucks (SU), and combination unit trucks (CU). MC, PV, LT, and BS represent the FHWA 13-category classes of 1, 2, 3, and 4, respectively. SU represents classes 5, 6, and 7, while CU represents classes 8, 9, 10, 11, 12, and 13 in the FHWA’s 13-category system. Monthly factors for the generalized classes can be computed as shown in Table 21. Fewer generalized categories may be sufficient if class counts are low or have similar patterns, e.g., combine PV and LT.

Removing the temporal bias in the estimates of class-specific volumes is the vehicle class factor’s objective. This is critical for many purposes, e.g., predicting pavement life requires seasonal and daily truck volume variations as the structural response of most pavements changes with environmental conditions.

Table 21. Monthly factors for generalized vehicle classes

	MC	PV	LT	BS	SU	CU	Total
MADT	35	3,111	811	61	191	1,111	5,320
AADT	33	4,311	911	51	211	1,211	6,728
Class factors	0.94	1.39	1.12	0.84	1.10	1.09	1.26

Additional Notes and Tips.

- Given the seasonal and daily variations of class counts and total volumes are not the same, class factors are computed and applied independently of volume factors.
- Class factors are computed from permanent classification counts and are used to adjust short duration class counts.
- Class-specific AADT, e.g., AADTT, is computed in the same manner as that of the general traffic AADT.
- Volumes of through and local delivery trucks, industrial activities, and population size affect class factors.
- Low daily volumes within some vehicle class categories result in unstable and unreliable class factors.
- There is a trade-off between accuracy and complexity of computing class factors when too many classes are used.
- Two alternative methods are used to estimate and apply class factors, i.e., roadway-specific and traditional. In the roadway-specific method, factor application is done one road at a time. The traditional procedure develops average factors for roadway groups of similar characteristics. The roadway-specific and traditional procedures can be combined, as a good compromise.

Related Traffic Data Items. AADTT, MADTT, Volume Factors, and ACFs.

Cross Reference. TMG Sec. 3.2.3., 3.3.1., and 3.3.3.

Vehicle Density

The number of vehicles occupying a given length of a transportation facility at a particular instant. Approximate density is calculated by dividing flow rate by average travel speed, and is expressed as vehicles per mile per lane.

$$Density = \frac{Flow\ rate}{Average\ travel\ speed}$$

Where:

Flow rate = traffic volume on a facility (vph)

Average travel speed = Average traffic speed of a vehicle platoon passing through a facility (mph)

Discussion and Illustration. Density is the key parameter in characterizing the quality of traffic operations on a transportation facility. Density is used as the measure of effectiveness to define the LOS of transportation facilities with uninterrupted flow.

Density computation from photographs and video recordings is usually difficult and subject to human error. Computing density from flow rate and average travel speed is relatively easy. The flow rate and travel speed data can be captured through loop detectors and speed sensors respectively.

Example. Table 22 depicts information about traffic counts and average travel speeds of two transportation facilities. If the flow rate values of the facilities are 1,600 and 2,250 veh/h and the respective average travel speeds are 45 and 65 mph, then the vehicle density values will be 35.5 and 34.6 veh/mi, respectively.

Table 22. Vehicle density calculation example

Transportation Facility	Flow Rate (veh/h)	Average Travel Speed (mph)	Density (veh/mi)
Arterial	1,600	45	35.5
Freeway	2,250	65	34.6

Given the length of an average vehicle and field detector, density can also be calculated from the occupancy values. For example, if the length of a detector is 3.5 feet and the length of a vehicle is 26 feet, and the occupancy recorded by the detector is 0.240, then the traffic density on the facility is:

$$Density = \frac{5{,}280 * Occupancy}{Length\ of\ vehicle + Length\ of\ Detector}$$
$$= \frac{5{,}280 * 0.240}{26 + 3.5} = 43 \frac{veh}{mi/ln}$$

Additional Notes and Tips.

- For basic freeway segments, 45 pc/mi/ln is considered as the traffic density when flow is at capacity.
- Density is a critical parameter for uninterrupted-flow facilities as it characterizes the quality of traffic operations. It is not applicable to interrupted flow facilities, as the flow is affected by traffic control devices (TCDs).

Related Traffic Data Items. AADT, Capacity, Occupancy, Critical Density, and Critical Speed.

Cross Reference. HCM Sec. 2-10, 2-18, 4-39 to 4-41, 5-9, 7-10, and 8-5.

Vehicle Miles Traveled (VMT)

VMT is the total miles traveled by vehicles in a specific area (e.g., a route, a functional road classification, or geographic area) over a period of one year. VMT is used for monitoring travel demand as well as analysis of a facility's performance on emissions, safety, and mobility. Daily vehicle miles traveled (DVMT) refers to total miles travelled by vehicles in one day.

$$Vehicle\ Miles\ Travelled = \mathrm{AADT_x} * \mathrm{Section\ length_x\ (miles)} * no\ of\ days\ in\ a\ year$$

Where:

$\mathrm{AADT_x}$ = AADT for section x
Section $\mathrm{length_x}$ = Length of section x in miles

Discussion and Illustration. VMT plays a pivotal role in analyzing the infrastructure performance at section and network levels. VMT can be estimated using a geometric boundary approach or a trip generation approach. The geometric boundary approach uses traffic counts to estimate VMT within a geographic boundary of interest. The trip generation method uses travel survey data to estimate VMT from travel demand modeling. The Federal Highway Administration (FHWA) estimates VMT based on the geometric boundary approach. Traffic Volume Trends (TVTs) monthly reports published by FHWA estimate VMT by state and functional classes of roads. VMT is not the same as Daily Vehicle Distance Traveled (DVDT), which measures the distance traveled by vehicles in a day, not how many vehicles traveled over a given distance in a day.

HPMS contains link level AADT for all roadway segments. Outside HPMS, given traffic classification counts at a point and the HPMS vehicle summary data table, the VMT share for each vehicle class on a given roadway class can be estimated.

VMT is calculated by multiplying the AADT value for each section of road by 365 and by the section length (in miles) and summing all sections to obtain VMT for a complete route.

Example: Table 23 depicts information about traffic counts and section length of two roadways. If the AADT values of a facility sections are 50,000 and 48,000 veh/day and the respective section lengths are 3 and 5.5 miles, then the VMT on the facility sections will be 150,000 and 264,000 vehicle miles, respectively.

Table 23. Computation of DVMT and VMT from AADT and section length

Roadway ID	Section AADT (veh/day)	Section Length (miles)	DVMT (veh-miles)	VMT (veh-miles) = DVMT*365
R120A	50,000	3	150,000	54,750,000
R280K	48,000	5.5	264,000	96,360,000

Additional Notes and Tips.

- The range of VMT for a specific roadway section depends on its functional class, section length, and traffic demand.
- In general, higher VMT values indicate good traffic throughput with less congestion. Similarly, lower VMT values indicates poor traffic performance with higher delays and safety issues. In this way, high crash locations could be identified using VMT data.

Related Traffic Data Items. AADT.

Cross Reference. HPMS Sec. 1.2.7; 3.3; 6.2; and Appendix A; TMG Sec. A-3.

Vehicle Speed

How fast vehicles are traveling, computed as distance traveled per unit time. It is an important variable for monitoring safety and mobility performance. Some applications of vehicle speed data include: design of highways, monitoring speed trends, establishing traffic operation and control parameters, analyzing accident data, estimating treatments effect, establishing speed zones and speed limits, and designing traffic signals timing.

Measurement of individual vehicles' speeds passing a roadway point is referred to as spot speeds. Such speed can be aggregated in two ways, i.e., time mean speed and space mean speed. Time mean speed measures traffic speed over a period of time, while space mean speed measures speed over a roadway segment.

$$v_t = \frac{1}{n}\sum_{i=1}^{n} v_i \qquad \text{and} \qquad v_s = \frac{n}{\sum_{i=1}^{n}\frac{1}{v_i}}$$

Where:

v_t is the time mean speed
v_s is the space mean speed
v_i is the spot speed of i^{th} vehicle
n is the number of vehicles observed

Discussion and Illustration. Speed, travel time, and delay are all related measures that describe the level of traffic mobility, though travel time and delays are based on space mean speed. Some important speed parameters include: median, mean, pace (10 mph speed increment containing the highest proportion of observed speeds), 85^{th} and 15^{th} percentiles, and standard deviation.

Example: In a 5-minute interval, 10 vehicles with spot speeds of 63, 52, 49, 65, 69, 57, 51, 62, 72, and 58 mph were observed. Then the time and space mean speeds will be:

$$v_t = \frac{63 + 52 + 49 + 65 + 69 + 57 + 51 + 62 + 72 + 58}{10} = 60\,mph$$

$$v_s = \frac{10}{\frac{1}{63} + \frac{1}{52} + \frac{1}{49} + \frac{1}{65} + \frac{1}{59} + \frac{1}{57} + \frac{1}{51} + \frac{1}{62} + \frac{1}{72} + \frac{1}{58}} = 59\,mph$$

Speed data are collected either per vehicle or aggregated at some level. Safety studies require per vehicle speed data, while aggregated measures are good for traffic operations.

States are encouraged to submit spot speed data to FHWA in 5 mph speed bins (minimum 12 and maximum 25 bins) in aggregation intervals of either 5 minutes, 15 minutes, or 1 hour for specified time periods.

Additional Notes and Tips.

- Traffic speed depends on traffic conditions, environmental factors, geometric features, and roadside interference level.
- Variations in the speed of vehicles within and across lanes are important traffic safety indicators.
- Vehicle speed can be aggregated by vehicle class.
- Generally, speed data should be collected from locations that adequately reflect traffic characteristics, e.g., avoid locations of excessive acceleration or deceleration.
- Vehicle speed varies by day of week and time of day; therefore, collected data should capture the variation.
- Though density is the primary measure of freeway traffic, speed is also an important performance measure.
- Speed data are often collected using inductive loops, radar, infrared, video, and GPS instrumented probe vehicles.

Related Traffic Data Items. Vehicle Weight, 85th Percentile Speed, and Free Flow.

Cross Reference. TMG Sec. 3.2.2.

Volume and Volume-to-Capacity Ratio

Volume is the number of vehicles passing through a point on either a lane, a direction, or a highway. It is expressed as vehicles per time. Volume-to-Capacity (v/c) ratio, also known as demand-to-capacity ratio, is the ratio of current or projected demand flow rate to capacity of a segment.

$$\frac{V}{C}ratio = \frac{Demand\ flow\ rate}{Capacity}$$

Where:

Demand flow rate = volume of vehicles on a transportation facility (vehicles per hour per lane, or veh/h/ln) for a given segment length

Capacity = the maximum number of vehicles a transportation facility can handle (veh/h/ln)) for a given segment length

Discussion and Illustration. V/C ratio is an indicator of quality of traffic operations on a segment. It also indicates how close a roadway is operating to its capacity. V/C ratios are used to perform capacity and LOS, intersection, or geographic boundary analyses. Capacity analysis determines the sufficiency of estimated capacity to match to the forecasted demand flow rate requirements. For LOS analysis, HCM uses the v/c ratio as a main indicator. As the v/c ratio get close to 1, traffic operations in and upstream of the segment are negatively affected.

Traffic volumes captured at count locations are customarily used in v/c ratio estimation. However, these volumes might not reflect the actual demand, as the capacity constraints upstream of the count location may limit the number of vehicles that can reach the count facility. The HCM provides base values of capacities for different facility types and settings. However, these values assume base conditions including ideal roadway conditions, a traffic stream of only passenger cars, and favorable weather. Any variations from the base conditions can be balanced by using adjustment factors for adverse roadway, weather, and traffic conditions. These adjustment factors are available in exhibits 11-20 and 11-23 in HCM Chapter 11.

Example. Table 24 depicts information about traffic volume and capacity for two transportation facilities. If the volumes of the facilities are 1,600 and 2,250 veh/h/ln and the respective capacity values are 1,700 and 2,300 veh/h/ln, then the volume-to-capacity ratios will be 0.94 and 0.98 respectively.

Table 24. Volume-to-capacity ratio calculation example

Roadway Type	Volume (veh/h/ln)	Capacity (veh/h/ln)	v/c ratio
Arterial	1,600	1,700	0.94
Freeway	2,250	2,300	0.98

Additional Notes and Tips.

- A v/c ratio less than 1 indicates under saturated traffic flow conditions.
- Similarly, a value of greater than 1 indicates over saturated flow conditions.
- The v/c ratio is directly proportional to density and travel time and inversely proportional to speed.
- Increase in v/c ratio indicates longer vehicle delays and queuing.

Related Traffic Data Items. AADT, Capacity, and LOS.

Cross Reference. HCM Sec. 2-10, 2-18, 4-39 to 4-41, 5-9, 7-10, and 8-5.

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