Traffic Characteristics

Traffic stream parameters

Traffic stream parameters represent the engineer's quantitative measure for understanding and describing traffic flow. Three essential macroscopic parameters describe the traffic stream: Speed, volume or rate of flow, and density.

1. Speed

The speed of vehicle is defined as the distance it travels per unit of time. It is in the inverse of the time taken by a vehicle to traverse a given distance.

$$\textbf{Speed}\ (\text{km/h}) = \frac{Distance}{Time}$$

Spot speed*—is the instantaneous speed of vehicle as it passes a specified point along a street or highway.*

Average travel speed*—a traffic stream measure based on travel time observed on a known length of highway. It is the length of the segment divided by the average travel time of vehicles traversing the segment, including all stopped delay times. It is also a space mean speed.*

Space mean speed*—A statistical term denoting an average speed based on the average travel time of vehicles to traverse a segment of roadway.*

$SMS = nd/\sum t_i$
n= no. of observed vehicles
d= distance traversed
t_i*= time for the* i^{th} *vehicle to traverse the section.*

Time mean speed—*the arithmetic average of speeds of vehicles observed passing a point on a highway; also referred to as the average spot speed. The individual speeds of vehicles passing a point are recorded and averaged arithmetically.*

TMS= ∑ (d/t_i)/n
d= distance traversed
t_i= time for the i^{th} vehicle to traverse the section.
n= no. of observed vehicles

TMS=951.1/10=95.1 (ft/sec)
SMS= (10x500) / (5.0+5.6+5.6+4.8+6.1+5.3+5.9+5.2+4.5+5.0)
= 94.3 ft/sec

Time (sec)	d (ft)	d/t (ft/sec)
5.0	500	100.0
5.6	500	89.3
5.6	500	89.3
4.8	500	104.2
6.1	500	82.0
5.3	500	94.3
5.9	500	84.7
5.2	500	96.2
4.5	500	111.1
5.0	500	100.0
		Total =951.1
		n= 10

Space mean speed is always less than time mean speed. Based on the statistical analysis of observed data, this relationship is useful because time mean speeds often are easier to measure in the field than space mean speeds.

***Types of Speed*:**

a. ***Travel (Journey) speed***: *it is the length of highway section divided by the overall travel time (including stopping time).*

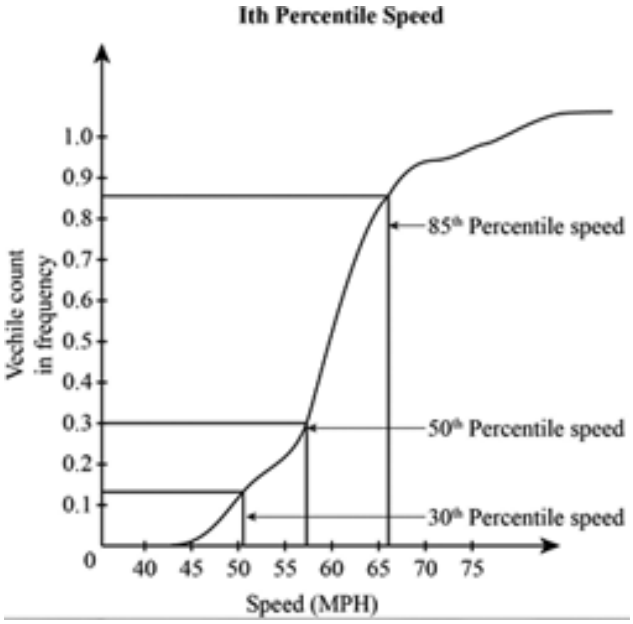
$$Travel\ (journey) speed = \frac{Distance}{Overall\ travel\ time}$$

b. ***Running speed***: *it is the length of the highway section divided by running time required for the vehicle to travel through the section.*

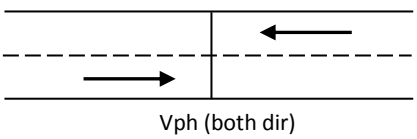
$$Running\ speed = \frac{Distance}{Overall\ travel\ time - Stopping\ time}$$

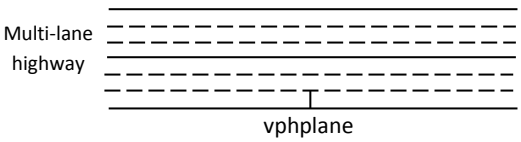
c. ***Design speed***: *It is a selected speed used to determine various geometric design features of the road (20 – 130) km/hr.*

d. ***Operating speed***: *It is the speed at which drivers are observed operating their vehicles during free flow condition (the 85th percentile of the distribution of observed speeds can be used as a measure for operating speed) (56-88 km/hr) in Iraq.*



2. ***Volume (vpd, vph):*** *The total number of vehicles that pass over a given point or section of a lane or roadway during specified time interval (usually one day or one hour).*





Traffic Volume can be expressed in several terms such as flow rate, ADT, AADT, AAWT, and DHV

- ***Flow rate***

Flow rate is the equivalent hourly volume based on time interval less than one hour (15 min).

The traffic variation within the peak hour is called Subhourly volume

*For example a volume of 200 vehicles observed over a 15-minute period may be expressed as a rate of 200*4=800 vehicle/hour.*

Actually, the 800 vehicles may not be observed if the full hour were counted.

The 800 vehicle/ hour becomes a rate of flow that exists for a 15-minute interval.

Example: *the table below shows the volume per 15-minute for two sections of road.*

Time	*Flow1 at section1*	*Flow2 at section 2*
8.00-8.15	*100*	*400*
8.15-8.30	*100*	*0*
8.30-8.45	*100*	*0*
8.45-9.00	*100*	*0*
Volume/hour	*400*	*400*
Flow rate (v/h)	*(100*4)400*	*(400*4)=1600*

The peak hour factor (PHF)

The peak hour factor is calculated to relate the peak flow rate to hourly volumes as follow:

$$PHF = \frac{Volume}{hourly\ flow\ rate\ (4 * V_{15})} \qquad 0.25 \leq PHF \leq 1$$

Where PHF =peak hour factor

V15=volume for peak 15-minute period

The peak hour factor is used to convert a peak hour volume to an estimated peak rate of flow within an hour as below:

v=Peak hourly volume/PHV

v=peak rate of flow within hour (veh/hour)

The maximum possible value of the PHF is 1.0 which occurs when the volume in each interval is constant. In the previous example, section1, the volume per each 15-minute was equal to

100. Then the PHF=400/4(100) = 1.0. This indicates a condition in which there is virtually no variation of flow within the hour.

The minimum values occur when the entire hourly volume occurs in one interval as the flow 2 in section 2 in the previous example. The PHF=400/4(400)=0.25. This indicates the most extreme case of volume variation.

In practical terms, the PHF generally varies between 0.7 in rural roads and 0.98 in dense urban areas.

Example

1000 vehicles counted over 15-minute interval could be expressed as 1000 veh/0.25h=4000veh/h.

The rate of flow of 4000 veh/h is valid for the 15-minute period in which the volume of 1000 vehicles was observed.

The table below illustrates the difference between volumes and flow rate

Time interval	Volume per time interval (veh)	Flow rate for time interval (veh/h)
5:00-5:15 pm	1000	1000/0.25=4000
5:15-5:30 pm	1100	1100/0.25=4400
5:30-5:45 pm	1200	1200/0.25=4800
5:45;6:00 pm	900	900/0.25=3600
5:00-6:00 pm	4200	

The full hourly volume is the sum of four 15-miumte volume observations = 4200veh/h

The flow rate for each 15-minute interval is the volume observed for the interval divided by the 0.25 hours over which it is observed.

In the worst period of time, 5:30-5:45 pm, the flow rate is 4800 veh/h.

*The PHF= 4200/4*1200= 0.875*

The peak rate of flow= 4200/0.875=4800 veh/h, which is equal to the flow rate in the worst interval.

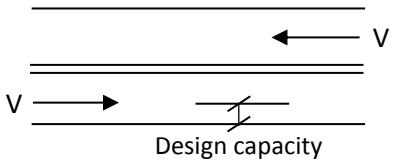
Current and Future traffic

Current traffic (existing or attracted traffic), *is the volume of the traffic that would use a new or improved highway if it is opened to traffic. It is the traffic already using the highway plus the traffic transferring to the new highway from less attracted routes.*

Generated traffic, *it represents the vehicle trips that would have been made if the new facility had not been provided.*

Current ADT: *Current Average Daily Traffic*

Average no. of vehicles per day during a specified time period (More than one day and less than 1 year)



$$Current\ ADT = \frac{Total\ No.of\ vehicles\ (Period\ more\ than\ 1\ day\ and\ less\ than\ 1\ year)}{Time\ period\ (days)}$$

$Units = \frac{vpd}{both\ dir}$ = vpd } *Otherwise specified*

Ex. Volume of 5 days = 500000 vehicles

$$current\ ADT = \frac{500000}{5} = 100000\,\frac{vpd}{both\ dir}$$

Current AADT: *Current Annual Average Daily Traffic*

Average no. of vehicles per day during one year

$$current\ AADT = \frac{Volume\ of\ one\ year}{365}$$

Units = vpd
vpd / both dir } *Otherwise specified*

Future (forecasted traffic)

The design of new highways or improvement of existing highways should not base on the traffic volumes, but on the future traffic expected to use the facilities.

Future ADT (AADT): F. ADT (AADT) = Current ADT (AADT) + normal traffic growth

Normal traffic growth is the increase in the current traffic due to general increase in the number and usage of vehicles.

Normal traffic growth = current traffic (existing traffic)*TPF

TPF: Traffic Projection Factor

$$TPF = (1 + r)^{x+n}$$

Where:

r= Annual rate of traffic increase (0 – 10%)

n= design life in years (20 – 50 years)

x= construction period in years (2 – 4 years)

Example

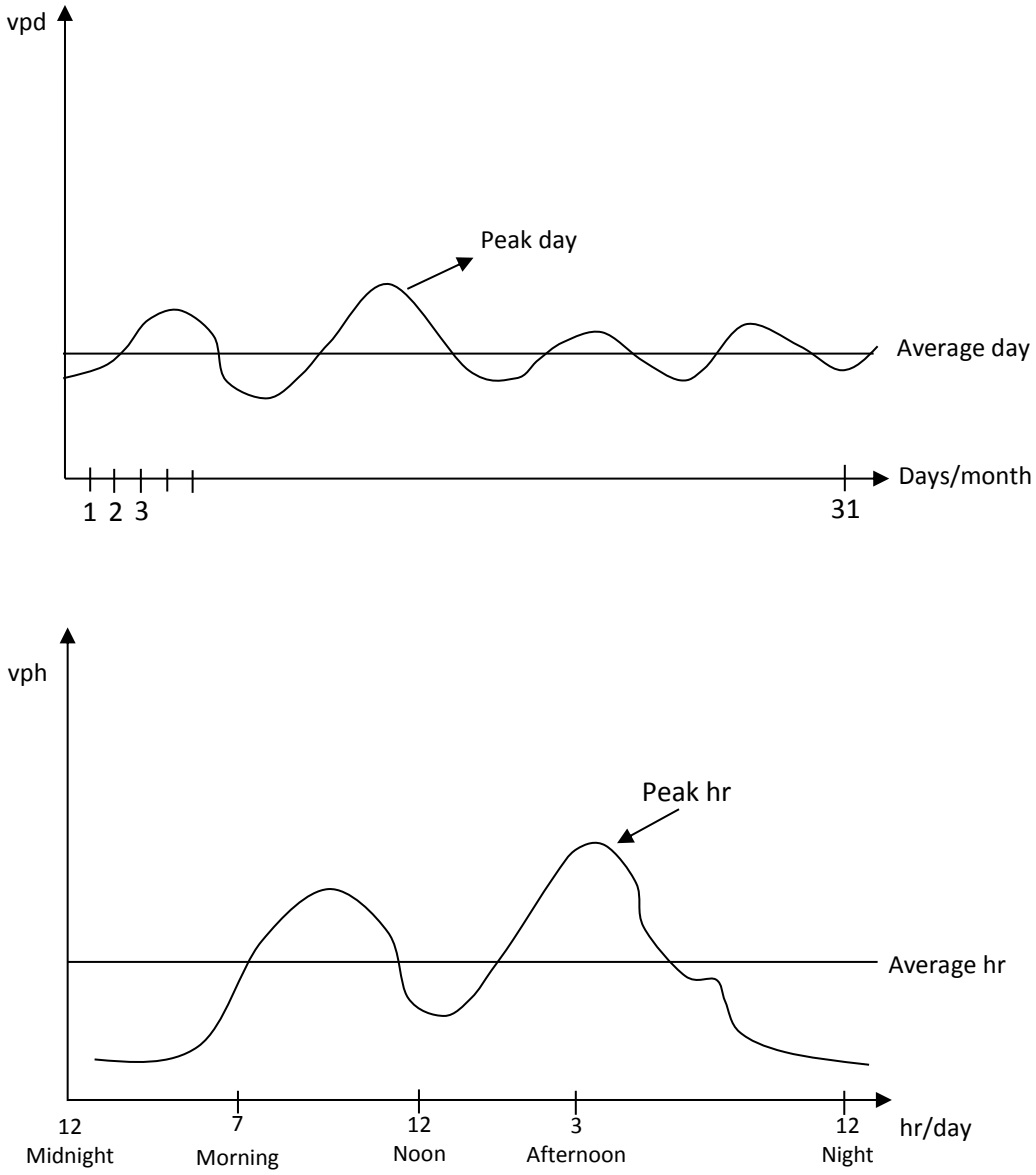
r = 0.06

X = 2 years

n = 20 years

TPF = $(1 + 0.06)^{20+2} = 3.6$

Future ADT (AADT)*: suitable for pavement structural design- not suitable for geometric design.*



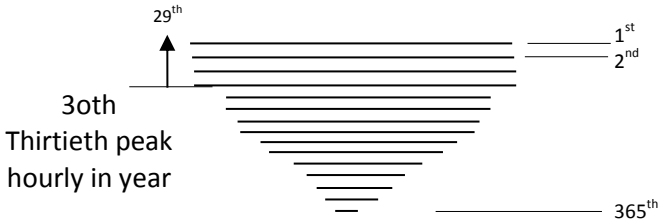
***The average weekly traffic (AWT**), is the average 24-hours traffic volume occurring on weekdays at a given location for a period of time less than a year*

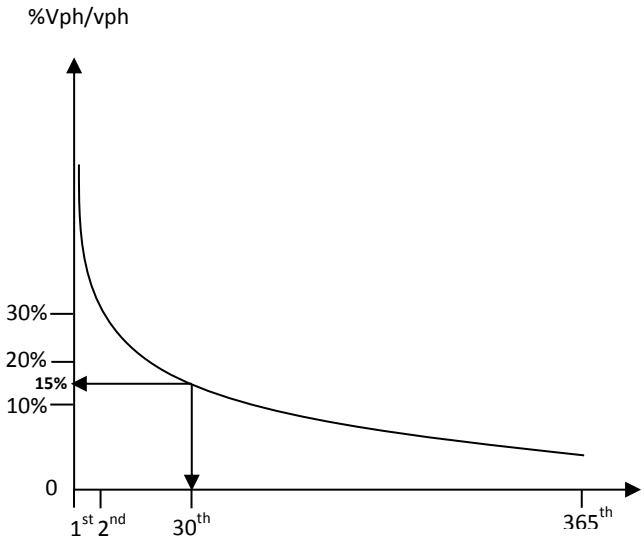
The Average Annual weekly traffic (AAWT), *is the 24-hour traffic volume occurring ne weekdays over a full year. AAWT is normally obtained by dividing the total weekday traffic for the year by the annual weekdays (usually 260 days). This volume is of particular importance since weekend traffic is usually low.*

Design Hourly Volume*: Peak hour volume used in design which is:*

- *Not exceeded to often*
- *Not rarely obtained*

Thirtieth Highest Hourly Volume (30HV): *is a DHV (design hourly volume), exceeded only during 29 hours each year.*





$$\frac{25-15}{15} * 100 = 67\% \; Saving$$

When the 365 peak hours volumes of a year at a given location are listed in descending order (as shown in the figure above), the 30th peak hour is the 30th on the list and represents a volume that is exceeded in only 29 hours of the year. For rural facilities, the 30th peak hour may have a significantly lower volume than the worst hour of the year. This means that the critical peaks may occur only infrequently.in such cases, it is not considered economically feasible to invest large amounts of capital in providing additional capacity that will be used only 29 hours of the year.

(0.12 – 0.18)

$$DHV\ (30^{th})\left(\frac{vph}{Both\ Dir}\right) = 0.15 * F.ADT\ (AADT)[Rural\ Area]$$

(0.08 – 0.12)

$$DHV\ (30^{th})\left(\frac{vph}{Both\ Dir}\right) = 0.1 * F.ADT\ (AADT)[Urban\ Area]$$

- Directional Distribution Factor (DDF): (50-80) %= the factor of proportion of traffic in peak direction

$$DDF = \frac{Volume\ of\ one\ dir.}{Vol.of\ Both\ dir.} * 100$$

DDHV= Directional design hourly traffic (vph/one dir) = DHV per one direction

$$DHV\ \left(\frac{vph}{Both\ dir}\right) * DDF = DHV\ (\frac{vph}{One\ dir})$$

$$No.of\ lanes\ for\ one\ dir = \frac{DHV\ for\ one\ dir}{Design\ capacity\ of\ lane}$$

No. of lanes for one dir $* 2 = No.of\ lanes\ for\ both\ dir$

As a result:

*Current ADT * TPF = F. ADT (vpd/both dir)*

*F. ADT * 0.15 = DHV (vph/both dir)*
0.1

*DHV * DDF = DHV (vph/one dir)*

$$\frac{DHV\ for\ one\ dir}{Design\ Capacity\ for\ lane\ (LOS)} = No.of\ lanes\ for\ one\ dir$$

$$No.of\ lanes\ for\ one\ dir * 2 = Total\ for\ both\ dir$$

Capacity and Level of Service

Capacity: *is a measure of the demand that a highway can potentially service*

Level of Service (LOS)*: is a qualitative measurement describing the operational condition within the traffic stream under a given demand. The parameters used to define the level of service called the measure of effectiveness (MOE) and based on several criteria such as travel time, speed, delay time and safety.*

The highway capacity manuals defines six levels of service designated A through F. the level A represents the highest level of service while F is the lowest and worst service.
The table below specifies the operational condition and operating speed for the level of service categories.

LOS	***Description (operational Condition)***	***Operating Speed (km/hr)***
A	Free flow	96
B	Stable flow	88
C	Stable flow with restriction	72
D	Approaching unstable flow	56
E	Unstable flow	48
F	Forced flow (stop and go condition)	< 48

Design Capacity (Design service flow rate): *The maximum hourly rate at which vehicles can be expected to pass a point or section of a lane or roadway during one hour under prevailing roadway, traffic and control condition for a designated level of service.*

The design capacity for different level of service is presented in the table below:

LOS	*Design Capacity (pcphpl)*
A	*660*
B	*1080*
C	*1550*
D	*1980*
E	*2200*

This table specifies the desired LOS for varies terrain

Highway	***LOS***		
	Level	***Rolling***	***Mountain***
Principal Arterial	*B*	*B*	*C*
Minor Arterial	*B*	*B*	*C*
Collector	*C*	*C*	*D*
Local	*D*	*D*	*D*

Example 1: *It is proposed to design a minor arterial within an urban rolling area to serve an anticipated current daily volume of 10000 pcpd. Find the required no. of lanes for this highway?*

Sol. Minor arterial within rolling area ⟶ Design LOS B

⟶ *Design capacity = 1080 pcphpl*

*F. volume = current volume * TPF Assume TPF = 3.6*

*= 10000 * 3.6 = 36000 pcph/Both*

*DHV/Both = F. Volume * 0.1*

*= 0.1 * 36000 = 3600 pcph/Both*

*DHV/One dir = DHV/Both * DDF*

*= 3600 * 0.8 = 2880 pcph/One dir*

No. of lanes / One dir = 2880/1080 = 2.6 use 3 lanes/ dir

 *Total no. of lanes = 3 * 2 = 6 lanes/ Both dir*

Example 2: A multilane principal arterial is being designed through a rolling rural area. The current daily volume = 8000 vpd in both dir. with 20% truck, peak hourly factor 90% and a (60 – 40%) Directional Distribution factor. How many lanes are required? What if this highway is in an urban area in a level terrain?

Sol.

*Current volume = 8000 (0.2 * 2.5 + 0.8 * 1) = 10400 pcpd*

*F. volume = 10400 * TPF = 37440 pcpd/Both*

*DHV = 0.15 * 37440 = 5616 pcph/Both*

Hourly flow rate = 5616/0.9= 6240 pcph/Both

*Hourly flow rate = 6240 * 0.6 = 3744 pcph/ 1 dir*

No. of lanes/ 1 dir = 3744/1080 = 3.46 use 4 lane/dir

*Total = 4*2 = 8 lanes/both dir*

3. Density

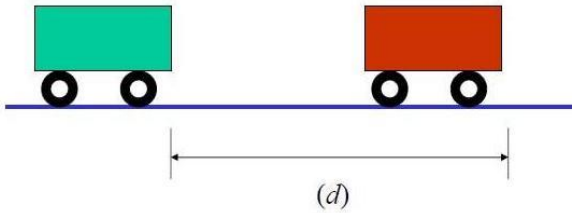
***Density** can be defined as the number of vehicles occupying a given length of road at a given instant. Density is usually expressed as vehicles per kilometer (veh/km). High densities indicate the vehicles are very close to each other, while low densities imply greater distances between vehicles.*

It is difficult to measure the density at the field. It can be measured through Ariel photography which is an expensive method, or it can be estimated theoretically from the density-flow-speed relationship.

$$Spacing\ (m) = \frac{1 \rightarrow 1000}{Density\ (vpkm)}$$

Density (vpkm) = 1 (or 1000)/Spacing (m)

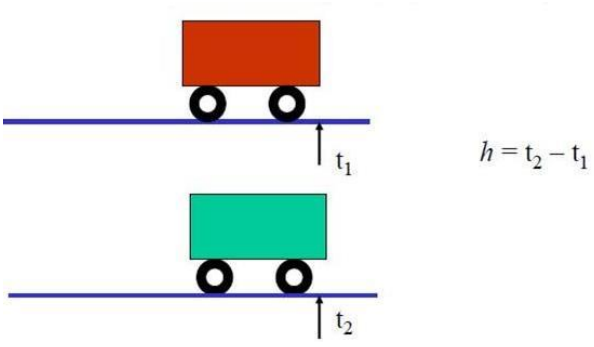
(Use 1 if the spacing in km, and use 1000 if the spacing in m)



4. Headway

Two types of headways describe the traffic characteristics, time headway and space headway

1. ***Time Headway (ht)***: Time between the arrivals of successive vehicles at specified time. It can be computed as the difference between the time of the front of a vehicle arrives at a point on the highway (t1) and the time the front of the next vehicle arrives at the same point (t2). It is usually expressed in seconds.



The average headway in a lane is directly related to the rate of flow:

$$ht = \frac{1 \rightarrow 3600}{Volume\ (vph)} \quad (1\ in\ hour\ unit, 3600\ in\ second\ unit)$$

$$ht = \qquad sec$$

2. ***Space headways (hs),*** *is the distance between the front of a vehicle and the front of the following vehicle. It is usually expressed in meter. The average spacing in the traffic lane can be directly related to the density of the lane*

Hs=1000/D

Where:

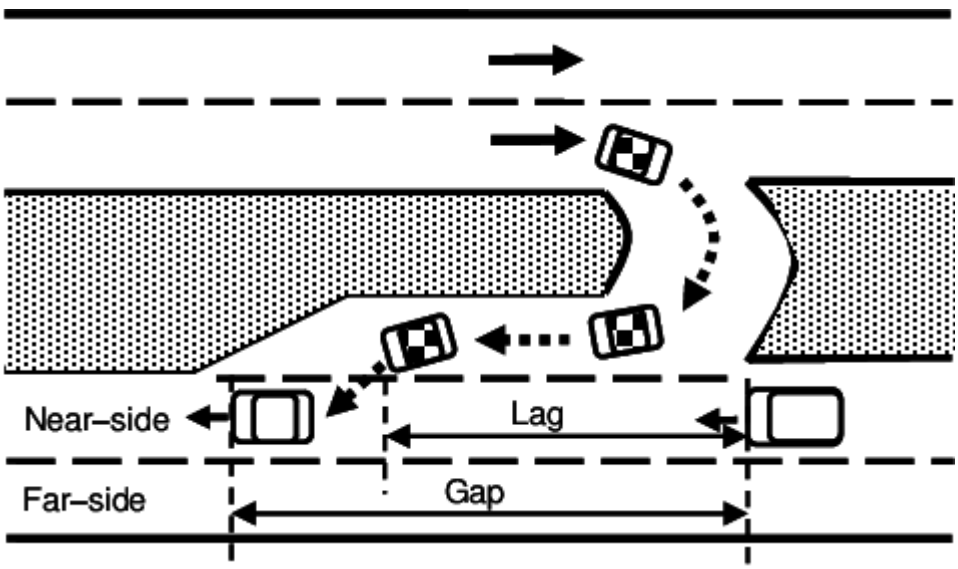
D= the density of a lane, veh/km/ln

hs = the average space headway (m)

Gap*: is the headway in a major stream which is evaluated by a vehicle driver in a minor stream who wishes to merge into the minor stream. It is expressed in either units of time (time gap) or units of distance (space gap)*

Time lag: is the difference between the time a vehicle that merges into a main traffic stream reaches a point on the highway in the area of merge and the time a vehicle in the main stream reaches the same point.

Space lag, is the difference, at an instant time, between the distance a merging vehicle is away from the a reference point in the area of merge and the distance a vehicle in the main steam is away from the same point.



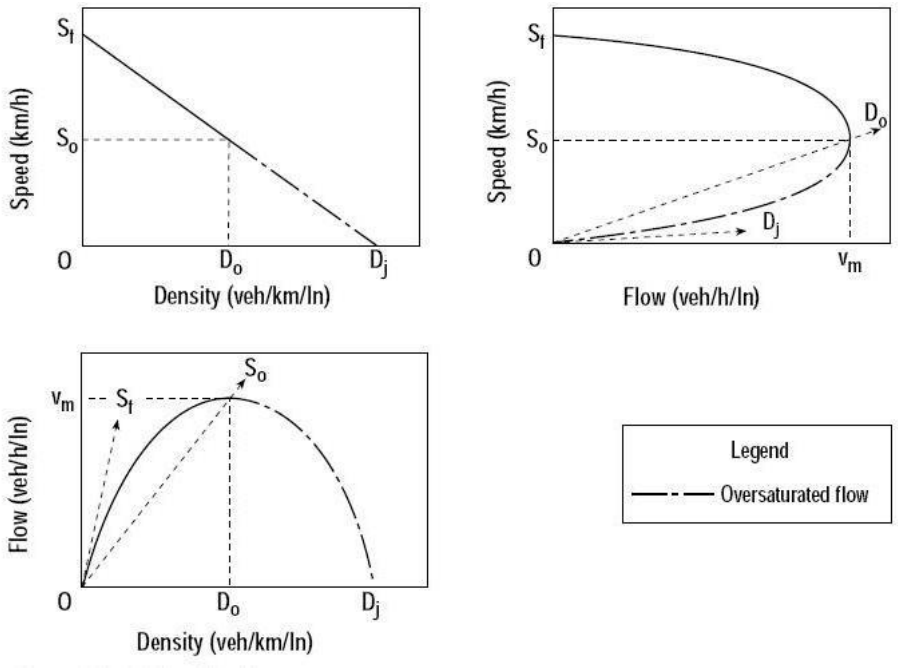
RELATIONSHIPS AMONG BASIC PARAMETERS

Flow- Density- Speed relationship

Speed, flow, and density are all related to each other and are fundamental for measuring the operating performance and level of service of transportation facilities.

Under uninterrupted flow conditions, these three parameters are related by the following equation: $Flow = Speed * Density$

This general relationship is shown in the following figure which is known as the fundamental diagram of traffic flow.

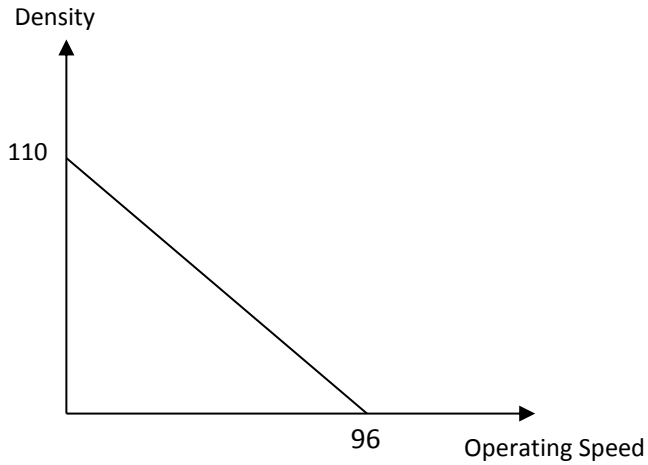


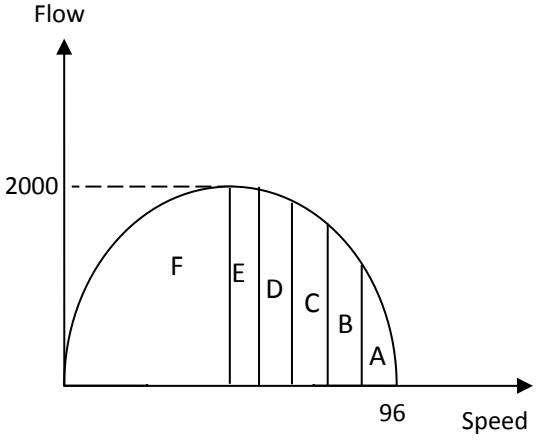
The relationship between speed and density is consistently decreasing. As density increase, speed decreases. This diagram shows that flow is zero under two different conditions:

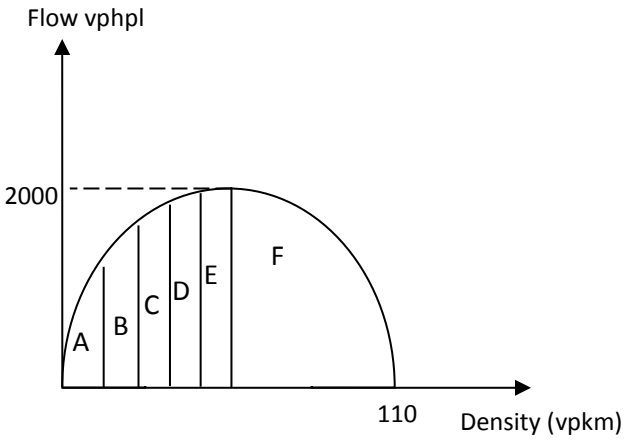
- *When density is zero, thus there is no vehicles on the road*
- *When speed is zero, vehicles are at complete stop because of the traffic congestion.*

***Example**:*

A highway segment with a rate of flow of 1,000 veh/h and an average travel speed of 50 km/h would have a density of
D = (1000 veh/h) / (50 km/h) = 20 veh/km







***Free-flow speed:** the average speed of vehicles on a given facility, measured under low-volume conditions, when drivers tend to drive at their desired speed and are not constrained by control delay.*

***Critical density:** is the density of traffic when the volume is at capacity on a given roadway or lane, critical density occurs when all vehicles are moving at or about the same speed.*

MCQ

-The number of vehicles that pass a given point on the roadway or a given lane or direction of a highway in a specified period of time

a. Volume	b. Density	c. Speed	d. Peak hour rate

-The most important vehicle features for highway design are:

a. Dimensions and minimum turning radius	b. Weight and axle loading	c. Passenger and heavy truck	***d. a and b***

-Dimensions and minimum turning radius as a control for:

a. Pavement structural design	***b. Highway geometric design***	c. Vertical Alignment	d. Horizontal Alignment

-Weight and axle loading as a control for

a. Pavement structural design	b. Highway geometric design	c. Vertical Alignment	d. Horizontal Alignment

-Vehicles that have four tires touching the pavement as

a. Passenger car (PC)	b. Heavy Truck (HV)	c. Truck combination (WB)	d. Single unit truck

-Vehicles that have more than four tires touching the pavement as

a. Passenger car (PC)	***b. Heavy Truck (HV)***	c. Truck combination (WB)	d. Single unit truck

-Minimum turn radius of vehicle is

a. 10m	***b. 15m***	c. 20m	d. 25m

-Maximum limit of height vehicle in highway is

a. 5.6m	***b. 4.6m***	c. 6m	d. 3.6m

-What is the gross weight of vehicle [Type 2-S-3]

a. 47	b. 20	c. 27	d. 66

-What is the gross weight of vehicle [Type 3-S-1-2]

a. 47	b. 20	c. 27	***d. 66***

-What is the gross weight of vehicle [Type 4-S-3]

a. 47	b. 20	***c. 61***	d. 66

-What is the equivalent passenger car for heavy vehicle in level area?

a. 1.5	b. 2.5	c. 3.5	d. 4.5

-What is the equivalent passenger car for heavy vehicle in rolling area?

a. 1.5	***b. 2.5***	c. 3.5	d. 4.5

-What is the equivalent passenger car for heavy vehicle in Mountain area?

a. 1.5	b. 2.5	c. 3.5	***d. 4.5***

-AADT is the number of vehicle count during

a. 365 day (each day in year)	b. 260 day	c. Workday and less 260	d. Workday less 365

-ADT is the number of vehicle count during

a. 365 day	b. 260 day	c. Workday and less 260	***d*. Daily and less 365**

-AAWT is the number of vehicle count during

a. 365 day	***b. Workday in year 260 day***	c. Workday and less 260	d. Workday less 365

-AWT is the number of vehicle count during

a. 365 day	b. 260 day	***c. Workday and less 260***	d. Workday less 365

-Why (30HV) is usually selected as a design hourly volume

a. It is not exceeded to often and not rarely obtain	b. It is truth volume in highway	***c. Save 67% from cost and cause delay 29 hour in year***	d. for lower value of volume in highway

-The value of Peak hour factor (PHF) for volume 1600 veh/hr and quarter hour volume 400 veh is?

a. PHF = 0.8	b. PHF = 0.25	***c.*** PHF = 1	d. PHF = 0.7

-Peak hour factor equal one meant that traffic stream is?

a. Non uniform and stable flow	b. Uniform and unstable flow	c. Non-uniform and unstable flow	***d. Uniform and stable flow***

-For design hourly volume 300veh/hr consists 10 percent of heavy vehicle. Determine the hourly volume expressed by passenger car in level area

a. 315	b. 415	c. 270.15	d. 330

- Indicated what is the meant by PHF

a. Time mean speed	b. Space mean speed	c. Spot speed	***d. Peak hour factor***

-What is the relationship of PHF?

$\sum$ (d/t)/n	D X N/$\sum t_i$	V/PHF	***V/(4 X V_{15})***

-What is the relationship of flow rate?

$\sum$ (d/t)/n	D X N/$\sum t_i$	***V/PHF***	V/(4 X V_{15})

-What is the relationship of SMS?

$\sum$ (d/t)/n	***D X N/$\sum t_i$***	V/PHF	V/(4 X V_{15})

-What is the relationship of TMS?

$\sum$ (d/t)/n	D X N/$\sum t_i$	V/PHF	V/(4 X V_{15})

-The number of vehicles present on a given length of roadway or lane called as?

a. Volume	***b. Density***	c. Speed	d. Peak hour rate

-The difference between the time the front of a vehicle arrives at a point on the highway and the time the front of the next vehicle arrives at the same point called as

a. Time Headway	b. Space Headway	c. Gap	d. Time lag

-The distance between the front of a vehicle and the front of the following vehicle and is usually expressed in meter called as

a. Time Headway	***b. Space Headway***	c. Gap	d. Time lag

- What is the unit measure volume?

a. Veh/day	b. Veh/hr	c. PC/hr	d. All previous

- What is the unit measure density?

a. Veh/km	b. Veh/hr	c. PC/km	d. A and C

- Future Traffic Rate (FTR) for highway with (5.5%) growth rate, (20 year) design life and (2 years) construction period is?

a. 3.6	***b. 3.248***	c. 2.982	d. 3.564

- Designer used flow rate in design because it is?

a. it is not exceeded to often and not rarely obtained	b. it is truth volume in highway	c. save 67% from cost and cause delay 29 hour in year	d. for lower value of volume in highway

-Measure of the demand that a highway can potentially service

a***. capacity***	b. speed	c. density	d. level of service

- Equivalency between the Passenger Car Unit (PCU) and truck for rolling highway is?

a. 1.5	***b. 2.5***	c. 3.5	d. 4.5

-The number of vehicles that pass a given point on the roadway or a given lane or direction of a highway in a specified period of time

a. Volume	b. Density	c. Speed	d. Peak hour rate

-The average speed of all vehicles passing a point on a highway over a specified time period defined as?

a. Time mean speed	b. Space mean speed	c. Spot speed	d. Density

-The average speed of all vehicles occupying a given section of a highway over a specified time period defined as?

a. Time mean speed	***b. Space mean speed***	c. Spot speed	d. Density

- Indicated what is the meant by TMS

a. Time mean speed	b. Space mean speed	c. Spot speed	d. Density

- Indicated what is the meant by SMS

a. Time mean speed	***b. Space mean speed***	c. Spot speed	d. Density

-The average speed of all vehicles passing a point on a highway over a specified time period defined as?

a. Time mean speed	b. Space mean speed	c. Spot speed	d. Density

-The average speed of all vehicles occupying a given section of a highway over a specified time period defined as?

a. Time mean speed	***b. Space mean speed***	c. Spot speed	d. Density

- Indicated what is the meant by TMS

a. Time mean speed	b. Space mean speed	c. Spot speed	d. Density

- Indicated what is the meant by SMS

a. Time mean speed	***b. Space mean speed***	c. Spot speed	d. Density