Transportation Engineering

Lecture 2: ***Traffic Stream Parameters***

Traffic Stream Parameters

- Flow (*q*)
- Density or Concentration (*k*)
- Average Speed (*v*)
- Headways

Flow

- Flow (q) or volume is the number of vehicles passing a point on a road or a lane during a specified time period
- Flow rate is the equivalent rate at which a vehicle passes a point on a road or a lane during unit time interval

Traffic Volume

- Traffic flow vary over time and is normally expressed as volume with respect to the duration of measurement (vehicles per unit time)
- Daily Volume
  - Annual Average Daily Traffic (AADT)
  - Average Daily Traffic (ADT)
  - Average Weekly Traffic (AWT)
- Hourly Volume
  - Peak Hourly Volume (PHV)
  - Design Hour Volume (DHV)

Daily Traffic Volume Measures

- Mainly used for transport planning
- The unit is *vehicles per day*

- **AADT:** The average daily traffic volume at a given location over a year- i.e., the total number of vehicles passing the site in a year divided by 365
- **ADT:** Average daily traffic volume at a given location for some period of time less than a year.
- **AWT:** Average daily traffic volume occurring on weekdays for some period less than a year, when averaged over a year then called **AAWT**

Hourly Traffic Volume Measures

- Used for traffic control as well as planning purposes
- The unit is *vehicles per hour*
- **PHV:** the traffic volume measured over the busiest hour of the day at a given location. PHV gives the highest hourly volume in a day
- **PHF:** Peak hour factor

$$PHF = \frac{\text{hourly volume}}{\text{peak flow rate within the hour}}$$

- For 15 min periods, $PHF = \dfrac{V}{4 \times V_{15}}$

Hourly Traffic Volume Measures

- **DHV:** Peak hourly volumes are different for every day of the year. The thirtieth highest peak hour volume is considered for rural design and the fiftieth highest peak hour volume is considered for urban design and are often called DHV

DHV = AADT X *k*

where, *k* denotes the proportion of daily volume occurring during the peak hour (expressed as decimal)

k is often the ratio of 30^{th} or 50^{th} HV to the AADT from a similar site

Density

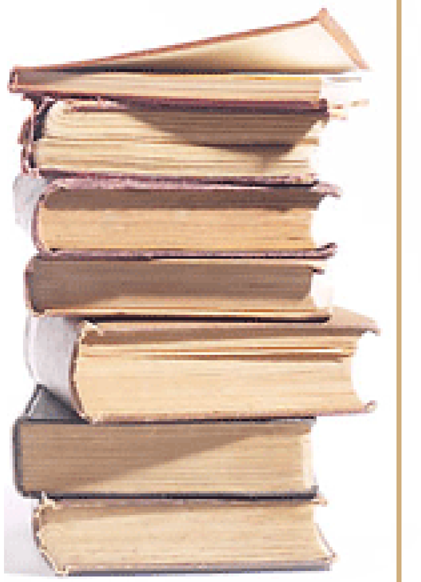
- Density is the number of vehicles occupying a given length of a lane or a roadway at a particular instant expressed as vehicles per kilometer (vpkm) or vehicles per kilometer per lane (vpkmpl)
- It is a measure directly related to traffic demand and
- It is a measure of the quality of traffic operation and driver’s behavior significantly depends on density

Speed

- Speed is the distance traversed by a vehicle in unit time, expressed in terms of kilometers per hour (kmph) or miles per hour (mph) or meter per second (m/s)
- Defined as the inverse of the time taken by a vehicle to traverse a given distance
- Speed is an important measure of the quality of traffic operation.
- Drivers can directly perceive this quantity.

Speed

- In a traffic stream, speed of different vehicles need not be the same at a given time and location.
- Therefore speed of a traffic stream is not a single value, but is a distribution of individual vehicle speeds.
- Different types of average values of speed are used to characterize a traffic stream.
  - TIME MEAN SPEED
  - SPACE MEAN SPEED



Time mean speed (TMS)

The average speed of vehicles measured at a point/location over a given interval of time also called spot speed.

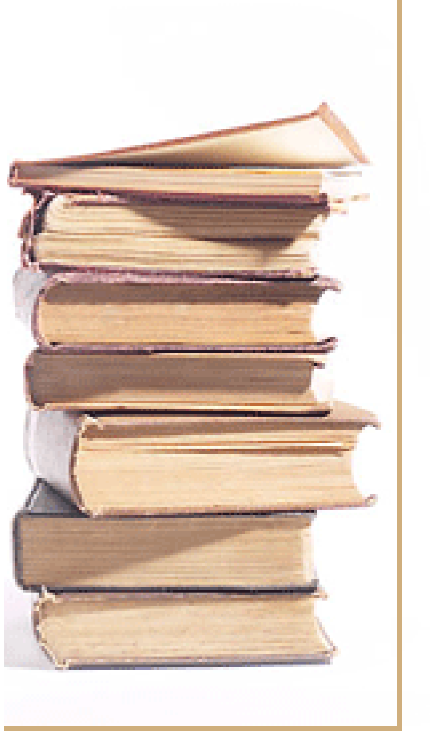
$$TMS = \frac{\sum v_t}{n}$$

TMS is the arithmetic mean of all speeds

E.G.

v_1=12 m/s, v_2 =15 m/s and v_3= 10 m/s

$$v_t = \frac{10+12+15}{3} = 12.3 m/s$$



Space mean speed (SMS)

The average speed of vehicles measured at an instant of time over a specified stretch of road.

$$SMS = \frac{n}{\sum 1/v_i}$$

SMS is the harmonic mean of all speeds.

E.G.

v_1=12 m/s, v_2 =15 m/s and v_3= 10 m/s

$$v_s = \frac{3}{1/12 + 1/15 + 1/10} = 12 m/s$$

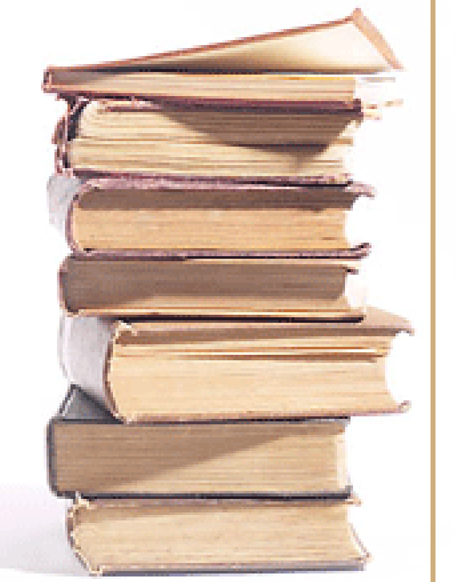
Speed Calculation

Computation of Time Mean Speed and Space Mean Speed

1 Vehicle No.	2 Distance (m)	3 Travel Time (sec)	2/3 Speed (mps)
1	1000	18.0	1000/18 = 55.6
2	1000	20.0	1000/20 = 50.0
3	1000	22.0	1000/22 = 45.5
4	1000	19.0	1000/19 = 52.6
5	1000	20.0	1000/20 = 50.0
6	1000	20.0	1000/20 = 50.0
Totals	6000	119.0	303.7
Averages		119/6 = 19.8	303.7/6 = 50.6

TMS = 50.6 mps

SMS = 1000/19.8 or 6000/119 = 50.4 mps

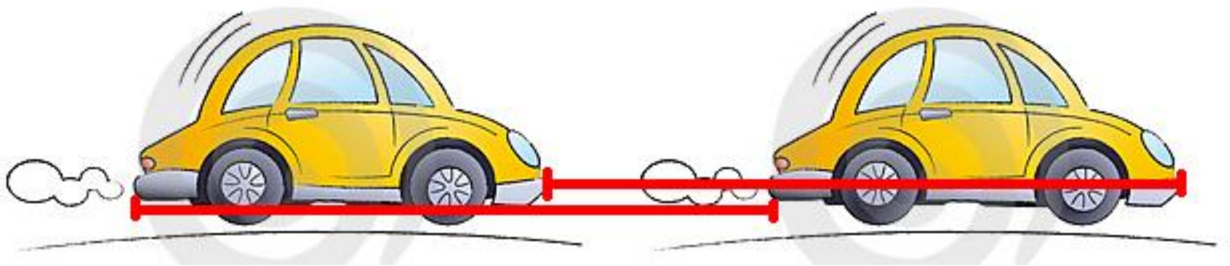


Other Speed Measures

- Average Running Speed: It is a type of SMS. Defined as the average speed of a vehicle in motion on a large stretch of road
- Average Travel Speed: It is a type of SMS. Average speed of a vehicle on a large stretch of road including the *stopped delay*.
- Free Flow Speed: The desired speed of a vehicle under 'no congestion conditions' or very low volume conditions
- Percentile Speed: A speed below which the stated percent of vehicles in the traffic stream will travel.

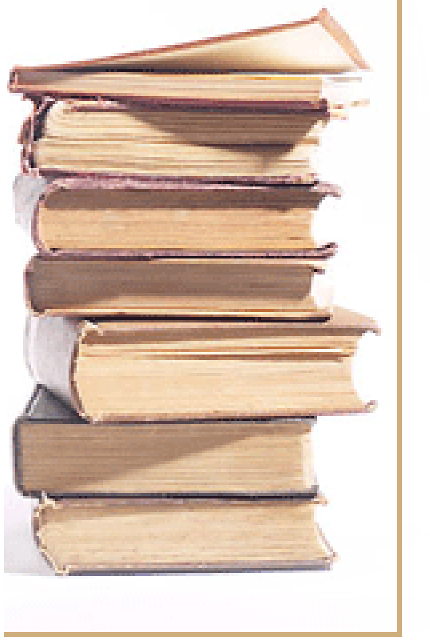
Headways

- Distance between successive vehicles in a traffic lane is *spacing* or space headway



- It is the inverse of density (k)
- If density is 100 veh/km then,

$$s = \frac{1000}{100} = 10m$$



Headways

- Time between successive vehicles in a traffic lane as they pass a point is *headway* or time headway

- It is the inverse of flow (*q*)
- If flow is 1200 vph then,

$$h = \frac{3600}{1200} = 3\text{sec}$$

Traffic Stream Parameters

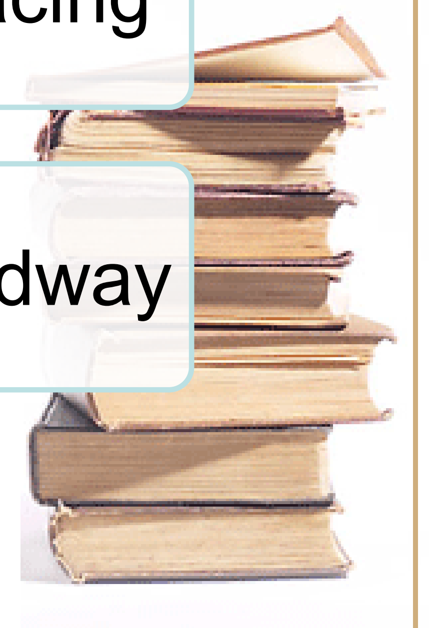
- Flow (q)
- Density or Concentration (k)
- Average Speed (v)
- Headways

macroscopic

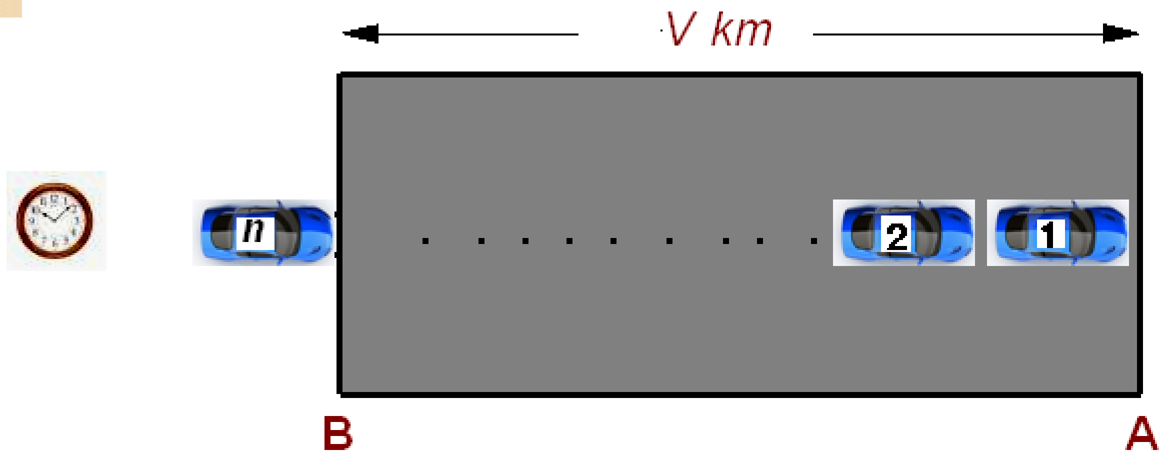
- Flow
- Speed
- Density

microscopic

- Spacing
- Headway



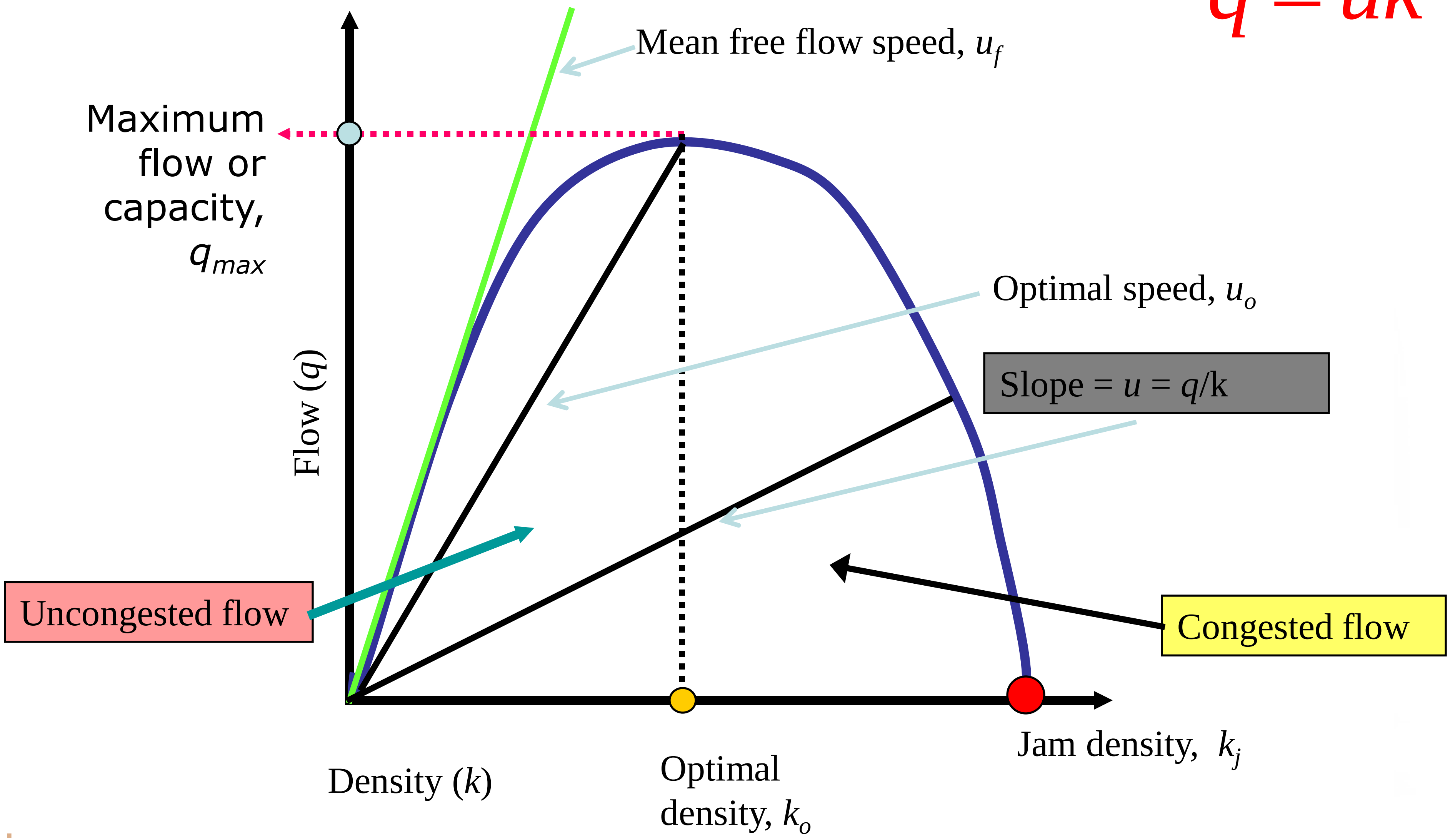
Fundamental Relationship



- No of vehicles observed in *t* hour, $q = \dfrac{\text{no. of vehicles}}{\text{total elapsed time}} = {}^{n}\!/_{t} \text{ vph}$
- Concentration/density of traffic over *v* km road during 1 hour period = $k = \dfrac{\text{no. of vehicles}}{\text{length of road}} = {}^{n}\!/_{l} \text{ veh/km}$
- Space mean speed of the vehicles, $u = \dfrac{\left({}^{1}\!/_{n}\right)\sum_{i=1}^{n} d_i}{\bar{t}} \text{ km/hr}$
- Time mean speed of vehicles, $u = \left({}^{1}\!/_{n}\right)\sum_{i=1}^{n} \dfrac{d_i}{t_i} \text{ km/hr}$

Fundamental Diagram

$$q = uk$$



Flow-Density Relationships

- The flow and density varies with time and location.
- When the density is zero, flow will also be zero, since there is no vehicles on the road.
- When the no. of vehicles gradually increases the density as well as flow increases.

$$\text{When, } q = 0,\ k = 0$$

$$\text{When, } q = 0,\ k = k_j$$

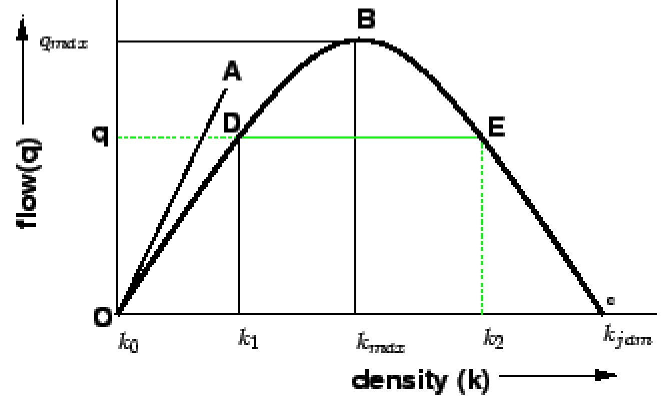
What is *kj* ?

Jam Density

- With continuous increase in vehicle number, it reaches a situation where vehicles can't move. This is called jam density or the maximum density.
- At jam density, flow will be zero because the vehicles are not moving.
- There will be some density between zero density and jam density, when the flow is maximum.

k_2 k_1

Flow-Density Relationships



The point O refers to the case with zero density and zero flow.

The point B refers to the max. flow and the corresponding density.

The point C refers to the max. density & corresponding zero flow.

OA is the tangent drawn to the parabola at O, and the slope of the line OA gives the mean free flow speed.

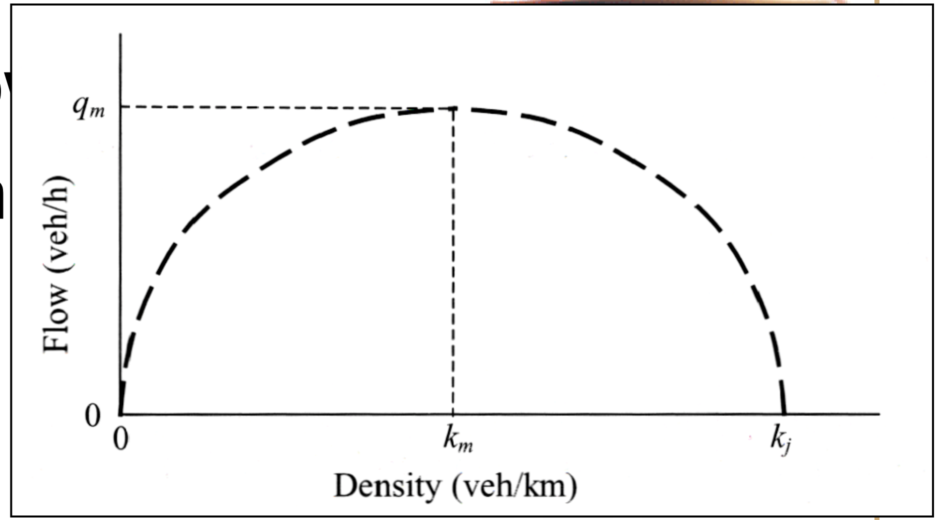
Points D and E correspond to same flow but has 2 different densities. The slopes of the lines OD and OE give the mean speed at density k_1 and k_2 . Speed is higher when there are less number of vehicles on the road

Flow-Density Relationships

$$q = uk = u_f\left(1 - \frac{k}{k_j}\right) \times k, \text{ therefore}$$

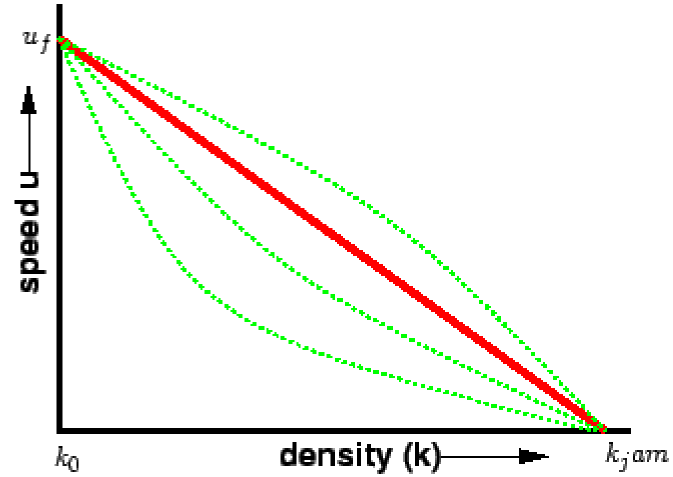
$$q = u_f\left(k - \frac{k^2}{k_j}\right)$$

- A parabolic relationship
- Density at which max flo[w]
  find maxima of the given



$$k_m = \frac{k_j}{2}$$

Speed-Density Relationships



- Speed decreases with increase in density
- At zero density speed will be maximum, referred to as the free flow speed
- When the density is jam density, the speed of the vehicles becomes zero

$$\text{When, } k = 0,\ U = u_f$$

$$\text{When, } u = 0,\ k = k_j$$

Greenshields' Equation

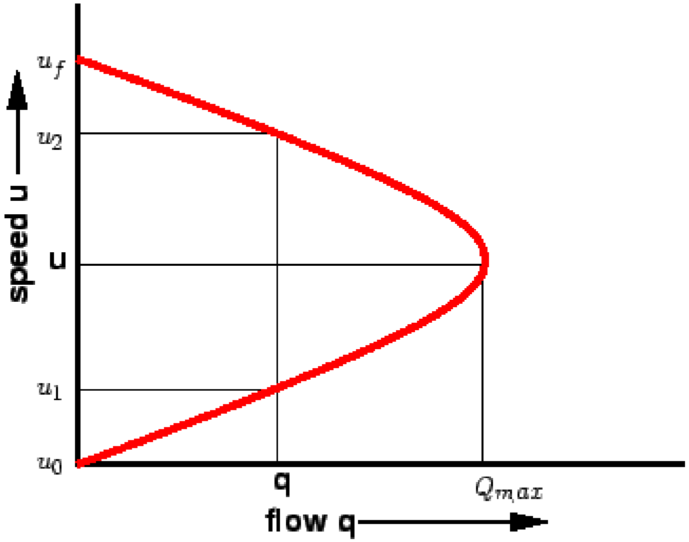
- Greenshields (1934) proposed a linear relationship between the speed and density

$$u = u_f \left(1 - \frac{k}{k_j} \right)$$

$$u = c_1 + c_2 k$$

- Other models, Greenberg used logarithmic relation

Speed-Flow Relationships



- At maximum flow, the speed will be in between zero and free flow speed. At zero density speed will be maximum, referred to as the free flow speed
- It is possible to have two different speeds for a given flow.

$$\text{When, } q = 0,\ U = u_f$$

$$\text{When, } q = 0,\ U = u_0$$

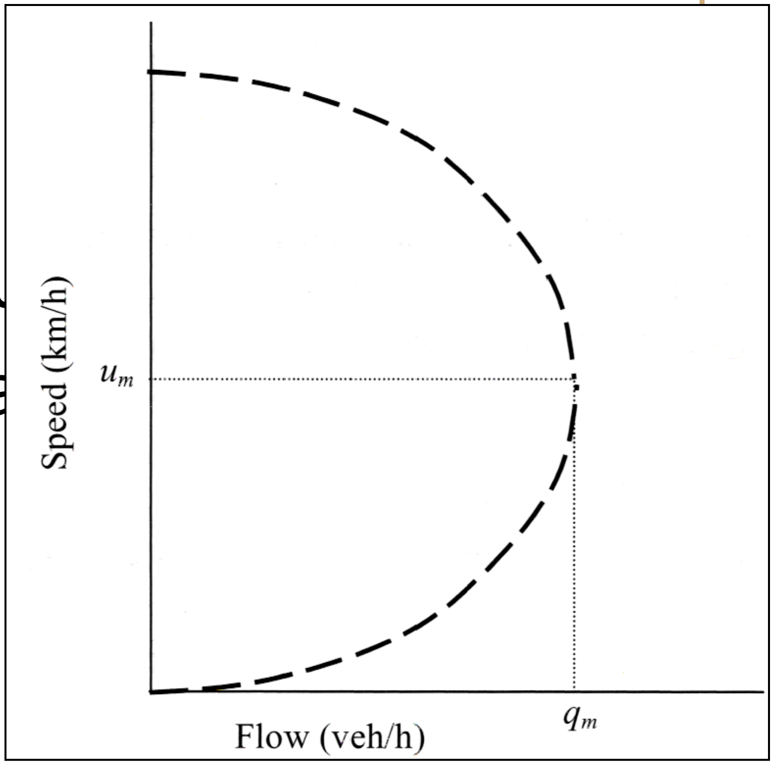
Speed-Flow Relationships

$$k = k_j\left(1 - \frac{u}{u_f}\right)$$

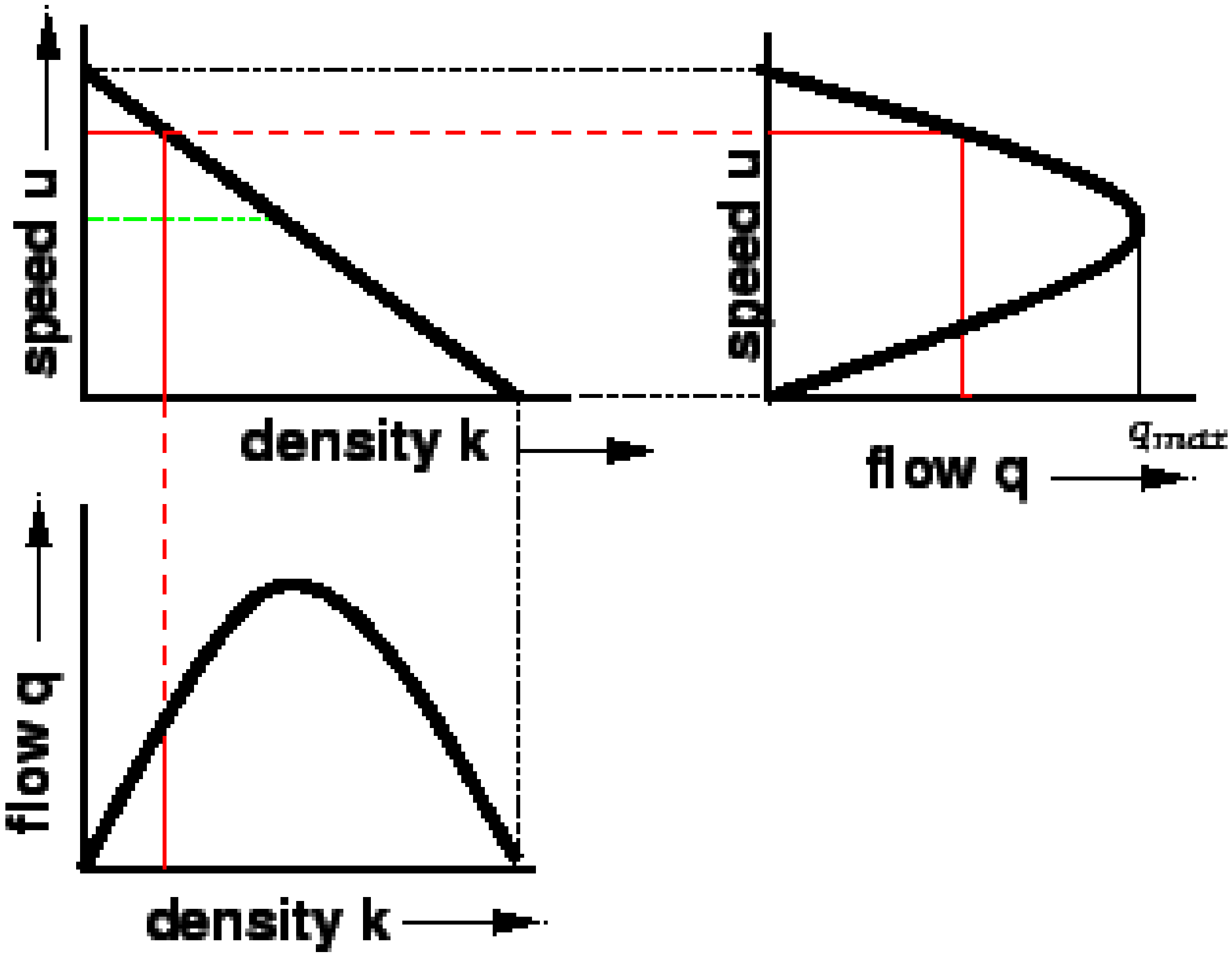
Hence, $$q = k_j\left(u - \frac{u^2}{u_f}\right)$$

- A parabolic relationship
- Speed at which max flow occu
  find maxima of the given equa

$$u_m = \frac{u_f}{2}$$



Fundamental Diagram



Example

Two platoons of cars are timed over a distance of 0.5 km. Their flows are recorded. The first group is timed at 40 seconds, with the flow at 1350 vehicles per hour. The second group take 45 seconds, with a flow of 1800 vehicles per hour.

Determine the maximum flow of the traffic stream.

Solution

Group 1 has an average speed of 45 km/h
Group 2 has an average speed of 40 km/h
Group 1 k value = 1350/45 = 30 v/km
Group 2 k value = 1800/40 = 45 v/km

To get the consequent relationship between speed and density based on the above two results, use co-ordinate geometry:

$$y - y_1 = m(x - x_1)$$

where

$$m = \frac{y_1 - y_2}{x_1 - x_2} \qquad y = \text{speed} \quad x = \text{density}$$

The slope, m, of the line joining the above two results = –5/15 = –1/3

$$y - 45 = -1/3(x - 30)$$
$$y + x/3 = 55$$

Examining the boundary conditions:

Free flow speed = 55 km/h
Jam density = 165 v/km
Max flow = 55 * 165/4 = 2269 v/h

Time-Space Diagram