CIVL2700 – Topic 6: Traffic States & Measurement

- Streams of traffic are comprised of individual vehicles, driven by individual drivers, interacting with each other and the roadway environment.
- Because each driver behaves in a unique way, it is not possible to describe traffic flow as theoretically concise.

Uninterrupted Flow:	A traffic stream which is not delayed or interfered with elements external to the traffic stream itself (e.g. pedestrian crossings, intersections), but only by its own internal traffic interactions (e.g. highways, rural roads).
Interrupted Flow:	A traffic stream which is affected significantly by external elements (e.g. urban links).

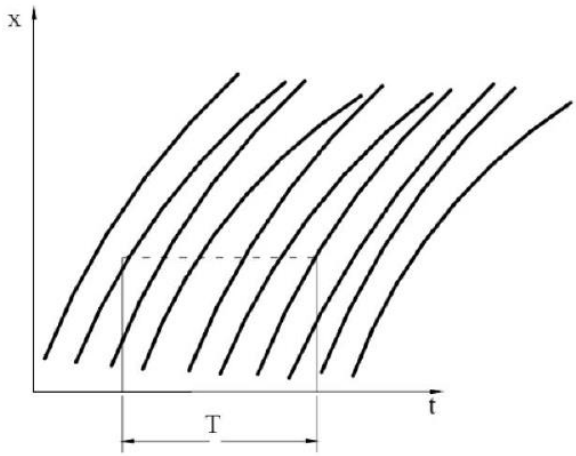
Vehicle Trajectories and Traffic States

- The three main parameters that form the basis of traffic analysis are:
  - Flow (q)
  - Density (k)
  - Speed (v)
- Traffic flow, average speed, and density address the traffic stream as a whole.
  - They are referred to as **macroscopic measures**.

Flow (q)

$$q = \frac{n}{T}$$

q = traffic flow [veh/unit time]
n = number of vehicles passing a designated roadway point during time T
T = duration of time interval.



- The **headway** is the time between the passage of a designated point of successive vehicles, at a fixed point.

$$T = \sum_{i=1}^{n} h_i$$

h_i = time headway of the i^{th} vehicle.

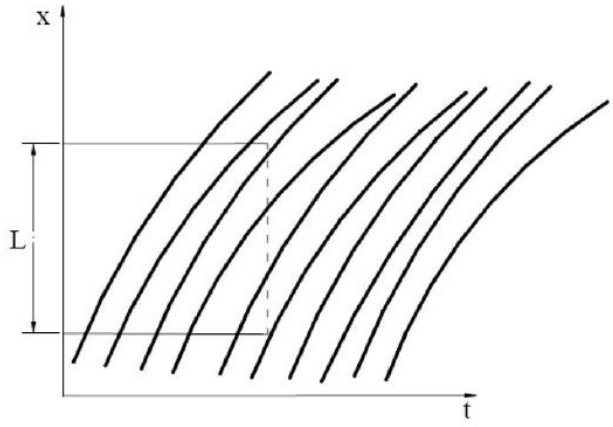
- Since $q = \frac{n}{T}$, then we can substitute the headway equation to get:

$$q = \frac{1}{\bar{h}}$$

$\bar{h}$ = average headway.

Density (k)

$$k = \frac{n}{L}$$



$L =$ length of the section.

- The **spacing** is the distance between a designated point of successive vehicles at a given time.

$$L = \sum_{i=1}^{n} s_i$$

$s_i =$ spacing of the i^{th} vehicle.

- Since $k = \frac{n}{L}$, then we can substitute the spacing equation to get:

$$k = \frac{1}{\bar{s}}$$

$\bar{s} =$ average spacing.

Speed (v)

Time Mean Speed ($\overline{v_t}$):	The arithmetic mean of the measured speed of all vehicles passing a fixed roadside point during a given time interval.
Space Mean Speed ($\overline{v_s}$):	The arithmetic mean of the measured speeds of all vehicles in the stream which are within a specified length of roadway at a given instant of time.

- Space Mean Speed (SMS) is often more useful in traffic analysis.
  - It is determined on the basis of the time necessary for a vehicle to travel some known length of roadway.

Time Mean Speed

$$\overline{v_t} = \frac{\sum_{i=1}^{n} v_i}{n}$$

Space Mean Speed

$$\overline{v_s} = \frac{\sum_{i=1}^{n} v_i}{n} = \frac{L}{\bar{t}}$$

$\bar{t} =$ average vehicle travel time.

$$\bar{t} = \frac{1}{n}\sum_{t=1}^{n} t_i$$

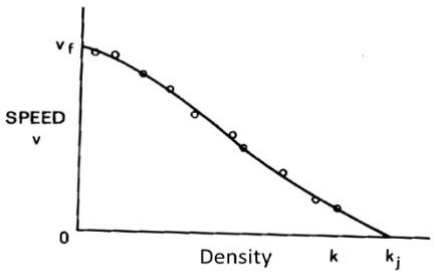
- Substituting the average time equation into the SMS equation, we get:

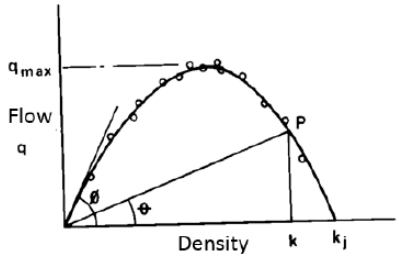
$$\overline{v_s} = \frac{L}{\bar{t}} = \frac{1}{\frac{1}{n}\sum_{i=1}^{n}\left(\frac{t_i}{L}\right)}$$

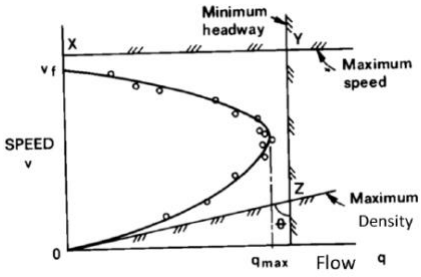
Traffic States Relationship

$$q = kv$$

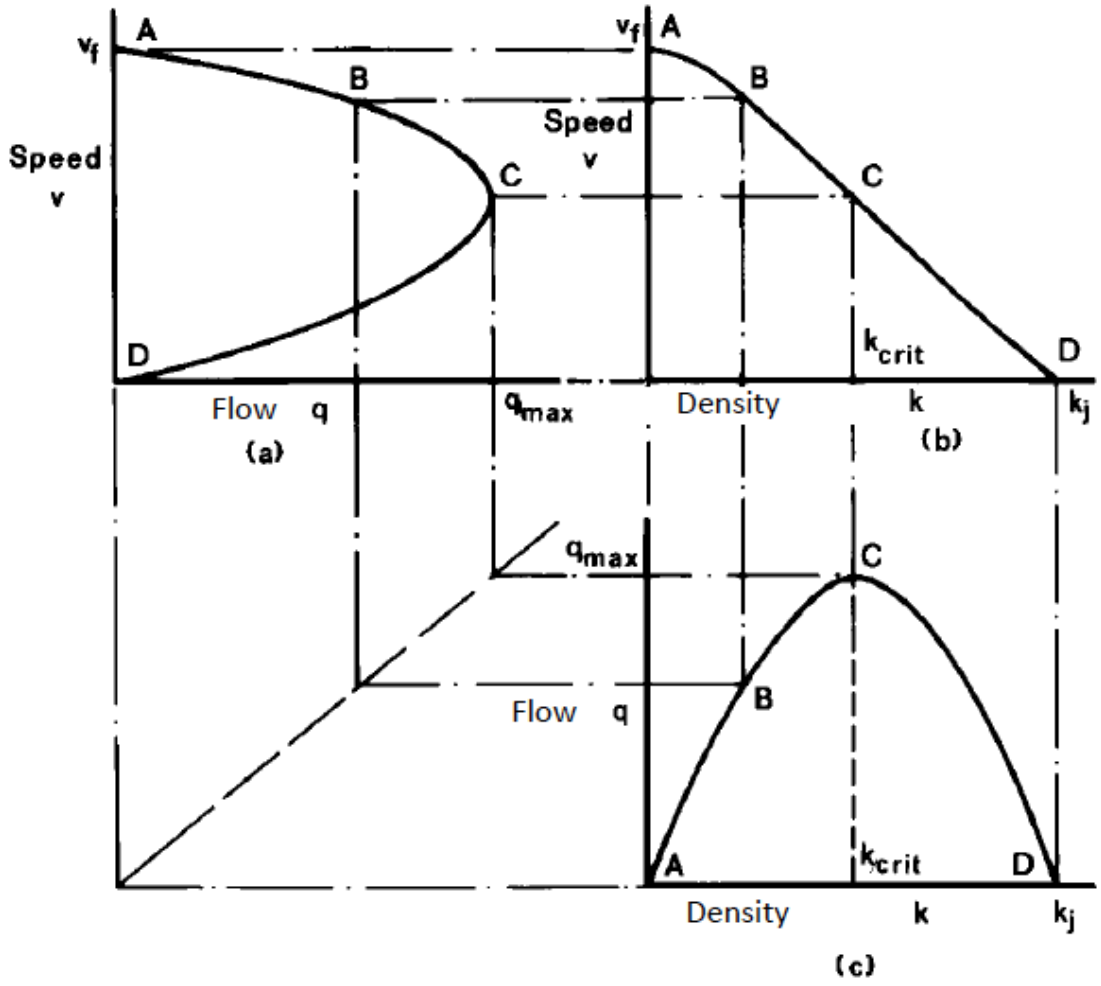
Fundamental Diagrams

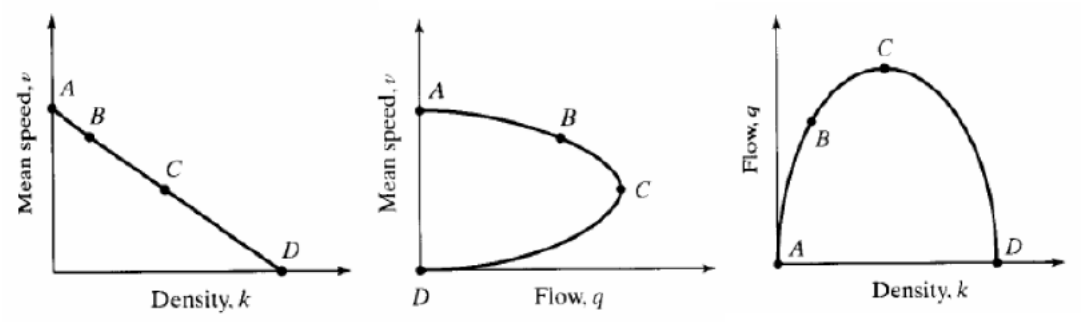






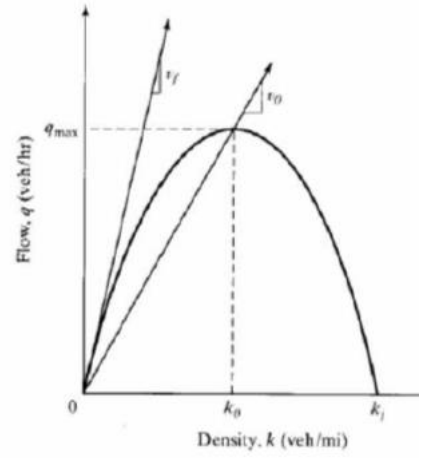
- The three fundamental diagrams can be combined into a single diagram.

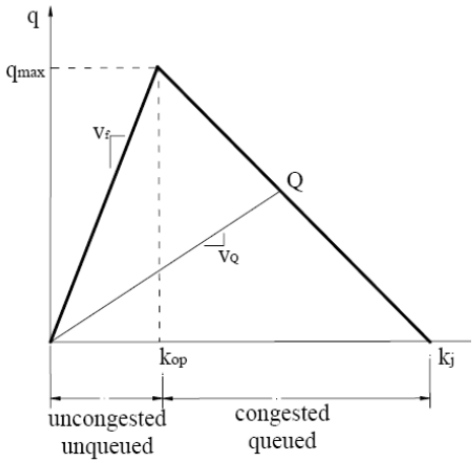




A:	Zero density, free-flow speed, low volume.
B:	Increased density, reduced speed, increased volume.
C:	Increased density, reduced speed, maximum volume.
D:	Jam density, minimum speed, low volume.

- The slope of a line connecting any point on the curve and the origin is the **space mean speed**.
- The maximum value of flow on the flow-density curve is the **capacity** of the link.





Capacity (q_{max}):	The maximum sustained flow that can pass through the link when there is a queue upstream feeding it and no restriction downstream blocking its exit.

Traffic Studies

- Aspects of traffic studies include:
  - **Inventories –** household surveys, street / highway links, intersections, etc.
  - **Special Purpose Studies –** Accident studies, parking studies, pedestrian studies, asset / pavement studies, land-use studies, etc.
  - **Operational Parameters –** Volume (flow) studies, speed studies, travel-time studies, delay studies, headway and spacing studies, etc.

Statistical Inference in Decision-Making

- Information obtained from sampled data is used to make generalizations about the populations from which the samples were obtained.

Sampling Methods

Simple Random Sampling:	• Selecting the sample at random. • This can be problematic as it might require large samples to ensure sufficient data.
Stratified Random Sampling:	• A priori information is used to subdivide the population into homogenous groups. • Simple random sampling is then conducted inside each group.

Error and Bias in Sampling:

Error:	• Due to random effects. • Due to the fact that we are dealing with a sample and not the entire population. • Sampling error insignificantly affects the expected value of the means of the estimated parameters. • It can significantly affect the variability around them.
Bias:	• Due to mistakes. • Due to the fact that mistakes can be made when defining the population or when selecting the sampling method. • Sampling bias can affect not only the variability around the mean values, but the values themselves. • Sampling bias can be avoided.

Statistical Measures

Central Tendency:	• Sample Mean: The arithmetic average of the observed values of one variable, $\bar{x} = \frac{\sum_{i=1}^{N} x_i}{N}$ • Sample Median: The middle value of the sorted sample set. • Sample Mode: The most frequent observation.
Dispersion:	• Sample Variance: Measures how far the observed values of one variable are spread out, $var(x) = \frac{\sum_{i=1}^{N}(x_i - \bar{x})^2}{N-1}$ • Sample Standard Deviation: The square root of the variance which has the same dimension as the data, $s(x) = \sqrt{\frac{\sum_{i=1}^{N}(x_i - \bar{x})^2}{N-1}}$ • Sample Coefficient of Variation: $CV(x) = \frac{s(x)}{\bar{x}}$

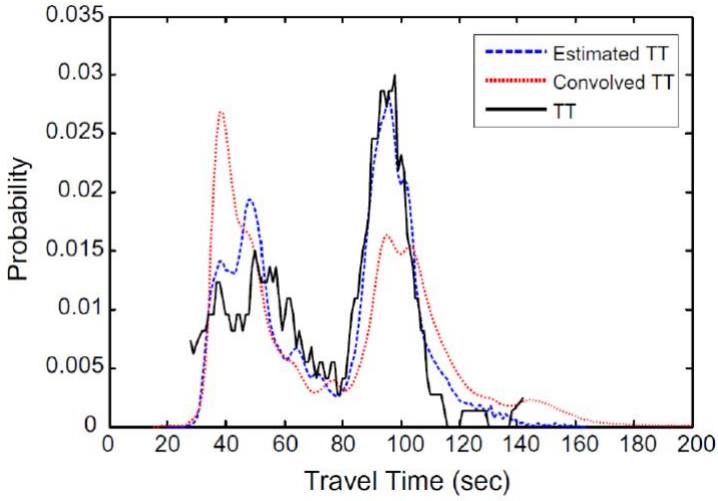
Vehicle Counts

Flow (Volume):	The actual number of vehicles traversing the segment per unit time.
Demand:	The number of vehicles that desire to traverse the segment per unit time.
Capacity:	The maximum number of vehicles that can pass through the segment per unit time.

- Inductive Loop Detectors can be used to measure both speed and classify vehicles.
- Video camera software can also be used to measure vehicles.
    - They can track the trajectories of the vehicles.
    - They may not be as accurate however.

Travel Time Studies

- Travel time is a popular performance measure.
- Can be compared across different modes of transport.
- It is easy to work with mathematically.
- It is easy to understand by travellers.
- Real-time monitoring.



Density Studies

- Includes aerial photographs and videos.
- Measures flow divided by speed.
- Loop detectors can measure this.

$$k = \frac{o}{L_d + L_v}$$

Where:

$$Occupancy\ (o) = \frac{Total\ Occupied\ Time}{Total\ Observation\ Time} \times 100$$