Introduction

- Traffic streams: Individual vehicles, piloted by individual drivers, interacting with each other and the roadway environment.
- Traffic stream models: Need quantitative techniques to assess highway performance so we can evaluate existing transportation facilities and alternative design improvements for those facilities.

Traffic Stream Parameters

Administration

- Group assignment for design project
- No class Wednesday – Group activity #1

Introduction

- Two general types of flow environments:
  - Uninterrupted flow – traffic streams influenced by...
    - roadway design and
    - vehicles interactions
  - Interrupted Flow – traffic streams also influenced by...
    - traffic control devices
The three main variables (parameters) for traffic analysis of highway performance:

- Flow, $q$ → vehicles per hour per lane (vphpl)
- Speed, $u$ → miles per hour (mph)
- Density, $k$ → vehicle per mile per lane (vpmpl)

**Definition:** The number of vehicles that pass a point on the roadway (sometimes per lane) during a specific time interval.

$$q = \frac{n}{t}$$  \hspace{1cm} (Eq. 5.1)

Where:
- $q$ = traffic flow in vehicles per unit time,
- $n$ = number of vehicles passing some designated roadway point during time $t$ and
- $t$ = duration of time interval.

**Time headway:**

- The time between the passage of the front bumpers of successive vehicles, at a given point.

$$q = \frac{n}{t}$$  \hspace{1cm} (Eq. 5.1)

$$t = \frac{1}{h_{avg}}$$  \hspace{1cm} (Eq. 5.2)

Where:
- $t$ = duration of time interval,
- $h_{avg}$ = average time headway, and
- $n$ = number of measured time headways at some designated roadway point.

Substituting Eq. 5.2 into Eq. 5.1 gives

$$q = \frac{n}{\sum_{i=1}^{n} h_i}$$  \hspace{1cm} (Eq. 5.3)

or

$$q = \frac{1}{\overline{h}}$$  \hspace{1cm} (Eq. 5.4)

Where:
- $\overline{h}$ = the average time headway, $\sum h_i / n$ in unit time per vehicle.
Average traffic speed is defined in two ways:

- **Time (spot) mean speed** – average speed of vehicles passing a point on a roadway over a specified time (instantaneous point speed) (e.g., radar gun)
  \[ \bar{v}_t = \frac{\sum v_i}{n} \]  
  (Eq. 5.5)
  
  Where:
  \( \bar{v}_t \) = time-mean speed in unit distance per unit time,
  \( v_i \) = \( i^{th} \) vehicle spot speed at designated point on highway, and
  \( n \) = number of measured vehicle spot speeds.

- **Space mean speed** – average speed of all vehicles occupying a given section of roadway over a specified time (inverse of travel time for all vehicles over the specified section length)
  
  More useful for traffic analysis
  
  Based on observed vehicle travel times through a highway section

- Why is this more useful than time mean speed?

**Substituting Eq. 5.7 into Eq. 5.6 gives**

\[ \bar{v}_s = \frac{i}{l} \left( \frac{1}{n} \sum \frac{1}{t_i} \right) \]  
(Eq. 5.8)  

or

\[ \bar{v}_s = \frac{1}{l} \left( \frac{1}{n} \sum \frac{1}{t_i} \right) \]  
(Eq. 5.9)

which is the harmonic mean of speed (space-mean speed). Again, space-mean speed is the speed variable used in traffic models.

\[ \bar{v}_s = \frac{\sum v_i}{n} \]
Definition: The number of vehicles occupying a given length of roadway at some specified time.

\[ k = \frac{n}{l} \]  
(Eq. 5.10)

Where:
- \( k \) = traffic density in vehicles per unit distance (sometimes per lane too),
- \( n \) = number of vehicles occupying some length of roadway at some specified time, and
- \( l \) = length of roadway.

The density can also be related to the individual spacing between successive vehicles (measured from front bumper to front bumper). The roadway length, \( l \), in Eq. 5.10 can be defined as

\[ l = \sum_{i=1}^{n} s_i \]  
(Eq. 5.11)

Where:
- \( s_i \) = spacing of the \( i \)th vehicle (the distance between vehicle \( i \) and \( i-1 \), measured from front bumper to front bumper), and
- \( n \) = number of measured vehicle spacings.

Substituting Eq. 5.11 into Eq. 5.10 gives

\[ k = \frac{n}{\sum_{i=1}^{n} s_i} \]  
(Eq. 5.12) or \[ k = \frac{1}{\bar{s}} \]  
(Eq. 5.13)

Where:
- \( \bar{s} \) is the average spacing.

Time headway and spacing are referred to as microscopic measures because they describe characteristics specific to individual pairs of vehicles within the traffic stream.

Measures that refer to the traffic stream as a whole, such as flow, average speed, and density are referred to as macroscopic measures because they describe characteristics of the traffic stream as a whole.

As indicated by the above equations, the microscopic measures can be aggregated and thus related to the macroscopic measures.
A simple identity provides the basic relationship between traffic flow \( q \), speed \( u \), and density \( k \)

- setting space-mean speed, \( \bar{u} \), as simply \( u \) for notational convenience,

\[
q = uk \quad \text{(Eq. 5.14)}
\]

Where:
- \( q \) = flow, typically in units of vehicles per hour (veh/h),
- \( u \) = speed (space mean speed), typically in units of mi/h (km/h), and
- \( k \) = density, typically in units of veh/mi (veh/km).