Outline: Chapter 3

3.1 Traffic Flow Elements

3.2 Flow-Density Relationships

1

Traffic Flow Theory

- **Traffic Flow Theory**: involves the development of mathematical relationships among the primary elements of a traffic stream: flow, density, and speed.
- These relationships help the traffic engineer in planning, designing, and evaluating the effectiveness of implementing traffic engineering measures on a highway system.
- Physical and empirical methods have been used in studying the description and quantification of traffic flow.

3.1 Traffic Flow Elements

Time Space Diagram

- A graph that describes the relationship between the location of vehicles in a traffic stream and the time as the vehicles progress along the highway.

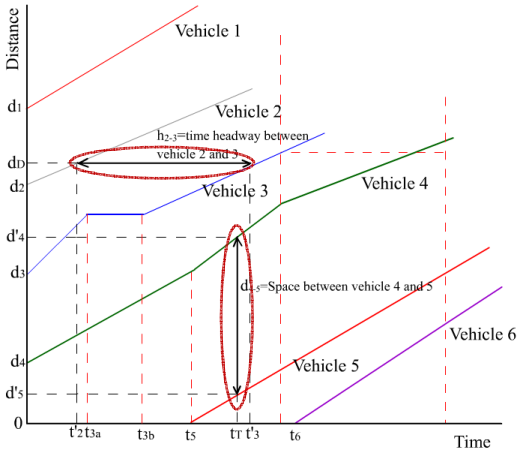


Figure 5.1 Time-Space Diagram

Time Space Diagram

- This Figure shows a time-space diagram for six vehicles with distance plotted on the vertical axis and time on the horizontal axis.
- At time zero, vehicles 1, 2, 3, and 4 are at respective distances d_1, d_2, d_3, *and* d_4 *from a reference point* .
- whereas vehicles 5 and 6 cross the reference point later at times t_5 *and* t_6, *respectively.*

interchange

5

Primary Elements of Traffic Flow

1. **Flow (q)**: the equivalent hourly rate at which vehicles pass a point on a highway during a time period less than 1 hour.

$$q = \frac{n \times 3600}{T} \text{ veh/h}$$

n = the number of vehicles passing a point in the roadway in T sec
q = the equivalent hourly flow

Primary Elements of Traffic Flow

2. **Density (*k*) *veh/mi or veh/km***: referred to as concentration, It is the number of vehicles traveling over a unit length of highway at an instant in time.

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

k = traffic density in vehicles per unit distance,
n = number of vehicles occupying some length of roadway at some specified time, and
l = length of roadway.

Primary Elements of Traffic Flow

Example:

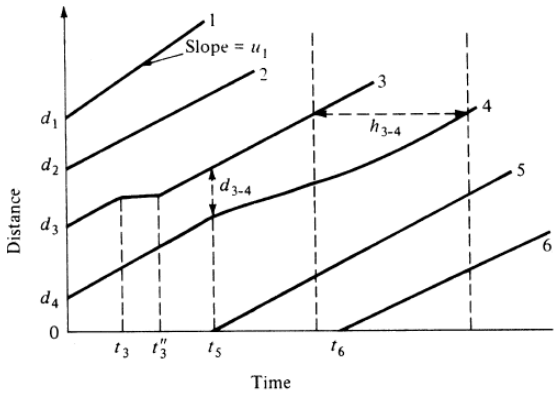
the Density = # of Cars / Distance = $\frac{4}{100 / 1000}$

= 40 Veh/km

Primary Elements of Traffic Flow

3. Speed (*u*) *mi/hr or km/hr*: the distance traveled by a vehicle during a unit of time

- Speed at time t is the slope of the time space diagram for that vehicle at time t



Primary Elements of Traffic Flow

3. Speed (*u*) *km/hr or mi/hr*:

a. Time mean speed $(\overline{u}_t)$: the arithmetic mean of the speeds of vehicles passing a point on a highway during an interval of time.

$$\overline{u}_t = \frac{1}{n}\sum_{i=1}^{n} u_i$$

n = number of vehicles passing a point on the highway

u_i = speed of the ith vehicle

Primary Elements of Traffic Flow

3. Speed (*u*) *mi/hr or km/hr*:

b. Space mean speed $(\overline{u}_s)$: the harmonic mean of the speeds of vehicles passing a point on a highway during an interval of time.

$$\overline{u}_s = \frac{n}{\sum_{i=1}^{n}(1/u_i)} = \frac{nL}{\sum_{i=1}^{n} t_i}$$

$\overline{u}_s$ = space mean speed (ft/sec)
n = number of vehicles
t_i = the time it takes the ith vehicle to travel across a section of highway (sec)
u_i = speed of the ith vehicle (ft/sec)
L = length of section of highway (ft)

Primary Elements of Traffic Flow

3. Speed (*u*) *km/hr or mi/hr*:

- **Time mean speed is always higher than the space mean speed**

$$\overline{u}_s \leq \overline{u}_t$$

- The difference between these speeds tends to decrease as the absolute values of speeds increase
- From empirical analysis

$$\overline{u}_t = \overline{u}_s + \frac{\sigma^2}{\overline{u}_s}$$

Primary Elements of Traffic Flow

4. **Time Headway (*h*) sec**: 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 that same point

$$\overline{h} = \frac{3600}{q}$$

where: $\overline{h}$ = the average time headway (sec)
q = the flow rate (veh/hr)

Primary Elements of Traffic Flow

5. **Space Headway (*d*) feet**: the distance between the front of a vehicle and the front of the following vehicle and is usually expressed in feet

$$\overline{d} = \frac{1000}{k}$$

where: $\overline{d}$ = the average space headway (m)
k = the density (veh/km)

Example 6.1

Example 6.1

Example 6.1 Determining Flow, Density, Time Mean Speed, and Space Mean Speed

Figure 6.3 shows vehicles traveling at constant speeds on a two-lane highway between sections X and Y with their positions and speeds obtained at an instant of time by photography. An observer located at point X observes the four vehicles passing point X during a period of T sec. The velocities of the vehicles are measured as 45, 45, 40, and 30 mi/h, respectively. Calculate the flow, density, time mean speed, and space mean speed.

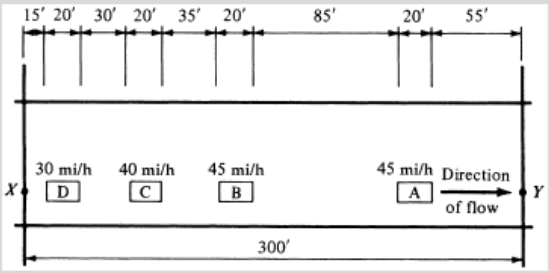


Figure 6.3 Locations and Speeds of Four Vehicles on a Two-Lane Highway at an Instant of Time

Example 6.1

Solution: The flow is calculated by

$$q = \frac{n \times 3600}{T} = \frac{4 \times 3600}{T} = \frac{14{,}400}{T} \text{ veh/h} \qquad (6.6)$$

With L equal to the distance between X and Y (ft), density is obtained by

$$k = \frac{n}{L} = \frac{4}{300} \times 5280 = 70.4 \text{ veh/mi}$$

The time mean speed is found by

$$u_t = \frac{1}{n}\sum_{i=1}^{n} u_i = \frac{30 + 40 + 45 + 45}{4} = 40 \text{ mi/h}$$

The space mean speed is found by

$$\bar{u}_s = \frac{n}{\sum_{i=1}^{n}(1/u_i)} = \frac{Ln}{\sum_{i=1}^{n} t_i} = \frac{300n}{\sum_{i=1}^{n} t_i}$$

Example 6.1

where t_i is the time it takes the ith vehicle to travel from X to Y at speed u_i, and L (ft) is the distance between X and Y.

$$t_i = \frac{L}{1.47u_i} \text{ sec}$$

$$t_A = \frac{300}{1.47 \times 45} = 4.54 \text{ sec}$$

$$t_B = \frac{300}{1.47 \times 45} = 4.54 \text{ sec}$$

$$t_C = \frac{300}{1.47 \times 40} = 5.10 \text{ sec}$$

$$t_D = \frac{300}{1.47 \times 30} = 6.80 \text{ sec}$$

$$\overline{u}_s = \frac{4 \times 300}{4.54 + 4.54 + 5.10 + 6.80} = 57 \text{ ft/sec}$$

$$= 39.0 \text{ mi/h}$$