Fundamental Principals of Traffic Flow

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Fundamental Principals of Traffic Flow

- Traffic flow theory involves mathematical relationships among the primary elements of a traffic stream:
- flow, density, and speed.
- help the traffic engineer in planning, designing, and evaluating the effectiveness such as:
  - adequate lane lengths for storing left-turn
  - the average delay at intersections and freeway ramp merging areas,
  - the level of freeway performance
  - simulation

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- **6.1 TRAFFIC FLOW ELEMENTS**
- **6.1.1 Time-Space Diagram**

- The time-space diagram is 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.

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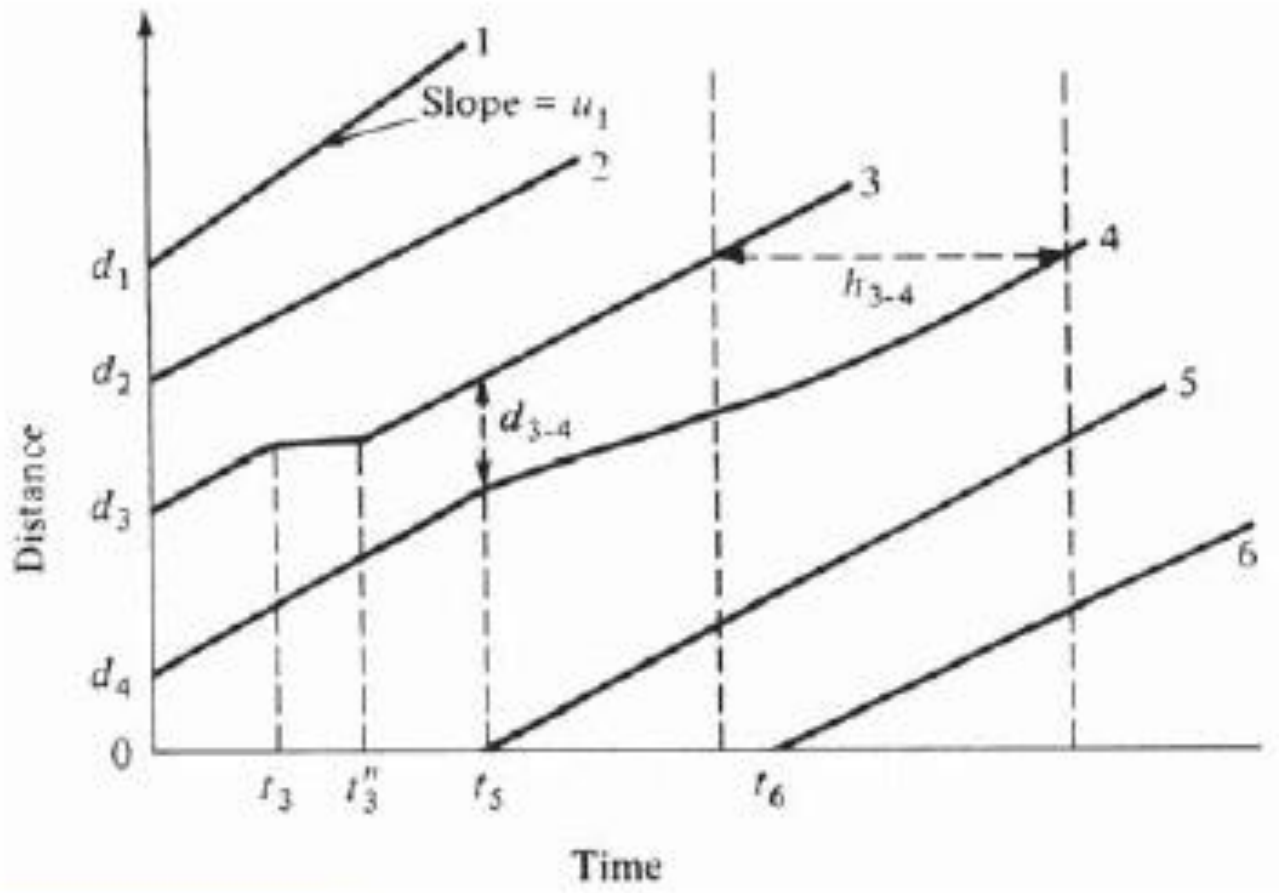


Figure 6.1 Time-Space Diagram

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6.1.2 Primary Elements of Traffic Flow

- flow,
- density,
- speed
- the gap or headway between two vehicles in a traffic stream

Flow

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

It can be determined by:

$$q = \frac{n \times 3600}{T} \text{ veh/h} \qquad (6.1)$$

Where

n = the number of vehicles passing a point in the roadway in T sec

q = the equivalent hourly flow

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Density:

- *Density (k)*
- *sometimes referred to as **concentration***,
- the number of vehicles traveling over a unit length of highway at an instant in time.
- The unit length is usually 1 kilometer (km)
- the unit of density is vehicles per km (veh/km).

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Speed:

Speed (u) is the distance traveled by a vehicle during a unit of time.
It can be expressed in miles per hour (mi/h) , kilometers per hour (km/h), or
feet per second (ft/sec).

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Time mean speed $(\overline{u}_t)$ ***:***

is the arithmetic mean of the speeds of vehicles passing a point on a highway during an interval of time.

The time mean speed is found by:

$$\overline{u}_t = \frac{1}{n} \sum_{i=1}^{n} u_i \qquad (6.2)$$

where

n = number of vehicles passing a point on the highway

U_i *= speed of the* i^{th} *vehicle (m/sec)*

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Space mean speed $(\bar{u}_s)$:

- is the harmonic mean of the speeds of vehicles passing a point on a highway during an interval of time.
- the total distance traveled by two or more vehicles on a section of highway divided by the total time required by these vehicles to travel that distance.
- This is the speed that is involved in flow-density relationships.

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- The space mean speed is found by:

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

- Where:
- U_s = space mean speed (m/sec)
- n = number of vehicles
- t_i = the time it takes the i^{th} vehicle to travel across a section of highway (sec)
- U_i = speed of the i^{th} vehicle (m/sec)
- L = length of section of highway (m)

The time mean speed is always higher than the space mean speed.

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Time Headway

- *Time headway* (*h*) is 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.
- Time headway is usually expressed in seconds.
- For example, in the time space diagram (Figure 6.1), the time headway between vehicles 3 and 4 at *d*1 is *h* 3 – 4.

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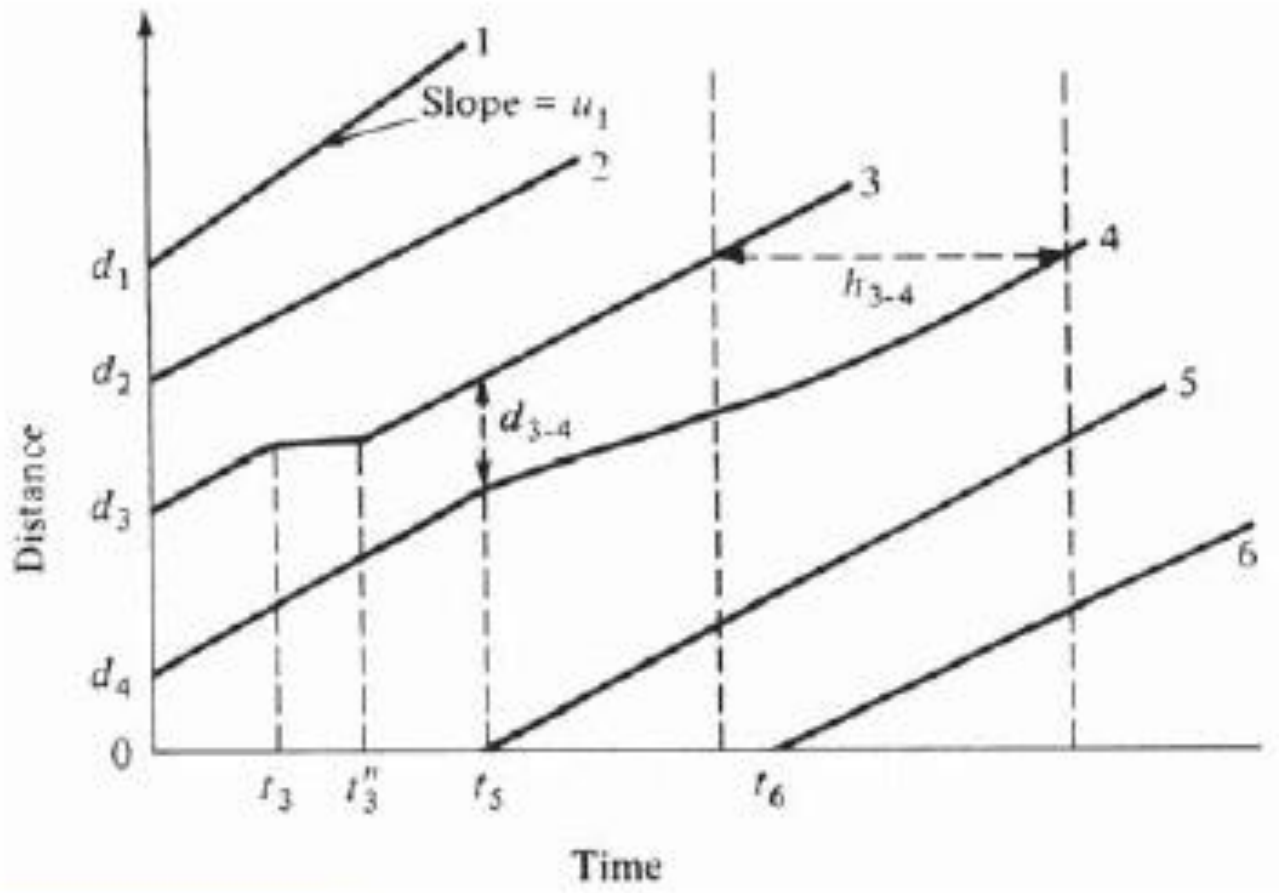


Figure 6.1 Time-Space Diagram

Space Headways

- *Space headway* (*d*) is the distance between the front of a vehicle and the front of the following vehicle and is usually expressed in meter (feet).
- The space headway between vehicles 3 and 4 at time *t* 5 is *d* 3 – 4 (see Figure 6.1).

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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.

Example 6.1 ….

- 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 km/h, respectively. Calculate the flow, density, time mean speed, and space mean speed.

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Example 6.1 ….

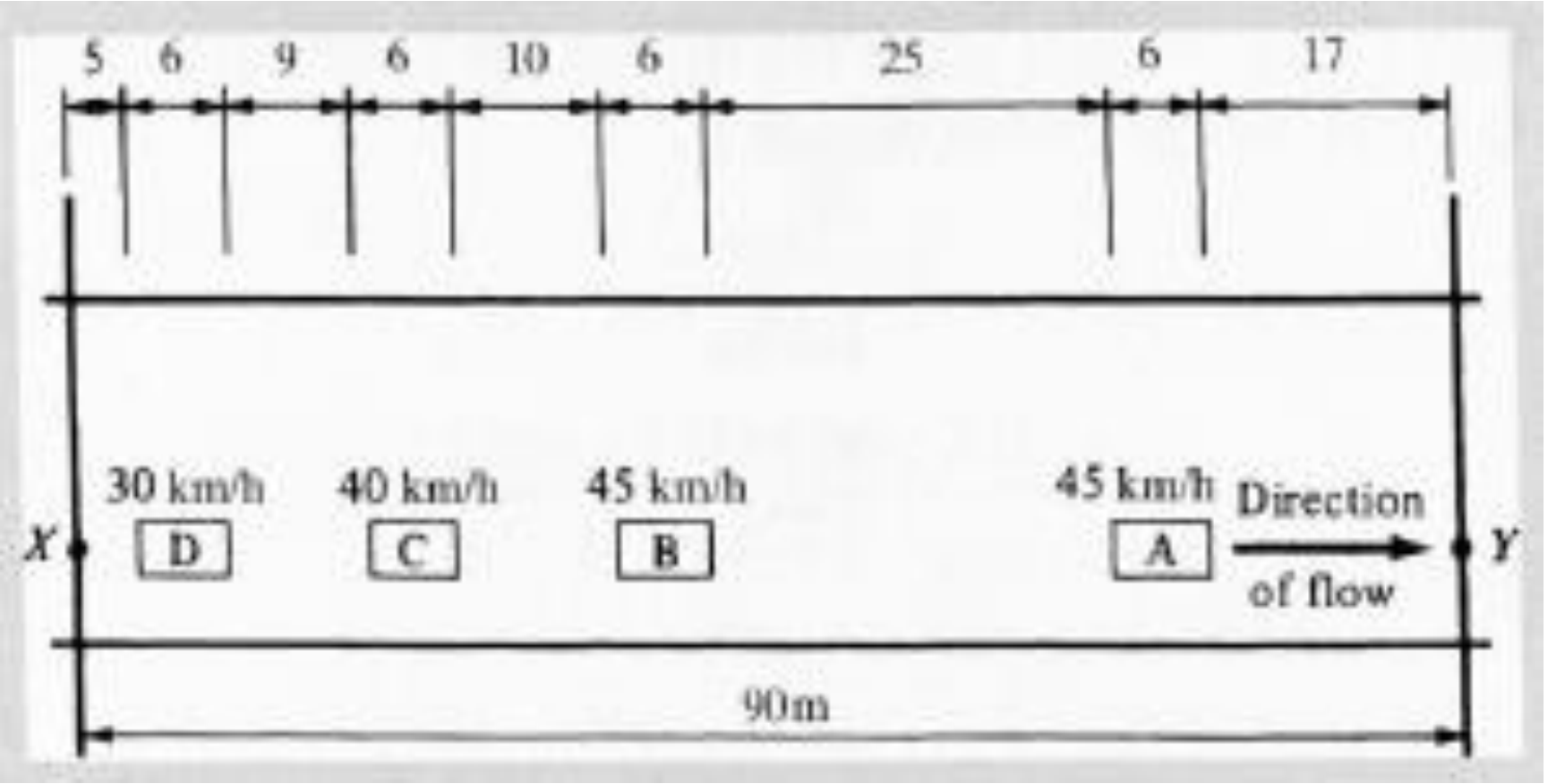


Figure 6.3 Locations and Speeds of Four Vehicles on a Two-Lane Highway at an Instant of Time

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- **Solution:** The flow is calculated by

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 (m), density is obtained by

$$k = \frac{n}{L} = \frac{4}{90} \times 1000 = 44.4 \text{ veh/km}$$

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The time mean speed is found by

$$u_t = \frac{1}{n}\sum_{i=1}^{n} u_i$$

$$= \frac{30 + 40 + 45 + 45}{4} = 40 \text{ km/h}$$

The space mean speed is found by

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

$$= \frac{Ln}{\sum_{i=1}^{n} t_i}$$

$$= \frac{90n}{\sum_{i=1}^{n} t_i}$$

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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.

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

$$t_A = \frac{90}{0.278 \times 45} = 7.2 \text{ sec}$$

$$t_B = \frac{90}{0.278 \times 45} = 7.2 \text{ sec}$$

$$t_C = \frac{90}{0.278 \times 40} = 8.1 \text{ sec}$$

$$t_D = \frac{90}{0.278 \times 30} = 10.8 \text{ sec}$$

$$\bar{u}_s = \frac{4 \times 90}{7.2 + 7.2 + 8.1 + 10.8} = 10.8 \text{ m/sec}$$

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

6.2 FLOW-DENSITY RELATIONSHIPS

The general equation relating flow, density, and space mean speed is given as:

Flow = density × space mean speed

$$q = k\bar{u}_s$$

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Space mean speed = (flow) × (space headway)

$$\bar{u}_s = q\bar{d}$$

Where:

d = (1/k) = average space headway

Density = (flow) × (travel time for unit distance)

$$k = q\bar{t}$$

Where:

t is the average time for unit distance.

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Average space headway =

(space mean speed) × (average time headway)

$$\overline{d} = \overline{u_s}\,\overline{h}$$

Average time headway =

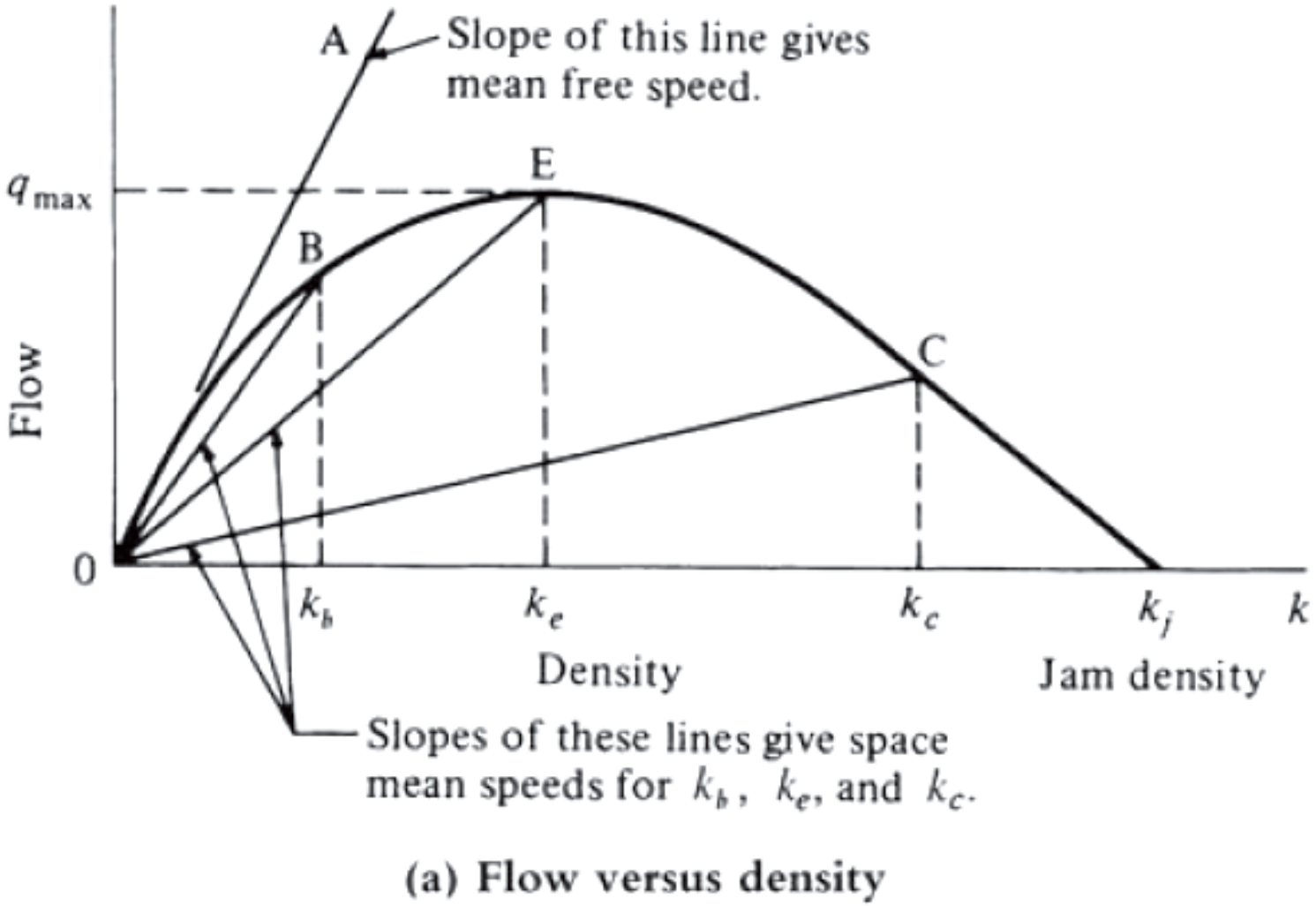
(average travel time for unit distance) ×

(average space headway)

$$\overline{h} = \overline{t}\,\overline{d}$$

6.2.1 Fundamental Diagram of Traffic Flow

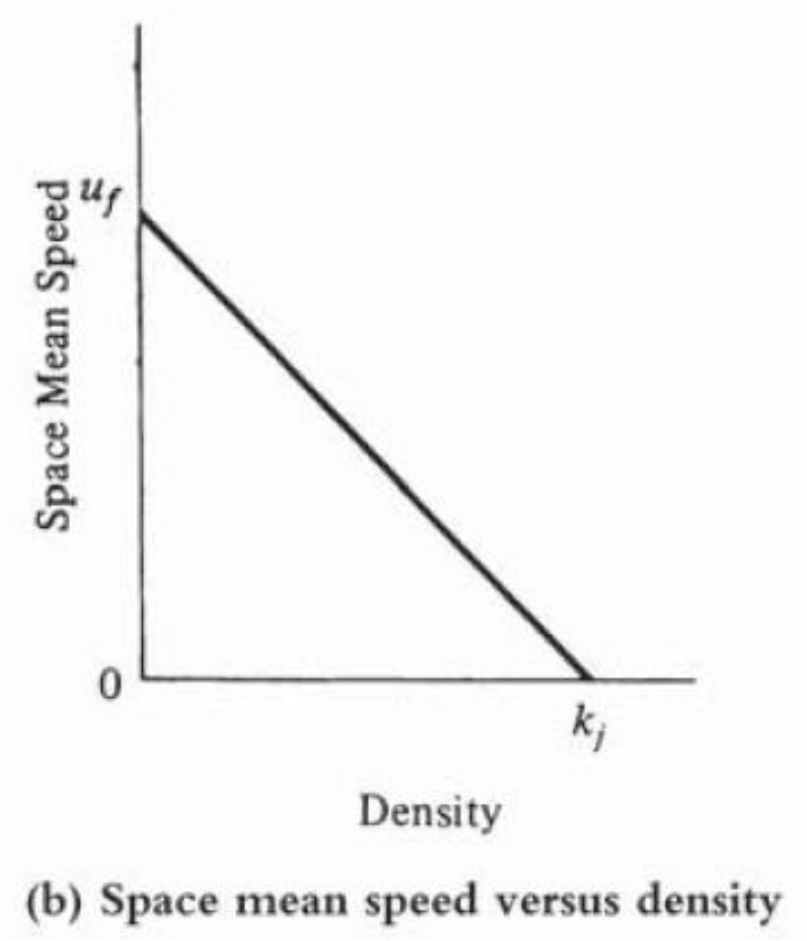
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(a) Flow versus density

Figure 6.4 Fundamental Diagrams of Traffic Flow

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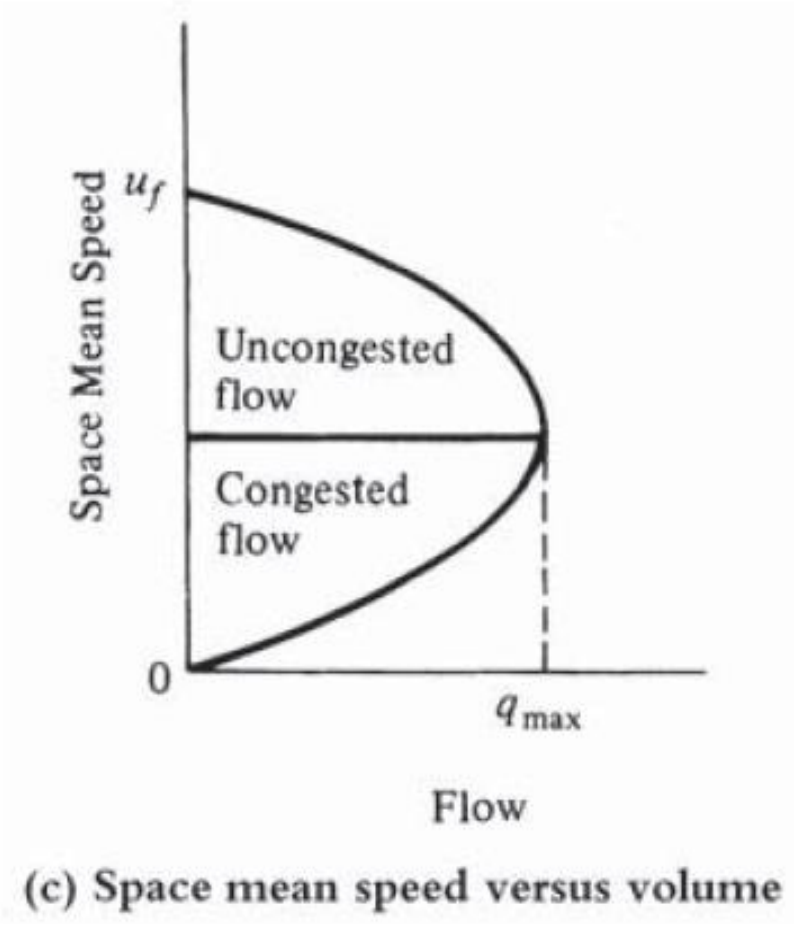


Figure 6.4 Fundamental Diagrams of Traffic Flow

6.2.2 Mathematical Relationships Describing Traffic Flow

- Mathematical relationships describing traffic flow can be classified into two general categories:

  macroscopic and microscopic

  depending on the approach used in the development of these relationships.

6.2.2 Mathematical Relationships Describing Traffic Flow

- The macroscopic approach considers flow density relationships whereas
- the microscopic approach considers spacings between vehicles and speeds of individual vehicles.