Traffic Flow Characteristics

CIVL 4162/6162

(Traffic Engineering)

Lesson Objective

- Define traffic stream parameters
- Establish the relationship between traffic stream parameters
- Calculate and compute parameters with given data

What is a Traffic Stream

- Traffic streams are made up of
  - Individual drivers
  - Vehicles
  - Roadway and environment
- Driver behavior and vehicle characteristics typically vary
- No two traffic streams will behave exactly in the same way

Variability in Traffic Stream *(1)*

- Traffic flow (movement of vehicles) involves variability
  - Unlike pipe flow (homogeneous)
- A given traffic flow will vary
  - By time
  - By space
- Constraints are defined by
  - Physical constraints
  - Complex driver characteristics

Variability in Traffic Stream *(2)*

- Although traffic characteristics vary there is a reasonable range
  - Example: In a 65 miles/hr roadway some drivers will drive 50 miles/hr and some will drive 80 miles/hr
    - There exists a range
- Before we study traffic characteristics let us see what are
  - Facilities
  - Basic flow parameters

Types of Facilities

- Uninterrupted Flow Facilities
  - No external interruptions
  - Primarily on freeways
  - Also on certain segments of long rural highways
  - In peak hours also freeways are uninterrupted
- Interrupted Flow Facilities
  - External interruptions exists
  - Most frequent are signals, stop/yield signs
  - Creates platoons of vehicles progress in traffic stream

Types of Facilities and Major Difference

- The major difference between two facilities
  - Impact of time (no interventions at any time)
  - Availability of roadways
    - On uninterrupted facilities roadways are available to users all the time
    - But sections of roadway are not available to users because of traffic control (signal, stop, and yield signs)

Traffic Stream Parameters

Macroscopic

- Volume
- Speed
- Density

Microscopic

- Speed of individual vehicles
- Headway
- Spacing

*These characteristics are primarily for uninterrupted flow

Volume

- Traffic volume is defined as the number of vehicles passing a point on highway or a given lane or direction of a highway in a specific time
- Unit: vehicles per unit time
- Usually expressed as vehicles / hour
- Denoted as veh/hr

Rate of Flow

- Rate of flow are generally expressed in units of “veh/hr” but represents flows that exists for period of time less than an hour.
- Example: 200 vehicles are observed for 15min.
- The equivalent hourly volume will be 800 veh/hr
- Even though 800 veh/hr would not be observed if one hour was counted

Daily Volumes (1)

- Average Annual Daily Traffic (AADT) -
  - The average 24 hour volume at a given location over a full 365 day year.
  - avg. 24-hour volume at a site over a full year
- Average Annual Weekday Traffic (AAWT) -
  - The average 24 hour volume at a given location occurring on weekdays over a full 365 day year.
  - Usually 260 days week days per year

Daily Volumes (2)

- Average Daily Traffic (ADT) -
  - The average 24 hour volume at a given location over a defined time period less than a year
- Average Weekday Traffic (AWT)
  - The average 24 hour weekday volume at a given location over a defined period less than one year

Example: Daily Volume

Table 5.1: Illustration of Daily Volume Parameters

1. Month	2. No. of Weekdays in Month (days)	3. Total Days in Month (days)	4. Total Monthly Volume (vehs)	5. Total Weekday Volume (vehs)	6. AWT 5/2 (veh/day)	7. ADT 4/3 (veh/day)
Jan	22	31	425,000	208,000	9,455	13,710
Feb	20	28	410,000	220,000	11,000	14,643
Mar	22	31	385,000	185,000	8,409	12,419
Apr	22	30	400,000	200,000	9,091	13,333
May	21	31	450,000	215,000	10,238	14,516
Jun	22	30	500,000	230,000	10,455	16,667
Jul	23	31	580,000	260,000	11,304	18,710
Aug	21	31	570,000	260,000	12,381	18,387
Sep	22	30	490,000	205,000	9,318	16,333
Oct	22	31	420,000	190,000	8,636	13,548
Nov	21	30	415,000	200,000	9,524	13,833
Dec	22	31	400,000	210,000	9,545	12,903
Total	**260**	**365**	**5,445,000**	**2,583,000**	—	—

AADT = 5,445,000/365 = 14,918 veh/day

AAWT = 2,583,000/260 = 9,935 veh/day

Hourly Volume

- Measured in volume/hour
- Used for design and operational purposes
- The hour with highest volume is referred as
  - Peak hour
- Peak hour volume is stated as directional volume
- Sometimes referred as Directional Design Hourly Volume (DDHV)

DDHV

- DDHV = directional design hourly volume

$$DDHV = AADT * K * D$$

where K = proportion of AADT that occurs during design hour

D = proportion of peak hour traffic traveling in the peak direction

K-Factor

- Typically, K factor represents proportion of AADT occurring during 30th peak hour of the year
- How does K-factor vary by urban density?
  - Urban, suburban, and rural
- D Factors
  - More variable than K
  - Influenced by development density, radial vs. circumferential route

K and D Factor

Table 5.2: General Ranges for *K* and *D* Factors

Facility Type	Normal Range of Values	
	K-Factor	*D*-Factor
Rural	0.15–0.25	0.65–0.80
Suburban	0.12–0.15	0.55–0.65
Urban:		
Radial Route	0.07–0.12	0.55–0.60
Circumferential Route	0.07–0.12	0.50–0.55

Flow Rate vs. Volume

Table 5.3: Illustration of Volumes and Rates of Flow

Time Interval	Volume for Time Interval (vehs)	Rate of Flow for Time Interval (vehs/h)
5:00–5:15 PM	1,000	1,000/0.25 = 4,000
5:15–5:30 PM	1,100	1,100/0.25 = 4,400
5:30–5:45 PM	1,200	1,200/0.25 = 4,800
5:45–6:00 PM	900	900/0.25 = 3,600
5:00–6:00 PM	Σ = 4,200	

Volume vs. Flow Rate

If capacity is 4,200 vph:

Table 5.4: Queuing Analysis for the Data of Table 5.3

Time Interval	Arriving Vehicles (vehs)	Departing Vehicles (vehs)	Queue Size at End of Period (vehs)
5:00–5:15 PM	1,000	1,050	0
5:15–5:30 PM	1,100	1,050	0 + 1,100 − 1,050 = 50
5:30–5:45 PM	1,200	1,050	50 + 1,200 − 1,050 = 200
5:45–6:00 PM	900	1,050	200 + 900 − 1,050 = 50

Peak Hour Factor

- 15 minutes is considered to be minimum period of time over which traffic can be considered statistically stable
- Peak hour factor (PHF) represents the uniformity of flow in the peak hour.

$$PHF = \frac{V}{4 * V_{m15}}$$

$where:$

$V = hourly\ volume, vehs$

$V_{m15} = \max 15 \min\ volume\ within\ the\ hour, vehs$

Peak Hour Factor *(2)*

- PHF = 4200/(4*1200) = 0.875

Table 5.3: Illustration of Volumes and Rates of Flow

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5:45–6:00 PM	900	900/0.25 = 3,600
5:00–6:00 PM	Σ = 4,200	

Peak Hour Factor *(3)*

- Peak hour factor lie between 0.25-1
  - 0.25 when all traffic is concentrated in one 15 minute period
  - 1.0 when traffic on all 15 minute period are same
- Under very congested conditions PHF~1
- Practical studies show that
  - PHF~0.7 for rural roadways
  - PHF~0.98 in dense urban roadways

Speed

- Speed and travel time are inversely related
  - S = d/t
  - Where S->speed in mi/hr; d->distance traversed in mi; t-> time to traverse distance d in hr
- Average speed in a traffic stream can be computed in two ways:
- Time mean speed (TMS) – average speed of all vehicles passing a point over a specified time period.
- Space mean speed (SMS) – average speed of all vehicles occupying a given section of roadway over a specific time period.

TMS and SMS

- Time Mean Speed (TMS)

$$TMS = \frac{\sum_i (\frac{d}{t_i})}{n}$$

- Space Mean Speed (SMS)

$$SMS = \frac{d}{\sum_i (\frac{t_i}{n})}$$

- Where
  - d-> distance traversed, ft
  - n-> number of observed vehicles
  - t_i->time for vehicle "i" to traverse the distance d

Example: TMS and SMS

Table 5.5: Illustrative Computation of TMS and SMS

Vehicle No.	Distance d (ft)	Travel Time t (s)	Speed (ft/s)
1	1,000	18.0	1,000/18 = 55.6
2	1,000	20.0	1,000/20 = 50.0
3	1,000	22.0	1,000/22 = 45.5
4	1,000	19.0	1,000/19 = 52.6
5	1,000	20.0	1,000/20 = 50.0
6	1,000	20.0	1,000/20 = 50.0
Total	**6,000**	**119**	**303.7**
Average	**6,000/6 = 1,000**	**119/6 = 19.8**	**303.7/6 = 50.6**

TMS = 50.6 ft/s

SMS = 1,000/19.8 = 50.4 ft/s

Example: Time Mean vs Space Mean Speed

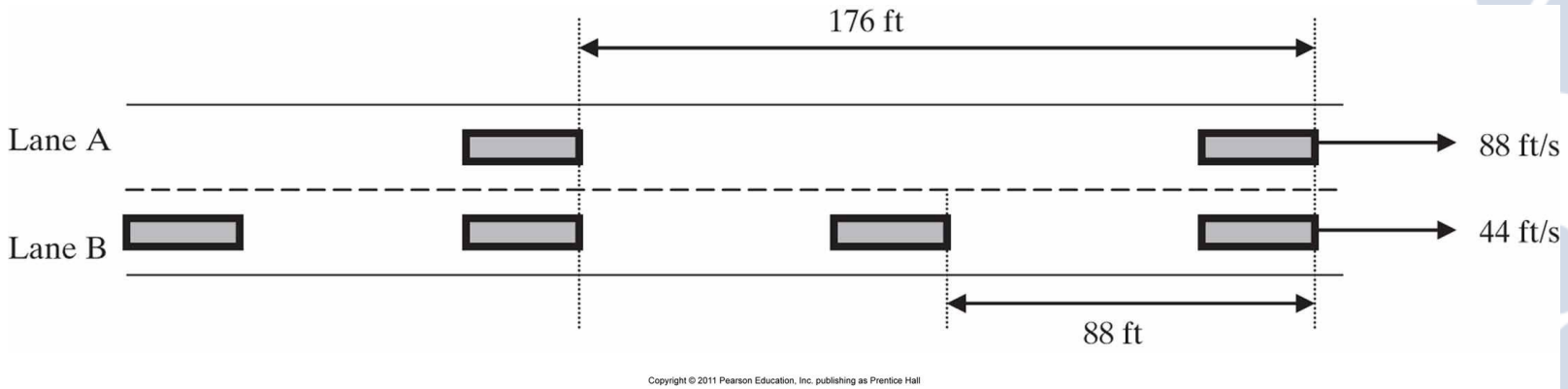
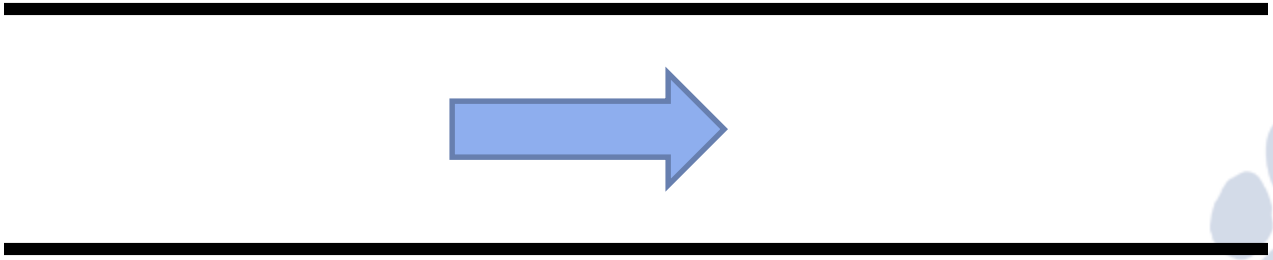


Figure 5.1 Time Mean Speed and Space Mean Speed Illustrated

TMS = (88n+44n)/(2n) = 66 ft/sec
SMS = (88n+44*2n)/(3n) = 58.7ft/sec

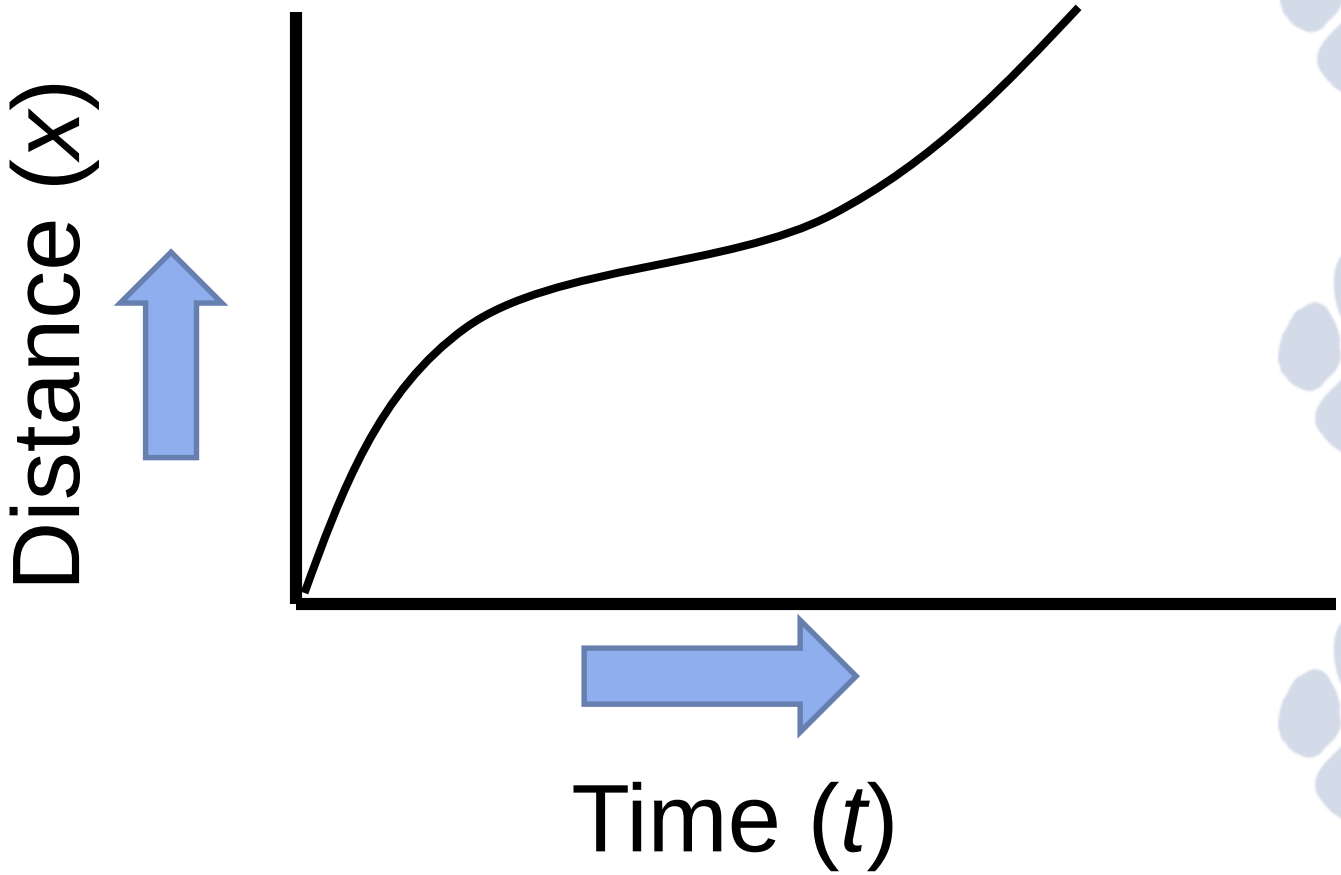
Traffic Flow Basics (1)

Consider a long, uninterrupted, single-lane roadway:

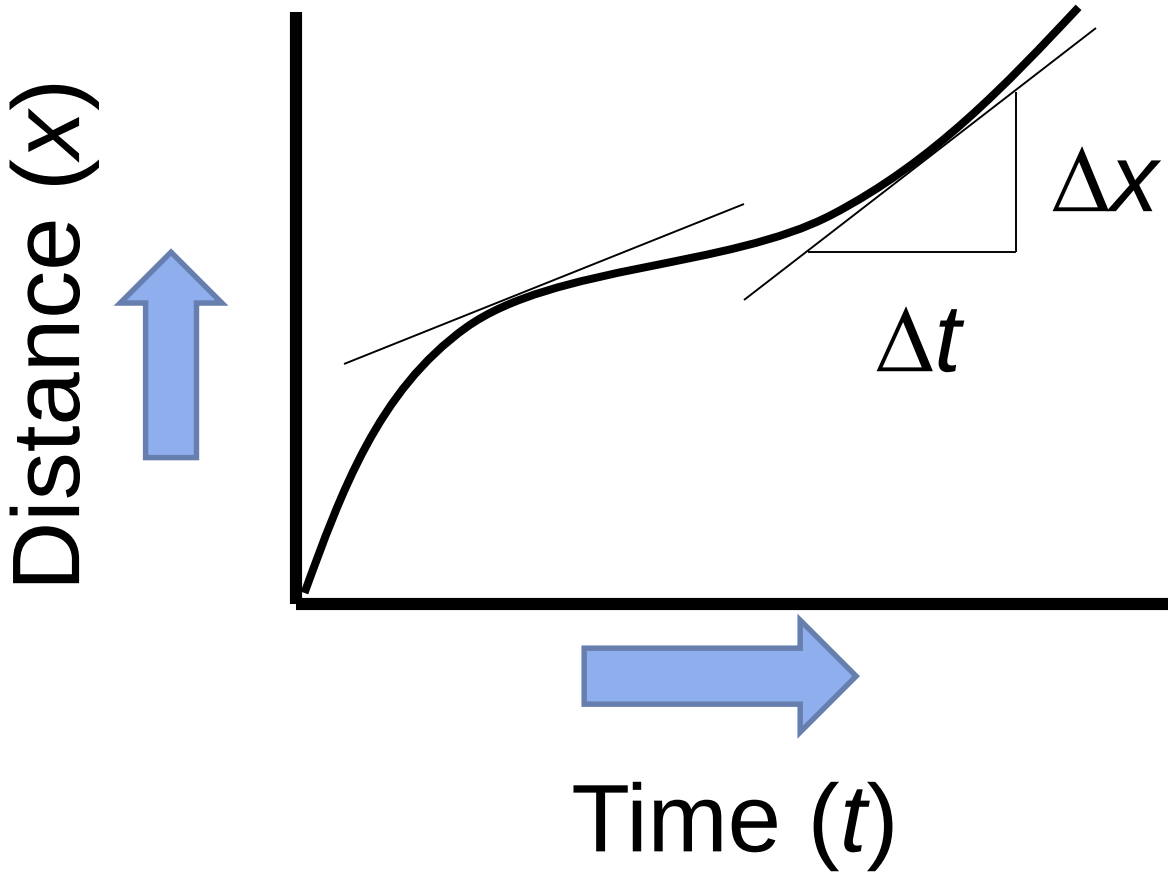


No passing, no opposing traffic, no intersections

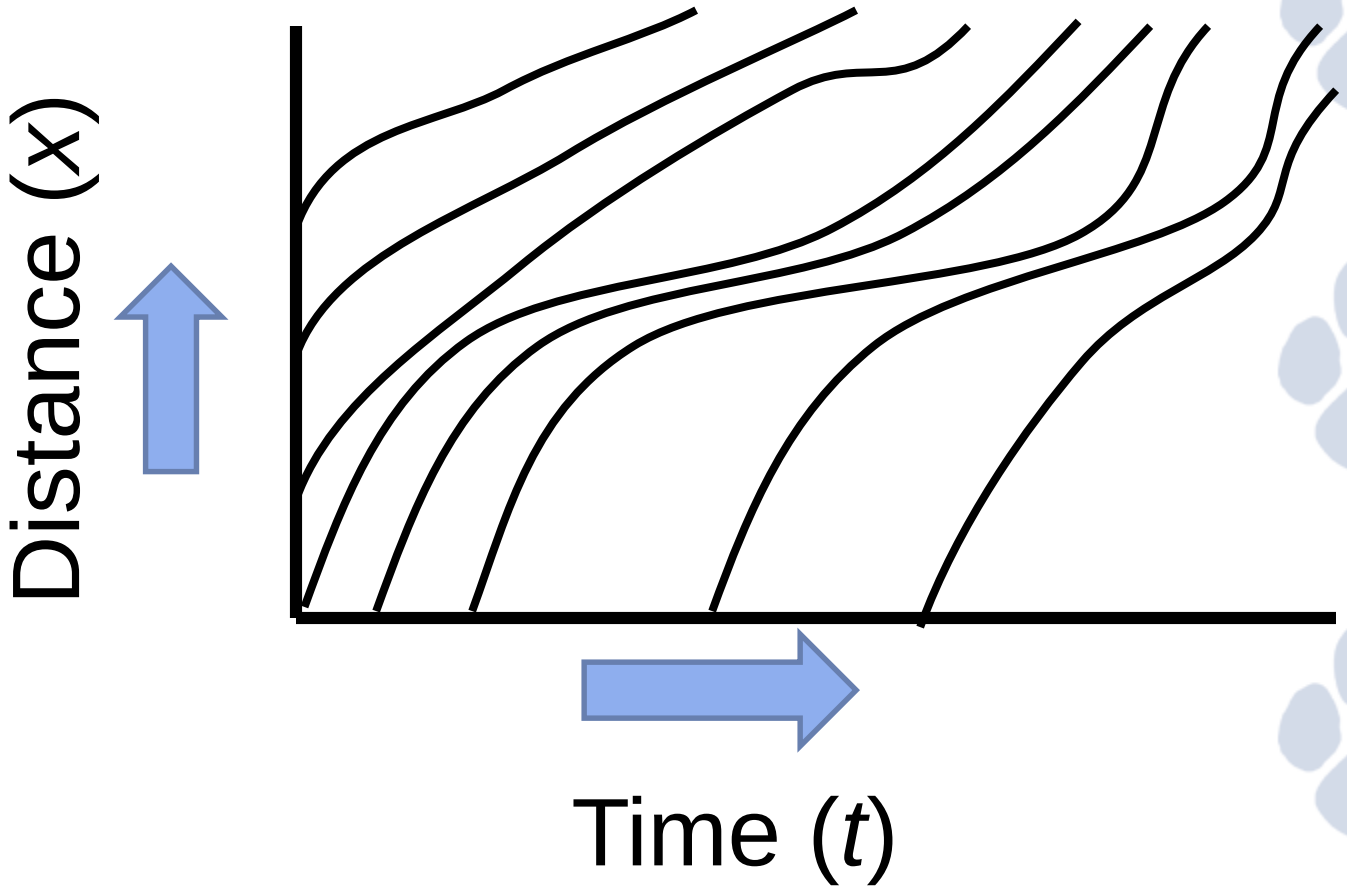
Traffic Flow Basics (2)



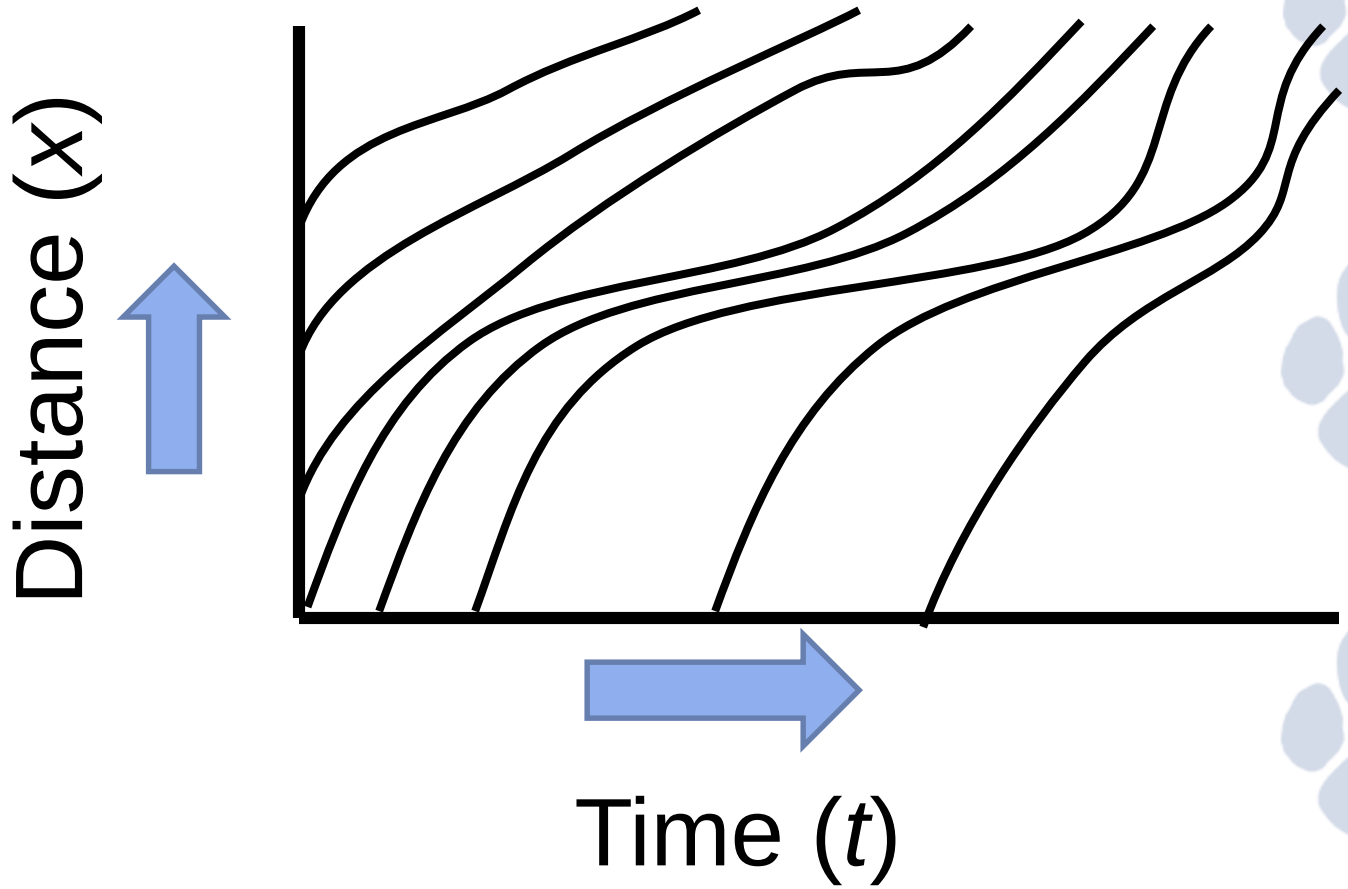
Traffic Flow Basics-Speed



Traffic Flow Basics-Trajectories

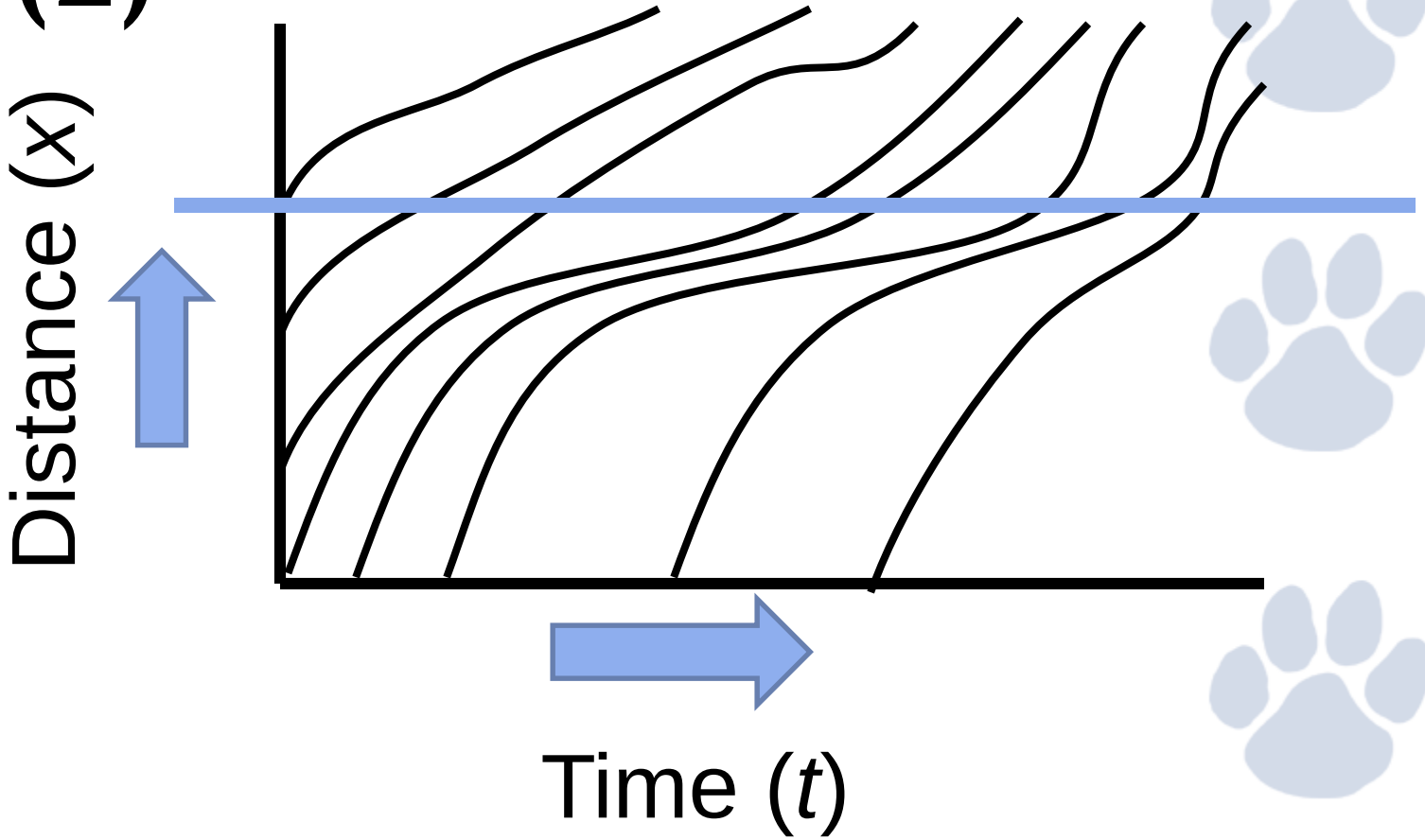


Traffic Flow Basics-Trajectory Plots



This is called a **time-space** diagram

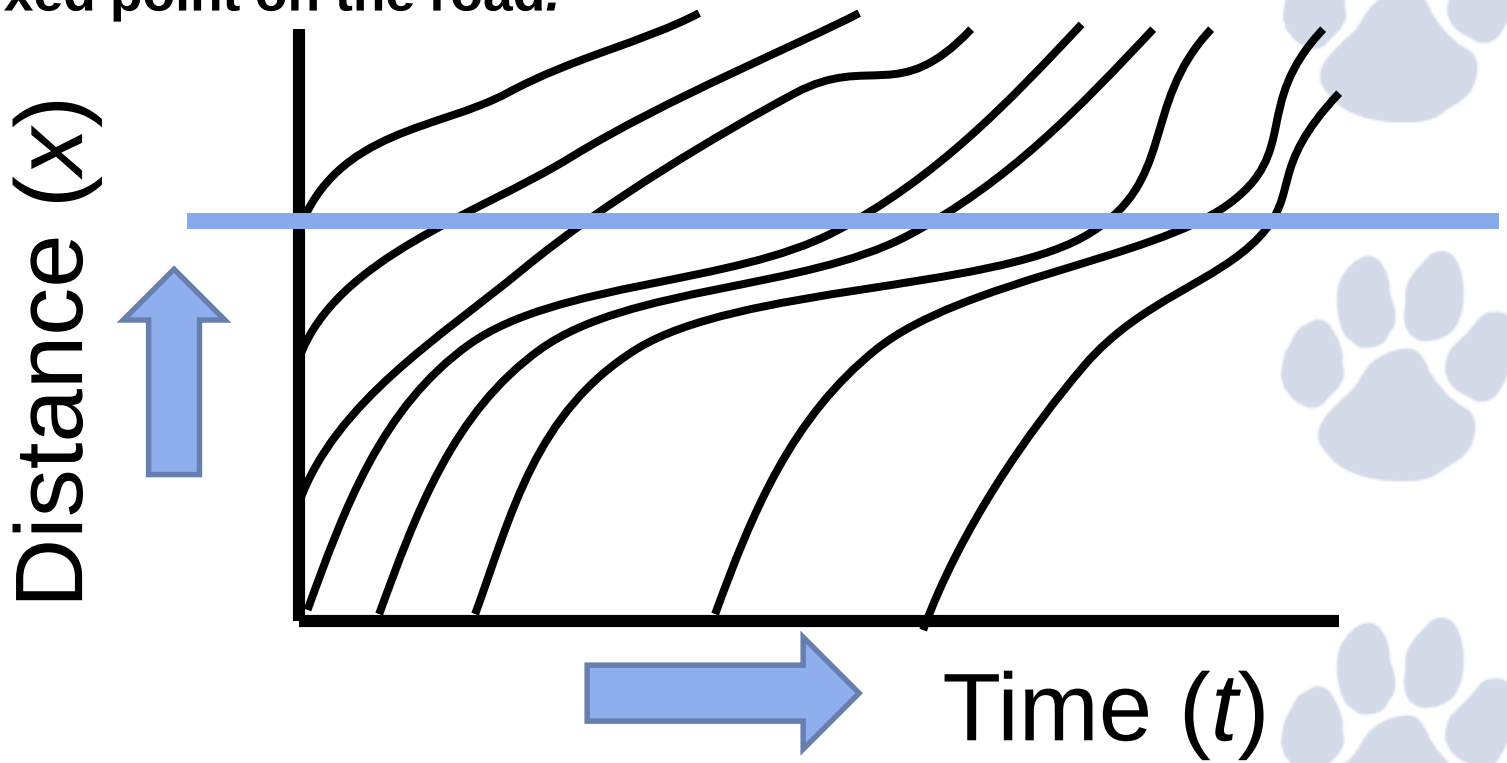
Traffic Flow Basics-Trajectory Plots (2)



Consider a horizontal “slice” of the diagram

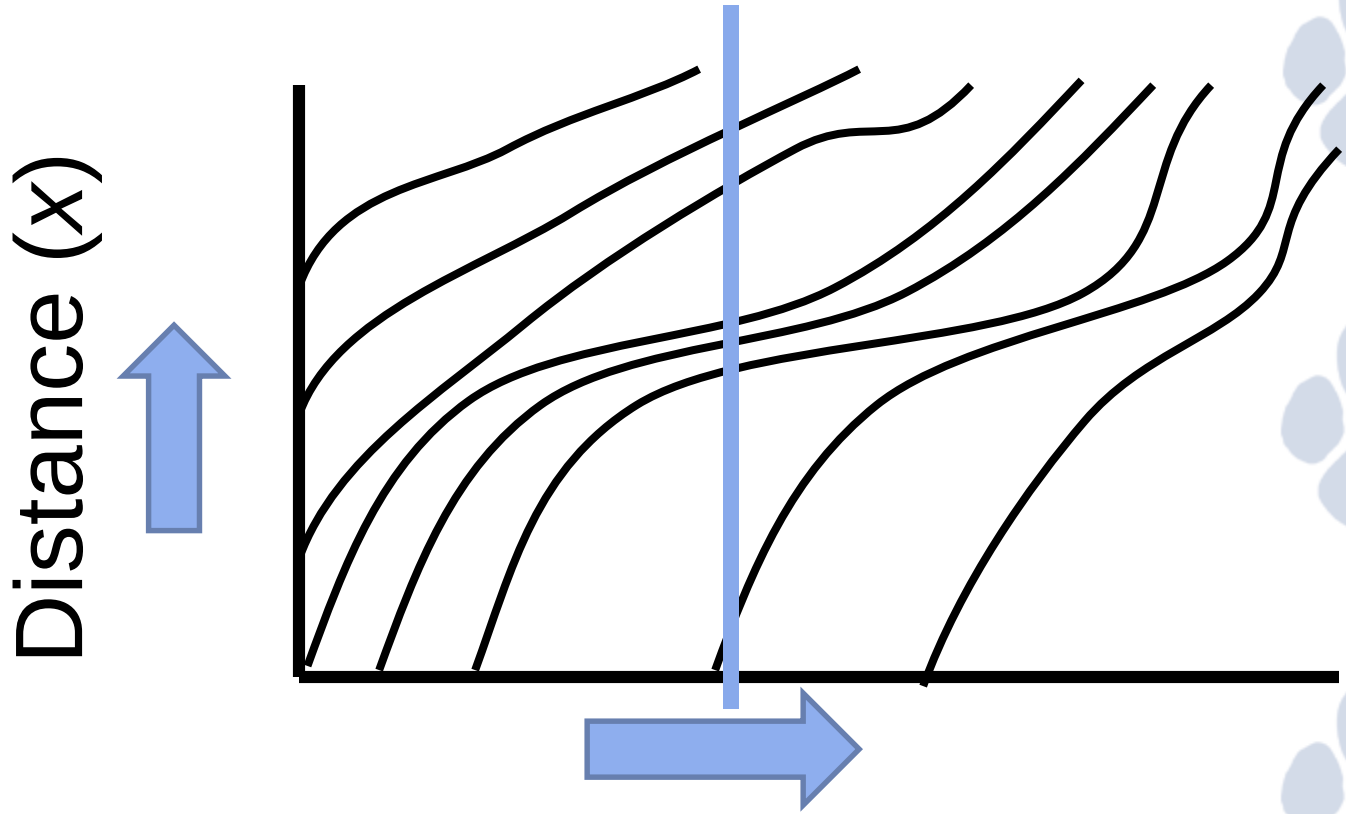
Traffic Flow Basics-Volume

The number of trajectories crossing this line is **the number of vehicles passing a fixed point on the road.**



This is called the **volume** or **flow**, and has units of vehicles per time (usually veh/hr)

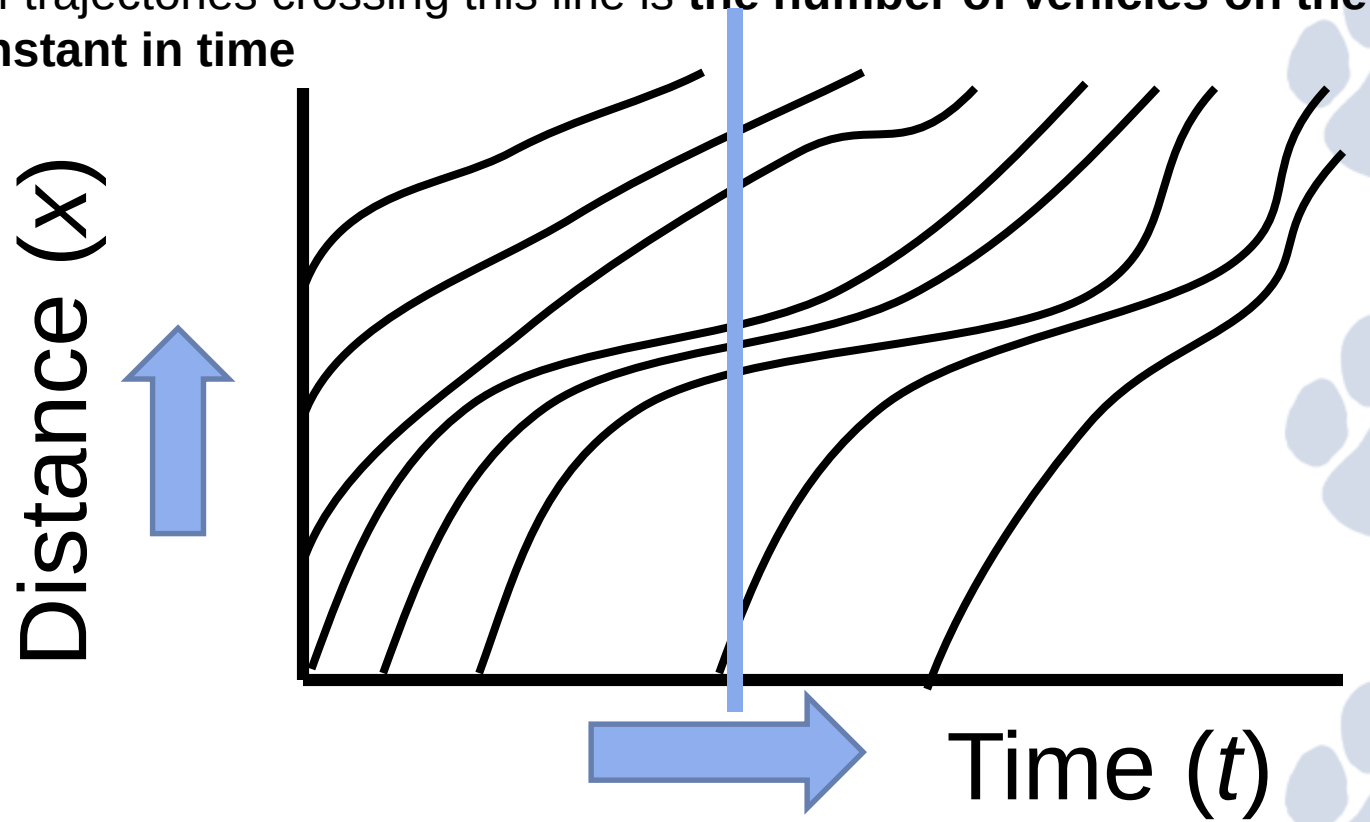
Traffic Flow Basics-Density



What does a vertical slice tell us?

Traffic Flow Basics-Density

The number of trajectories crossing this line is **the number of vehicles on the road at one instant in time**



This is called the **density**, and has units of vehicles per distance (usually veh/mi)

Density

- Most direct measure of traffic demand
- Difficult to measure directly
- Important measure of quality of traffic flow
- Occupancy is related, and can be measured directly
- Occupancy – proportion of time that a detector is occupied by a vehicle in a defined time period.

Density and Occupancy

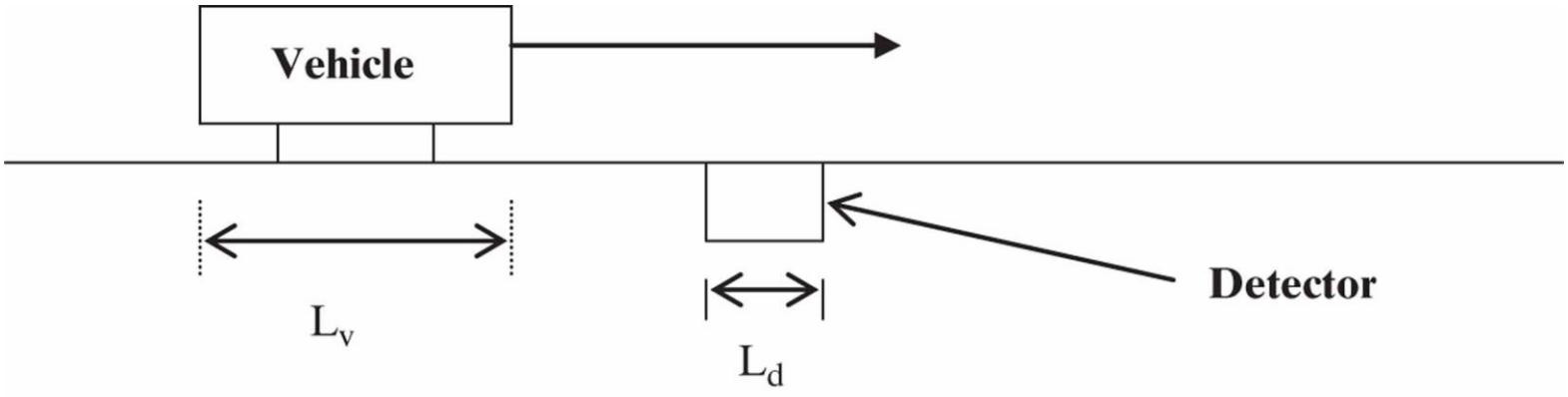


Figure 5.2 Density and Occupancy Illustrated