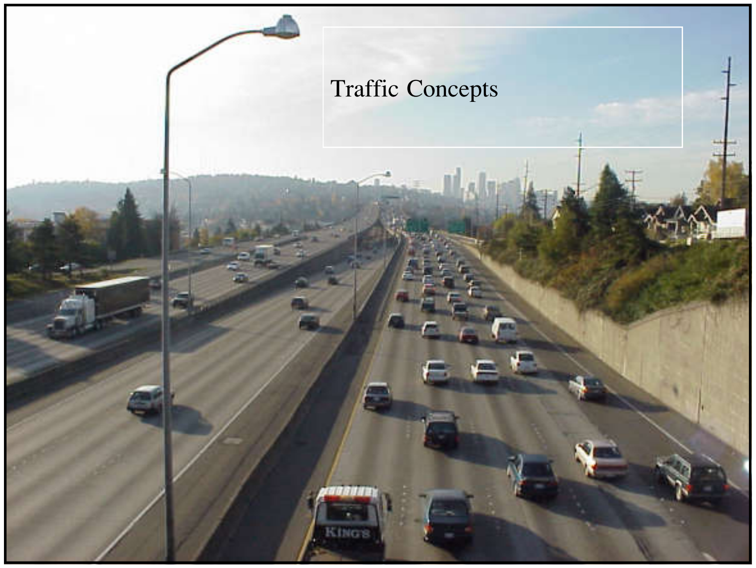
Traffic Concepts



Outline

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2. **Traffic Stream Parameters**
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   b. **Spacing**
   c. **Headway**
   d. **Speed**
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3. **Relationships**
4. **Example**

INTRODUCTION

- It is important to realize that the primary function of a highway is to provide mobility.
- This mobility must be provided with safety in mind while achieving an acceptable level of performance (such as acceptable vehicle speeds).
- The analysis of vehicle traffic provides the basis for measuring the operating performance of highways. e.g. Volume, Speed, Density

TRAFFIC STREAM PARAMETERS

- **Uninterrupted Flow**
  A traffic stream that operates free from the influence of such traffic control devices as signals and stop signs.
- **Interrupted Flow**
  Traffic streams that operate under the influence of signals and stop signs

Flow Rate (q)

- **The number of vehicles (n) passing some designated roadway point in a given time interval (t)**

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

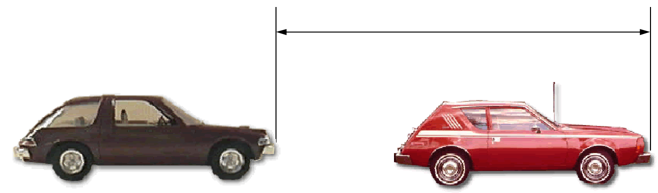
where

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.

- **Units are typically vehicles/hour**
- **Flow rate is different than volume**

Spacing

- **The distance (ft) between successive vehicles in a traffic stream, as measured from front bumper to front bumper**



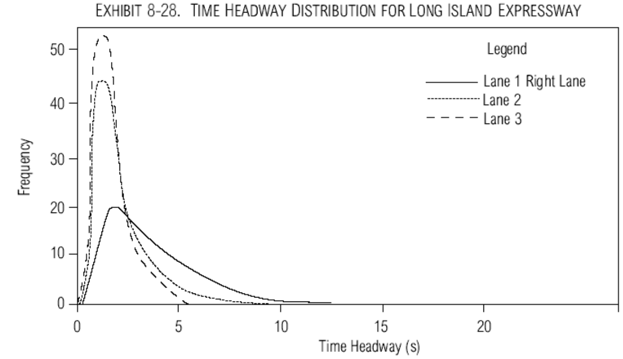
Headway (h)

- **The time (in seconds) between successive vehicles, as their front bumpers pass a given point.**

$$t = \sum_{i=1}^{n} h_i \qquad q = \frac{n}{\sum_{i=1}^{n} h_i} = \frac{1}{\bar{h}}$$

Headway

EXHIBIT 8-28. TIME HEADWAY DISTRIBUTION FOR LONG ISLAND EXPRESSWAY



Source: Berry and Gandhi (*13*).

From HCM 2000

Speed

- **Time mean speed (spot speed)**
  - **Arithmetic mean of all instantaneous vehicle speeds at a given "spot" on a roadway section**

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

$\bar{u}_t$ = time-mean speed in unit distance per unit time,

u_i = spot speed (the speed of the vehicle at the designated point on the highway, as might be obtained using a radar gun) of the ith vehicle, and

n = number of measured vehicle spot speeds.

Space mean speed (u)

- **The mean travel speed of vehicles traversing a roadway segment of a known distance (d)**

$$\bar{u}_s = \frac{l}{\bar{t}}$$

$\bar{u}_s$ = space-mean speed in unit distance per unit time,

l = length of roadway used for travel time measurement of vehicles, and

$\bar{t}$ = average vehicle travel time, defined as

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

t_i = time necessary for vehicle i to travel a roadway section of length l, and

n = number of measured vehicle travel times.

Space Mean Speed

- **More useful for traffic applications**

$$\bar{u}_s = \frac{l}{\frac{1}{n}\sum_{i=1}^{n} t_i}$$

$$\bar{u}_s = \frac{1}{\frac{1}{n}\sum_{i=1}^{n}\left[\frac{1}{(l/t_i)}\right]}$$

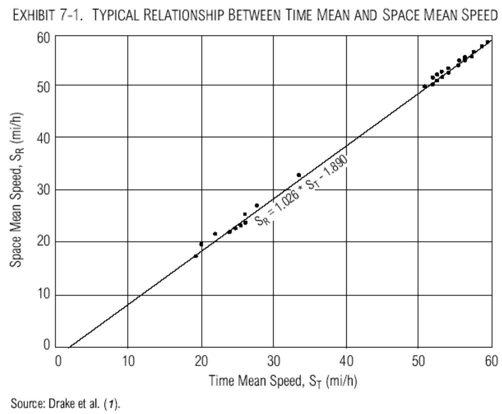
- **Space mean speed is always less than time mean speed**

Example 1

- **You are in a vehicle traveling a total of 10 miles. For the first 5 miles you travel at exactly 40 mph and for the next 5 miles you travel at exactly 60 mph. What is your average speed over the time you spent traveling that 10 miles?**
- **Intuitively, you were going at 40 mph for longer than you were going at 60 mph so your average velocity for the entire trip is going to be less than the arithmetic mean of 50 mph???**

- **It's 48 mph by harmonic mean**
- **distance = speed * time**
- **5 miles at 40 mph = 7.5 minutes**
- **5 miles at 60 mph = 5 minutes**
- **weighted average = (40(7.5) + 60(5))/(7.5 + 5) = 48 mph**

Time Mean vs. Space Mean Speed



From HCM 2000

Example 2

- The speeds of five vehicles were measured (with radar) at the midpoint of a 0.5-mile section of roadway. The speeds for vehicles 1, 2, 3, 4, and 5 were 44, 42, 51, 49, and 46 mi/h, respectively. Assuming all vehicles were traveling at constant speed over this roadway section, calculate the time-mean and space-mean speeds.

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

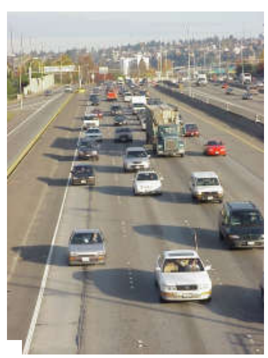
$$\bar{u}_s = \frac{1}{\frac{1}{n}\sum_{i=1}^{n}\left[\frac{1}{(l/t_i)}\right]}$$

Density (k)

- **The number of vehicles (n) occupying a given length (l) of a lane or roadway at a particular instant**
- **Unit of density is vehicles per mile (vpm).**

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

$$l = \sum_{i=1}^{n} s_i \qquad k = \frac{n}{\sum_{i=1}^{n} s_i} \qquad k = \frac{1}{\bar{s}}$$



Other Concepts

- **Free-flow speed (u_f)**
- **Jam density (k_j)**
- **Capacity (q_m)**

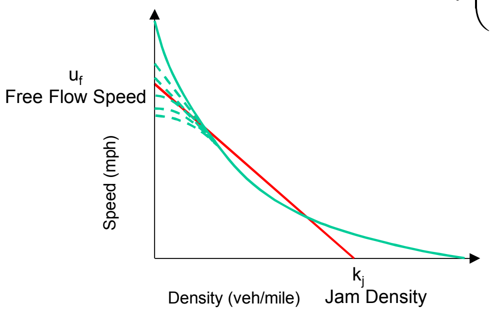
$$Density\ (veh/mi) = \frac{5{,}280}{spacing\ (ft/veh)}$$

$$Headway\ (s/veh) = \frac{spacing\ (ft/veh)}{speed\ (ft/s)}$$

$$Flow\ rate\ (veh/hr) = \frac{3{,}600}{headway\ (s/veh)}$$

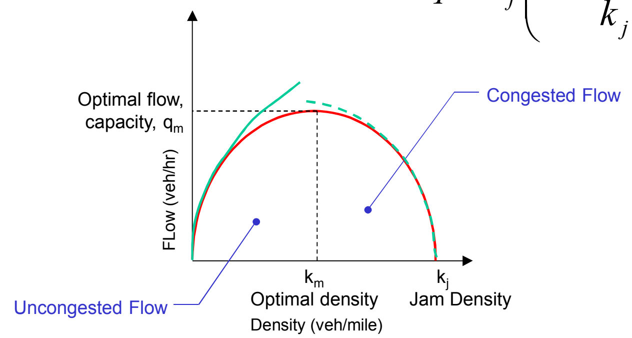
Speed vs. Density

$$u = u_f\left(1 - \frac{k}{k_j}\right)$$



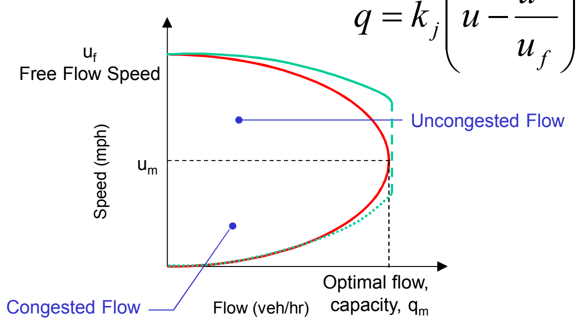
Flow vs. Density

$$q = u_f\left(k - \frac{k^2}{k_j}\right)$$



Speed vs. Flow

$$q = k_j\left(u - \frac{u^2}{u_f}\right)$$



3-D Model

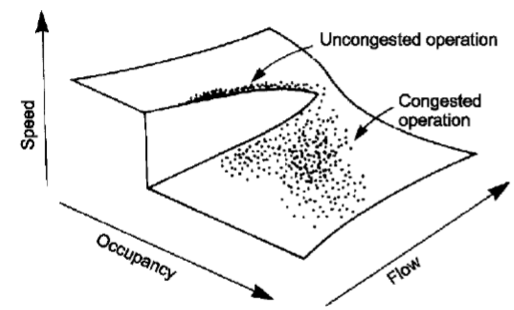


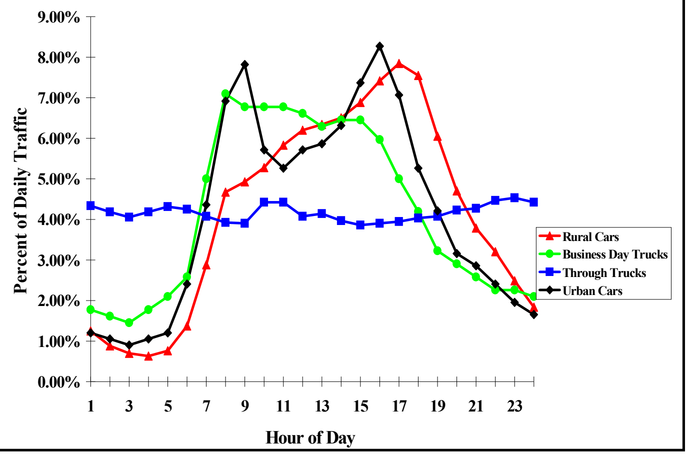
Figure 2.20
Conceptualization of Traffic Operations on a Catastrophe Theory Surface Using the Maxwell Convention (Persaud and Hall 1989).

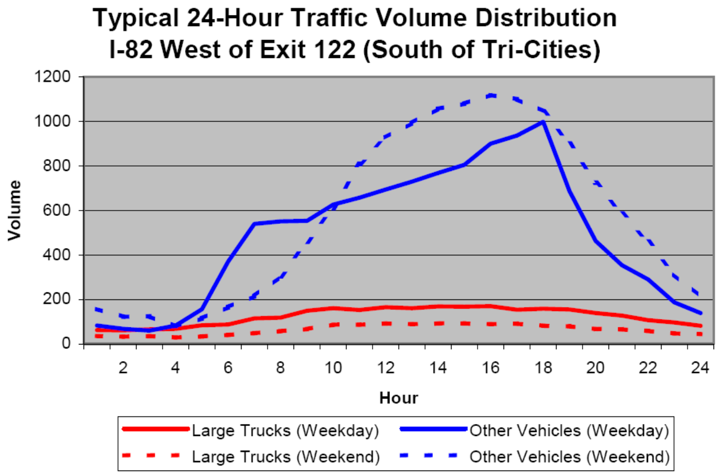
Example 3

I-5 over the ship canal bridge has 4 lanes in each direction. The northbound capacity is 8200 veh/hr/lane and the free-flow speed is 65 mph. What is the maximum flow rate, maximum density, jam density? If a one-hour vehicle count in the northbound direction for the outside lane gives 7034 vehicles in a non-congested condition, what is the estimated space mean speed of these 7034 vehicles?

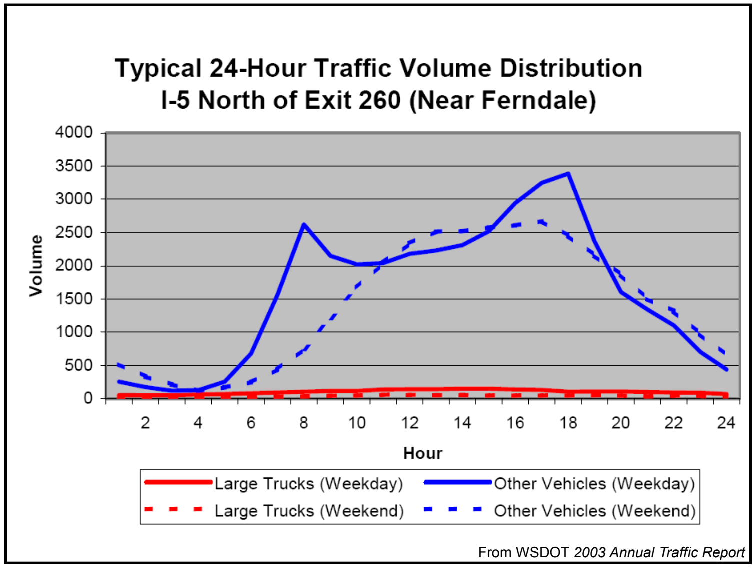
- **Solution:**
- **Maximum flow rate, q_m = 8200 veh/hr as given**
- **At maximum flow: $dq/dk = u_f(1-2k_m/k_j) = 0$**
- **Since u_f is not zero, $1-2k_m/k_j = 0$**
- **Therefore $k_m = k_j/2$**
- **Similarly, $u_m = u_f/2$**
- **Therefore, $u_m = 65/2 = 32.5$ mph.**
- **Therefore, maximum density, $k_m = q_m/u_m = 8200/32.5 = 252.31$ vehicles/mile**
- **$k_j = 2*k_m = 2*(252.31) = 504.62$ veh/mile/lane**
- **Using the speed-flow relationship:**
- **$q = k_j(u - u^2/u_f)$**
- **Solve for $q = 7034 = 504.62(u - u^2/65)$**
- **$13.94 = u - u^2/65$**
- **$906.06 = 65u - u^2$**
- **$u^2 - 65u + 906.06 = 0$**
- **u = 44.7 or 20.2 mph**
- **Choose 44.7 since this is the higher of the two and the observed flow is less than q_m so we know we are not in the congested area of the curve**

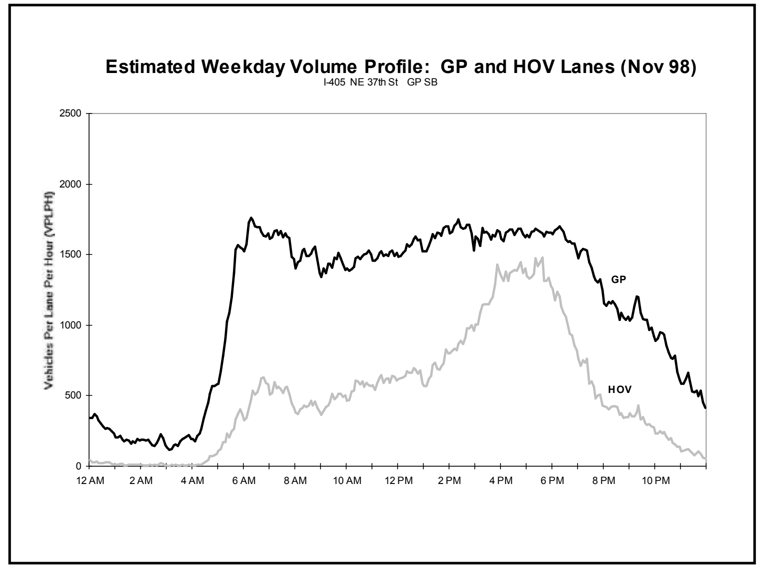
Traffic – Time of Day Patterns

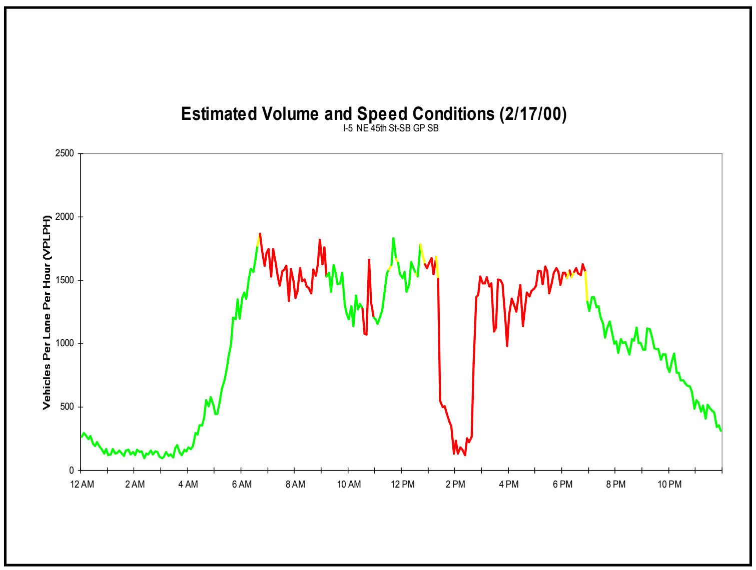


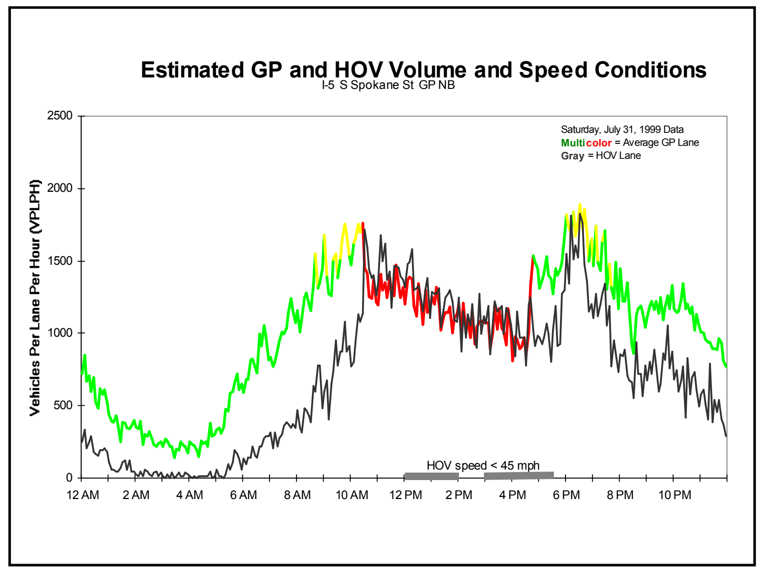


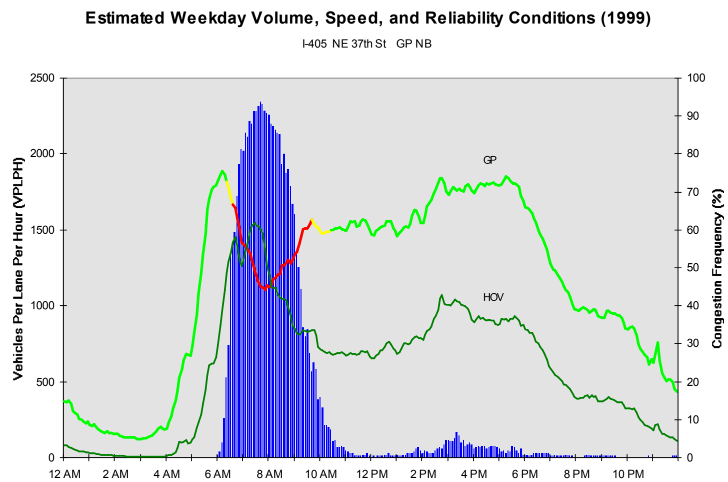
From WSDOT *2003 Annual Traffic Report*

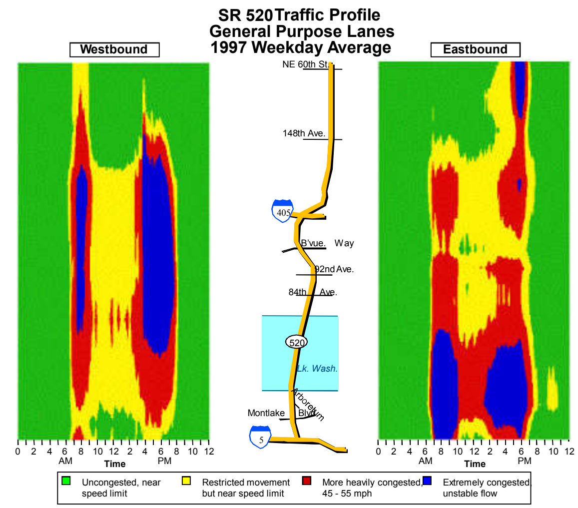

Typical 24-Hour Traffic Volume Distribution
I-5 North of Exit 260 (Near Ferndale)
Volume
Hour
Large Trucks (Weekday)
Other Vehicles (Weekday)
Large Trucks (Weekend)
Other Vehicles (Weekend)
From WSDOT 2003 Annual Traffic Report


Estimated Weekday Volume Profile: GP and HOV Lanes (Nov 98)
I-405 NE 37th St GP SB
Vehicles Per Lane Per Hour (VPLPH)
GP
HOV


Estimated Volume and Speed Conditions (2/17/00)
I-5 NE 45th St-SB GP SB
Vehicles Per Lane Per Hour (VPLPH)


Estimated GP and HOV Volume and Speed Conditions
I-5 S Spokane St GP NB
Vehicles Per Lane Per Hour (VPLPH)
Saturday, July 31, 1999 Data
Multicolor = Average GP Lane
Gray = HOV Lane
HOV speed < 45 mph





Primary References

- Mannering, F.L.; Kilareski, W.P. and Washburn, S.S. (2005). *Principles of Highway Engineering and Traffic Analysis*, Third Edition. Chapter 5
- Transportation Research Board. (2000). *Highway Capacity Manual 2000*. National Research Council, Washington, D.C.