SPEED STUDY

Lecture Outline

1. Definition
2. Objectives of Speed Study
3. Fundamentals of Traffic Flow
4. Types of Speed
5. Different Forms of Speed
6. Methods of speed Measurement
7. Spot Speed Study
8. Analytical Problems related to Speed Study

REF

References

"Traffic Engineering Design" by Mike Slin and others

"Highways and Traffic", Volume 1, Second Edition, 1983. **O'Flaherty, C.A.**,

Transportation Research Board, "Highway Capacity Manual", Special Report 209, Third Edition, 1994.

Traffic and Highway Engg Fourth edition Garber & Hoel

Traffic Speed Study

Speed – The rate of movement of a vehicle, generally expressed in fps, kph or mph.

- It is a basic measure of traffic and roadway performance
- Influence the traveler in selecting routes or transportation modes.

Objectives

The main objectives of speed studies are:

- Capacity studies(LOS)
- Geometric design
- Accident analysis
- Economic studies

Objectives

- Performance study of a traffic control measure (before and after studies)(Right turn ban, speed reducing devices etc.)
- Planning and designing traffic control measures viz.
  - Traffic signal design (new or improvement/ signal phase)
  - Designing road signs (for school/ hospital/ bazaar)
  - Designing pedestrian crossings (at midblock or intersection)
  - Establishing speed limits (for varied road classification)
  - Speed zoning (along a corridor)
  - Placing speed reducing devices (where applicable)

Fundamental Principals of Traffic Flow

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 number of vehicles passing a specified point during a stated period of time. It is expressed in vehicles per 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

Fundamental Principals of Traffic Flow

Density:

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

Types of Speeds

- **Time-mean speed:** The speed obtained when the sum of all values is divided by the number of observation. It gives **arithmetic mean** of the spot speeds of vehicles passing a point. Useful for traffic regulating purposes.

$$v_t = (1/m)\sum_{i=1}^{m} v_i$$

Where m represents the number of vehicles passing the fixed point

Space-mean speed: **Harmonic mean** of speeds passing a point during a period of time. It also equals the average speeds over a length of roadway. Useful for establishing Speed-Flow relationships.

$$v_s = (n/\sum_{i=1}^{n}(1/v_i)$$

Where *n* represents the number of vehicles passing the roadway segment

- Time mean speed (v_t) = arithmetic mean of speeds of vehicles passing a point

$$\overline{v}_t = \frac{1}{N}\sum_{n=1}^{N} v_n$$

- Space mean speed (v_s) harmonic mean of speeds passing a point during a period of time. It also equals the average speeds over a length of roadway

$$\overline{v}_s = \frac{N}{\sum_{n=1}^{N}\frac{1}{v_n}} = \frac{NL}{\sum_{n=1}^{N} t_n}$$

where

N = number of vehicles

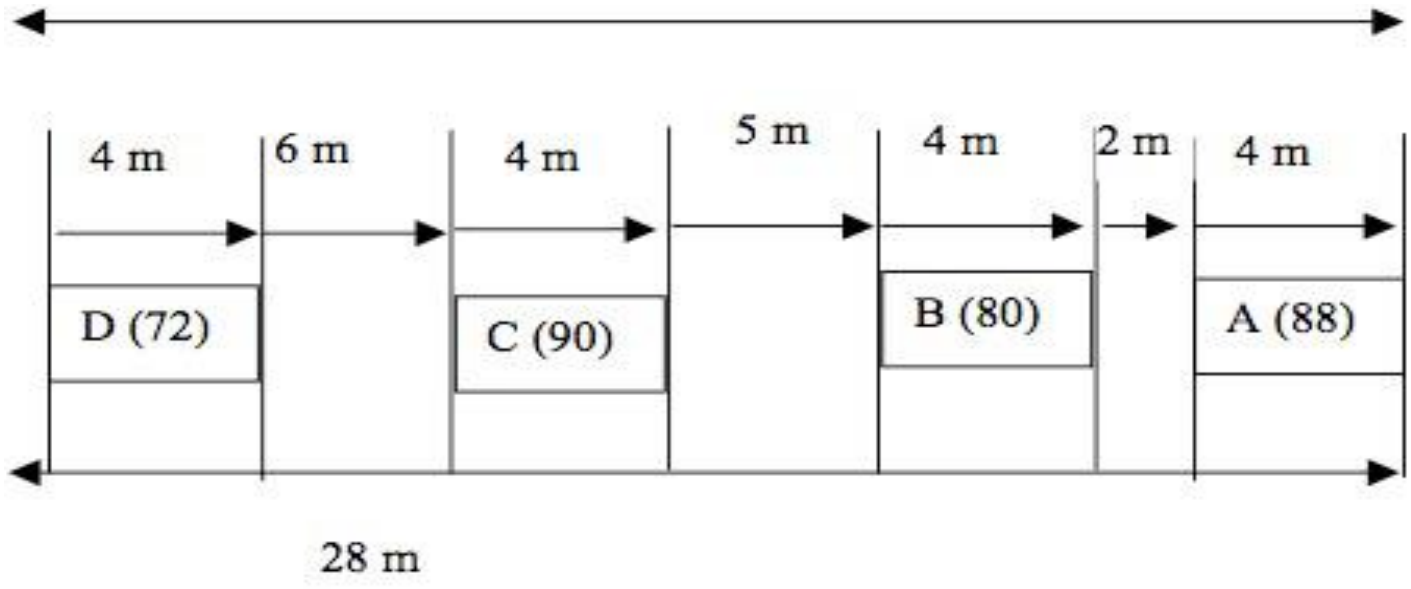
t_n = time it takes n^{th} vehicle to traverse a section of highway

v_n = speed of n^{th} vehicle

L = length of section of highway

Problem

Four vehicles are traveling at constant speeds between sections X and Y with their positions and speeds observed at an instant in time. An observer at point X observes the four vehicles passing point X during a period of **15 seconds**. The speeds of the vehicles are measured as 88, 80, 90, and 72 km/hr respectively. Calculate the flow, density, time mean speed, and space mean speed of the vehicles.



Solution: Flow, Density, Time Mean Speed

- Flow
- Density
- Time Mean Speed

$$q = N\left(\frac{3600}{t_{measured}}\right) = 4\left(\frac{3600}{15}\right) = 960 veh/hr$$

$$k = \frac{N}{L} = \frac{4}{28} = 142 veh/km$$

$$\overline{v_t} = \frac{1}{N}\sum_{n=1}^{N} v_n = \frac{1}{4}(72+90+80+88) = 82.5 km/hr$$

Solution: Space Mean Speed

$$\bar{v}_s = \frac{N}{\sum_{n=1}^{N} \frac{1}{v_i}} = \frac{4}{\frac{1}{72}+\frac{1}{90}+\frac{1}{80}+\frac{1}{88}} = 81.86$$

$$t_i = L / v_i$$

$$t_A = L / v_A = .028 / 88 = 0.000318 hr$$

$$t_B = L / v_B = .028 / 80 = 0.000350 hr$$

$$t_C = L / v_C = .028 / 90 = 0.000311 hr$$

$$t_D = L / v_D = .028 / 72 = 0.000389 hr$$

$$\bar{n}_s = \frac{NL}{\sum_{n=1}^{N} t_n} = \frac{4 * 0.028}{(0.000318+0.000350+0.000311+0.000389)} = 81.87 km / hr$$

The following travel times were observed for 4 vehicles traversing a 1 mile segment of highway:

Vehicle	Time (min)
1	1.6
2	1.2
3	1.5
4	1.7

Calculate the space and time mean speeds of the vehicles.

More math....

The following travel times were observed for 4 vehicles traversing a 1 mile segment of highway:

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4	1.7

Calculate the space and time mean speeds of the vehicles.

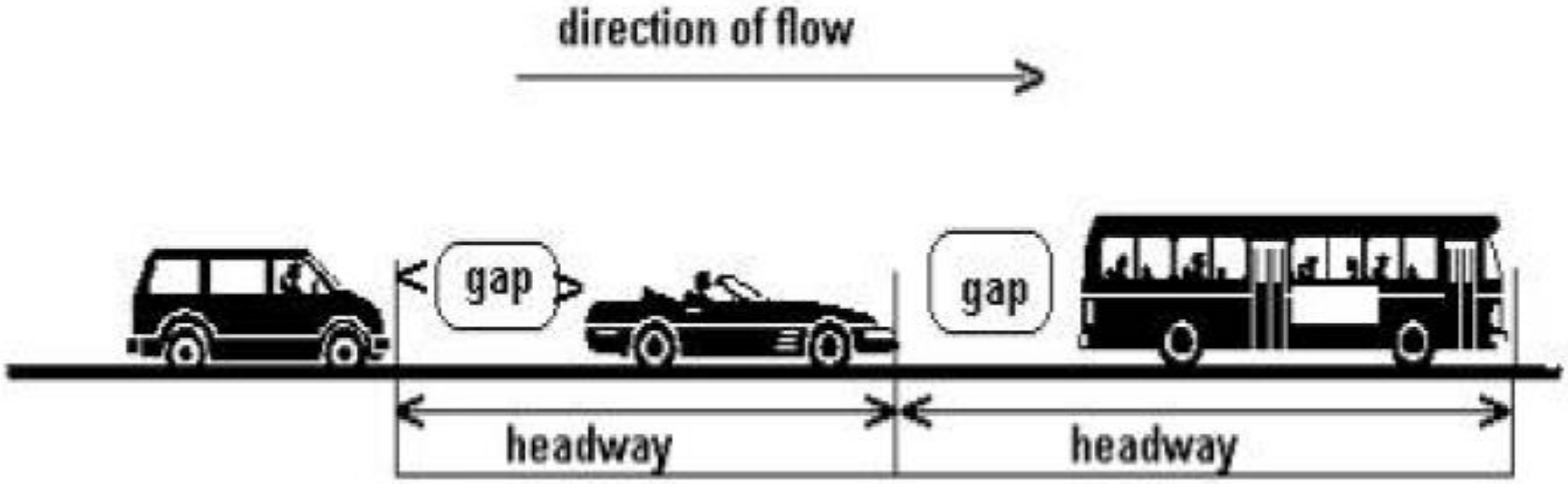
Time Mean Speed = [(1/1.6)+(1/1.2)+(1/1.5)+(1/1.7)]/4
= 0.68 miles per minute = 40.8 mph

Space Mean Speed = 4/(1.6+1.2+1.5+1.7)
= 0.67 miles per minute = 40.0 mph

Headway:Time Headway (*h*) v/s Space Headway

Time headway: **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 the same point.

Space headway : **distance between** the front of a vehicle and the front of the following vehicle.



Time Headway

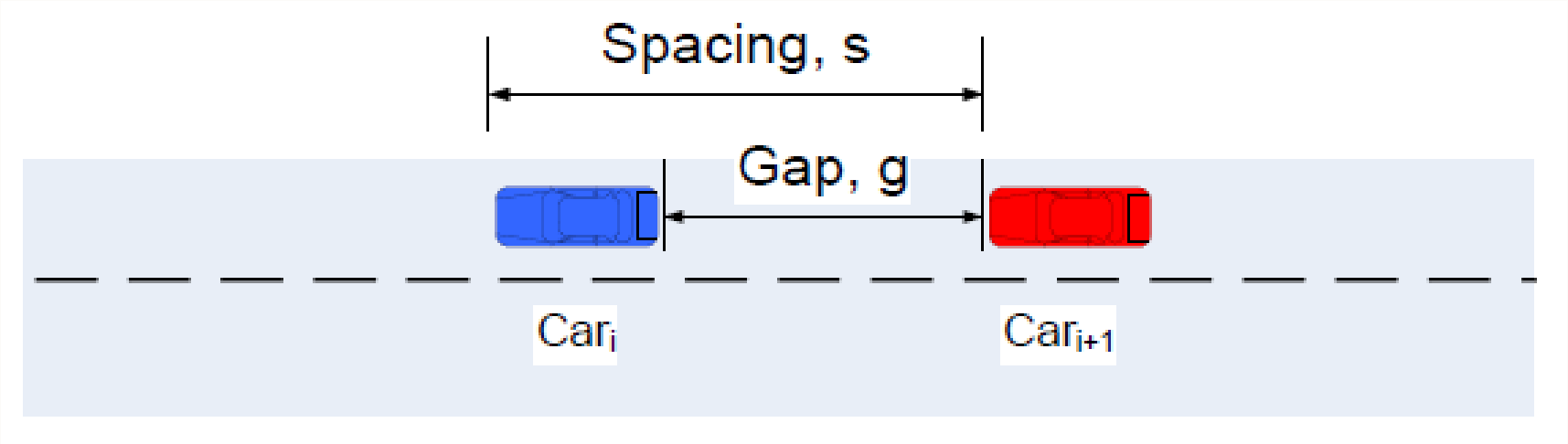
Time headway (h) = time "gap" between successive vehicles as they pass a point on the roadway.

Vehicle #	Time (s) Passing Pt. A	Headways
4	1.62	$h_{4-5} = 4.54$ s
5	6.16	$h_{5-6} = 2.44$ s
6	8.60	$h_{6-7} = 4.47$ s
7	13.07	

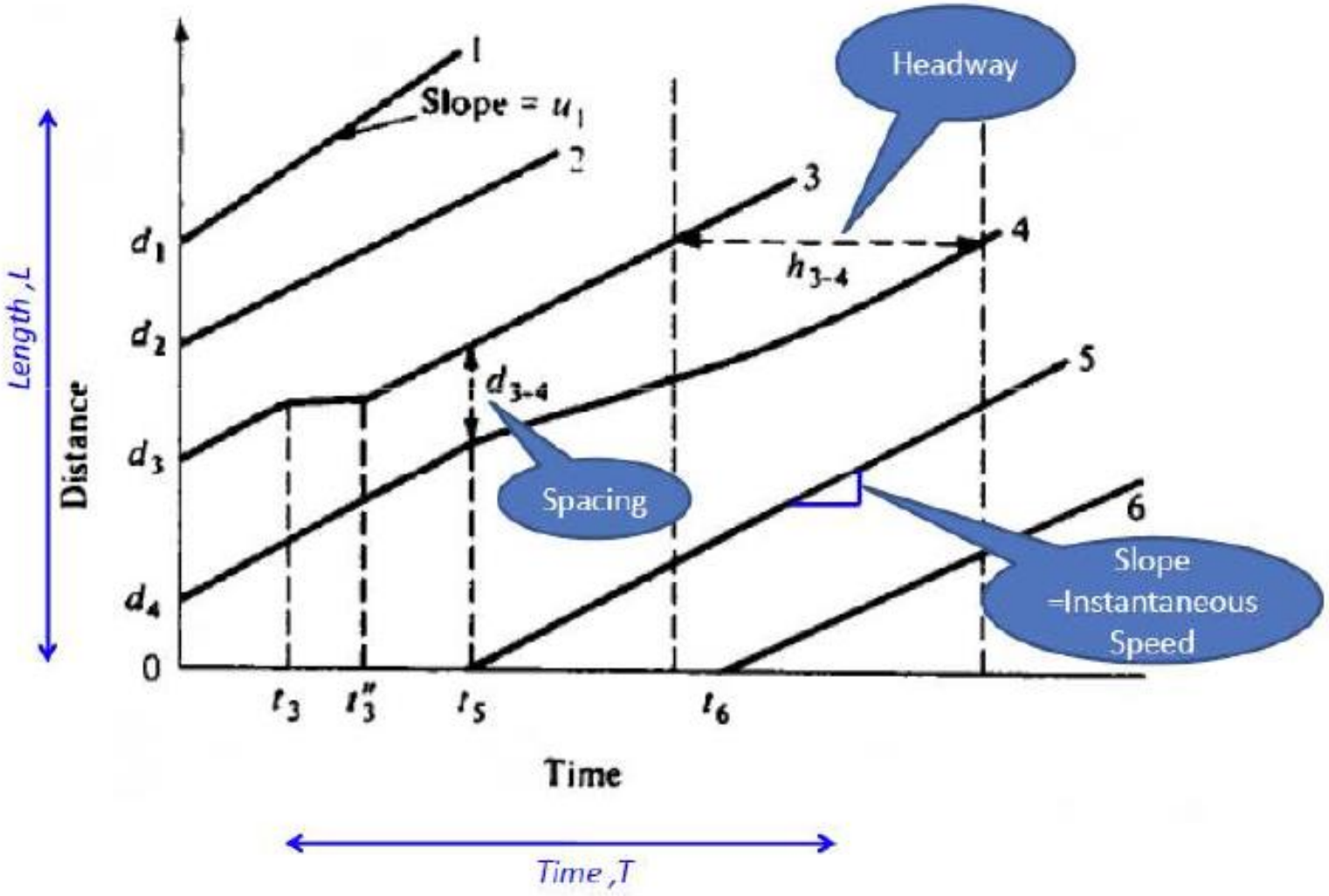
Distance Headway

Spacing or Distance Headway (s)

- = distance between successive vehicles in a traffic stream as measured from two corresponding points on the vehicles (e.g. front bumpers)



Time Space Diagram



Different Forms of Speed

- **Spot speed:** Instantaneous speed of a vehicle at a point.
- **Running speed:** Average speed while in motion
- **Journey speed:** Overall speed including stops.
- **Free Flow speed:** When drivers face no restriction in driving and can maintain their desired speeds.

OPERATING SPEED

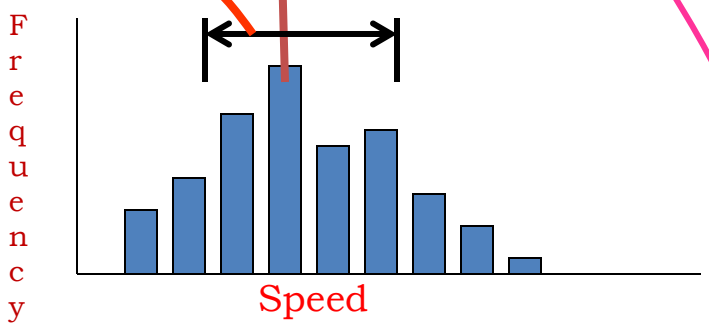
- The **operating speed** of a road is the speed at which motor vehicles generally operate on that road.
- The precise definition of "operating speed", however, is open to debate. Some sources, such as the AASHTO, have changed their definitions recently to match the common use of the word. In 1994, the AASHTO *Green Book* defined the operating speed as "the highest overall speed at which a driver can travel on a given highway under favorable weather conditions and under prevailing traffic conditions without at any time exceeding the safe speed as determined by the design speed on a section-by-section basis," a definition which a majority of US states still use.In July 2001, however, the AASHTO revised their definition for the new edition of the *Green Book* and defined it as "the speed at which drivers are observed operating their vehicles during free-flow conditions."

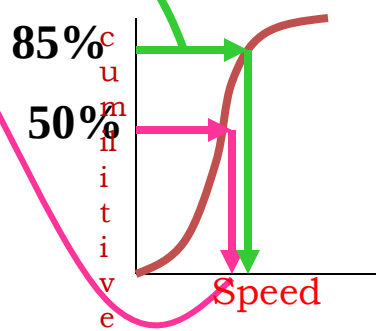
Different Forms of Speed

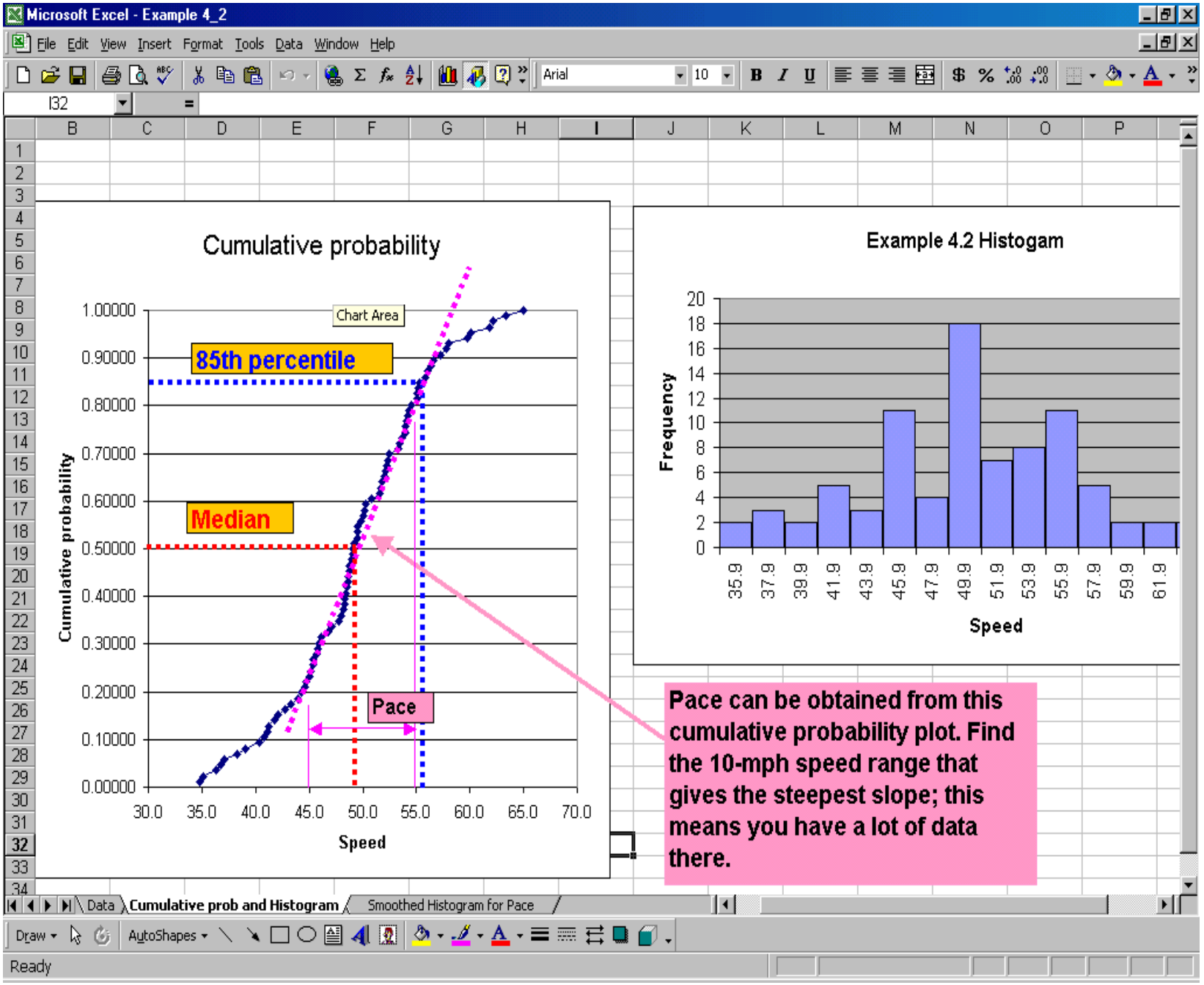
- **Safe speed: 85**th percentile speed.
- **Design speed:** 98th percentile speed.
- **Median speed:** 50th percentile speed.
- **Modal speed:** Speed at the highest frequency.
- **Pace:** **It** is the range of speed—usually taken at 10-mi/h intervals—that has the greatest number of observations. For example, if a set of speed data includes speeds between 30 and 60 mi/h, the speed intervals will be 30 to 40 mi/h, 40 to 50 mi/h, and 50 to 60 mi/h, assuming a range of 10 mi/h. The pace is 40 to 50 mi/h if this range of speed has the highest number of observations
- **Speed limits:** Upper limit at 85th percentile speed.; Lower limit at 15th percentile speed.

Types of Speed Measurements

Median speed	The speed at the middle value in a series of spot speeds. Or, 50th-percentile speed
Modal speed	The speed value that occurs most frequently in a sample of speeds
ith-percentile speed	The spot speed below which i percent of the vehicles travel, e.g. 85th-percentile speed
Pace	The range of speed that has the greatest number of observations; usually 10-mph range






Microsoft Excel - Example 4_2
File Edit View Insert Format Tools Data Window Help
Arial
10
I32
Cumulative probability
Chart Area
85th percentile
Median
Pace
Cumulative probability
1.00000
0.90000
0.80000
0.70000
0.60000
0.50000
0.40000
0.30000
0.20000
0.10000
0.00000
30.0
35.0
40.0
45.0
50.0
55.0
60.0
65.0
70.0
Speed
Example 4.2 Histogam
Frequency
20
18
16
14
12
10
8
6
4
2
0
35.9
37.9
39.9
41.9
43.9
45.9
47.9
49.9
51.9
53.9
55.9
57.9
59.9
61.9
Speed
Pace can be obtained from this cumulative probability plot. Find the 10-mph speed range that gives the steepest slope; this means you have a lot of data there.
Data
Cumulative prob and Histogram
Smoothed Histogram for Pace
Draw
AutoShapes
Ready

Methods of Speed Measurement

Spot/ Time Mean Speed: Measured at free flow/unobstructed conditions by using:

- Manual method- measuring travel time over a short distance.
- Automatic method-
  - ✓Radar speed meters.
  - ✓Pressure contact strip.
  - ✓Video camera method.
  - ✓Tachometer/ graph

Methods of Speed Measurement

Travel/ Space-mean speed: **Measured at existing operating condition by using:**

- License plate method.
- Floating car method- by use of test vehicle.
- Elevated observer method

General

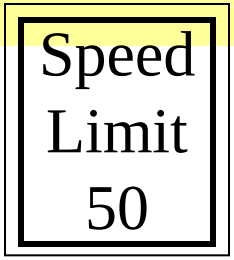
- The data is to be used for assessing general speed trends and for setting speed limits.
- The equipment for data collection procedure is a hand-held radar.




MILITARY POLICE

When are spot speed studies needed?

Spot speed studies are conducted to estimate the distribution of speeds of vehicles in a stream of traffic at a particular location on a highway.



Used for:

- ✓ Establish **speed zones**
- ✓ Determine whether complaints about speeding are valid
- ✓ Establish **passing and no-passing zones**
- ✓ Design **geometric alignment**
- ✓ Analyze **accident data**
- ✓ Evaluate the effects of **physical improvements**, etc., etc.

Data Collection

4.1.2 Time of Day and Duration of Spot Speed Studies

The time of day for conducting a speed study depends on the purpose of the study. In general, when the purpose of the study is to establish posted speed limits, to observe speed trends, or to collect basic data, it is recommended that the study be conducted when traffic is free-flowing, usually during off-peak hours. However, when a speed

The duration of the study should be such that the minimum number of vehicle speeds required for statistical analysis is recorded. Typically, the duration is at least 1 hour and the sample size is at least 30 vehicles.

- Choose section of road
- Not close to intersection, at midblock
- Off-peak period during daylight hours on a typical weekday

Spot Speed Study
Data Collection Form

Location:_____ Observer/s (group #)_____
Date:_____ Time:_____ Direction of Travel:_____ Posted Speed:_____

Weather Conditions: _____
Safety officer_____

Vehicle number	Speed, mph	Vehicle number	Speed, mph	Vehicle number	Speed, mph	Vehicle number	Speed, mph

Math

Following data was collected while conducting spot speed studies at certain stretch of a road within the urban area. Determine:

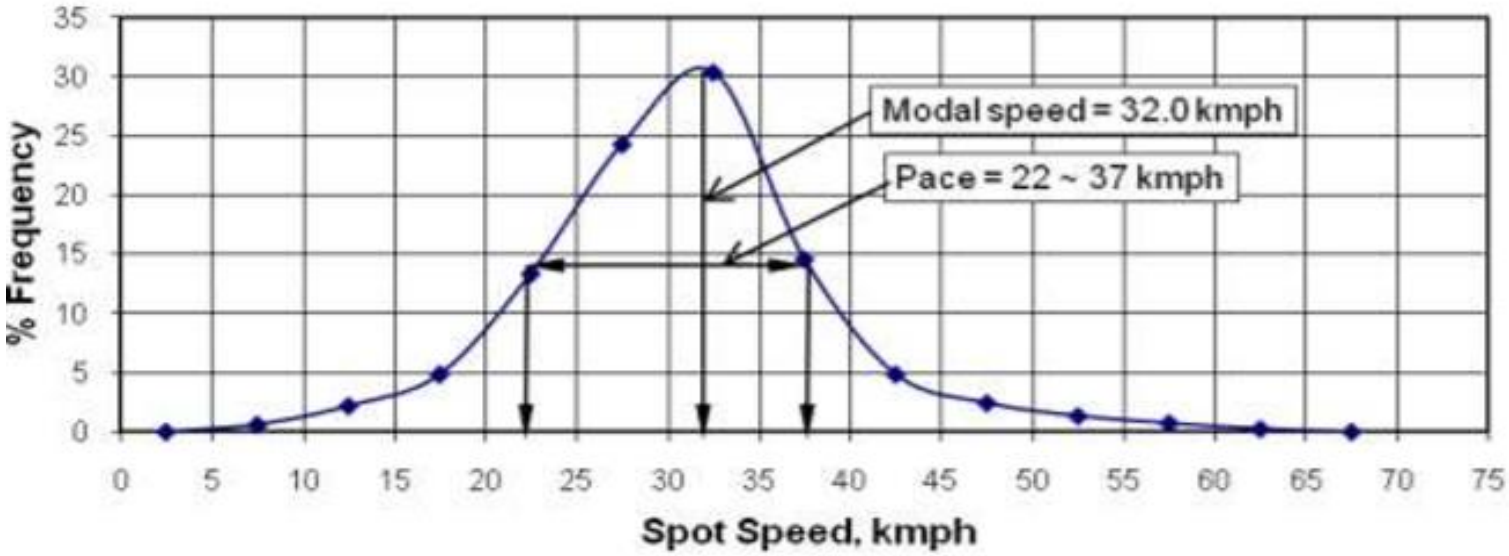
- Average speed of traffic speed.
- Modal speed and pace of the traffic stream.
- Upper and lower values of speed limits for regulation.
- Design speed for checking the design speed.

Solution

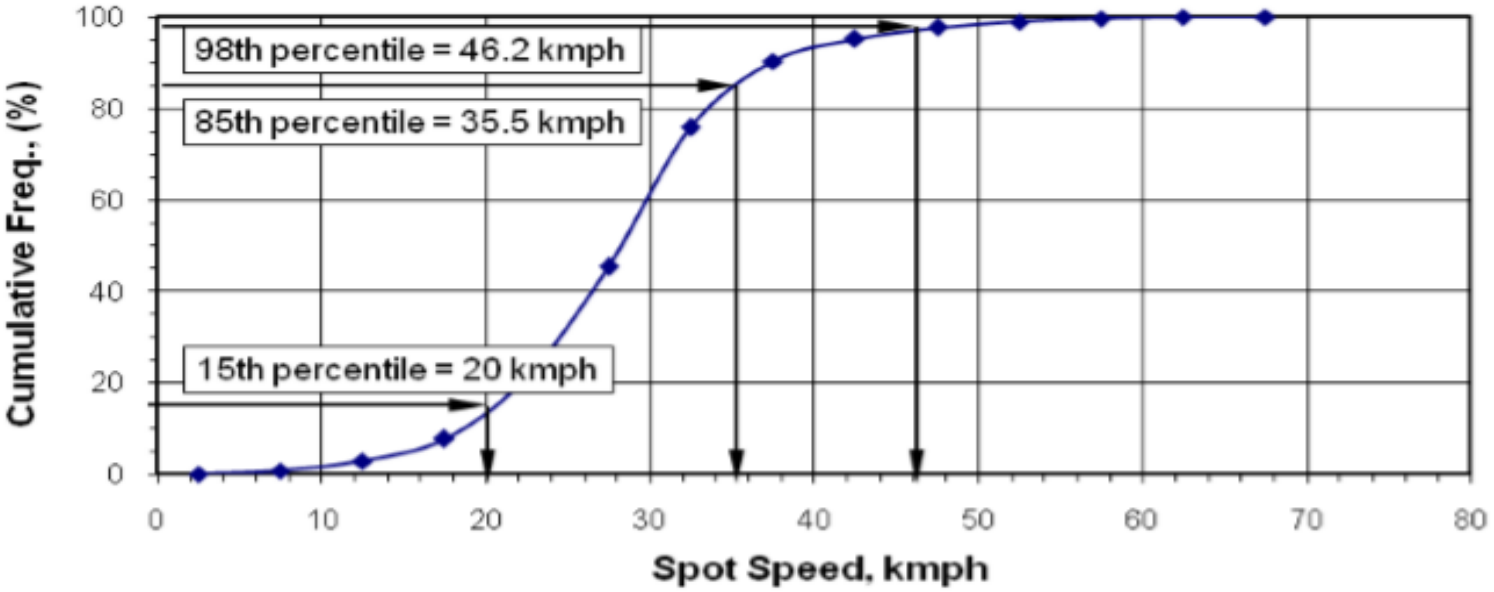
Speed Range (kmph)	No. of vehicle observed (f)	Mid-speed, V (kmph)	% Frequencies	Cumulative % Frequencies
0 - 5	0	2.5	0.00	0.00
5 - 10	5	7.5	0.61	0.61
10 - 15	18	12.5	2.19	2.80
15 - 20	40	17.5	4.87	7.66
20 - 25	110	22.5	13.38	21.05
25 - 30	200	27.5	24.33	45.38
30 - 35	250	32.5	30.41	75.79
35 - 40	120	37.5	14.60	90.39
40 - 45	40	42.5	4.87	95.26
45 - 50	20	47.5	2.43	97.69
50 - 55	11	52.5	1.34	99.03
55 - 60	6	57.5	0.73	99.76
60 - 65	2	62.5	0.24	100.00
65 - 70	0	67.5	0.00	100.00
Total	822			

V_{avg} = Sum (f * V)/Sum(f)
= 30.73 mph

Frequency Distribution for Spot Speed



Cumilative Frequency Distribution of Spot Speed



Sample Size of Speed Data

The minimum sample size depends on the precision level desired. The precision level is defined as the degree of confidence that the sampling error of a produced estimate will fall within a desired fixed range. Thus, for a precision level of 90–10, there is a 90 percent probability (confidence level) that the error of an estimate will not be greater than 10 percent of its true value. The confidence level is commonly given in terms of the level of significance (α), where α = (100 − confidence level). The commonly used confidence level for speed counts is 95 percent.

The basic assumption made in determining the minimum sample size for speed studies is that the normal distribution describes the speed distribution over a given section of highway. The normal distribution is given as

$$f(x) = \frac{1}{\sigma\sqrt{2\pi}} e^{-(x-\mu)^2/2\sigma^2} \text{ for } -\infty < x < \infty \qquad (4.4)$$

μ = true mean of the population
σ = true standard deviation
σ^2 = true variance

The properties of the normal distribution are then used to determine the minimum sample size for an acceptable error d of the estimated speed. The following basic properties are used (see Figure 4.1):

Table 4.1 Constant Corresponding to Level of Confidence

Confidence Level (%)	*Constant Z*
68.3	1.00
86.6	1.50
90.0	1.64
95.0	1.96
95.5	2.00
98.8	2.50
99.0	2.58
99.7	3.00

$$N = \left(\frac{Z\sigma}{d}\right)^2 \tag{4.5}$$

where

N = minimum sample size
Z = number of standard deviations corresponding to the required confidence
= level 1.96 for 95 percent confidence level (Table 4.1)
σ = standard deviation (mi/h)
d = limit of acceptable error in the average speed estimate (mi/h)

The standard deviation can be estimated from previous data, or a small sample size can first be used.

As part of a class project, a group of students collected a total of 120 spot speed samples at a location and determined from this data that the standard variation of the speeds was ± 6 mi/h. If the project required that the confidence level be 95% and the limit of acceptable error was ± 1.5 mi/h, determine whether these students satisfied the project requirement.

Solution: Use Eq. 4.5 to determine the minimum sample size to satisfy the project requirements.

$$N = \left(\frac{Z\sigma}{d}\right)^2$$

where

$Z = 1.96$ (from Table 4.1)
$\sigma = \pm 6$
$d = 1.5$

$$N = \left(\frac{1.96 \times 6}{1.5}\right)^2$$
$$= 61.45$$

Therefore, the minimum number of spot speeds collected to satisfy the project requirement is 62. Since the students collected 120 samples, they satisfied the project requirements.

Discussion