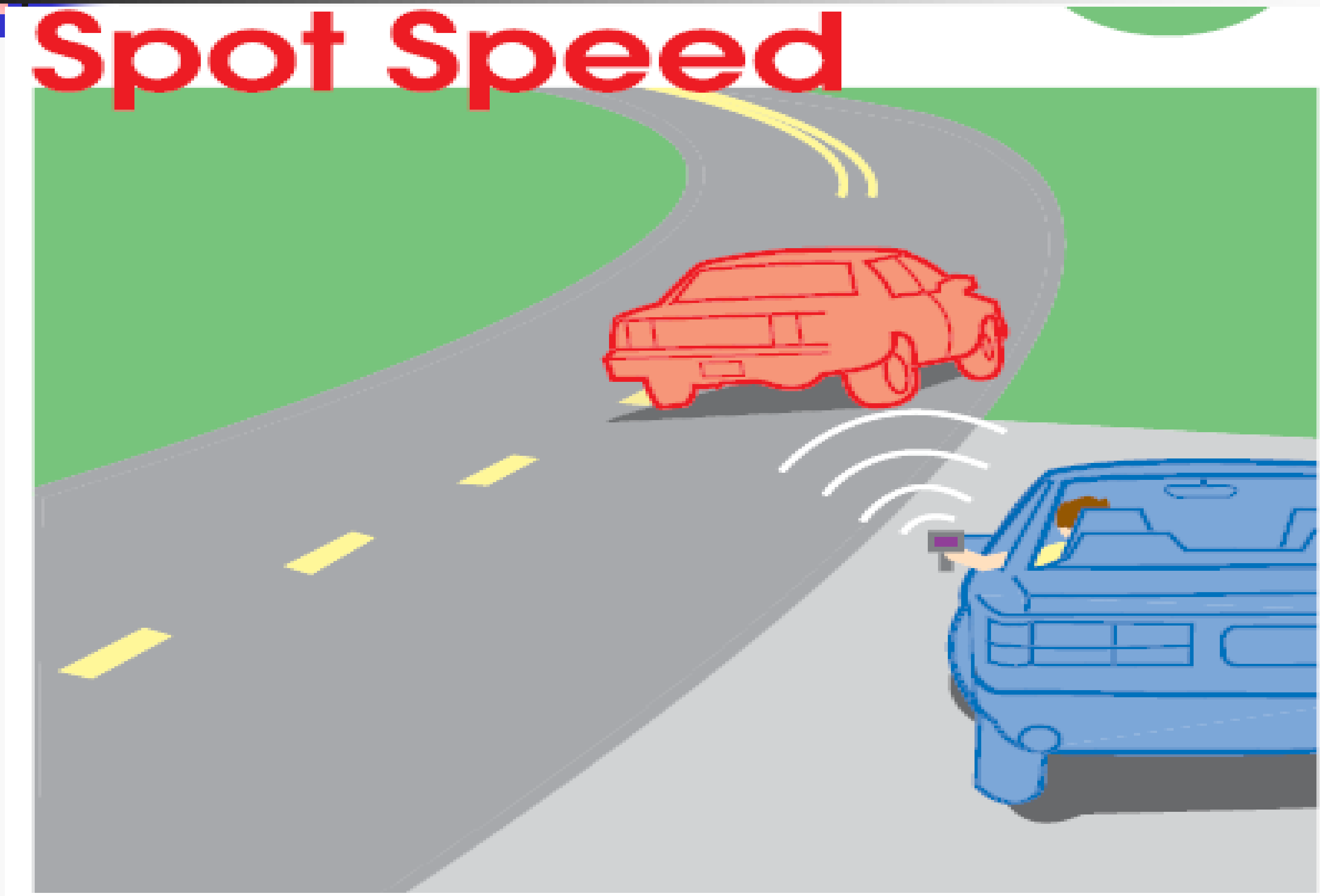
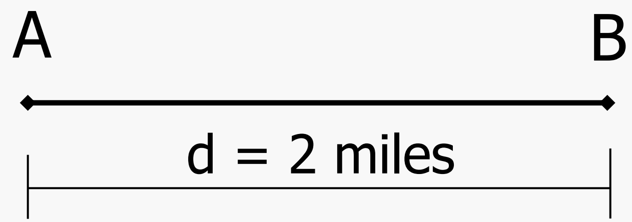

20
km/h
130


Spot Speed

Speed Measures

- Time Mean Speed
- Space Mean Speed
- 85^{th} Percentile Speed

Sample Calculation of TMS and SMS



Run #1: t_1 = 2 min, d/t_1 = 60 miles/hour
Run #2: t_2 = 2.5 min, d/t_2 = 48 miles/hour
Run #3: t_3 = 3 min, d/t_3 = 40 miles/hour

$\Sigma(d/t_i)$ = 60+48+40 = 148 miles/hour

TMS = $\Sigma(d/t_i)/n$ = 148/3 = 49.33 miles/hour

Calculation of TMS and SMS

$\Sigma(t_i) = t_1+t_2+t_3 = 2+2.5+3 = 7.5$ min

$\Sigma(t_i/n) = 7.5/3 = 2.5$ min

$$SMS = \frac{2 \text{ miles x } 60 \text{ min/hour}}{2.5 \text{ min}}$$

$= 48$ miles/hour

Spot Speed Studies

دراسات السرعة اللحظية

➢ **Application of Spot Speeds**

1. Speed Limit Studies
2. Establishing Speed Trends
3. Specific Design Applications
4. Specific Control Applications
5. Investigation of High Accident Locations

Spot Speed Studies
دراسات السرعة اللحظية

Where to take the studies:

1. **Trend locations**
2. **Problem locations for specific purposes**
3. **Representative locations for basic data surveys**
4. **Locations where before-and-after studies are being conducted**
5. **The specific location for the speed study should be selected to reduce the influence of the observer and the measuring equipment as much as possible**

Spot Speed Studies
دراسات السرعة اللحظية

Time and duration

- 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 study is conducted in response to citizen complaints, it is useful if the time period selected for the study reflects the nature of the complaints.

Spot Speed Studies
دراسات السرعة اللحظية

Time and duration

- 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.

Factors Affecting Spot Speeds

- Driver
- Vehicle
- Roadway
- Traffic
- Environment

Speed Study: Ways to Measure Speed

Methods

- Methods of Conducting Spot Speed Studies are divided into two main categories:
  1. Manual
  2. Automatic
     - ➔ Road Detectors
     - ➔ Doppler-Principle Meters
     - ➔ Electronic-Principle Detectors

Speed Study: Ways to Measure Speed

Methods (Manual)

- Spot speeds may be estimated by manually measuring the time it takes a vehicle to travel between two defined points on the roadway a known distance apart (short distance).
- Manual methods are seldom used these days.

Speed Study: Ways to Measure Speed

Manual:

1. Using a stop watch and measuring the time it takes to travel over a specified distance

time_1 **time_2**

Speed = $d/(\text{time}_1 - \text{time}_2)$

Speed Study: Ways to Measure Speed

Methods (Automatic)

1. Road Detectors

➔ Pneumatic Road Tubes or Induction Loops.

➔ Can be used to collect data on speeds at the same time as volume data are being collected.

- An Example of a Sensor Setup of a Surface Detector Using Pneumatic Road Tubes

Speed Study: Ways to Measure Speed

Methods (Automatic)

1. Road Detectors *(contd...)*

- ➔ The advantage of the detectors is that human errors are considerably reduced.
- ➔ The disadvantages are that they are expensive and may affect the driver behavior.
- ➔ Pneumatic Road Tubes are laid across the lane in which data are to be collected.

Speed Study:
Ways to Measure Speed

Methods (Automatic)

1. Road Detectors *(contd...)*

- Tubes are usually separated by 6 ft (or could also be between 3 to 15 ft).
- When a moving vehicle passes over the tube, an impulse is transmitted through the tube to the counter.
- The time elapsed between the two impulses and the distance between the tubes are used to compute the speed of the vehicle.

Speed Study: Ways to Measure Speed

Methods (Automatic)

1. Road Detectors *(contd...)*

- ➔ Induction Loops is a rectangular wire loop buried under the roadway surface.
- ➔ When a motor vehicle passes across it, an impulse is sent to the counter.

Speed Study:
Ways to Measure Speed

Methods (Automatic)

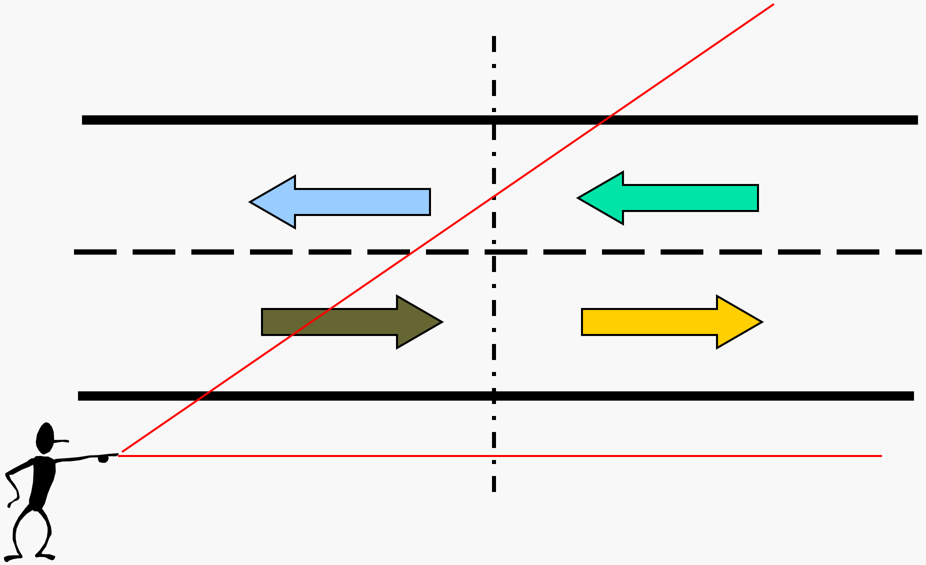
2. Doppler-Principle Meters

➔ Doppler meters work on the principle that when a signal is transmitted onto a moving vehicle, the change in frequency between the transmitted signal and the reflected signal is proportional to the speed of the moving vehicle.

➔ The difference between the frequency of the transmitted signal and that of the reflected signal is measured by the equipment, then converted to speed in mph or km/h.

Speed Study: Ways to Measure Speed

2. Using a Radar Gun



Speed Study: Ways to Measure Speed

Methods (Automatic)

Radar Gun

Speed Study: Ways to Measure Speed

Methods (Automatic)

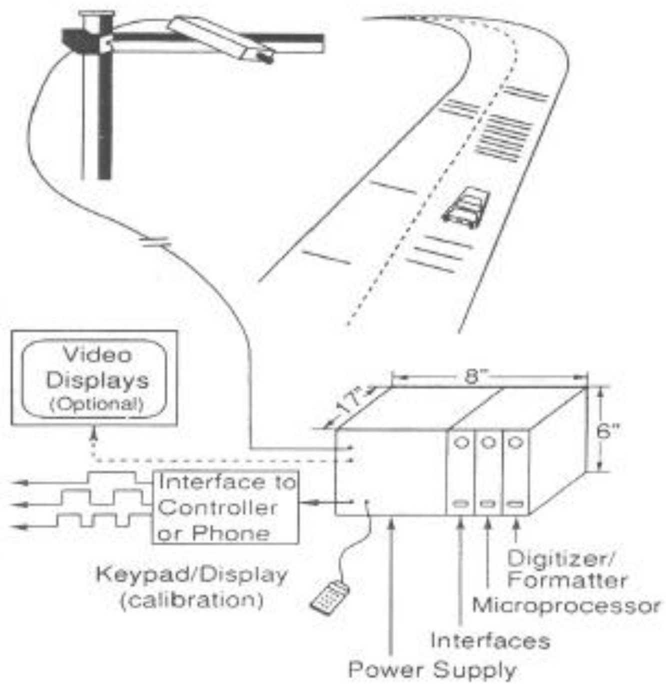
3. Electronic-Principle Detectors

- The presence of vehicles is detected through electronic means, and information on these vehicles is obtained, from which traffic characteristics such as speed, volume, queues, and headways are computed.
- The most promising technology using electronics is video image processing, sometimes referred to as a machine-vision system.
- One such system is the Autoscope.

Speed Study: Ways to Measure Speed

Methods (Automatic)

■ Real-Time Autoscope: A Fieldable Configuration



Time Mean Speed (TMS)

Average speed of all vehicles passing a point on a highway over a specified time period

$$\text{TMS} = \frac{\Sigma(d/t_i)}{n} \quad \text{(ft/sec or miles/hour)}$$

where d = distance traversed (ft or mile)

t_i = travel time of i^{th} vehicle (sec or hour)

n = number of travel times observed

Space Mean Speed (SMS)

Speed corresponding to the average travel time over a given distance

$$SMS = \frac{d}{\Sigma(t_i)/n} \quad \text{(ft/sec or miles/hour)}$$

where d = distance traversed (ft or mile)

t_i = travel time of i^{th} vehicle (sec or hour)

n = number of travel times observed

Relationship between TMS and SMS

$$v_t = v_s + \frac{\sigma_s^2}{v_s}$$

Data analysis

Speed Data Obtained on a Rural Highway

Car No.	Speed (mph)	Car No.	Speed (mph)	Car No.	Speed (mph)	Car No.	Speed (mph)
1	35.1	23	46.1	45	47.8	67	56.0
2	44.0	24	54.2	46	47.1	68	49.1
3	45.8	25	52.3	47	34.8	69	49.2
4	44.3	26	57.3	48	52.4	70	56.4
5	36.3	27	46.8	49	49.1	71	48.5
6	54.0	28	57.8	50	37.1	72	45.4
7	42.1	29	36.8	51	65.0	73	48.6
8	50.1	30	55.8	52	49.5	74	52.0
9	51.8	31	43.3	53	52.2	75	49.8
10	50.8	32	55.3	54	48.4	76	63.4
11	38.3	33	39.0	55	42.8	77	60.1
12	44.6	34	53.7	56	49.5	78	48.8
13	45.2	35	40.8	57	48.6	79	52.1
14	41.1	36	54.5	58	41.2	80	48.7
15	55.1	37	51.6	59	48.0	81	61.8
16	50.2	38	51.7	60	58.0	82	56.6
17	54.3	39	50.3	61	49.0	83	48.2
18	45.4	40	59.8	62	41.8	84	62.1
19	55.2	41	40.3	63	48.3	85	53.3
20	45.7	42	55.1	64	45.9	86	53.4
21	54.1	43	45.0	65	44.7		
22	54.0	44	48.3	66	49.5		

Data analysis

SPEED DATA COLLECTION FORM

SPEED GROUP (MPH)	FREQUENCY	TOTAL
0-5		0
6-10		0
11-15		0
16-20	卌 /	6
21-25	卌 ///	8
26-30	卌 卌 卌 卌 卌 ////	29
31-35	卌 卌 卌 卌 卌 卌 卌 卌 卌 卌 卌 卌	60
36-40	卌 卌 卌 卌 卌 卌 卌 卌 卌 卌 卌 卌 ///	63
41-45	卌 卌 卌 卌 卌 卌 卌 卌 卌 卌 卌 卌 卌 卌 ////	74
46-50	卌 卌 卌 卌 卌 ////	29
51-55	卌 卌 卌 ////	19
56-60	卌 卌	10
61-65	//	2

Weather: CLEAR On (Main Street): DIVISION

150 feet NORTH Of (Cross Street): FRANKLIN

Time (from): 3:00 (to): 3:20 PM Date: 8/15/01

Data analysis

Data Presentation

- The speed data can be presented by:

1. Frequency Distribution Table, and
2. Frequency and Cumulative Frequency Distribution Curves

Data analysis

1. Frequency Distribution Table

- The individual speeds of vehicles collected from the field are used to prepare the frequency distribution table.
- The frequency distribution table shows the total number of vehicles observed in each speed group.
- Speed groups of more than 5 mph are not used.

Frequency table

speed group		mean group (Xi)	Frequency f	% in Group	Cumm %	fi Xi	f (Xi-X')2
11	15	13	0	0	0	0	0
16	20	18	6	2	2	108	2701
21	25	23	8	3	5	184	2104
26	30	28	29	10	15	812	3649
31	35	33	60	20	35	1980	2319
36	40	38	63	21	56	2394	93
41	45	43	74	25	81	3182	1059
46	50	48	29	10	91	1392	2237
51	55	53	19	6	97	1007	3610
56	60	58	10	3	99	580	3528
61	65	63	2	1	100	126	1131
			300	100		11765	22431

Statistical Calculations

1. Measures of Central Tendency

I. ***Average or Mean Speed***- summation of all of the individual observations divided by the number of observations.

$$\bar{x} = \frac{\sum n_i S_i}{N}$$

II. ***Median Speed***- the speed that divides the distribution into halves, i.e., there are as many drivers traveling at speeds higher than the median as are driving slower than it. On the cumulative frequency distribution curve, 50th percentile sped is the median speed.

Statistical Calculations

1. Measures of Central Tendency

III.Pace- defined as the 10 mph increment in speed in which the highest percentage of drivers were observed. It is found using the frequency distribution curve.

IV. Modal Speed- the single value of speed that is most likely to occur.

➔ *If a curve is perfectly symmetric around the mean, then the average speed, the median speed, and the modal speed are all the same.*

85th Percentile Speed

The speed below which 85% of all traffic units travel, and above which 15% travel.

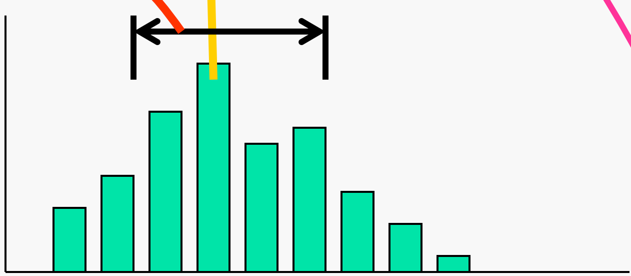
Speed limits are determined based on 85th percentile speeds.

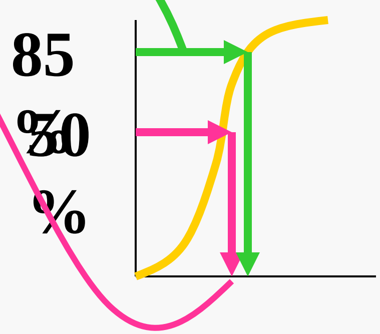
Speed Statistics

Average speed	Speed data Grouped $$\bar{u} = \frac{\sum f_i u_i}{\sum f_i}$$	Not grouped $\bar{u} = \Sigma u_j / N$
Standard deviation	Speed data Grouped $$s = \sqrt{\frac{\Sigma f(u_i - \bar{u})^2}{N - 1}}$$	Not grouped $$s = \sqrt{\frac{\sum (u_j - \bar{u})^2}{N - 1}}$$
Variance	s^2	

Types of Speed Measurements

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





Statistical Calculations

TMS = $X' = \sum X_i f_i / n = 39.2$ mph

Standard Deviation, $\sigma_s = \sqrt{\dfrac{\sum f(u - \overline{X})^2}{n - 1}} = 22442/299$

$= 8.66$ mph

Variance, $\sigma_s^2 = 8.66^2 = 75.06$ mph

Graph Showing Percentile Speeds

2. Frequency and Cumulative Frequency Distribution Curves

➔ Curves are prepared from the Frequency Distribution Table.

➔ Once the points are plotted, they are connected by a **smooth** curve.

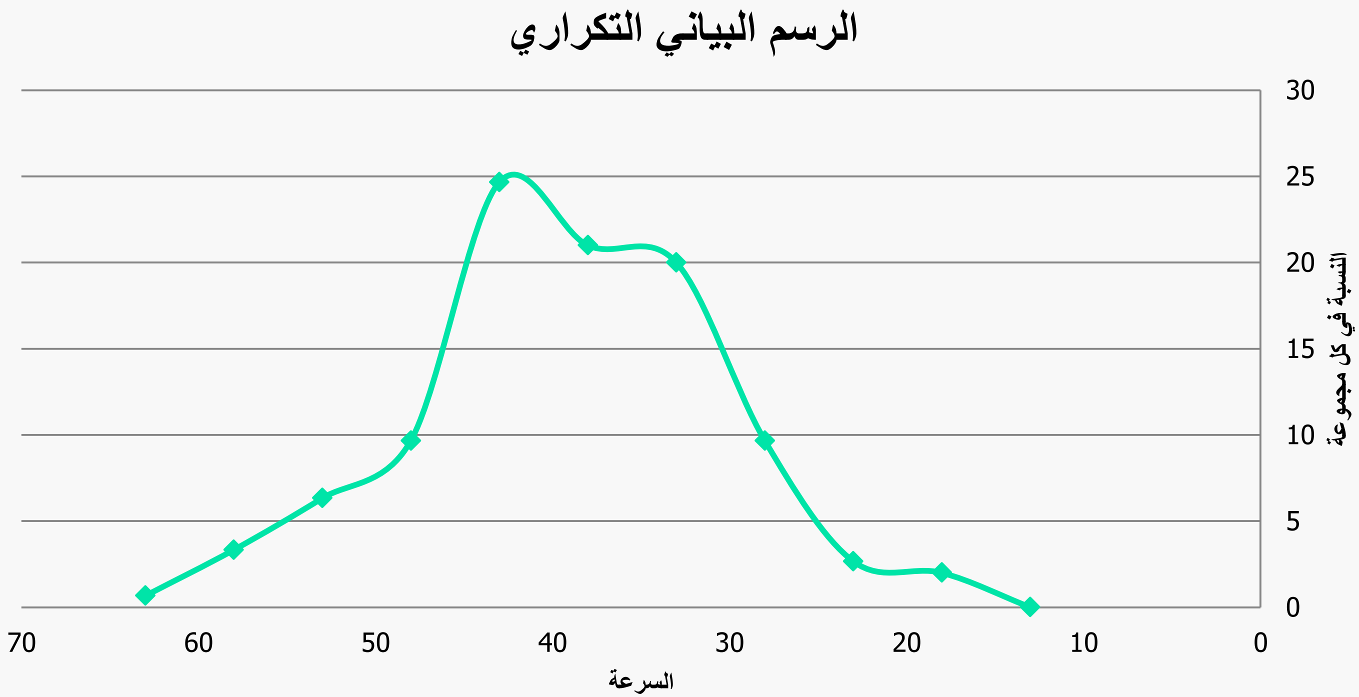
➔ They are usually plotted one above the other, using the same horizontal axis for speed.

Graph Showing Percentile Speeds

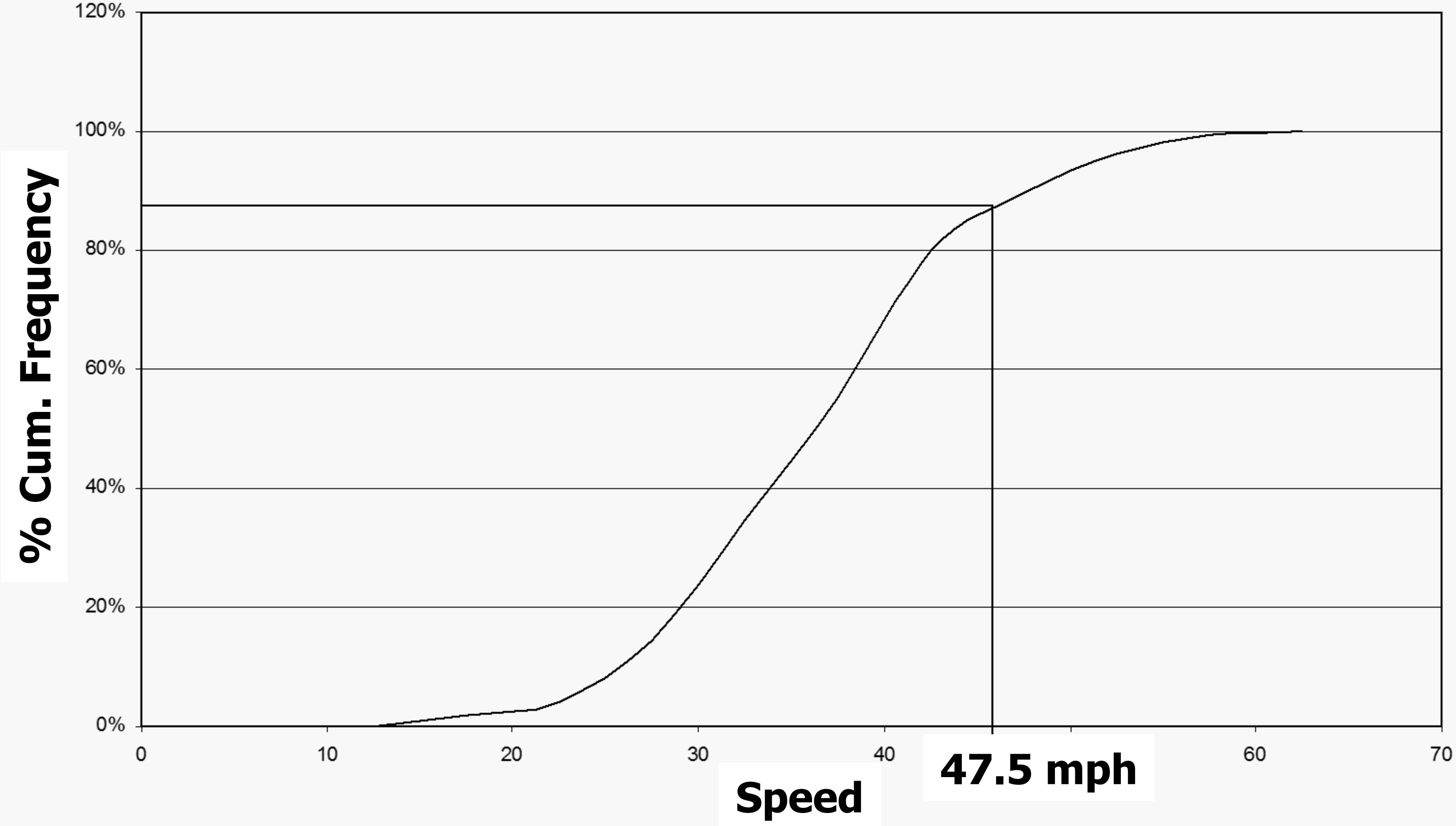
- The <u>frequency</u> distribution curve plots points which represent the middle speed of each speed group versus the % frequency in the speed group.

- Since the <u>cumulative % frequency</u> is defined as the percentage of vehicles traveling at or below a given speed, the cumulative frequency distribution curve plots the upper limit of the speed group (NOT the middle speed).

Graph Showing Percentile Speeds



Graph Showing Percentile Speeds



Precision and confidence intervals

Precision and Confidence Intervals

- The confidence interval for the true mean is

$$\overline{x} \pm ZE$$

$\overline{x}$ = sample mean speed, and $E = \frac{s}{\sqrt{n}}$

s = sample standard deviation, n = sample size

Z value to be calculated from Standard Normal Distribution Table for a particular level of confidence

for 95% confidence, $Z = 1.96$

for 95.5% confidence, $Z = 2.00$

for 99.7% confidence, $Z = 3.00$

Precision and confidence intervals

- **Precision and Confidence Intervals**
- For the example problem, standard deviation of the sample is 4.94 mph, sample size is 283, and the sample mean speed is 48.1 mph.

$$E = \frac{4.94}{\sqrt{283}} = 0.294 \ mph$$

- The 95% confidence interval for the true mean speed is 48.1± 1.96(0.294) mph or from 47.52 mph to 48.68 mph.
- Therefore, we can be 95% confident that the true mean speed would be between 47.52 mph and 48.68 mph.

Sample size

Statistical Applications to Analyze to the Speed Distribution

❖ **Required Sample Size**

$$n = \frac{Z^2 s^2}{e^2}$$

✓ Where "e" is the tolerance or acceptable limit of error.

Sample size

❖ Required Sample Size

- **Example problem:** How many speeds must be measured to determine the average speed to within ±1.0 mph with 95% confidence? Assume a standard deviation of 5 mph. How many samples for a tolerance of ±0.5 mph?

✓ 95% confidence, ±1.0 mph → n = 96 samples

✓ 95% confidence, ±0.5 mph → n = 384 samples

Before and after studies

- **Before-and-After Study**

- Consider the following typical situation. An accident analysis at a critical location indicates that excessive speeds are a principal causative factor in the frequent accidents. As a result, new speed limit signs are installed, and a lower limit is applied. Enforcement procedures are intensified. Six months later, speed studies at the location show some reduction in average speed.
- Were the new speed limit, signs, and enforcement procedures effective?

Before and after studies

Before-and-After Study

- To answer this question, we need to first calculate the standard deviation of the difference in means (S_d) as follows

$$S_d = \sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}}$$

→ Now if U_1 is the mean speed of the "before" study and U_2 is the mean speed of the "after" study, and if $|U_1 - U_2| > ZS_d$, then it can be said that the mean speeds are significantly different at the confidence level corresponding to Z.

Before and after studies

- **Before-and-After Study**

Example

- A speed study with n=50 results in an average speed of 65.3 mph and a standard deviation of 5 mph. After making traffic improvements intended to reduce average speeds, a second study was made six months later. This study, with n=60, resulted in an average speed of 64.5 mph and a standard deviation of 6 mph. Was the observed reduction in speeds statistically significant?

Before and after studies

Before-and-After Study

- Standard deviation of the difference in means, S_d, for the given data is 1.05 mph. The "Z" value for 95% confidence level is 1.96.
- Now, $ZS_d = (1.96)(1.05) = 2.058$ mph
- And, $|U_1 - U_2| = 65.3 - 64.5 = 0.8$ mph
- Since $|U_1 - U_2| < ZS_d$, we say that at 95% confidence level, the observed reduction in average speeds is NOT statistically significant!