Speed Studies

CIVL 4162/6162
(Traffic Engineering)

Learning Objectives

- Determine following characteristics of spot speed
  - mean, median, mode, pace, 85^{th} percentile, sd
- Fit a speed distribution
- Check for normality
- Comparison of assumed versus observed distribution

Introduction

- Speed data is needed for a variety of traffic analyses
- Spot speed data refers to measurement of individual speeds of vehicles passing a point on a roadway.
- Care must be taken to conduct the study appropriately so that the sample data will adequately reflect speed characteristics of the population.

Spot Speed Studies

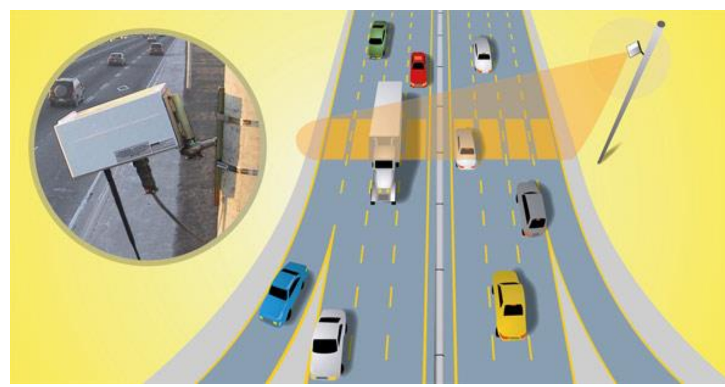
- Useful for:
  - Monitoring speed trends
  - Establishing traffic operation and control parameters
  - Establishing highway design elements
  - Evaluating highway capacity
  - Assessing highway safety
  - Measuring effectiveness of changes

Parameters of Interest

- Median spot speed
- Mean spot speed
- Modal spot speed
- Pace
  - 10 mi/hr increment in speed in which the higher percentage of drivers is observed
- 85th percentile speed
- Standard Deviation

Data Collection

- Individual vehicle
  - Manual
  - Radar
  - Video



- All-vehicle sampling
  - Road detectors
  - Radar-based traffic sensors
  - Electronic-principle detectors

Study Considerations

- Select roadway section with typical travel speed;
- Unless a specific requirement of the speed study, make an attempt to avoid the following, primarily to avoid accelerating/decelerating vehicles:
  - Traffic signals and other junctions
  - Intersections
  - Work zones
  - Curves
  - Parking zones
  - Active crosswalks
- Consider free flow vehicles only (those not impacted by speed of preceding vehicle, such as the first vehicle in a platoon);

Study Considerations

- Consider date and time
  - Typical weekdays (Tues., Wed., Thur.) preferred
- Avoid unusual conditions, including:
  - Unique events
  - Inclement weather
  - Holidays
- If using Radar, consider:
  - the angle of measurement to assure accurate speeds
  - remain inconspicuous so as not to influence speeds
- **Remember safety first!!!**

Spot Speed Study Analysis

- Data reduction (tabular and graphical presentation)
- Descriptive statistics (mean, median, mode, standard deviation, pace, etc.)
- Statistical inference (do significant differences exist between mean speeds for different conditions, etc.)
- A sample size of 100 veh per lane is acceptable for most circumstances

Data presentation

- Frequency distribution
- Cumulative frequency distribution
- Indicate central tendency and dispersion
- Evaluation depends on whether or not individual speeds or speed classes collected

Date: MM/DD/YY
Name: John Doe
Location: 6th Street and Main Street
Speed Limit: 35 mph
Start Time: 0700
End Time: 0725
Down Time: N.A.
Weather: Clear

Speed	Passenger Vehicles		Buses		Trucks		Total
	Record	No.	Record	No.	Record	No.	
15							
16							
17							
18							
19							
20							
21	II	2					2
22					I	1	1
23	I	1			II	2	3
24	IIII	4					4
25	I	1					1
26	III	3					3
27	II	2			I	1	3
28	II	2					2
29	~~IIII~~	5	II	2			7
30	II	2			I	1	3
31	III	3					3
32	~~IIII~~	5					5
33	III	3					3
34	III	3	I	1	I	1	5
35	~~IIII~~ I	6			II	2	8
36	~~IIII~~ I	6					6
37	~~IIII~~ I	6			II	2	8
38	IIII	4					4
39	~~IIII~~ I	6					6
40	IIII	4					4
41	~~IIII~~	5			II	2	7
42	III	3					3
43	II	2					2
44	IIII	4					4
45	II	2					2
46							
47	I	1					1
48							
49							
50							
Total							100

Uninterrupted Flow Conditions

- Sample Mean

$$\overline{\mu} = \frac{\sum_{i=1}^{N} \mu_i}{N}$$

- Sample Standard Deviation

$$s^2 = \frac{\sum_{i=1}^{N} (\mu_i - \overline{\mu})^2}{N - 1}$$

- Where,
- $\overline{\mu}$ -> Sample mean speed, mph
- μ_i->Speed of vehicle *i*, mph
- *N*->Total number of speed observations
- s^2->Sample variance
- *s*->Sample standard deviation

Grouped Observations

- Sample Mean

$$\bar{\mu} = \frac{\sum_{i=1}^{g} f_i \mu_i}{N}$$

- Sample Standard Deviation

$$s^2 = \frac{\sum_{i=1}^{g} f_i (\mu_i)^2 - \frac{1}{N}\left(\sum_{i=1}^{g} f_i \mu_i\right)^2}{N-1}$$

- Where,

- $\bar{\mu}$ -> Sample mean speed, mph
- μ_i-> Speed of vehicle *i*, mph
- *N*-> Total number of speed observations
- s^2-> Sample variance
- *s*-> Sample standard deviation
- f_i-> Number of observations in speed group I
- *g*-> Number of speed groups

Speed Exercise

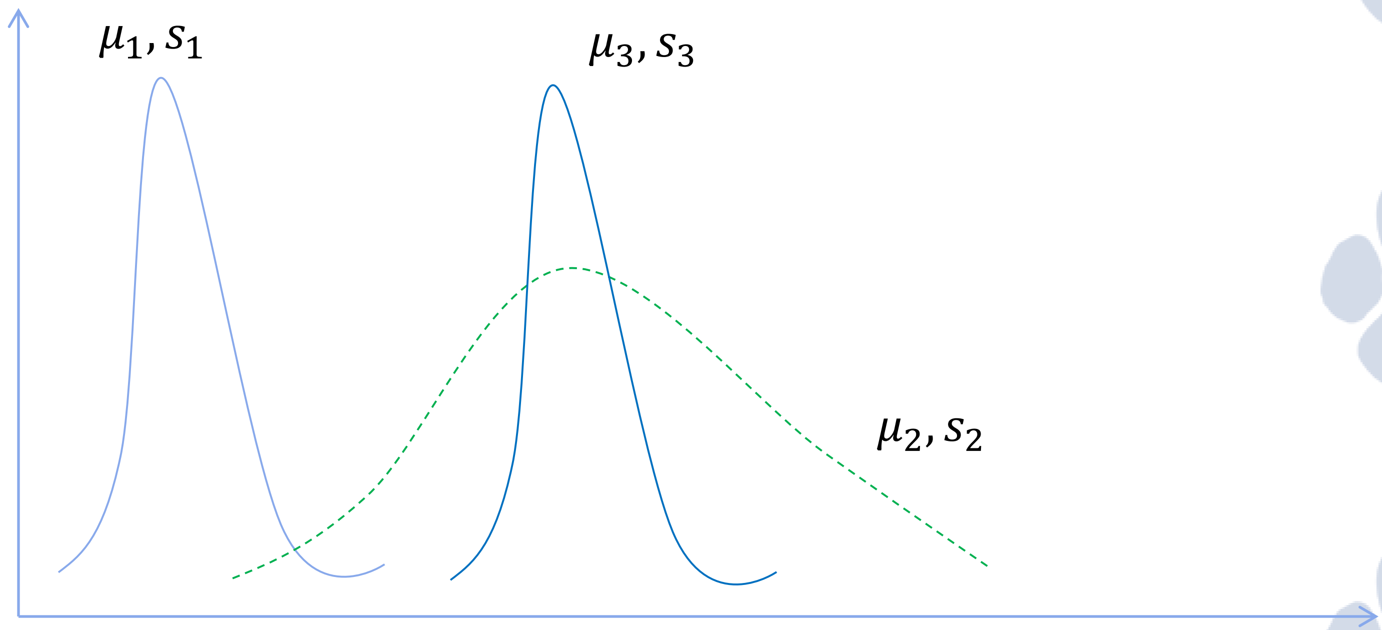
Statistical inference

- Most speed data tends to follow normal distribution
- This can be evaluated using chi-square test for goodness of fit
- If the data is normally distributed, confidence intervals may be determined, and required sample sizes may be estimated

Normal Distribution

- A unique normal distribution is defined when mean and standard deviation are specified
- The normal distribution is
  - Symmetrical about the mean
  - Dispersion is a function of the standard deviation

Normal Distribution

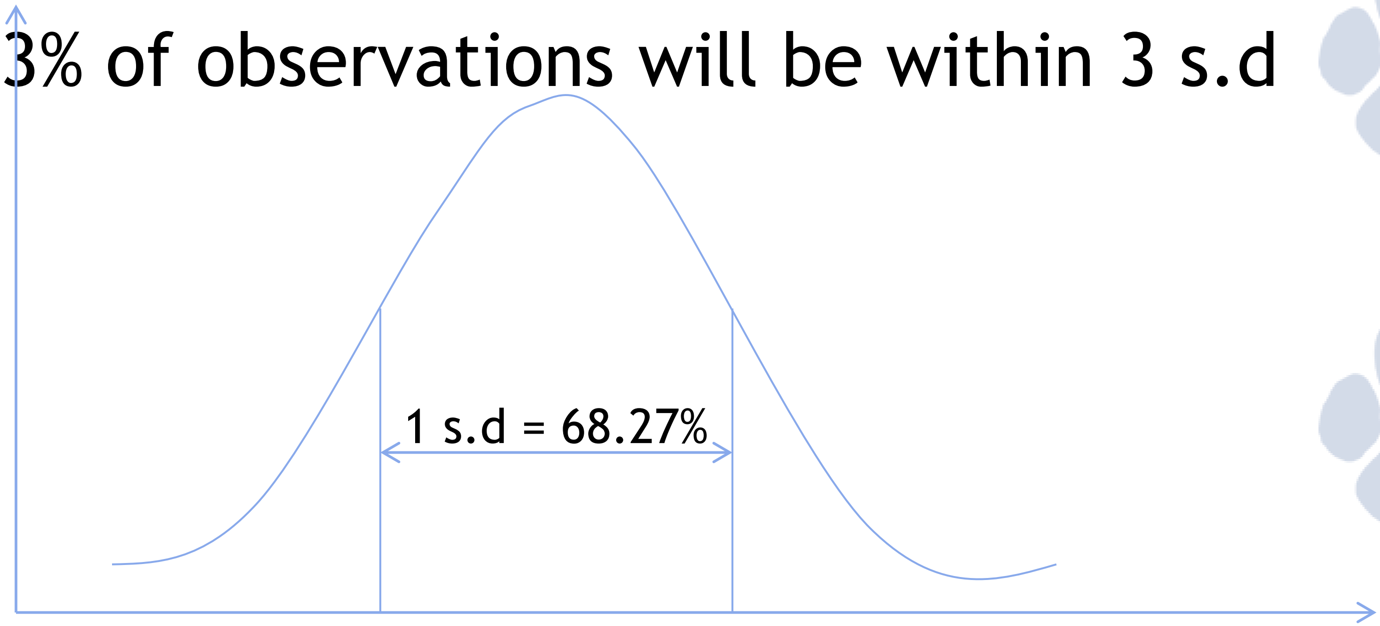


$s_1 = s_2, but\ \mu_1 < \mu_2$

$\mu_2 = \mu_3$, but $s_2 < s_3$

Normal Distribution

- The dispersion is such that
  - 68.27% of observations will be within 1 s.d
  - 95.45% of observations will be within 2 s.d
  - 99.73% of observations will be within 3 s.d



Two Issues with Normal Distribution

- Issue-1: Sample mean and sample s.d are known for most studies; population mean and population standard deviation are very difficult to estimate
- Issue-2: Estimating population s.d from the sample s.d is even more complex

Sample Size

- The relationship between sample and population is *N*
- As *N* increases to infinite, then sample s.d is equivalent to population s.d
- In practice it is found that
  - If N>30, then sample s.d = mean s.d
  - If N<30, then t-distribution rather than normal distribution is used

Question

- What is the probability of individual speeds between 35 and 40 mph

$$\left(\frac{x}{\sigma}\right)_{35\rightarrow 52.3} = \frac{52.3-35.0}{6.3} = 2.75$$

$$\left(\frac{x}{\sigma}\right)_{40\rightarrow 52.3} = \frac{52.3-40.0}{6.3} = 1.95$$

- Probability value for 2.75, = 0.4970
- Probability value for 1.95, = 0.4744
- Probability of speed between 35 and 40 = 0.4970-0.4744 = 0.0226
- With sample size of 200, the expected frequency is 0.0226*200 = 4 or 5

Evaluation of Selected Mathematical Distribution *(1)*

- Rule-1: The variance of measured speed distribution normally should be less than the variance of a random distribution (i.e. poisson)
  - s^2=6.3^2 = 39.3 mph
  - s^2_r= m = 52.3 mph
  - $s^2 < s^2_r$
- Rule-2: The s.d should be approximately 1/6th of total range since plus or minus 3 s.d encompasses 99.73% of the observations of a normal distribution

$$s_{est} = \text{total range}/6 = 32/6 = 5.3 \text{ mph}$$

$$s \sim s_{est}$$

Evaluation of Selected Mathematical Distribution *(2)*

- Rule-3: The standard deviation should be approximately one half of the 15 to 85 percentage range
  - s_{est} = (15 – 85 percentile range) / 2
  - =12.3/2 = 6.15
  - $s \sim s_{est}$
- Rule-4: The 10 mile per hour pace should be approximately equal to the sample mean
  - 10 mile hour pace= 52 or 53
  - Mean = 52.3
  - Pace ~ Mean

Evaluation of Selected Mathematical Distribution *(3)*

- Rule-5: The normal distribution has little skewness and the coefficient of skewness should be close to zero.
  - Coeffieicent of skewness = mean-mode/s
  - =52.3-53/6.3 = 0.1

  Or
  - 3[(mean-median)/s] = 3[(52.3-52.5)/6.3]=0.1
- *The numerical checks appear to support the assumption of a normal distribution*

Testing for Normalcy

- *Null Hypothesis:* There is no statistical difference between the measured distribution and normal distribution
- *Alternate Hypothesis:* There exists statistical difference between the measured distribution and normal distribution

Testing for Normalcy: The Chi-Square Test *(1)*

- Group the data and find the estimated frequency

Class Interval Limit	z	z/s	P	Pt	Ft
				0.0038	0.77
35.5	16.8	2.666667	0.4962	0.0104	2.08
38.5	13.8	2.190476	0.4858	0.0290	5.80
41.5	10.8	1.714286	0.4568	0.0646	12.92
44.5	7.8	1.238095	0.3922	0.1152	23.04
47.5	4.8	0.761905	0.2769	0.1645	32.90
50.5	1.8	0.285714	0.1125	0.1880	37.60
53.5	1.2	0.190476	0.0755	0.1720	34.40
56.5	4.2	0.666667	0.2475	0.1259	25.19
59.5	7.2	1.142857	0.3735	0.0738	14.77
62.5	10.2	1.619048	0.4473	0.0527	10.54

Testing for Normalcy: The Chi-Square Test (2)

Class Interval Limit	f0	ft	f0-ft	(f0-ft)^2	[(f0-ft)^2]/ft
	4	0.766076			
35.5	2	2.082896			
38.5	4	5.798655	1.352373	1.828914	0.315403155
41.5	10	12.92045	-2.92045	8.529019	0.660117863
44.5	19	23.04361	-4.04361	16.35078	0.709558121
47.5	31	32.89801	-1.89801	3.602447	0.109503502
50.5	41	37.5967	3.403296	11.58242	0.308070208
53.5	40	34.39509	5.604908	31.41499	0.91335674
56.5	23	25.18872	-2.18872	4.79048	0.190183585
59.5	18	14.76609	3.233911	10.45818	0.708256568
62.5	8	10.5437	-2.5437	6.470419	0.61367619
				Sum	4.528125932

Conclusion

- χ^2 from the table for α = 0.05, and degrees of freedom=6; is 12.6
- Since χ^2 calculated is less than the table value, we fail to reject the hypothesis.
- The conclusion is
  - There is no statistical difference between the measured distribution and normal distribution

Sample size

- $n = \left(\frac{ts}{\epsilon}\right)^2$
- Where
  - *n*-> required sample size
  - *t*- coefficient of standard error that represents user specified probability level
  - ϵ: user specified probable error
  - *s*: standard deviation