Speed Studies

CIVL 4162/6162
(Traffic Engineering)
Learning Objectives

- Determine following characteristics of spot speed
  - mean, median, mode, pace, 85th 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
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Uninterrupted Flow Conditions

- **Sample Mean**
  \[ \bar{\mu} = \frac{\sum_{i=1}^{N} \mu_i}{N} \]

- **Sample Standard Deviation**
  \[ s^2 = \frac{\sum_{i=1}^{N} (\mu_i - \bar{\mu})^2}{N - 1} \]

**Where,**
- \( \bar{\mu} \) -> Sample mean speed, mph
- \( \mu_i \) -> 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
- \( \mu_i \) -> 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

\[ s_1 = s_2, \text{ but } \mu_1 < \mu_2 \]
\[ \mu_2 = \mu_3, \text{ but } s_2 < s_3 \]
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

\[
\left(\frac{x}{\sigma}\right)_{35\rightarrow52.3} = \frac{52.3 - 35.0}{6.3} = 2.75
\]

\[
\left(\frac{x}{\sigma}\right)_{40\rightarrow52.3} = \frac{52.3 - 40.0}{6.3} = 1.95
\]

- 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)
  \[ s^2 = 6.3^2 = 39.3 \text{ mph} \]
  \[ s^2_r = \mu = 52.3 \text{ mph} \]
  \[ s^2 < s^2_r \]

- Rule-2: The s.d should be approximately \(1/6\)th 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
  \[ s_{est} = \frac{(15 - 85 \text{ percentile range})}{2} \]
  \[ = \frac{12.3}{2} = 6.15 \]
  \[ s \sim s_{est} \]

- Rule-4: The 10 mile per hour pace should be approximately equal to the sample mean
  \[ \text{10 mile hour pace} = 52 \text{ or } 53 \]
  \[ \text{Mean} = 52.3 \]
  \[ \text{Pace} \sim \text{Mean} \]
Evaluation of Selected Mathematical Distribution (3)

- Rule-5: The normal distribution has little skewness and the coefficient of skewness should be close to zero.
  - Coefficient of skewness = \( \frac{\text{mean} - \text{mode}}{\text{s}} \)
  - \( = \frac{52.3 - 53}{6.3} = 0.1 \)

Or
- \( 3[\frac{\text{mean}-\text{median}}{\text{s}}] = 3[\frac{52.3-52.5}{6.3}] = 0.1 \)

- *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

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Conclusion

• $\chi^2$ from the table for $\alpha = 0.05$, and degrees of freedom=6; is 12.6
• Since $\chi^2$ 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

\[ n = \left( \frac{ts}{\varepsilon} \right)^2 \]

Where

- \( n \rightarrow \) required sample size
- \( t \) - coefficient of standard error that represents user specified probability level
- \( \varepsilon \): user specified probable error
- \( s \): standard deviation