CIVL - 7904/8904

TRAFFIC FLOW THEORY

LECTURE -7

Microscopic Speed Characteristics (1)

- Characteristics of individual vehicles passing a point or a short segment during a specified period of time.
- Speed is a fundamental measurement of traffic performance on the highway system
- Most simulation models if traffic predict speed as the measure of performance in
  - Design
  - Demand
  - Control

Microscopic Speed Characteristics (2)

- Mpst models also use speed as the input for the estimation of
  - Fuel consumption
  - Vehicle emissions
  - Traffic noise
- Speed is also used as an indication of level of service, in accident analysis, and in economic studies
- Therefore, traffic analyst must be familiar with
  - speed characteristics and
  - associated statistical techniques

Vehicular Speed Trajectories

- Three equations of motion

$$t = \frac{\mu_e - \mu_b}{a} \qquad (1)$$

$$d = 1.47\mu_b t + 0.733 a t^2 \qquad (2)$$

$$S = \frac{(\mu_b)^2}{30(f \mp g)} \qquad (3)$$

- where,
- μ_b->Speed at the beginning of acceleration (deceleration), mph
- μ_e->Speed at the end of acceleration (deceleration), mph
- a->Acceleration/Deceleration at rate, mph/sec
- d->Distance for vehicle to accelerate at rate a from the beginning speed to ending speed
- t-> Time for vehicle to accelerate at rate a from the beginning speed to ending speed
- S-> Minimum stopping distance, ft
- f-> Coefficient of friction between tires and the pavement
- g-> Grade situation expressed in decimal

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
- 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

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

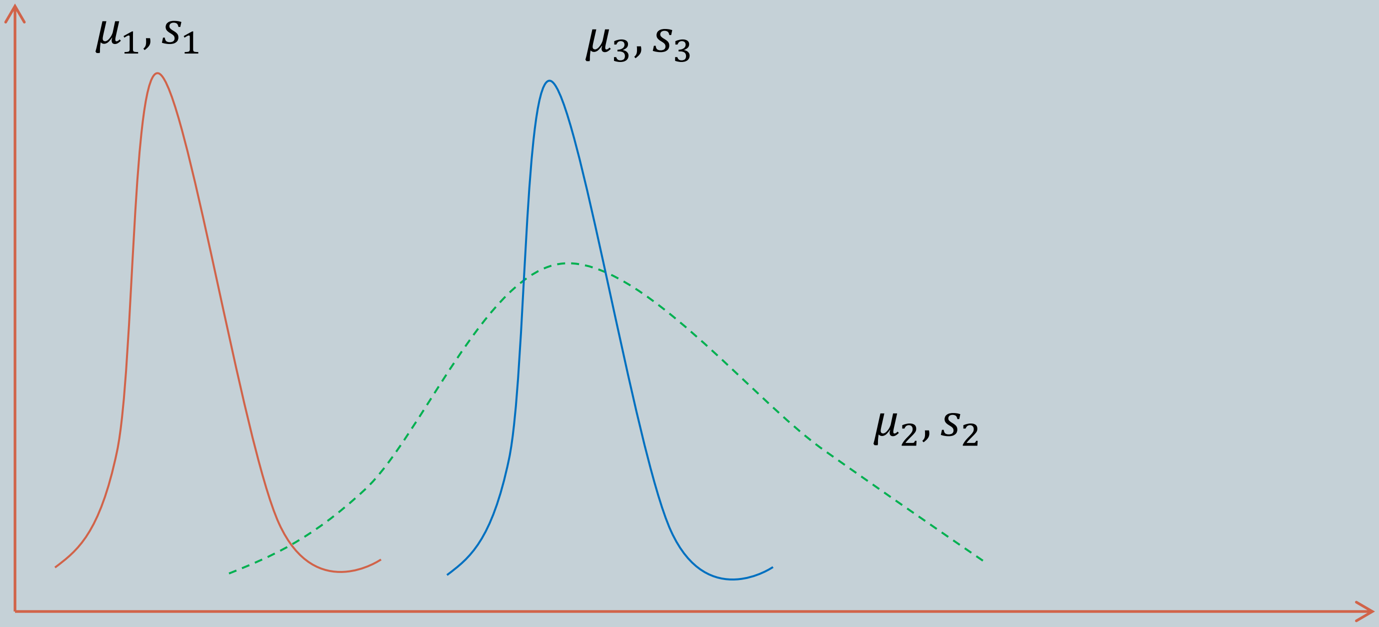
- Where,
- $\bar{\mu}$ -> Sample mean speed, mph
- μ_i-> Speed of vehicle i, mph
- N-> Total number of speed observations
- s^2-> Sample variance
- s-> Sample standard deviation
- f_i-> Number of observations in speed group I
- g-> Number of speed groups

Speed Exercise

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

Normal Distribution- PDF

$$f(\mu_i) = \frac{1}{\sigma\sqrt{2\pi}} e^{-(\mu_i - \overline{U})^2 / 2\sigma^2}$$

- $f(\mu_i)$->Probability density function of individual speeds
- μ_i->Speed value being investigated
- $\overline{U}$->Population mean speed
- σ ->Population s.d
- σ^2->Population variance

Question

- What is the probability of an individual speed over $\overline{U}$ + 1σ

- Outside 1σ area = 1-0.6827 = 0.3173
- Normal distribution is symmetrical about mean,
- So the probability is 0.3173/2 = 0.1586

- Conclusion: *If the individual speeds are normally distributed then 15%-16% vehicles of every 100 vehicles would be expected to travel at speeds greater than* $\overline{U} + 1\sigma$

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

- Rule-1: The variance of measured speed distribution normally should be less than the variance of a random distribution
  - $s^2 = 6.3^2 = 39.3$ 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

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

$$s \sim s_{est}$$

- 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

- 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*

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