# Traffic Engineering Studies

# Traffic Engineering Studies

- **Traffic studies may be grouped into three main categories:**
  - **(1) Inventories,**
  - **(2) Administrative studies, and**
  - **(3) Dynamic studies.**

# Traffic Engineering Studies

## (1) Inventories:

provide a list or graphic display of existing information, such as:

- street widths,
- parking spaces,
- transit routes,
- traffic regulations.

# Traffic Engineering Studies

**(2) Administrative studies**

- use existing engineering records, available in government agencies and departments.
- include the results of surveys, which may involve:
  - field measurements and/or
  - aerial photography.

# Traffic Engineering Studies

**(3) Dynamic traffic studies**

- involve the collection of data under operational conditions and
- include studies of:
  - speed,
  - traffic volume,
  - travel time and delay,
  - parking, and
  - crashes.
- They are described in detail in this chapter.

# Traffic Engineering Studies

- **4.1 SPOT SPEED STUDIES**
  - 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.
  - carried out by recording the speeds of a sample of vehicles at a specified location.

# Traffic Engineering Studies

- **SPOT SPEED STUDIES**

  **Used to:**

  - Establish parameters for traffic operation and control, such as:
    - speed zones,
    - speed limits (85th-percentile speed)

# Traffic Engineering Studies

- **4.1.1 Locations for Spot Speed Studies**
  - Represent different traffic conditions on a highway for *basic data collection*.
  - Mid-blocks of urban highways and straight, level sections of rural highways for *speed trend analyses*.
  - Any location may be used for solution of a *specific traffic engineering problem*.

# Traffic Engineering Studies

- **4.1.1 Locations for Spot Speed Studies**

  **Should be selected to achieve the following:**

  - Unbiased data
  - Drivers be unaware
  - Equipment concealed from the driver,
  - Observers inconspicuous.

# Traffic Engineering Studies

- **4.1.1 Locations for Spot Speed Studies**
  - statistical analysis,
  - statistically adequate number of vehicle speeds be recorded.

# Traffic Engineering Studies

- **4.1.2 Time of Day and Duration of Spot Speed Studies**
  - depends on the purpose of the study.
  - recommended when traffic is free-flowing,
  - during off-peak hours.
  - typically:
    - the duration is at least 1 hour and
    - the sample size is at least 30 vehicles.

# Traffic Engineering Studies

- **4.1.3 Sample Size for Spot Speed Studies**
  - The larger the sample size, will give an estimated mean within acceptable error limits.
    - Average Speed
    - Median Speed
    - Modal Speed
    - The ith-percentile Spot Speed
    - Pace
    - Standard Deviation of Speeds

# Traffic Engineering Studies

- **4.1.4 Methods for Conducting Spot Speed Studies**
  - manual and automatic
  - manual method is seldom used
  - automatic devices
    1. road detectors
    2. radar-based
    3. the principles of electronics.

# Traffic Engineering Studies

- Road Detectors
  - pneumatic road tubes & induction loops collect data on speeds & volume at the same time
  - **Advantage:**
    - Human errors are considerably reduced
  - **Disadvantages:**
    - expensive
    - may, affect driver behavior,

# Traffic Engineering Studies

- Pneumatic road tubes
  - laid across the lane in which data are to be collected.
  - When moving vehicle passes over, an air impulse is transmitted to the counter.
  - two tubes are placed across the lane, 2 m apart.
  - An impulse is recorded when the front wheels of a moving vehicle pass over the first tube;

# Traffic Engineering Studies

- Pneumatic road tubes
  - a second impulse is recorded when the front wheels pass over the second tube.
  - The time elapsed between the two impulses and the distance between the tubes are used to compute the speed of the vehicle.

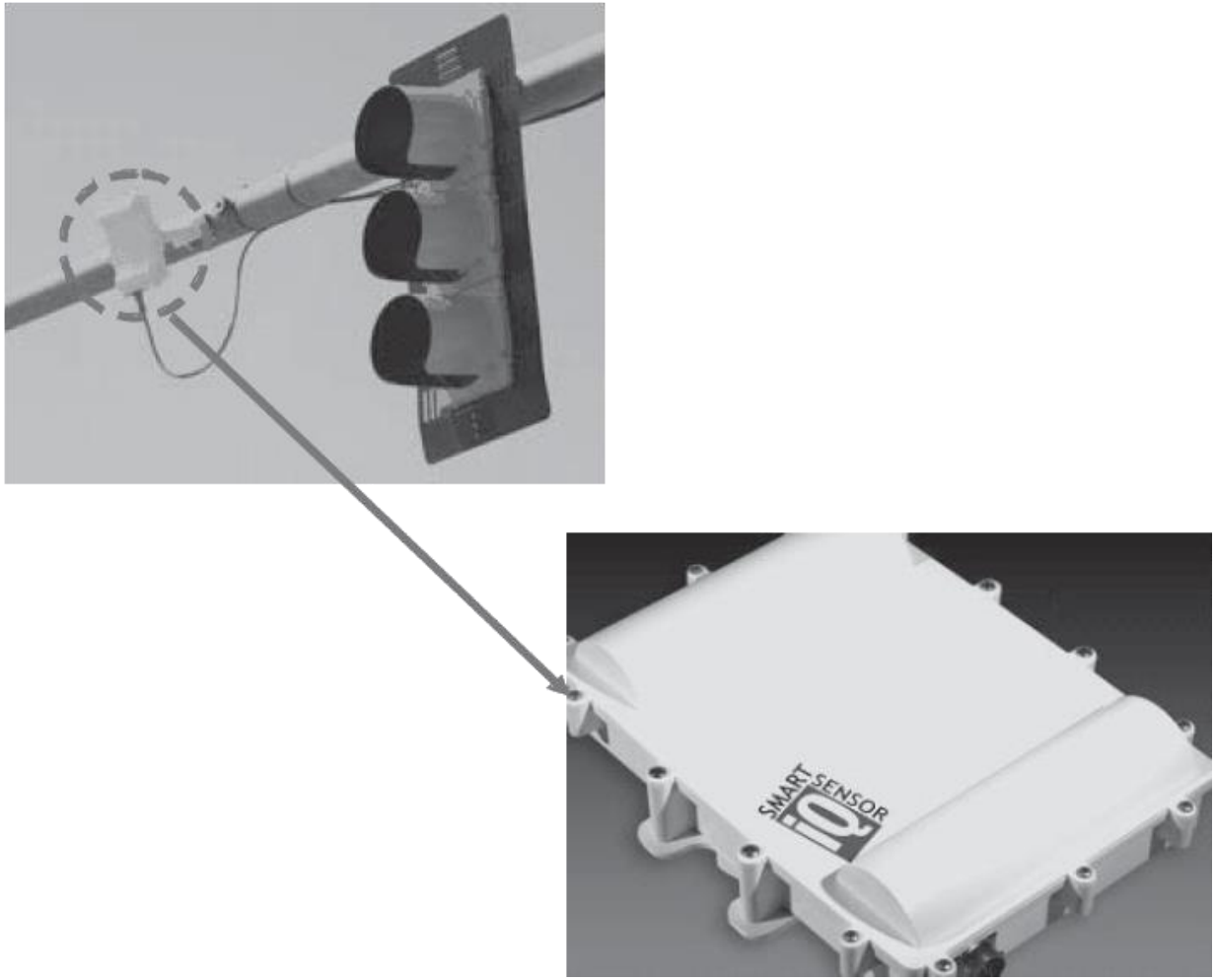
# Traffic Engineering Studies

- inductive loop
  - a rectangular wire loop buried under the roadway surface.
  - It operates on the principle that a disturbance in the electrical field is created when a motor vehicle passes across it.

# Traffic Engineering Studies

- Radar-Based Traffic Sensors
- Electronic-Principle Detectors
  - traffic characteristics, such as speed, volume, queues, and headways are computed.
  - Using video image processing

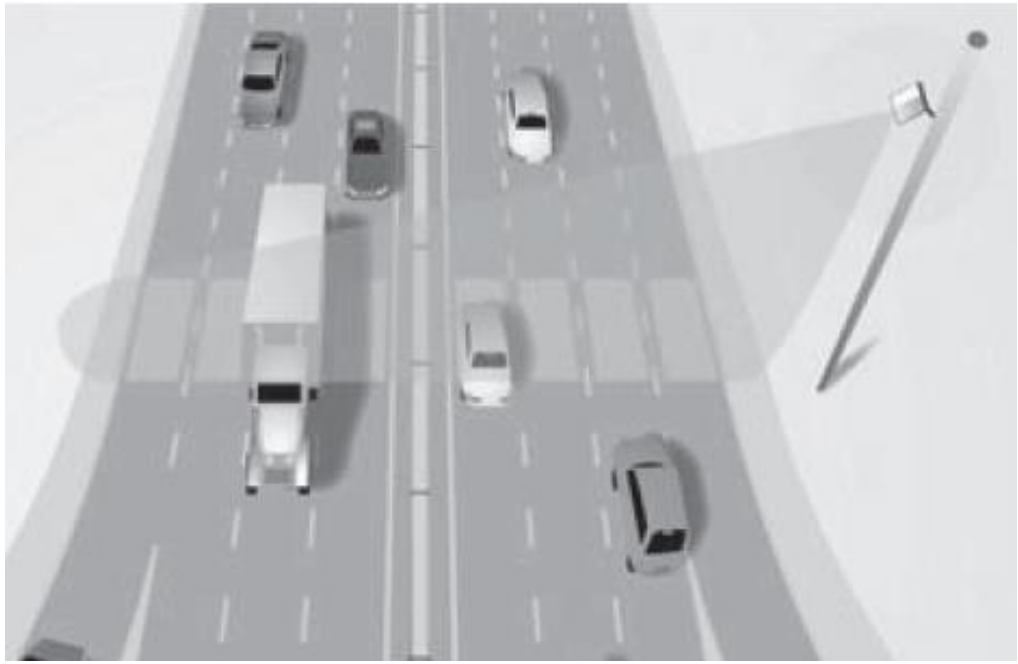
# Traffic Engineering Studies




(a) RTMS Deployed **in** the Forward Looking Mode

# Traffic Engineering Studies

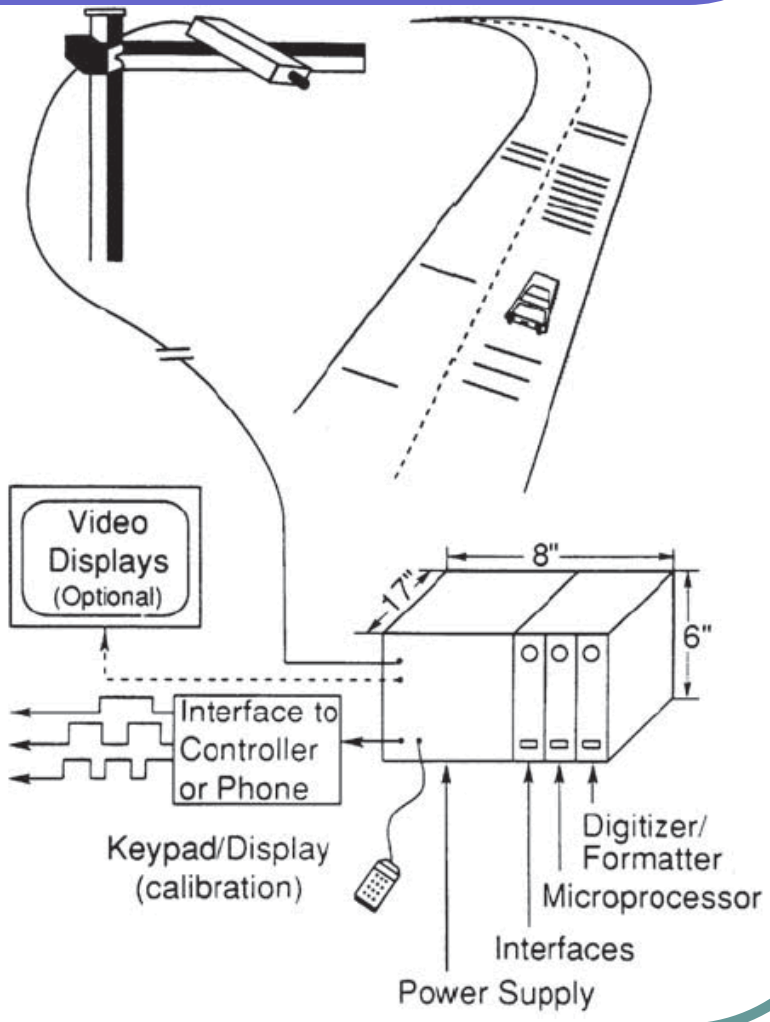




(b) RTMS Deployed in the Side-fire Mode

# Traffic Engineering Studies

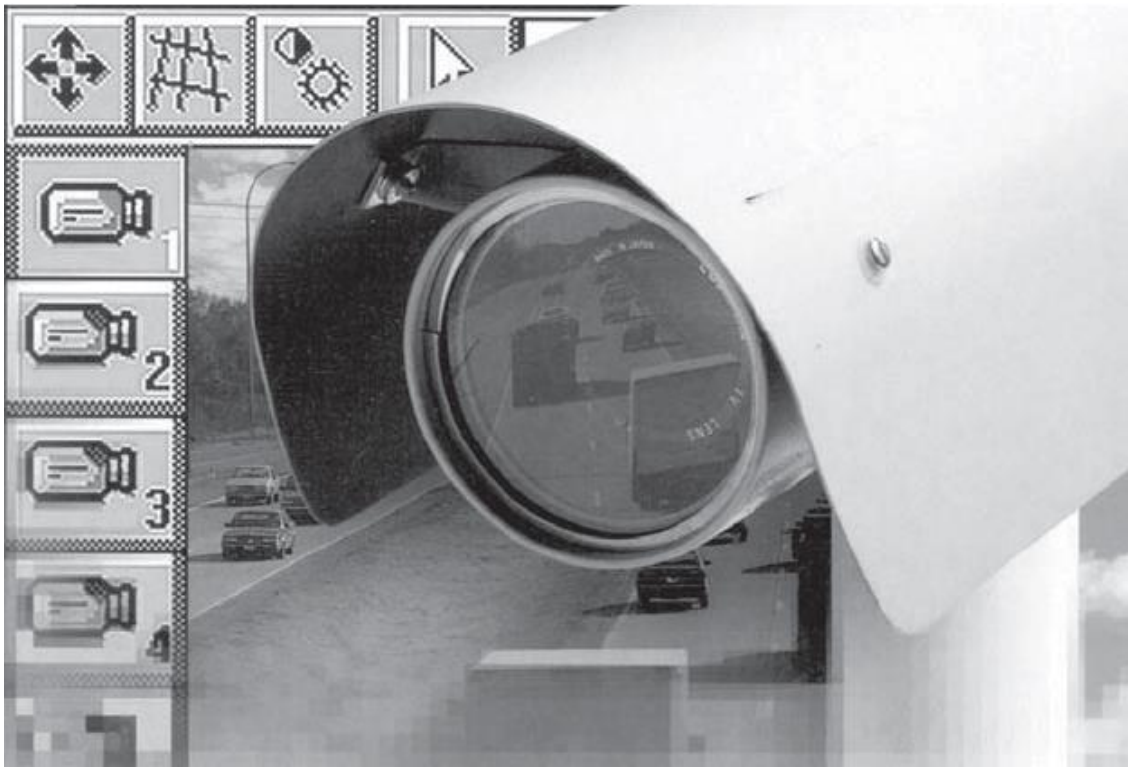
(a) Schematic Illustration of the Auto scope



# Traffic Engineering Studies

(b) The Auto scope Deployed



# Traffic Engineering Studies

- **4.1.5 Presentation and Analysis of Spot Speed Data**
  - Statistical methods
  - Analyzing data
  - frequency histogram
  - cumulative frequency distribution curve

# Traffic Engineering Studies

- **Example 4.2** Determining Speed Characteristics from a Set of Speed Data.

  Table 4.2 shows the data collected on a rural highway in Virginia during a speed study. Develop the frequency histogram and the frequency distribution of the data and determine:

# Traffic Engineering Studies

1. The arithmetic mean speed
2. The standard deviation
3. The median speed
4. The pace
5. The mode or modal speed
6. The $85^{th}$-percentile speed

# Traffic Engineering Studies

- **Solution:**
- The speeds range from 34.8 to 65.0 km/h, giving a speed range of 30.2.
- For eight classes, the range per class is 3.75 km/h;
- for 20 classes, the range per class is 1.51 km/h.
- It is convenient to choose a range of 2 km/h per class which will give 16 classes.
- A frequency distribution table can then be prepared, as shown in Table 4.3.

# Traffic Engineering Studies

| Car No. | Speed (mi/h) | Car No. | Speed (mi/h) | Car No. | Speed (mi/h) | Car No. | Speed (mi/h) |
|---|---|---|---|---|---|---|---|
| 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 | | |

**Table 4.2** Speed Data Obtained on a Rural Highway

# Traffic Engineering Studies

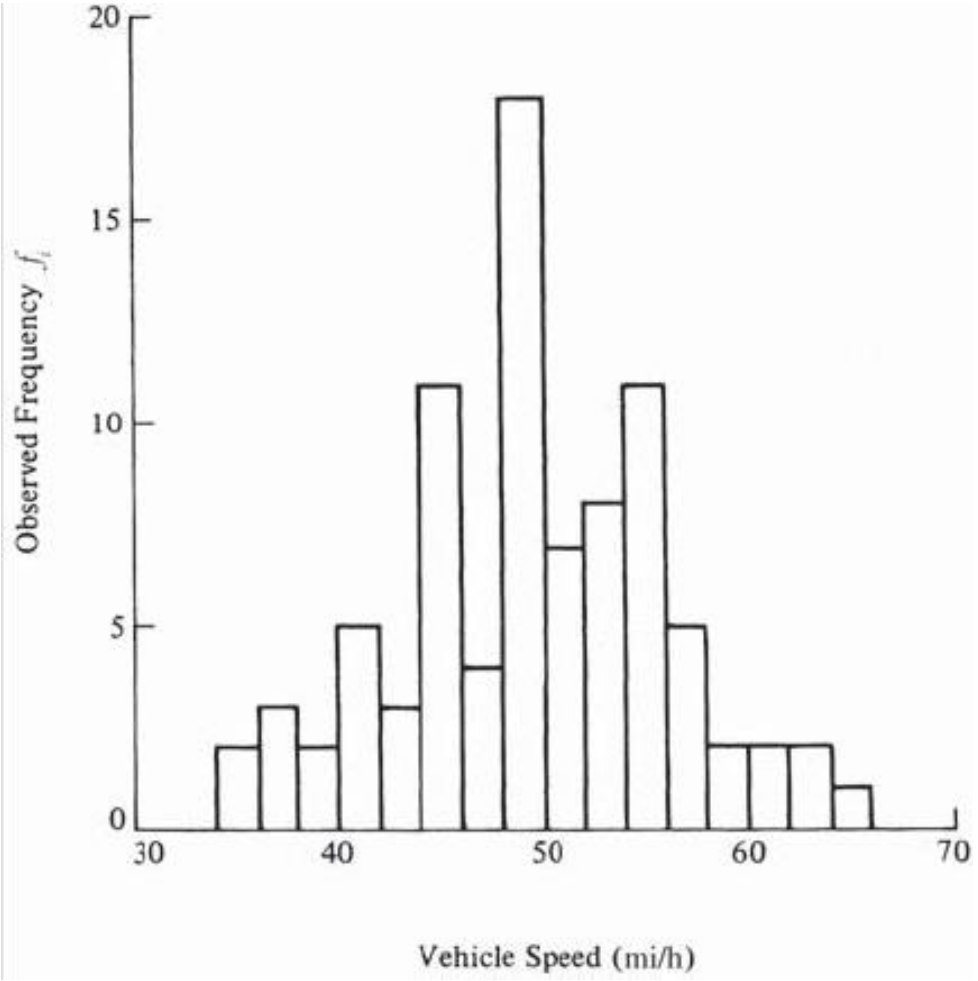



**Figure 4.4** Histogram of Observed Vehicles' Speeds

# Traffic Engineering Studies

| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|
| *Speed Class (mi/hr)* | *Class Midvalue, $u_i$* | *Class Frequency (Number of Observations in Class), $f_i$* | $f_i u_i$ | *Percentage of Observations in Class* | *Cumulative Percentage of All Observations* | $f(u_i - \bar{u})^2$ |
| 34–35.9 | 35.0 | 2 | 70 | 2.3 | 2.30 | 420.5 |
| 36–37.9 | 37.0 | 3 | 111 | 3.5 | 5.80 | 468.75 |
| 38–39.9 | 39.0 | 2 | 78 | 2.3 | 8.10 | 220.50 |
| 40–41.9 | 41.0 | 5 | 205 | 5.8 | 13.90 | 361.25 |
| 42–43.9 | 43.0 | 3 | 129 | 3.5 | 17.40 | 126.75 |
| 44–45.9 | 45.0 | 11 | 495 | 12.8 | 30.20 | 222.75 |
| 46–47.9 | 47.0 | 4 | 188 | 4.7 | 34.90 | 25.00 |
| 48–49.9 | 49.0 | 18 | 882 | 21.0 | 55.90 | 9.0 |
| 50–51.9 | 51.0 | 7 | 357 | 8.1 | 64.0 | 15.75 |
| 52–53.9 | 53.0 | 8 | 424 | 9.3 | 73.3 | 98.00 |
| 54–55.9 | 55.0 | 11 | 605 | 12.8 | 86.1 | 332.75 |
| 56–57.9 | 57.0 | 5 | 285 | 5.8 | 91.9 | 281.25 |
| 58–59.9 | 59.0 | 2 | 118 | 2.3 | 94.2 | 180.50 |
| 60–61.9 | 61.0 | 2 | 122 | 2.3 | 96.5 | 264.50 |
| 62–63.9 | 63.0 | 2 | 126 | 2.3 | 98.8 | 364.50 |
| 64–65.9 | 65.0 | 1 | 65 | 1.2 | 100.0 | 240.25 |
| Totals | | 86 | 4260 | | | 3632.00 |

**Table 4.3** Frequency Distribution Table for Set of Speed Data

# Traffic Engineering Studies

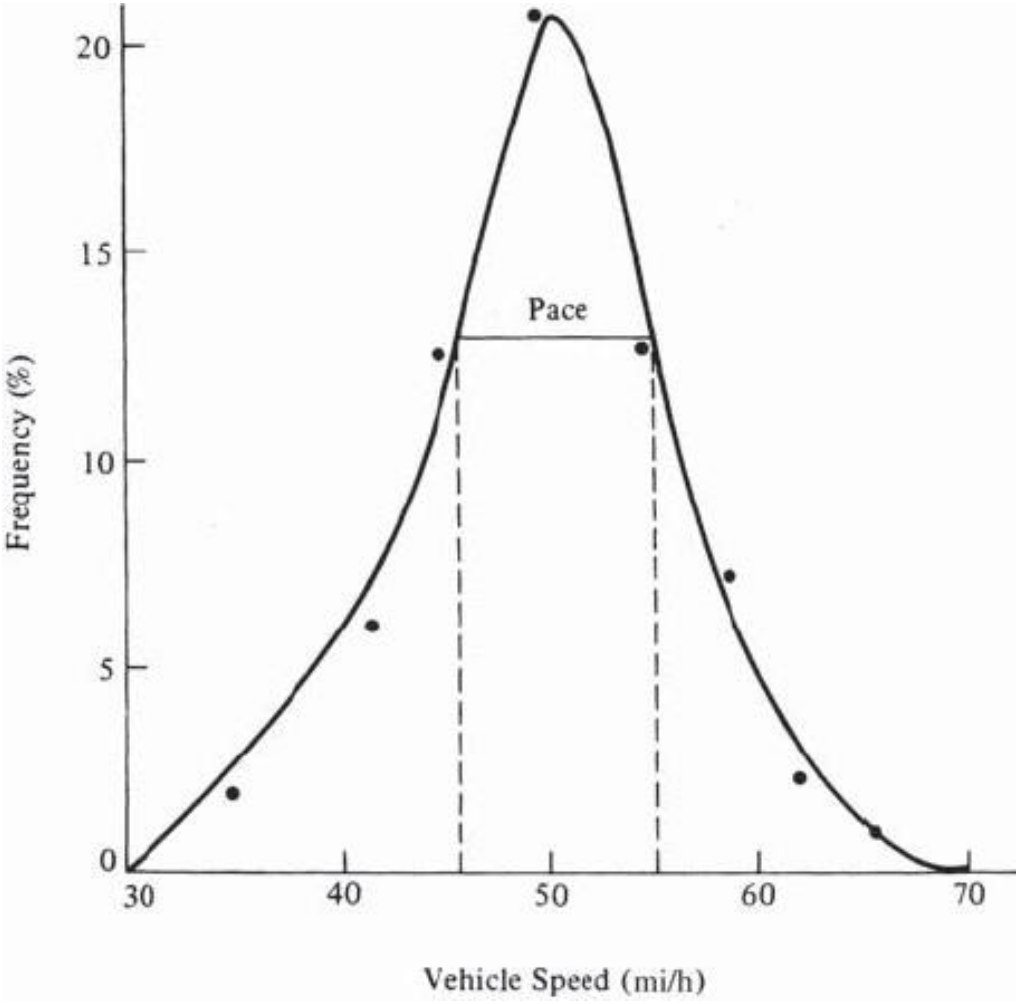



**Figure 4.5** Frequency Distribution

# Traffic Engineering Studies

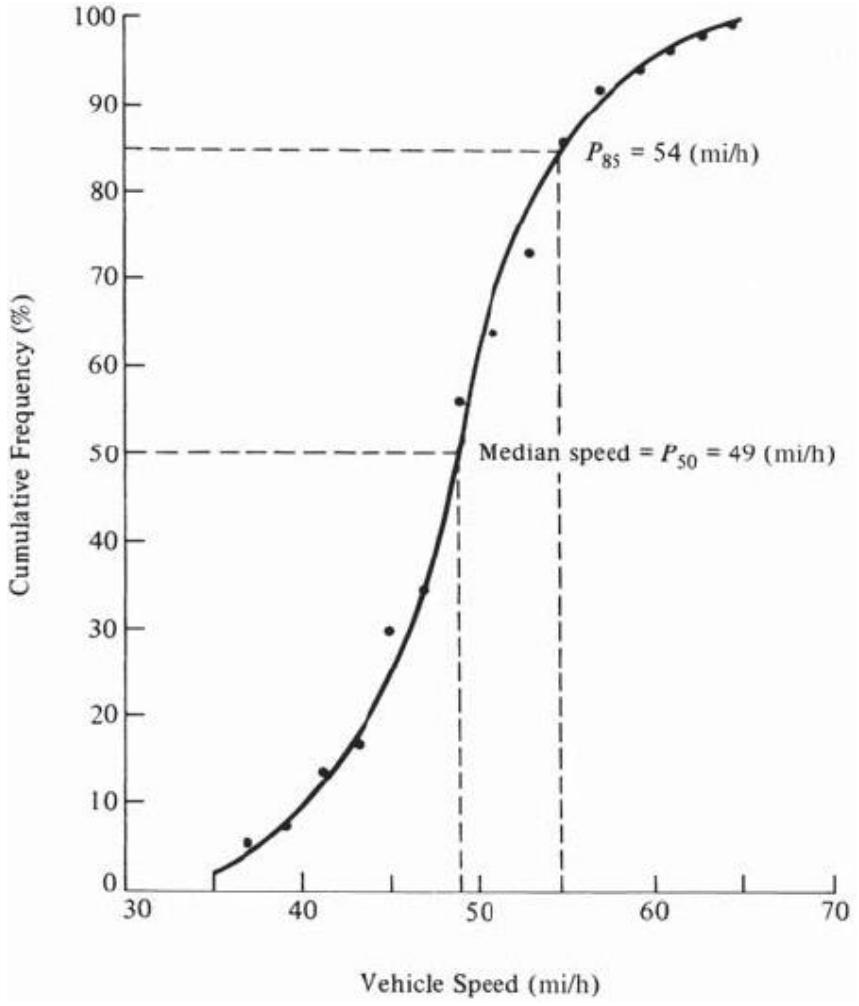



**Figure 4.6** Cumulative Distribution

# Traffic Engineering Studies

- The median speed 49 km/h,

  the $50^{th}$-percentile speed.
- $85^{th}$-percentile speed is 54 km/h

# Traffic Engineering Studies

- **4.2 VOLUME STUDIES**

1. **Average Annual Daily Traffic** (AADT)

   the average of 24-hour counts collected every day of the year.

2. **Average Daily Traffic** (ADT)

   the average of 24-hour counts collected over a number of days greater than one but less than a year.

# Traffic Engineering Studies

- **4.2 VOLUME STUDIES**

3. **Peak Hour Volume** (PHV)

   the maximum number of vehicles that pas a point on a highway during a period of 60 consecutive minutes.

4. **Vehicle Classification** (VC) with respect to the type of vehicles for cars, two-axle trucks, or three-axle trucks.
5. **Vehicle Miles of Travel** (VMT)

# Traffic Engineering Studies

- **4.2.1 Methods of Conducting Volume Counts**
  - Manual Method
  - Automatic Method

# Traffic Engineering Studies



**Figure 4.7** Jamar Traffic Data Collector TDC-1 2 Hooked to a Computer

# Traffic Engineering Studies



Figure 4.9 Apollo Traffic Counter/Classifier

# Traffic Engineering Studies




**Figure 4.10** Example of Counters that Require the Laying of Subsurface Detectors

# Traffic Engineering Studies

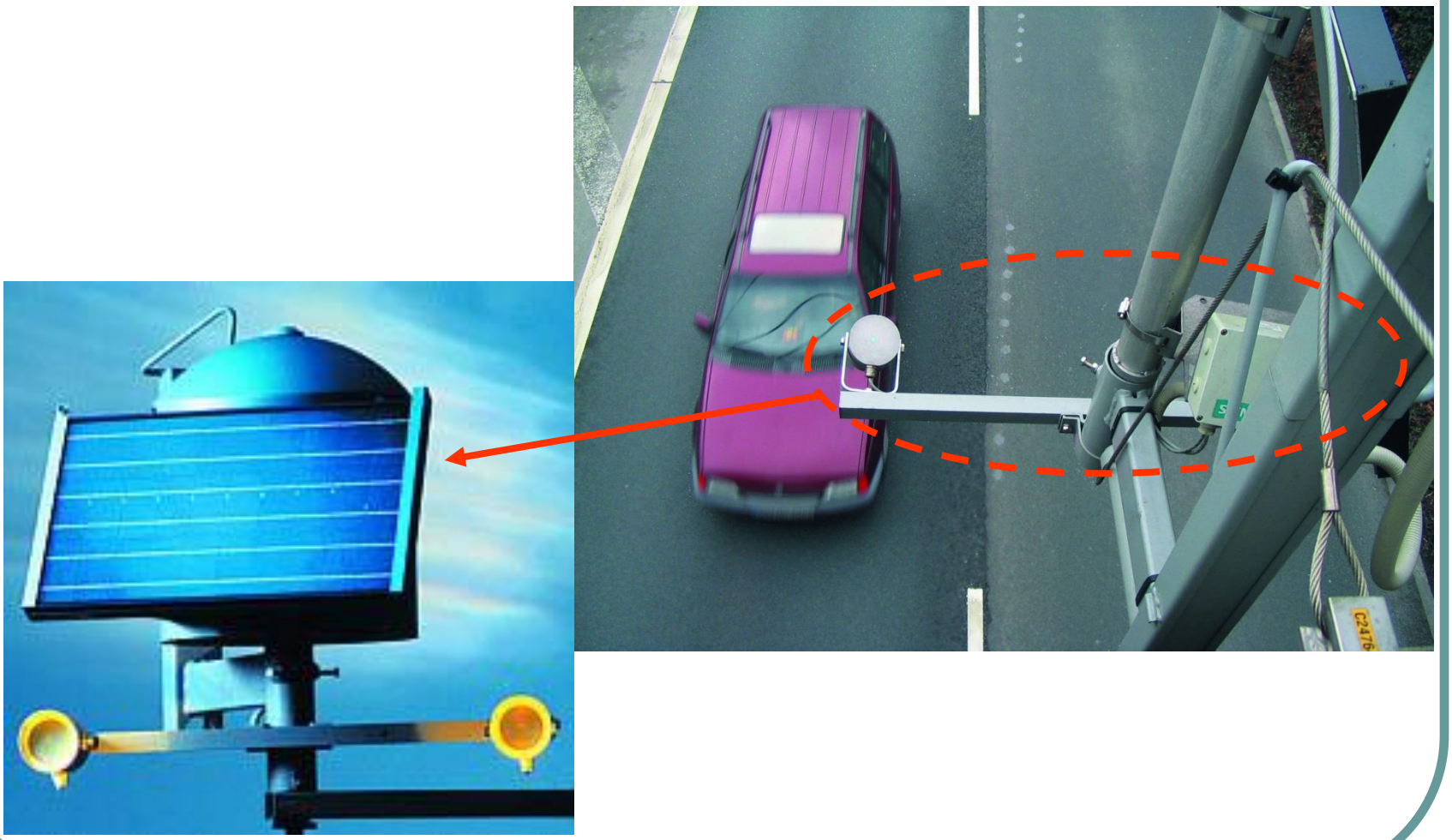


**Figure 4.11** Traffic Eye Universal System

# Traffic Engineering Studies

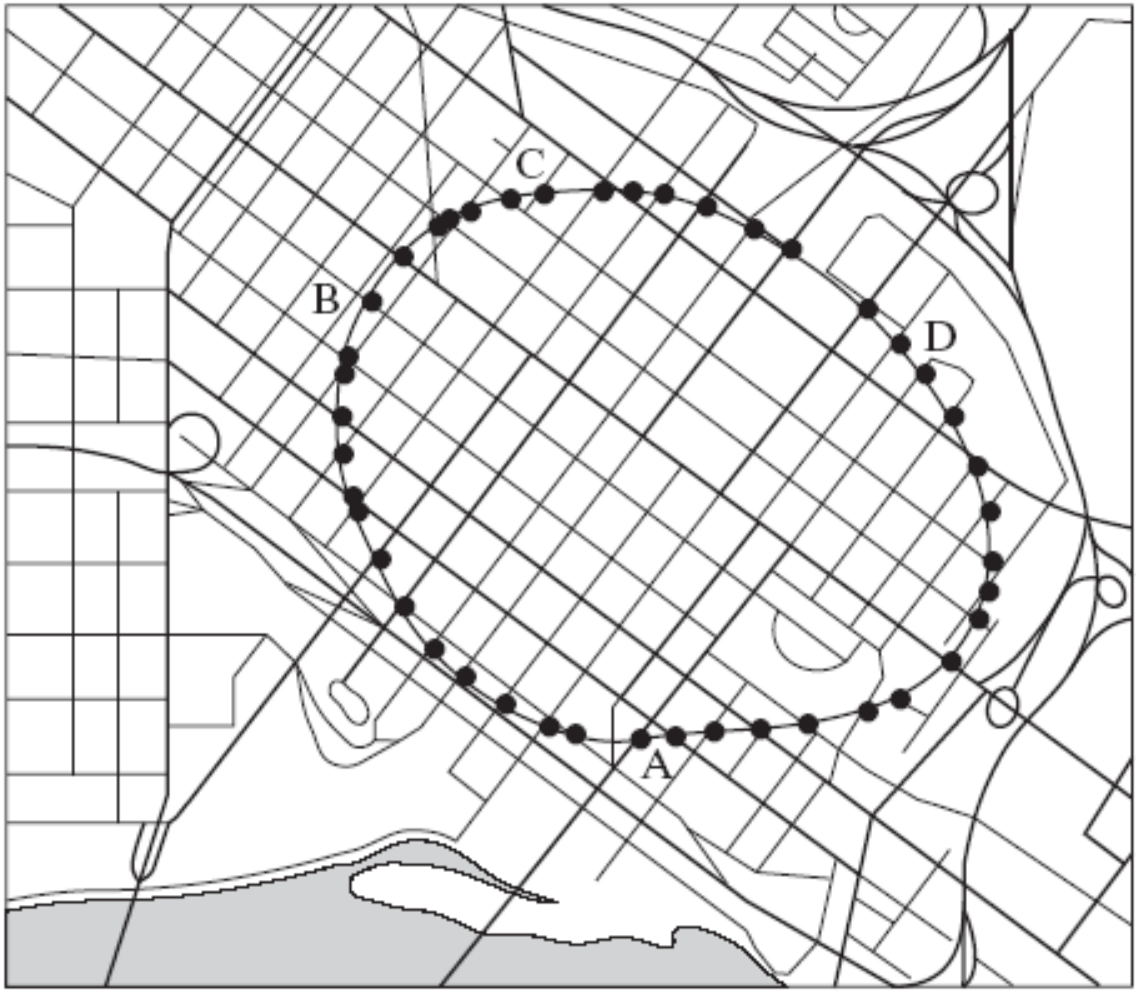



**Figure 4.12** Example of Station Locations for a Cordon Count

# Traffic Engineering Studies

- **4.2.2 Types of Volume Counts**
  - Depending on the anticipated use of the data to be collected.
- Intersection Counts
  - **vehicle classifications,**
  - **through movements,**
  - **turning movements.**

# Traffic Engineering Studies

- **4.2.2 Types of Volume Counts**
  - Pedestrian Volume Counts
  - Periodic Volume Counts (AADT)

# Traffic Engineering Studies

- **4.2.3 Traffic Volume Data Presentation**
  - **Traffic Flow Maps:** volume of traffic on each route is represented by the width of a band.

    *Figure 4.13 shows a typical traffic flow map.*

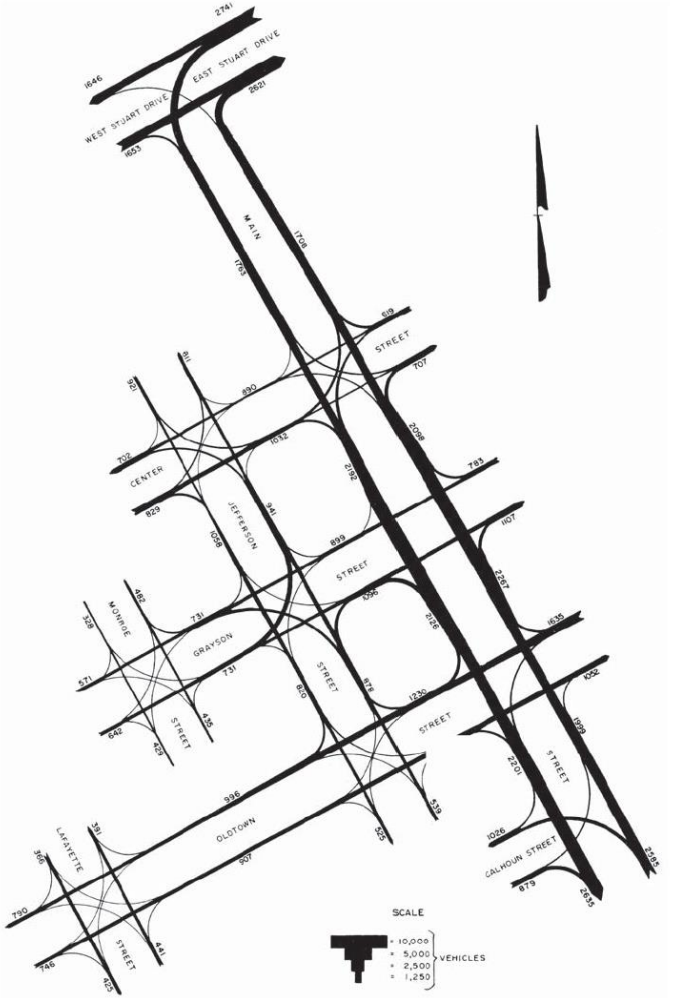



**Figure 4.13** Example of a Traffic Flow Map

# Traffic Engineering Studies

**Intersection Summary Sheets:**

***Figure 4.14 shows a typical intersection summary sheet.***

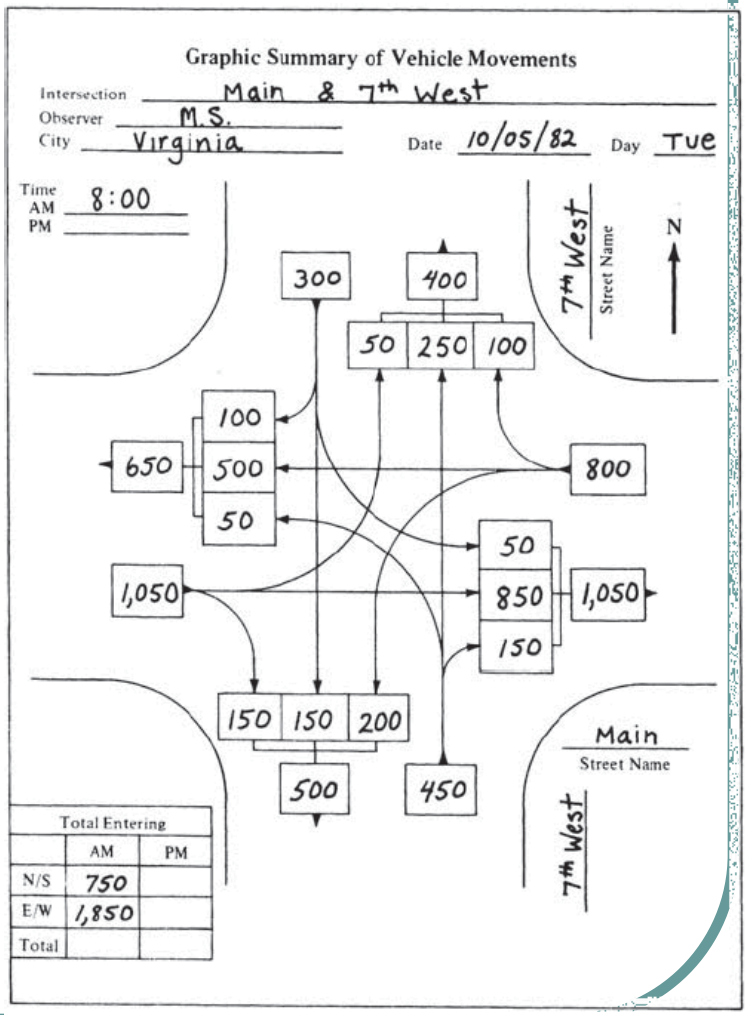



**Figure 4.14** Intersection Summary Sheet

# Traffic Engineering Studies

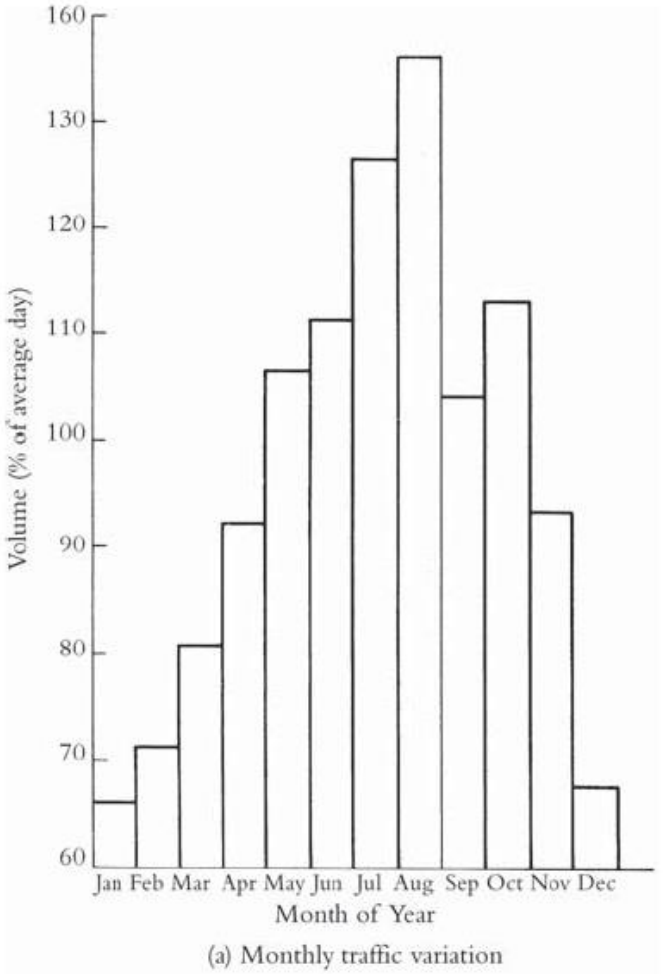
- **4.2.3 Traffic Volume Data Presentation**
  - Time-Based Distribution Charts:

    see Figure 4.15

# Traffic Engineering Studies

**Daily variations:**

**see Figure 4.15b**



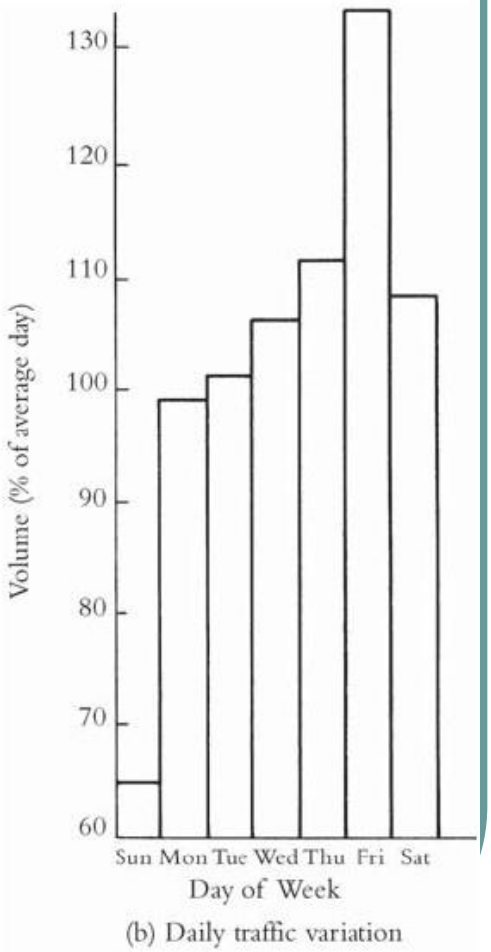




**Figure 4.15** Traffic Volumes on an Urban Highway (A&B)

# Traffic Engineering Studies

**Hourly variations in traffic volume:**

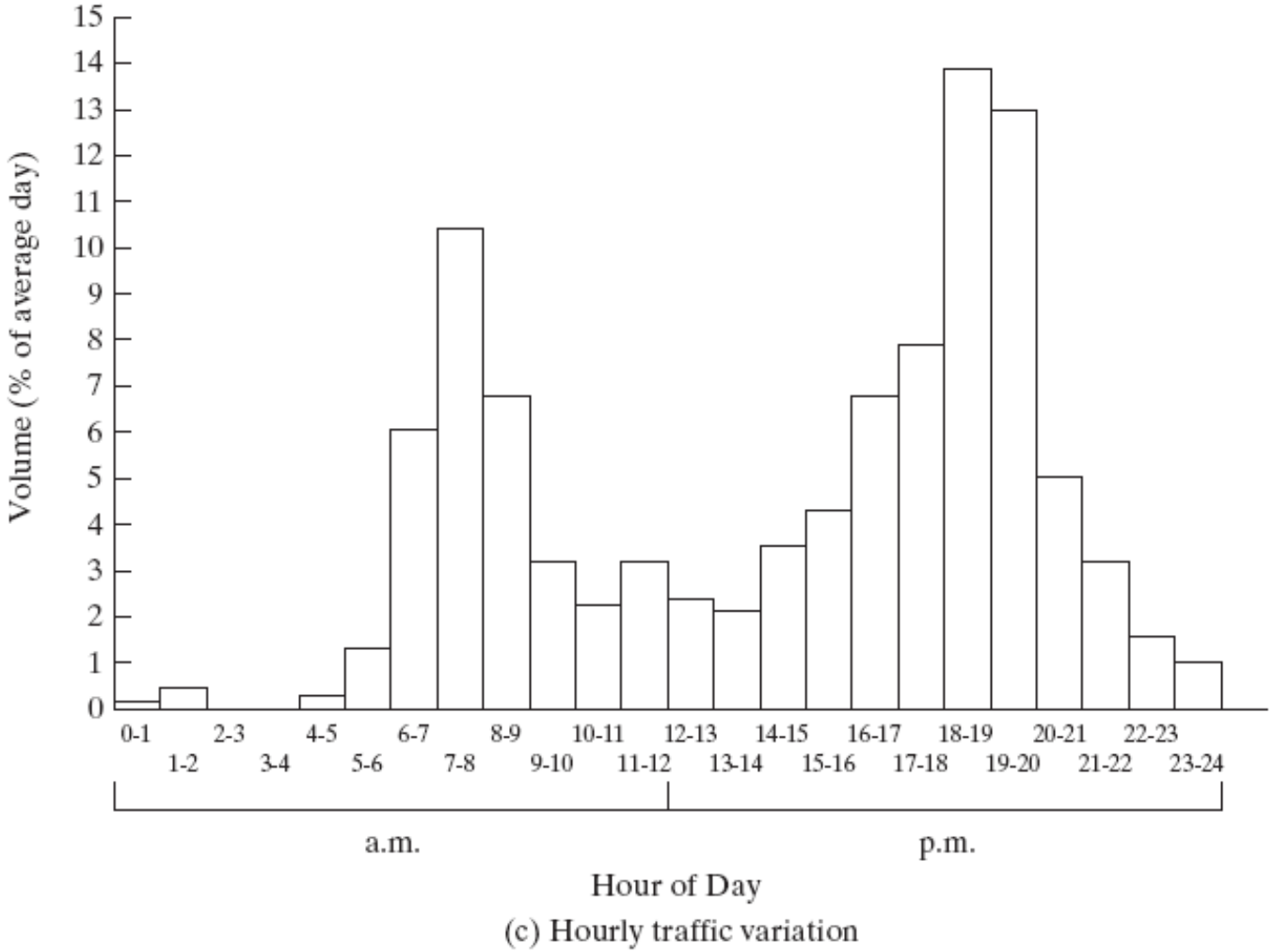



**Figure 4.15** Traffic Volumes on an Urban Highway (C)

# Traffic Engineering Studies

**Summary Tables:**

**PHV, Vehicle Classification (VC), and ADT. See Table 4.4**

**Table 4.4** Summary of Traffic Volume Data for a Highway Section

| | |
|---|---|
| PHV | 430 |
| ADT | 5375 |
| Vehicle Classification (VC) | |
| Passenger cars | 70% |
| Two-axle trucks | 20% |
| Three-axle trucks | 8% |
| Other trucks | 2% |

# Traffic Engineering Studies

- Adjustment of Periodic Counts
- Expansion Factors from Continuous Count Stations.
- Hourly expansion factors (HEFs) are determined by the formula

$$\text{HEF} = \frac{\text{total volume for 24-hr period}}{\text{volume for particular hour}}$$

# Traffic Engineering Studies

- Daily expansion factors (DEFs) are computed as

$$\text{DEF} = \frac{\text{average total volume for week}}{\text{average volume for particular day}}$$

- Monthly expansion factors (MEFs) are computed as

$$\text{MEF} = \frac{\text{AADT}}{\text{ADT for particular month}}$$

# Traffic Engineering Studies

**Table 4.5** Hourly Expansion Factors for a Rural Primary Road

| *Hour* | *Volume* | *HEF* | *Hour* | *Volume* | *HEF* |
|---|---|---|---|---|---|
| 6:00–7:00 a.m. | 294 | 42.00 | 6:00–7:00 p.m. | 743 | 16.62 |
| 7:00–8:00 a.m. | 426 | 29.00 | 7:00–8:00 p.m. | 706 | 17.49 |
| 8:00–9:00 a.m. | 560 | 22.05 | 8:00–9:00 p.m. | 606 | 20.38 |
| 9:00–10:00 a.m. | 657 | 18.80 | 9:00–10:00 p.m. | 489 | 25.26 |
| 10:00–11:00 a.m. | 722 | 17.10 | 10:00–11:00 p.m. | 396 | 31.19 |
| 11:00–12:00 p.m. | 667 | 18.52 | 11:00–12:00 a.m. | 360 | 34.31 |
| 12:00–1:00 p.m. | 660 | 18.71 | 12:00–1:00 a.m. | 241 | 51.24 |
| 1:00–2:00 p.m. | 739 | 16.71 | 1:00–2:00 a.m. | 150 | 82.33 |
| 2:00–3:00 p.m. | 832 | 14.84 | 2:00–3:00 a.m. | 100 | 123.50 |
| 3:00–4:00 p.m. | 836 | 14.77 | 3:00–4:00 a.m. | 90 | 137.22 |
| 4:00–5:00 p.m. | 961 | 12.85 | 4:00–5:00 a.m. | 86 | 143.60 |
| 5:00–6:00 p.m. | 892 | 13.85 | 5:00–6:00 a.m. | 137 | 90.14 |
| Total daily volume = 12,350. | | | | | |

# Traffic Engineering Studies

Table 4.6 Daily Expansion Factors for a Rural Primary Road

| *Day of Week* | *Volume* | *DEF* |
|---|---|---|
| Sunday | 7895 | 9.515 |
| Monday | 10,714 | 7.012 |
| Tuesday | 9722 | 7.727 |
| Wednesday | 11,413 | 6.582 |
| Thursday | 10,714 | 7.012 |
| Friday | 13,125 | 5.724 |
| Saturday | 11,539 | 6.510 |

Total weekly volume = 75,122.

# Traffic Engineering Studies

**Table 4.7** Monthly Expansion Factors for a Rural Primary Road

| *Month* | *ADT* | *MEF* |
|---|---|---|
| January | 1350 | 1.756 |
| February | 1200 | 1.975 |
| March | 1450 | 1.635 |
| April | 1600 | 1.481 |
| May | 1700 | 1.394 |
| June | 2500 | 0.948 |
| July | 4100 | 0.578 |
| August | 4550 | 0.521 |
| September | 3750 | 0.632 |
| October | 2500 | 0.948 |
| November | 2000 | 1.185 |
| December | 1750 | 1.354 |

Total yearly volume = 28,450.
Mean average daily volume = 2370.

# Traffic Engineering Studies

**Example 4.5** Calculating AADT Using Expansion Factors

A traffic engineer urgently needs to determine the AADT on a rural primary road that has the volume distribution characteristics shown in Tables 4.5, 4.6, and 4.7. She collected the data shown below on a Tuesday during the month of May. Determine the AADT of the road.

| | |
|---|---|
| 7:00–8:00 a.m. | 400 |
| 8:00–9:00 a.m. | 535 |
| 9:00–10:00 a.m. | 650 |
| 10:00–11:00 a.m. | 710 |
| 11:00–12 noon | 650 |

# Traffic Engineering Studies

Solution:

- Estimate the 24-hr volume for Tuesday using the factors given in Table 4.5.

$$\frac{(400 \times 29.0 + 535 \times 22.05 + 650 \times 18.80 + 710 \times 17.10 + 650 \times 18.52)}{5} \approx 11{,}959$$

- Adjust the 24-hr volume for Tuesday to an average volume for the week using the factors given in Table 4.6.

$$\text{Total 7-day volume} = 11{,}959 \times 7.727$$

$$\text{Average 24-hr volume} = \frac{11{,}959 \times 7.727}{7} = 13{,}201$$

- Since the data were collected in May, use the factor shown for May in Table 4.7 to obtain the AADT.

$$\text{AADT} = 13{,}201 \times 1.394 = 18{,}402$$

# Traffic Engineering Studies

- **4.3 TRAVEL TIME AND DELAY STUDIES**
  - Travel time: time required to travel from one point to another on a given route.
  - the locations, durations, and causes of delays.
  - good indication of the level of service
  - identifying problem locations,

# Traffic Engineering Studies

- **4.3.1 Applications of Travel Time and Delay Data**
  - efficiency of a route
  - locations with relatively high delays
  - causes for delays
  - before-and-after studies
  - relative efficiency of a route
  - travel times on specific links
  - economic studies

# Traffic Engineering Studies

- **4.3.2 Definition of Terms Related to Time and Delay Studies**

1. **Travel time:** time taken by a vehicle to traverse a given section of a highway.
2. **Running time:** time a vehicle is actually in motion

# Traffic Engineering Studies

- 4.3.2 Definition of Terms Related to Time and Delay Studies

3. **Delay** time lost due to causes beyond the control of the driver.
4. **Operational delay:** delay caused by the impedance of other traffic.

   (for example, parking or unparking vehicles),

# Traffic Engineering Studies

5. **Stopped-time delay**
6. **Fixed delay:** caused by control devices such as traffic signals, regardless of the traffic volume
7. **Travel-time delay:** difference between the actual travel time and the travel time obtained by assuming that a vehicle traverses at an average speed equal to that for an uncongested traffic flow

# Traffic Engineering Studies

- **4.3.3 Methods for Conducting Travel Time and Delay Studies**
  - Methods Requiring a Test Vehicle: floating-car, average-speed, and moving-vehicle techniques.

# Traffic Engineering Studies

**Table 4.8** Speed and Delay Information

*Street Name: 29 North* *Date: July 7, 1994*
*Weather: Clear* *Non-peak* *Time: 2:00–3:00 p.m.*

| *Cross Streets* | *Distance (ft)* | *Travel Time (sec)* | *Segment Speed (mi/h)* | *Stop Time (sec)* | *Reason for Stoppage* | *Speed Limit (mi/h)* | *Ideal Travel Time (sec)* | *Segment Delay (sec)* | *Net Speed (mi/h)* |
|---|---|---|---|---|---|---|---|---|---|
| Ivy Road | 0 | 0.0 | – | 0.0 | | – | 0.0 | 0.0 | – |
| Massie Road | 1584 | 42.6 | 25.4 | 20.1 | Signal | 40 | 27.0 | 15.6 | 17.2 |
| Arlington Blvd. | 1320 | 27.7 | 32.5 | 0.0 | | 40 | 22.5 | 5.2 | 32.5 |
| Wise Street | 792 | 19.7 | 27.4 | 8.9 | Signal | 40 | 13.5 | 6.2 | 18.9 |
| Barracks Road | 1320 | 32.1 | 28.0 | 15.4 | Signal | 40 | 22.5 | 9.6 | 18.9 |
| Angus Road | 2244 | 49.8 | 30.7 | 9.2 | Signal | 40 | 38.3 | 11.5 | 25.9 |
| Hydraulic Road | 1584 | 24.4 | 44.3 | 0.0 | | 45 | 24.0 | 0.4 | 44.3 |
| Seminole Court | 1584 | 42.6 | 25.4 | 19.5 | Signal | 45 | 24.0 | 18.6 | 17.4 |
| Greenbrier Drive | 1848 | 41.5 | 30.4 | 15.6 | Signal | 45 | 28.0 | 13.5 | 22.1 |
| Premier Court | 1320 | 37.4 | 24.1 | 11.8 | Signal | 45 | 20.0 | 17.4 | 18.3 |
| Fashion Square I | 1584 | 23.6 | 45.8 | 4.9 | Signal | 45 | 24.0 | −0.4 | 37.9 |
| Fashion Square II | 1056 | 19.7 | 36.5 | 0.0 | | 45 | 16.0 | 3.7 | 36.5 |
| Rio Road | 1056 | 20.2 | 35.6 | 14.1 | Signal | 45 | 16.0 | 4.2 | 21.0 |
| Totals | 17292 | 381.3 | 30.9 | 119.5 | | | 275.8 | 105.5 | 23.5 |

*Note*: Segment delay is the difference between observed travel time and calculated ideal travel time.
SOURCE: Study conducted in Charlottesville, VA, by Justin Black and John Ponder.

# Traffic Engineering Studies

***Moving-Vehicle Technique***

***(moving observer):***

- the observer makes a round trip on a test section Figure 4.16,
- The observer starts at section X-X, drives the car eastward to section Y-Y,
- turns the vehicle around
- drives westward to section X-X again

# Traffic Engineering Studies

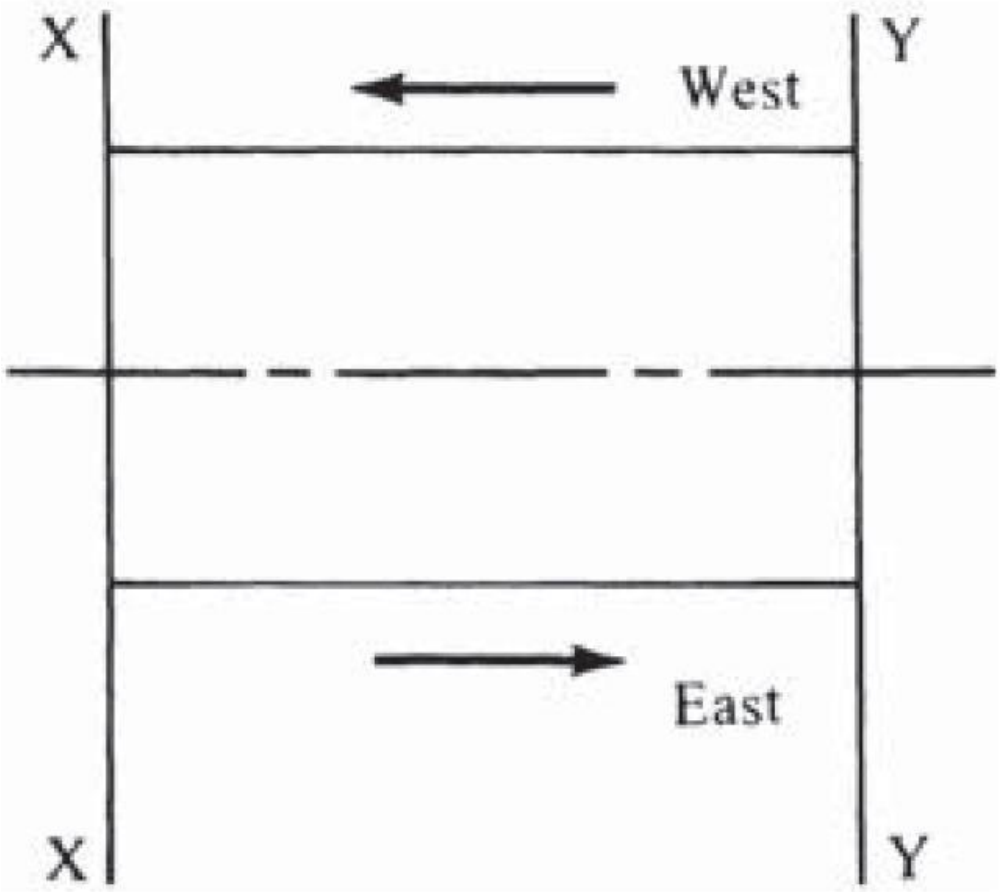
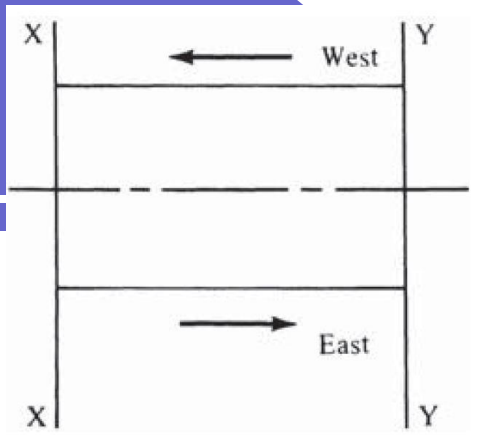



**Figure 4.16** Test Site for Moving-Vehicle Method

# Traffic Engineering Studies




***Moving-Vehicle Technique.***

- **following data are collected as**
  - The time it takes to travel east from X-X to Y-Y (*Te*), in minutes
  - The time it takes to travel west from Y-Y to X-X (*Tw*), in minutes
  - The number of vehicles traveling west in the opposite lane while the test car is traveling east (*Ne*)

# Traffic Engineering Studies

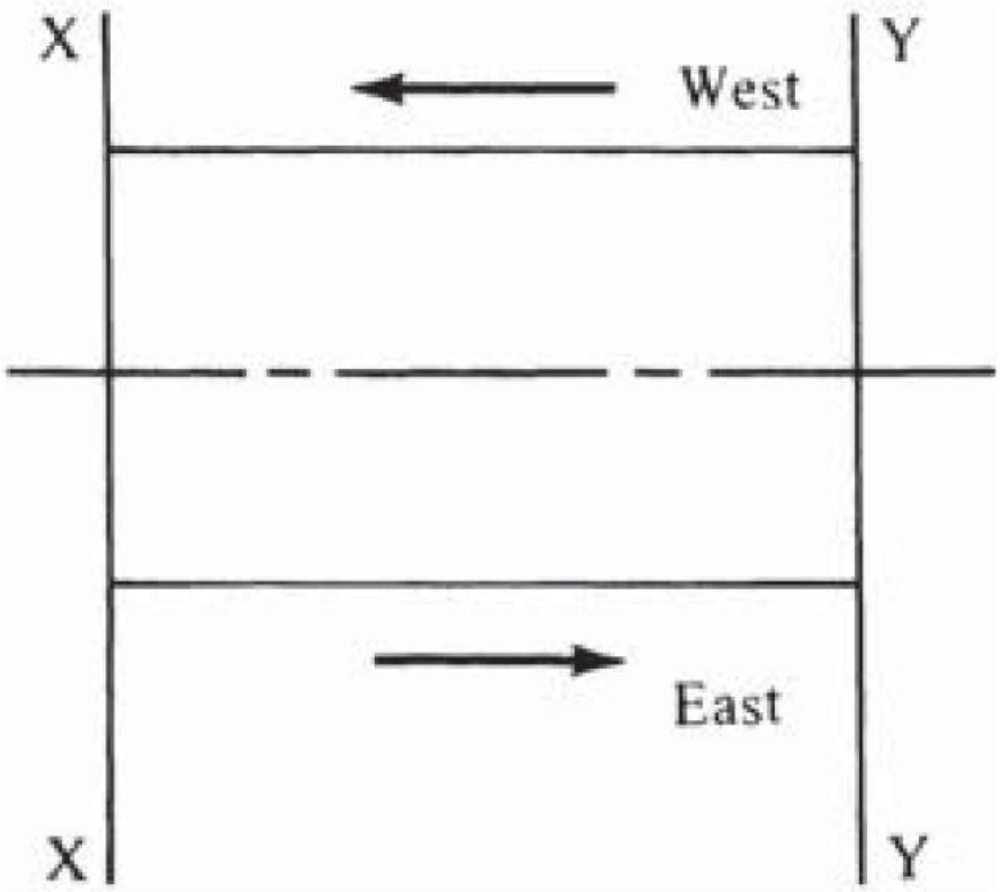
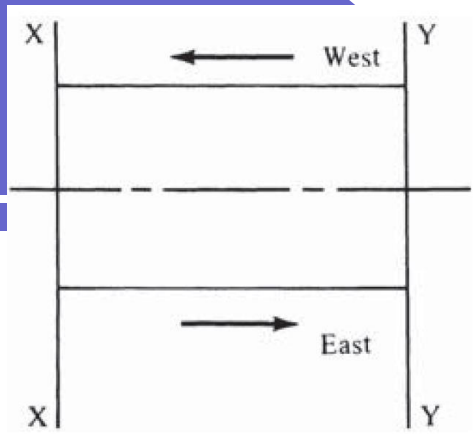



**Figure 4.16** Test Site for Moving-Vehicle Method

# Traffic Engineering Studies




***Moving-Vehicle Technique.***

- The number of vehicles that overtake the test car while it is traveling west from Y-Y to X-X, that is, traveling in the westbound direction (*Ow*)
- The number of vehicles that the test car passes while it is traveling west from Y-Y to X-X, that is, traveling in the westbound direction (*Pw*)

# Traffic Engineering Studies

***Moving-Vehicle Technique.***

- The volume ($V_w$) in the westbound direction can then be obtained from the expression:

$$V_w = \frac{(N_e + O_w - P_w)60}{T_e + T_w}$$

# Traffic Engineering Studies

- where ($N_e$ $O_w$ $P_w$) is the number of vehicles traveling westward that cross the line X-X during the time ($T_e T_w$).
- Similarly, the average travel time in the westbound direction is obtained from

$$\frac{\overline{T}_w}{60} = \frac{T_w}{60} - \frac{O_w - P_w}{V_w}$$

$$\overline{T}_w = T_w - \frac{60(O_w - P_w)}{V_w}$$

# Traffic Engineering Studies

**Example 4.6** Volume and Travel Time Using Moving-Vehicle Technique

The data in Table 4.9 were obtained in a travel time study on a section of highway using the moving-vehicle technique. Determine the travel time and volume in each direction at this section of the highway.

Mean time it takes to travel eastward ($T_e$) = 2.85 min

Mean time it takes to travel westbound ($T_w$) = 3.07 min

Average number of vehicles traveling westward when test vehicle is traveling eastward ($N_e$) = 79.50

Average number of vehicles traveling eastward when test vehicle is traveling westward ($N_w$) = 82.25

Average number of vehicles that overtake test vehicle while it is traveling westward ($O_w$) = 1.25

# Traffic Engineering Studies

**Table 4.9** Data from Travel Time Study Using the Moving-Vehicle Technique

| *Run Direction/ Number* | *Travel Time (min)* | *No. of Vehicles Traveling in Opposite Direction* | *No. of Vehicles That Overtook Test Vehicle* | *No. of Vehicles Overtaken by Test Vehicle* |
|---|---|---|---|---|
| Eastward | | | | |
| 1 | 2.75 | 80 | 1 | 1 |
| 2 | 2.55 | 75 | 2 | 1 |
| 3 | 2.85 | 83 | 0 | 3 |
| 4 | 3.00 | 78 | 0 | 1 |
| 5 | 3.05 | 81 | 1 | 1 |
| 6 | 2.70 | 79 | 3 | 2 |
| 7 | 2.82 | 82 | 1 | 1 |
| 8 | 3.08 | 78 | 0 | 2 |
| Average | 2.85 | 79.50 | 1.00 | 1.50 |

# Traffic Engineering Studies

**Table 4.9** Data from Travel Time Study Using the Moving-Vehicle Technique

| | | | | |
|---|---|---|---|---|
| Westward | | | | |
| 1 | 2.95 | 78 | 2 | 0 |
| 2 | 3.15 | 83 | 1 | 1 |
| 3 | 3.20 | 89 | 1 | 1 |
| 4 | 2.83 | 86 | 1 | 0 |
| 5 | 3.30 | 80 | 2 | 1 |
| 6 | 3.00 | 79 | 1 | 2 |
| 7 | 3.22 | 82 | 2 | 1 |
| 8 | 2.91 | 81 | 0 | 1 |
| Average | 3.07 | 82.25 | 1.25 | 0.875 |

Average number of vehicles that overtake test vehicle while it is traveling eastward ($O_e$) = 1.00

Average number of vehicles the test vehicle passes while traveling westward ($P_w$) = 0.875

Average number of vehicles the test vehicle passes while traveling eastward ($P_e$) = 1.5

# Traffic Engineering Studies

Solution:

- From Eq. 4.9, find the volume in the westbound direction.

$$V_w = \frac{(N_e + O_w - P_w)60}{T_e + T_w}$$

$$= \frac{(79.50 + 1.25 - 0.875)60}{2.85 + 3.07} = 809.5 \qquad \text{(or 810 veh/h)}$$

- Similarly, calculate the volume in the eastbound direction.

$$V_e = \frac{(82.25 + 1.00 - 1.50)60}{2.85 + 3.07} = 828.5 \qquad \text{(or 829 veh/h)}$$

# Traffic Engineering Studies

Solution:

- Find the average travel time in the westbound direction.

$$\overline{T}_w = 3.07 - \frac{(1.25 - 0.875)}{810} 60 = 3.0 \text{ min}$$

- Find the average travel time in the eastbound direction.

$$\overline{T}_e = 2.85 - \frac{(1.00 - 1.50)}{829} 60 = 2.9 \text{ min}$$

# Traffic Engineering Studies

- **Methods Not Requiring a Test Vehicle**
- ***License-Plate* Observations:** observers at the beginning and end of the test section.
- Each observer records the last three or four digits of the license plate of each car that passes, together with the time at which the car passes.

# Traffic Engineering Studies

- in the office by matching the times of arrival at the beginning and end of the test section for each license plate recorded.
- difference between these times is the traveling time of each vehicle.
- average of these is the average traveling time on the test section.

# Traffic Engineering Studies

- a sample size of 50 matched license plates.
- ***Interviews:*** obtaining information from people who drive on the study site regarding their travel times, experience of delays, requires the cooperation of the people.

# Traffic Engineering Studies

- ***ITS Advanced Technologies:***
  - Advanced technologies
  - Cell phones
  - GPS satellite system
  - technology is used to determine average speeds and travel times along highways

# Traffic Engineering Studies

## 4.4 PARKING STUDIES

- Any vehicle will at one time be parked short time or longer time, provision of parking facilities is essential
- need for parking spaces is usually very great in areas of business, residential, or commercial activities.
- park-and-ride

# Traffic Engineering Studies

- Providing adequate parking space to meet the demand for parking in the Central Business District (CBD)
- This problem usually confronts a city traffic engineer.
- solution is not simple, Parking studies are used to determine the demand for and the supply of parking facilities.

# Traffic Engineering Studies

## 4.4.1 Types of Parking Facilities

- On-Street Parking Facilities
  - also known as curb facilities. Parking bays are provided alongside the curb on one or both sides of the street.
  - unrestricted parking
  - unlimited and free
  - Restricted parking facilities

# Traffic Engineering Studies

- On-Street Parking Facilities
  - limited to specific times for a maximum duration.
  - may or may not be free.
  - handicapped parking
  - bus stops
  - loading bays.

# Traffic Engineering Studies

- Off-Street Parking Facilities
  - privately or publicly owned;
  - surface lots and garages.
  - Self-parking garages
  - attendant-parking garages

# Traffic Engineering Studies

## 4.4.2 Definitions of Parking Terms

1. **A space-hour** is a unit of parking that defines the use of a single parking space for a period of 1 hour.
2. **Parking volume** is the total number of vehicles that park in a study area during a specific length of time, usually a day.

# Traffic Engineering Studies

3. **Parking accumulation** is the number of parked vehicles in a study area at any specified time.
4. **parking load** the number of space-hours used during the specified period of time.
5. **Parking duration** length of time a vehicle is parked at a parking indication of how frequently a parking space becomes available.

# Traffic Engineering Studies

6. **Parking turnover** rate of use of a parking space.

   Obtained by dividing the parking volume for a specified period by the number of parking spaces.

# Traffic Engineering Studies

## 4.4.3 Methodology of Parking Studies

- Inventory of Existing Parking Facilities
  - detailed listing of the location and all other relevant characteristics of each legal parking facility, private and public.
  - The study area includes both on- and off-street facilities.

# Traffic Engineering Studies

- Type and number of parking spaces at each parking facility
- Times of operation and limit on duration of parking, if any
- Type of ownership (private or public)
- Parking fees, method of collection
- Restrictions
- Other restrictions, loading and unloading zones, bus stops, taxi ranks
- Permanency

- The inventory should be updated at regular intervals of about four to five years.

# Traffic Engineering Studies

## 4.4.3 Methodology of Parking Studies

- Collection of Parking Data
  - ***Accumulation:***
    - by checking the amount of parking during regular intervals on different days of the week.
    - Carried out on an hourly or 2-hour basis
    - used to determine hourly variations of parking and peak periods of parking demand.

# Traffic Engineering Studies

- Collection of Parking Data
  - ***Turnover and Duration:***
    - collecting data on a sample of parking spaces in a given block.
    - recording the license plate of the vehicle parked on each parking space in the sample at the ends of fixed intervals during the study period.
    - The length of the fixed intervals depends on the maximum permissible duration.

# Traffic Engineering Studies

- ***Turnover and Duration:***
  - For example, if the maximum permissible duration of parking at a curb face is 1 hour, a suitable interval is every 20 minutes.
  - If the permissible duration is 2 hours, checking every 30 minutes would be appropriate. Turnover is then obtained from the equation

$$T = \frac{\text{number of different vehicles parked}}{\text{number of parking spaces}}$$

# Traffic Engineering Studies

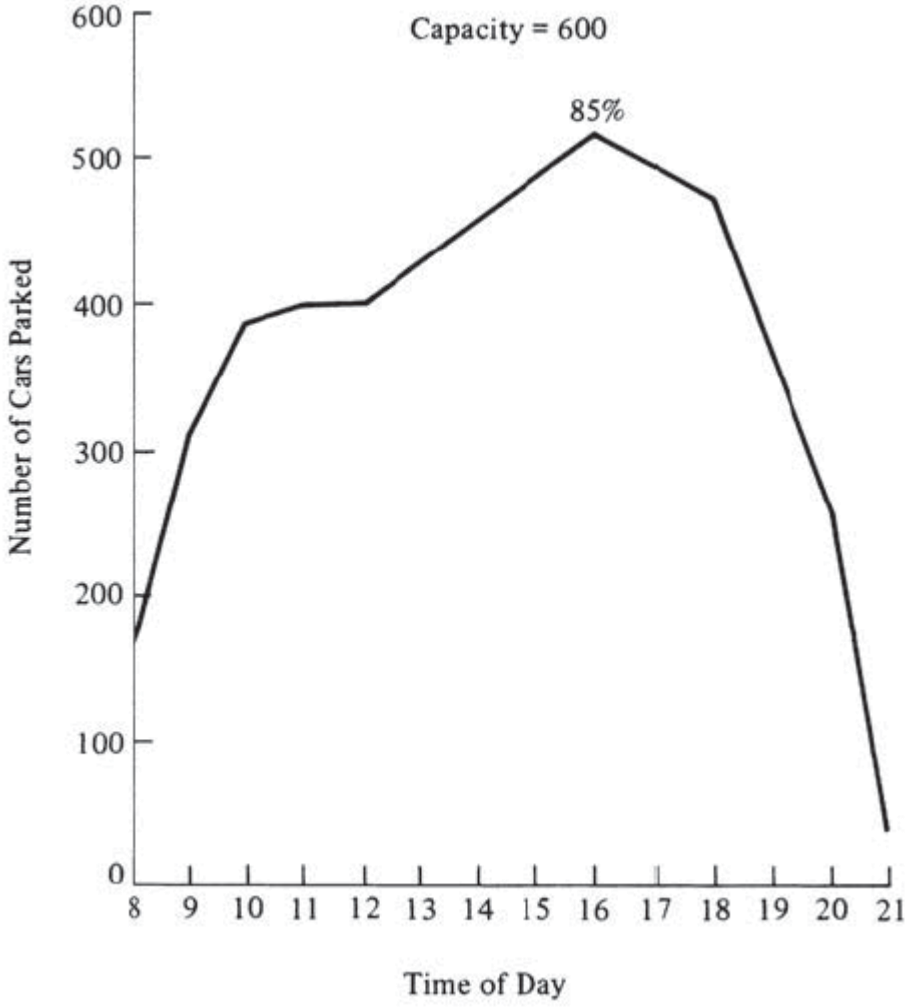



**Figure 4.17** Parking Accumulation at a Parking Lot

# Traffic Engineering Studies

- **Parking Demand**
  - by interviewing drivers at the various parking facilities
  - Interview all drivers using the parking facilities on a typical weekday between 8:00 a.m. and 10:00 p.m.
  - Information include (1) trip origin, (2) purpose of trip, (3) driver's destination after parking.
  - the location of the parking facility, times of arrival and departure, vehicle type.

# Traffic Engineering Studies

- **Parking Demand**
  - Parking interviews also can be carried out using the postcard technique,
  - about 30 to 50 percent of the cards distributed are returned.

# Traffic Engineering Studies

**Example 4.7** Space Requirements for a Parking Garage

The owner of a parking garage located in a CBD has observed that 20% of those wishing to park are turned back every day during the open hours of 8 a.m. to 6 p.m. because of lack of parking spaces. An analysis of data collected at the garage indicates that 60% of those who park are commuters, with an average parking duration of 9 hr, and the remaining are shoppers, whose average parking duration is 2 hr. If 20% of those who cannot park are commuters and the rest are shoppers, and a total of 200 vehicles currently park daily in the garage, determine the number of additional spaces required to meet the excess demand. Assume parking efficiency is 0.90.

# Traffic Engineering Studies

Solution:

- Calculate the space-hours of demand using Eq. 4.12.

$$D = \sum_{i=1}^{N} (n_i t_i)$$

Commuters now being served = $0.6 \times 200 \times 9 = 1080$ space-hr
Shoppers now being served = $0.4 \times 200 \times 2 = 160$ space-hr
Total number of vehicles turned away = $\frac{200}{0.8} - 200 = 50$
Commuters not being served = $0.2 \times 50 \times 9 = 90$ space-hr
Shoppers not being served = $0.8 \times 50 \times 2 = 80$ space-hr
Total space-hours of demand = $(1080 + 160 + 90 + 80) = 1410$
Total space-hours served = $1080 + 160 = 1240$
Number of space-hours required = $1410 - 1240 = 170$

# Traffic Engineering Studies

- Determine the number of parking spaces required from Eq. 4.13.

$$S = f \sum_{i=1}^{N} t_i = 170 \text{ space-hr}$$

- Use the length of time each space can be legally parked on (8 a.m. through 6 p.m. = 10 hr) to determine the number of additional spaces.

$$0.9 \times 10 \times N = 170$$
$$N = 18.89$$

At least 19 additional spaces will be required, since a fraction of a space cannot be used.