Chapter 4

Traffic Engineering Studies

Reference:
Traffic & Highway Engineering
N. J. Garber & L. A. Hoel pp 99-150
2009
Traffic studies may be grouped into three main categories:

1. Inventories,
2. Administrative studies, and
3. Dynamic studies.
(1) Inventories: provide a list or graphic display of existing information, such as:

- street widths,
- parking spaces,
- transit routes,
- traffic regulations.
(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.
(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.
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.
SPOT SPEED STUDIES

Used to:

- Establish parameters for traffic operation and control, such as:
  - speed zones,
  - speed limits (85th-percentile speed)
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*. 
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.
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.
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
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.
Spot Speed Study
Data Collection Form

Location: ___________________________ Observer's (group #): ___________________________
Date: ___________ Time: ___________ Direction of Travel: ___________________________ Posted Speed: ______

Weather Conditions: ___________________________
Safety officer: ___________________________

<table>
<thead>
<tr>
<th>Vehicle number</th>
<th>Speed, mph</th>
<th>Vehicle number</th>
<th>Speed, mph</th>
<th>Vehicle number</th>
<th>Speed, mph</th>
<th>Vehicle number</th>
<th>Speed, mph</th>
</tr>
</thead>
<tbody>
<tr>
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</tr>
</tbody>
</table>
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,
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
<table>
<thead>
<tr>
<th>Speed Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Median speed</td>
<td>The speed at the middle value in a series of spot speeds. Or, 50\textsuperscript{th}-percentile speed</td>
</tr>
<tr>
<td>Modal speed</td>
<td>The speed value that occurs most frequently in a sample of speeds</td>
</tr>
<tr>
<td>\textit{i}\textsuperscript{th}-percentile speed</td>
<td>The spot speed below which \textit{i} percent of the vehicles travel, e.g. 85\textsuperscript{th}-percentile speed</td>
</tr>
<tr>
<td>Pace</td>
<td>The range of speed that has the greatest number of observations; usually 10-mph range</td>
</tr>
</tbody>
</table>
Traffic Engineering Studies

(a) RTMS Deployed in the Forward Looking Mode
(b) RTMS Deployed in the Side-fire Mode
(a) Schematic Illustration of the Auto scope
(b) The Auto scope Deployed
4.1.5 Presentation and Analysis of Spot Speed Data

- Statistical methods
- Analyzing data
- Frequency histogram
- Cumulative frequency distribution curve
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 85th-percentile speed
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

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

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

Table 4.2 Speed Data Obtained on a Rural Highway
Figure 4.4 Histogram of Observed Vehicles' Speeds
### Traffic Engineering Studies

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

<table>
<thead>
<tr>
<th>Speed Class (mi/hr)</th>
<th>Class Midvalue, $u_i$</th>
<th>Frequency (Number of Observations in Class), $f_i$</th>
<th>$f \mu_i$</th>
<th>Percentage of Observations in Class</th>
<th>Cumulative Percentage of All Observations</th>
<th>$f(u_i - \bar{u})^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>34–35.9</td>
<td>35.0</td>
<td>2</td>
<td>70</td>
<td>2.3</td>
<td>2.30</td>
<td>420.5</td>
</tr>
<tr>
<td>36–37.9</td>
<td>37.0</td>
<td>3</td>
<td>111</td>
<td>3.5</td>
<td>5.80</td>
<td>468.75</td>
</tr>
<tr>
<td>38–39.9</td>
<td>39.0</td>
<td>2</td>
<td>78</td>
<td>2.3</td>
<td>8.10</td>
<td>220.50</td>
</tr>
<tr>
<td>40–41.9</td>
<td>41.0</td>
<td>5</td>
<td>205</td>
<td>5.8</td>
<td>13.90</td>
<td>361.25</td>
</tr>
<tr>
<td>42–43.9</td>
<td>43.0</td>
<td>3</td>
<td>129</td>
<td>3.5</td>
<td>17.40</td>
<td>126.75</td>
</tr>
<tr>
<td>44–45.9</td>
<td>45.0</td>
<td>11</td>
<td>495</td>
<td>12.8</td>
<td>30.20</td>
<td>222.75</td>
</tr>
<tr>
<td>46–47.9</td>
<td>47.0</td>
<td>4</td>
<td>188</td>
<td>4.7</td>
<td>34.90</td>
<td>25.00</td>
</tr>
<tr>
<td>48–49.9</td>
<td>49.0</td>
<td>18</td>
<td>882</td>
<td>21.0</td>
<td>55.90</td>
<td>9.0</td>
</tr>
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<td>50–51.9</td>
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<td>8.1</td>
<td>64.0</td>
<td>15.75</td>
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<td>52–53.9</td>
<td>53.0</td>
<td>8</td>
<td>424</td>
<td>9.3</td>
<td>73.3</td>
<td>98.00</td>
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<td>54–55.9</td>
<td>55.0</td>
<td>11</td>
<td>605</td>
<td>12.8</td>
<td>86.1</td>
<td>332.75</td>
</tr>
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<td>56–57.9</td>
<td>57.0</td>
<td>5</td>
<td>285</td>
<td>5.8</td>
<td>91.9</td>
<td>281.25</td>
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<td>58–59.9</td>
<td>59.0</td>
<td>2</td>
<td>118</td>
<td>2.3</td>
<td>94.2</td>
<td>180.50</td>
</tr>
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<td>60–61.9</td>
<td>61.0</td>
<td>2</td>
<td>122</td>
<td>2.3</td>
<td>96.5</td>
<td>264.50</td>
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<tr>
<td>62–63.9</td>
<td>63.0</td>
<td>2</td>
<td>126</td>
<td>2.3</td>
<td>98.8</td>
<td>364.50</td>
</tr>
<tr>
<td>64–65.9</td>
<td>65.0</td>
<td>1</td>
<td>65</td>
<td>1.2</td>
<td>100.0</td>
<td>240.25</td>
</tr>
<tr>
<td><strong>Totals</strong></td>
<td><strong>86</strong></td>
<td><strong>4260</strong></td>
<td></td>
<td></td>
<td><strong>3632.00</strong></td>
<td></td>
</tr>
</tbody>
</table>
Figure 4.5 Frequency Distribution
Figure 4.6 Cumulative Distribution

- $P_{85} = 54 \text{ (mi/h)}$
- Median speed $= P_{50} = 49 \text{ (mi/h)}$
Traffic Engineering Studies

- The median speed 49 km/h, the 50\textsuperscript{th}-percentile speed.
- 85\textsuperscript{th}-percentile speed is 54 km/h
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.
4.2 VOLUME STUDIES

3. Peak Hour Volume (PHV)
   the maximum number of vehicles that pass 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)
4.2.1 Methods of Conducting Volume Counts

- Manual Method
- Automatic Method
Figure 4.7 Jamar Traffic Data Collector TDC-1 2 Hooked to a Computer
Figure 4.9 Apollo Traffic Counter/Classifier
Figure 4.10 Example of Counters that Require the Laying of Subsurface Detectors
Figure 4.11 Traffic Eye Universal System
Figure 4.12 Example of Station Locations for a Cordon Count
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.
4.2.2 Types of Volume Counts

- Pedestrian Volume Counts
- Periodic Volume Counts (AADT)
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*
Intersection Summary Sheets:

**Figure 4.14 shows a typical intersection summary sheet.**
4.2.3 Traffic Volume Data Presentation

- Time-Based Distribution Charts:
  see Figure 4.15
Daily variations: see Figure 4.15b
Hourly variations in traffic volume:

Figure 4.15 Traffic Volumes on an Urban Highway (C)
Summary Tables:
PHV, Vehicle Classification (VC), and ADT. See Table 4.4

Table 4.4 Summary of Traffic Volume Data for a Highway Section

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>PHV</td>
<td>430</td>
</tr>
<tr>
<td>ADT</td>
<td>5375</td>
</tr>
<tr>
<td>Vehicle Classification (VC)</td>
<td></td>
</tr>
<tr>
<td>Passenger cars</td>
<td>70%</td>
</tr>
<tr>
<td>Two-axle trucks</td>
<td>20%</td>
</tr>
<tr>
<td>Three-axle trucks</td>
<td>8%</td>
</tr>
<tr>
<td>Other trucks</td>
<td>2%</td>
</tr>
</tbody>
</table>
Traffic Engineering Studies

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

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

\[
\text{MEF} = \frac{\text{AADT}}{\text{ADT for particular month}}
\]
### Table 4.5 Hourly Expansion Factors for a Rural Primary Road

<table>
<thead>
<tr>
<th>Hour</th>
<th>Volume</th>
<th>HEF</th>
</tr>
</thead>
<tbody>
<tr>
<td>6:00–7:00 a.m.</td>
<td>294</td>
<td>42.00</td>
</tr>
<tr>
<td>7:00–8:00 a.m.</td>
<td>426</td>
<td>29.00</td>
</tr>
<tr>
<td>8:00–9:00 a.m.</td>
<td>560</td>
<td>22.05</td>
</tr>
<tr>
<td>9:00–10:00 a.m.</td>
<td>657</td>
<td>18.80</td>
</tr>
<tr>
<td>10:00–11:00 a.m.</td>
<td>722</td>
<td>17.10</td>
</tr>
<tr>
<td>11:00–12:00 p.m.</td>
<td>667</td>
<td>18.52</td>
</tr>
<tr>
<td>12:00–1:00 p.m.</td>
<td>660</td>
<td>18.71</td>
</tr>
<tr>
<td>1:00–2:00 p.m.</td>
<td>739</td>
<td>16.71</td>
</tr>
<tr>
<td>2:00–3:00 p.m.</td>
<td>832</td>
<td>14.84</td>
</tr>
<tr>
<td>3:00–4:00 p.m.</td>
<td>836</td>
<td>14.77</td>
</tr>
<tr>
<td>4:00–5:00 p.m.</td>
<td>961</td>
<td>12.85</td>
</tr>
<tr>
<td>5:00–6:00 p.m.</td>
<td>892</td>
<td>13.85</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Hour</th>
<th>Volume</th>
<th>HEF</th>
</tr>
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<tbody>
<tr>
<td>6:00–7:00 p.m.</td>
<td>743</td>
<td>16.62</td>
</tr>
<tr>
<td>7:00–8:00 p.m.</td>
<td>706</td>
<td>17.49</td>
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<tr>
<td>8:00–9:00 p.m.</td>
<td>606</td>
<td>20.38</td>
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<tr>
<td>9:00–10:00 p.m.</td>
<td>489</td>
<td>25.26</td>
</tr>
<tr>
<td>10:00–11:00 p.m.</td>
<td>396</td>
<td>31.19</td>
</tr>
<tr>
<td>11:00–12:00 a.m.</td>
<td>360</td>
<td>34.31</td>
</tr>
<tr>
<td>12:00–1:00 a.m.</td>
<td>241</td>
<td>51.24</td>
</tr>
<tr>
<td>1:00–2:00 a.m.</td>
<td>150</td>
<td>82.33</td>
</tr>
<tr>
<td>2:00–3:00 a.m.</td>
<td>100</td>
<td>123.50</td>
</tr>
<tr>
<td>3:00–4:00 a.m.</td>
<td>90</td>
<td>137.22</td>
</tr>
<tr>
<td>4:00–5:00 a.m.</td>
<td>86</td>
<td>143.60</td>
</tr>
<tr>
<td>5:00–6:00 a.m.</td>
<td>137</td>
<td>90.14</td>
</tr>
</tbody>
</table>

Total daily volume = 12,350.
Table 4.6 Daily Expansion Factors for a Rural Primary Road

<table>
<thead>
<tr>
<th>Day of Week</th>
<th>Volume</th>
<th>DEF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sunday</td>
<td>7895</td>
<td>9.515</td>
</tr>
<tr>
<td>Monday</td>
<td>10,714</td>
<td>7.012</td>
</tr>
<tr>
<td>Tuesday</td>
<td>9722</td>
<td>7.727</td>
</tr>
<tr>
<td>Wednesday</td>
<td>11,413</td>
<td>6.582</td>
</tr>
<tr>
<td>Thursday</td>
<td>10,714</td>
<td>7.012</td>
</tr>
<tr>
<td>Friday</td>
<td>13,125</td>
<td>5.724</td>
</tr>
<tr>
<td>Saturday</td>
<td>11,539</td>
<td>6.510</td>
</tr>
</tbody>
</table>

Total weekly volume = 75,122.
### Table 4.7 Monthly Expansion Factors for a Rural Primary Road

<table>
<thead>
<tr>
<th>Month</th>
<th>ADT</th>
<th>MEF</th>
</tr>
</thead>
<tbody>
<tr>
<td>January</td>
<td>1350</td>
<td>1.756</td>
</tr>
<tr>
<td>February</td>
<td>1200</td>
<td>1.975</td>
</tr>
<tr>
<td>March</td>
<td>1450</td>
<td>1.635</td>
</tr>
<tr>
<td>April</td>
<td>1600</td>
<td>1.481</td>
</tr>
<tr>
<td>May</td>
<td>1700</td>
<td>1.394</td>
</tr>
<tr>
<td>June</td>
<td>2500</td>
<td>0.948</td>
</tr>
<tr>
<td>July</td>
<td>4100</td>
<td>0.578</td>
</tr>
<tr>
<td>August</td>
<td>4550</td>
<td>0.521</td>
</tr>
<tr>
<td>September</td>
<td>3750</td>
<td>0.632</td>
</tr>
<tr>
<td>October</td>
<td>2500</td>
<td>0.948</td>
</tr>
<tr>
<td>November</td>
<td>2000</td>
<td>1.185</td>
</tr>
<tr>
<td>December</td>
<td>1750</td>
<td>1.354</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Time Slot</th>
<th>Traffic Volume</th>
</tr>
</thead>
<tbody>
<tr>
<td>7:00 – 8:00 a.m.</td>
<td>400</td>
</tr>
<tr>
<td>8:00 – 9:00 a.m.</td>
<td>535</td>
</tr>
<tr>
<td>9:00 – 10:00 a.m.</td>
<td>650</td>
</tr>
<tr>
<td>10:00 – 11:00 a.m.</td>
<td>710</td>
</tr>
<tr>
<td>11:00 – 12 noon</td>
<td>650</td>
</tr>
</tbody>
</table>
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.
  
  Total 7-day volume = \(11,959 \times 7.727\)

  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.
  
  \[\text{AADT} = 13,201 \times 1.394 = 18,402\]
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,
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
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
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),
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.
4.3.3 Methods for Conducting Travel Time and Delay Studies

- Methods Requiring a **Test Vehicle**: floating-car, average-speed, and moving-vehicle techniques.
## Table 4.8 Speed and Delay Information

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

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

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

The following data are collected as:

- The time it takes to travel east from X-X to Y-Y ($T_e$), in minutes
- The time it takes to travel west from Y-Y to X-X ($T_w$), in minutes
- The number of vehicles traveling west in the opposite lane while the test car is traveling east ($N_e$)
Figure 4.16 Test Site for Moving-Vehicle Method
**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 ($O_w$)
- 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 ($P_w$)
Moving-Vehicle Technique.

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

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

\[
\bar{T_w} = \frac{T_w}{60} - \frac{O_w - P_w}{V_w}
\]

\[
\bar{T_w} = T_w - \frac{60(O_w - P_w)}{V_w}
\]
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 \((T_e) = 2.85 \text{ min}\)

Mean time it takes to travel westbound \((T_w) = 3.07 \text{ min}\)

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

<table>
<thead>
<tr>
<th>Run Direction/Number</th>
<th>Travel Time (min)</th>
<th>No. of Vehicles Traveling in Opposite Direction</th>
<th>No. of Vehicles That Overtook Test Vehicle</th>
<th>No. of Vehicles Overtaken by Test Vehicle</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eastward 1</td>
<td>2.75</td>
<td>80</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Eastward 2</td>
<td>2.55</td>
<td>75</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Eastward 3</td>
<td>2.85</td>
<td>83</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>Eastward 4</td>
<td>3.00</td>
<td>78</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Eastward 5</td>
<td>3.05</td>
<td>81</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Eastward 6</td>
<td>2.70</td>
<td>79</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>Eastward 7</td>
<td>2.82</td>
<td>82</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Eastward 8</td>
<td>3.08</td>
<td>78</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>Average</td>
<td>2.85</td>
<td>79.50</td>
<td>1.00</td>
<td>1.50</td>
</tr>
</tbody>
</table>
Table 4.9  Data from Travel Time Study Using the Moving-Vehicle Technique

<table>
<thead>
<tr>
<th>Westward</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>2.95</td>
<td>78</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>3.15</td>
<td>83</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>3.20</td>
<td>89</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>2.83</td>
<td>86</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>3.30</td>
<td>80</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>3.00</td>
<td>79</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>7</td>
<td>3.22</td>
<td>82</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>8</td>
<td>2.91</td>
<td>81</td>
<td>0</td>
</tr>
<tr>
<td>Average</td>
<td>3.07</td>
<td>82.25</td>
<td>1.25</td>
<td>0.875</td>
</tr>
</tbody>
</table>

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
Solution:

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

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

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

- Similarly, calculate the volume in the eastbound direction.

\[ V_e = \frac{(82.25 + 1.00 - 1.50)60}{2.85 + 3.07} = 828.5 \quad \text{(or 829 veh/h)} \]
Solution:

- Find the average travel time in the westbound direction.

\[
\bar{T}_w = 3.07 - \frac{(1.25 - 0.875)}{810} \times 60 = 3.0 \text{ min}
\]

- Find the average travel time in the eastbound direction.

\[
\bar{T}_e = 2.85 - \frac{(1.00 - 1.50)}{829} \times 60 = 2.9 \text{ min}
\]
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
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.
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
On-street parking (curb parking)

Angle Parking

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

\[ T = \frac{\text{number of different vehicles parked}}{\text{number of parking spaces}} \]
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.
Parking Demand

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