Traffic Flow Characteristics

CIVL 4162/6162
(Traffic Engineering)
Lesson Objective

- Define traffic stream parameters
- Establish the relationship between traffic stream parameters
- Calculate and compute parameters with given data
What is a Traffic Stream

- Traffic streams are made up of
  - Individual drivers
  - Vehicles
  - Roadway and environment

- Driver behavior and vehicle characteristics typically vary

- No two traffic streams will behave exactly in the same way
Variability in Traffic Stream (1)

• Traffic flow (movement of vehicles) involves variability
  - Unlike pipe flow (homogeneous)

• A given traffic flow will vary
  - By time
  - By space

• Constraints are defined by
  - Physical constraints
  - Complex driver characteristics
Variability in Traffic Stream (2)

• Although traffic characteristics vary there is a reasonable range
  - Example: In a 65 miles/hr roadway some drivers will drive 50 miles/hr and some will drive 80 miles/hr
    • There exists a range

• Before we study traffic characteristics let us see what are
  - Facilities
  - Basic flow parameters
Types of Facilities

• **Uninterrupted Flow Facilities**
  - No external interruptions
  - Primarily on freeways
  - Also on certain segments of long rural highways
  - In peak hours also freeways are uninterrupted

• **Interrupted Flow Facilities**
  - External interruptions exists
  - Most frequent are signals, stop/yield signs
  - Creates platoons of vehicles progress in traffic stream
Types of Facilities and Major Difference

• The major difference between two facilities
  - Impact of time (no interventions at any time)
  - Availability of roadways
    • On uninterrupted facilities roadways are available to users all the time
    • But sections of roadway are not available to users because of traffic control (signal, stop, and yield signs)
Traffic Stream Parameters

Macroscopic
- Volume
- Speed
- Density

Microscopic
- Speed of individual vehicles
- Headway
- Spacing

*These characteristics are primarily for uninterrupted flow
Volume

- Traffic volume is defined as the number of vehicles passing a point on highway or a given lane or direction of a highway in a specific time
- Unit: vehicles per unit time
- Usually expressed as vehicles / hour
- Denoted as veh/hr
Rate of Flow

• Rate of flow are generally expressed in units of “veh/hr” but represents flows that exist for period of time less than an hour.
• Example: 200 vehicles are observed for 15 min.
• The equivalent hourly volume will be 800 veh/hr
• Even though 800 veh/hr would not be observed if one hour was counted
Daily Volumes (1)

- **Average Annual Daily Traffic (AADT)** -
  - The average 24 hour volume at a given location over a full 365 day year.
  - avg. 24-hour volume at a site over a full year

- **Average Annual Weekday Traffic (AAWT)** -
  - The average 24 hour volume at a given location occurring on weekdays over a full 365 day year.
  - Usually 260 days week days per year
Daily Volumes (2)

- **Average Daily Traffic (ADT)** -
  - The average 24 hour volume at a given location over a defined time period less than a year

- **Average Weekday Traffic (AWT)**
  - The average 24 hour weekday volume at a given location over a defined period less than one year
# Example: Daily Volume

## Table 5.1: Illustration of Daily Volume Parameters

<table>
<thead>
<tr>
<th>Month</th>
<th>2. No. of Weekdays in Month (days)</th>
<th>3. Total Days in Month (days)</th>
<th>4. Total Monthly Volume (vehs)</th>
<th>5. Total Weekday Volume (vehs)</th>
<th>6. AWT 5/2 (veh/day)</th>
<th>7. ADT 4/3 (veh/day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jan</td>
<td>22</td>
<td>31</td>
<td>425,000</td>
<td>208,000</td>
<td>9,455</td>
<td>13,710</td>
</tr>
<tr>
<td>Feb</td>
<td>20</td>
<td>28</td>
<td>410,000</td>
<td>220,000</td>
<td>11,000</td>
<td>14,643</td>
</tr>
<tr>
<td>Mar</td>
<td>22</td>
<td>31</td>
<td>385,000</td>
<td>185,000</td>
<td>8,409</td>
<td>12,419</td>
</tr>
<tr>
<td>Apr</td>
<td>22</td>
<td>30</td>
<td>400,000</td>
<td>200,000</td>
<td>9,091</td>
<td>13,333</td>
</tr>
<tr>
<td>May</td>
<td>21</td>
<td>31</td>
<td>450,000</td>
<td>215,000</td>
<td>10,238</td>
<td>14,516</td>
</tr>
<tr>
<td>Jun</td>
<td>22</td>
<td>30</td>
<td>500,000</td>
<td>230,000</td>
<td>10,455</td>
<td>16,667</td>
</tr>
<tr>
<td>Jul</td>
<td>23</td>
<td>31</td>
<td>580,000</td>
<td>260,000</td>
<td>11,304</td>
<td>18,710</td>
</tr>
<tr>
<td>Aug</td>
<td>21</td>
<td>31</td>
<td>570,000</td>
<td>260,000</td>
<td>12,381</td>
<td>18,387</td>
</tr>
<tr>
<td>Sep</td>
<td>22</td>
<td>30</td>
<td>490,000</td>
<td>205,000</td>
<td>9,318</td>
<td>16,333</td>
</tr>
<tr>
<td>Oct</td>
<td>22</td>
<td>31</td>
<td>420,000</td>
<td>190,000</td>
<td>8,636</td>
<td>13,548</td>
</tr>
<tr>
<td>Nov</td>
<td>21</td>
<td>30</td>
<td>415,000</td>
<td>200,000</td>
<td>9,524</td>
<td>13,833</td>
</tr>
<tr>
<td>Dec</td>
<td>22</td>
<td>31</td>
<td>400,000</td>
<td>210,000</td>
<td>9,545</td>
<td>12,903</td>
</tr>
<tr>
<td>Total</td>
<td>260</td>
<td>365</td>
<td>5,445,000</td>
<td>2,583,000</td>
<td>—</td>
<td>—</td>
</tr>
</tbody>
</table>

\[
\text{AADT} = \frac{5,445,000}{365} = 14.918 \text{ veh/day}
\]

\[
\text{AAWT} = \frac{2,583,000}{260} = 9.935 \text{ veh/day}
\]

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Hourly Volume

- Measured in volume/hour
- Used for design and operational purposes
- The hour with highest volume is referred as Peak hour
- Peak hour volume is stated as directional volume
- Sometimes referred as Directional Design Hourly Volume (DDHV)
DDHV

- DDHV = directional design hourly volume
  \[ DDHV = \text{AADT} \times K \times D \]
  where \( K \) = proportion of AADT that occurs during design hour
  \( D \) = proportion of peak hour traffic traveling in the peak direction
K-Factor

- Typically, K factor represents proportion of AADT occurring during 30\textsuperscript{th} peak hour of the year
- How does K-factor vary by urban density?
  - Urban, suburban, and rural
- D Factors
  - More variable than K
  - Influenced by development density, radial vs. circumferential route
## K and D Factor

<table>
<thead>
<tr>
<th>Facility Type</th>
<th>Normal Range of Values</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><strong>K-Factor</strong></td>
</tr>
<tr>
<td>Rural</td>
<td>0.15–0.25</td>
</tr>
<tr>
<td>Suburban</td>
<td>0.12–0.15</td>
</tr>
<tr>
<td>Urban:</td>
<td></td>
</tr>
<tr>
<td>Radial Route</td>
<td>0.07–0.12</td>
</tr>
<tr>
<td>Circumferential Route</td>
<td>0.07–0.12</td>
</tr>
</tbody>
</table>

Table 5.2: General Ranges for K and D Factors

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### Table 5.3: Illustration of Volumes and Rates of Flow

<table>
<thead>
<tr>
<th>Time Interval</th>
<th>Volume for Time Interval (vehs)</th>
<th>Rate of Flow for Time Interval (vehs/h)</th>
</tr>
</thead>
<tbody>
<tr>
<td>5:00–5:15 PM</td>
<td>1,000</td>
<td>1,000/0.25 = 4,000</td>
</tr>
<tr>
<td>5:15–5:30 PM</td>
<td>1,100</td>
<td>1,100/0.25 = 4,400</td>
</tr>
<tr>
<td>5:30–5:45 PM</td>
<td>1,200</td>
<td>1,200/0.25 = 4,800</td>
</tr>
<tr>
<td>5:45–6:00 PM</td>
<td>900</td>
<td>900/0.25 = 3,600</td>
</tr>
<tr>
<td>5:00–6:00 PM</td>
<td>(\Sigma = 4,200)</td>
<td></td>
</tr>
</tbody>
</table>
Volume vs. Flow Rate

If capacity is 4,200 vph:

### Table 5.4: Queuing Analysis for the Data of Table 5.3

<table>
<thead>
<tr>
<th>Time Interval</th>
<th>Arriving Vehicles (vehs)</th>
<th>Departing Vehicles (vehs)</th>
<th>Queue Size at End of Period (vehs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>5:00–5:15 PM</td>
<td>1,000</td>
<td>1,050</td>
<td>0</td>
</tr>
<tr>
<td>5:15–5:30 PM</td>
<td>1,100</td>
<td>1,050</td>
<td>$0 + 1,100 - 1,050 = 50$</td>
</tr>
<tr>
<td>5:30–5:45 PM</td>
<td>1,200</td>
<td>1,050</td>
<td>$50 + 1,200 - 1,050 = 200$</td>
</tr>
<tr>
<td>5:45–6:00 PM</td>
<td>900</td>
<td>1,050</td>
<td>$200 + 900 - 1,050 = 50$</td>
</tr>
</tbody>
</table>

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Peak Hour Factor

- 15 minutes is considered to be minimum period of time over which traffic can be considered statistically stable.
- Peak hour factor (PHF) represents the uniformity of flow in the peak hour.

\[ PHF = \frac{V}{4 \times V_{m15}} \]

where:
- \( V \) = hourly volume, vehs
- \( V_{m15} \) = max 15 min volume within the hour, vehs
Peak Hour Factor (2)

- PHF = \( \frac{4200}{4 \times 1200} = 0.875 \)

<table>
<thead>
<tr>
<th>Time Interval</th>
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<th>Rate of Flow for Time Interval (vehs/h)</th>
</tr>
</thead>
<tbody>
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<td>1,000</td>
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</tr>
<tr>
<td>5:15–5:30 PM</td>
<td>1,100</td>
<td>1,100/0.25 = 4,400</td>
</tr>
<tr>
<td>5:30–5:45 PM</td>
<td>1,200</td>
<td>1,200/0.25 = 4,800</td>
</tr>
<tr>
<td>5:45–6:00 PM</td>
<td>900</td>
<td>900/0.25 = 3,600</td>
</tr>
<tr>
<td>5:00–6:00 PM</td>
<td>( \Sigma = 4,200 )</td>
<td></td>
</tr>
</tbody>
</table>
Peak Hour Factor (3)

• Peak hour factor lie between 0.25-1
  - 0.25 when all traffic is concentrated in one 15 minute period
  - 1.0 when traffic on all 15 minute period are same

• Under very congested conditions PHF~1

• Practical studies show that
  - PHF~0.7 for rural roadways
  - PHF~0.98 in dense urban roadways
Speed

- Speed and travel time are inversely related
  - \( S = \frac{d}{t} \)
  - Where \( S \) -> speed in mi/hr; \( d \) -> distance traversed in mi; \( t \) -> time to traverse distance \( d \) in hr

- Average speed in a traffic stream can be computed in two ways:
  - **Time mean speed (TMS)** - average speed of all vehicles passing a point over a specified time period.
  - **Space mean speed (SMS)** - average speed of all vehicles occupying a given section of roadway over a specific time period.
TMS and SMS

• **Time Mean Speed (TMS)**

\[ TMS = \frac{\sum_i \left( \frac{d}{t_i} \right)}{n} \]

• **Space Mean Speed (SMS)**

\[ SMS = \frac{d}{\sum_i \left( \frac{t_i}{n} \right)} \]

• **Where**

  - \( d \rightarrow \) distance traversed, ft
  - \( n \rightarrow \) number of observed vehicles
  - \( t_i \rightarrow \) time for vehicle “i” to traverse the distance \( d \)
## Example: TMS and SMS

### Table 5.5: Illustrative Computation of TMS and SMS

<table>
<thead>
<tr>
<th>Vehicle No.</th>
<th>Distance d (ft)</th>
<th>Travel Time t (s)</th>
<th>Speed (ft/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1,000</td>
<td>18.0</td>
<td>1,000/18 = 55.6</td>
</tr>
<tr>
<td>2</td>
<td>1,000</td>
<td>20.0</td>
<td>1,000/20 = 50.0</td>
</tr>
<tr>
<td>3</td>
<td>1,000</td>
<td>22.0</td>
<td>1,000/22 = 45.5</td>
</tr>
<tr>
<td>4</td>
<td>1,000</td>
<td>19.0</td>
<td>1,000/19 = 52.6</td>
</tr>
<tr>
<td>5</td>
<td>1,000</td>
<td>20.0</td>
<td>1,000/20 = 50.0</td>
</tr>
<tr>
<td>6</td>
<td>1,000</td>
<td>20.0</td>
<td>1,000/20 = 50.0</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>6,000</strong></td>
<td><strong>119</strong></td>
<td><strong>303.7</strong></td>
</tr>
<tr>
<td><strong>Average</strong></td>
<td><strong>6,000/6 = 1,000</strong></td>
<td><strong>119/6 = 19.8</strong></td>
<td><strong>303.7/6 = 50.6</strong></td>
</tr>
</tbody>
</table>

\[
TMS = \frac{6,000}{6} = 1,000 \\
SMS = \frac{1,000}{19.8} = 50.4 \text{ ft/s}
\]

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Example: Time Mean vs Space Mean Speed

Figure 5.1  Time Mean Speed and Space Mean Speed Illustrated

\[ TMS = \frac{(88n+44n)}{(2n)} = \frac{66}{2} = 66 \text{ ft/sec} \]

\[ SMS = \frac{(88n+44*2n)}{(3n)} = \frac{58.7}{2} = 58.7 \text{ ft/sec} \]
Traffic Flow Basics (1)
Consider a long, uninterrupted, single-lane roadway:

No passing, no opposing traffic, no intersections
Traffic Flow Basics (2)
Traffic Flow Basics - Speed

Distance ($x$) vs. Time ($t$)

$\Delta x$, $\Delta t$
Traffic Flow Basics - Trajectories

Distance ($x$) vs. Time ($t$)
Traffic Flow Basics-Trajectory Plots

This is called a **time-space** diagram
Consider a horizontal “slice” of the diagram.
Traffic Flow Basics - Volume

The number of trajectories crossing this line is the number of vehicles passing a fixed point on the road.

This is called the **volume** or **flow**, and has units of vehicles per time (usually veh/hr).
Traffic Flow Basics-Density

What does a vertical slice tell us?

Distance (x)  
Time (t)
Traffic Flow Basics - Density

The number of trajectories crossing this line is the number of vehicles on the road at one instant in time.

This is called the **density**, and has units of vehicles per distance (usually veh/mi).
Density

- Most direct measure of traffic demand
- Difficult to measure directly
- Important measure of quality of traffic flow
- Occupancy is related, and can be measured directly
- Occupancy - proportion of time that a detector is occupied by a vehicle in a defined time period.
Density and Occupancy

Figure 5.2 Density and Occupancy Illustrated