Traffic Signal Timing: Basic Principles

- 2 types of signals
  - Pre-timed
  - Traffic actuated

Objectives of signal timing
- Reduce average delay of all vehicles
- Reduce probability of accidents by minimizing possible conflict points

Objectives may conflict!

Development of a Traffic Signal Phasing and Timing Plan

- Select Signal Phasing
  - Determine if protected or permitted left turns will be used
    - HCM Guidelines - Consider using protected phase when the product of left turning vehicles and opposing traffic volume exceeds:
      - 50,000 during the peak hour for one opposing lane
      - 90,000 for two opposing lanes
      - 110,000 for three or more opposing lanes

Two Phase and Three Phase Signal Operation

- Allowed traffic movements
  - Two phase operation
    - Phase 1
    - Phase 2
  - Three phase operation
    - Phase 1
    - Phase 2
    - Phase 3
Typical Phasing Configurations and Sequencing

Example: Determining Signal Phasing Plan

Example: Recommended Signal Phasing
Development of a Traffic Signal Phasing and Timing Plan

- Establish Analysis Lane Groups
- Determine critical lane groups
- Calculate cycle length
- Allocate green time

Summary

- There is one lane (or lane group) for each phase requiring the maximum amount of effective green time. For this lane or lane group, we have the critical lane volume (CLV).
- There is an effective green time requirement and critical lane volume for each phase in the cycle.
- The "required green" for the cycle is the sum of the effective green requirements for each phase. We must provide at least this amount of effective green (per hour) to pass the traffic (without queuing).
Determining Cycle Length

Typically will minimize delay to stopped vehicles (thus minimize $C$).

$$ C = \frac{L}{1 - \sum_{i=1}^{n} \left( \frac{CLV}{x} \right)_i} $$

*This equation assumes $X_c = 1$. $X_c$ is the critical v/c ratio for the intersection. If $X_c = 1$, this implies intersection operates at full capacity. Occasional cycle failures could occur using this approach, because of the randomness of vehicle arrivals.

Determining Cycle Length

From Mannering text:

$$ C_{\infty} = \frac{L + X_c}{X_c \sum_{i=1}^{n} \left( \frac{CLV}{x} \right)} $$

*Round $C$ to nearest 5 seconds. Choose $X_c$ based on desired degree of utilization of the intersection. Cycle lengths should be in the range of 40 – 120 seconds (unless intersection is very complex (5+ phases).

Determine Splits

Determine how long each phase will receive right-of-way

$$ (G + A)_i = \frac{(CLV)_i}{\sum_{j=1}^{n} \left( \frac{CLV}{x} \right)_j} \cdot (C - L) + l_i $$

*Equation in your book is for Effective Green Time (section 7.5.6)

$L = \text{total lost time for Cycle}$
Real World Constraints

- **Cycle length constraints:**
  We would like to implement cycle lengths in the range of 40-120 seconds. Cycle lengths of less than 40 seconds waste too much time (lost time), and for cycles much over 120 seconds, motorists sometimes think that the "light" is malfunctioning, and enter the intersection on red.

- **Display time constraints:**
  We don't show the driver such things as two second greens ("Show the driver things he's seen before.") Some traffic engineers might use different values, but in this class, we will use minimum (G+TA) values of: 
  - 12 sec (exclusive left turns)
  - 15 sec (through)

- **Peaking:**
  We time traffic signals for the peak 15 minute flow rate, just like we made our calculations on for capacity and level of service for uninterrupted flow.

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Real World Constraints

- **Composition:**
  As a rough approximation, assume that each truck is the equivalent of 2.0 passenger cars (this value is compatible with the Highway Capacity Manual (HCM)). The HCM uses this to adjust saturation flow rate from its "ideal" value of 1900 pphpd (passenger cars per hour of green per lane). As an approximation, we will use:
  
  \[
  s = 1900 \times f_{pv} 
  \]

  where
  
  \( s \) = saturation flow rate (vphgpl)
  
  \( f_{pv} \) = proportion of trucks in the stream. Since we are taking \( E_1=2 \), this reduces to:
  
  \[
  f_{pv} = \frac{1}{1+2} = \frac{1}{3}
  \]

  Our approximation to saturation flow rate, then, is:
  
  \[
  s = \frac{1900}{3}
  \]

  (This is both a slight variation and simplification of the HCM technique for signalized intersections, but it is sufficient for our purposes).

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Real World Constraints

- **Unprotected left turns:**
  Unprotected left turns are those who turn left on the "green ball." We call those turning left on a green arrow "protected" left turns. As an approximation, assume that each unprotected left turn is the equivalent of 2.0 through vehicles.

- **Pedestrian constraints (where pedestrian volumes are significant):**
  Ped time = 5 sec + walk time
  (Walk rate is about 4 ft/sec)

- **All signal timing methods are approximate - checking and adjustments must be made in the field.**
Example 1

Find cycle length and splits for the intersection configuration shown below. Assume saturation headways of 2.1 sec/veh-lane and lost times of 5 sec/phase for all approaches.

Example 2 – Part A

As city traffic engineer of Attapulgus, Georgia, you are responsible for timing the town’s traffic signal, which operates with two phases. Lost time is 4.5 seconds for each of the two phases and peak hour factor is 0.83. Peak hour data for each of the four approaches is given in the table below.

<table>
<thead>
<tr>
<th>Approach</th>
<th>Peak Hour Percent</th>
<th>Percent</th>
<th>Percent</th>
</tr>
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<tbody>
<tr>
<td>EB</td>
<td>548</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>WB</td>
<td>672</td>
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<td>NB</td>
<td>598</td>
<td>4</td>
<td>8</td>
</tr>
<tr>
<td>SB</td>
<td>606</td>
<td>2</td>
<td>6</td>
</tr>
</tbody>
</table>

Intersection geometry is as shown below. Find the required cycle length and splits.

Example 2 – Part B

The mayor is up for re-election and has promised, if returned to office, to provide funds to significantly improve these two streets. What cycle length and splits would you implement if the intersection was improved by adding lanes as shown below?
Example – Part C

Well, the mayor’s opponent, who campaigned on a platform of fiscal conservatism, won the election. This means that there will be no major improvements to the intersection. However, the new mayor is willing to foot the bill for a can of paint, and you do have enough pavement width to add left-turn bays for the east-west approaches. For your “new” intersection (shown below), can you re-time the signal to give a more reasonable operation than what you got in part a?