Transportation Systems Management

CEE 495/771
Spring 2006
Zong Tian
Lecture 1
(Chapters 17, 18)

Signal Timing Principles
and Terminologies
Intersection Control

- Hierarchy of intersection control
  - Unsignalized
    - Uncontrolled
    - Yield
    - Stop controlled
      - TWSC
      - AWSC
    - Roundabout
  - Signalized
Signal Timing Terminologies

- Basic signal timing terms
  - Cycle and cycle length
  - Interval
    - Change interval (yellow)
    - Clearance interval (all-red)
    - Green interval
    - Red interval
  - Phase = Green + Yellow + All-red
    (*A signal phase is associated with a particular traffic movement*)
Traffic Movements

One-way Streets

Main Street

Side Street

N

EB

Main Street

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Traffic Movements

One-way Streets

Main Street

Side Street

N

EB

Main Street

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Traffic Movements
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Side Street

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Traffic Movements

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Side Street

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Traffic Movements

One-way Streets

Main Street

Side Street

EB

Main Street

N

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Two-Phase Operation

\[ \phi_1 \quad \phi_2 \]
Traffic Movements
Full Intersection

Main Street

Side Street

SB

EB

NB

WB

N
Controlled Movements

Main Street

Side Street

SB

EB

NB

WB

N
Conflicting Movements

Main Street

Side Street
SB
WB

EB
NB

N

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Phase, Ring and Barrier Structure

Barrier

Ring 1

Ring 2

Main Street

Side Street

Cycle Length

N

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Phasing Sequence

- **Left-turn Treatment**
  - Permitted (no phase)
  - Protected
  - Protected/Permitted

- **Left-turn Sequence**
  - Dual LT Leading (preferred)
  - Dual LT Lagging
  - Split
  - Lead/Lag
Phasing Sequence

Left-turn Leading

\[ \phi_1 \quad \phi_2 \quad \phi_3 \quad \phi_4 \\
\phi_5 \quad \phi_6 \quad \phi_7 \quad \phi_8 \]

Similarly for Ring 2:

\[ \phi_1 \quad \phi_2 \quad \phi_2 \\
\phi_5 \quad \phi_5 \quad \phi_6 \]

\[ \phi_1 \quad \phi_1 \quad \phi_2 \\
\phi_5 \quad \phi_6 \quad \phi_6 \]
Phasing Sequence

Lead-Lag

\[ \phi_2 \leftrightarrow \phi_5 \quad \phi_1 \rightarrow \phi_6 \quad \phi_3 \rightarrow \phi_7 \quad \phi_4 \rightarrow \phi_8 \]

Ring 1

Ring 2

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Phasing Sequence

Lagging Left-Turn

\[ \phi_2 \rightarrow \phi_1 \rightarrow \phi_6 \rightarrow \phi_5 \rightarrow \phi_3 \rightarrow \phi_7 \rightarrow \phi_4 \rightarrow \phi_8 \]
Right-Turn Phase

SB
φ8 φ3

EB
φ1 φ6

NB
φ7 φ4

WB
φ2 φ5

φ4+ φ5

N
Right-Turn Phase

- **Right-turn Treatment**
  - Permitted (same with adjacent through)
    - Right-turn-on-red (RTOR)
    - No RTOR
  - Protected
    - Right-turn arrow display
    - Overlap phase (adjacent through phase + right-side cross street left-turn phase)
Pedestrian Phase

- Pedestrian phase (WALK + FDW) is usually concurrent with the through movement phase.
- WALK and FDW normally show only when pedestrian crossing button is pushed.
Pedestrian Phase

- **WALK** time is usually between 5~7 sec
- **FDW** is also called the pedestrian clearance time, which is to allow pedestrians entering the crosswalk to safely cross

\[ G \geq WALK + FDW \]
Determine the appropriate signal phasing and control, assuming left-turn is protected wherever exclusive left-turn lanes are provided.
Questions

- Name the types of left-turn signal control
- Name the possible phasing sequences for left-turns
- For a full intersection with 8 phases, does the cycle length equal to the sum of all 8 phases? Why?
- What is the purpose of pedestrian clearance time (i.e., FDW)? How is it related to a vehicle phase?
Change and Clearance Intervals

Change interval (yellow)
- can safely stop when green ends and yellow starts
- or can enter the intersection at the end of yellow
- about 3~4 seconds
Change and Clearance Intervals

- **Change interval (yellow) – ITE**

  \[ y = t + \frac{1.47S_{85}}{2d + 64.4 \times 0.01G} \]

- **Clearance Interval (all-red)**

  \[ ar = \frac{w + L}{1.47S_{15}} \]
Clearance Intervals and Lost Times

- **Clearance interval (all-red)**
  - vehicles entering in yellow can clear the intersection
  - about 1.0~2.5 sec

- **Lost times**
  - time that cannot be effectively used by vehicles
  - start-up lost time, \( l_1 \), 2 sec (default in HCM)
  - use of end of green, \( e \), 2 sec (default in HCM)

\[
 t_L = l_1 + y + AR - e
\]
Saturation Headway and Saturation Flow Rate

\[ s = \frac{3600}{h} \]
Effective Green and Capacity

- Effective green of $\Phi_i$, $g_i$

\[ g_i = G_i + y_i + (ar)_i - t_{Li} \]

- Phase capacity, $c_i$

\[ c_i = s_i \times \frac{g_i}{C} \]

- Volume-to-capacity ratio, $x_i$

\[ x_i = \frac{v_i}{c_i} = \frac{v_i}{s_i \left( \frac{g_i}{C} \right)} = \frac{v_i}{s_i} \times \frac{C}{g_i} \]
Example

Given the following:

- C = 60 s
- G = 27 s
- y = 2.5 s
- ar = 0.5 s
- h = 2.4 s
- Start up lost time $l_1 = 2.0$ s, Clearance lost time $l_2 = 1.0$ s

What is the capacity for an approach with two lanes of identical traffic flow characteristics?
Required Green and Phase Time

- Required effective green, $g_i$ to achieve degree of saturation, $x_i$

$$g_i = \frac{v_i}{s_i} \times \frac{C}{x_i} = y_i \frac{C}{x_i}$$

- Minimum effective green, $g_i$

$$g_i = y_i C$$

- Minimum phase, $\Phi_i$

$$\phi_i = g_i + \ell_i = y_i C + \ell_i$$
Critical Phases

- **Critical phases**: conflicting phases that require the most time

- **Possible critical phases**
  - \( \varphi_1, \varphi_2, \varphi_3, \varphi_4 \)
  - \( \varphi_1, \varphi_2, \varphi_7, \varphi_8 \)
  - \( \varphi_5, \varphi_6, \varphi_3, \varphi_4 \)
  - \( \varphi_5, \varphi_6, \varphi_7, \varphi_8 \)
Critical Phases

- For a 8-phase signal, there are 4 critical phases

\[ \phi_{c1} + \phi_{c2} + \phi_{c3} + \phi_{c4} = C \]

\[ g_{c1} + g_{c2} + g_{c3} + g_{c4} = C - (l_{c1} + l_{c2} + l_{c3} + l_{c4}) = C - L \]

\[ \sum_{i=1}^{4} g_i = \sum_{i=1}^{4} y_i \frac{C}{x_i} = C - L \]

\[ Y_{cl} = \frac{C-L}{C} X_{cl} \]

\[ X_{cl} = \frac{C}{C-L} Y_{cl} \]

\[ C = \frac{LX_{cl}}{X_{cl}-Y_{cl}} \]

\[ C = \frac{1.5L+5}{1-Y_{cl}} \]

\[ g_i = y_i \frac{C}{X_{cl}} = y_i \frac{C-L}{Y_{cl}} = \frac{y_i}{Y_{cl}} (C - L) \]

Webster’s Equation

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**Example**

Determine signal timing given the following data. Assume 8-phase, dual-ring, and $\ell = 4.0$ sec/phase

<table>
<thead>
<tr>
<th>$\Phi_i$</th>
<th>Direction</th>
<th>$v_i$, vph</th>
<th>$s_i$, vph</th>
<th>$y_i$</th>
<th>Sum of Ring $y_i$</th>
<th>$g_i$</th>
<th>Min. Phase, $\Phi$</th>
<th>Phase, $\Phi$</th>
<th>$x_i$</th>
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