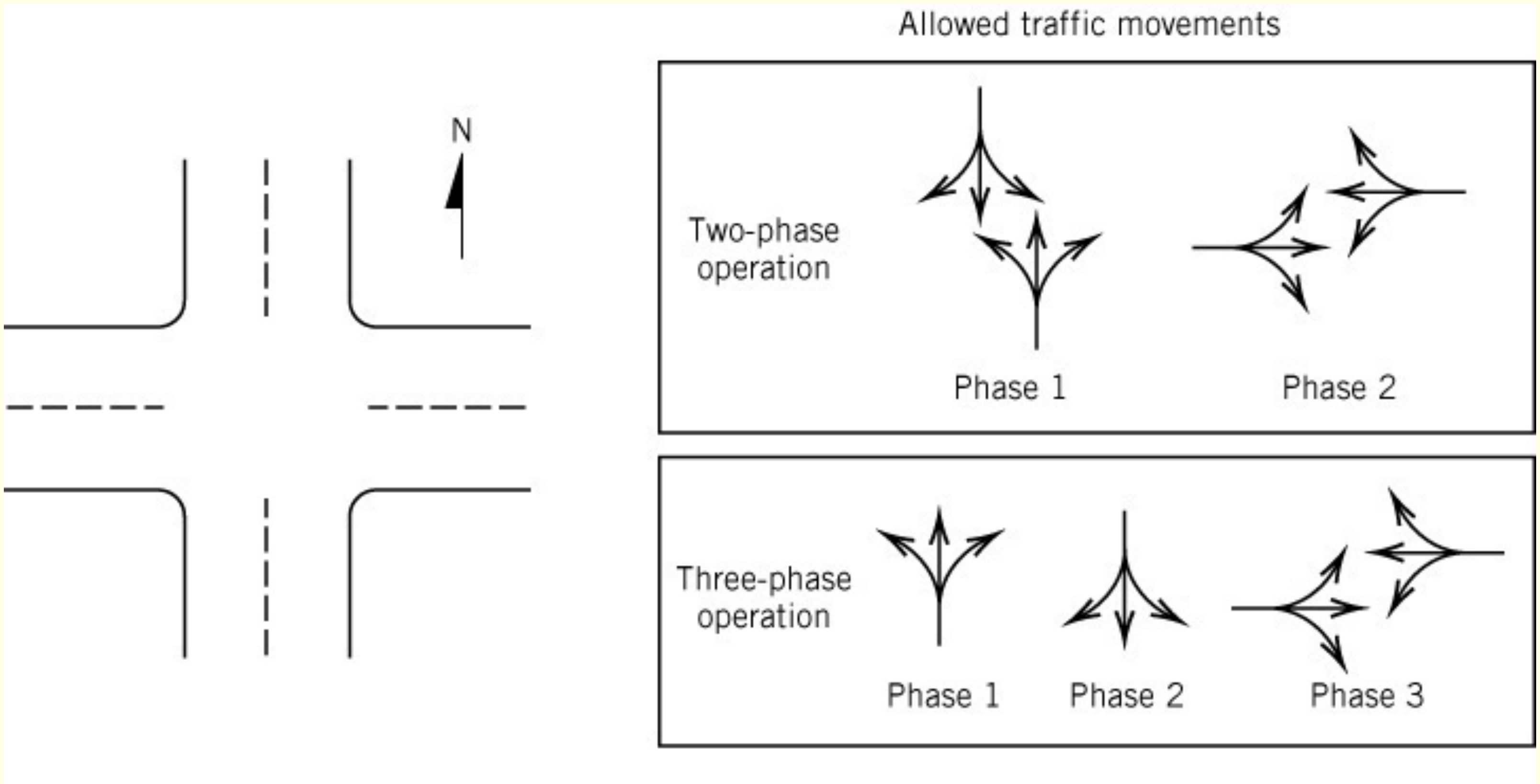
Traffic Signal Timing: Basic Principles

- 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



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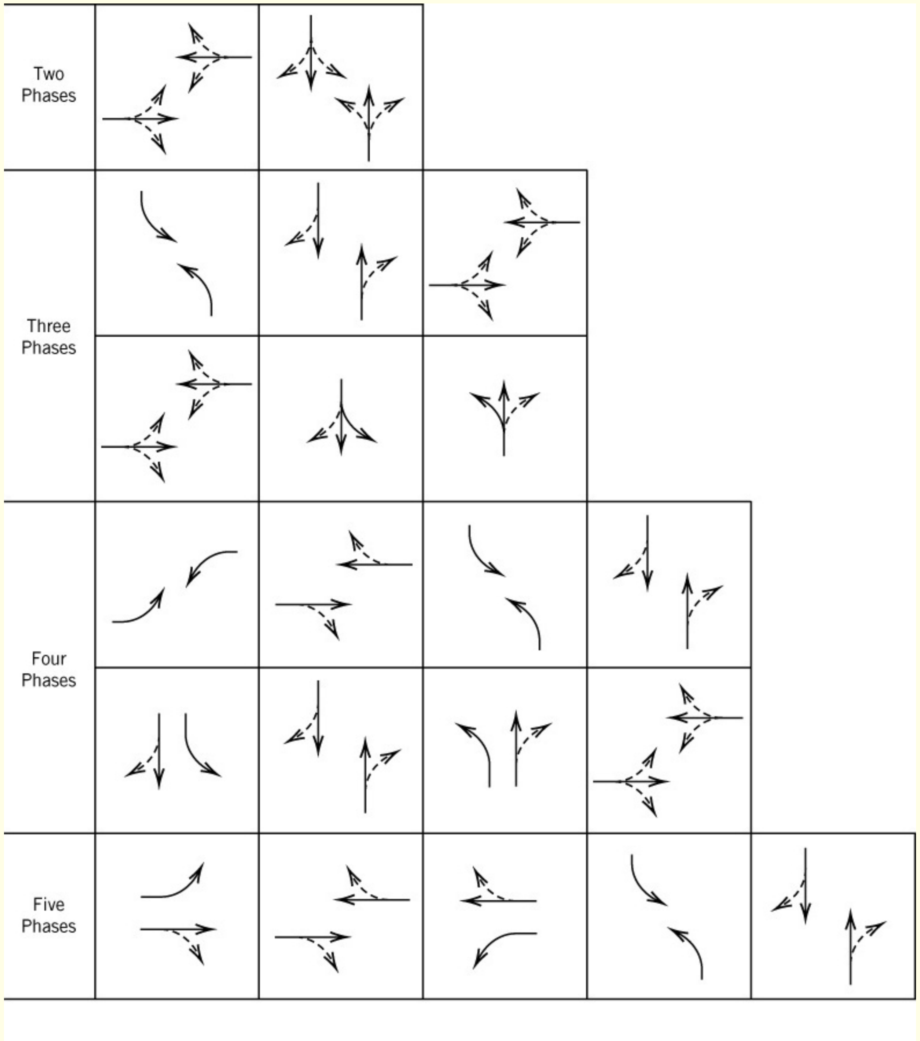
Typical Phasing Configurations and Sequencing



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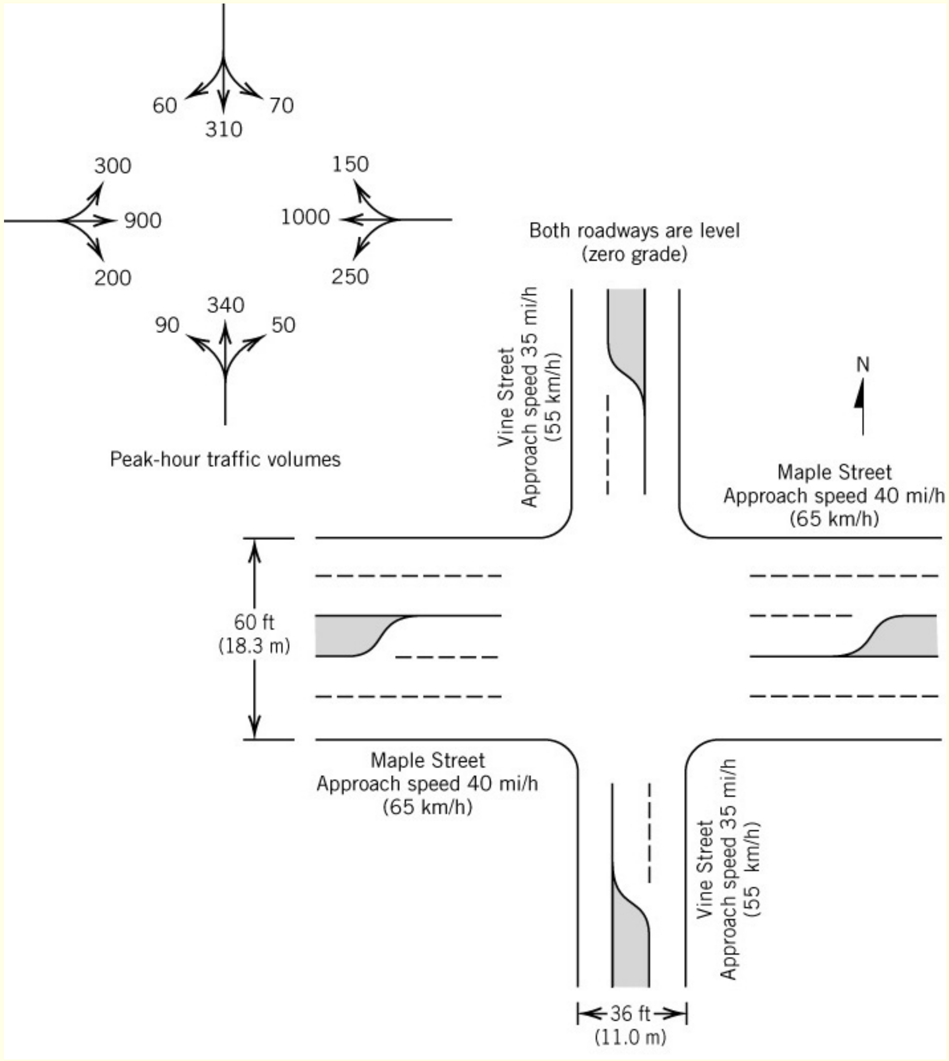
Example:
Determining Signal Phasing Plan



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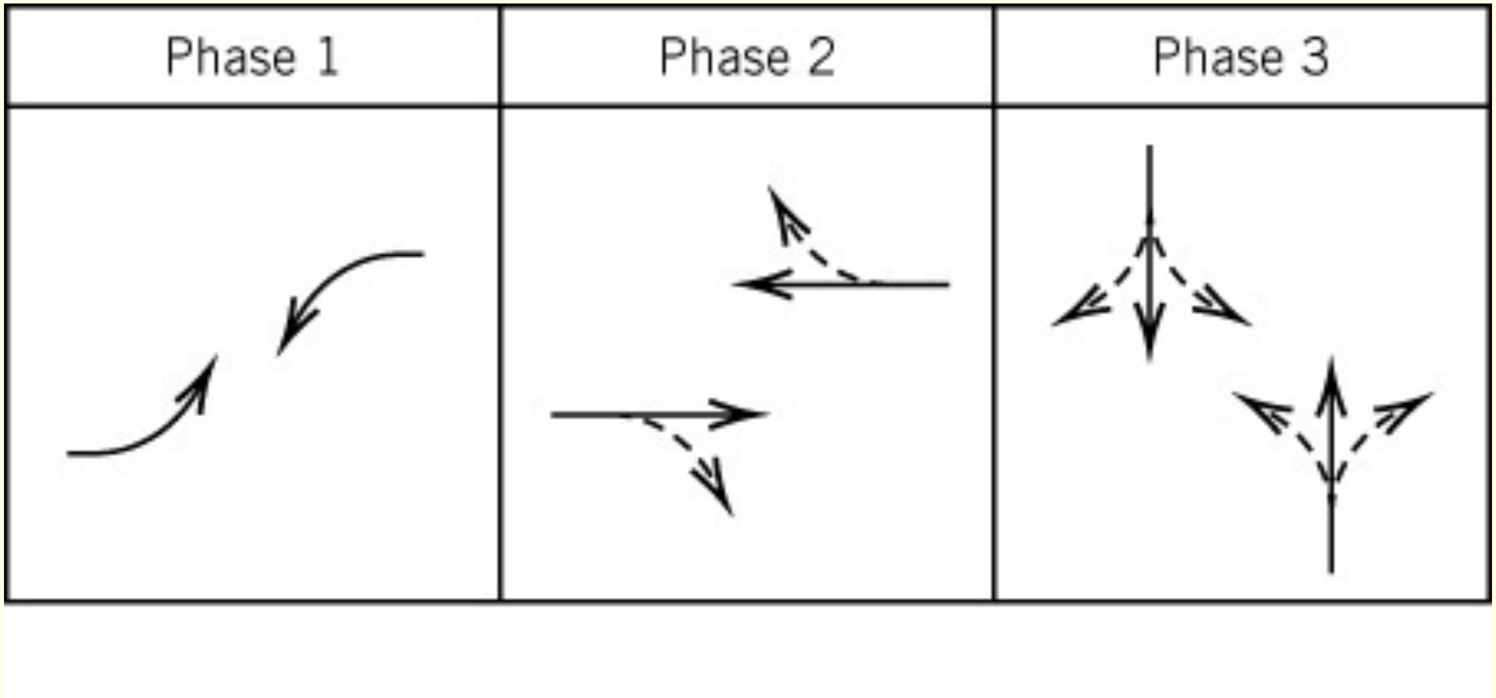
Example: Recommended Signal Phasing



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Development of a Traffic Signal Phasing and Timing Plan

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

Typical Lane Groupings for Analysis

Number of lanes	Movements by lane	Number of possible lane groups
1	LT + TH + RT	① (Single-lane approach)
2	EXC LT TH + RT	②
2	LT + TH TH + RT	① or ②
3	EXC LT TH TH + RT	② or ③

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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

$$C_{\min} = \frac{L \times X_c}{X_c - \sum_{i=1}^{n} \left(\frac{CLV}{s} \right)_i}$$

where:

C_{min} = minimum cycle length

L = total lost time in cycle, sec

X_c = critical v/c ration for the intersection

*Round C to nearest 5 seconds. Choose Xc based on desired degree of utilization of the intersection.

Cycle lengths should typically be in the range of 40 – 120 seconds (unless intersection is very complex (5+ phases).

Determining Cycle Length

- Webster's Optimal Cycle Length

$$C_{opt} = \frac{1.5L + 5}{1.0 - \sum_{i=1}^{n} \left(\frac{CLV}{s} \right)_i}$$

*approximately minimizes vehicle delay

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Equation 31-67

$$X_c = \left(\frac{C}{C-L}\right)\sum_{i\in ci} y_{c,i}$$

Equation 31-68

$$C = \frac{L\,X_c}{X_c - \sum_{i\in ci} y_{c,i}}$$

Equation 31-69

$$g_i = \frac{v_i C}{N_i\, s_i\, X_i} = \left(\frac{v}{N\,s}\right)_i \left(\frac{C}{X_i}\right)$$

where

C = cycle length (s),

L = cycle lost time (s),

X_c = critical intersection volume-to-capacity ratio,

$y_{c,i}$ = critical flow ratio for phase $i = v_i/(N\, s_i)$,

ci = set of critical phases on the critical path,

X_i = volume-to-capacity ratio for lane group i,

v_i = demand flow rate for lane group i (veh/h),

N_i = number of lanes in lane group i (ln),

s_i = saturation flow rate for lane group i (veh/h/ln), and

g_i = effective green time for lane group i (s).

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Procedure

1. Determine flow ration for each lane group and identify critical ratio for each phase.

2. Estimate cycle length. (desired Xc typically ranges from 0.8-0.9. Xc of 1 is capacity operation.)

3. Estimate effective green time for each phase.

4. Check C = g_i + L.

Real World Constraints

- Cycle length constraints:
  - Cycle lengths typically minimized (increases L, and decreases capacity!)
  - C typically ranges 40-120 sec, do not use excessive cycle length unless have very complex/unusual circumstances
- Display time constraints:
  - Do not show drivers something unexpected. General guidelines:
  - 12 sec (minimum for exclusive left turns)
  - 15 sec (minimum for through)
- Design flow – we use peak 15 minute flowrate for design of intersections.

Real World Constraints

- Composition:

  Saturation flow rate should be adjusted from its "ideal" value (s_0) of 1900 (large metro areas) or 1750 (all other areas) pc/hr/ln. As an approximation, we will use:

  $$s = s_0 \times f_{hv}$$

  where

  s = saturation flow rate (pc/hr/lnl)

  Where f_{hv} is the proportion of trucks in the stream. Assume E_T=2, this reduces to:

  $$f_{hv} = \frac{1}{1 + P_T}$$

Our approximation to saturation flow rate, then, is: $$s = \frac{s_0}{1 + P_T}$$

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

Real World Constraints

- Unprotected left turns:

  Assume that each unprotected left turn is the equivalent of 2.0 through vehicles.

- Pedestrian constraints (where pedestrian volumes are significant):

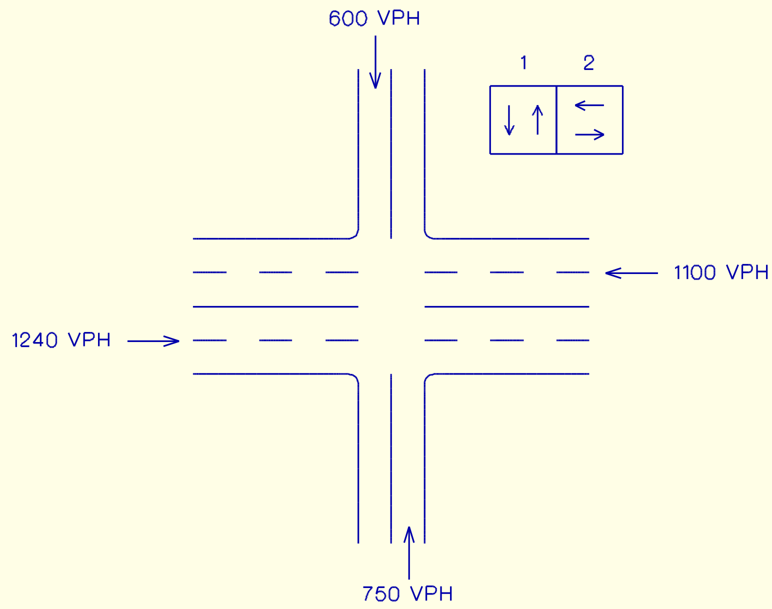
  Ped time = 5 sec + walk time

  (Typical walk rate was 4 ft/sec, now 3.5 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 1.9 sec/veh-lane and lost times of 5 sec/phase for all approaches.

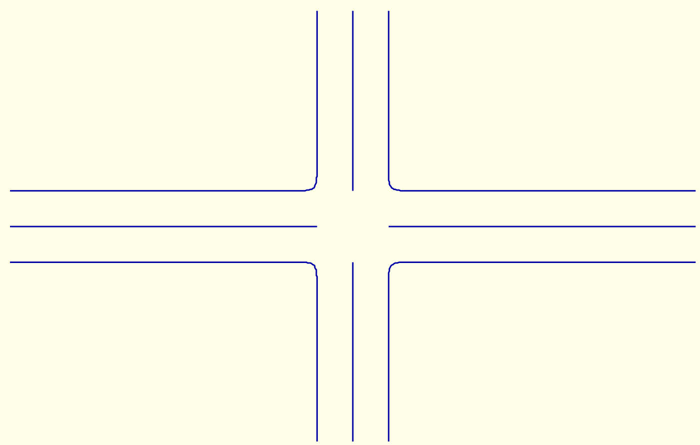


Example 2 – Part A

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.

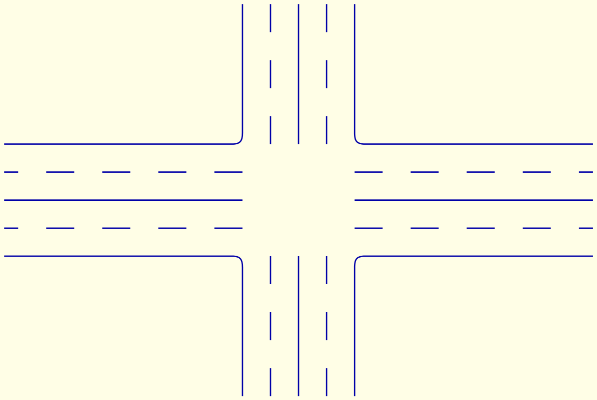
APPROACH	Peak Hour Volume	Percent Trucks	Percent Left Turns
EB	548	5	6
WB	672	7	7
NB	598	4	8
SB	606	2	6

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?