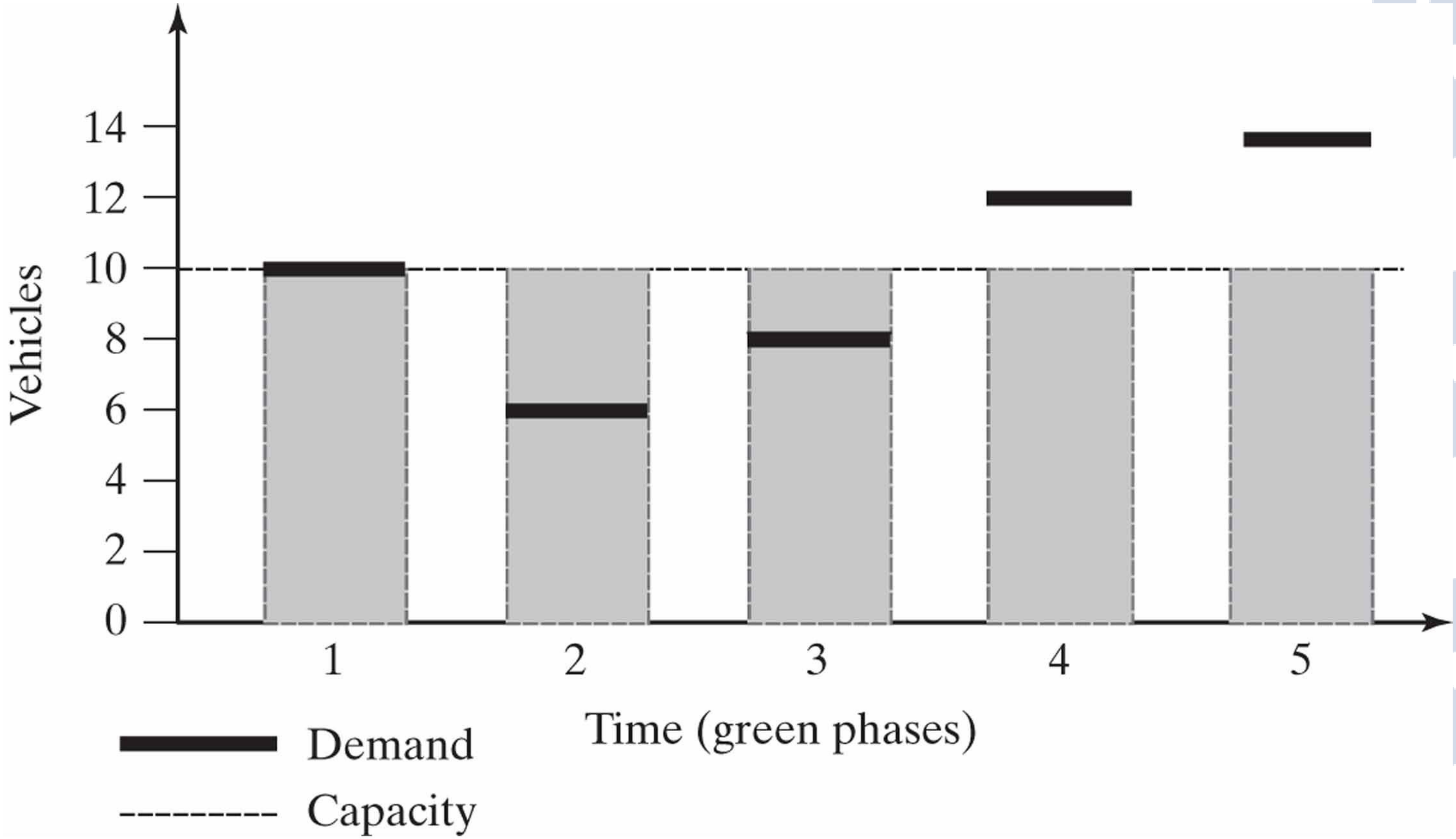
Actuated Signal Timing Design

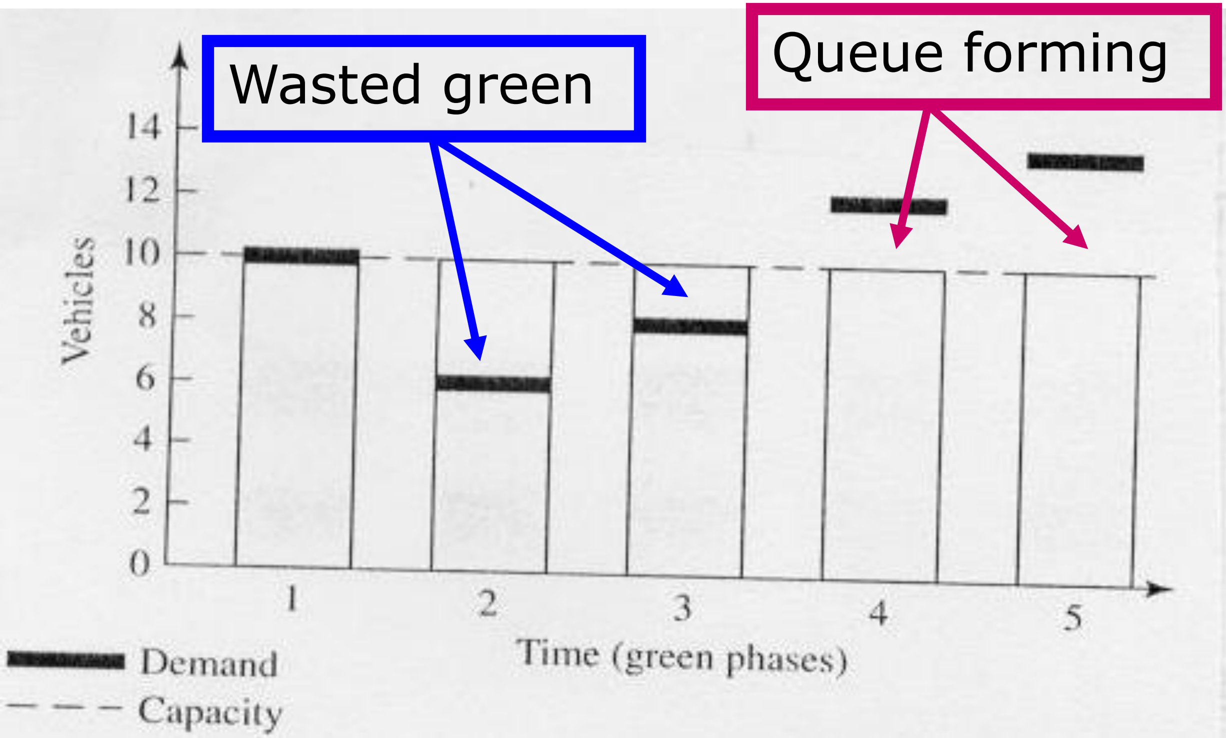
CIVL 4162/6162

Session Objective

- Explain terms related to actuated signals
- Explain why and where actuated signals are used
- Determine detector locations given traffic conditions
  - Explain how semi-,full-actuated, volume-density signals work
- Explain how presence and passage detectors work

Demand Variation





- Pretimed signals operate with constant cycle lengths, phase sequence, and interval timings ➔ Capacity with a pretimed controller is constant.

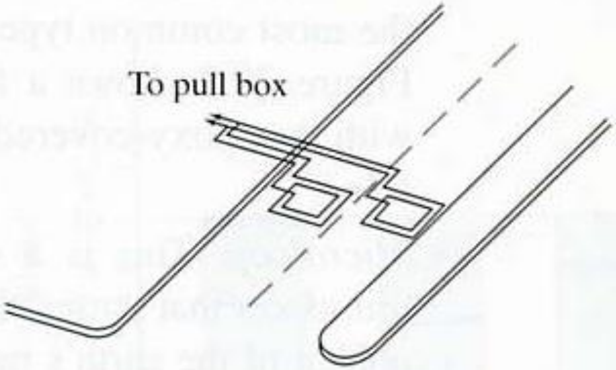
- When demand varies significantly from time to time, either green time is wasted or queue forms.
- In a coordinated system, however, all signals must operate on a single fixed cycle length to maintain offsets and progression patterns ➔ Actuated controllers are not good for such cases

Types of Actuated Control

The cycle length, phase splits, even the phase sequence may vary from cycle to cycle.

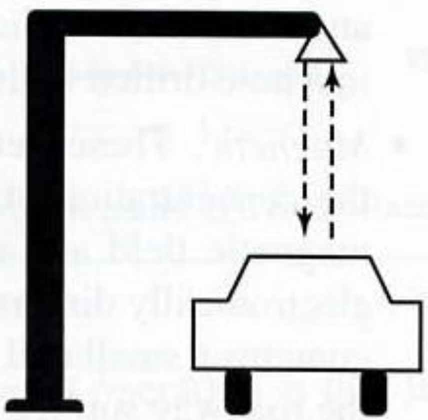
Semi-actuated control	Detection only on minor side-street approaches; green remain on the main until a "call" for service on the side street is registered. When warrant 1b (interruption of main traffic) is used.
Full-actuated control	All approaches have detectors; equal importance of the direction of traffic; for relatively isolated intersections;
Volume-density control	Basically functions like full-actuated control; good for high-speed approaches (>= 45 mph); Has extra features to adjust initial timing and reduce the gap extension during green extension time

Mechanisms of Actuation



(a) Loop Detector Installation

(b) Loop Detector at Intersection



(c) Ultrasonic Detector Operation

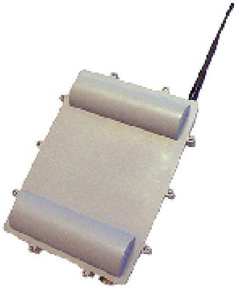
(d) Ultrasonic Detector Unit

Mechanisms of Actuation (2)

Area sensing

Imaging and virtual detectors

SmartSensor Makes Roadways More Intelligent



October 1, 2001 (Provo, UT, USA)-Wavetronix, LLC announces the product release of SmartSensor with Digital Wave Radar technology that will change the way that traffic information is gathered, analyzed and reported.

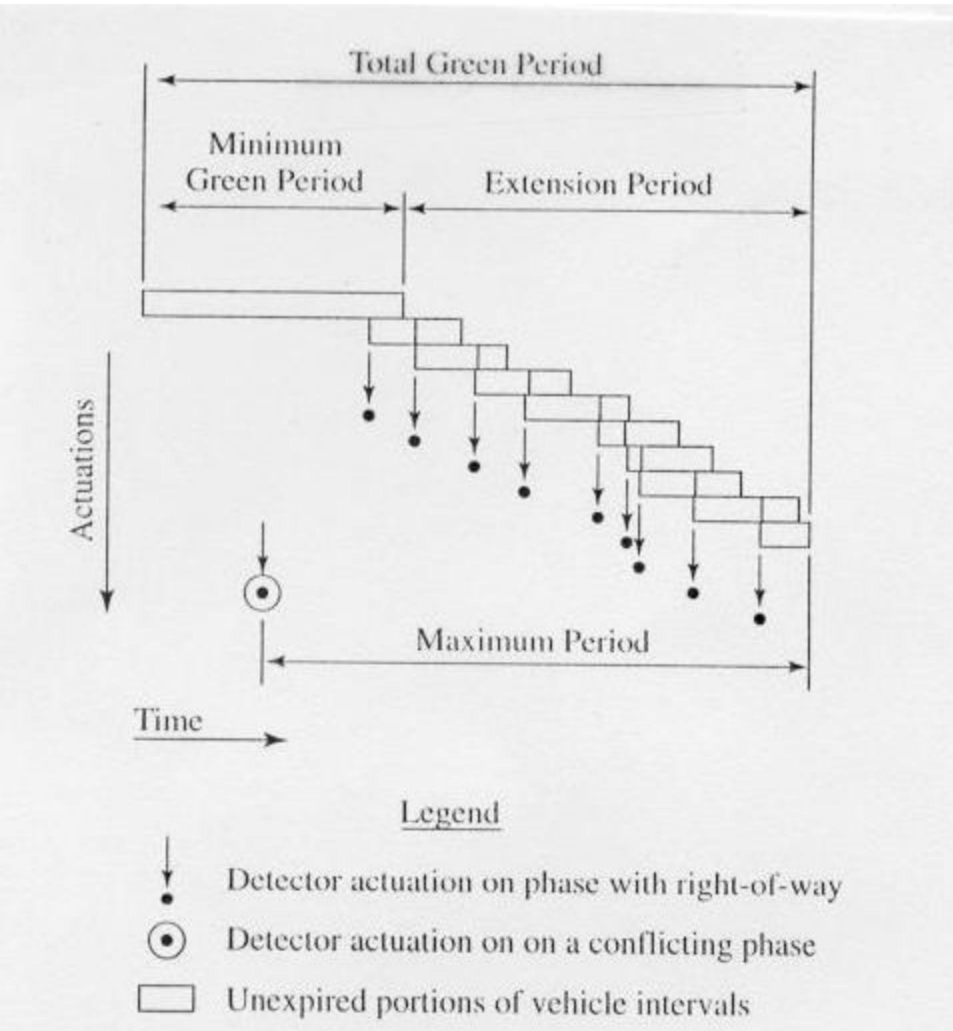
SmartSensor is the only above ground traffic sensor with the capability to detect up to 12 lanes of traffic and report lane by lane speed, volume, occupancy and trends. SmartSensor will automatically adapt and reconfigure if lanes change due to weather, construction, lane closures or other incidents. By collecting all this

Microwave sensing

Detection Type

Point detection ("passage" type)	❑ A single detector is placed for each approach lane to be actuated. ❑ The detector relays information as to whether a vehicle has passed over the detector.
Area detection ("presence" type)	❑ Generally used in conjunction with volume-density controllers. ❑ The importance is placed on the existence of a vehicle (s) in the detection area. ❑ They "count" the number of vehicles stored in the detection area.

Actuated Control Features and Operations



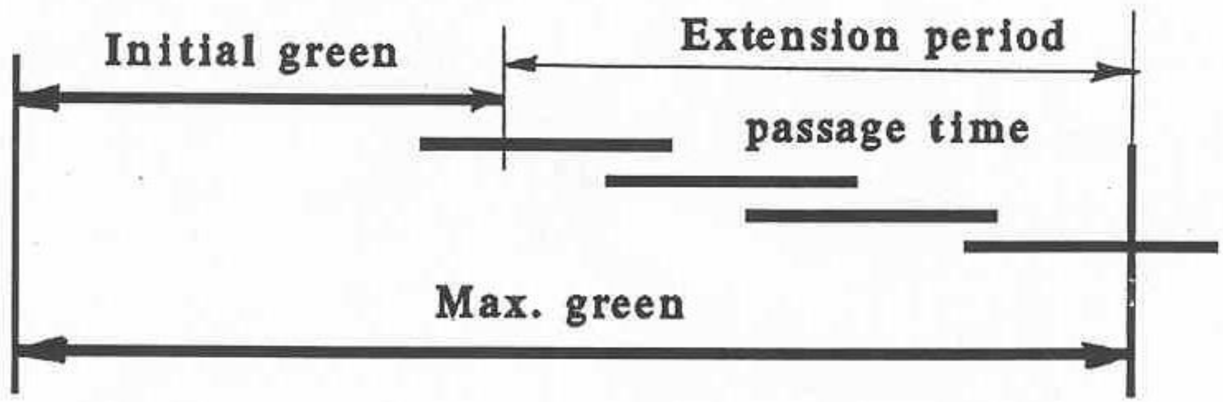
- ❑ Minimum green time (Initial green + unit extension)
- ❑ Passage time interval, unit or vehicle extension
- ❑ Maximum green time
- ❑ Recall switch (unless the subsequent phase has the recall "on" green remains to the previous phase unless demand exists)
- ❑ Yellow and all red

How the maximum green time works (Semi-actuated)

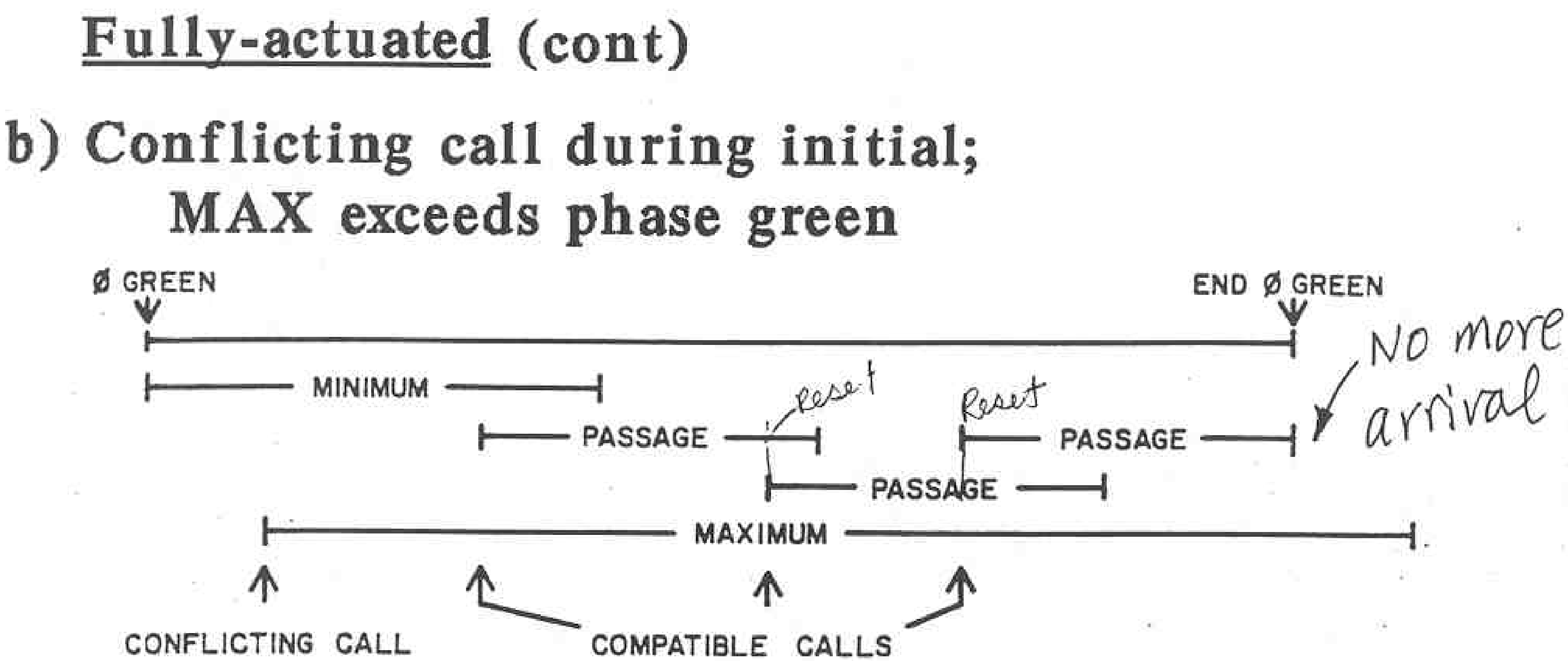
* How the MAXIMUM green time works:

<u>Semi-actuated:</u>

The MAX green starts right when the minor street receives green



How the maximum green time works (Fully actuated)



Steps for Actuated Signal Timing Design

- Step-1: Phase Plan
- Step-2: Minimum Green Time
- Step-3: Passage Time
- Step-4: Critical Lane Volumes
- Step-5: Yellow and All Red Intervals
- Step-6: Initial Cycle Length
- Step-7: Pedestrian Requirements

Step-1: Phasing

- We already know this step from last class

Step-2: Minimum Green Time

"Minimum green times must be set for each phase in an actuated signalization, including the nonactuated phase of a semi-actuated controller.

Point or passage detectors:

$$G_{\min} = l_1 + 2 * Int\left(\frac{d}{25}\right)$$

(d/20) the number of vehicles between the stop bar and the detector.

Area or presence detectors:

$$G_{\min} = l_1 + 2n$$

n = the number of vehicles queued at the beginning of green.

Gmin = minimum green time, s

l_1 = start-up lost time, s

D = distance between detector and STOP line, ft

25 = assumed head-to-head spacing between vehicles in queue, ft

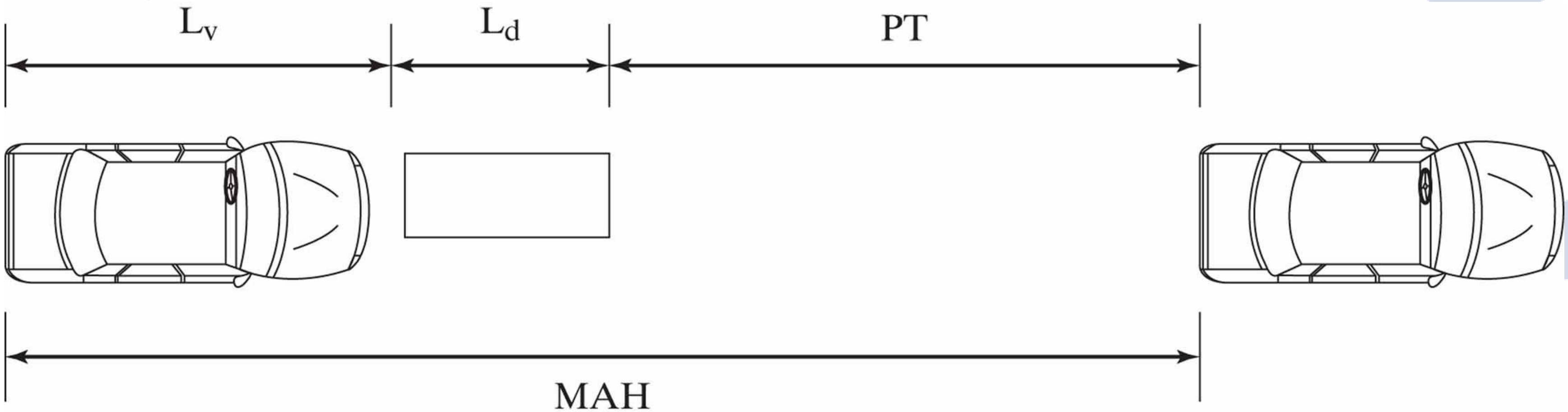
2 = 2 sec headway

Step-3: Passage Time

- Area or Presence Detection

$$PT = MAH - \frac{L_v + L_d}{1.47\ S_a}$$

PT: Passage Time in sec
MAH: Maximum Allowable Headway
Sa: Average approach speed
Lv: Length of the vehicle
Ld: Length of the detection zone



Step-3: Passage Time

- Point Detection
  - Equal to MAH

- Minimum Passage Time

$$PT_{min} = \frac{d}{1.47\,S_{15}}$$

S_{15} is the 15th percentile approach speed

Step-4: Critical Lane Volumes

- We already know this step

Step-5: Yellow Interval

- ITE recommends the following methodology for determining length of yellow or change interval

$$y = t + \frac{1.47S_{85}}{2a + (64.4 * 0.01G)}$$

Where,
y-> length of the yellow interval
t->driver reaction time, s
S_{85} -> 85th percentile speed of approaching vehicles in mi/hr
a-> decelleration rate of vehicles, ft/sec
G-> Grade of approach, %

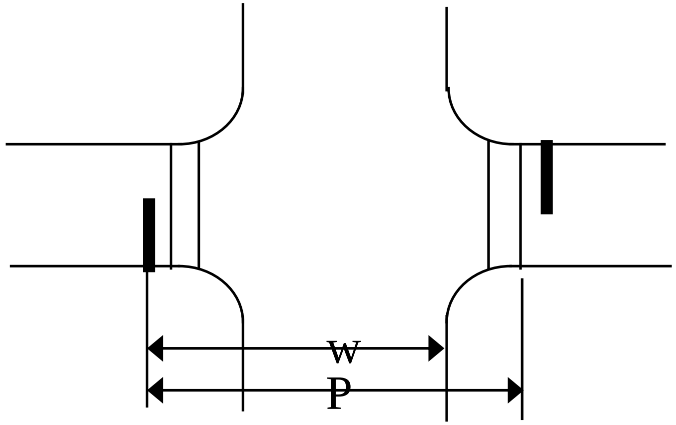
Step-5: All Red Interval

$$\text{All Red} = AR = \frac{w + L}{S_{15}} \quad \text{or} \quad \frac{P + L}{S_{15}}$$

L = length of the clearing vehicle, normally 20 feet

W = width of the intersection in feet, measured from the upstream stop bar to the downstream extended edge of pavement

P = width of the intersection (feet) measured from the near-side stop line to the far side of the farthest conflicting pedestrian crosswalk along an actual vehicle path



Step-5: Determine Lost Time

$$L = \sum_{i} t_{Li}$$

$$t_{Li} = l_{1i} + l_{2i}$$

$$l_{2i} = Y_i - e_i$$

$$Y_i = y_i + ar_i$$

- L: total lost time in the cycle, sec/cycle
- t_{Li} : Total lost time for phase i
- l_{1i} : Start-up lost time for phase i (2 sec)
- l_{2i} : Clearance lost time for phase i
- e_i : encroachment of effective green (2 sec)

Step-6: Initial Cycle Length

$$C_{des} = \frac{L}{1 - \left[\frac{V_c}{1615 * PHF * (\frac{v}{c})}\right]}$$

C_{des}-> Desirable cycle length, s
L-> total lost time per cycle, s/cycle
PHF-> Peak Hour Factor
v/c-> target v/c ratio for the critical movements in the intersection
Vc-> Sum of critical lane volumes

Step-6: Phase Green Times

- $g_i = (C - L) * \left(\frac{V_{ci}}{V_c}\right)$
- Where,
- g_i -> effective green time for phase *i*, sec
- V_{ci} -> CLV for phase or sub-phase *i*, veh/hr
- V_c -> Sum of all CLVs

Step-6: Critical Cycle Length

$$C_c = \sum_i (G_i + Y_i)$$

- Cc: Critical cycle length, sec
- Gi: Actual maximum green time for phase *i*
- Yi: Sum of yellow and all red intervals for phase *i*

Step-7: Pedestrian Requirements

$G_p = 3.2 + (2.7 * N_{ped}) + \frac{L}{S_p}$ for Where,

G_p -> Minimum pedestrian crossing time
L-> Length of the crosswalk, ft
□S_p> Average walking speed of the pedestrians
N_{ped} -> Number of pedestrians crossing per cycle in a single crosswalk, Nped
W_E-> Width of the crosswalk, ft

- 3.2-> Allocated as minimum start-up time for pedestrians
- L/Sp - > Time to cross safely
- Additional start up time based on the volume of pedestrians that need to cross the street

Step-7: Pedestrian WALK Indication

- Walk Indication

$$WALK_{min} = 3.2 + (2.7 * N_{ped})$$

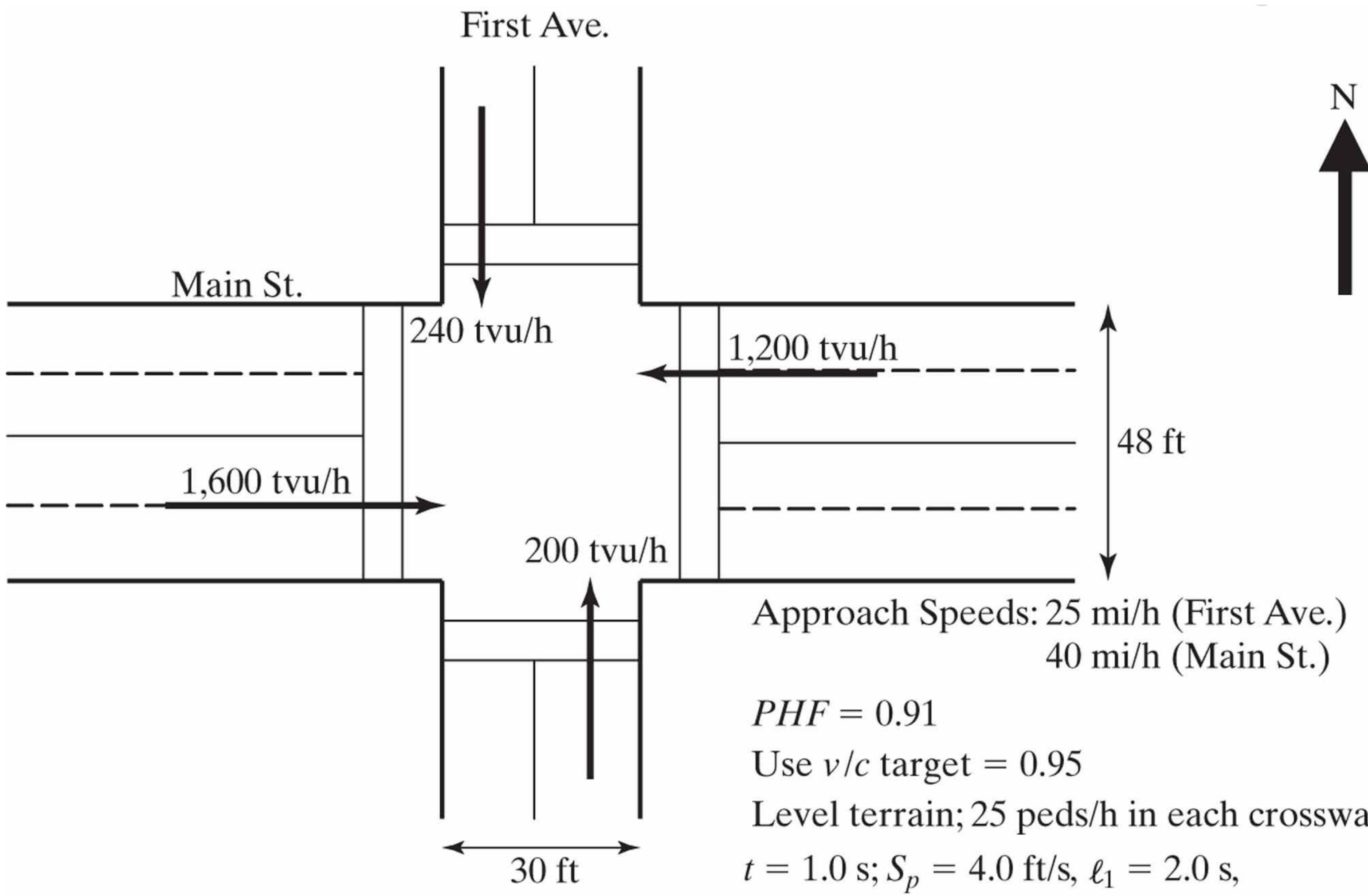
Where,

G_p -> Minimum pedestrian crossing time
L-> Length of the crosswalk, ft
□ S_p> Average walking speed of the pedestrians
N_{ped} -> Number of pedestrians crossing per cycle in a single crosswalk, Nped
W_E-> Width of the crosswalk, ft

- Up-raise hand flashing

$$Up - raise\ hand\ flashing = \frac{L}{S_p}$$

Example



Approach Speeds: 25 mi/h (First Ave.)
40 mi/h (Main St.)

$PHF = 0.91$

Use v/c target $= 0.95$

Level terrain; 25 peds/h in each crosswa

$t = 1.0$ s; $S_p = 4.0$ ft/s, $\ell_1 = 2.0$ s,
$e = 2.0$ s, $a = 10$ ft/s^2, $L = 20$ ft.