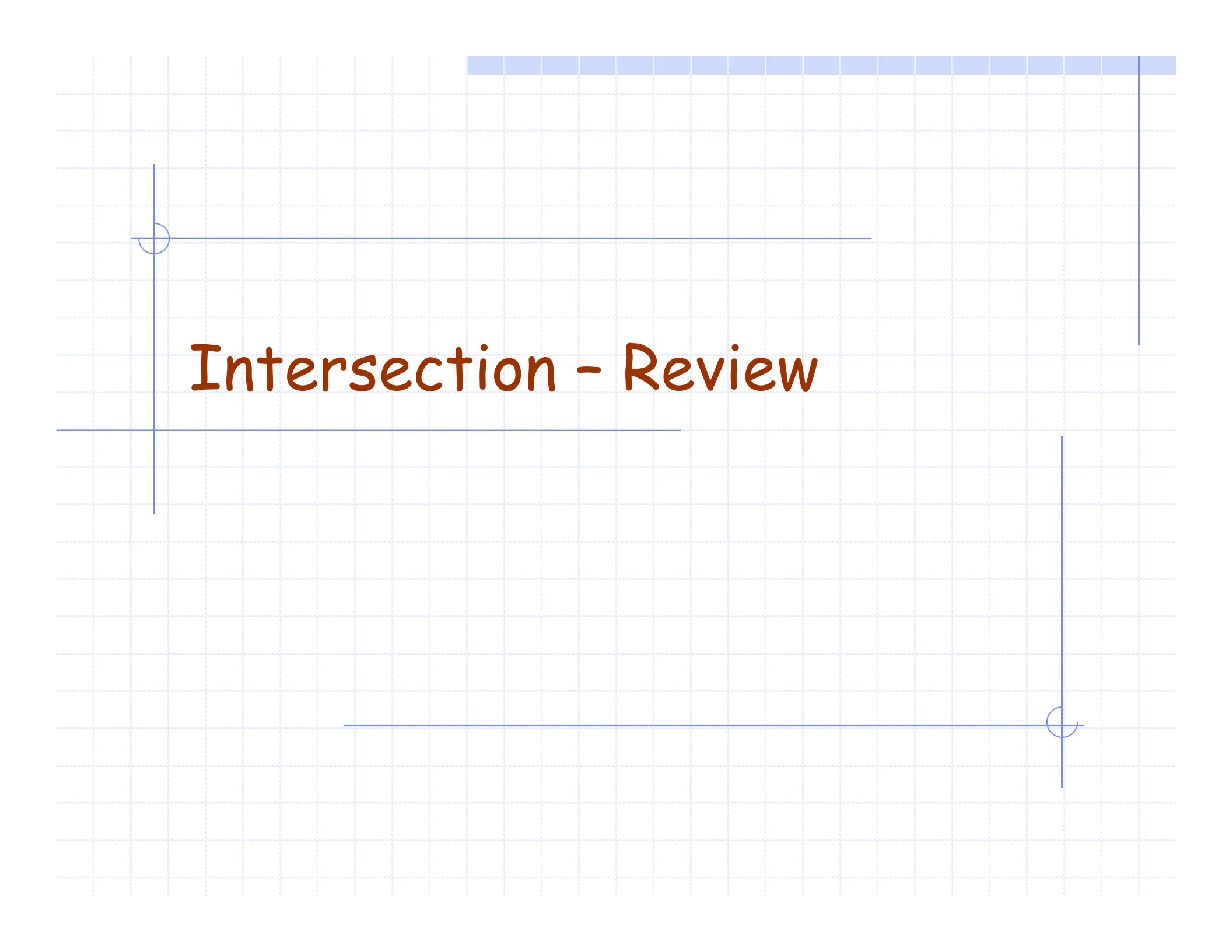




Intersection - Review



Signal Basics

- ◆ **Signal Warrants**

- Volume
- Crash
- Pedestrian

- ◆ **Definitions**

- Phase (protected/permitted)
- Change and clearance interval
- Cycle length
- Effective green
- Green split
- Offset
- Saturation flow
- Green ratio



Signal Timing Fundamentals

- ◆ **Change and Clearance interval = Yellow + All Red**
- ◆ **Lost time = Start/end loss + All Red**
- ◆ **Critical movement**
 - **Movement or combination of movements with the highest volume for EACH phase**
 - **One critical movement per phase**



Signal Timing Design

1. Determine lane configurations and lane volumes
2. Propose Phase Plans (provide diagrams)
3. Critical Volumes for each phase (for each proposed plan)
4. Recommend phase plan
5. Clearance Intervals
6. Lost Time
7. Cycle length
8. Green Splits
9. Display Greens
10. Provide Final Timing Diagram

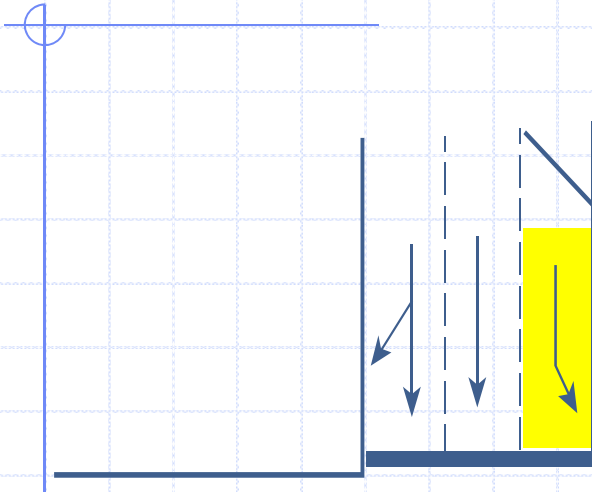


Lane Volume Allocation

- ◆ All turning movements are placed in exclusive left or right turn lanes, if present
- ◆ Through traffic is distributed evenly among through lanes
- ◆ Right turns are equivalent to through movements, if they share one lane
- ◆ Find equivalent through volume for left turns for shared left and through lane
 - Equivalent factor is based on opposing total through and right turn volume

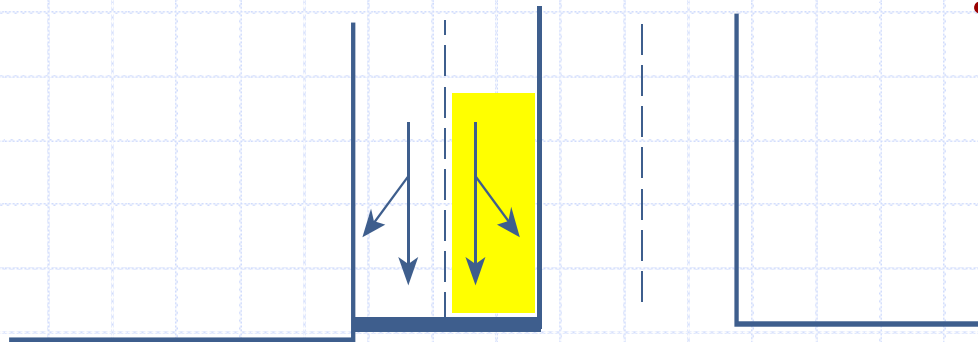


Left Turn Equivalents?



~~Yes~~ / No

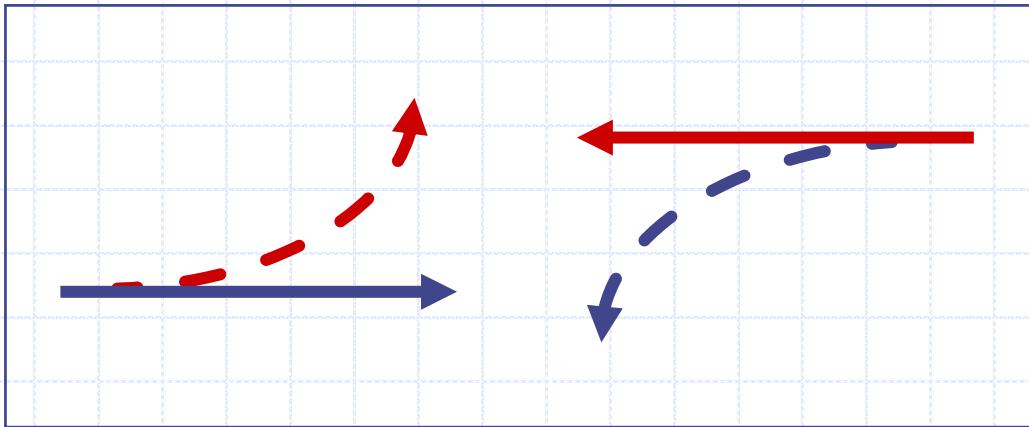
Phasing NO effect!!!



Yes / ~~No~~



Permitted Left Turns?

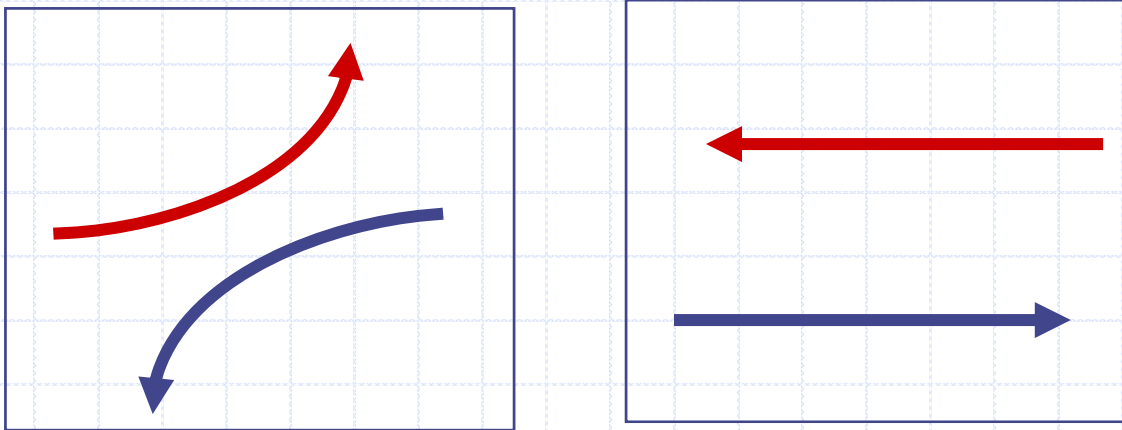


ALWAYS!!!

Left turn lane configuration NO effect



Protected Left Turns?



Max for each phase

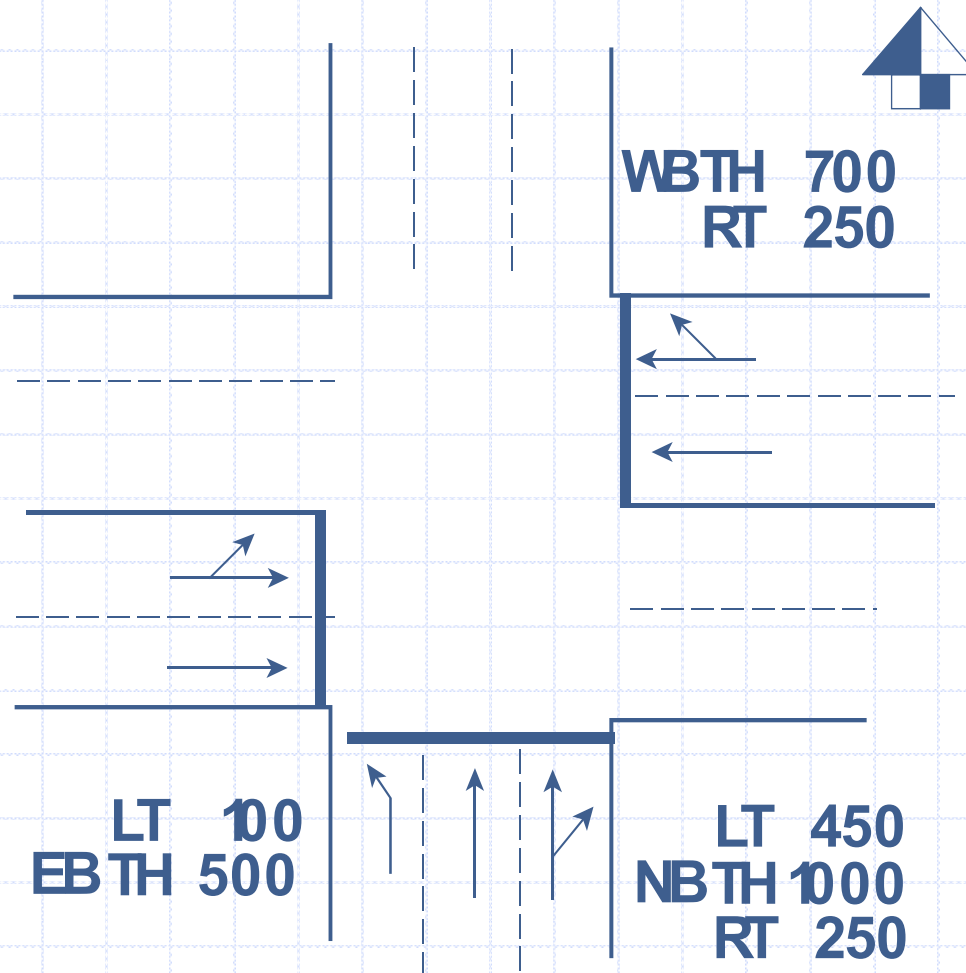


Important Notes

- ◆ Shared LT+TH lanes
 - Find through equivalents for left turns for lane volume allocation
 - Adjust the equivalent factor if left turn protected
- ◆ Overlapping phase: **exception** to the “highest volume is critical” rule
- ◆ Every intersection is different in terms of which phase plan works best



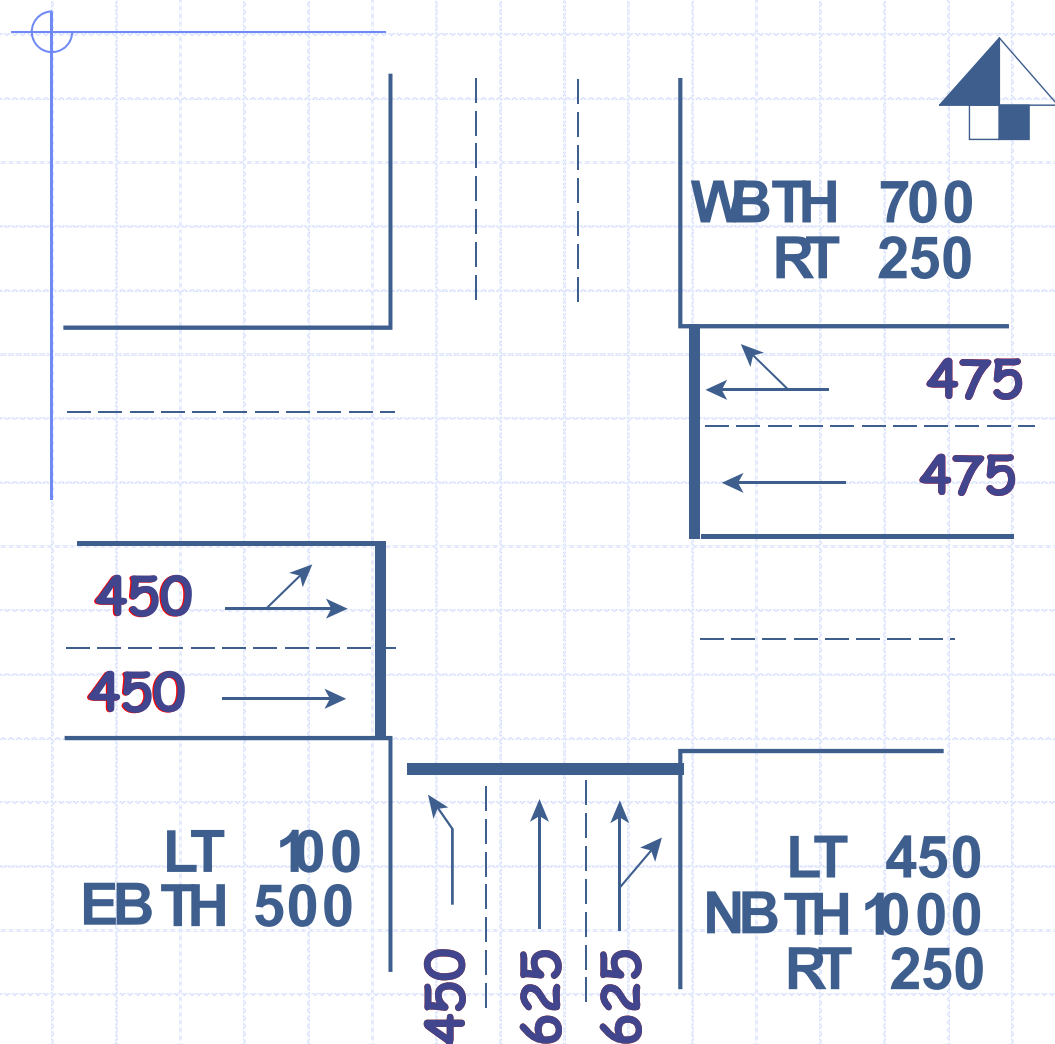
Example



Speed = 35
mph $t_r = 1.5$ s
 $s = 1875$
vphpgpl $a = 15$
ft/s² start
and end loss =
3 s
11 ft lanes
20 ft vehicles



Lane Allocation



NB

1. Exclusive LT lane
2. Thru+Right evenly sp

WB

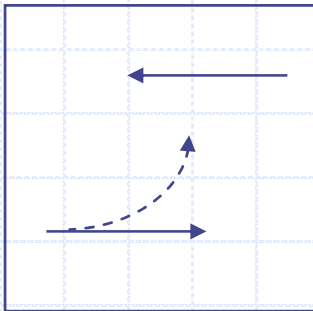
1. Thru+Right evenly s

EB

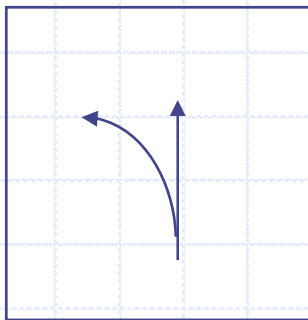
1. LT Equiv=2
2. Total equiv. $4(100)+5$
3. Vol per lane 450



Phase Plans



$$\text{Max} \{(450+0), (475+100)\} = 575$$



$$\text{Max} \{450, 625\} = 625$$

$$\Sigma_{cv} = 1200$$



EB/WB Clearance Interval

$$\tau_1 = t_r + [(W+L)/u_0] + [u_0 / (2a)]$$
$$= 1.5 + 53/51 + 51/30 = \mathbf{4.2 \text{ sec}}$$

W is road width to be cleared (ft or m) = 33 ft

L is vehicle length (ft or m) = 20 feet

u_0 is approach speed of vehicles (f/s or m/s) = 51 f/s

t_r is driver's reaction time (sec) = 1.5 sec

a is deceleration rate (ft/s² or m/s²) = 15 fps²



NB Clearance Interval

$$\tau_2 = t_r + [(W+L)/u_0] + [u_0 / (2a)]$$
$$= 1.5 + 64/51 + 51/30 = \mathbf{4.5 \text{ sec}}$$

W is road width to be cleared (ft or m) = 44 ft

L is vehicle length (ft or m) = 20 feet

u_0 is approach speed of vehicles (f/s or m/s) = 51 f/s

t_r is driver's reaction time (sec) = 1.5 sec

a is deceleration rate (ft/s² or m/s²) = 15 fps²



AR and Yellow

- ◆ **EB / WB**
 - 3.5 seconds yellow
 - 0.7 seconds all red
- ◆ **NB**
 - 3.5 seconds yellow
 - 1.0 second all red



Lost Time

- ◆ $L = \text{start/end loss} + \text{AR}$
 $= 3 + 0.7 + 3 + 1 = 7.7 \text{ seconds}$

Note: All red needs to be added to lost time

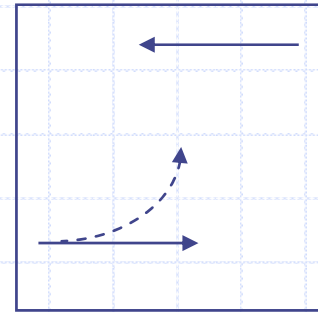


Optimum Cycle Length

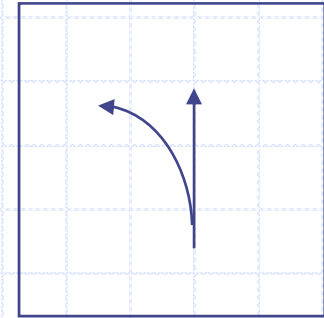
$$C_o = \frac{1.5 L + 5}{1 - \Sigma y_i} = \frac{1.5 * 7.7 + 5}{1 - (1200/1875)} = 45.9 \text{ sec. } 50 \text{ sec}$$



Green Splits



CV₁ 575



CV₂ 625

$$g_T = C - L = 50 - 7.7 = 42.3 \text{ seconds}$$

$$g_i = g_T (y_i / \Sigma y_i)$$

$$g_1 = 42.3 (575 / 1200) = 20.3 \text{ seconds}$$

$$g_2 = 42.3 (625 / 1200) = 22.0 \text{ seconds}$$

$$\text{Check } 20.3 + 22.0 = 42.3$$



Display Greens

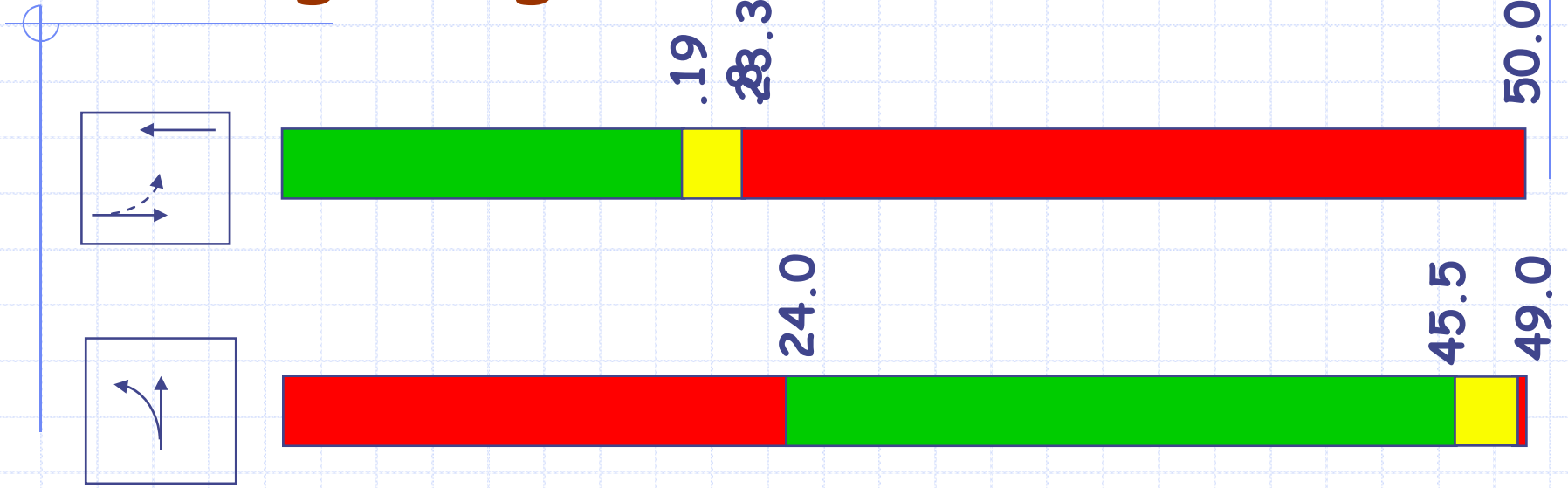
$$G_i = g_i + I_i - T_i$$

$$G_1 = 20.3 + (3+0.7) - 4.2 = 19.8 \text{ seconds}$$

$$G_2 = 22.0 + (3+1) - 4.5 = 21.5 \text{ seconds}$$



Timing Diagram





Unsignalized Intersection

- ◆ **Movement**
- ◆ **Stop Control (2-way, all-way)**
- ◆ **Rank**
- ◆ **Critical Gap**
- ◆ **Follow-up Gap**
- ◆ **Gap Acceptance/Rejection**



Unsignalized Intersection

- ◆ **Vehicle Arrival Distribution**
 - **Time headway: Negative Exponential Distribution**

$$P(h \geq t) = e^{-t/\bar{h}}$$