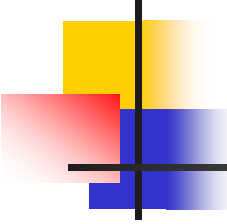


Signal Design

The process of designing the different components of traffic signals



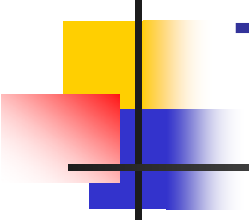


Objectives of Signal Timing

- Minimize delay
- Minimize conflicts
- Maximize capacity
- Reduce crashes

Each objective leads to a different solution

We must find an **appropriate compromise**



Types of Signal Timing

- Isolated Signals:

- Fixed / Pretimed

Signals which have a designated cycle which does not change regardless of flow or time of day

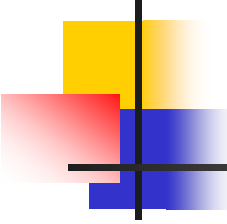
- Semi-actuated

Signals in which a major flow sees green unless: a detector on a minor approach is triggered **AND** a preset, minimum green time is exceeded on the major approach

- Fully actuated

Signals in which current flow sees green unless: a detector is triggered **AND** the preset, minimum green time is exceeded on the current approach **OR** the preset, maximum green time is exceeded

Terms



Cycle: a complete rotation through all the indications provided. Every legal movement receives a “green”

Cycle Length (C): time (seconds) for the signal to complete one full cycle.

Interval: an interval of time during which none of the lights at a signalized intersection changes

Change interval: yellow indication for a given movement

Clearance interval: all red, after yellow

Green interval: green indication for a particular movement

Red interval: red indication for a particular movement

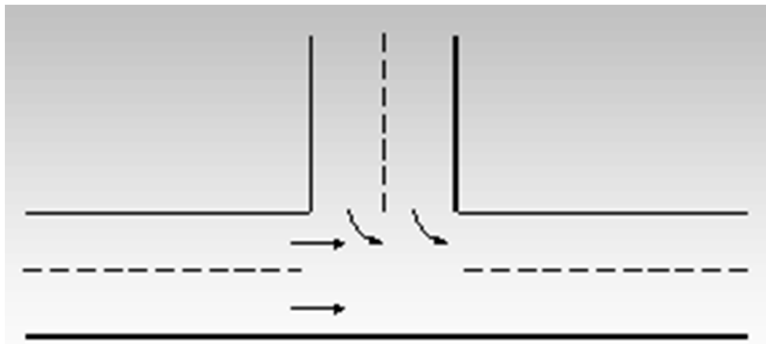
All-Red: red indication for all approaches

Terms



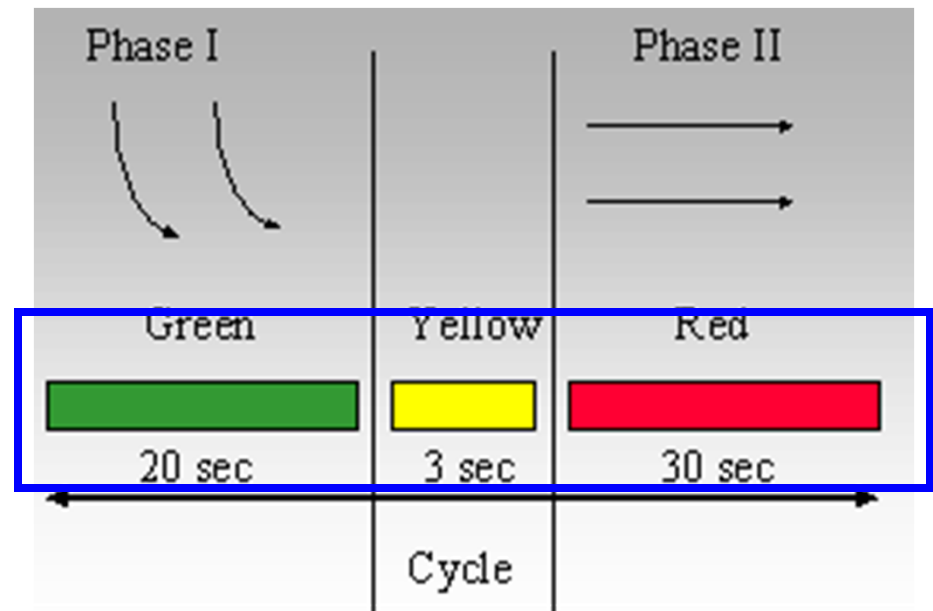
Phase: the aspect of a cycle allocated to one or more streams of traffic

Example: "T" intersection of two one-way streets



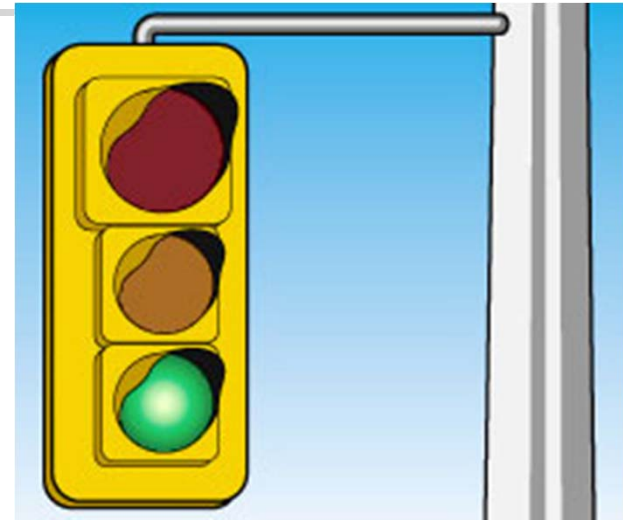
Cycle: a complete rotation through all the indications provided. Every legal movement receives a "green"

Cycle length: $20 + 3 + 30 \text{ sec}$
 $= 53 \text{ sec}$



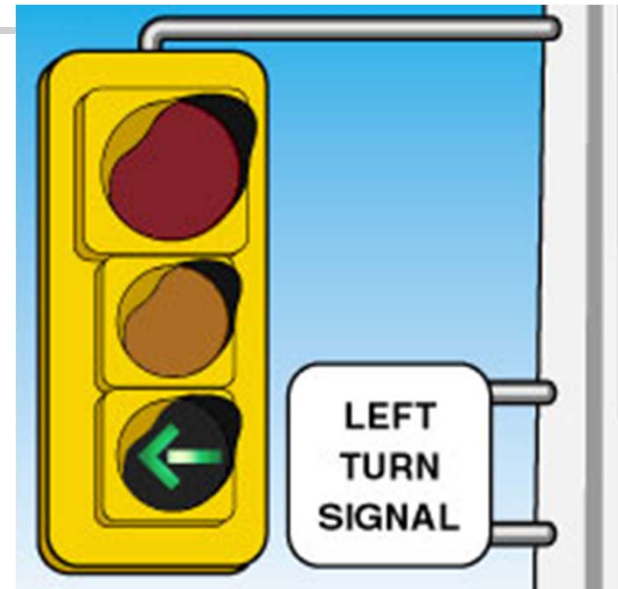
Terms

Permitted Left Turns: a permitted left turn receives a “green” ball but must yield right of way to opposing movements, used when left turn movements are reasonable and gaps in opposing traffic flow are adequate



Terms

Protected Left Turns:
provided separate phase,
left turn movements are
protected by arrow, left
turns on one-way or T-
intersection are considered
“protected” within that
phase



<http://www.drivingschool.ca/drivereducation/page16.html>

Terms

Protected/Permitted :

left turns are given permitted for part of the cycle and then protected for another part of the cycle or protected and then permitted

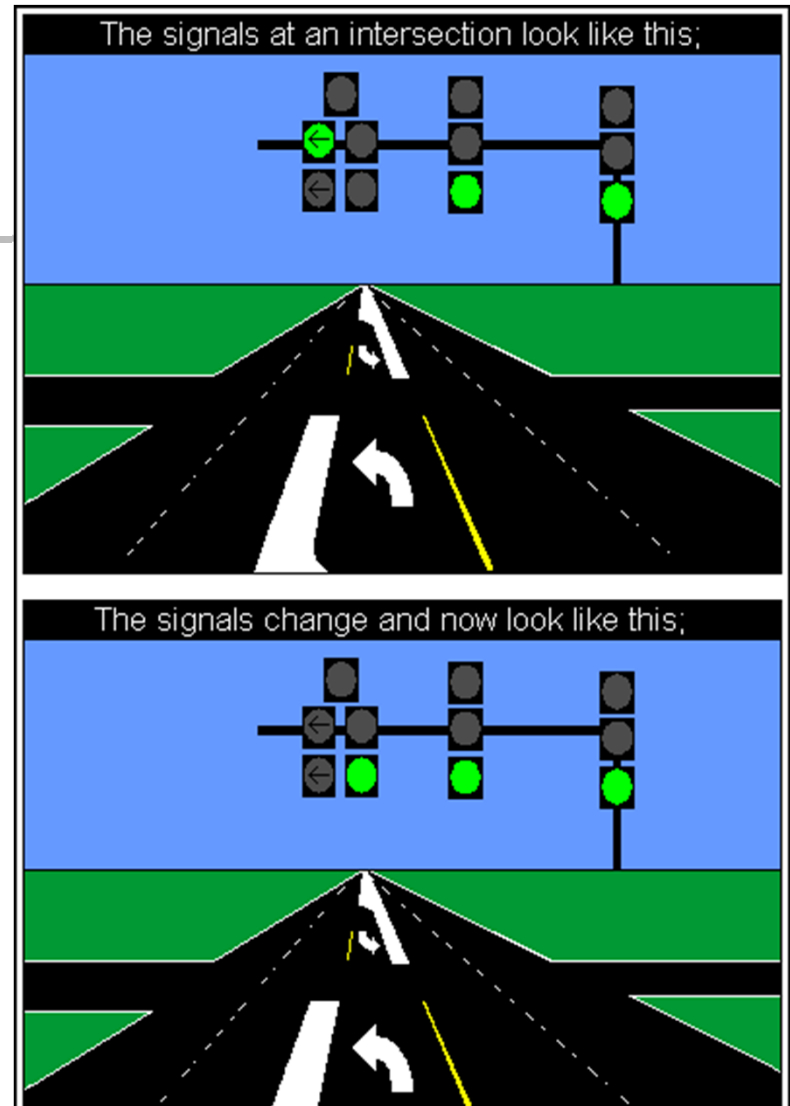
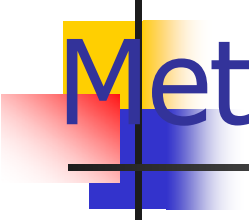
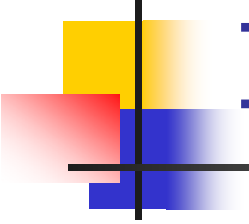


Image source: <http://www.fhwa.dot.gov/aard/signals.gif>

Design Process (Webster's Method)



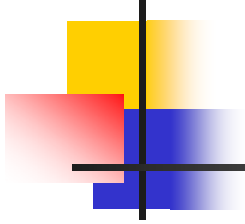
- Collect Traffic Variables:
 - Hourly volume
 - Peak hour volumes for all movements
 - Peak 15-min volumes for all movements
- Design



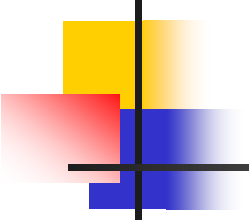
Isolated Intersections

- Basic Timing Elements:
 - Green: Green time
 - Yellow: Yellow time
 - Effective Green: $\text{Green} + \text{Yellow} - \text{time vehicles are discharging}$
 - All-Red: All movements have red
 - Intergreen time: $\text{Yellow} + \text{All-Red}$
 - Pedestrian WALK: 4-7 seconds when sign says WALK
 - Pedestrian crossing time (PCT): time required for a pedestrian to cross the intersection

Intergreen Time



- Determined based on:
 - Stopping Sight Distance (SD) – Chapter 3
 - Intersection clearance time
 - Pedestrian crossing time (PCT) – if there are no pedestrian signals (will discuss under minimum green)



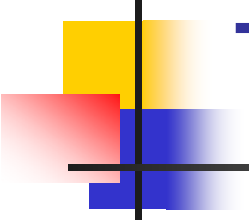
Intergreen Example

2% grade, 50 feet across intersection, vehicle length is 20 feet, design speed = 45 mph (66 ft/sec), acceleration rate = 11.2 ft/sec², assume 1.0 sec P/R (event is expected)

- $\tau_{\min} = \delta + \frac{(W + L)}{u_o} + \frac{u_o}{2(a + Gg)}$
-

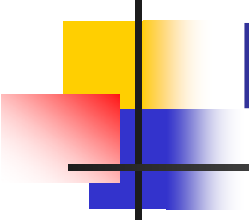
$$\tau_{\min} = 1 + \frac{(50 + 20)}{66} + \frac{66}{2(11.2 + 0.02 \cdot 32.2)} = \underline{\underline{4.84 \text{ sec}}}$$

Use 5 seconds



General Approach for Signal Timing

- Select phasing plan
- Calculate design flow rate using peak hour volume and PHF

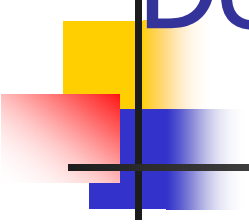


Peak Hour Factor (PHF)

- Design Hourly Volume (DHV):

$$\text{DHV} = (\text{Peak-Hour Volume} / \text{PHF})$$

Design Hour Volume is the one hour traffic volume used as the basis of design (usually as a prediction of a future condition)



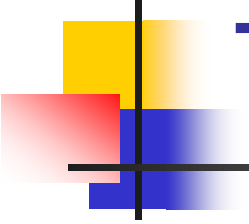
Design Hour Volume

PHF Adjusts volume to match peak 15 minutes

PHF = 0.85

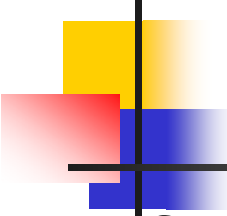
Calculated Volume = 1200 v/hr

$$\text{DHV} = \frac{1,200 \text{ vph}}{0.85} = 1,411 \text{ vph}$$



General Approach for Signal Timing

- Find the critical movements or lanes and calculate the critical flow ratios

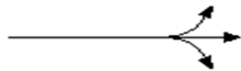
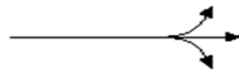
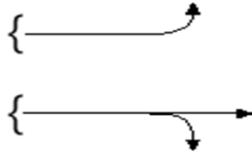
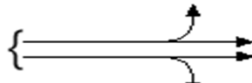
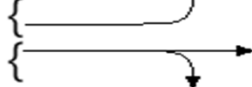
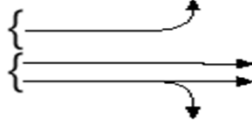
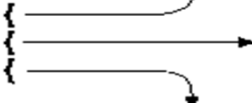


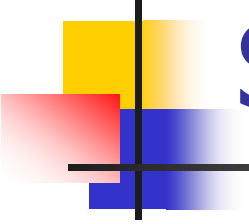
Lane Group

- Separates traffic into consecutive movements
- Lane group
 - set of movements that has same green phase and move together
 - Can be one or more lanes
- Guidelines for deciding lane groups:
 - use separate lane groups for exclusive left-turn lane(s) unless a shared left-through also exists for the approach
 - use separate lane groups for exclusive right-turn lane(s) unless a shared right-through also exists for the approach

Lane Group

EXHIBIT 16-5. TYPICAL LANE GROUPS FOR ANALYSIS

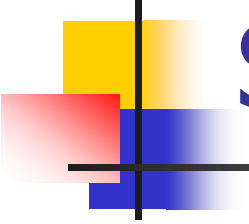
Number of Lanes	Movements by Lanes	Number of Possible Lane Groups
1	LT + TH + RT 	①  (Single-lane approach)
2	EXC LT  TH + RT 	② 
2	LT + TH  TH + RT 	①  OR ② 
3	EXC LT  TH  TH + RT 	②  OR ③ 



Saturation Flow Rate

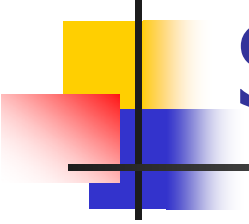
service rate: maximum vehicles that can be served in 1 hour assuming continuous green and a continuous queue of vehicles

- Represents capacity for the lane group
- when signal turns green – reaction and delay time as vehicles start up, then flow becomes uniform – headway becomes uniform



Saturation Flow Rate

- sat. flow can be determined directly in the field or calculated
- ideal $s_0 = 1,900$ pcphgpl (passenger cars per hour of green per lane)
- adjust s_0 to reflect non-ideal conditions



Saturation Flow Rate

Number of vehicles that could enter the intersection after initial startup if constant queue existed and constant green

$$s = \frac{3600}{h} \text{ (sec/hour)}$$

where:

s = saturation flow rate in vehicles per hour of green per lane(vphgpl)

h = saturation headway (seconds)

Table 16-1 Saturation Flow Rates and Headways
from a Nationwide Study

Item	Single-Lane Approaches	Two-Lane Approaches
Number of approaches	14	26
Number of 15-min periods	101	156
Avg saturation flow rate	1280 vphgpl	1337 vphgpl
Avg saturation headway	2.81 sec/veh	2.69 sec/veh
Maximum saturation flow rate	1705 vphgpl	1969 vphgpl
Minimum saturation headway	2.11 sec/veh	1.83 sec/veh
Minimum saturation flow rate	636 vphgpl	748 vphgpl
Maximum saturation headway	5.66 sec/veh	4.81 sec/veh

prevailing saturation flow for a specific lane group:

$$S = S_o * N * f_w * f_{HV} * f_g * f_p * fa * f_{bb} * f_{LU} * f_{RT} * f_{LT} * f_{Lbp} * f_{Rbp}$$

N = number of lanes in lane group

f_w = lane width adjustment factor

f_{HV} = heavy vehicle adjustment factor

f_g = grade adjustment factor

f_p = parking adjustment

fa = area type

f_{bb} = bus blockage factor

f_{LU} = lane utilization factor

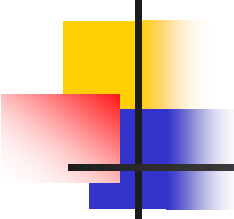
f_{RT} = right turn adjustment factor

f_{LT} = left turn adjustment factor

f_{Lbp} = pedestrian and bike adjustment factor for left turn movement

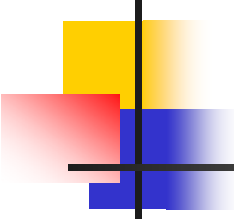
f_{Rbp} = pedestrian and bike adjustment factor for right turn movement

Ideal saturation flow rate is adjusted to represent all the factors for the lane group which decrease capacity (non-ideal conditions)



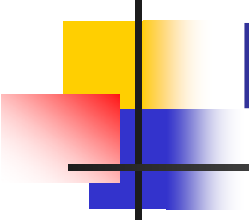
Critical Lane Group

- For a given phase: several lanes of traffic on one or more approaches move simultaneously
- One of those movements has the most intense traffic
- One lane (movement) requires the most time, all others require less
- Becomes the “design” lane
- If sufficient time is given to the critical lane, all other lanes moving within the phase will be accommodated
- Only one critical lane (movement) per phase
- Except for lost time one critical lane is always moving



Critical Movement or Lane

- Movement that requires the most time to execute
- If phase is long enough for the most critical movement, other movements in phase will be serviced as well
- Can be determined using flow ratios
- Movement with highest flow ratio is critical movement (ratio of flow to capacity)



Flow Ratio

■ Flow ratio =
$$\frac{\text{actual flow}}{\text{saturation flow rate}}$$

Flow = 1,200 vph

Saturation flow = 1500 vph

$$\text{Flow ratio} = \frac{1,200 \text{ vph}}{1,500 \text{ vph}} = 0.80$$

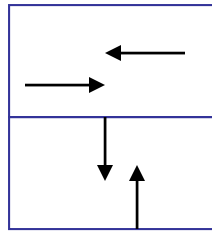
Same as volume/capacity

Critical Lane Example

Find critical lanes for each phase

Phase 1

Phase 2



$$(v/s)_{\text{north}} = 250/1700 = 0.15$$

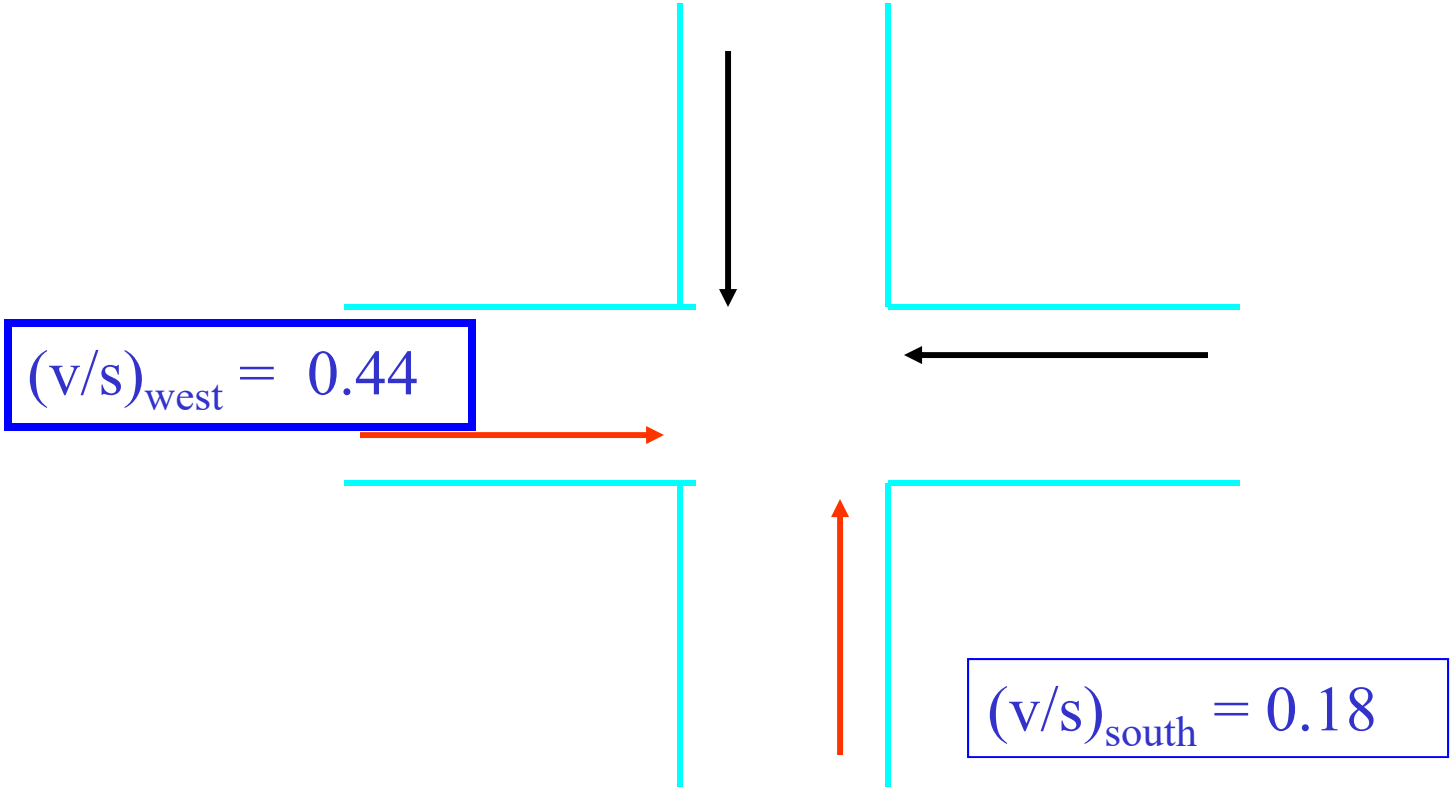
$$(v/s)_{\text{west}} = 750/1700 = 0.44$$

$$(v/s)_{\text{east}} = 600/1700 = 0.35$$

$$(v/s)_{\text{south}} = 300/1700 = 0.18$$

Critical Lane Example

v/s for critical lane group



The diagram illustrates a four-way intersection with cyan lines representing the road boundaries. Black arrows indicate the primary traffic flows: a vertical arrow pointing down from the top and a horizontal arrow pointing left from the right. Red arrows indicate secondary traffic flows: a horizontal arrow pointing right from the left and a vertical arrow pointing up from the bottom. Two blue-bordered boxes provide the volume-to-saturation ratio (v/s) for the critical lane groups: the westbound approach (left) has a value of 0.44, and the southbound approach (bottom) has a value of 0.18.

$$(v/s)_{\text{west}} = 0.44$$

$$(v/s)_{\text{south}} = 0.18$$

Example

For a NB/SB phase the following flows and saturation flow rates are available

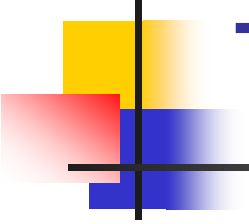
Movement	Design Flow Rate (pcu/hr)	Sat Flow Rate (pcu/hr)
NB L,T	600	1200
NB R,T	500	1700
SB L,T	450	1330
SB R,T	720	1600

Which is the critical lane movement?

What is the critical flow ratio?

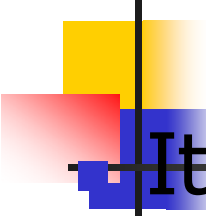
Solution: for NB L,T flow ratio = $600/1200 = 0.5$

Movement	Flow Ratio
NB L,T	0.50
NB R,T	0.29
SB L,T	0.34
SB R,T	0.45



General Approach for Signal Timing

- Calculate length of clearance time



Clearance Interval

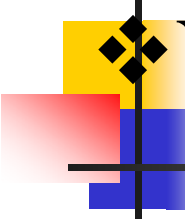
It allows all vehicles to clear the intersection after the green interval, before conflicting movements are released

Very important for Safety

Clearance interval = Yellow + ALL-RED

Avoid "Dilemma zone": where vehicle cannot stop safely before intersection and cannot clear the intersection before end of clearance interval

Clearance Interval

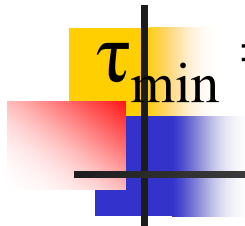


❖ Yellow interval

- ❖ time to warn drivers
- ❖ allow drivers in the intersection to clear
- ❖ Allow drivers behind the stop bar to either stop or clear the intersection if they cannot stop

For class we are assuming no all-red

Clearance Interval


$$\tau_{\min} = \delta + \frac{(W + L)}{u_o} + \frac{u_o}{2(a + Gg)}$$

$\tau_{\min}$ = minimum clearance interval

δ = perception/reaction time (lower than 2.5 because expected)

W = width of intersection (feet)

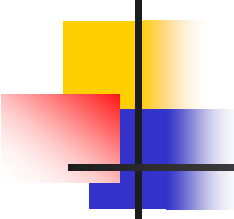
L = length of vehicle (feet)

u_o = speed of vehicle

a = constant rate of deceleration (ft/sec²)

G = grade

g = acceleration due to gravity (32.2 ft/sec²)



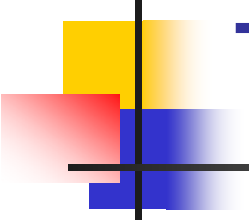
Clearance Example

2% grade, 50 feet across intersection, vehicle length is 20 feet, design speed = 45 mph (66 ft/sec), acceleration rate = 11.2 ft/sec², assume 1.0 sec P/R (event is expected)

$$\tau_{\min} = \delta + \frac{(W + L)}{u_o} + \frac{u_o}{2(a + Gg)}$$

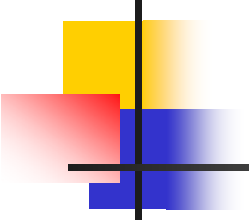
$$\tau_{\min} = 1 + \frac{(50 + 20)}{66} + \frac{66}{2(11.2 + 0.02 \cdot 32.2)} = \underline{\underline{4.84 \text{ sec}}}$$

Use 5 seconds



General Approach for Signal Timing

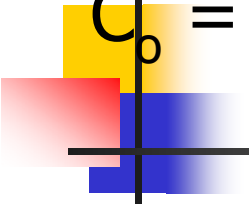
- Calculate the optimum cycle length



Cycle Length

- Cycle should be long enough to serve critical movements but no longer
- If cycle is too short -- inefficient because of time lost to too many changes high compared to usable green time
- If too long, delays will be lengthened as vehicles wait
- Several ways to calculate optimum cycle length
 - Webster's:
 - most common
 - minimizes intersection delay
 - Gives optimum cycle length as a function of lost time and critical flow ratio

Cycle Length


$$C_o = \frac{1.5L + 5}{1 - \sum(Y_i)}$$

where:

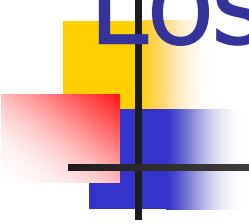
C_o = optimum cycle length

L = sum of the lost time for all phases

Y_i = ratio of the design flow rate to the saturation flow rate for the critical approach or lane in each phase

cycle length should be increased to the nearest multiple of 5 seconds

once have cycle length subtract intergreen time allocate green based on critical movements

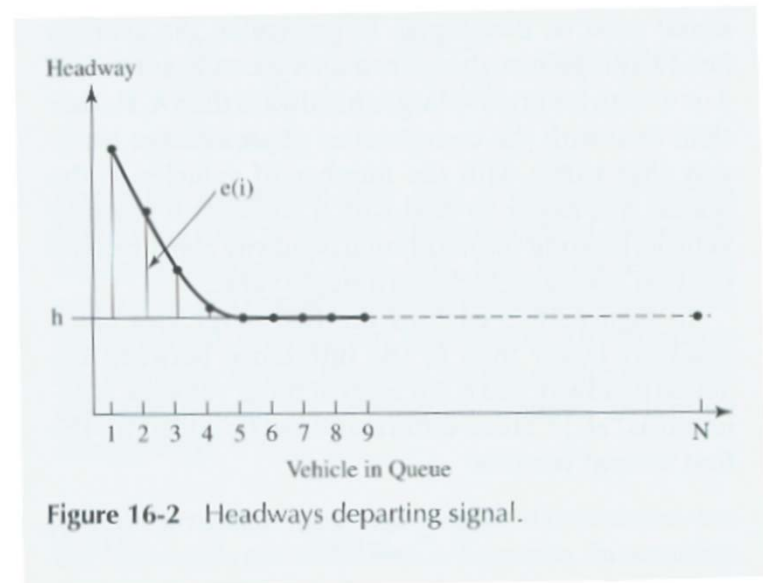


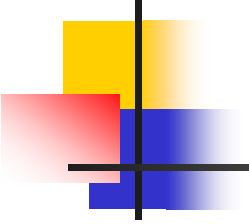
Lost Time

- Some time is “lost” as vehicles start up from a stop until vehicles are progressing at the saturation flow rate through the intersection
- Vehicles utilize some the yellow interval so this adds to the actual time available to vehicles

Start up lost time

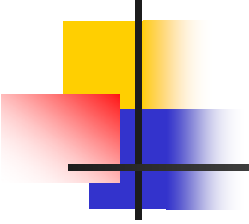
- Average headway is greater than h
- First 3 or 4 vehicles at signal require more time to react and accelerate than subsequent





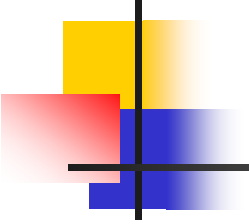
Start up lost time

- h = saturation headway (seconds)
- Average headway for first few vehicles in queue $> h$
- Start up lost time
- $$l_1 = \sum \Delta_i$$
 - where
 - l_1 = start-up lost time (sec/phase)
 - Δ_i = incremental headway (time $> h$) for vehicle i



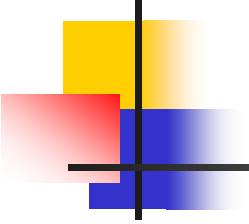
Time to discharge Queue

- Green time to discharge queue of vehicles
- $T_n = I_1 + nh$
- Where
- T_n = GREEN time to move queue of n vehicles through signalized intersection for phase
- I_1 = start-up lost time
- n = number of vehicles in queue
- h = saturation headway (s/veh)



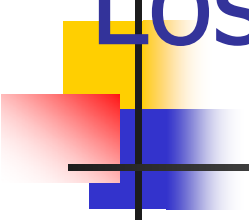
Clearance Lost time

- Lost time associated with stopping queue at end of GREEN signal (I2)
- Difficult to observe in field
- Time between last vehicle's front wheels crossing stop line and initiation of GREEN for next phase



Total lost time

- Lost time due to vehicles starting up at beginning of green and vehicles stopping at end of green
- $t_L = l_1 + l_2$
- Where:
- t_L = total lost time (sec/phase)
- l_1 = start-up lost time (sec/phase)
- l_2 = clearance lost time (sec/phase)



Lost Time for Phase i

$$l_i = G_{ai} + y - G_{ei}$$

Where:

l_i = lost time for phase i

G_{ai} = actual green time for phase i

y = yellow interval for phase i

$y = \tau_{min}$ (yellow interval) if all red is not included

G_{ei} = effective green time for phase i

Lost time includes start-up delay plus any portion of yellow not used for vehicle movement

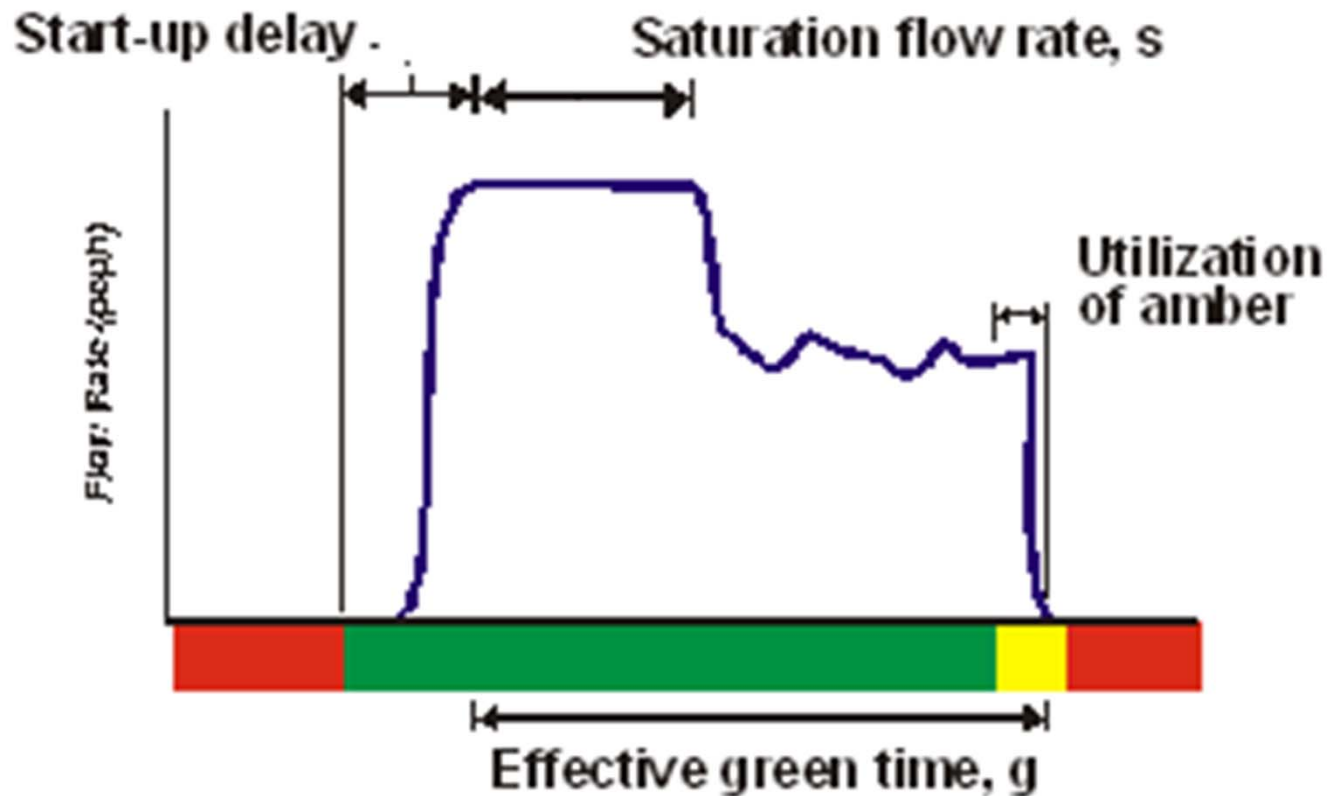
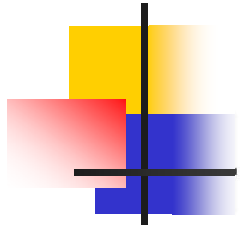


Image source: http://hcmdev.kittelson.com/Case1/popup_terms/effgreen_popup.htm

Effective green time

Amount of time during cycle that vehicles are moving for a particular movement

- $$g_i = G_i + Y_i - t_{Li}$$

- Where:

- g_i = effective green time (sec) for movement i

- G_i = actual green time (sec) for movement i

- Y_i = sum of yellow interval for movement i

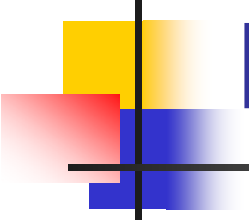
- t_{Li} = total lost time for movement i

- $$Y_i = y_i + a_{ri}$$

- Where:

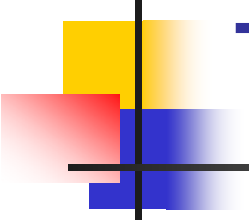
- y_i = yellow interval for movement i

- a_{ri} = all red interval for movement i



Effective Red time

- Amount of time vehicles for a particular movement are not moving



Total Lost Time

- Total lost time for a cycle is given by:

$$L = \sum l_i + R$$

Where

L = lost time per cycle

l_i = lost time for phase i

R = total all red during cycle

Example

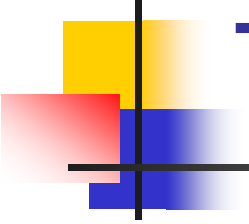
Given: 3 phases, Calculate the optimum cycle length based on the following information

Phase	Critical Flow Ratio	Lost Time (sec)
1	0.23	6
2	0.13	4
3	0.26	7

Solution:

$$C_o = \frac{1.5L + 5}{1 - \sum (V/s)} = \frac{1.5(6+4+7) + 5}{1 - (0.23+0.13+0.26)} = \frac{1.5(17) + 5}{1 - 0.62}$$

$$C_o = 80.3 \text{ sec, use 80 sec}$$



General Approach for Signal Timing

- Allocate available green based on critical flow ratios



Green Split Calculations

- With C_o , allocate available green to phases
- Allocated by critical flow ratios
- Each phase receives green consistent with its ratio of critical flow compared to that for other phases



Green Split Calculations

For phase I:

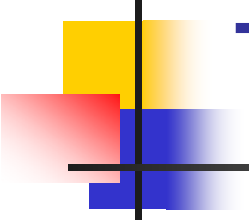
$$g_i = \frac{(V/s)_i * G_{te}}{\Sigma (V/s)}$$

where:

g_i = length of green interval for phase i (sec)

$(V/s)_i$ = critical flow ratio for phase i

G_{te} = available green for the cycle (sec)



Total Available Green

- $G_{te} = C - L$

Where:

G_{te} = total effective green time per cycle

C = actual cycle length

L = total lost time

Example



Given:

2 phase cycle

s = same for both cycles = 900 pcu/hr

available green time = 60 sec

Phase 1: critical flow rate = 500 pcu/hr

Phase 2: critical flow rate = 250 pcu/hr

Example

Given:

2 phase cycle

$s = \text{same for both cycles} = 900 \text{ pcu/hr}$

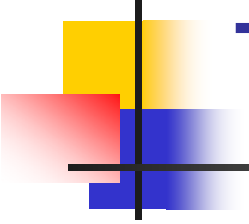
available green time = 60 sec

Phase 1: critical flow rate = 500 pcu/hr, flow ratio = 0.56

Phase 2: critical flow rate = 250 pcu/hr, flow ratio = 0.28

Solution for phase I:

$$g_1 = \frac{(V/s)_1 * G_{TE}}{\sum (V/s)} = \frac{0.56 * 60}{(0.56 + 0.28)} = \underline{40 \text{ sec}}$$



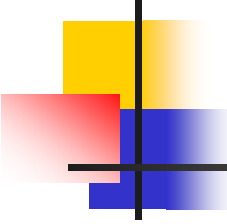
General Approach for Signal Timing

- Calculate length of minimum green time



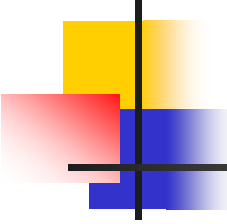
Minimum Green Interval

- Pedestrian crossing time is the minimum green that can be given
- Pedestrians can only cross intersection as long as no conflicting movements are present (with the exception of permitted left and right turns)
- Sum of green and intergreen must provide time for ped. to cross approach



Minimum Green Interval

- **With pedestrian signal Assumptions:**
 - pedestrian walk signal will be on for approx. 7 sec
 - a pedestrian may begin crossing the street as DON'T WALK begins to flash
 - pedestrians walk about 4 ft/sec
 - WALK interval is contained in the green interval of the corresponding approach



Minimum Green Interval

$$G_t = 3.2 + \frac{L}{S_p} + \frac{2.7(N_{ped})}{W_E} \quad \text{for } W_E > 10 \text{ ft}$$

$$G_t = 3.2 + \frac{L}{S_p} + 2.7(N_{ped}) \quad \text{for } W_E \leq 10 \text{ ft}$$

where:

G_t = pedestrian crossing time (sec) for pedestrian signal

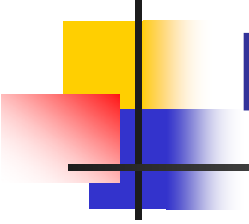
L = width of intersection (feet)

S_p = velocity of the pedestrian (usually 4 ft/sec) --depends on ped.

N_{ped} = number of pedestrians crossing during an interval

3.2 = pedestrian start-up time

W_E = effective crosswalk width (feet)



Minimum Green Interval

$$g_{\min} = P_t - I$$

where:

$g_{\min}$ = minimum green time (sec)

P_t = pedestrian crossing time (sec)

I = clearance interval (sec)

Example

Given:

Intersection width = 60 feet 12 peds/interval

$S_p = 4$ feet/sec 9 ft crosswalk

WALK interval = 10 sec

Clearance time is 6 sec.

$$G_t = 3.2 + \frac{L}{S_p} + \frac{0.27(N_{\text{ped}})}{W_E} \quad \text{for } W_E \leq 10 \text{ ft}$$

$$G_t = 3.2 + \frac{60 \text{ ft}}{4 \text{ ft/sec}} + \frac{0.27(12)}{9} = 18.6 \text{ sec}$$

Example

Given:

Intersection width = 60 feet 12 peds/interval

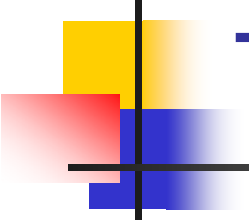
$S_p = 4$ feet/sec 9 ft crosswalk

WALK interval = 10 sec

Clearance time is 6 sec.

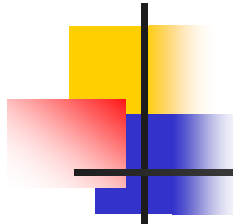
$$G_t = 18.6 \text{ sec}$$

$$g_{\min} = P_t - I = 18.6 \text{ sec} - 6 \text{ sec} = 12.6 \text{ sec}$$



General Approach for Signal Timing

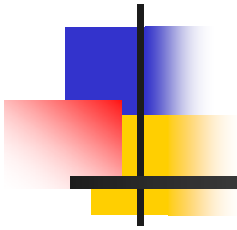
- Allocate available green based on critical flow ratios
- Calculate the capacity
- Check capacity/design flow rates and green intervals/minimum green intervals
- Adjust cycle timing if necessary

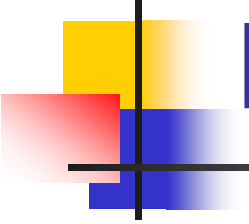


Adjustments

- Once done need to see if results work
- Make sure green meets requirements or adjust until it does (ped crossing)
- Check capacity
- If significantly below capacity, reduce green time
- If close increase
- Compute LOS and delay and check
- Will worry about LOS next time

Determination for Left Turn Phasing



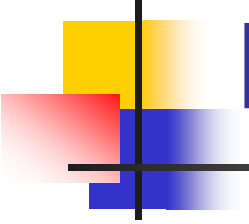


Left turn phasing

- Additional phases increase lost time
- Consider protected or protected/permitted:
 - $VLT \geq 200 \text{ veh/hr}$
 - $VLT * (v_o / N_o) \geq 50,000$

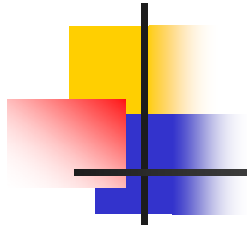
Where

- VLT = left-turn flow rate
- V_o = opposing thru movement flow rates
- N_o = number of lanes for opposing through movement



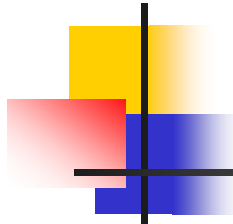
Left turn phasing

- Usually not provided when $V_{lt} < \text{two}$ vehicles per cycle (sneakers)
- When protected left is used for opposing left, consider even if not needed



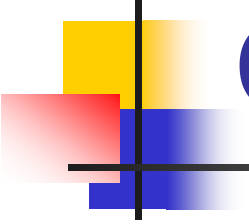
Protected

- Safest
- Recommended when 2 of following are met
 - Left-turn flow rate > 320 veh/h
 - Opposing flow rate $> 1,100$ veh/hr
 - Opposing speed limit ≥ 45 mph
 - Two or more left turn lanes



Protected

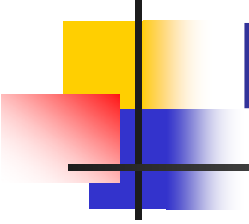
- Recommended when 1 of following is met
 - Three opposing traffic lanes with ≥ 45 mph speed limit
 - Left turn flow rate > 320 and % of HV $> 2.5\%$
 - ≥ 7 left turn accidents in 3 years have occurred
 - Average stopped delay to left turning traffic is acceptable for fully protected phasing and engineer judges that additional left-turn accidents will occur



Traffic Engineering Handbook

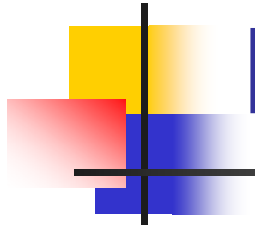
Guidelines for Left-Turn Phase

- Developed by University of Texas-Arlington
- Favors least restrictive option – permitted



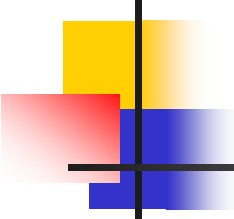
Permissive Only

- Left turn volume and speed limit fall within shaded portion of Figure 13-8, page 476 (TE Handbook)
- Sight distance for left-turning vehicles is not restricted
- < 8 left-turn related accidents (sum over 3 years) at any one approach
- < 450 left-turn related conflicts per million entering vehicles² (vphpl²)



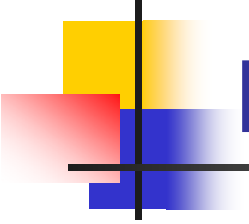
Protected Only

- Recommended when any two are met:
 - Peak 15-min flow rate for LT > 320 vph
 - Peak 15-min flow rate for opposing traffic > 1,100 vph
 - Opposing traffic speed limit $\geq$ 45 mph
 - 2 + left turn lanes



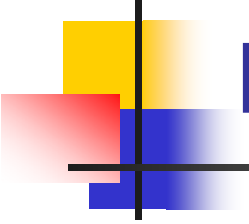
Protected Only

- Recommended when any one is met:
 - 3+ opposing lanes & opposing speed ≥ 45 mph
 - LT volumes > 320 vph & heavy vehicles $> 2.5\%$
 - Opposing volume $> 1,100$ & heavy vehicle LT traffic $> 2.5\%$
 - ≥ 7 LT-related accidents within 3 yrs for protected-permitted option
 - > 260 LT-related conflicts per million vphpl²
 - Average stopped delay for LT is acceptable for protected-only phasing and engineer judges more LT accidents would occur under protected/permitted option



Lead or Lag? (protected/permitted or protected only)

- Lead Advantages:
 - Clearing left first minimized LT-Thru conflicts
 - Moves spilled back vehicles out of thru lane
 - LT drivers quicker reaction time
 - Increases capacity and safety when left-turn lanes do not exist
- Lead Disadvantages
 - LT vehicles may continue after phase ends
 - Adjacent through vehicles— false start



Lead or Lag?

- Lead:

- Recommended unless lag is necessary for progression (**protected** first or protected only)
- **Permissive**/protected lead when LOS is unacceptable
- **Permissive**/protected lead when > 7 accidents and unacceptable delay with **protected**/permitted



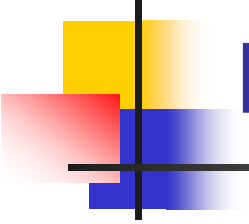
Lead or Lag?

■ Lag Advantages:

- Both directions of through traffic start at same time
- Ensures that LT vehicles not able to clear on permitted clear
- Allows LT vehicles to use permitted first, minimized protected
- Complete stopping of LT vehicles

■ Lag Disadvantages

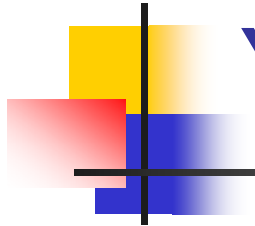
- Yellow trap
- Through vehicles are inhibited when spillback from LT occurs
- More severe collisions if through drivers speed through clearance interval and encounter LT



Lead or Lag?

- Lag

- Protected phase is recommended when intended to improve safety of of installed leading sequence with > 190 conflicts per million vphpl²
- Necessary to accommodate progression



Yellow Trap

- LT driver expects opposing display to be yellow when they receive yellow
- Yellow trap occurs when opposing traffic does not receive yellow and LT driver mistakenly assumes that is the case