

CEE 370

Transportation Engineering

Intersection Control and Design (II)



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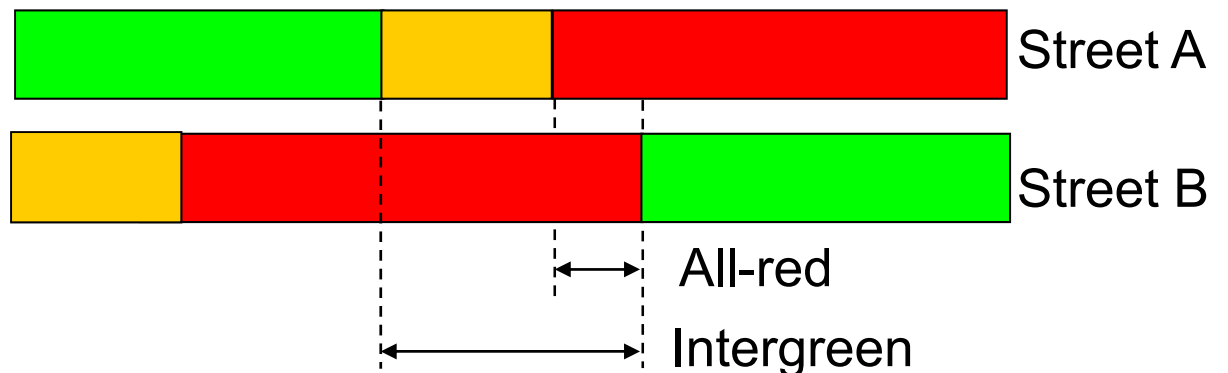
Learning Objectives

- To define lost, effective green time, and saturation flow
- To design signal timing for pretimed isolated signals (Webster's method)
- To understand the operation of actuated signals
- To perform warrant analysis for signal control

(Chapter 8, p.306-313; 322-330)

Basic Timing Elements

- Elements within a phase:
 - **Green interval:** the period of the phase during which the green signal is illuminated.
 - **Yellow/amber interval:** the portion of the phase during which the yellow light is illuminated.
 - **All-red interval:** the period during which the red light is illuminated for all approaches
 - **Intergreen interval:** the interval between the end of green for one phase and the beginning of green for another phase

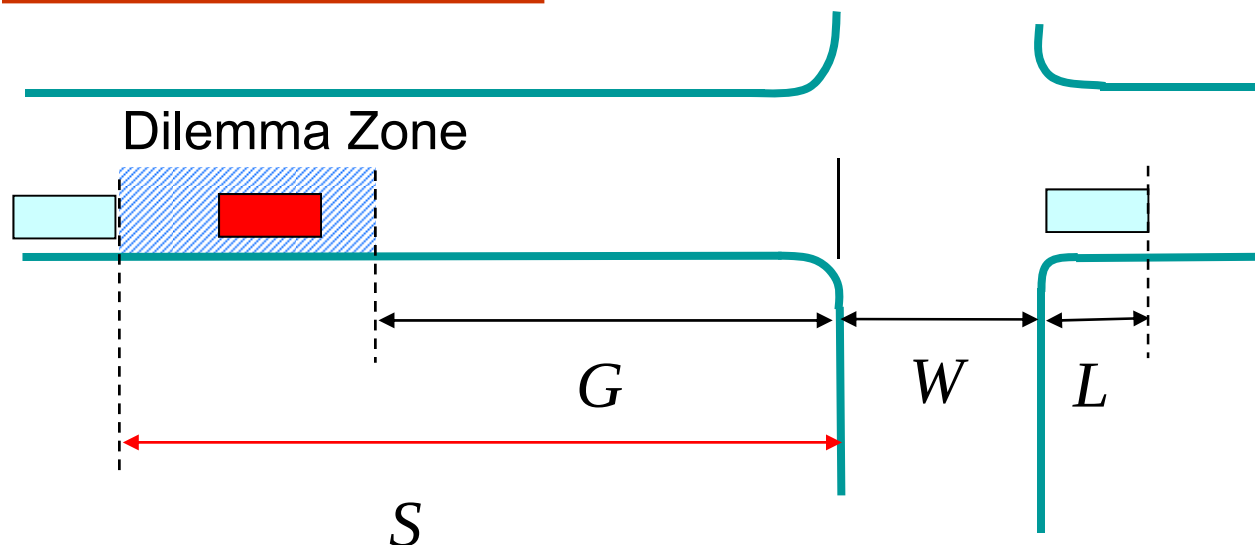


Intergreen Period

To Eliminate dilemma zone:

$$D = S - G = v_0 I - (W + L) - \left(t_r v_0 + \frac{v_0^2}{2a} \right) \rightarrow 0$$

$$I = t_r + \frac{v_0}{2a} + \frac{W + L}{v_0}$$



Practice Problem

Given the following information pertaining an intersection and its signal timing:

- Intergreen time of 6 sec
- Intersection width of 60ft
- Level grade with coefficient of friction of 0.5

Does a dilemma zone exist for a 18ft-long vehicle approaching at 50mph? Assume a perception-reaction time of 1sec

Solution

$$S = 1.47V_0t_r + \frac{V^2}{30(f \pm G)}$$

$$\rightarrow S = 1.47 \cdot 50 \cdot 1 + \frac{50^2}{30(0.5 + 0)} = 240.17_{(\text{ft})}$$

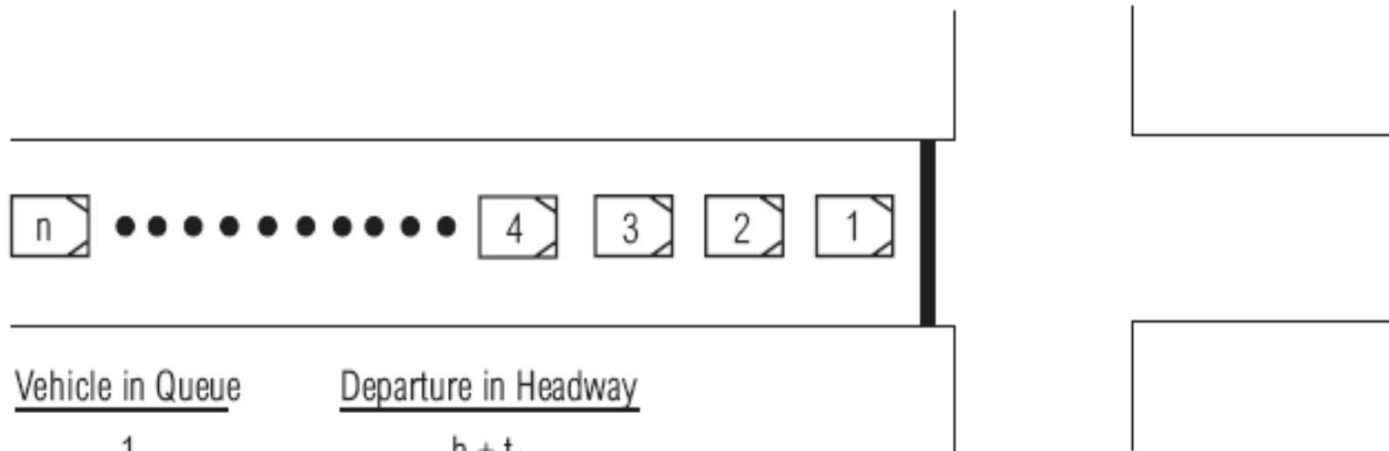
$$\rightarrow \frac{W + L + S}{1.47V_0} = \frac{60 + 18 + 240.17}{1.47 \cdot 50} = 4.33_{(\text{sec})} < 6_{(\text{sec})}$$

$\therefore$ No presence of dilemma zone

Types of Signal Controllers

- Pretimed
 - Fixed interval lengths in fixed sequence
- Semi-actuated (traffic-adjusted)
 - Predefined timing schemes selected based on traffic flow information
- Actuated
 - Varied length and/or sequence of signal indications
 - React to arrivals of vehicles/pedestrians
 - Isolated or coordinated

Condition at Start-up

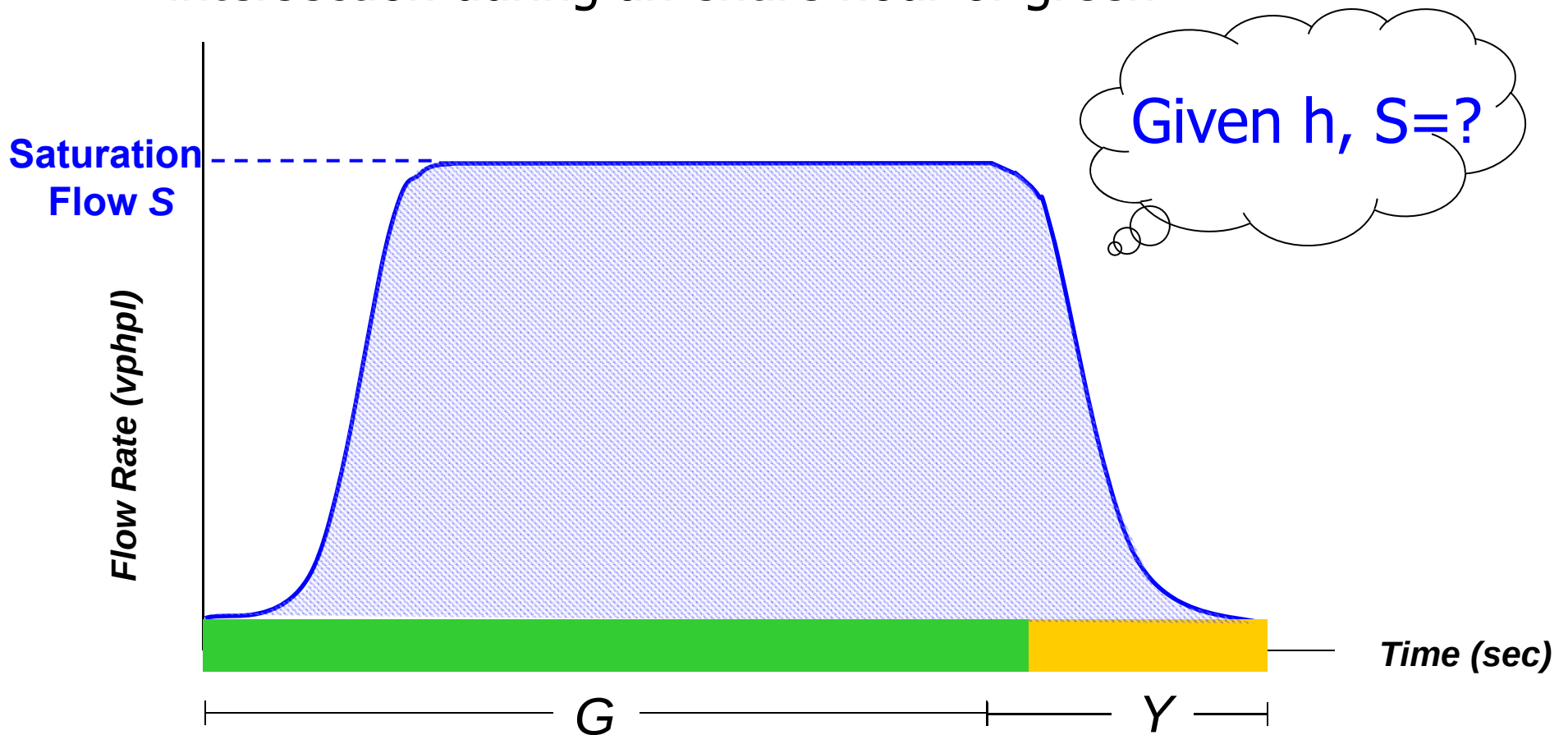


<u>Vehicle in Queue</u>	<u>Departure in Headway</u>
1	$h + t_1$
2	$h + t_2$
3	$h + t_3$
4	$h + t_4$
.	h
.	h
.	.
.	.
.	.
n	h

Queue Position	Observed Avg. Headway	Saturation Headway	Difference (Obs.-Est.)
1	3.14	2.14	1.00
2	2.74	2.14	0.50
3	2.52	2.14	0.38
4	2.37	2.14	0.23
≥ 5	2.14	2.14	0.00
Start-up Lost Time			2.11

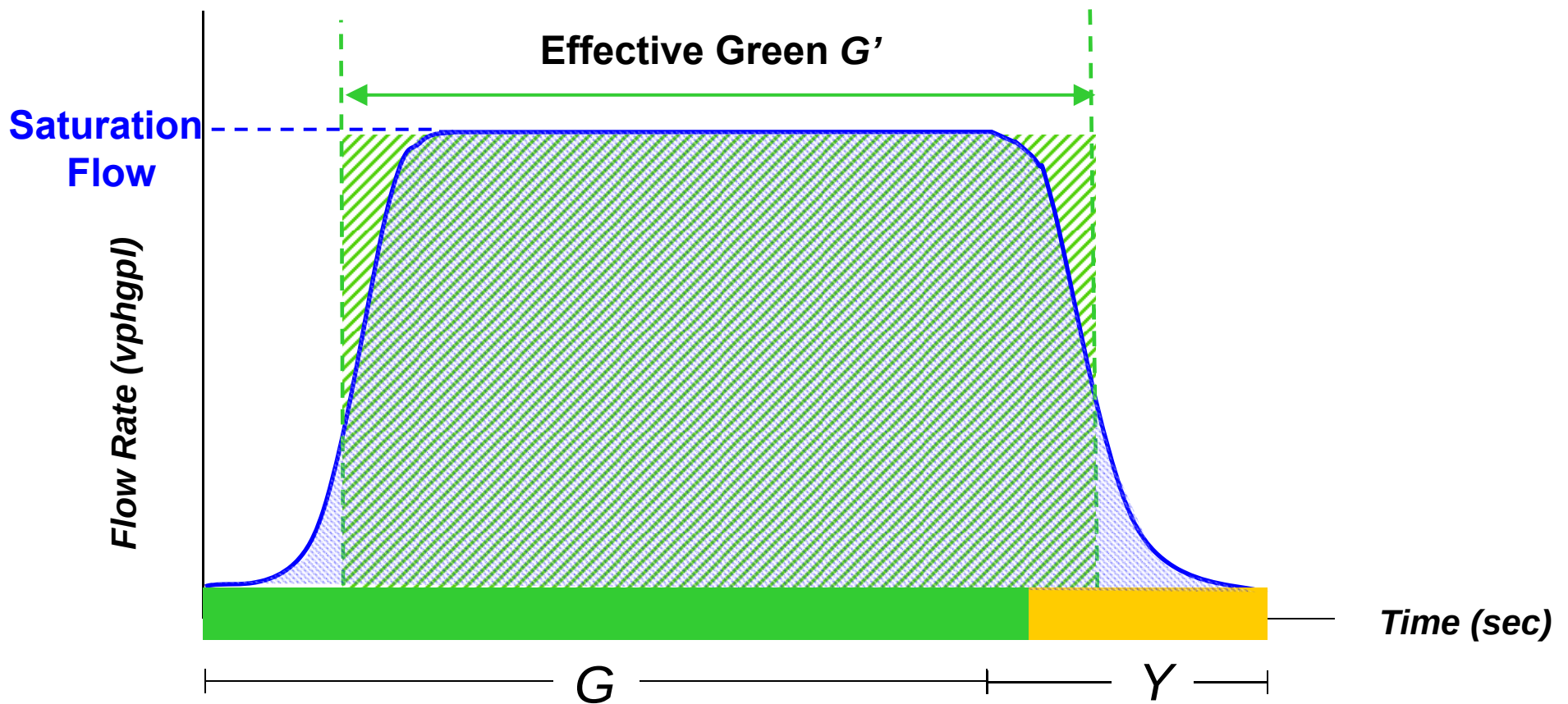
Saturation Flow

Number of vehicles that would pass through the intersection during an entire hour of green



Effective Green Time

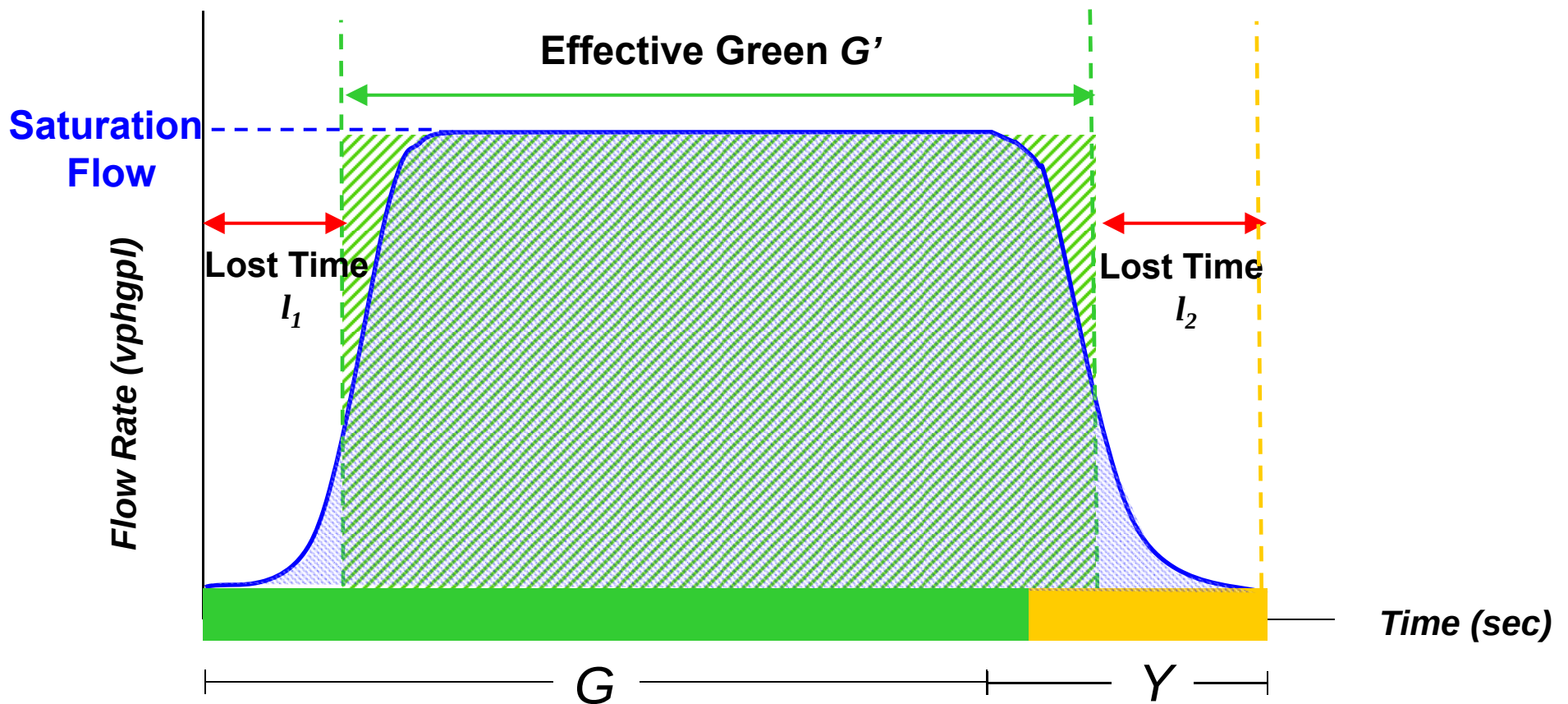
Time during which the flow is assumed to take place at saturation flow



Lost Time

Time during which no flow takes place

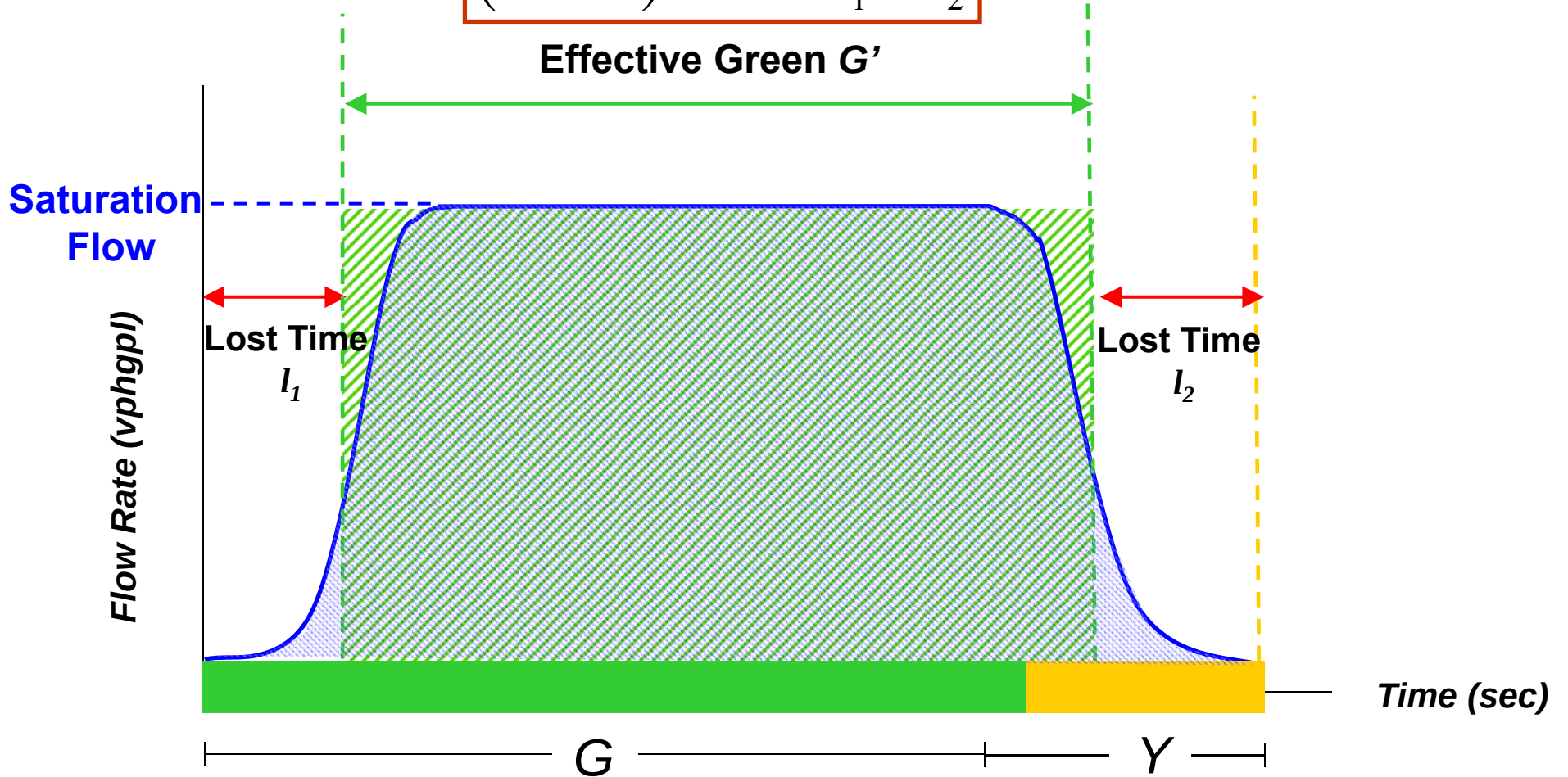
$$(G + Y) - G' = l_1 + l_2$$



Lost Time

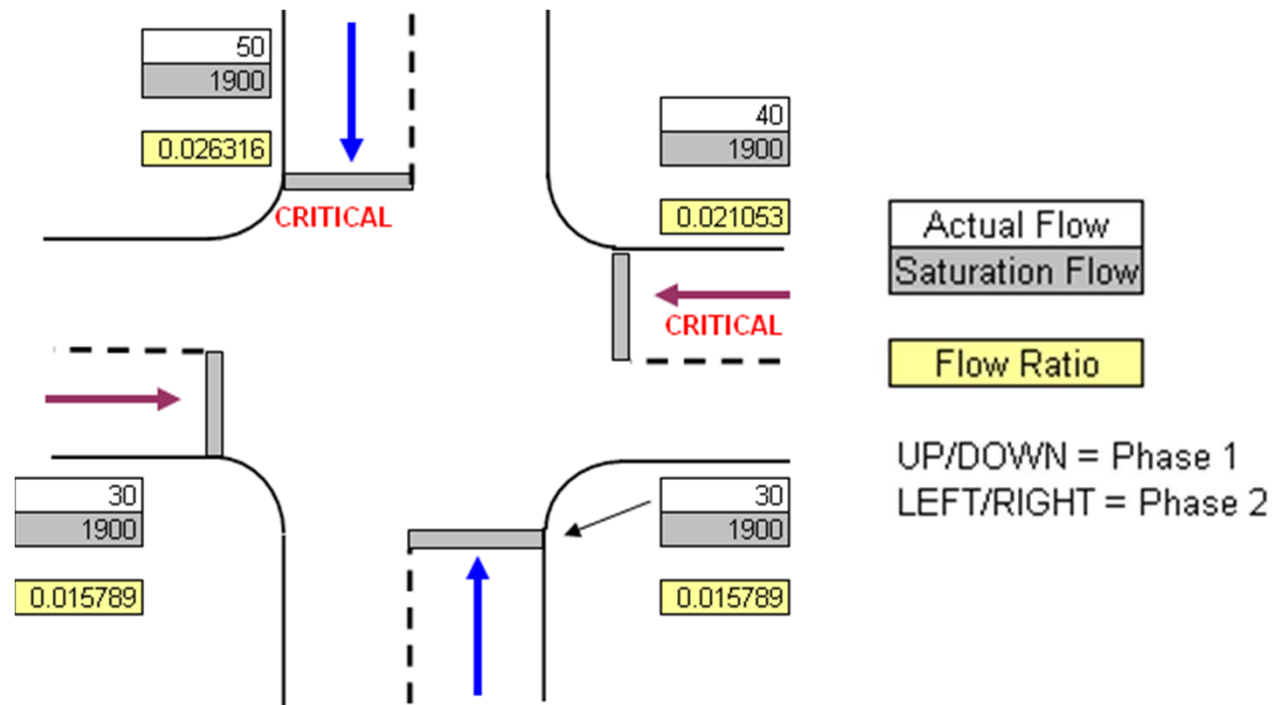
$$(G + Y) - G' = l_1 + l_2$$

Effective Green G'



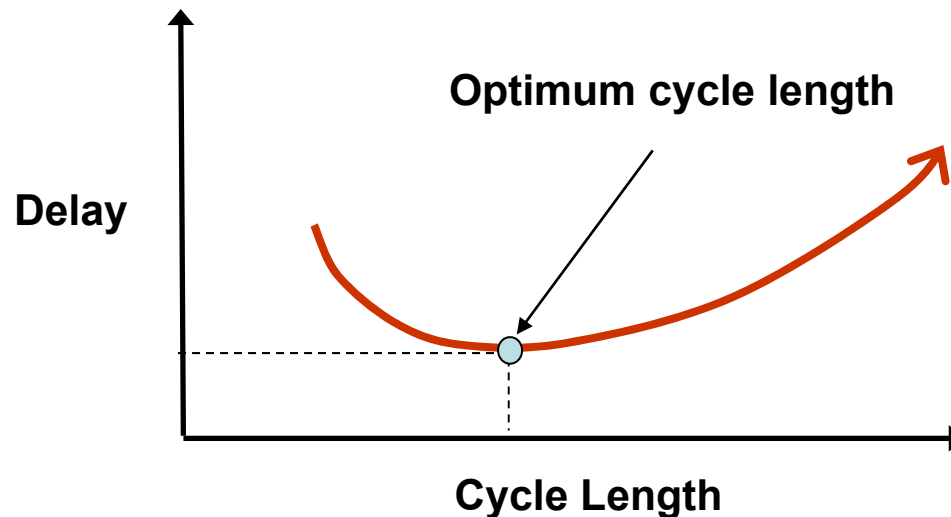
Critical Approach or Lane

- The approach or lane for a given phase that requires the most green time (highest flow ratio)
- Flow should be in **straight-through passenger-car units per hour** (e.g. 1 HV = 1.75 PCU)



Cycle Length Determination for Pretimed Signals

- Long enough to serve all critical movements, but no longer
- If too short: high lost/green time ratio
- If too long: lengthened queues



Webster's Method

- Most prevalent
- Minimizes intersection delay

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

C_o = **Optimum cycle length** (sec)

L = Total lost time per cycle, usually taken as the sum of the total yellow and all-red intervals (sec) (i.e. total intergreen intervals)

Y_i = Ratio of the observed flow rate (in straight-through passenger cars per hour) to the saturation flow rate for the critical approach or lane in each phase

Allocate Green Time to Phases

- Split according to critical flow ratios across phases

$$G_i = (C_o - L) \frac{Y_i}{\sum Y_i}$$

$C_o - L$ = Available green time

Y_i = As before

Traffic-Actuated Signals

- Begin with $G_{\min}$
- If no calls from detector
 - Switch to the next phase
- Otherwise extend green time by h , i.e. the **unit extension of green** or **critical gap**
 - h small for high arrival rates, and vice versa
- If vehicles keep arriving at headways shorter than or equal to h , then terminate only when $G_{\max}$ is reached
- Equivalent to pretimed, fixed cycle if saturated

Benefits of Traffic Signals

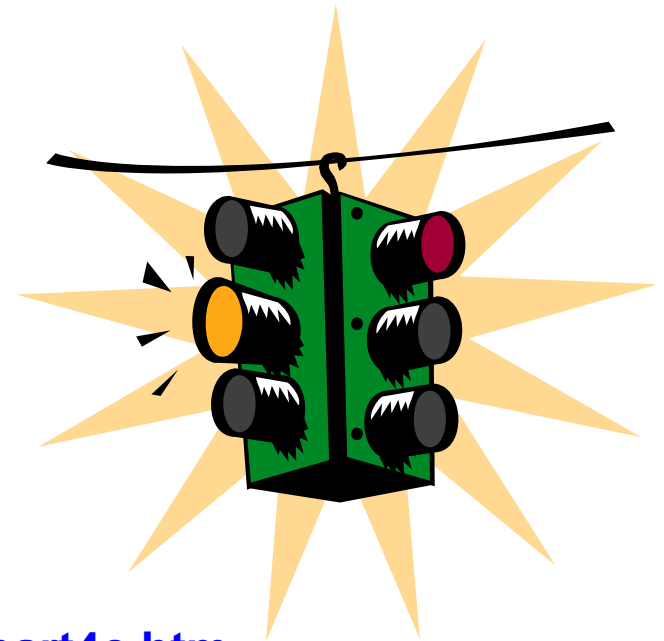
- Reduce right-angle collisions
- Orderly traffic
- Continuous flow
- Allow other vehicles and pedestrians to cross a heavy traffic stream
- Control traffic more economically than by manual methods

Drawbacks of Traffic Signals

- Unjustified, ill-designed, improperly operated signals
 - Increased rear-end collisions
 - Excessive delay
 - Disregard of signal indications
 - Circuitous travel by alternative routes

Signal Warrants

- Eight warrants to consider
 - Eight-hour vehicular volume
 - Four-hour vehicular volume
 - Peak hour
 - Pedestrian volume
 - School crossing
 - Coordinated signal system
 - Crash experience
 - Roadway network



<http://mutcd.fhwa.dot.gov/HTM/2003r1/part4/part4c.htm>