

Traffic signal design-I

Traffic Engineering

Overview

- **For conflict resolution**
 - Time sharing principle
- **Advantages**
 - Orderly movement of traffic
 - Increases the capacity
 - Simple geometric design
- **Disadvantages**
 - Large stopped delay
 - Complex signal design

Definitions and notations

- Cycle
 - A signal cycle is one complete rotation through all of the indications provided
- Cycle length **C**
 - Cycle length is the time in seconds that it takes a signal to complete one full cycle of indications
 - time interval between start of a green till next green for a any approach

Definitions and notations

- Interval
 - indicates change from one stage to another
- ***Change interval / Yellow / Amber***
 - interval between the green and red
- ***Clearance interval / All-Red***
 - after each yellow
 - all signals show red
 - used for clearing off the vehicles

Definitions and notations

- Green interval G_i
 - Duration the green light of a traffic signal is turned on
- Red interval R_i
 - Duration the red light of a traffic signal is turned on

Definitions and notations

- Phase
 - Green interval + change interval + clearance interval
 - During green interval non-conflicting movements are cleared
- Lost time
 - Time during which intersection is not effectively utilized for any movement
 - E.g. reaction time of the first driver in the queue

Signal Design Stages

- Phase Design
- Interval Design
- Cycle Length Determination
- Green Splitting
- Pedestrian Requirements
- Performance Evaluation

Phase Design

- Objective
 - Separate the conflicting movements into various phases
 - Complete separation implies large number of phases
 - So design phases with minimum conflicts or with less severe conflicts

Phase Design

- Major conflicts

- Through – Through

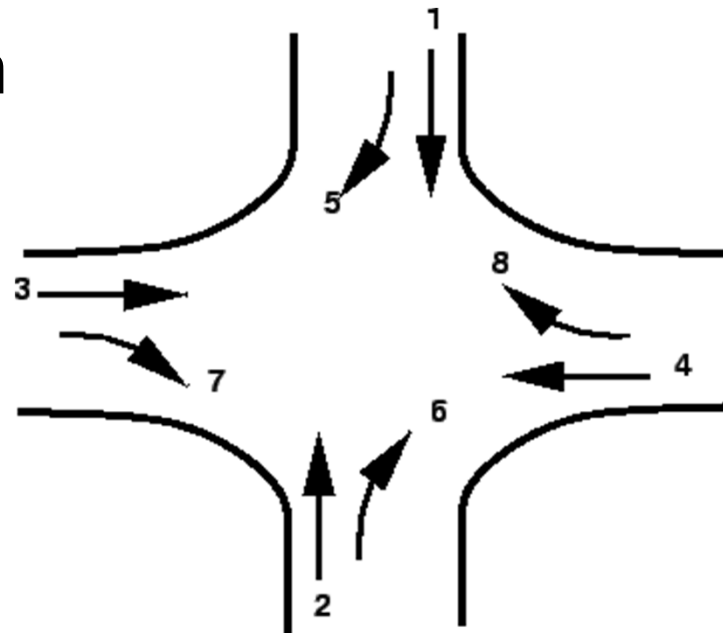
- E.g 1-3

- Through – Right

- E.g 3-5

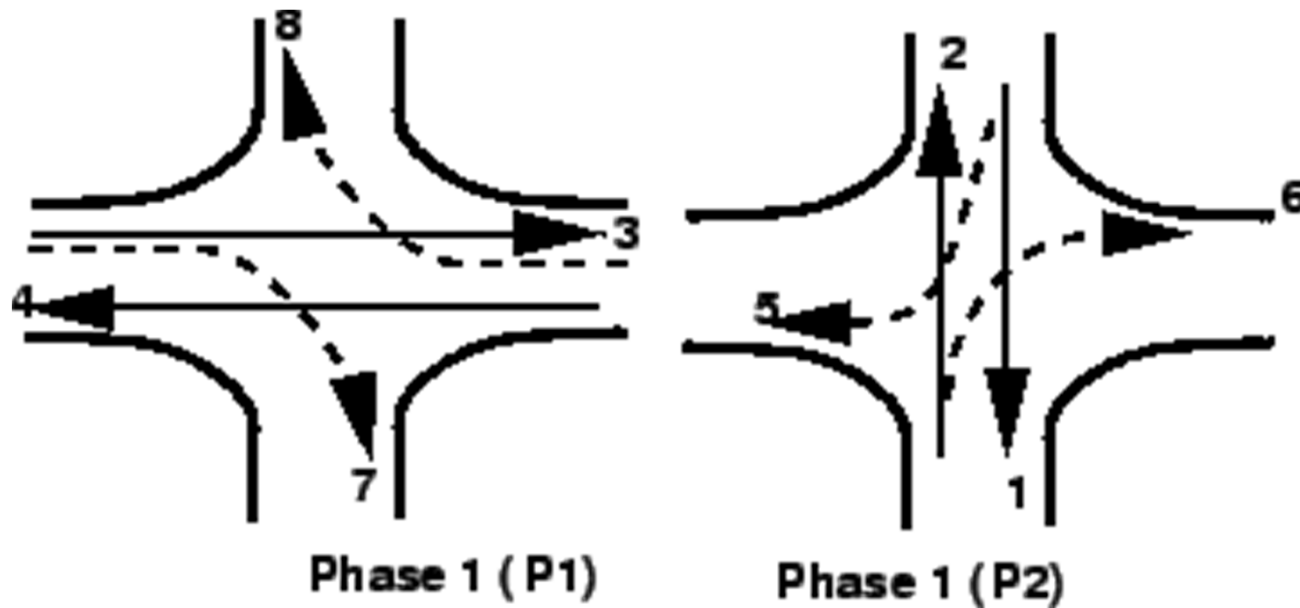
- Right – Right

- E.g 8-5



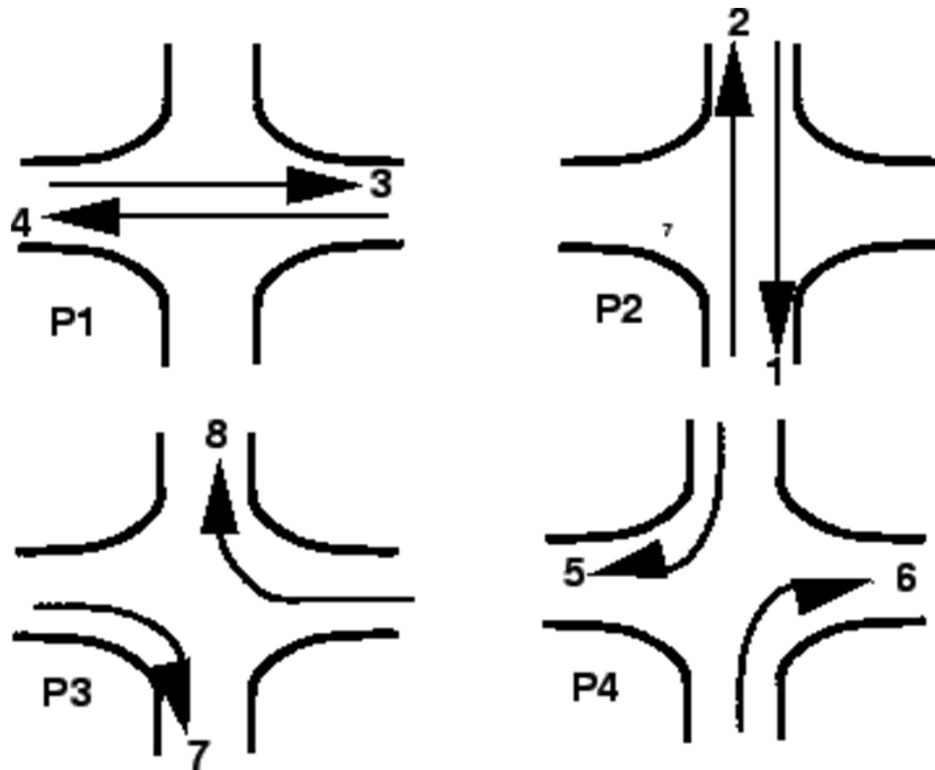
Phase Design

- Two phase signals



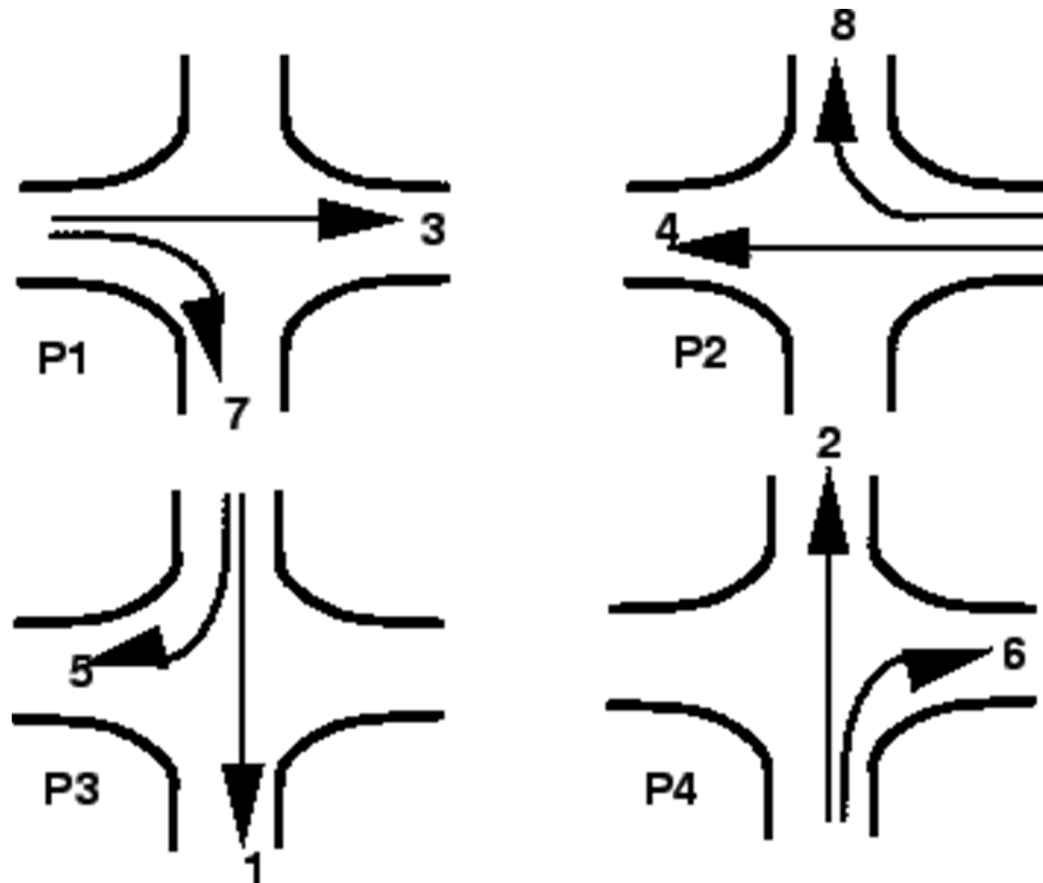
Phase Design

- Four phase signal: Option I



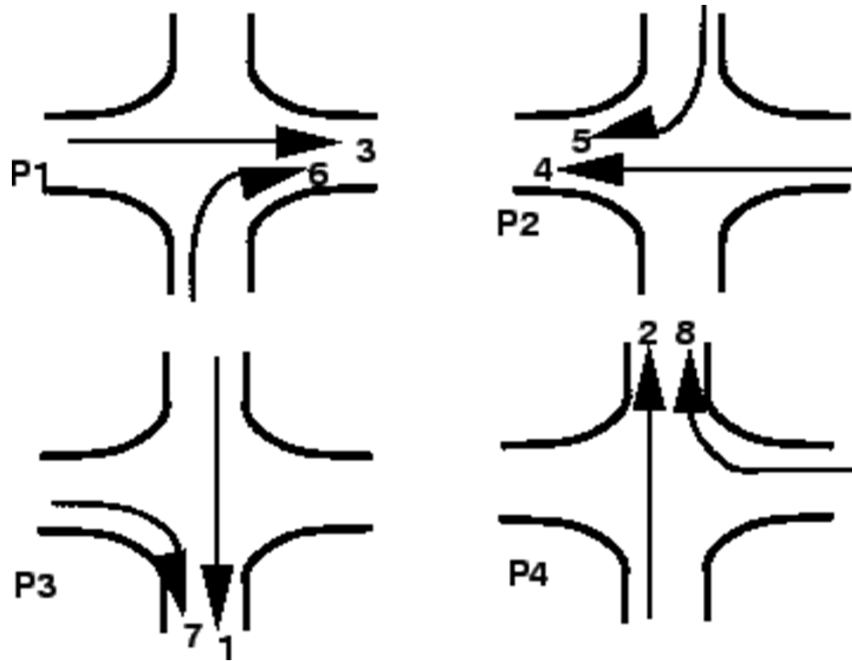
Phase Design

- Four phase signal: Option II



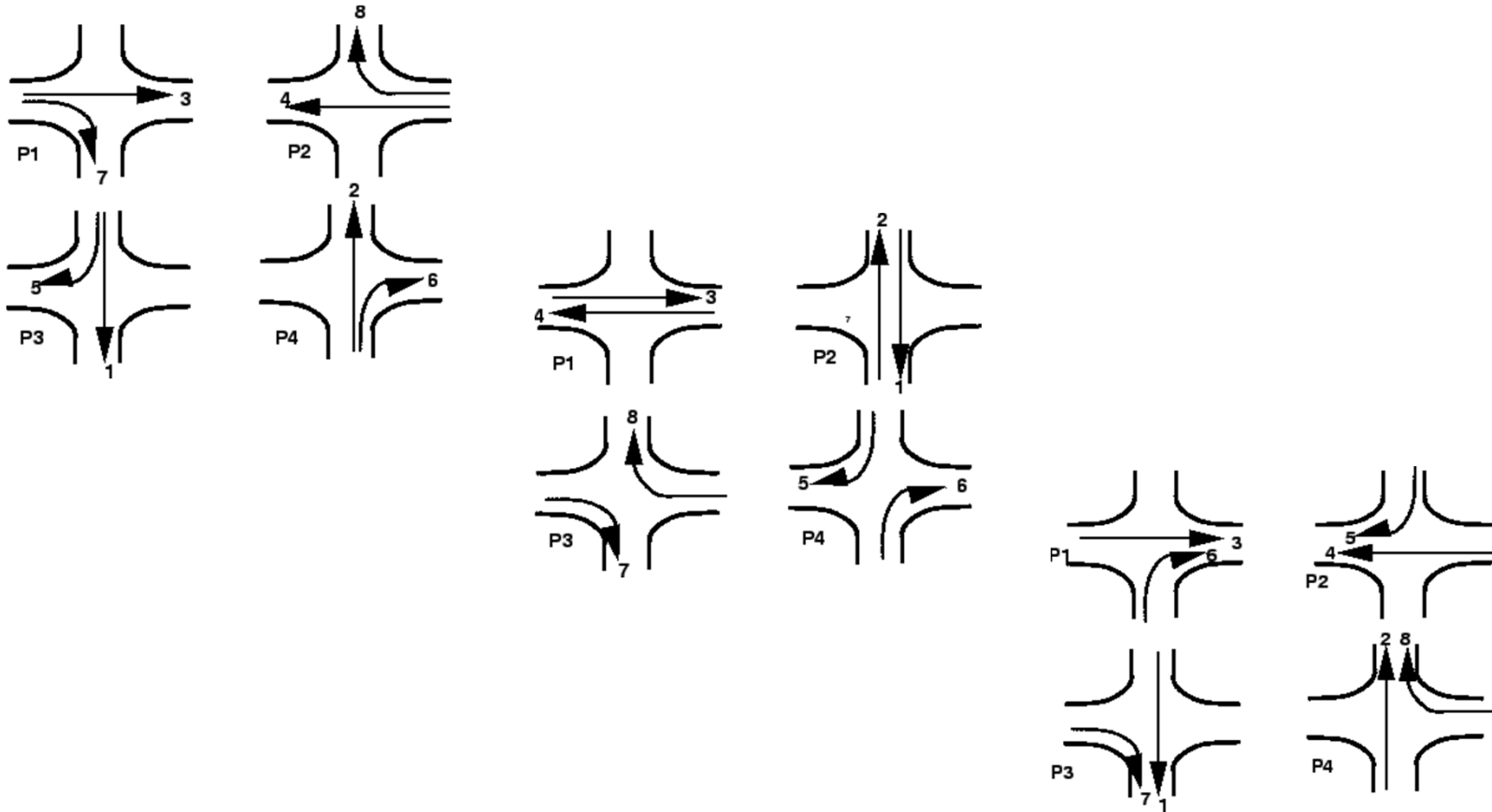
Phase Design

- Four phase signal: Option III



Phase Design

- Four phase signal: All Options



Signal Design Stages

- Phase Design
- Interval Design
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- Pedestrian Requirements
- Performance Evaluation

Interval Design

- Change Interval
 - Yellow time / Amber time
 - To warn a driver of the end of a green time
 - Given after green time (3- 6 Sec)
- Clearance Interval
 - All-Read
 - to clear off vehicles already in the intersection
 - Given after Yellow time (2-4 Sec)

Interval Design: Amber

- **Design Consideration**

- a driver approaching the intersection with design speed should be able to stop at the stop line of the intersection before the start of red time
- Simple formulae
 - $y = SSD/v$
 - y is the length of yellow interval in seconds
 - SSD is the stopping sight distance
 - v is the speed of the vehicle

Interval Design: Amber

- **Design Consideration**

- ITE's recommendation

$$y = t + \frac{v_{85}}{2a + 19.6g}$$

- **y** length of yellow interval in seconds
- **t** reaction time of the driver
- **v₈₅** 85th percentile speed (m/sec)
- **a** deceleration rate of vehicles in m/sec²
- **g** grade of approach expressed as a decimal

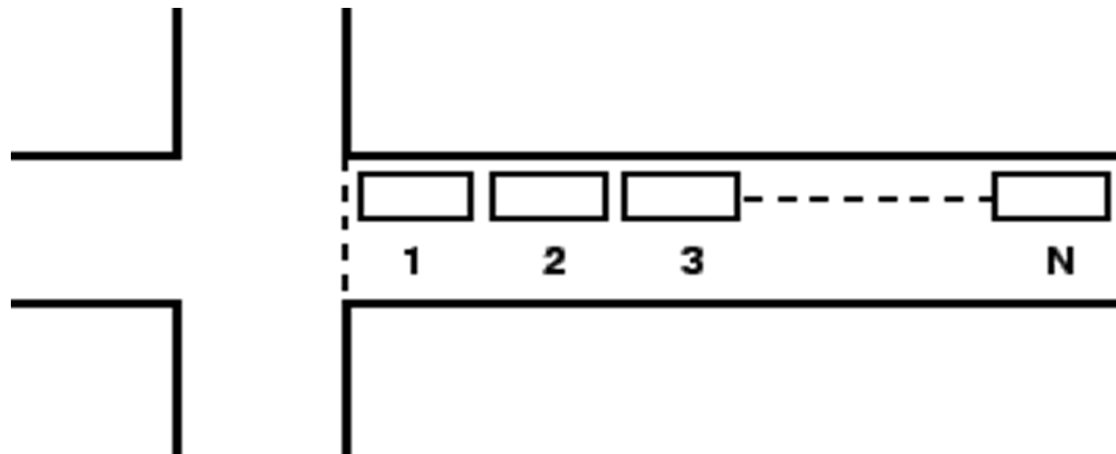
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Cycle Time

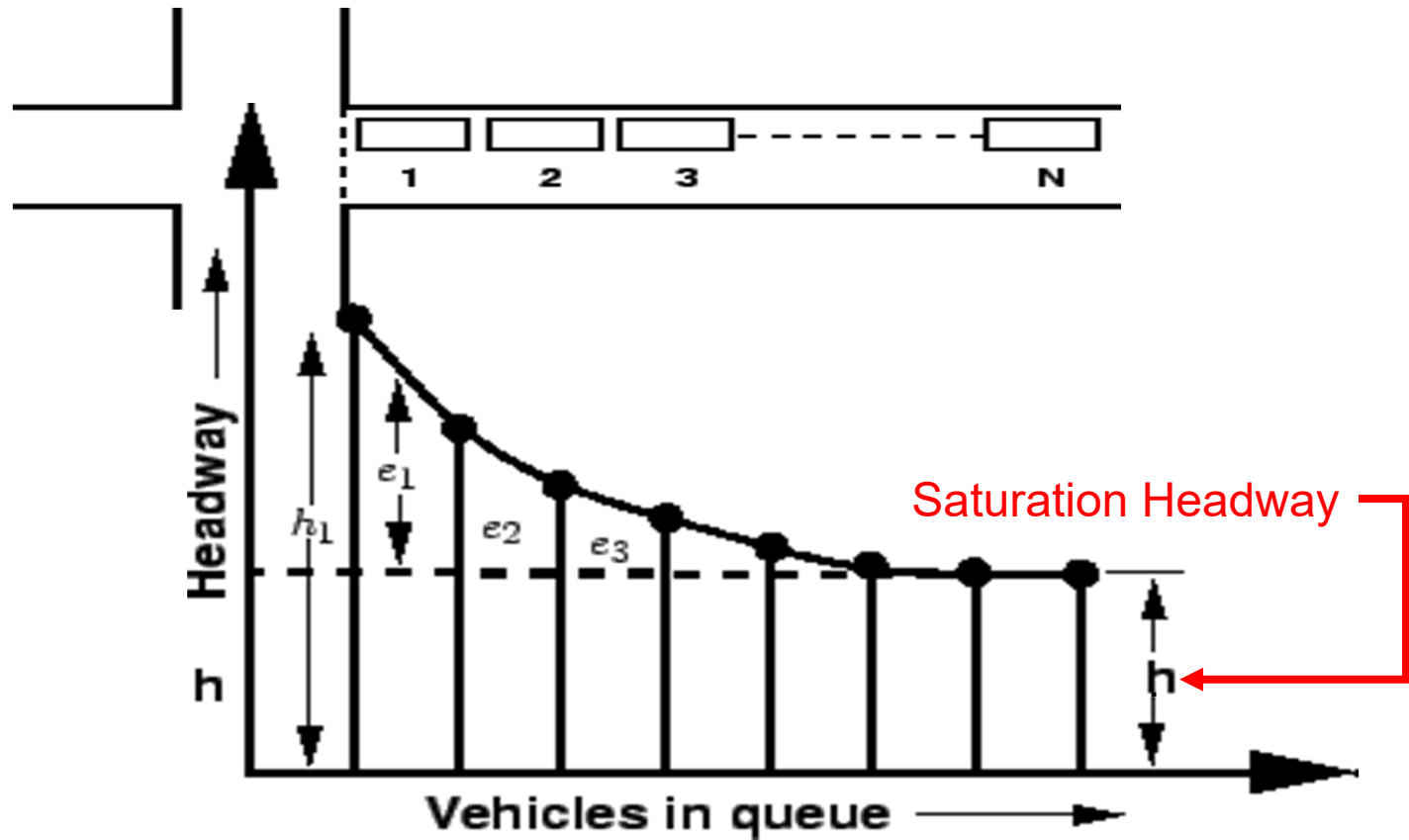
- **Definition**

- Time taken by a signal to complete one full cycle of iterations **C**
- Understanding of
 - Saturation Flow **s** and Lost Time **t_L**
 - a group of **N** vehicles waiting for green



Cycle Time

- Saturation flow



Cycle Time

- **Saturation Flow**

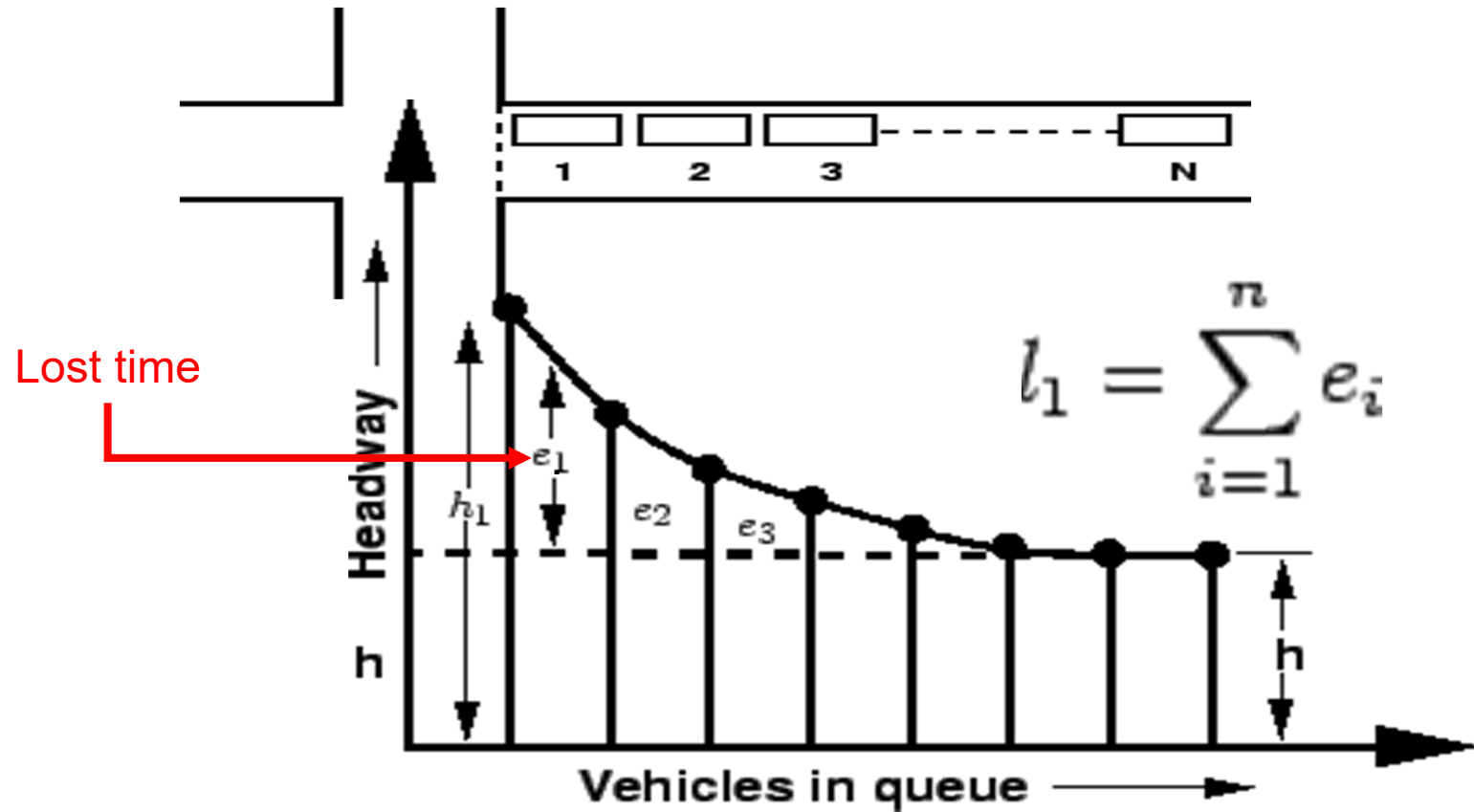
- Saturation flow rate $s = \frac{3600}{h}$

- **s** is the saturation flow rate in vehicles per hour of green time per lane

- **h** is the saturation headway in seconds

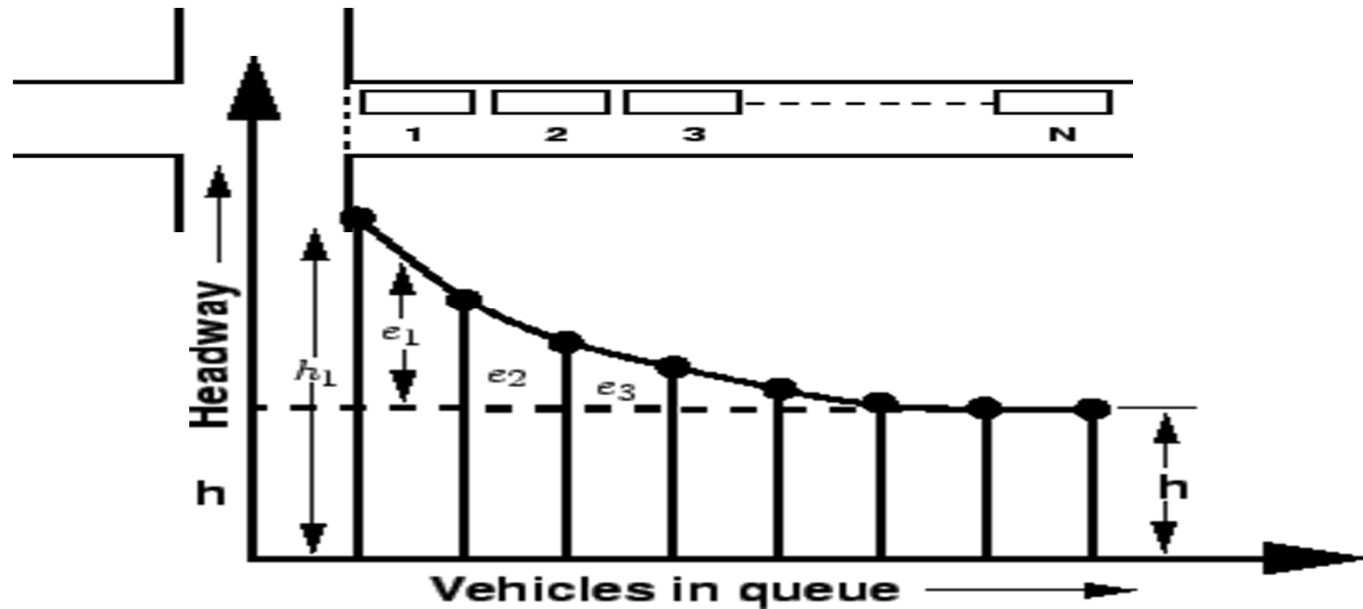
Cycle Time

- Lost Time



Cycle Time

- Lost Time



- Green time require to clear N vehicles

$$T = l_1 + h.N \quad l_1 = \sum_{i=1}^n e_i$$

Cycle Time

- **Effective green time**

- Actual time available for the vehicles to cross the intersection
- Actual green time G_i + yellow Y_i - lost times t_L

$$g_i = G_i + Y_i - t_L$$

Cycle Time

- **Lane capacity**

- green ratio : ratio of effective green time to the cycle length g_i/C

$$c_i = s_i \frac{g_i}{C}$$

- c_i = capacity of lane in veh/hr
- s_i = the saturation flow rate in veh/hr/lane
- C = cycle time in seconds

- **Critical Lane and critical lane volume**

Cycle Time

- Determination of cycle length
 - time taken for complete indication of signals
 - Start up lost time $L = \sum_{i=1}^N t_L$
 - or $L = Nt_L$
 - No of cycles per hour $3600/C$

Cycle Time

- **Determination of cycle length**

- total lost time per hour $\frac{3600}{C} \cdot L = \frac{3600 \cdot N \cdot t_l}{C}$

- total effective green time per hour T_g

$$\begin{aligned} T_g &= 3600 - \frac{3600 \cdot N \cdot t_L}{C} \\ &= 3600 \left[1 - \frac{N \cdot t_L}{C} \right] \end{aligned}$$

Cycle Time

- **Determination of cycle length**

- maximum volumes per hour

$$V_c = \frac{T_g}{h}$$

$$V_c = \frac{3600}{h} \left[1 - \frac{N.t_L}{C} \right]$$

$$= s_i \left[1 - \frac{N.t_L}{C} \right]$$

$$C = \frac{N.t_L}{1 - \frac{V_c}{s}}$$

Cycle Time

- **Determination of cycle length**
 - To account for hourly variation of traffic
 - PHF (peak Hour Factor)
 - Ratio of hourly volume to the maximum flow rate
 - Introducing quality of service
 - The Volume to Capacity Ratio v/c

Cycle Time

- Determination of cycle length

$$C = \frac{N.t_L}{1 - \frac{V_c}{s_i \times PHF \times \frac{u}{c}}}$$

Cycle Time

- **Determination of cycle length**
 - Highway capacity manual (HCM)

$$C = \frac{N.L.X_C}{X_C - \sum(\frac{V}{s})_i}$$

- X_c Degree of saturation

Signal Design Stages

- Phase Design
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Green Splitting

- **Definition**

- Green splitting or apportioning of green time
- Splitting or proportioning of effective green time into each of the signal phase
- Green time is proportional to the critical volume for each phase

$$g_i = \left[\frac{V_{ci}}{\sum_{i=1}^n V_{ci}} \right] \times t_g$$

Green Splitting

- **Total effective green time T_g**

$$T_g = C - n.t_L \quad \text{OR} \quad T_g = C - \sum_{i=1}^n t_{Li}$$

- **Actual green time**

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

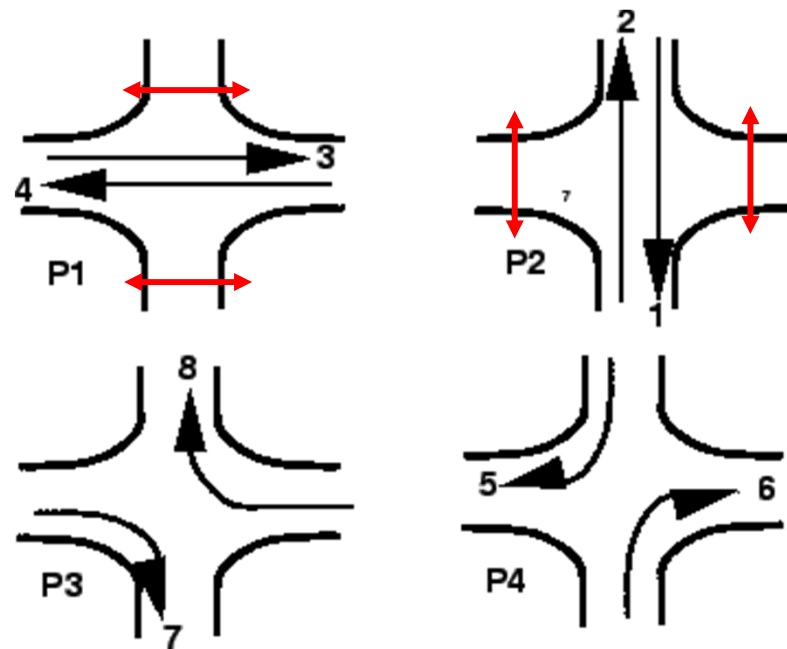
Signal Design Stages

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Pedestrian

- **Crossing requirements**

- By Phase Design



- Or by Exclusive Pedestrian Phase

Pedestrian

- **Green time for Exclusive Ped. Phase**

$$G_p = t_s + \frac{dx}{u_p}$$

- G_p Ped. green time in seconds
- t_s start-up lost time (4-7 seconds)
- d_x crossing distance
- u_p walking speed (1.2 m/sec)

Signal Design Stages

- Phase Design
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Performance Evaluation

- **Parameters**

- Average delay per vehicles
- Queue length in no. of vehicles
- Average No. of Stops

- **Delay**

- Most perceived impact by the driver
- Direct correlation to fuel consumption and emission

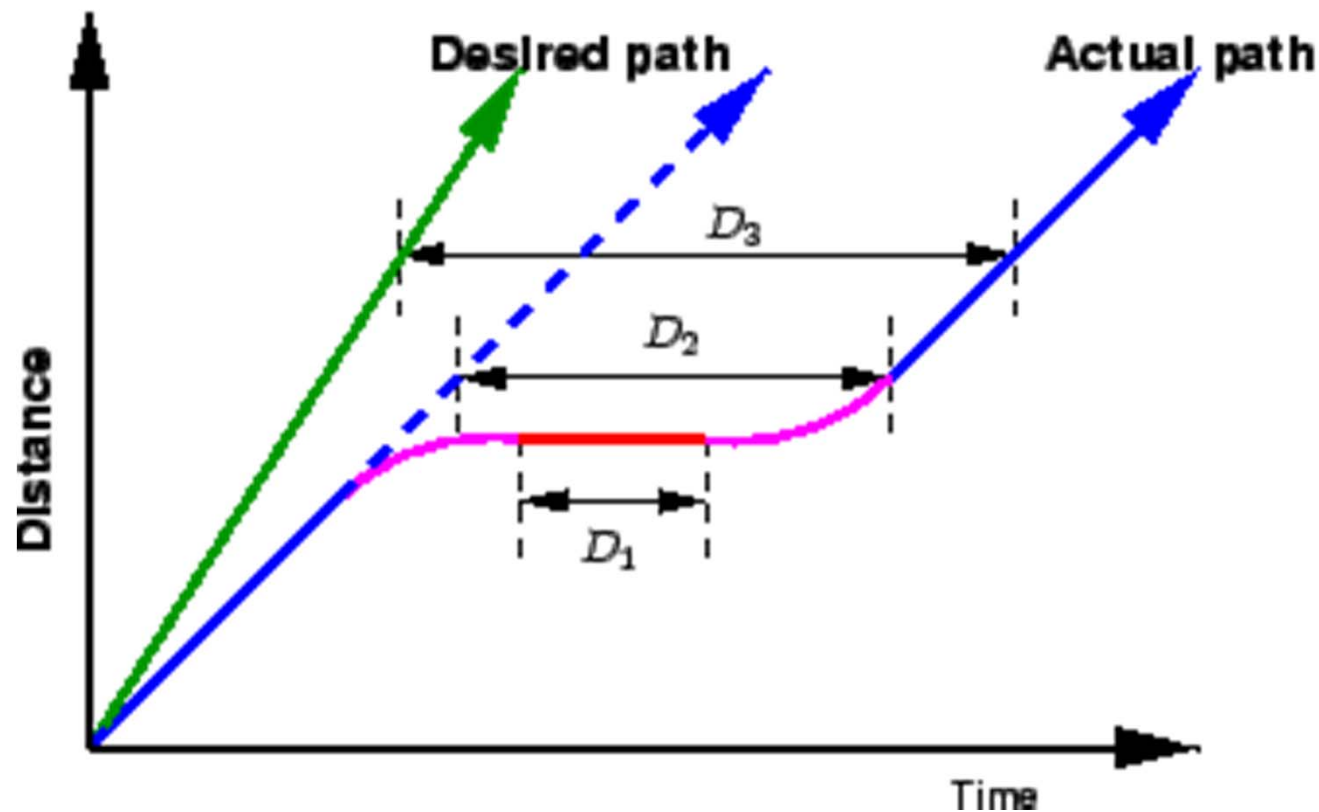
Performance Evaluation

- Types of Delay

D_1 = Stopped time delay

D_2 = Approach delay

D_3 = Travel time delay

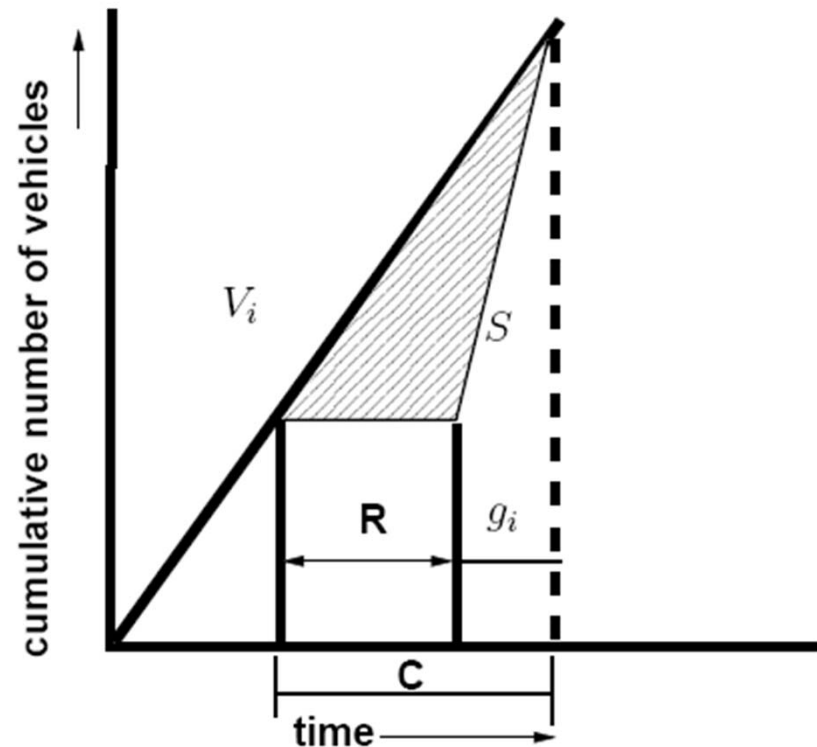


Performance Evaluation

- **Webster's Stopped Delay Model**

- Vehicle arrival uniform and not random

- V_i arrival rate
 - S discharge rate or saturation flow
 - g_i eff. Green time
 - R_i effective red time
 - C cycle length

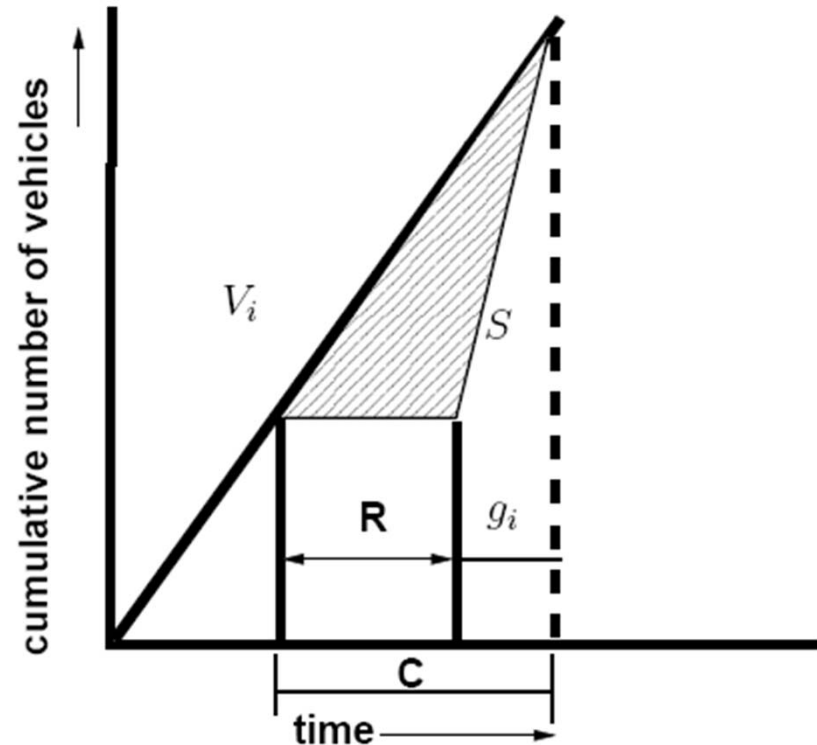


Performance Evaluation

- **Webster's Stopped Delay Model**

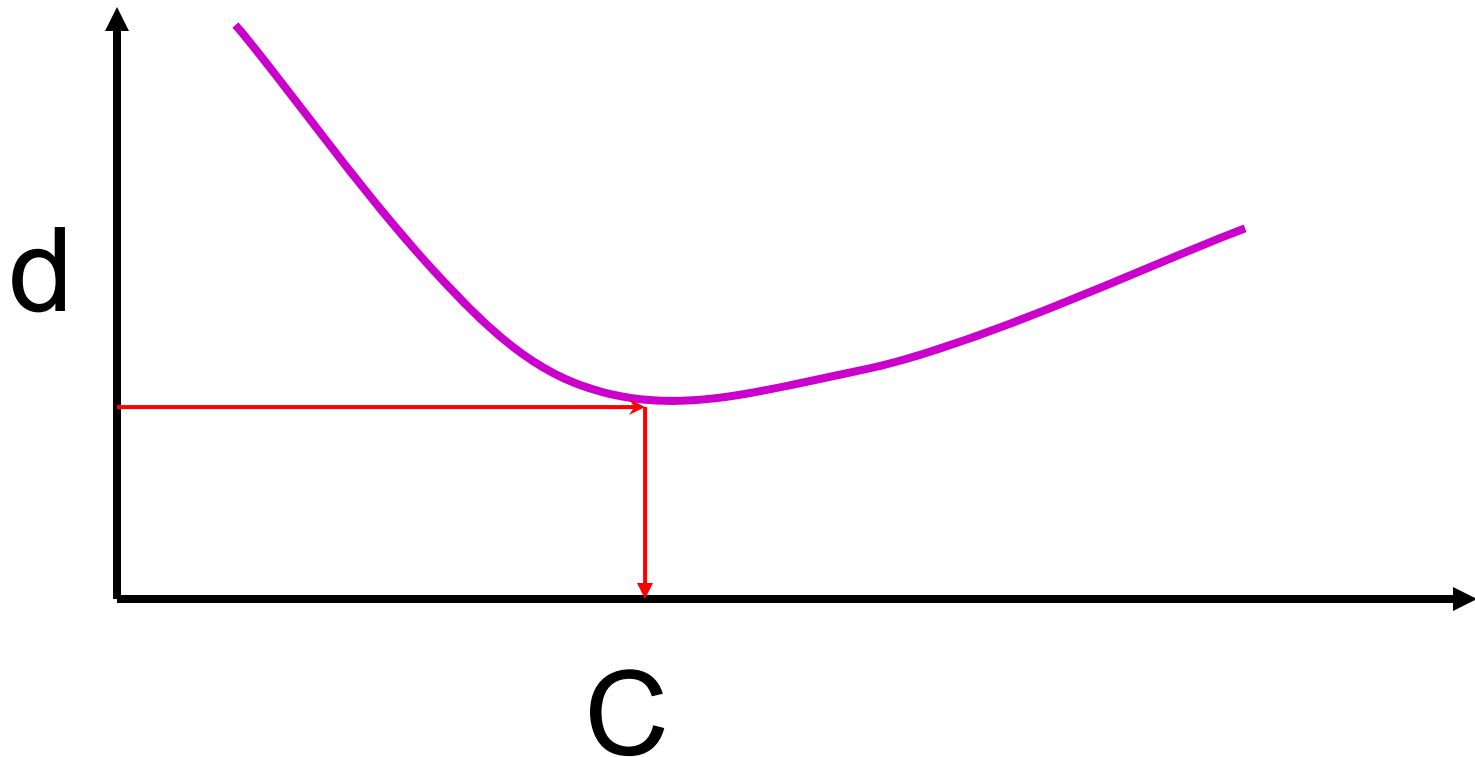
- Average delay per vehicle per cycle

$$d_i = \frac{\frac{C}{2} \left[1 - \frac{g_i}{C} \right]^2}{1 - \frac{V_i}{S}}$$



Performance Evaluation

- **Cycle time verses Stopped Delay**



Signal Design Stages

- Phase Design
- Interval Design
- Cycle Length Determination
- Green Splitting
- Pedestrian Requirements
- Performance Evaluation
- Problems

Thank You