



Introduction to Transport

Lecture 2: Traffic Signal



Traffic Signals

Any power-operated traffic control device other than a barricade warning light or steady burning electric lamp, by which traffic is warned or directed to take some specific action (MUTCD, 1988 amended in 1994).

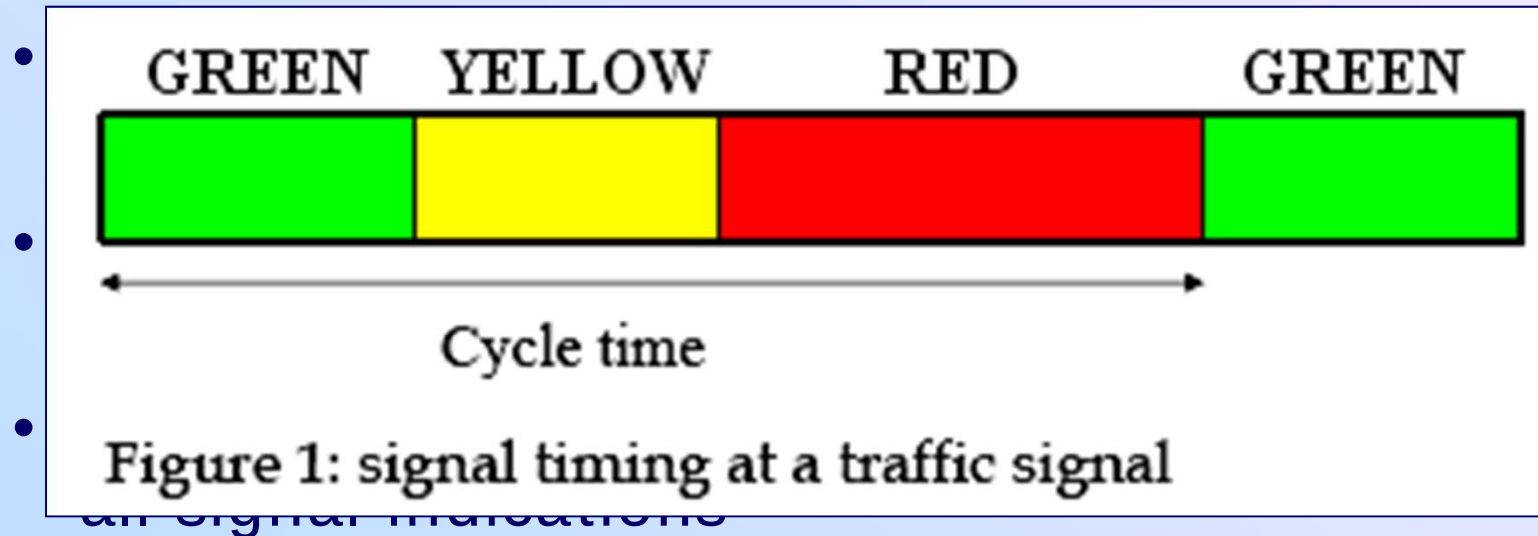
- Traffic control signals are used primarily at intersections
- Traffic lights use a universal colour code and a precise sequence



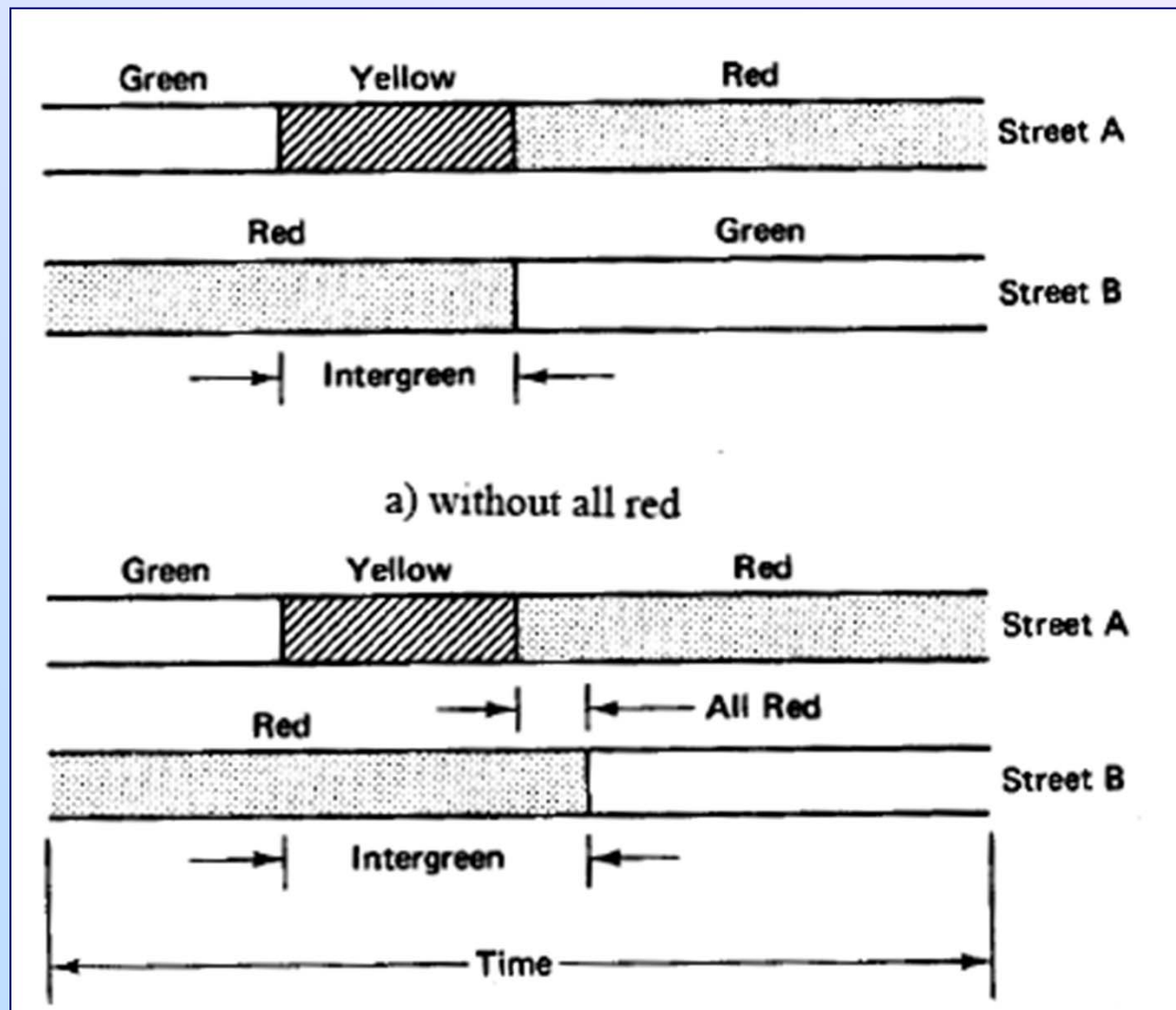
Terminology

1

- **Green time:** The time period in which the traffic signal has the green indication



- **Cycle time (or cycle length):** The total time for the signal to complete one sequence of signal indication.





Terminology

2

- **Interval / Period:** A period of time during none of the lights at the signalised intersection changes
 - **All red interval:** The display time of a red indication for all approaches
 - **Inter-green interval:** The yellow plus all red times
- **Effective green time:** The effective green time, for a phase, is the time during which vehicles are actually discharging through the intersection.
- **Pedestrian crossing time:** The time required for a pedestrian to cross the intersection.



Terminology

3

- **Permitted movement:** A movement that is made through a conflicting pedestrian or other vehicle movement.

This is commonly used for right-turning movements where right-turn volumes are reasonable and where gaps in the conflicting movement are adequate to accommodate turns.

- **Protected movement:** A movement that is made without conflict with other movements.

The movement is protected by traffic control signal design with a designated green time for the specific movement.



Terminology

4

- **(Signal) Phase:** A set of intervals that allows a/a set of designated movements to flow and to halt safely. Each phase is divided into intervals.
A phase is typically made up of three intervals: green, yellow, and all-red
- **Signal group:** A set of signals that must always show identical indications. A signal group controls a/a set of traffic streams that are always given right-of-way simultaneously.
The timing of a signal group is specified by periods

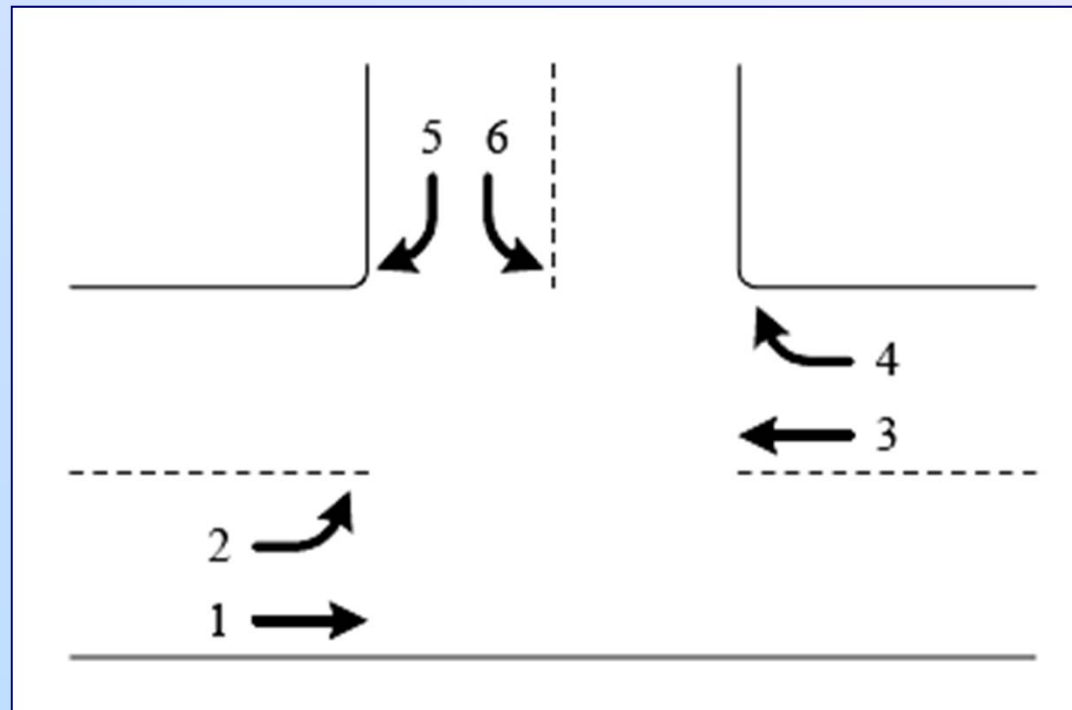


Phase, Group

1

Example Intersection

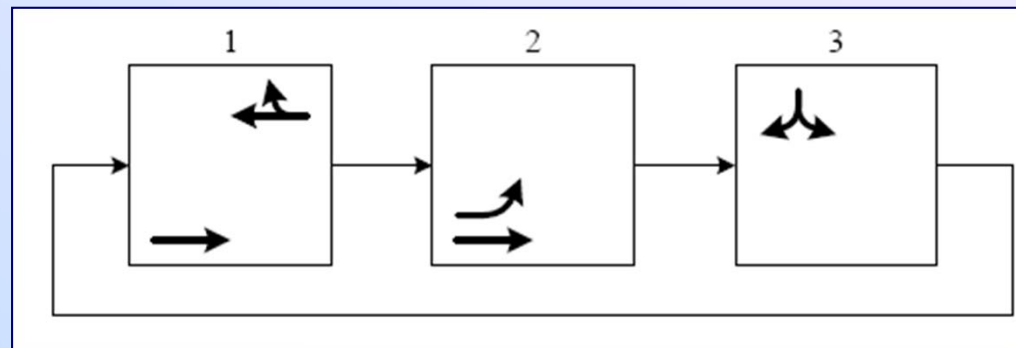
- The intersection has 3 approaches and 6 possible movements (numbered)



Phase, Group

2

Potential Phase Diagram

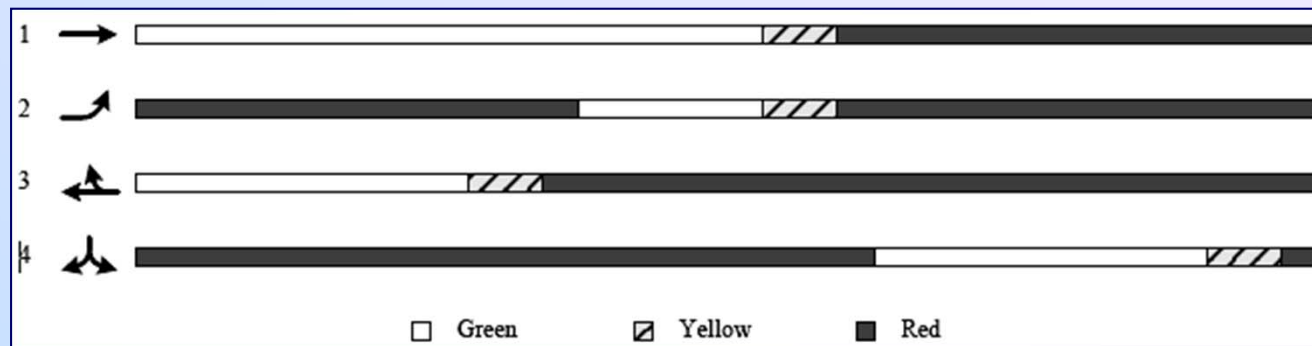


- Each phase represents a distinct time period within the cycle
- The signal timing is defined by specifying the percentages of the cycle length (*phase splits*) allocated to each phase
- This split time is further divided among the intervals of each phase

Phase, Group

3

Potential Signal Group Diagram



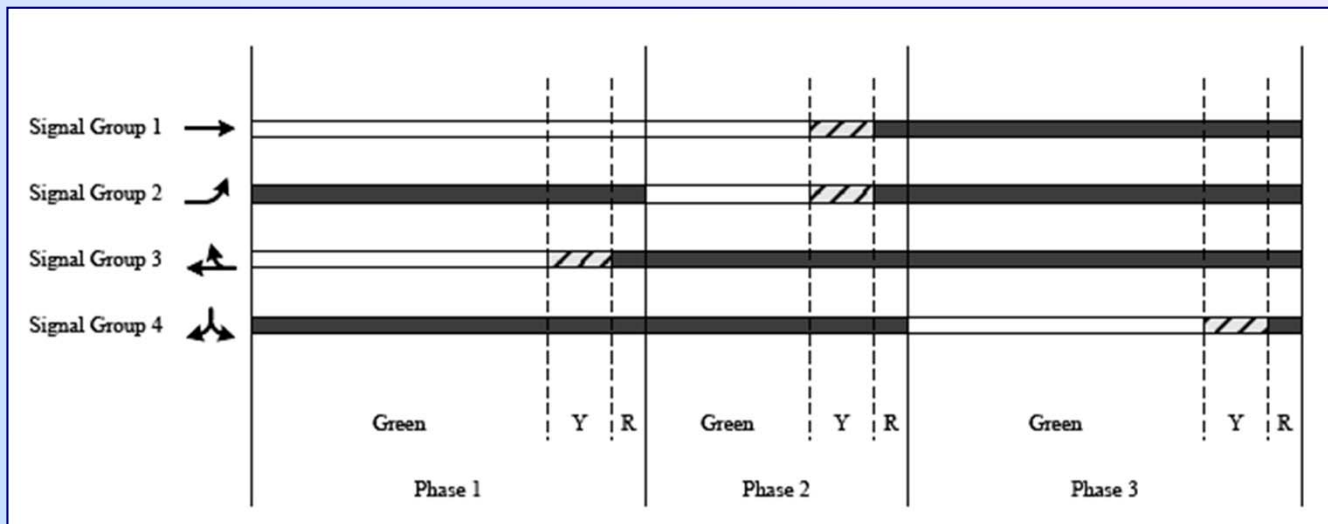
- The timing of each signal group is represented by a horizontal bar whose length is the cycle length
- Each bar for each signal group is divided into different periods
- In operation, these signal groups advance in time independently



Phase, Group

3

Relation between phase and groups



- Signal phasing can be inferred by reading the signal group diagram vertically
- The start of every green period corresponds to the start of a phase, and the time in which all signal groups remain in a single period corresponds to an interval



Types of control signals

- **Pretimed operation:** The cycle length, phases, green times and change intervals are all preset

Several preset timing patterns may be used, each being implemented automatically at fixed times of the day

- **Semiactuated operation:** The major approach has a green indication at all times until detectors on the minor approaches sense a vehicle/vehicles. The signal then provides a green time for the minor approach, after an appropriate change interval.

The cycle length and green times may vary from cycle to cycle in response to demand.



Types of operations

- **Fully-actuated operation:** All signal phases are controlled by detector actuations (embedded on every intersection approach and is subjected to limiting values preset in detector)

Preset minimum and maximum green times and minimum gaps between detector actuation.

The cycle lengths, phase sequence and interval lengths may vary from cycle to cycle in response to demand.



Types of control logic

- **Pretimed Control:** Follows the pretimed operation not demand-responsive
the cycle length and the phase splits and durations of each interval within each phase are set at fixed values
- **Actuated control:** Follows the semi-actuated and full actuated operations
able to extend the length of the green interval for a particular phase
able to skip a phase if no demand for that phase is present



Types of control logic

- **Adaptive control:** Follows the full actuated operation responds to traffic demand in real time
common adjustments made are to the cycle time and to the phase splits
detector data is used by controller to estimate conditions at the intersections and to respond to them in real-time
Logic is often optimization-based, allocating green time to maximize vehicle throughput or to minimize measures such as vehicle delays or stops
Adaptive logic can also be predictive

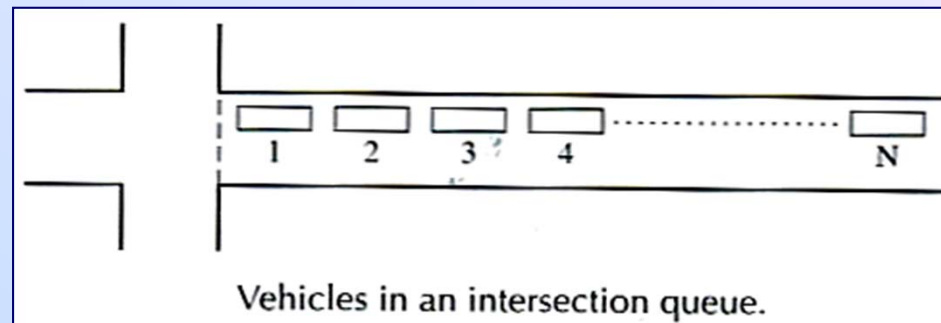


Basic Principles of Intersection Signalisation

- **Four basic mechanisms**
 1. Discharge headways at signalised intersections
 2. The critical lane and time budget concept
 3. Effects of right turning vehicles
 4. Delay

Discharge Headways

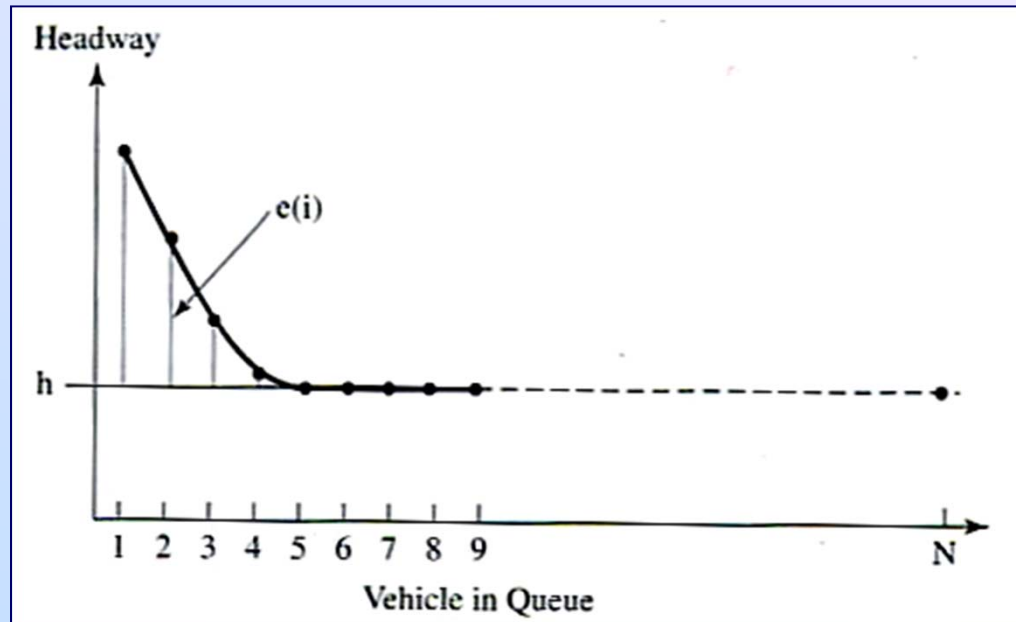
- Consider N vehicles discharging from the intersection when a green indication is received.



- The first discharge headway* is the time between the initiation of the green indication and the rear wheels of the first vehicle to cross over the stop line.
- The N th discharge headway* ($N > 1$) is the time between the rear wheels of the $(N-1)^{\text{th}}$ and N^{th} vehicles crossing over the stop line.



Discharge Headways



- The *headway* begins to level off with 4 or 5th vehicle.
- The level headway = *saturation headway*



Saturation flow rate

In a given lane, if every vehicle consumes an average of h seconds of green time, and if the signal continues to be uninterruptedly green, then S vph could enter the intersection where S is the saturation flow rate (vehicles per hour of green time per lane) given by

$$S = \frac{3600}{h}$$



Lost time

Start-up lost time: At the beginning of each green indication as the first few cars in a standing queue experience start-up delays,

$$l_1 = \sum e(i)$$

$e(i)$ = (actual headway- h) for vehicle i

Calculated for all vehicles with headway $> h$

green time necessary to clear N vehicles,

$$T = l_1 + h(N)$$



Lost time

The change interval lost time: It is estimated by the amount of the change interval not used by vehicles; this is generally a portion of the yellow plus all-red intervals

The 1994 Highway Capacity Manual (HCM) adds the two lost times together to form one lost time and put it at the beginning of an interval. Default value = 3.0 seconds per phase



Effective green time

$$g_i = G_i + Y_i - t_L$$

$$t_L = l_1 + l_2$$

- Actual green time
- Yellow + all red time
- The ratio of effective green time to cycle length is 'green ratio'
- Capacity of a lane,

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