Lecture 3.18

3.3 Traffic Signals

Operational Purpose and Advantages of Traffic Signals

At busy intersections, uncontrolled vehicle movements lead to extreme congestion, gridlock, and high collision risks. Traffic signals eliminate major conflict points by allocating time slots to opposing approaches.

When properly designed and operated, signals provide orderly traffic movement, increase intersection capacity, reduce right-angle collisions, and provide crossing opportunities for pedestrians.

- Orderly Flow: Eliminates driver aggressive negotiation at busy junctions
- Conflict Elimination: Converts spatial intersection conflicts into time separation
- Crash Reduction: Significantly reduces right-angle and broadside collisions
- Progressive Movement: Allows signal coordination along arterial corridors

Disadvantages and Operational Limitations of Signals

Installing a traffic signal is not a universal solution for all intersection problems. Improperly designed or unwarranted signals cause severe traffic operational penalties.

Unwarranted signals create excessive vehicle delay, encourage route diversion into residential side streets, foster driver frustration leading to red-light running, and increase rear-end collision rates.

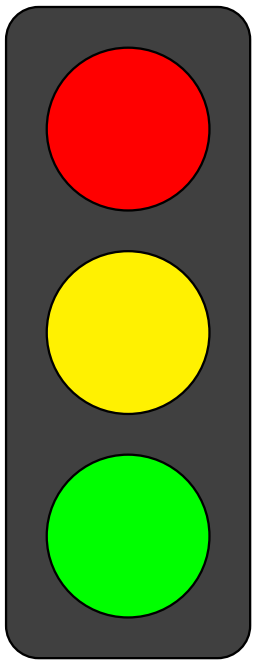
- Increased Delay: Unnecessary stoppage during off-peak hours with low traffic
- Rear-End Collisions: Higher incidence of rear-end crashes due to sudden stops
- Red-Light Running: Driver non-compliance caused by excessively long cycle times
- High Capital & Operational Cost: Electricity, control hardware, sensors, maintenance

Signal Head Components and Standard Aspect Sequences

A standard traffic signal head consists of three circular optical lenses arranged vertically: Red at the top, Amber (Yellow) in the middle, and Green at the bottom.

The standard aspect sequence in India follows: RED $\rightarrow$ GREEN $\rightarrow$ AMBER $\rightarrow$ RED. Each aspect conveys a legally binding directive to approaching drivers.

- RED: Absolute mandate to stop behind line
- GREEN: May proceed straight or turn if clear
- AMBER: Warns red is imminent; stop or clear
- ARROW: Directional control for turn lanes



Classification of Traffic Signals by Control Mode

Traffic signals are classified into three primary categories according to their operational flexibility and control mechanism.

The selection of control mode depends on traffic flow predictability, volume variability between peak and off-peak periods, and available control technology budget.

- Pre-Timed / Fixed-Time Signals: Operates on fixed, pre-programmed signal timing plans
- Semi-Traffic-Actuated Signals: Detectors placed on minor side-street approaches only
- Full Traffic-Actuated Signals: Detectors installed on all intersection approaches
- Area Traffic Control Systems (ATCS): Network-wide computer synchronized adaptive signals

Pre-Timed (Fixed-Time) Traffic Signals

Pre-timed signals execute preset cycle lengths, green splits, and phase intervals based on historical traffic count data. Multiple timing plans can be stored for morning peak, evening peak, and off-peak periods.

They are simplest and cheapest to install, but cannot adapt to real-time fluctuations, unpredicted traffic surges, or temporary blockages.

- Operating Principle: Microprocessor clock repeats programmed cycle times continuously
- Best Suited For: Intersections with highly predictable, stable traffic flows
- Key Advantage: Low maintenance cost, reliable, easy coordination along corridors
- Key Limitation: Inflexible; causes wasted green time on empty approaches

Traffic-Actuated Control Systems

Traffic-actuated signals continuously adjust green time allocations and cycle durations based on real-time vehicle arrivals registered by vehicle detectors.

In fully actuated control, green light is held on an approach as long as vehicles arrive within a threshold gap time, up to a pre-set maximum green limit.

- Detection Mechanism: Inductive loops embedded in pavement, radar, or video cameras
- Initial Green & Extension: Extends green phase per arriving vehicle ('passage time')
- Efficiency: Eliminates wasted green time on approaches with no waiting queue
- Complexity: Requires sophisticated controllers, detector maintenance, tuning

Special Purpose Signals

In addition to standard vehicular signals, specialized signal heads are deployed to control specific modes or hazardous operational scenarios.

These devices ensure vulnerable road users (pedestrians, cyclists) and emergency vehicles receive dedicated priority.

- Pedestrian Signals: Red Standing Man / Green Walking Man symbols at crosswalks
- Flashing Beacons: Flashing Amber (Caution) or Flashing Red (Stop-and-Proceed)
- Lane Control Signals: Overhead green arrows and red X signs for reversible lanes
- Emergency Preemption: Infrared/GPS triggers giving immediate green to fire/ambulances

Traffic Signal Warrants (IRC:93)

An engineering warrant is a threshold condition that must be satisfied before a traffic signal installation can be justified. IRC:93 defines standard signal warrants based on traffic data.

A signal should not be installed unless one or more warrants are satisfied after comprehensive traffic volume, delay, and crash studies.

Warrant Type	**Condition / Description**
1: Min. Vehicular Volume	High volume on major and minor streets for 8 hours
2: Interruption of Traffic	Heavy major street traffic blocking minor street
3: Min. Pedestrian Volume	High pedestrian count attempting to cross high-speed road
4: Accident Experience	5 or more preventable right-angle crashes per year

Signal Head Mounting and Visibility Requirements

Signal heads must be mounted so that approaching drivers have an unobstructed view of at least one signal face for a distance corresponding to safe stopping sight distance.

IRC standards mandate at least two signal heads per approach to provide redundancy in case of single bulb or LED failure.

- Post-Mounted Signals: Installed on roadside curb posts (height 2.5m to 3.0m)
- Overhead Cantilever Signals: Mounted above traffic lanes (vertical clearance min 5.5m)
- Primary & Secondary Faces: Primary on near side / overhead; secondary on far side
- Visors & Backplates: Sun visors and black backplates to enhance LED aspect contrast

Signal Phasing Fundamentals

A signal phase is a part of a signal cycle allocated to any combination of traffic movements receiving right-of-way simultaneously without physical path intersections.

Increasing the number of phases reduces movement conflicts but increases total lost time per cycle, reducing overall intersection capacity.

- 2-Phase Signal: Simple cross junction separating North-South and East-West flows
- 3-Phase Signal: Dedicated phase for heavy right-turning traffic streams
- 4-Phase Signal: Separate phase for every individual approach arm
- Phase Trade-off: More phases increase safety but reduce effective green capacity

Summary of Traffic Signals

In this lecture, we studied the operational purpose, classifications, signal components, warrants, and phasing concepts for traffic signals as per IRC:93.

Selecting the appropriate control mode and verifying engineering warrants ensures that traffic signals enhance intersection safety and capacity.

- Traffic signals convert spatial intersection conflicts into time-separated intervals
- Aspect Sequence: Red (Stop) -¿ Green (Go) -¿ Amber (Clearance) -¿ Red
- Control Modes: Pre-timed (predictable), Actuated (adaptive), ATCS (network wide)
- IRC:93 Warrants: Minimum volume, traffic interruption, pedestrian volume, accident history
- Signal Phasing: 2, 3, or 4 phases balance safety against cycle capacity