

Transport Engineering

Traffic Light signals



What is traffic light signals

- All power-operated devices (except sign) for regulating, directing or warning motorists or pedestrians are classified as **traffic signals**

Purpose of traffic light signals

- To improve overall safety?
- To decrease average travel time through an intersection which results in increasing the junction capacity.
- To equalize the quality of service for all or most traffic streams.

Traffic light signals are installed on the basis of warrants (justifications)

Traffic volume (minor and major roads)

Pedestrian volume

Accident history

Definitions related to traffic light signal intersections

- **Cycle (cycle length or cycle time):** any complete sequences of signal indications.
- **Phase (signal phase)** the part of a cycle allocated to any combination of traffic movements receiving right-of-way simultaneously during one or more intervals.
- **Interval:** the part or parts of the signal cycle during which signal indications do not change.
- **Offset:** the time laps, in seconds, between the beginning of a green phase at the intersection and the beginning of a green phase at the next intersection.
- **Intergreen** (clearance interval): The time between the end of a green indication for one-phase and the beginning for another (Figure??)

Definitions related to traffic light signal intersections

- **All-red interval:** the display time of a red indication for all approaches. In some cases, an all-red interval is used for pedestrian crossing very wide intersections.
- **Peak-hour factor (PHF):** in the case of street intersection, the ratio of the number of vehicle entering the intersection during the peak hour to four times the number of vehicles entering during the peak 15 minute period. If no data is available a value of 0.85 can be used.
- **Average departure headways:** Observations made by Greenshields et al (1974) show that for green interval of 20 to 30 seconds, the average headway per vehicle is about 2.5
- **Passenger car equivalent (PCEs)** to account for the adverse effect of commercial vehicles and turning movements on startup time. Vehicles types of vehicles are converted to an equivalent number of passenger car units [PCE] (one bus or truck is equivalent to 1.5 PCE)

Definitions related to traffic light signal intersections

- **Approach:** the portion of an intersection leg that is used by traffic approaching the intersection.
- **Capacity:** the maximum number of vehicles that has a reasonable expectations of passing over a given roadway or roadway section in one direction during a given time period of time under prevailing conditions.
- **Critical volume:** a volume for a given street that produces the greatest utilization of capacity (needs the greatest green time) for that street (number of vehicle/PC units per hour per lane)
- **Delay:** the stopped time delay per approach vehicle (seconds per vehicle)
- **Green time:** the length of green phase plus its change interval, in seconds.
- **Green ratio:** the ratio of effective green time to the cycle length

Definitions related to traffic light signal intersections

- **Hourly volume:** the number of mixed vehicles that pass a given section of a lane or roadway during a time period of an hour.
- **Saturation flow:** the maximum number of vehicles that can be served in 1 hour, assuming a continuous display of green and a continuous queue of vehicles
- **Level of service:** a measure of the mobility characteristics of an intersection, as determined by vehicle delay, volume to capacity ratio.
- **Local bus:** a bus having a scheduled stop at an intersection.
- **Passenger-car volume:** volume expressed in terms of passenger cars, following the application of passenger car equivalency factors to vehicular volume.
- **Period volume:** a design volume, based on the flow rate within the peak 15 minutes of the hour, and converted to an equivalent hourly volume.

Components of a signal system

A SIGNAL INSTALLATION CONSISTS OF:

- **ILLUMINATED DISPLAYS**
- **CONTROLLING MECHANISM**
- **VEHICLE/ PEDESTRIAN DETECTION DEVICES**

Displays

- Displays (indications) are grouped into signal faces, each of which controls one or more traffic streams arriving from the same direction. A signal head contains one or more signal faces. It can be mounted on a post or suspended from a wire.
- Signal indications differ by color, shape and continuity
 - **Color used**
 - Green: to give the right of way to one or a combination of traffic streams
 - Red: to prohibit movement or to require to stop.
 - Amber: to regulate the switching of the right of way from one set of traffic streams to another
 - **Continuity [flashing or steady]**
 - Flashing red: indication has the same meaning as a stop sign
 - Flashing amber: allows one to proceed with caution
 - Flashing walk: cautions a pedestrian that a vehicular stream is concurrently permitted to cross his or her line of movement.
 - Flashing “don’t walk” is the equivalent of an amber indication

Signal controller

- Signal controller are electromechanical or electronic devices that regulate the length and sequence of signal indications at an intersection.
- There are different types of controller:
 - Permitted: controllers operate with a fixed amount of time allotted to specific traffic movement in a fixed sequence. The timing is based on historical flow pattern at an intersection.
 - Traffic adjusted controller are equipped to receive information on traffic flow pattern from various measuring devices at present time interval. This information is used to select one of several timing schemes in the controller's memory.

Signal controller

- Traffic-actuated controller: controller use some sensing device to alter the length and/or the sequence of signal indications.
 - These controllers react to arrival of individual vehicles rather the change of patterns of traffic at an intersection.
 - Traffic actuated timing schemes are usually constrained by specified minimum lengths of green indication for various traffic streams and extended by vehicle arrivals up to specified maxima.
- Traffic actuated controllers are classified as
 - Semis actuated controller: sensors are placed only on minor road approaches.
 - Fully actuated controller: sensors are placed on all intersection approaches.
- Intersections can be controlled individually or a sequence of intersections along a road can be connected and controlled as a group.

Semi actuated signal

Actuators are located on the minor street only. The green rests on the major street unless there are actuations on the side street. Once actuation on the minor street ceases or the maximum green interval for the minor street is reached, the green is returned to the major street and remains there for a present minimum green interval or until another actuation on the minor street.

Fully actuated signals

- Signals are used when the overall traffic volume are more nearly equal.
- Detectors are placed on all approaches.
- In the absence of actuations, the green may either rest where it is or be transferred by means of a recall switch to some particular approach.

Detectors

- Detectors can be activated by the passage or the presence of vehicles.
- Different physical principles are used for detection
 - Pressure
 - Distortion in magnetic field.
 - Interruption of a light beam.
 - A change of wave frequency.
 - Change in inductance of a conducting loop
 - Video detection using image processing techniques
- They can be placed above the road or under the road surface.

Element of signal timing

- A signal phase is a period during which one or more movements concurrently are shown a green indications. Safety consideration dictate that a phase may be shared only by those traffic streams whose paths do not intersects, even though some conflicts may be tolerable(pedestrian with turning vehicles; If and only if the volume of turning vehicle is relatively slow)
- The time between the end of a green indication for one phase and the beginning of a green of another is called intergreen or “clearance interval” An amber indication is shown through the intergreen followed by red. If the computed clearance interval is long, a combination of amber and an all red interval may be used instead.

Element of signal timing

- Design of signal phase specifies the sequence of various phases following each other.
- Safety and level of service are the most important factor in designing the signal phasing
- Factors affecting the length of intergreen include
 - Safe stopping distances.
 - Approach speeds of vehicles
 - Walking speeds of pedestrians
 - Pavement width
- The sum of intergreen overall phases is subtracted from cycle time, the remaining is the total green time per cycle.
- The selection of green times depends on whether
 - to minimizing the overall average travel time through the intersection or
 - to equalize demand and capacity over a given period of time or
 - To minimize the maximum individual travel time through an intersection.
- Each objective of the above may result in a different set of cycle time and green indication.

Intergreen period calculation

- When the amber indications appears , driver who are at a distance (from the stop line) greater than their stopping distance will be able to stop comfortably.
- When the amber indications appears, driver who are at a distance (from the stop line) nearer to the stop line than their safe stopping distance will accelerate and clear the intersection.
- When the amber indications appears, driver who are at a distance (from the stop line) which is at or near the safe stop distance away (the so called “dilemma zone”) should be able to (1) either to stop or (2) accelerate (when near the stop line) and clear.

Intergreen period calculation

- To consider the dilemma zone in calculating the intergreen period, the path of the vehicle covers a distance of $S+W+l$

Where

S=safe stopping distance (ft)

W= distance from the stop line until the rear of vehicle is clear (ft)

l= length of vehicle (ft)

- The intergreen time I is*

$$I = \frac{S + W + l}{v} = \delta + \frac{v}{2f \times g} + \frac{W + l}{v}$$

V= speed of vehicle (ft/s)

G= 32.2 ft/s²

δ =perception reaction time (2.5 sec)

f=friction coefficient
(0.33 wet and 0.62 dry
pavement at 30 to 40mph)

Intergreen period calculation

If there is no all-red interval $I=A$ (integreen equal to an amber indication)

- If amber indication time based on pedestrian movement, in the same direction as the car, crossing street B. If there are no pedestrian signals, assume that the last pedestrian start crossing exactly as the amber indication comes on, then the pedestrian clearance time is

$$R_i = \frac{W_j}{V_{ped}}$$

W_j = is the street width or up to the median

V_{ped} = walking pedestrian speed (4ft/s)

- if R_i is longer than I_i , use R_i ad I_i

Shortest cycle based on pedestrian requirements

- In urban areas when pedestrian phase is necessary due to the high volume of pedestrians. This phase length might govern the green indication for that approach. Pedestrian need a total time to cross an intersection of $Z+R_i$
 - Z = initial period during which walk signal is displayed = 7sec
 - R_i = clearance time for the last pedestrian who starts crossing the intersection when pedestrian signal turns flashing
- As part or all R_i can coincide with intergreen period, pedestrian phase (P_i) requires only

$$P_i = Z + R_i - I_i$$

- P_i Is the pedestrian phase (sec) during the green indication (it is assumed that R_i is longer than I_i ; if I is the larger, $P_i = Z$) it follows that $P_i = \min G_i$

Signal timing for permitted isolated signals

- Three manual methods are used, namely
 - Homburger and Kell's method
 - Pignataro's method
 - Webster's method

Homburger and Kell's method for signal timing

- This method utilize traffic volumes as the basis for allocating time to approaches, keeping off-peak cycles as short as possible. (40-60 seconds). Peak-hour cycles can be longer, favoring movement on the major street.
- The following seven steps are used.
 1. Select yellow change intervals between 3 to 5 seconds for speeds less than 35 mph to speed greater than 50 mph
 2. Determine the need for additional clearance time using the following equation and ensure that all-red phase is necessary

$$Y = \delta + \frac{v}{2a} + \frac{W + l}{v} \qquad a = 10\text{ft/sec}^2$$

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Homburger and Kell's method for signal timing

3. Determine pedestrian clearance times, assuming pedestrian walking speed as 4ft/sec
4. Compute minimum green. With pedestrian signals "the walk period should be at least 7 seconds.
5. Compute green times based on an approach volume in the critical lane on each street at peak hour
6. Adjust the cycle length (sum of all greens and yellows) to the next-higher-5 second interval and re-distribute extra green time.
7. Compute percentage values for all intervals

Webster method

- The cycle length is given by

$$C = \frac{1.5L + 5}{1 - \sum_i Y_i}$$

Where

C= Cycle length, s

L= loss time, s; normally the sum of all yellow and all red intervals

Y_i = critical volume/saturation flow ratio for phase *i*

- *Determine critical flow ratios.*
- *define the overlap phasing*
- *Determine cycle length*
- *Determine yellow as fraction of a cycle.*
- *Distribute green time*
- *Determine each phasing time*
- *Calculate green time/cycle ratio*
- *Check the minimum green*