



The Institute of Transportation Engineers  
and its members  
the application  
operation of  
of members  
professionals

Founded in 1907  
and through  
local and  
exchange

# TRAFFIC ENGINEERING HANDBOOK 6TH EDITION

---

Institute of Transportation Engineers

## The Editorial Board

Walter H. Kraft, D.Eng.Sc., P.E.  
*Editor*

Wolfgang S. Homburger, P.E.  
*Co-Editor*

James L. Pline, P.E.  
*Co-Editor*

.....

The Institute of Transportation Engineers (ITE) is an international educational and scientific association of transportation and traffic engineers and other professionals who are responsible for meeting mobility and safety needs. ITE facilitates the application of technology and scientific principles to research, planning, functional design, implementation, operation, policy development and management for any mode of transportation by promoting professional development of members, supporting and encouraging education, stimulating research, developing public awareness, exchanging professional information and maintaining a central point of reference and action.

Founded in 1930, ITE serves as a gateway to knowledge and advancement through meetings, seminars and publications, and through our network of nearly 17,000 members working in more than 92 countries. ITE also has more than 90 local and regional chapters and more than 130 student chapters that provide additional opportunities for information exchange, participation and networking.



Institute of Transportation Engineers  
1099 14th Street, NW, Suite 300 West  
Washington, DC 20005 USA  
Telephone: +1 202-289-0222  
Fax: +1 202-289-7722  
ITE on the Web: [www.ite.org](http://www.ite.org)

ISBN-13: 978-1-933452-34-0  
ISBN-10: 1-933452-34-X

© 2010 Institute of Transportation Engineers. All rights reserved.  
Publication No. TB-010B



a head start or the pedestrians can be held until the initial queue of vehicles has been served. However, such controller phasing may have a detrimental effect on vehicle flow and, if part of a system, on system capacity.

The goals of traffic safety and traffic capacity must be balanced when determining controller phasing for an intersection. The following section describes the various components of controller phasing. More in-depth discussion can be found in the *Manual of Traffic Signal Design* and *Signalized Intersections: Informational Guide*.<sup>14,15</sup>

**Green Interval.** Ideally, the length of the green display on each approach to an intersection will be sufficient—but not excessive—to serve all the vehicles and pedestrians queued during the red interval. Several PC-based computer programs are available to assist in determining the green interval timing.

For semi- or fully-actuated controllers, a minimum and maximum amount of green time must be determined and allocated for each phase and programmed into the controller. These values are derived from the analysis results of the timing software or other method of analysis used by the designer.

For pre-timed signal controllers, the length of the green display is based on engineering judgment. Traffic and pedestrian counts for a specific period of time are often used in determining the signal timing.

**Yellow Change Interval.** The purpose of the yellow change interval, which is required to be the first interval following every circular green or green arrow indication, is to warn approaching traffic of the termination of the related green interval or that a red signal indication will follow (see “Vehicle Detector Placement”).

MUTCD states that yellow change intervals should have duration of 3 to 6 sec.<sup>16</sup> To determine the appropriate yellow time for the approach, this should be calculated using the Kinematic Model—Formula 1 found in ITE’s *Determining Vehicle Signal Change and Clearance Intervals*:<sup>17</sup>

$$Y = t + [v/(2a+2Gg)]$$

where:

Y = yellow clearance interval (sec)

t = reaction time (typically 1 sec.)

v = design speed (ft./sec.)

a = deceleration rate (typically 10 ft./sec.<sup>2</sup>)

g = acceleration due to gravity (32.2 ft./sec.<sup>2</sup>)

G = grade of approach (percent/100, downhill is negative grade)

The equation shown above includes a reaction time, a deceleration element and an intersection clearing time. In view of the operational history of the yellow change interval and the assumptions used in the formula, applying the formula requires the exercise of engineering judgment.

Because a long yellow change interval may encourage drivers to use it as a part of the green interval, maximum care should be used when exceeding 5 sec. If the interval is too short, rear-end crashes may result. When the calculation for yellow change interval time indicates a time longer than 5 sec., a red clearance interval typically provides the additional time.

Some jurisdictions time the yellow change interval to enable a vehicle to clear the intersection before the onset of a conflicting green display. Other jurisdictions allow a conflicting green display to be shown before the intersection is cleared. Still others allow a conflicting green display to be shown after the vehicles have cleared the center line of the conflicting approach. Engineering judgment should be exercised in selecting the operation of the yellow change interval to ensure safe passage of vehicles in the intersection.

As can be seen from the formula above, slower speeds result in higher values of yellow clearance time. When calculating the needed time, consideration should be given to the values for the 15th-percentile speed, particularly at wider intersections.

The calculations for steep downgrades will yield values that some drivers may consider excessive. Simply reducing the interval times may create dangerous operating conditions. The engineer should consider lowering the approach speeds by reducing the speed limit or by the use of a warning beacon or other measures.



**Red Clearance Interval.** The red clearance interval is an optional interval that follows a yellow change interval and precedes the next conflicting green interval. The red clearance interval is used to provide additional time following the yellow change interval before conflicting traffic is released.

MUTCD states that the red clearance interval should not exceed 6 sec.<sup>18</sup> The appropriate red time for the approach should be calculated using the following formula found in ITE's *Determining Vehicle Signal Change and Clearance Intervals*:<sup>19</sup>

$$R = (w+L)/v$$

where

R = all red interval (sec.)

w = width of stop line to far side no-conflict point (ft.)

v = design speed (ft./sec.)

L = length of vehicle (typically 20 ft.)

For exclusive turn movements, the value of w should be measured along the vehicle turn path from the stop line to the no-conflict point.

The decision to use a red clearance interval is determined by intersection geometrics, crash experience, pedestrian activity, approach speeds, local practices and engineering judgment.

## 6. Left Turns

Three operational modes are available when provisions for left turns are made in the phasing of a traffic control signal:

1. **Permissive (permitted) mode only**—in which drivers may turn left after yielding to conflicting traffic or pedestrians during the circular green indication, along with the parallel through movements. A separate left-turn lane is often provided but not required. No regulatory sign is required, but an informational sign may be used.
2. **Protected (exclusive) mode only**—during which left turns are permitted only when a left green arrow is displayed. There is no conflicting vehicular or pedestrian traffic. Typically, a separate left-turn lane is provided. If the left-turn movement occurs when the adjacent through movement is shown a circular red indication, a separate left-turn lane must be provided.

A separate left-turn signal face must be used where the signal sequence does not provide for the simultaneous movement of the parallel through traffic. The change interval display may consist of either a yellow left arrow or a circular yellow. The yellow indication must match the green indication; that is, if the separate left-turn face provides a circular green, a circular yellow is provided. If the separate left-turn signal face provides a green left arrow, the yellow indication must be a left arrow. MUTCD requires that all green arrow indications must be followed by yellow arrow indications. The red interval may use a red arrow only if a yellow arrow indication is used. Otherwise, a circular red is required.

When a separate signal face is used, it should be positioned in line with the turning movement approach. A left-turn signal sign (R10-10) is required unless the signal face consists of arrows only or unless it is properly hooded, shielded, or louvered to ensure that conflicting circular yellow or red indications are not readily visible to motorists in the through lanes.

3. **Protected/permissive (exclusive/permitted) mode**—a combination of both the protected and the permissive modes whereby left turns may be made during the green display as defined under the respective modes. Green and yellow arrow indications are required for this type of operation.

The controller phasing for protected/permissive mode is the most complicated of the three modes in that it combines the other two modes. Four distinct controller-phasing schemes are commonly employed:

- lead-left turn with parallel, non-conflicting through traffic;
- simultaneous lead-left turns with no parallel through traffic;
- lag-left turn with parallel, non-conflicting through traffic; and
- simultaneous lag-left turns with no parallel through traffic.