A state's Uniform Vehicle Code directly affects yellow change interval timing, as it determines whether a *permissive* or *restrictive* yellow law is in place.

- Permissive Yellow Law: A driver can enter the intersection during the entire yellow interval and be in the intersection during the red indication as long as the vehicle entered the intersection during the yellow interval. Under permissive yellow law, an all-red clearance interval must exist as a timing parameter to ensure safe right-of-way transfer at an intersection. This rule is consistent with paragraph 11-202 of the Uniform Vehicle Code (9).
- Restrictive Yellow Law: There are two variations of this law (10). In one variation, a vehicle may not enter an intersection when the indication is yellow unless the vehicle can clear the intersection by the end of yellow. This implies that the yellow duration should be sufficiently long as to allow drivers the time needed to *clear* the intersection if they determine that it is not possible to safely stop. In the other variation, a vehicle may not enter an intersection unless it is impossible or unsafe to stop. With restrictive yellow law, the presence of an all-red interval is optional and good engineering judgment should be applied.

Due to the varying interpretations of the yellow change use, it is encouraged that traffic engineers refer to the local and regional statutes for guidance in determining the purpose of the yellow change time.

Red Clearance

The red clearance interval, referred to in some publications as an all-red interval, is an interval at the end of the yellow change interval during which the phase has a red-signal display before the display of green for the following phase. The purpose of this interval is to allow time for vehicles that entered the intersection during the yellow-change interval to clear the intersection prior to the next phase. Note that the use of the "all-red" nomenclature is generally incorrect, as the red clearance interval only applies to a single phase, not to all phases.

The use of a red clearance interval is optional, and there is no consensus on its application or duration. Recent research has indicated that the use of a red clearance interval showed some benefit to the reduction of red-light-running violations. In these studies, there was a significant reduction in right-angle crashes after implementing a red clearance interval. Other research suggests that this reduction may only be temporary. A comprehensive study of long-term effects for the Minnesota Department of Transportation (11), indicated short-term reductions in crash rates were achieved (approximately one year after the implementation), but long-term reductions were not observed, which implies that there may not be safety benefits associated with increased red clearance intervals.

A disadvantage of using the red clearance interval is that there is a reduction in available green time for other phases. At intersections where the timing for minor movements is restricted (e.g., to split times under coordinated operation (see Chapter 6)), the extra time for a red clearance interval comes from the remaining phases at the intersection. In cases where major movements are already at or near saturation, the reduction in capacity associated with providing red clearance intervals for safety reasons should be accounted for in an operational analysis.

The MUTCD provides guidance on the application and duration of the yellow change and red clearance intervals. It recommends that the interval durations shall be predetermined based on individual intersection conditions, such as approach speed and intersection width. The MUTCD advises that the yellow change interval should last approximately 3 to 6 seconds, with the longer intervals being used on higher-speed approaches. It also advises that the red clearance interval should not exceed 6 seconds. A recent survey conducted by The Urban Transportation Monitor indicated that practitioners who used a standard red clearance interval used a range from 0.5 to 2.0 seconds.

Kell and Fullerton (12) offer the following equation for computing the phase change period (yellow change plus red clearance intervals):

$$CP = \left[t + \frac{1.47v}{2(a + 32.2g)} \right] + \left[\frac{W + L_V}{1.47v} \right] \tag{5-2}$$

where:

- CP = change period (yellow change plus red clearance intervals), s;
- t = perception-reaction time to the onset of a yellow indication, s;
- v = approach speed, mph;
- a = deceleration rate in response to the onset of a yellow indication;
- g = grade, with uphill positive and downhill negative (percent grade / 100), ft/ft;
- W = width of intersection, ft; and
- L_v = length of vehicle.

Equation 5-2 is based on driver reaction time, approach speed, approach grade, and intersection width and consists of two terms. The first term (yellow change) represents the time required for a vehicle to travel one safe stopping distance, including driver perception-reaction time. This permits a driver to either stop at the intersection if the distance to the intersection is greater than one safe stopping distance or safely enter the intersection (and clear the intersection under the restrictive yellow law) if the distance to the intersection is less than one safe stopping distance. The second term (red clearance) represents the time needed for a vehicle to traverse the intersection ($[W + L_v]/v$). Although values will vary by driver population and local conditions, the values of t = 1.0 s, a = 10 ft/s^2, and L_v = 20 ft are often cited for use in Equation 5-3 (13,14,15). These values of perception-reaction time and deceleration rate are different from those cited in highway geometric design policy documents because they are based on driver response to the yellow indication, which is an expected condition. They are not based on the longer reaction time necessary for an unexpected (or surprise) condition.

When applying Equation 5-2 to through movement phases, the speed used is generally either the 85th-percentile speed or the posted regulatory speed limit, depending on agency policy (16). When applying Equation 5-2 to left-turn movement phases, the speed used should reflect that of the drivers that intend to turn. This speed can equal that of the adjacent through movement but it can also be slower as left-turn drivers inherently slow to a comfortable turning speed. Regardless, if the left-turn phase terminates concurrently with the adjacent through phase, it will have the same total change and clearance interval durations as the through phase because the phases are interlocked by the ring-barrier operation.

The width of the intersection is often defined by local policy or state law. For instance, in Arizona intersection width is defined by state law as the distance between prolongations of the curb lines. Where intersection width is not defined by local policies, engineering judgment should be used when measuring the width of the intersection, *W.* One approach is to measure from the near-side stop line to the far edge of the last conflicting traffic lane along the subject movement travel path. If crosswalks are present at the intersection, some agencies have policies to measure from the near-side stop line to the far side of the pedestrian crosswalk on the far side of the intersection (for through-movement phases) or to the far side of the pedestrian crosswalk across the leg of the intersection which the left-turn is entering. This is a jurisdiction-wide issue that must be carefully applied.