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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

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Various methods have been used to assist drivers in the dilemma zone. True active advance warning signs (TAAWS) use flashing lights to warn the driver a few seconds before the onset of the yellow interval. These were compared to a continuous flasher at two rural, high-speed signalized intersections—one with a tangent and the other with a curved approach.[191] Drivers who passed when the flashers were off and faced a green or yellow signal indication sped up, particularly on the tangent approach. This led the authors to recommend continuous flashers on such approaches, which alert drivers to the existence of the signal without letting them know the signal state.

Small changes in the yellow interval have been shown to have major effects on driver behavior at signalized intersections. The yellow interval was increased from 3 to 4 sec. at 30-mph (50-km/hr.) intersections and from 4 to 5 sec. at 50-mph (80-km) intersections. A before- and 1-year-after-study showed that this small change in the clearance interval reduced the percentage of drivers caught in the dilemma zone from 13.4 percent to 6.7 percent; the percentage of red-light-running offenses decreased from 1.1 percent to 0.5 percent.[192]

Dewar et al. examined the effect of different yellow signal durations (3, 4, 5 and 6 sec.) to determine the point at which most drivers would stop rather than proceed through the intersection.[193] The study was carried out at four urban intersections in 30-mph (50-km/hr.) speed zones. Only vehicles traveling with no other vehicles within five car lengths were selected. The yellow signal was activated when the subject vehicle (traveling at no more than the speed limit) was at a distance corresponding to the travel distance to the intersection stop line that would be covered in 3, 4, 5, or 6 sec. Approximately 90 percent of drivers failed to stop for the 3-sec. signal; however, a similar proportion did stop for the 6-sec. signal. The theoretical point at which half the drivers would stop (the maximum dilemma) was determined to be 3.8 sec.

Because drivers choose to decelerate more rapidly when they have to stop from higher speeds, good coefficient of pavement friction is important on high-speed approaches. However, the most effective countermeasure is likely to be long-distance detection. Loop detectors are used to wait until there is a gap in traffic before the signal changes to yellow so drivers are not caught in the dilemma zone. Because this countermeasure is hidden from drivers (no signs need be used), it is unlikely to lead to adaptation and red-light-running as drivers depend on the light staying green. This removes drivers from the dilemma of making a difficult stop/go decision. Such installations are most appropriate for high-speed, isolated rural intersections. At urban intersections, the use of signal synchronization is an effective countermeasure because it reduces the frequency with which drivers must stop and, consequently, reduces their exposure to the dilemma.

6. Roundabouts

Intersections are associated with high numbers of conflict points between crossing and turning vehicles and other road users. Roundabouts reduce those conflict points from 32 at a standard right-angle intersection with four legs to eight. With respect to the driver task, the driver must slow, follow a curving path and, in a two-lane roundabout, may need to change lanes to access the exit. The driver also must be aware of vehicles on both sides while driving on a curving path. The geometry forces drivers to reduce speed and eliminates right-angle conflicts. Due to their novelty as well as the task requirements, North American drivers are likely to find roundabouts intimidating and the attentional requirements higher than at standard intersections. Nonetheless, crash studies show that when signalized urban intersections are replaced with modern roundabouts, using U.S. sites only, *where drivers are unfamiliar with roundabouts*, all crashes (property damage only, injury and fatal) are reduced to 68 percent and injury crashes are reduced to 32 percent of their previous values.[194]

Pedestrians might be at greater risk at roundabouts because there is no mechanism for stopping traffic to allow them to cross. However, O'Brien et al. indicate that at roundabouts, a moderate to high reduction in both vehicle-vehicle and vehicle-pedestrian collisions occurs compared to other types of intersections.[195] Single-lane designs are associated with greater safety, due in part to less confusion among drivers about which lane to be in. However, there is concern about pedestrian and bicycle safety at multilane roundabouts. One method used to enhance pedestrian safety is to increase chances of their being detected by drivers by placing crosswalks upstream of the entry to the roundabout.

One of the difficulties with the use of roundabouts in the United States is that many drivers are unaware of the rules about their use (who has right of way, for example) because they are a novelty in many areas and little information is provided about these devices in drivers' manuals. A review of the contents of 33 manuals revealed that less than one-third of these gave directions for the use of traffic circles and none addressed roundabouts.[196] In addition, none discussed the differences between traffic circles and roundabouts; right-of-way issues of pedestrians and bicyclists; and signing (with the exception of one state that mentioned signs).