The Dilemma with Dilemma Zones

Tom Urbanik, Professor
The University of Tennessee
and
Peter Koonce, Associate Engineer
Kittelson and Associates

Introduction

The fundamental problem, "the dilemma," with dilemma zones is a lack of rigor with regard to defining terminology and the documenting of assumptions when discussing dilemma zones. This makes it difficult to have an informed discussion of issues. Further, it creates poor practice because practitioners often resort to "standard practice," what the industry has always done, or status quo because of potential liability and because practitioners do not understand the inconsistent use of terms. Here, the term "standard practice" denotes things like past agency practices that cannot be explained or documented, or practices that do not reflect a modern understanding of complex issues.

Some recent papers (1, 2, 3, and 4) cover the range of issues associated with dilemma zones. They clearly point out the existence of two types of dilemma zones, although these are discussed with varying terminology, reflecting the general lack of consensus on terms. It is clear that two types of dilemma zones (I'll call them Type I and Type II) exist. They are not, however, totally independent concepts, which explains some of the confusion. Type I dilemma zones (or they might be called classic yellow time dilemma zones) were first described in the literature in 1960 by Gazis *et. al.* (5). Type I dilemma zones are associated with signal timing for clearance intervals. Type II dilemma zones (better described as option or indecision zones) were first documented in a Southern Section ITE Technical Report (6). Type II dilemma zones are associated with driver behavior. Before these dilemma zones can be discussed, some additional context must be established.

Assumptions

The law regarding yellow indications varies across the country. However, this reality is not commonly understood, as demonstrated in the recent ITE document: *History of the Yellow and All-Red Intervals for Traffic Signals, Executive Summary* (8), which seemed to overlook this fact. This is unfortunate as the local state vehicle code complicates the issue of yellow timing. For simplicity, we are going to use the Uniform Vehicle Code(7) (or permissive yellow law) as the basis of discussion; some alternative definitions made the problem intractable. The permissive yellow law is defined as a situation when a vehicle can enter the intersection during the entire yellow interval and be in the intersection during the red indication as long as he/she entered the intersection during the yellow interval. Restrictive yellow law is defined as a situation when vehicles can neither enter the intersection nor be in the intersection on red; or Vehicles must stop upon receiving the yellow indication, unless it is not possible to do so safely. This paper assumes that the yellow change interval and red clearance provide sufficient time for the approaching vehicle to clear the intersection at its approach speed .Failure to provide

adequate yellow and red clearance time produces a Type I dilemma zone as discussed in the following section.

Type I Dilemma Zones

Type I dilemma zones deal with the period of time during which a driver either proceeds through the intersection because he/she is too close to stop or stops because he or she can safely do so. As originally formulated by Gazis, the yellow indication needed to be long enough for a vehicle to either stop or clear the intersection as shown in Figure 1. At the time, this was consistent with the ITE recommended practice (8). Since that time, the ITE formula has been modified several times and now provides for red clearance to better manage the length of the yellow interval.
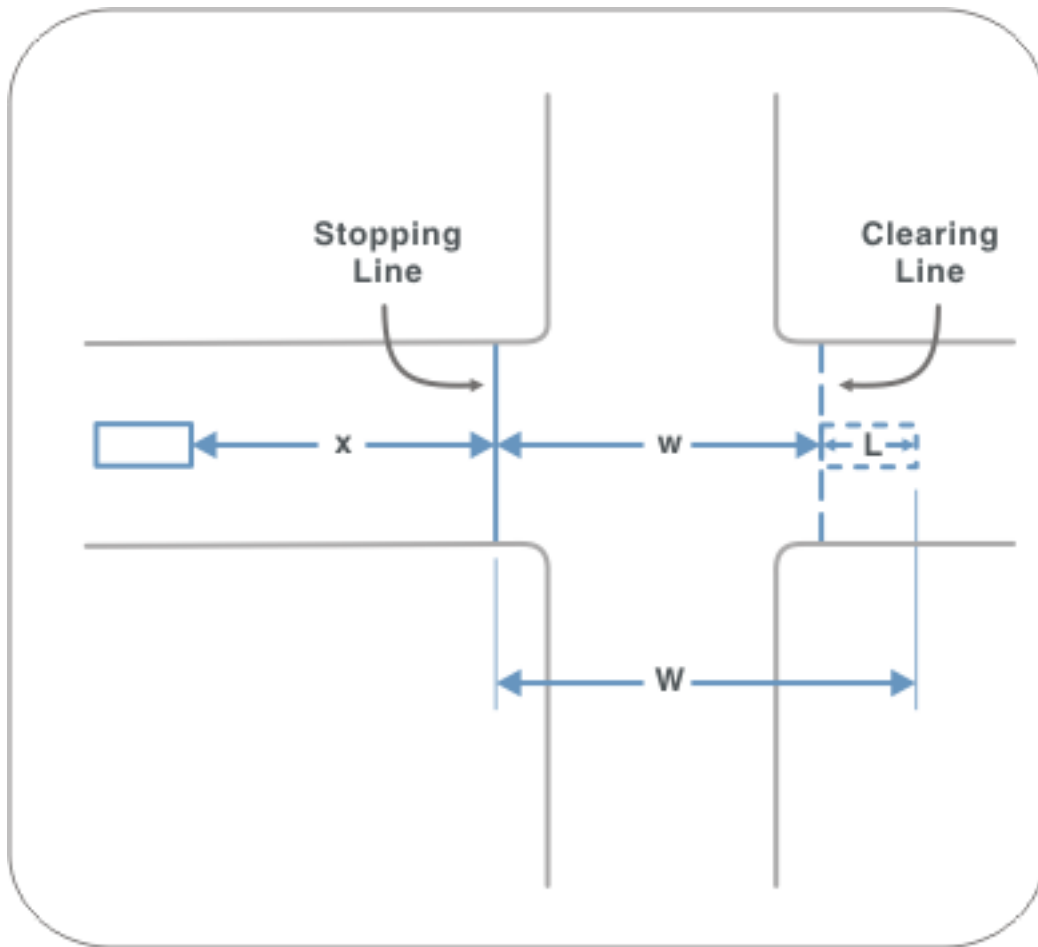
Figure 1: Gazis Formulation: Stopping and Clearing

Figure 2 shows the Type I dilemma zone which corresponds with the timing of the change period. If the change period is timed according to the *Traffic Engineering Handbook, 5th ed.*, a Type I dilemma zone does not exist because, based on the assumed parameters, a vehicle can either safely stop or clear the intersection. In this case, the driver is NOT placed in a dilemma caused by a short yellow plus red

clearance. There are some important caveats to observe related to the Type I dilemma. The formula is based on the sound laws of physics. However, the formula is only as good as the assumed parameters. Because drivers vary in their performance, the issue of human factors differences can alter the situation, which leads to the second type of dilemma zone, discussed in the next section.

It should be noted the AASHTO guidance as reflected in the Green Book (9) uses criteria that are different from ITE. Furthermore, the research on which all the criteria are based is very old. This has resulted in the wide variety of opinion and practice presently employed regarding signal timing for Type I dilemma zones.
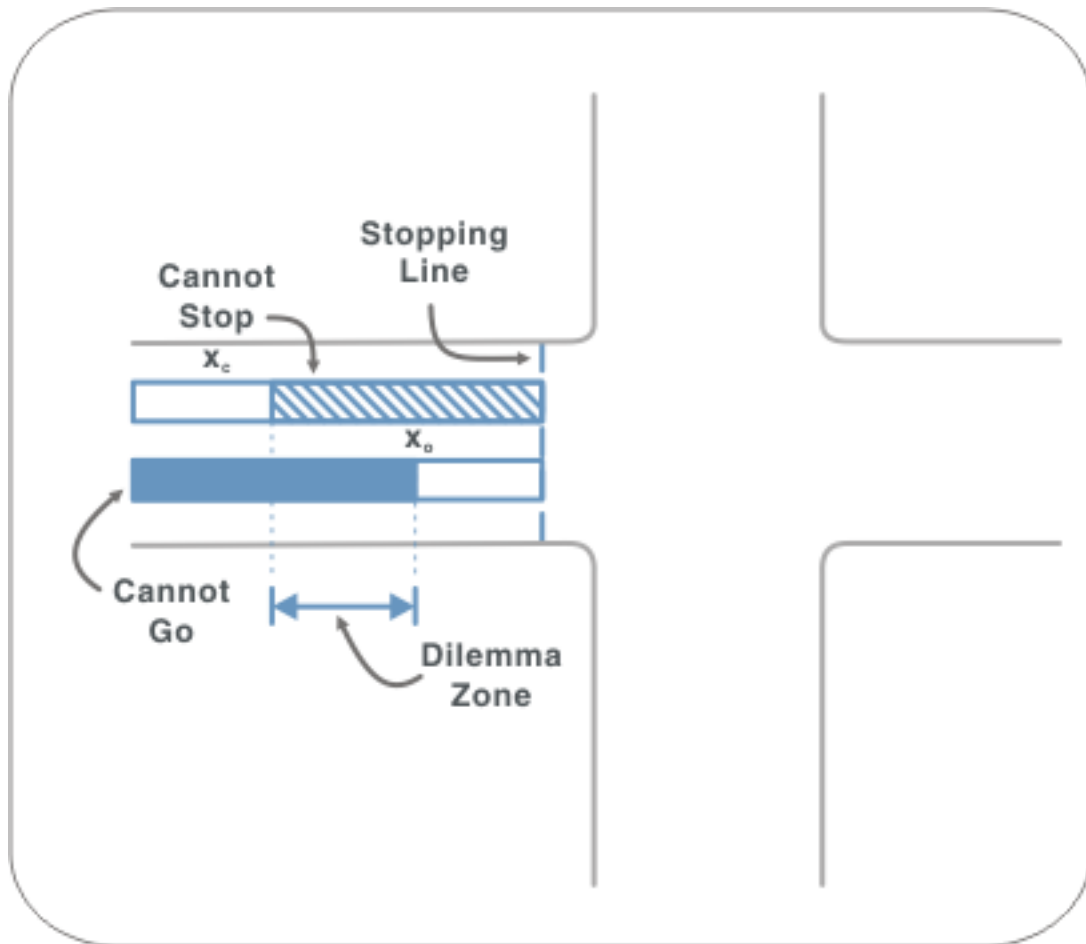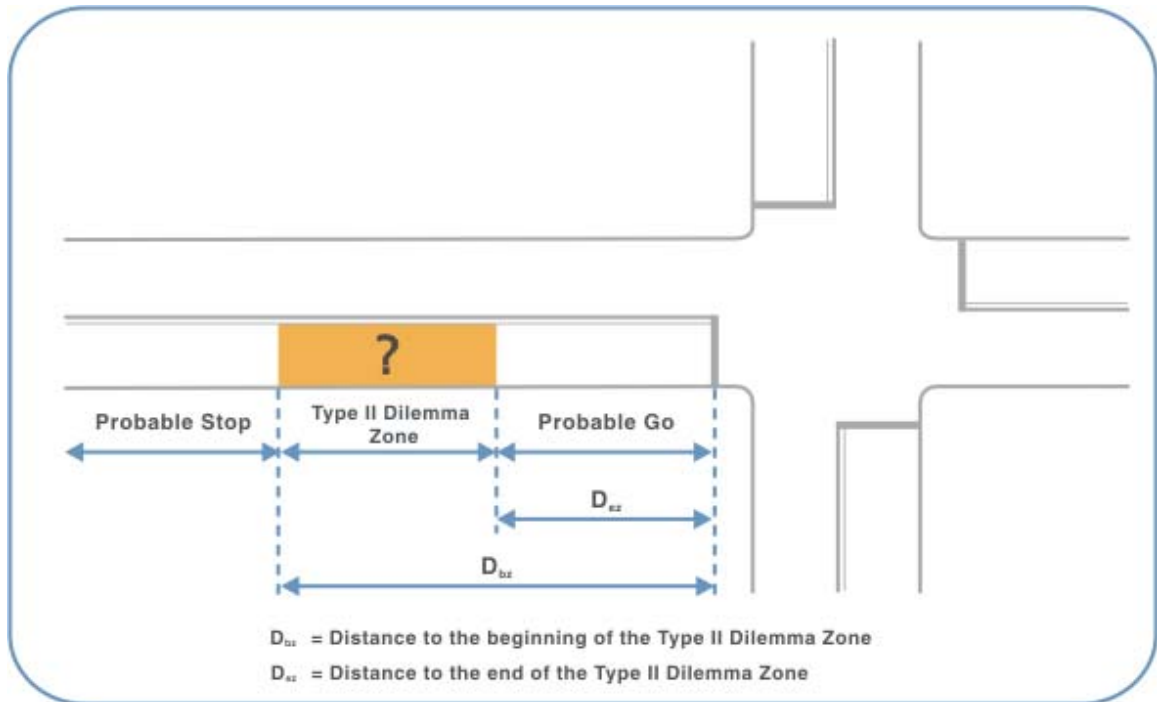

Figure 2: Type I Dilemma Zone

Type II Dilemma Zones

Type II dilemma zones have also been called "indecision zones" and "option zones," reflecting their probabilistic nature. As a group, drivers within a few seconds travel time of the intersection tend to be indecisive about their ability to stop at the onset of the yellow indication. This behavior yields a "zone of indecision" in advance of the stop line where some drivers may proceed and others may stop. Figure 3 shows the location of this Type II dilemma zone.

Figure 3: Type II Dilemma Zone

The Type II dilemma zone has been defined in several ways. Zegeer defined it in terms of distance from the stop line (10). He defined the beginning of the Type II dilemma zone as the distance beyond which 90 percent of all drivers would stop if presented with a yellow indication. He defined the end of the zone as the distance within which only 10 percent of all drivers would stop. The distance to the beginning of the Type II dilemma zone recommended by Zegeer corresponds to about 5 seconds of travel time. The beginning of the Type II dilemma zones as contained in guidance developed by the Southern District of the Institute of Transportation Enginners (6) varies from 4.2 to 5.2 seconds of travel time, with the larger values corresponding to higher speeds.

The Type II dilemma zone has also been defined as the observed travel time to the stop line. Chang et al. (1985) found that 85 percent of drivers stopped if they were more than 3 seconds from the stop line, regardless of their speed. Similarly, the research found that drivers less than 2 seconds from the stop line would almost always continue through the intersection.

Based on the research data, all of which was gathered at least 20 years ago, the beginning and end of the Type II dilemma zone tends to be about 5.5 seconds and 2.5 seconds, respectively, from the stop line. These times equate to the decision times of the 90th and 10th percentile drivers, respectively.

The Type II dilemma zone exists at the onset of *every* yellow indication, regardless of the yellow interval duration. Exposure to the Type II dilemma zone is minimized through the design of the detection system and the associated signal timing parameters. While

detection design and timing is beyond the scope of this paper, some basic principles can be established.

The upstream (advance) detector should be located approximately 5.5 seconds from the stop bar. The detection system, in concert with the passage timer or an individual detector(s) extension timer, should extend the green until the vehicle is within 2.5 seconds of the stop bar. At this point, the onset of yellow, plus 1 second of perception-reaction time virtually assures that a vehicle will enter the intersection. The important point is that extending the green to the stop bar or to clear the intersection is very inefficient because if represents a very low flow threshold.

Using a single detector, placed 5.5 seconds from the stop bar, requires a 3-second passage time to get a vehicle to the 2.5 second point. Because some consider a 3 second passage time as inefficient, multiple detection schemes have been used. However, some of these multiple detection schemes are inefficient or, worse yet, virtually assure that the phase will max-out under moderate traffic volumes. What is often not understood in many multiple lane configurations is that every actuation, regardless of which detector or which lane, resets the passage timer. For multiple detection schemes to be effective, the timing must be associated with individual detectors.

Alternative Systems

The current detection scheme approaches are largely based on traditional controller and detector logic. These approaches can only approximately respond to the many variables associated with individual vehicles and drivers. While some new concepts like the Detection-Control System (11) are more robust (3), ultimately, advanced systems using dedicated short-range communication between vehicles and the roadside traffic signal controller will enable more intelligent phase termination systems.

Summary and Conclusions

Understanding the two types of dilemma zones is essential for good traffic signal operations and safety. Type I dilemma zones are addressed by the selection of appropriate yellow change and red clearance intervals. Type II dilemma zones are addressed by the proper design of the detection system and the appropriate selection of controller timing parameters.

References

[1] Liu, Chang, Tao, Hicks, and Tabacek, "Empirical Observations of Dynamic Dilemma Zones at Signalized Intersections," TRB 2007 Annual Meeting CD-ROM.

[2] Sharma, Bullock and Peeta, "Recasting Dilemma Zone Design as a Marginal Costs-Benefits Problem," ," TRB 2007 Annual Meeting CD-ROM.

[3] Si, Urbanik, and Han, "Effectiveness of Alternative Detector Configurations for Option Zone Protection on High-Speed Approaches to Traffic Signals," 2007 Annual Meeting CD-ROM.

[4] Gates, Noyce, and Laracuente, "Analysis of Dilemma Zone Driver Behavior at Signalized Intersections," 2007 Annual Meeting CD-ROM.

[5] Gazis, Herman, and Maradudin, The Problem with the Amber Signal Light in Traffic Flow, Operations Research, Vol. 8, No. 1 (Jan.-Feb., 1960), pp. 112-132.

[6] Small-Area Detection at Intersection Approaches, Traffic Engineering, February, 1974.

[7] Uniform Vehicle Code, National Committee on Uniform Traffic Laws and Ordinances 2000

[8] Eccles and McGee, A History of the Yellow and All-Red Intervals for Traffic Signals, Executive Summary, Prepared for Institute fo Transportation Engineers, BMI, July 27, 2001.

[9] A Policy on Geometric Design of Highways and Streets, 5th Edition, American Association of State and Highway Transportation Officials, Nov-2004

[10] Zegeer, Effectiveness of Green-Extension Systems at High-Speed Intersections, Research Report 472, Division of Research, Kentucky Bureau of Highways, Lexington, KY, May 1977.

[11] Bonneson, Middleton, Zimmerman, Charrara and Abbas, Intelligent Detection-Control System For Rural Signalized Intersections, Texas Department of Transportation, Research Report 4022-2, Austin, TX, May 2002.