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July 23, 2013

Mr. Devinder Singh
Executive Secretary
California Traffic Devices Committee

Dear Mr. Singh:

I have learned that the California Traffic Devices Committee is meeting on Thursday, July 25, 2013 and that it is possible that it will be taking up the question of the proper setting of the amber signal time at this meeting. If this is indeed the case, I respectfully offer the following remarks to the committee for its consideration.

I am the sole surviving co-author of the paper: D.C. Gazis, R. Herman, and A.A. Maradudin, "The problem of the amber signal light in traffic flow," Operations Research 8, 112-132 (1960), in which this question was addressed. Several specific assumptions were made in our work, but they have not always been noticed in discussions of it. Consequently, in what follows I summarize the results of what we did and when they apply, as well as conditions under which they don't apply, in the hope that our work not be misunderstood and therefore misused.

The 1960 paper, "The Problem of the Amber Signal Light in Traffic Flow" produced the formula which traffic engineers recognize today as the "ITE Yellow Change Interval Formula" (equation 9 in the paper),

$$t_{min} = t_{pr} + v_0 /2a + (w+L)/2.$$

When properly applied, the formula eliminates the "type 1 dilemma zone", an area in the roadway where, upon the initiation of the amber phase, a driver cannot stop safely nor clear the intersection before the initiation of the red light phase.

The formula was not intended to determine the "correct" amber time for a given roadway, but rather to calculate a minimum amber time that will provide a motorist with a solvable solution to one specific stop or go problem encountered when the amber signal is illuminated.

The formula provides this solvable solution only for a specific set of circumstances, i.e. a previously assumed initial velocity, perception/reaction time, and deceleration rate.

The formula does not ensure that every driver on the roadway will be able to stop appropriately upon commencement of the amber signal, as not all drivers are traveling at the previously assumed initial velocity, exhibit the assumed perception/reaction time, or are driving vehicles capable of the assumed deceleration rate.

The formula can only be applied to vehicles which start at the maximum allowable speed v_0 measured at the critical stopping distance ($t_{pr} v_0 + v_0^2 / 2a$) and which proceed at a constant speed v_0 into the intersection. In order for traffic to move legally, the formula assumes that drivers can perceive and react correctly to the onset of the amber signal phase in time t_{pr}, that drivers can decelerate safely and comfortably at a deceleration rate "a" and that v_0 is at least the speed limit. The formula does not work for any other circumstance.

Applying the formula to circumstances where a driver must decelerate within the critical distance into the intersection results in a minimum amber time that is shorter than what is necessary to eliminate the dilemma zone. Below is a partial list of common situations where the formula does not provide a long enough minimum amber time:

1.Traffic turning left where the speed limit is greater than the intersection entry velocity.

2.Traffic turning right where the speed limit is greater than the intersection entry velocity.

3.Traffic executing a U-turn. U-turning requires almost double the $v_0 / 2a$ time as drivers must decelerate to close to velocity = 0 in order to negotiate the U-turn.

4.Traffic approaching two close-by intersections. Traffic may have to slow down for the second light (or traffic waiting for the second light) before arriving at the first light.

5. Traffic preceding straight that slows down for vehicles entering and exiting the roadway to and from business entrances and side-streets near the intersection.

6.Traffic slowing down because of traffic density within the intersection making it impossible to continue at the initial velocity when entering the intersection.

7.Traffic slowing down because the speed limit decreases on the far side of the intersection.

8.Traffic slowing down for vehicles changing lanes in front of them.

9.Traffic slowing down for railroad tracks, bumps or potholes near the intersection.

10.Traffic slowing down for hazards like pedestrians suddenly entering the highway near or in the intersection in front of them.

In closing I would like to say that I would be delighted if someone were to extend our work to make it applicable to a broader set of driving and traffic conditions than is the case for our results. Perhaps your committee can accomplish this.

I hope you find these comments useful.

Sincerely,

Alexei A. Maradudin

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