Short Yellows and Turns

Brian Ceccarelli, Joseph Shovlin

Traffic engineers use the Institute of Transportation Engineers (ITE) Yellow Light Change Interval Formula to set yellow light durations. When the engineer sets the yellow duration less than that computed from the Formula, he creates a dilemma zone which forces certain drivers to run red lights. And because the Formula is designed only for straight-thru unimpeded traffic, the engineer cannot apply the Formula to turning vehicles. The Formula mathematically forbids the case of vehicles decelerating then entering the intersection. Turning vehicles decelerate in preparation to turn. Using the laws of physics, we compute the required yellow light durations for unimpeded straight-thru and turning traffic. Given on-the-ground yellow durations, we also compute the length and location of the dilemma zones.

Analytical Considerations

In our previous paper, *Misapplied Physics in the International Standards that Set Yellow Light Durations Forces Drivers to Run Red Lights*[1], we described how the ITE Yellow Change Interval Formula opposes the laws of physics because it is not an equation of motion. We described the history of the Formula and how today's traffic engineers have taken this formula out of context. We described how the Formula systematically forces certain drivers to run red lights and to receive unjust legal penalties.

This paper focuses on one aspect of *Misapplied Physics.* This paper focuses on the time required for a driver to traverse the critical distance. The entire yellow light duration problem boils down to solving the problem of how much time it takes a driver to traverse the critical distance. The length of the critical distance is the same for a turning driver as it is for a straight-thru driver. The distance is fixed because both types of drivers need equal opportunity to stop from the approach speed. For this paper we consider the case where approach speed is the speed limit because all drivers may legally approach at the speed limit. The only difference between a turning driver and a straight-thru driver is the time it takes to traverse the critical distance. Because turning drivers slow down just before entering the intersection, turning drivers need more time than the Formula provides. Over a fixed distance, slowing down expends more time than not slowing down. Today's traffic engineers have gotten this backwards. Today's engineers give turning drivers less time. We discuss their rationale later.

We start with the ITE Yellow Change Interval Formula. We first consider the straight-thru driver. We calculate the critical distance. The critical distance is the distance the driver needs to stop. For the case when the driver commits himself to go, we compute the time he needs to traverse the critical distance at the speed limit. By definition of the ITE Yellow Change Interval Formula, the time it takes for the driver to traverse the critical distance is the duration of the yellow light[2].

We consider what happens when the engineer shortens the length of the yellow duration. We compute the region on the road where the driver's ability to safely stop ends to the point where the driver's ability to proceed legally begins. This region is called a type 1 dilemma zone[3]. If the driver is in this region when the light turns yellow, the engineer forces him to run a red light.

We then consider the turning driver. As opposed to the straight-thru driver, the turning driver proceeds at the speed limit for a part of the critical distance and decelerates to a comfortable turn execution speed for the remainder of the distance. Given the on-the-ground yellow time and the turn execution speed, we compute the location and length of the turning driver's type 1 dilemma zone.

Following the descriptions of the failures, we provide a solution.

The ITE Yellow Change Interval Formula

Equation 1 is the Formula as it appears in ITE's *Traffic Engineering Handbook*[4] and *Traffic Signal Timing Manual*[5]. This Formula appears in traffic signal specifications for almost every jurisdiction in the world.

Equation 1. ITE Yellow Change Interval Formula

$$\mathbf{Y} = \mathbf{t_p} + \left[\frac{\mathbf{v}}{\mathbf{2a + 2Gg}}\right]$$

Variable	Description
Y	yellow light duration
t_p	perception/reaction time constant
v	vehicle's approach speed. v >= speed limit If v < speed limit, engineer takes away driver's legal right to travel at the speed limit.
a	safe deceleration constant of vehicle ITE's value = 10 ft/s^2 AASHTO's value[6] = 11.2 ft/s^2
G	Earth's gravitation acceleration constant
g	grade of the road in %/100. Downhill is negative grade.
a + Gg	effective deceleration of car

Equation 2 expresses the fact that the yellow light duration equals the time it takes for the driver to perceive and decide what to do when the light turns yellow, plus the time it takes for the driver to traverse the safe braking distance at the approach speed.

Eq 2. The Formula is Derived From Braking Distance

$$\mathbf{Y = t_p + \frac{\left[\frac{v^2}{2(a + Gg)}\right]}{v}}$$

$$\textbf{Yellow Duration} = \textbf{Perception Time} + \frac{[\textbf{Safe Braking Distance}]}{\textbf{Approach Speed}}$$

Let us define the *critical distance*. In equation 3, traffic engineers define the critical distance as the safe braking distance plus the distance the driver travels during the time that he perceives and reacts to the signal change to yellow[7].

Eq 3. The Critical Distance

$$\mathbf{c} = \mathbf{v}\,\mathbf{t_p} + \left[\frac{\mathbf{v}^2}{2(\mathbf{a} + \mathbf{Gg})}\right]$$

Fig 1. Vehicle Position in Relation to Yellow Light Change Interval Formula

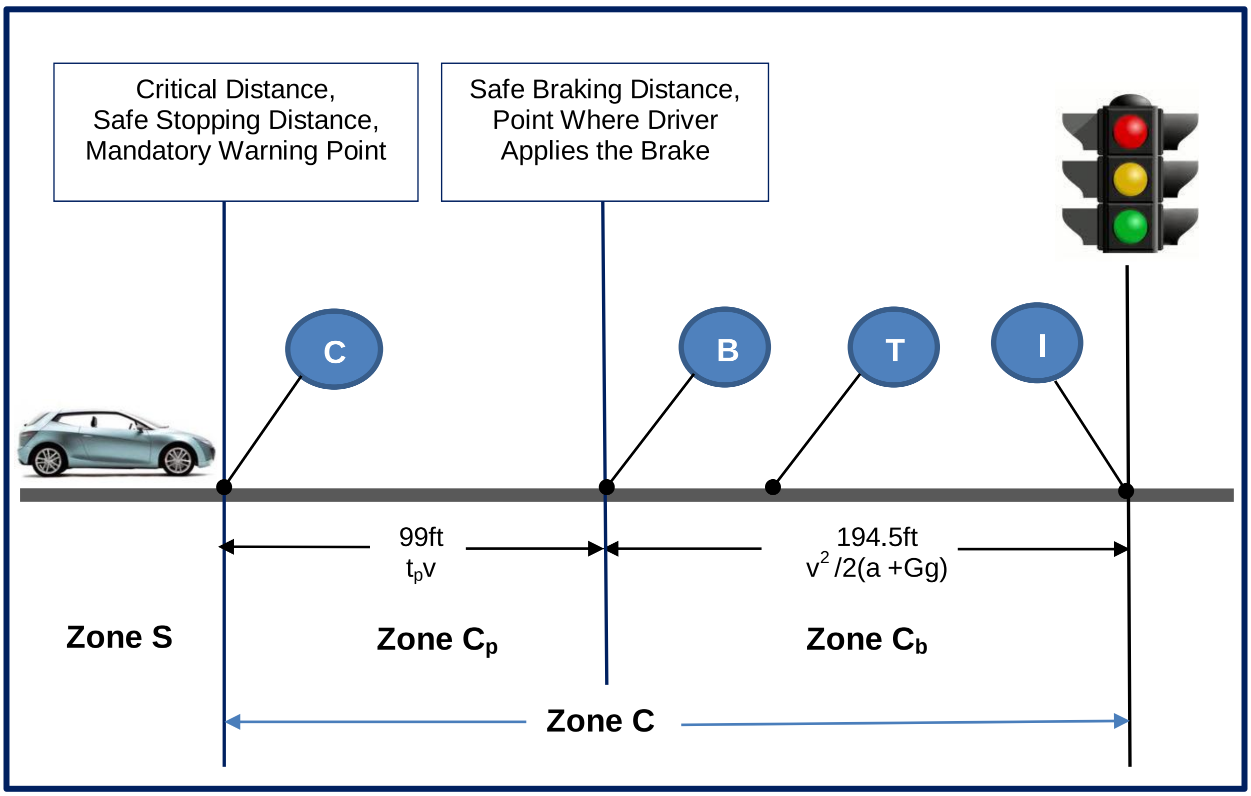

Table 1. Zones Along the Approach

Zone	Description
S	When the light turns yellow, a driver in zone S must come to stop. He has the distance to stop.
C	Zone C is the critical distance.
C_p	Zone C_p is the perception-reaction segment of the critical distance. Consider that the light turned yellow when the vehicle crossed point C. The driver has the distance of zone C_p to perceive the signal change, to decide whether to stop or go, and if stop then move his foot to the brake.
C_b	Zone C_b is the braking segment of the critical distance. Consider that the light turned yellow when the vehicle crossed point C. The Formula assumes that the driver knows the exact location of point B. If the driver decides to stop, his foot must be on the brake by point B and be decelerating at least at rate (a + Gg) in order to stop. The signal will have already changed to red by the time he gets to the intersection. The signal will have been red for $(Y - t_p)/2$ seconds. If the driver decides to go, he must proceed into the intersection at constant rate v. If he proceeds at velocity v, he enters the intersection at the exact moment the light turns red. If he accelerates above v; that is he attempts to beat the light, he gives himself a margin of safety and enters the intersection while the light is still yellow.

Table 2. Points Along the Approach

Point	Description
C	The beginning of the critical distance.
B	If the driver decides to stop, point B is the latest he must apply his brakes. All drivers proceed to point B at the speed limit.
T	For a turning driver only. For a turning driver committed to enter the intersection, point T is the latest location where the driver can apply the brake in order to safely decelerate to a comfortable turn execution speed. The turn execution speed is the same as the intersection entry speed. Point T is closer to the intersection than point B because a turning driver does not decelerate to a stop but rather to about 20 mph. Because the turning driver does not decelerate to the degree as the stopping driver, the turning driver requires less deceleration distance than the stopping driver. The turning driver goes the speed limit v up to point T. When the light turns yellow after the driver crosses point C, straight-thru drivers are equally committed to enter the intersection as turning drivers. Both must proceed because both no longer have the distance to react and stop. The turning driver's foot may or may not be on the brake when the light is green. The only certainty is that the turning driver must apply his brake at point T. The light is not necessarily green at point T. The light may have changed to yellow anywhere between point C and point T.
I	Point I is the intersection entry point.

Table 3. Properties of the Formula

	Property
1	*An unimpeded zone S driver goes the speed limit.* An unimpeded zone S driver has his foot on the accelerator. An unimpeded zone S driver is too far from the intersection to consider braking for any reason.
2	*An unimpeded zone S driver needs at least the Formula time to provide him the distance to stop from the speed limit.* It does not matter what lane the driver is in. It does not matter if he is in the right lane, the middle lane, the left lane or a turn lane. It does not matter whether he intends to go straight, to turn right, to turn left or to U turn. A zone S driver travelling legally at the speed limit requires the full Formula time in order to receive the required distance to stop.
3	*The length of the critical distance is a fixed distance.* For any speed limit, grade of road and perception time, the Formula computes the same critical distance for all approaching vehicles. The length of the critical distance neither depends on the color of the traffic signal nor the location of the driver's foot or the driver's intent to turn.
4	*Once the driver crosses point C and then the light turns yellow, the driver must proceed into the intersection.* The driver no longer has the enough perception-reaction time and braking distance to stop.
5	*Once the driver crosses point C and then the light turns yellow, the yellow light must remain yellow for as long as it takes the driver to traverse zone C and cross over the intersection entry point (point I).*
6	*The Formula comes with the precondition that drivers proceeding into the intersection must travel at the speed limit throughout zone C.*
7	*The Formula comes with the precondition that the drivers proceeding into the intersection must not decelerate for any reason throughout zone C.* Acts of deceleration lengthen the time it takes to traverse zone C. The Formula time does not extend to accommodate deceleration.
8	*v in the Formula is the 85^{th} percentile velocity of free-flowing traffic at the point C.* v >= speed limit.

9	*The Formula always has the potential of creating a type I dilemma zone.* Even when the engineer applies the yellow light duration Formula correctly, any obstacle causing a zone C committed driver to slow down will open the possibility that the driver will be forced to run a red light.
10	*The Formula always creates a type II dilemma zone, also called an indecision zone.* Even when the engineer applies the yellow light duration Formula correctly, the Formula always forces drivers to gamble between stop and go.. The closer the driver is to point C when the light turns yellow, the harder it is for the driver to make the right guess. If a driver guesses the location of point B incorrectly, he will either have to slam on the brakes or accelerate and beat the light. The Formula is responsible for both behaviors.

Assumptions about the Constants

Denos Gazis, the inventor of the Formula, confined his formula to the singular case of an unimpeded driver travelling at a constant speed--the speed limit--through the critical distance[8]. And along with that restriction, Gazis warned traffic engineers that his chosen constants for deceleration and perception-reaction time vary greatly upon human demographic and road situation. Because of the imprecision of these constants, Gazis classified red light runners into two groups: violators and non-violators[9]. Gazis deemed most red light runners as non-violators who are systematically subjected to the imprecise constants. Gazis then instructed traffic engineers “to educate both the driving public and the law-enforcing agencies as to the exact operational definition of the amber light” so that the police would not condemn everybody[10]. That crucial bit of information has been lost in the advent of red light cameras.

We do not examine or elaborate these established constants. However traffic engineers make false assumptions about these constants, namely that their conservative nature compensates for shorting left turn yellows. We do address those false assumptions.

Table 4. Assumptions about the Constants

Constant	Assumption
t_p	The perception-reaction time. ITE sets this value to 1 second. The American Association of State Highway Traffic Officials (AASHTO) recommends 2.5 seconds[11]. Oregon State University recommends 1.5 to 3.0 seconds[12]. Some traffic engineers assume that the driver's foot is already on the brake when the light turns yellow and therefore the driver does not need perception-reaction time. This assumption is false. About ⅓ to ½ of the time the driver's foot is on the accelerator during the critical distance. The signal can turn to yellow any point along the way. Refer to Table 2, Point T.
a	The underlying assumption of the Formula is that a vehicle's brakes can exert a force to decelerate the vehicle at a rate of at least "a". It does not matter if the vehicle is a 10 ton 18 wheeler or a ¾ ton Smart Car. The brakes must be capable of decelerating the vehicle at rate "a". The heavier the vehicle, the stronger the brakes.
	For the deceleration constant, ITE uses 10 ft/s^2. AASHTO uses 11.2 ft/s^2. Some traffic engineers believe 10 ft/s^2 is too conservative. They use that conservative value to justify shorting a turn yellow. Engineers point out that most vehicles can decelerate at 15 ft/s^2. While that is true, is it also true that 15 ft/s^2 is aggressive and uncomfortable. Also people driving behind you are not prepared to stop that quickly and will most likely rear-end you if you try it. The University of Wisconsin did an interesting study[13] on deceleration rates. One of the interesting points is that average deceleration rates significantly vary from one intersection to the next. Among all subject intersections, the University of Wisconsin found that the 15th percentile deceleration rate is about 8 ft/s^2. The 85th percentile is about 12 ft/s^2. It so happens that ITE's value is 10 ft/s^2 – right in the middle. That means that at an average intersection, half the vehicles decelerate slower and half the vehicles decelerate faster than ITE's constant.

Problem Defined

We analyze the motion of drivers who pass point C after which the light turns yellow. We do not concern ourselves with drivers in zone S when the light turns yellow. Drivers in zone S stop. Using the laws of physics, we compute the amount of time a zone C driver needs to traverse the critical distance.

Given that the critical distance is a fixed distance (Table 3/Property 3),

1. We calculate the yellow change interval necessary for drivers to traverse the critical distance.

2. We use the on-the-ground value of the yellow light duration to determine the length and location of the type 1 dilemma zone.

We will use the North Carolina Department of Transportation's (NCDOT) constants for perception/reaction time and deceleration.

$$\mathbf{t_p = 1.5\ s}$$

$$\mathbf{a = 11.2\ ft/s^2}$$

The Problem of the Straight-Thru Movement Short Yellow

Consider a driver approaching the intersection at 45 mph on a level road.

How much time does the driver need to traverse the critical distance at the speed limit? This will be the required yellow light duration for such a driver.

Step	**Equation**
From Eq 1a.	$Y = t_p + \left[\frac{v}{2(a + Gg)}\right]$
Eq 5. **1.47 converts mph to ft/s**	$\left[\frac{5280\ ft/mile}{3600\ s/hr}\right] = 1.47$

Eq 6.	$Y = 1.5 + \left[\frac{45 * 1.47}{2(11.2 + G * 0)}\right]$
Eq 7.	$Y = 1.5 + [3.0]$
Eq 8.	$Y = 4.5\ s$
	The driver needs 4.5 seconds to traverse the critical distance.

How long is the critical distance?   Where is point C?

Step	Equation
From Eq 3.	$c = v\,t_p + \left[\frac{v^2}{2(a + Gg)}\right]$
Eq 9.	$c = 45 * 1.47 * 1.5 + \left[\frac{(45 * 1.47)^2}{2(11.2 + G * 0)}\right]$
Eq 10.	$c = 99 + 195$
Eq 11.	$c = 294\ ft$
	The critical distance is 294 feet long. **Point C is 294 feet from the intersection.** **The driver needs 294 feet to safely stop.**

But the engineer shorted the yellow light change interval to 4.0 seconds. How far can the driver travel in 4.0 seconds?

Step	**Equation**
Eq 12.	**Distance = rate * time**
Eq 13.	Distance = 45 * 1.47 * 4.0 = 265 feet
	The driver can travel 265 feet in 4.0 seconds.

What is the length and location of the type 1 dilemma zone? If the driver is travelling within this zone on the onset yellow, he is forced to run a red light.

The start of the dilemma zone is point C—where the driver no longer can stop safely. The end of the dilemma zone is the farthest point from the intersection the driver can be and still enter the intersection before the light turns red.

Start of Dilemma Zone	294 feet from the intersection
End of Dilemma Zone	265 feet from the intersection
Length of Dilemma Zone	32 feet

The actual yellow light change interval is 3.0 seconds. How far can the driver proceed in 3.0 seconds? What is the size of the dilemma zone?

Step	**Equation**
Eq 12.	**distance = rate * time**
Eq 13.	distance = 45 * 1.47 * 3.0 = 198 feet
	The driver can travel 198 feet in 3.0 seconds.

Start of Dilemma Zone	294 feet from the intersection
End of Dilemma Zone	198 feet from the intersection
Length of Dilemma Zone	96 feet

The act of applying the ITE Formula to turning yellow change intervals is the mathematical equivalent of shorting a yellow duration for straight-thru movement.

The following figure illustrates the problem for the turning driver.

Fig 2. The Critical Distance for a Committed Turning Driver

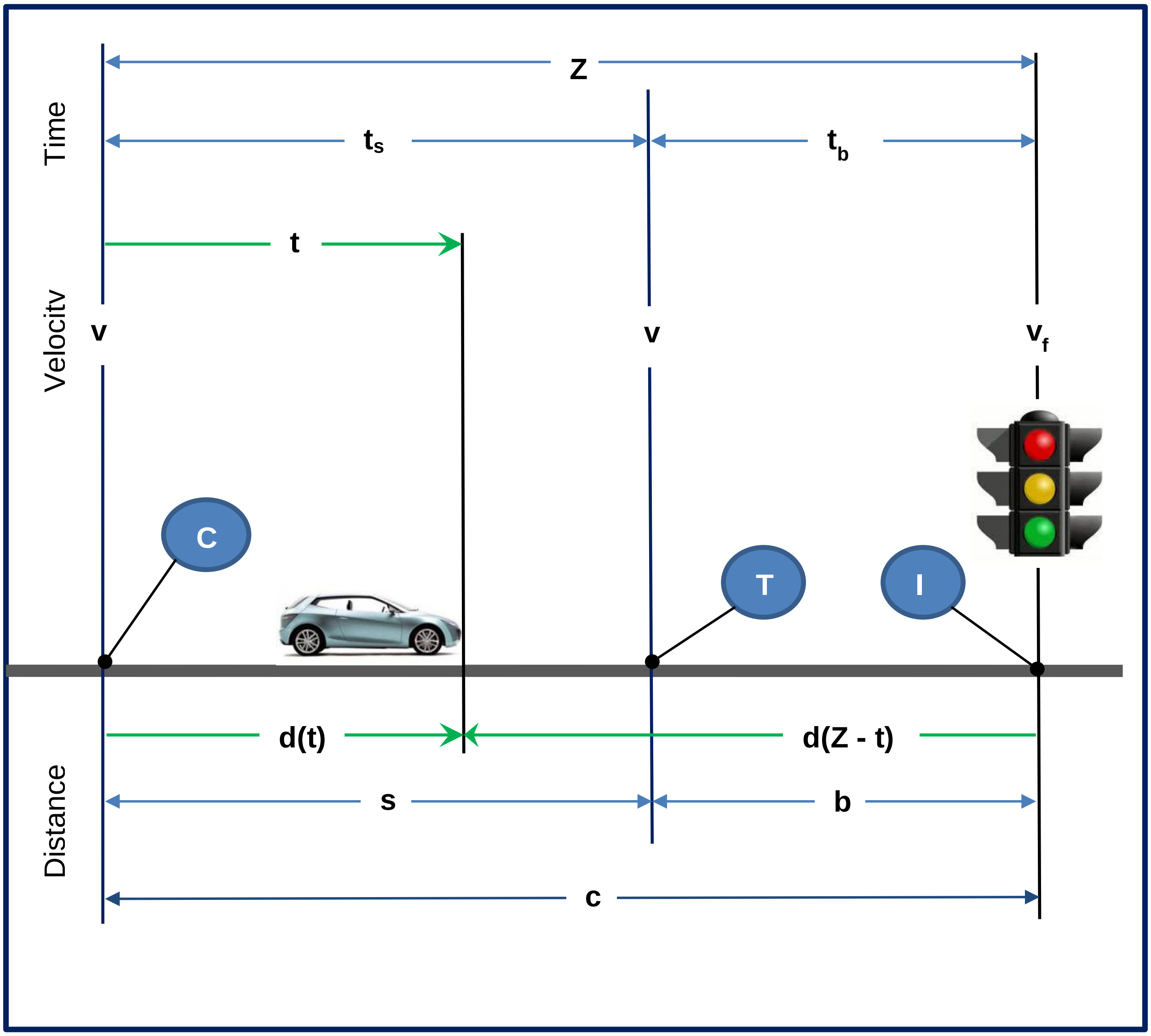

Table 5. Turning Vehicle Equations

Eq	Variable	Description
14	c	The critical distance $$\mathbf{c = v\,t_p + \left[\frac{v^2}{2(a+Gg)}\right]}$$
	v	Initial velocity. The speed limit in this case.
	v_f	The intersection entry velocity.
15	t_b	Time vehicle takes to decelerate from v to v_f at deceleration[14] a: $$\mathbf{t_b = \frac{v - v_f}{a+Gg}}$$
16	b	Distance vehicle travels while decelerating[14]: $$\mathbf{b = \frac{v^2 - v_f^2}{2(a+Gg)}}$$
17	s	Distance vehicle travels until driver applies brake in order to get ready to turn. The distance from point C to point T. $$\mathbf{s = c - b}$$
18	t_s	Time vehicle takes to travel from point C to the point where driver begins to brake. $$\mathbf{t_s = \frac{s}{v}}$$
19	Z	Time it takes vehicle to traverse the critical distance. This is the required yellow light change interval for turning traffic. $$\mathbf{Z = t_s + t_b}$$

	t	Time vehicle has travelled once arriving at point C.
	d(t)	Distance vehicle travels into critical distance in time t. t = 0 when driver crosses point C.
20	d(t) $t \le t_s$	$$\mathbf{d(t) = vt}$$
21	d(t) $t_s < t \le t_b$	Time $(t - t_s)$ has elapsed since driver began braking. What is the distance[9] the vehicle travelled in that time? $$\mathbf{d(t) = s + v(t - t_s) - \frac{1}{2}(a + Gg)(t - t_s)^2}$$
	y	Actual yellow time
	c	Beginning of dilemma zone
21	Z - y	The time it takes the driver to travel from the point C to the end of the dilemma zone.
22	d(Z – y)	The location of the end of the dilemma zone. At this distance from the intersection, a vehicle can proceed and enter the intersection while the light is still yellow.
23	D	Length of dilemma zone. $$\mathbf{D = c - d(Z - y)}$$

Using the equations above, here are computed values[15] for a 45 mph vehicle on a level road.

Table 6. Traversal Times for a Vehicle with Different Intersection Entry Speeds

The vehicle approaches at 45 mph.
The critical distance is 294 feet.
The ITE Formula-computed yellow change interval is 4.5 seconds.
Z is the required yellow change interval.

#	y Actual Yellow Time	V_f Intersection Entry Speed	Z Time To Traverse Critical Distance	Length of Dilemma Zone
1	3.0 s	25 mph	5.0 s	134 ft
2	3.0 s	20 mph	5.4 s	155 ft
3	3.0 s	10 mph	6.2 s	199 ft
4	4.5 s	25 mph	5.0 s	35 ft
5	4.5 s	20 mph	5.4 s	56 ft
6	4.5 s	10 mph	6.2 s	114 ft
7	4.5 s	0 mph	7.4 s	180 ft
8	7.4 s	0 mph	7.4 s	0 ft

Solution

As you can see from Table 6, the only way to remove the dilemma zone is to set the yellow duration to the time it takes a vehicle to stop. (A zero intersection entry speed means the vehicle stops.) The slower a driver enters the intersection, the longer the yellow light must be. A left turning driver at a wide intersection enters the intersection at about 25 mph. But if a driver wants to do a U-turn, the driver practically has to stop. The sharper the turning radius, the slower a driver must go to execute the turn and the longer the yellow light must be. Turning right is no exception. The turning radius of a right turn is between a left turn and a U-turn. Engineers must consider also that protected left phases appear in tandem with cross-traffic protected right phases.

The solution to the entire yellow light problem is simple. It has always been simple. Apply Newton's laws of motion straight up. Equation 24 is a formula drivers can actually obey.

Eq 24. The Solution

$$\mathbf{Y} = \mathbf{t_p} + \frac{\mathbf{v_0}}{\mathbf{a} + \mathbf{Gsin}(\mathbf{tan^{-1}}\,\mathbf{g})}$$

Variable	**Description**
Y	duration of yellow light
$\mathbf{t_p}$	perception + reaction + air-brake time
$\mathbf{v_0}$	85th percentile velocity of freely-flowing traffic measured at $v_0^2/2[a + Gsin(tan^{-1}(g))]$ from the intersection $v_0 \geq$ posted speed limit
a	safe deceleration The value assumes that all vehicles from motorcycles to 18-wheelers have brakes which can exert a force to decelerate the vehicle at rate ***a***.
G	Earth's gravitational constant
g	grade of road (rise over run, negative values are downhill)
$\mathbf{Gsin(tan^{-1}(g))}$	precise expression for the contribution of Earth's gravity towards a vehicle's deceleration on a hill of grade g. When $g < 0.10$, $Gg \approx Gsin(tan^{-1}(g))$.

False Justifications to Short a Turn Yellow Duration

We believe that most traffic engineers misunderstand their own Formula. They assume that the Formula is a sound implementation of physics. Based on that assumption, engineers form reasons rationalizing a short turn yellow. Their reasons do seem intuitive and true, and they would be true had the ITE Formula been real physics. But in the presence of the ITE Formula, intuition and common sense go out the window.

Table 7. False Justifications for Shorting a Turn Yellow

#	Justification
1	The driver is already decelerating when the light is green. Rebuttal: While traversing the critical distance, the driver is not necessarily decelerating and the light is not necessarily green. Engineers may get this false assumption from ITE's *Determining Vehicle Signal Change and Clearance Intervals*[16].
2	Engineers use the average of the speed limit and the intersection entry speed for input into the Formula. ITE recommends this in *Determining Vehicle Signal Change and Clearance Intervals*[16]*.* Rebuttal: But the v in the Formula is the *initial* velocity at the critical distance. Using an average does all the bad things a short yellow does.
2	Engineers *feel* that traffic moves slower in the left lane. Feelings were the reason given by the Town of Cary's traffic engineer, David Spencer, in an deposition in the case *Ceccarelli vs. Town of Cary*[17] to short left turn yellows. Rebuttal: Feelings are arbitrary. The laws of physics are not.
3	The NCDOT applied the ITE NCSITE Task Force's 20–30 mph velocity[18] for the all-red clearance interval to the yellow change interval formula instead. Rebuttal: The speed the all-red clearance interval requires is different than the speed a yellow change interval requires. An all-red clearance interval requires the slowest speed of vehicles while they travel within the intersection. The yellow change interval requires the approach speed. The approach speed is the 85th percentile speed of freely-flowing traffic[19] at the critical

	distance from the intersection. The approach speed must equal or exceed the speed limit.
4	NCDOT traffic engineers got confused by technical writer errors in the NCDOT Signal Design specs[20]. The error implies to traffic engineers all over North Carolina that left-turn intersection entry speeds measured for the purposes of all-red clearance intervals can be applied to yellow change intervals.
5	Traffic engineers consider turning vehicles as vehicles congested in a queue. Engineers use the speed of queued cars as they accelerate toward the intersection[21]. Rebuttal: But using such speeds violates the 85th percentile rule.
7	Traffic engineers systematically sacrifice safety on behalf of traffic capacity. If traffic engineers can squeeze a few more cars through the intersection, even if means forcing cars to run red lights, they will do it[22].
8	At the behest of their bosses and of red light camera companies, traffic engineers reduce the yellow light to 3.0 seconds because the MUTCD spec 4D.26 states that 3.0 seconds is the minimum yellow duration[23]. About 8 years ago in North Carolina, State legislators passed Session Law 2004-141 which takes the focus off of engineering specifications and places it on this MUTCD requirement[24]. The 3 second minimum becomes the legal justification for bad engineering and an avenue of profit for red light camera companies.

Side by side with justifications to short a yellow light, engineers maintain two main arguments against lengthening a yellow light as we suggest:

Table 8. False Arguments Against a Lengthening a Yellow Light

#	Argument
1	If engineers make a yellow light too long, drivers will treat the yellow light as if it is a green light[25]. Rebuttal: What is the problem with running yellow lights?

	Actually, behind the argument are the engineers' expectations of driver behavior under the current engineering standards. The feelings of a long yellow light promoting contrary habits arises from the fact that such habits would be contrary to the bad habits engineers have been teaching drivers for decades. Since before 1965 engineers have conditioned drivers into wrong-thinking. Engineers have been teaching drivers that the yellow light means gamble with the proffered challenge to beat the light. Engineers teach drivers that the yellow means neither stop nor go and that slowing down leads to running a red light. Then engineers teach drivers that running a red light by a second or two is normal. Engineers unfortunately teach law enforcement that all red light running and crashes are the driver's fault even though engineers force drivers to run red lights by design. What should happen is that yellow should give a clear command to the driver. Instead of the current DMV explanation that "yellow means red is coming" which does not tell the driver what to do, yellow should mean slowing down without penalty is always possible.
2	If we make yellow lights longer, we reduce the traffic capacity on the road. It is a capacity versus safety issue. It is cheaper to short a yellow than to add a lane to the roadway. One of the ways traffic engineers increase a roadway's capacity is to reduce the yellow light duration. The more green time in a given signal cycle allows more cars to move. That means more traffic capacity. If we imagined this practice carried out to its conclusion, we would not see yellow lights anymore. Perhaps red lights would even disappear. All that would be left would be green lights and roundabouts.

Conclusion

By setting a yellow duration to a time less than the Formula disables drivers from being able to stop safely from the speed limit.

By setting a yellow duration to a time less than the Formula for unimpeded straight-thru drivers, engineers create a dilemma zone and force drivers to run a red light.

By setting a yellow duration to the Formula, engineers create a dilemma zone for any drivers who must slow down before proceeding into the intersection. Engineers force certain turning drivers, drivers near intersections with nearby business entrances, drivers at intersections with nearby intersections, drivers near railroad tracks, etc., to run red lights.

By setting a yellow duration to a time less than or equal to [(2 x Formula-time) – perception time] for unimpeded turning movement, engineers create a dilemma zone that forces drivers to run a red light.

The solution is to replace the ITE Formula with equation 24 and reeducate drivers. That means undoing 50 years of bad engineering practices and the bad driving habits those practices have induced. The yellow light will now mean, “You can always brake without penalty. The duration of the yellow light equals the time it takes for you to stop. Once you see a light turn yellow and you decide to stop, the light will turn red when you arrive at the intersection. (The old behavior is that the light turns red half way toward your arrival at the intersection.) You now have the time to brake for other vehicles and pedestrians that may interfere with your progression. You may drive defensively.”

Authors

Brian Ceccarelli is a science and engineering software consultant in Cary, North Carolina. Mr. Ceccarelli received a B.S. in physics in 1983 from the University of Arizona. Mr. Ceccarelli is a member of the American Physical Society.

Joseph Shovlin is a research scientist at Cree Labs in Research Triangle Park, North Carolina. Dr. Shovlin received his Ph.D. in physics in 1990 from Ohio University.

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