Missouri Traps
Commercial Truck Drivers

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The State of Missouri forces commercial truck drivers in common scenarios to run red lights. MoDOT uses the ITE yellow change interval formula to set the duration of yellow lights[1] but the constants MoDOT uses for perception-reaction time, air-brake lag time and deceleration do not provide fair warning for the commercial truck driver to stop comfortably and safely. Like most departments of transportation in the United States, MoDOT sets the yellow light durations only to accommodate the average car. MoDOT purposefully does not design the yellow light duration to accommodate semi-tractor trailers, school and public buses or any vehicle with air-brakes.

The constants MoDOT plugs into the yellow change interval formula undercuts those the Commercial Driver's License Manual says truck drivers need. By the laws of physics, MoDOT forces many legally-moving reasonably-perceptive commercial truck drivers to run red lights.

Constant	**MoDOT ITE Yellow Change Interval**	**MoDOT Commercial Drivers License Manual**
Perception-Reaction Time	1.0 s	1.5 s
Air Brake Lag Time	0.0 s	0.4 seconds on a dry pavement
Deceleration Rate	10 ft/s^2	8.4 ft/s^2

Perception-Reaction Time

MoDOT uses 1.0 second for the perception reaction time to set yellow light durations. The MODOT Commercial Driver License Manual[2] requires 1.5 seconds. *Measurements of the commercial vehicle driver's 85th percentile perception-reaction time is 2.13 seconds.*[3]

Air Brake Lag Time

MoDOT uses the ITE Formula but the ITE Formula does not include air brake lag time. According to the MoDOT Commercial Driver License Manual, air-brake lag time is "32 feet at 55 mph on a dry pavement." 55 mph = 81 ft/s. 32 ft / 81 ft/s = 0.4 seconds.[4] Though MoDOT uses 0.4 seconds, 0.4 seconds is extremely aggressive. It usually takes at least twice that amount for air-brakes to fully pressurize.[5]

Deceleration

MoDOT sets yellow light durations with the assumption that all vehicles safely and comfortably decelerate at 10 ft/s^2. But the MODOT Commercial Driver License Manual says that truck drivers cannot decelerate so rapidly. The Manual says 8.4 ft/s^2. The CDL Manual does not explicitly print the deceleration, but we can compute the deceleration by invoking physics on other information given in the Manual. Figure 5.6 in Manual says that a 55 mph truck has 390 ft braking distance. Using the physics equation relating initial velocity, distance and acceleration:

$$a = \frac{v^2}{2d} = \frac{(55 \times 1.47)^2}{2(390)} = 8.4\ ft/s^2$$

MoDOT says truck drivers decelerate at 8.4 ft/s^2. Deceleration is less for transit vehicles. USDOT[7] states that a standing passenger holding an overhead strap will lose balance at 7.4 ft/s^2.

CDL Manual Computation Mistake in Braking Time

The MoDOT CDL Manual makes a serious mistake which can endanger lives. The Manual miscomputes the time it takes a driver to brake. On page 2-14 under the heading **Braking Distance**, the manual says it takes a driver 390 feet to stop from 55

mph and that he do it in 4.5 seconds. That is off by 100%. From physics, the time it takes to stop equals:

$$t = \frac{v}{a} = \frac{(55 \times 1.47)}{8.4} = 9.6\ s$$

It takes 9.6 seconds for a driver to stop his truck.

(The 8.4 ft/s^2 is the decelerate rate from the previous computation.)

Observation

The yellow light duration provides only *half* the time it takes a vehicle to stop. Most drivers and traffic engineers do not realize this. The author of the CDL manual certainly did not. My guess is that the author tried to compute the time to stop but could not believe his result. In his disbelief he lifted his time to stop from some speed/yellow interval table somewhere.

There are three truths to the yellow light:

1. No one can stop within the time the light is yellow.

2. Upon seeing the light turn yellow, there is an invisible line on the highway where the mandate to stop turns into the mandate to go. Judge wrong by an inch and you run the red light. The imprecise judgment necessitated by the use of the ITE formula causes 83% of all red light incursions to occur within 1 second—the bread and butter of the red light camera industry.

3. Upon seeing the light turn yellow and you decide you must go, then the yellow light demands that you must go the speed limit *or more* in order to enter the intersection while the light is still yellow. Though we joke about beating the light, ITE admits that beating the light is an intermittent necessity[6] of the formula. The worst consequence of the yellow light is that it forbids a driver from decelerating (other than to stop) whatsoever. The yellow light does not allow a driver to slow down to turn, to avoid for upcoming hazards or to be cautious for any reason. Most people who run a red light are clocked at speeds 1 – 5 mph under the speed limit.

There is a detailed explanation of the yellow light formula, its history, its application and misapplications in the paper *Misapplied Physics in the International Standards Forces Drivers to Run Red Lights.*[8]

Missouri Actual Yellow Durations and CDL Manual Required Yellow Durations

The follow table shows ITE's typical yellows in contrast with yellows required by commercial vehicles. I computed these values for vehicles on a level highway on dry pavement travelling straight through the intersection approaching and continuing at the constant maximum allowable speed. (Use of the ITE formula is limited to this one special case. Turning and impeded movement require more time.[9])

Speed Limit (mph)	Actual Yellow (seconds)	Truck Driver Required Yellow (seconds)
25	3.0	5.1
30	3.2	5.6
35	3.6	6.1
40	4.0	6.6
45	4.3	7.1
50	4.7	7.6
55	5.1	8.1
60	5.4	8.6
65	5.8	9.1

I used the online interactive spreadsheet at http://redlightrobber.com/red/yellow-time-table/yellow-time-table.htm. I used a 2.2 second perception-reaction time (Gates), a 7.4 ft/s^2 deceleration (USDOT) and a 0.4 second brake lag time (MoDOT). Given the speed limit, grade of road, constants for perception-reaction time and deceleration, and the actual yellow duration, the spreadsheet computes the minimum ITE yellow change interval, braking time, stopping time and the location and length of the type I dilemma zone. A type I dilemma zone is a region on the highway where if you are it when the light turns yellow, the driver will be physically forced to run a red light.

Consider the table below. A truck driver travels at 45 mph on a dry pavement on a level highway. He sees the traffic signal change to yellow. If he is between 462 feet and 284 feet from the intersection, then the State of Missouri will force him to run a red light. He needs 462 feet to stop but he has to be closer than 284 feet from the intersection to proceed legally.

Speed Limit (mph)	Dilemma Zone Start Distance Upstream from Intersection (ft)	Dilemma Zone End Distance Upstream from Intersection (ft)
25	185	106
30	244	141
35	309	189
40	382	235
45	462	284
50	549	348
55	644	411
60	745	475
65	854	553

References

[1] Missouri Department of Transportation, Engineering Policy Guide, **902.5.36.2** (2016).

[2] Missouri Department of Revenue, Missouri Commercial Driver License Manual, **2-14** (2008).

[3] Gates, Dilemma Zone Behavior as a Function of Vehicle Type, Time of Day and Platooning, Transportation Research Board: Journal of Transportation Research Board, No 2149; Transportation Research Board of the National Academies, Washington D.C., **88** (2010).

[4] Missouri Department of Revenue, Missouri Commercial Driver License Manual, **5-14** (2008).

[5] Fawzi Bayan, et. al., Brake Timing Measurements for a Tractor-Semitrailer Under Emgergency Braking, **8** (2009).

[6] Institute of Transportation Engineers, Transportation and Traffic Engineering Handbook, Second Edition, Institute of Transportation Engineers, **759** (1982).

[7] Abernathy, et al., Effects of Deceleration and Rate of Deceleration on Live Seated Human Subjects, **1** (1977).

[8] Brian Ceccarelli, J. Shovlin, Misapplied Physics in the International Standards Forces Drivers to Run Red Lights, (2015).

[9] Brian Ceccarelli, Yellow Change and All-Red Clearance Equations of Physics, (2016).