STATE OF NORTH CAROLINA

COUNTY OF WAKE

IN THE GENERAL COURT OF JUSTICE
SUPERIOR COURT DIVISION
10-CVS-019930

BRIAN CECCARELLI and LORI MILLETTE,

Plaintiffs,

v.

TOWN OF CARY,

Defendant.

AFFIDAVIT OF JOSEPH E. HUMMER, Ph.D., P.E.

I, Joseph E. Hummer, Ph.D., P.E. hereby attest that I am over twenty one years of age and I am competent to testify in the above matter.

1. I am a licensed North Carolina Professional Engineer. Since 1989, I have taught engineering students classes in the principals of traffic engineering. I have taught many classes on how to determine the best yellow time to use at a traffic signal. I am familiar with the standards of practice and generally accepted practices used by traffic engineers in traffic operations, highway safety, and highway design. I am a Member of the Institute of Transportation Engineers.

2. This affidavit is intended to express my opinion as an expert in traffic operations, highway safety, and highway design on two issues pertinent to this case. The first is the derivation of the "ITE formula" for computing the recommended length of a yellow clearance time ("Yellow Time.") The second issue is the harmful effects of using Yellow Times that are much longer than those recommended by the formula.

3. A generally accepted formula for recommended Yellow Time at the end of a traffic signal phase that is taught by traffic engineering professors and is used by practicing traffic engineers appears in the last several editions of the *Traffic Engineering Handbook* published by the Institute of Transportation Engineers (ITE), and will be referred to in the remainder of this document as the "ITE formula." The ITE formula is:

$$Y = t + (v / (2 * a + 2 * G * g)) \qquad \text{(equation 1)}$$

Where Y = recommended Yellow Time in seconds, t = the driver perception and reaction time in seconds, v = the vehicle speed in feet per second, a = the deceleration rate in feet per second-squared, G = grade of the approach expressed as a proportion, and g = acceleration due to gravity in feet per second-squared. Typical values for some of the terms in this formula in standard engineering practice in North Carolina are t = 1.5 seconds, a = 11. 2 feet per second-squared, and g = 32.2 feet per second-squared. To convert from vehicle speed in miles per hour to vehicle speed in feet per second, one needs to multiply by 1.47, so that a speed of 35 mph equals a speed of 35 * 1.47 = 51.4 feet per second.

4. The ITE formula is derived from the standard formula to calculate the distance it takes a vehicle to stop once a hazard appears. That formula appears in all standard highway and traffic engineering textbooks and manuals, including the manual all US highway agencies use to design highways (the *Policy on Geometric Design of Streets and Highways* by the American Association of State Highway and Transportation Officials). The formula, from pages 113 and 114 of the 2004 *Policy*, is:

$$d = 1.47 * V * t + [V^2 / 30 * ((a / g) + G)] \qquad \text{(equation 2)}$$

Where d is the stopping distance in feet, V = the initial speed of the vehicle in mph, and all other terms are as previously defined. In this formula the first term (1.47 * v * t) represents the distance a vehicle moves while the driver is seeing and reacting to the hazard, while the second term, in brackets, represents the distance a vehicle moves while the driver is pressing the brake pedal to bring the vehicle from its initial speed to a halt. Since the $g * 2 / 1.47^2 = 30$, we can substitute that expression into equation 2 to get:

$$d = 1.47 * V * t + [V^2 / (g * 2 / 1.47^2) * ((a / g) + G)] \qquad \text{(equation 3)}$$

Since v in feet per second = V * 1.47, we can substitute this into equation 3 to find:

$$d = v * t + [v^2 / (g * 2) * ((a / g) + G)] \qquad \text{(equation 4)}$$

Simplifying the bottom of the fraction in the second term provides:

$$d = v * t + [v^2 / (2 * (a + (G * g))] \qquad \text{(equation 5)}$$

5. The ITE formula for Yellow Time is designed to eliminate the possibility of a dilemma zone for drivers and vehicles on the approach to the signal that have speeds, perception

and reaction times, and deceleration rates at the values used in the formula. If a driver and vehicle meeting those conditions is further away from the stop bar than the stopping distance in equation 5 when the signal turns yellow, the vehicle will be able to stop before crossing the stop bar. However, we need to insure that a driver and vehicle meeting those conditions that is closer to the stop bar than the stopping distance in equation 5 (does not have enough distance to stop) has enough time to be able to proceed past the stop bar before the signal turns red. The ITE formula turns on this key point: it eliminates the dilemma zone by providing enough Yellow Time for a driver just inside the stopping distance to get past the stop bar legally at its chosen speed. The Yellow Time is therefore equal to the time it takes a vehicle traveling the chosen speed to traverse the stopping distance. Speed is defined as distance divided by time, so rearranging provides:

$$\text{Time} = \text{distance} / \text{speed} \qquad \text{(equation 6)}$$

In this case, the time we are interested in is the Yellow Time (Y in seconds), the distance is the stopping distance, and the speed is v as defined above, so:

$$Y = d / v \qquad \text{(equation 7)}$$

Plugging equation 5 into equation 7 shows:

$$Y = \{v * t + [v^2 / (2 * (a + (G * g))]\} / v \qquad \text{(equation 8)}$$

Simplifying by dividing both terms by v and by multiplying the "2" by both part of the bottom of the second term gives:

$$Y = t + (v / (2 * a + 2 * G * g)) \qquad \text{(equation 9)}$$

Which is exactly equation 1. Thus, we have shown that the ITE formula is derived from the stopping distance formula that has been universal in traffic and highway engineering practice for decades.

6. The ITE formula eliminates a dilemma zone for drivers and vehicles operating at the conditions plugged into the formula, typically $t = 1.5$ seconds, and $a = 11.2$ feet per second-squared as mentioned above for North Carolina. The professional engineering standard speed

typically used in the ITE formula in North Carolina is the speed limit for through movement phases and 20 mph for exclusive left turn phases. It is possible for a driver and vehicle to create a dilemma zone for itself by operating beyond the conditions plugged into the formula. However, that possibility is rare. There is plentiful published literature that the typical values for t and a are at approximately the 95th percentile for drivers and vehicles on the roads today (that is, only 5 percent of so of drivers in this situation have perception and reaction times greater than 1.5 seconds and only 5 percent of so of vehicles in this situation have deceleration rates less than 11.2 feet per second-squared). For the speed parameter, the speed limit is typically set at the 85th percentile speed observed during a speed study, and cannot be lawfully exceeded, so through vehicles should not be traveling faster. For left-turning vehicle speeds, plentiful evidence exists that left turns are made at a typical intersection at a speed of about 15 mph, so an approach speed of 20 mph again covers most drivers. So, the chances that a driver or vehicle on the approach to a signal creates a dilemma zone for itself by exceeding a parameter are low.

7. In addition, drivers almost always compensate for one operating deficiency by changing other conditions—this is a well-known human factors engineering concept called "feedback." Drivers who are struggling to see well at night will typically compensate by slowing down, for example. In the Yellow Time context, drivers who know they cannot decelerate at a sufficient rate will typically slow down, and drivers who are speeding will typically exhibit greater situational awareness and be able to decrease their perception and reaction times. Therefore, for example, drivers who are both too fast and have slow reactions, or are too fast and have poor brakes and tires, are fortunately rare. Dilemma zones are rare due to this compensation or feedback mechanism.

8. Note that the perception and reaction time typically used in the ITE Yellow Time formula in North Carolina is 1.5 seconds. This value is typical in many other states, while some agencies use lower values like 1.0 seconds (and some texts and manuals recommend lower values like 1.0 seconds as well).

9. While it is true that an important highway design manual called the *Policy on Geometric Design of Streets and Highways* by the American Association of State Highway and Transportation Officials (AASHTO), mentioned above, recommends perception reaction times

used for highway design of 2.5 seconds, it is important to realize that the 2.5-second value recommended by AASHTO for highway design has no bearing on the length of Yellow Time. Traffic and transportation engineers universally recognize that the 2.5-second recommendation by AASHTO is for designing highway geometries, such as hill crests, and not for designing clearance times. Drivers have to be able to see far enough over the top of a hill crest to see a hazard on the other side, typically a stopped car, animal, or pedestrian in the lane ahead. This object in the road is a surprise to the driver, and the fact that the stimulus is unexpected means that it takes longer for drivers to perceive the hazard and decide what to do. On the approach to a signal, the stimulus is not a surprise, as the driver should have been able to see the signal for a long distance. It is likely that the driver has looked at the signal several times on the approach, noticed that the green indication has been on for a long time, and would not be surprised by a signal turning yellow. Regular or commuter drivers probably have a good sense for how long the green phase will last at a signal along their route, and drivers can use other clues like a flashing don't walk signal in an adjacent crosswalk to know that the signal is about to turn yellow as well. Thus, the 1.5-second perception and reaction time typically used in North Carolina, while generously high for almost all drivers, is an appropriate value and is generally universally accepted by traffic engineers and falls within the professional standards of engineering practice.

10. The second issue I wished to address in this affidavit is the recognized harmful effects of Yellow Times that are longer than the ITE formula recommends. There are two main causes of that harm: the loss of capacity to move vehicles past the stop bar and the fact that drivers would begin to treat the yellow interval as green eroding respect for the yellow signal.

11. The loss of capacity at an intersection is easy to see and could in turn lead to many harmful symptoms. Intersection capacity will be lost if drivers react just as quickly to a longer yellow as they do to a Yellow Time of standard length. This will create more time during the yellow interval in which nobody is using the intersection. In traffic engineering, the term "lost time" is used to denote the time during each signal cycle when no vehicles are using the intersection, either because a green interval has just come on or because the intersection is clearing during the yellow and all-red intervals. If drivers react to a yellow interval lengthened

by one second in the same way they did to a standard yellow length, the lost time will increase by one second.

12. The effects of an increase in lost time can be large and harmful. For example, at large and busy intersections like those in Cary that are the subject of this suit, there are typically four basic signal phases--left turn green arrow for eastbound and westbound traffic, through and right green ball for eastbound and westbound traffic, left turn green arrow for northbound and southbound traffic, and through and right green ball for northbound and southbound traffic. Typical timing for those phases might be 20 seconds apiece for the left turn phases and 40 seconds apiece for the through and right turn phases, or 120 seconds for an overall cycle length. One second of additional lost time per phase means four seconds of additional lost time per cycle, or that 3.3% more of the cycle is now lost. Making further assumptions that are accepted traffic engineering values typical for the subject intersections, and using the equations from the 2010 *Highway Capacity Manual* (the industry standard for such calculations), it is easy to see that in a peak hour of traffic the additional Yellow Time will add around 10% extra delay to each vehicle that wants to use the intersection. Note that the effects of extra lost time on delay are not linear—a certain percent increase in lost time will result in a larger percent increase in delay in peak times. In the case of an intersection operating near capacity in the peak hour, as most of the intersections in this lawsuit do, that 10% increase in delay will mean around 10 seconds per vehicle of extra delay. As annoying as that is for each driver involved, when viewed at the intersection scale the harm is obvious. At intersections like we are discussing around 5,000 vehicles use the facility in a peak hour. Ten seconds per vehicle in extra delay is the same as 14 hours of wasted time for all—almost the equivalent of two full-time workers wasted in just one peak hour. Extra delay will be accumulated during the other hours of the day as well. Delay of course means wasted fuel consumption, wasted emissions, and a host of other ills.

13. Extra delay also has a safety cost. Collisions increase when drivers encounter the back of an unexpectedly long queue of vehicles. Collisions also increase when drivers jockey for position and make last-minute lane changes trying to minimize their time in a queue. Furthermore, some drivers will change routes to avoid a congested intersection, creating cut-through traffic on surrounding streets with its inherent dangers. As a resident of Kildaire Farms

for ten years, I know firsthand the troubles those neighbors experienced already due to cut-through drivers trying to avoid the congestion at Cary Parkway and Kildaire Farm Road, for example. An increase in Yellow Time at that congested intersection and others like it would only make that problem worse.

14. An increase in Yellow Time leads to a serious loss of intersection capacity if drivers continue to react to the yellow the same way. There is another possibility, which is equally or more harmful, in that drivers will react to the longer yellow differently, using more of it. After a few times through an intersection, drivers will likely gain a sense for the length of the yellow interval. When the consequences of stopping are over a minute of extra delay, and knowing that they can make it past the stop bar during the yellow from even further back more easily than before, many drivers will make the adjustment. Traffic engineers fear the erosion of respect for any traffic control device, especially for the really important ones like yellow signals. Drivers treating yellow as a long green at one or a couple of intersections will come to expect that same at other intersections, and may be surprised with nasty consequences. Also, with a longer Yellow Time, drivers will still have to make a decision on when to begin to stop, but the information available to them to make that decision will be much less clear than with a standard Yellow Time because they will not be able to use the start of the yellow as a basis for that decision. Another possibility is that one driver is following another on an approach to a signal when a longer yellow interval begins; the first driver, not knowing the yellow is longer, will try to stop, while the second driver, knowing the yellow is longer, will be expecting to maintain speed and get through the intersection, resulting in a nasty rear-end conflict between the two vehicles.

15. The main references in the traffic engineering profession are clear on the need to maintain respect for traffic control devices. The 2010 edition of the *Traffic Engineering Handbook* by the ITE, just below its presentation of the "ITE formula" for determining the length of yellow, states, "… a long yellow change interval may encourage drivers to use it as part of the green interval…" The *Manual on Uniform Traffic Control Devices* (MUTCD), from the Federal Highway Administration, is the national legal authority on signs, markings, and signals used in North Carolina and throughout the US. The MUTCD promotes a uniform application of

devices nationwide so that drivers will respect the devices and the maximum safety and efficiency can be achieved on the roads. Page 1 of the 2009 edition provides, as one of the five "basic requirements" of traffic control devices that they should, "command respect from road users." Later, to encourage uniformity, the MUTCD provides the guidance that Yellow Times should be between 3 and 6 seconds. Yellow intervals that are so long that drivers begin to treat them as green erode respect for the signal and could lead to collisions.

16. Finally, as I testified during my deposition, I have reviewed all of the Yellow Times on the official NCDOT Signal Plans of Record that are the subject of Plaintiffs' lawsuit, and they all are in full conformance with the MUTCD, were all designed using generally accepted engineering principles, and all meet the applicable traffic engineering standard of care for designing Yellow Times.

17. Further this affiant says naught.

Joseph H. Hummer, Ph.D., P.E.

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Oakland County, Michigan

Sworn to and subscribed before me this day by Joseph Hummer

Date: December 7th 2012

(Seal).

Notary Public

Tierra Pugh
Notary Public Printed Name

My Commission Expires: 11-19-18

TIERRA PUGH
NOTARY PUBLIC, STATE OF MI
COUNTY OF WAYNE
MY COMMISSION EXPIRES Nov 19, 2018
ACTING IN COUNTY OF Oakland