NORTH CAROLINA — IN THE GENERAL COURT OF JUSTICE

WAKE COUNTY — SUPERIOR COURT DIVISION

BRIAN CECCARELLI and LORI MILLETTE, individually and as class representatives,	)	
Plaintiffs,	)	
v.	)	No. 10-CvS-019930
TOWN OF CARY,	)	
Defendant.	)	

DEPOSITION OF DAREN MARCEAU, P.E.

WEDNESDAY, OCTOBER 31, 2012

Conference Room

Town of Cary Town Hall

316 North Academy Street

Cary, North Carolina

10:00 a.m.

Volume 1 of 1

Pages 1 through 134

A P P E A R A N C E S

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Also Present:

Brian Ceccarelli

T A B L E   O F   C O N T E N T S

T A B L E   O F   C O N T E N T S
(continued)

TABLE OF CONTENTS
(continued)

P R O C E E D I N G S 10:10 a.m.

(This deposition was taken pursuant to the North Carolina Rules of Civil Procedure.)

(Whereupon,

DAREN MARCEAU, P.E.

was called as a witness, duly sworn, and testified as follows:)

D I R E C T E X A M I N A T I O N 10:10 a.m.

By Mr. Stam:

Q My name is Paul Stam. I represent Brian Ceccarelli and Lori Millette. And I understand that you have been designated as an expert witness for the Town of Cary. Is that correct?

A That is correct.

Q And your name and address is what?

A Is Daren Marceau, M-a-r-c-e-a-u, and my office is at 113 Montauk, M-o-n-t-a-u-k, Point Place, Cary, North Carolina 27513.

(Plaintiffs Exhibit 1 was marked for identification.)

Q I place before you what's been marked for identification as Plaintiffs Deposition Exhibit 1, if you would identify that?

A That is my CV.

Q And is it true and accurate?

A It's fairly current. I just printed it, yes.
Q How many years were you a police officer?
A Just a couple years, just a few years with the City of Raleigh.
Q What were your principal duties as a police officer?
A I was a line officer, a street officer. I handled traffic crashes, traffic crash investigations, anything that came up on my beat area.
Q And then your education thereafter was where?
A Well, during and after. I was kind of on the ten year plan for my undergrad degree. I have a bachelor's in civil engineering from North Carolina State University as well as a master's in civil engineering from N.C. State as well.
Q When did you graduate with the master's?
A I came out with my master's in December of '95.
(Plaintiffs Exhibit 2 was marked for identification.)
Q I show you what's been marked for identification as Exhibit 2. See if you can identify that.
(Witness peruses document.)
A This looks like civil engineering curriculum requirements for N.C. State for students entering in the fall of 2010 or later, unless it's changed between now and then.
Q Could you just circle on there the courses that you had either at the bachelor's level or the master's level?

And if it's not the identical name, if it's the same---

Ms. Martineau: (interposing) I guess that's assuming he remembers all the courses that he took.

A I was just going to answer I really don't remember half the courses I took, and I'm laughing because that was a long time ago.

Q Did you take Introduction to Engineering and Problem Solving?

A Not that I recall; I don't recall that ever being offered back in the '80s.

Q Have you had Calculus I?

A Yes. I took several calculus classes, I think I, II, and III actually.

Q Have you had Physics for Engineers and Science?

A No.

Q Have you had physics?

A Yes. I--there was one physics requirement. It was like Physics 20-something, and I actually took a physics elective also as a second class.

Q So you've had two courses in physics?

A Correct.

Q Okay. Have you had Mechanics of Solids?

A Yeah, sure. Yes, I did.

Q Did you take Hydraulics?

A Yes.

Q Differential Equations?
A Yes.
Q Algebra?
A No, I never did, not in college.
Q High school?
A Yes.
Q Okay. Do you use algebra all the time in your work?
A Yes; not much, but some.
Q Electrical Engineering?
A I did take an electrical engineering elective.
Q Is engineering a humanities or a science? How would you describe it?
A I've never been asked that. Engineering is the application of math and physics and science to specific problems, specific cases. And those cases are typically already well wrapped in human factors, which would be part of humanities. So it's really sometimes kind of a chicken and egg thing as far as one day maybe more human factors, humanities if you will, and another day it may be more math and science.
Q Now, by humanities you mean human factors?
A Human factors is one component of it.
Q You don't mean literature or philosophy?
Ms. Martineau: He's out there with Shakespeare books all the time.

The Witness: No.

Ms. Martineau: No?

The Witness: I don't use too much Shakespeare in my engineering work.

By Mr. Stam:

Q Have you read *Battlefield Earth* by Ron Hubbard?

A No, I have not. At the end of the day I don't do too much leisure reading. I'm usually tired from reading other stuff.

Q All right. Did you write a book, *Accident Reconstruction at Traffic Signal Intersections*?

A Yes, I did. Back in 2006 it was published.

(Plaintiffs Exhibit 3 was marked for identification.)

Q All right. I'm going to show you what's been marked for identification as--the title page and--let's keep the actual exhibits at that end (indicating).

A That's fine.

Q You can refer to any of them that you would like.

A I'm used to attorneys wanting them back. I get them out of order and make everybody mad.

Q These are the pages I think may be somewhat relevant for this case, but if you--I have the entire book here. And at the end of my discussion of your book, if you think there are other parts of the book that are relevant, please feel free to refer to it. I have it here if you need it.

A Sure.

Q Are the copies that are attached to page (sic) 3 true and accurate copies of excerpts from your book?

A They appear to be. I actually don't dig through my own book all that often.

Q Do you have your students dig through your book?

A Yes. I don't force them to buy it, but I encourage them to.

Q What is the yellow--referring to page 70 but also anything else you want to refer to, what is the yellow change interval?

A Well, let's see what I wrote here. It's been quite a while since I read this.

(Witness peruses document.)

It says yellow change interval is "expected to mean a driver needs to slow down and prepare to stop before the red signal." It takes into consideration certain parameters, like grade and deceleration and perception/reaction time. Going downhill we see longer yellows.

Some agencies calculate and publish them in a table. Some agencies use flat rates, provide a consistent message to drivers. Other agencies calculate every single one. It's critical for crash investigators to understand yellows. You need to consult your local traffic engineer to find out what yellows were in use.

Q Was this book written for students who were going to look at crash investigations? Is that the principal purpose of this book?

A Correct. My intended audience was mostly police officers. The intent here is to--is not to educate police officers on how we get yellows and really what they're used for, but to tell them there may be--when I'm teaching--I'll back up here a second.

When I'm teaching a class in Houston, for example, I may have engineers from all around the country attending that conference. We'll have people from Oregon, from British Columbia, from New York, Florida, and in their jurisdictions the calculations may be different.

So the intent was to tell these students there's a million different ways to skin the cat, but there's going to be a yellow time in use at that intersection and you need to go get that and use it in your investigation.

Q Well, laws change from jurisdiction to jurisdiction, I suppose.

Ms. Martineau: What laws?

Q All laws, including traffic laws; is that correct?

Ms. Martineau: Are you asking him if traffic laws are different in each state?

Mr. Stam: Yes.

Ms. Martineau: Okay.
A They may be. The standard practice for calculating yellow is in use at that time and place. You know, the accepted practice in Raleigh may be different than the accepted practice in Houston and British Columbia. It's not really--the police officers who are my students or sometimes the engineers who are my students don't really need to know that or understand that, except that they find a difference.
When I have students in class I usually tell them to bring some sample traffic signal plans from their jurisdiction. And if we have two guys at a table next to each other they may see differences. I try to ease the level of questions I get.
Q Right. Do the laws of motion that you learned at N.C. State when you studied physics vary from jurisdiction to jurisdiction?
A Not unless our legislators repeal the laws. They're not going to change.
Q Can legislators repeal the laws of physics?
A No, sir.
Q So you agree that the laws of motion do not vary from place to place. Do human factors vary from jurisdiction to jurisdiction?
A I've never been asked that.
Q Just within the United States; I'm not referring to

South Sudan or Belarus.

A As a general rule of thumb I would say no. I think if we look under a bell curve of for example reaction times we would get when a driver is in a situation, we're going to see except for some subtle changes pretty much the same thing.

Q All right. And I will be asking about perception/ reaction time in detail. Just generally, you would say that that would not vary depending upon what city or state you're in within the continental United States?

A It actually can. As an example, I would expect drivers in Chicago to be more urbanized, a little quicker on the brake, a little quicker on the gas, and they might actually do things a little bit faster than a driver in central Wyoming, just as an example.

Q Would a driver in downtown Chicago have generally the same human factors as a driver in downtown Atlanta? My question is, is it because they're in different states that human factors change or is it because they're in a different driving environment?

A The driving environment. It has nothing to do with the actual geographic location that I'm aware of. It's just the driving environment.

Q All right. And I'll come back to perception/reaction. If you would look on page 70, the second sentence under Yellow Interval Timing that you read?

A Where it starts out with "Specific"?
Q Correct. You did read that to us, I think.
A Yes.
Q In addition to yellow meaning--expected to mean that a driver needs to slow down and prepare to stop before the red signal, does a yellow mean anything else?
Ms. Martineau: I'm going to object to that. I don't think he said that's what the definition of yellow---
Mr. Stam: (interposing) All right. I'll back up.
Ms. Martineau: ---change interval is---
Mr. Stam: (interposing) All right. I'll back up.
Ms. Martineau: ---but go ahead.
By Mr. Stam:
Q Would you read that second sentence again for the record?
A Sure. I kind of just paraphrased it the first time. The second sentence says, "Specific guidelines usually exist in each jurisdiction for calculating yellow times since yellow is usually expected to mean a driver needs to slow down and prepare to stop before the red signal."
Q All right. If that's what it usually means, at other times what is it expected to mean? Is there another answer other than what you say it's usually expected to mean?

A I think I know what you're after. If I was writing this book for a group of traffic engineers, I would quote the meaning out of the MUTCD. The intended audience here are police officers who are investigating crashes.

If I went into a group of police officers and I try to explain to them what the real engineering meaning of a yellow signal is--which they don't need to know anyway; it's not in their field of work--it would be like Christopher Columbus trying to explain to the queen that the earth is really round. It doesn't work. And so I word it in a way that's going to meet their expectations, so to speak.

Q How would you explain it to the presiding judge in this trial?

A I would explain to him that the intent and purpose of a yellow signal is to warn drivers that the green just ended and a red is approaching and they need to make a decision.

Q A decision about what?

A To go or to stop.

Q Okay. And if you go, should you slow down and prepare to stop?

A Say that again?

Q If you've decided to go through the intersection, should you slow down as you approach the intersection?

A Well, if you've made a decision to go, I would hope you're not slowing down after you make the decision. I mean that sounds--that's kind of intuitive.

Q Right. Does the yellow change interval give you sufficient--is it intended to give you sufficient time to perceive the situation, react to it, and effectuate your decision?

A No.

Q What is it intended to do? What is the length of the yellow change interval designed to do?

A It is intended to give you time to perceive and react, make a decision. That's part of the perception/reaction. There are four components and one of them is making a decision, and then to continue on if your wish is to--if your decision and desire is to go ahead and continue on.

Q Anything else?

A No.

Q The second paragraph, if you would take a look at that for just a second?

(Witness peruses document.)

A Okay.

Q 11 feet per second for normal deceleration. I'm assuming that that's just shorthand for police officers. What it actually is---

A (interposing) Per second squared.

Q Per second squared, okay. We agree on that.

A There's a couple typos in the book and I've never written an addendum to it.

Q So that would be a typo. That should be second squared?

A Right.

Q Okay. Would you agree that that's a standard in the trade, profession, industry of what a normal deceleration rate would be?

Ms. Martineau: Well, it says "a normal deceleration rate of about."

A About 11 feet per second is in the range of normal rates that I see used around the country.

Q Okay. Obviously in an emergency a driver can decelerate more rapidly; is that correct?

A Given that the allowable friction is there, there is not ice or something, or even on a seriously wet road, they can use a much higher deceleration.

Q What is the--now, we're not analyzing a crash right now. We're analyzing the yellow change interval. What would be the problem with using a much higher deceleration rate for calculating the yellow change interval?

A This comes back to a question you asked earlier about engineering being comprised of science versus--I said human factors. You said humanities. It would be nice for an engineer to use a number like 20 feet per second.

Q Squared?

A Squared, yes; I---
Q (interposing) That's all right.
A I apologize.
Q Go ahead.
A I'm keeping it simple. But we also have to look at what people are comfortable with. And somewhere between maybe 10 to 15, 16, 17, no higher than that, is about what people seem to be comfortable with at different speeds. It's in a range of what humans--if you just let them go decelerate what they're going to do.
Q And if a driver ahead--let's say Driver A is ahead of Driver B and Driver A decelerates much more rapidly than Driver B feels comfortable about decelerating. What's going to happen?
A You mean like one is following the other? They're colinear?
Q Correct.
A And they're both traveling at the same speed?
Q Right, to start with.
A Depending on the headway between them, there could be a rear-end crash.
Q Okay. The second item in here, you say about 1.5 seconds for driver perception/reaction time; is that right?
A Yes.
Q Where did you get that, about 1.5 seconds?

A At the time that I was writing this back in late 2005-2006, I was seeing values typically about 1 second being used around the country for the most part. NCDOT was moving towards 1.5 seconds.

Now, I'll change gears a little and talk about crash reconstruction. In the crash reconstruction world, there's a magic perception/reaction number that's used almost universally of 1.5 seconds. They're not related to traffic signals, but just related to a driver's known response to a known stimulus, in other words seeing a stop sign. And my intended audience here is a bunch of cops and engineers doing crash reconstruction work. There again, I'm not going to try to---

Q (interposing) And traffic enforcement---

A ---reinvent the world.

Q ---work too; is that correct? Well, I don't know. I shouldn't have interrupted you.

A No, that's fine. Well, many of the officers who do reconstruction work are on what we call a traffic team, and if they're not running radar, they're doing investigations. But these guys are used to seeing 1.5 seconds in everything they do. And there again, I'm trying to drive home two or three important points. I'm not trying to make them reinvent the world.

It's easier to use that value, and that value is within an acceptable range for perception/reaction that people were starting to use in '05 and '06 in the ITE calculation.

Q Is that the--let me--it's sort of a multiple choice question.

Ms. Martineau: You know I don't like your multiple choice questions.

Mr. Stam: I know.

Q But the last choice could be something else other than what I've presented. Is 1.5 seconds perception/reaction time the mean, average, for drivers, the median average for drivers, one standard deviation from the mean, average, the 85th percentile, the 95th percentile, or is that 100 percent of drivers normally react within--perceive and react within 1.5 seconds, or something else?

Now, I've presented it as multiple choice because I just want your true answer of all of the above or none of the above or some combination of the two.

A You're going to hate my answer: their response to what stimuli or what expected response? As I discussed earlier, in crash reconstruction 1.5 seconds typically is a good starting point for known stimulus, known response.

A driver is driving along in a test situation and a red light pops up on the dashboard and they have to slam on their brakes, someone like that, or they see a stop sign and they slam on their brakes. It's been tested about 23 million times and we see it, but your question didn't tell me what response.

You asked me what would be a typical time, is it the median 1 percent, whatever. To what response? I mean to what stimulus? I'm sorry for being---

Q (interposing) All right. Let me reask my question. If you tested a statistically significant number of drivers--I don't know how many that would be. I know polling. I don't know drivers. But we would test 1,050 voters if we wanted to get a really statistically significant number. You may want to test 20,000. I don't know, whatever that number is.

If you took all of your subjects to an identical situation on the road, hazards, traffic, et cetera, an identical situation, would you come up--is the 1.5 figure the average, mean, or median or is it one standard deviation above the mean, two standard deviations, the 85th percentile, the 95th percentile? What is it?

Ms. Martineau: What's the stimulus, though, that you want him to---

Q (interposing) What I said was for every driver an identical stimulus, whatever you say it is, but the stimulus you're talking about for traffic that you're measuring and you come up with 1.5, identical. Where does--what are you measuring when you say 1.5?

A It's impossible to answer your question as asked because the perception/reaction time is going to vary based on the stimulus and based on what the possible responses could be.

The only--in crash reconstruction work the most common thing we're looking at is all of a sudden Driver A sees Driver B run a stop sign. How long did it take the nonoffending driver to do something? How long did it take them to swerve and hit their brakes, as we would expect a reasonable evasive response to be? Those are the kind of situations we look at.

Now, I do get involved in a lot of work that involves other things, like perception/reaction in a work zone, at night, to an unknown sign or a pavement marking or something like that. We use a wide range of perception/reaction times there, and we have to build it based on the circumstances.

Q Let me---

A (interposing) And I'm sorry for the---

Q (interposing) No, no.

A There's no way to answer exactly what you asked.

Q Mr. Marceau, you're doing a great job of answering. I really appreciate it. I'm understanding exactly what you're saying, and that means you're answering. My question may not have been precise enough.

The same question but with this change, and that is a driver is coming up upon a signal light. The driver knows that there is a signal light ahead but doesn't know when the yellow will occur, multi-lanes both sides, you know, four lanes each way let's just say, businesses at every corner, possibly people coming out. That's the road situation.

A Okay.

Q Now, the human factor is you have a wide variety of drivers, from the Richard Petty race car driver--although he did hit somebody on I-85 one time when he was running for election.

A He had a flashback. He thought he was racing.

Q Right, but you have the race car driver, who presumably is on top of the game. You have the little old man who's 85, a little slow on his reactions, and everything in between. You know what the stimulus is, zero grade, clear weather, da, da, da, da, da. It's not raining. So my question is the same question.

When you say 1.5 seconds perception/reaction, are you measuring the average, mean or median, standard deviation, above or below? I've seen a reference to 85th percentile in some of the literature. I've seen a reference to 95th percentile. Do you know what you're measuring when you say 1.5 seconds perception/reaction time?

A I have no idea.

Q Okay. If you will turn to page 71 and 72 and just briefly peruse that because I'm going to ask you a little bit about red interval timing?
A Do you want me to read it word for word?
Q No, no, no. Read it to yourself and then I'm going to ask you some questions about it.
A Okay.
(Witness peruses document.)
I remember writing this a long time ago.
(Witness peruses document.)
Okay.
Q Are you done reading that section?
A Section 4.4, the red interval?
Q Yes.
A Sure. I took a look at it.
Q All right. Explain to the judge what the red interval is.
A The red interval is intended to clear the cars through the intersection.
Q And why do you need a red interval?
A It is one of the factors of safety that we design into traffic signals to help avoid crashes.
Q Does it depend upon--I mean how is it calculated? And I don't mean the exact precise terms. But it's legal to enter an intersection when a light is yellow; is that

correct?
A Correct.
Q A car could be moving just into the intersection with the opposing traffic waiting there. If a vehicle from the opposing lane of travel enters while the other vehicle has not cleared, you might have a crash.
A You likely would have a crash.
Q Right. So how do you measure how long the red clearance interval should be?
A There have been different iterations of the exact formula over the years. But in general, some variation of the width of the intersection divided by speed is going to give you the time it takes to cross through.
Q And what speed do they use?
A Typically the same approach speed that's used for the yellow calculation.
Q Now, when you say approach speed, the car going through presumably is at the--what do you use, the speed limit?
A The speed limit is used unless there's been a speed study done.
Ms. Martineau: Are we talking about through or left-hand turns?
Mr. Stam: We're talking about through traffic right now.

Ms. Martineau: Okay.

Mr. Stam: We're giving that car enough time to get through.

By Mr. Stam:

Q So you're saying use the approach speed, which would be the speed limit, times the distance of the intersection; is that correct?

A No. We're considering the width of the intersection plus or minus length of car and pedestrian consideration. But generally the width of the intersection divided by the speed is going to give us a time for a car to make it through that intersection.

Q What's--is it Greenfields' rule or law or Greenshield?

A Greenshields.

Q Yeah. Explain Greenshields.

A Greenshields deals with green signal time. There's no pun intended on his name, but it deals with green signal time.

Q And is that related to how fast it takes for a queue to start up?

A Yes, exactly.

Q All right. So in the example I gave--do you mind if I use this board right here?

A It's not mine. Help yourself.

Q I just want to make sure we're talking about the same thing. So straight through, Vehicle A is entering the intersection (indicating).

A Okay.

Q Vehicle B is sitting here (indicating).

A Correct.

Q And so what is--I'm sorry. Is it Greenshields?

A Greenshields.

Q What is Greenshields' law about, how fast they get going?

Ms. Martineau: Who's "they," B?

Mr. Stam: The cars in B, C, D, in that queue.

Ms. Martineau: Okay.

A What Greenshields' law is used for--and it's actually still used today by many agencies whether they know they're using it or not. It's looking--it used to look at how much green time do we need to get a column of vehicles moving. In other words, if you expect four cars to queue up, how much green time would you want to give to that green signal to get those cars started up and moving?

In crash reconstruction work we don't use that. I use it in my teaching to explain to people that there's a start- up time. Greenshields' formula takes into account that the first vehicle has to get rolling and move out and the subsequent vehicles are typically going to roll out a little faster.

Q All right. My only question is going to be on the first vehicle. How long does it take the first vehicle to roll out under Greenshields' formula?

A Four seconds.

Q Four seconds, okay. So that if A is proceeding through and it's going to take B four seconds to get wound up and proceed, there's some lag time, is there not, in here?

A I like that term, "get wound up and proceed." I've never used that, but yes, you're right. There is lag time, exactly.

Q All right. But what happens if B is not in the queue but B is back here at the speed limit (indicating) and is just anticipating when the light's going to change? Can you rely on that lag time then, because if B is at let's say 45 miles an hour here (indicating) and A is at 45 miles an hour proceeding through, is that what the all-red clearance formula is designed to---

Ms. Martineau: (interposing) When you say "that," what do you mean by "that"?

Q That situation.

A A long time ago---

Ms. Martineau: (interposing) Objection to the form of the question. Go ahead.

Q Is that what that situation is designed--the all-red clearance formula is designed to obviate or ameliorate or avoid or whatever?

Ms. Martineau: Objection. Go ahead.

A The all-red clearance is intended to clear the proceeding continuing car through the intersection to add a factor of safety before opposing traffic is given a green signal, right of way transfer to opposing traffic. We could look at that red clearance in a number of situations, that being just one of them.

Q Okay.

A A number of years ago someone asked me about a similar situation. It might have been 35 and 35. It doesn't matter. But, you know, if a car is in position exactly correctly--and I remember stepping through it with that student and showing them how I was not concerned about it happening.

It was--the traffic signal was at the I-40 exit next to the Home Depot just outside of Asheville. I remember it. It was an interstate ramp, and they were concerned that the crash had occurred because there was a problem with the signal.

And I walked him through it and showed him why it was physically impossible and it wasn't going to happen unless you had a driver that was coming in--Driver B was coming in so hot that they would have ended up sliding out into the intersection by the time they tried to get stopped and everything anyway. The crash didn't happen that way. The driver just blew the red light.

Going back to your original question, I think, is the red interval designed just for that situation, no. It's designed for general safety and many sorts of questions.

Q Okay. But going back to this situation, in determining the all-red clearance interval, it's the approach speed, the speed limit of the car that is already in the intersection. Is that what is used for the v in that part of the equation?

Ms. Martineau: I'm going to object to the form of the question.

A For through traffic we're using the approach speed to calculate the yellow and the red for the same car, for the yellow and then their continuing red. It's--maybe I missed the point of your question.

Q Well, are we using the approach speed for both---

Ms. Martineau: (interposing) When you say "we," do you mean traffic engineers in general? Do you mean North Carolina traffic engineers? Do you mean ITE traffic engineers?

By Mr. Stam:

Q Mr. Marceau, in determining the appropriate yellow change interval and the appropriate all-red interval, should an engineer use the approach speed for through traffic for both the yellow change interval and the red change interval?

A Yeah. Current practice is to use one speed limit in the formula.

Q Okay, one speed limit in the formula.

A We're using the same speed for both calculations. We're not changing the speed.

Q Thank you. Okay. If you would turn to page 77, and it goes over to 78?

(Witness complies.)

Q If you would take a minute to peruse Section 5.2, titled Dilemma Zones?

(Witness peruses document.)

Ms. Martineau: While he's perusing and--off the record.

The Reporter: Off the record. 10:47 a.m.

(Discussion off the record.)

The Reporter: On the record. 10:48 a.m.

The Witness: I remember this.

By Mr. Stam:

Q What is the dilemma zone?

A A dilemma zone is a region or an area--in traffic engineering terms, a dilemma zone is a range or an area upstream from a traffic signal, in advance of a traffic signal, before a driver would get to it, where a driver may have a concern--may have a problem making a decision, do I go or do I stop, when he sees a yellow signal.

Q Now, imagine a driver who's driven every day for 40 years, in the prime of life, never had a ticket in her life, and you compare that with a 16 year old who just finished driver's ed. They are two different drivers, and one will have more dilemmas than the other.

My question is does the driver with 40 years of experience driving every day--how long have you been a driver? Then I'll break up my question that way.

A I started driving when I was 16. I'm 51, so quite a long time, 35 years?

Q 35 years. So let's take you, Mr. Marceau. Are there dilemma zones that even affect a driver like yourself, not an inexperienced driver, but an experienced, good driver who's alert?

A Dilemma zones are not related to a certain age or driving experience. They're just there.

Q All right. And what causes--let me back up. Have you read Gazis' article, "The Problem of the Amber Signal Light in Traffic Flow"?

A Yes, I have.

Q You have read it?

A Yes.

Q And you've heard the discussion of dilemma zones?

A Yes.

Q What causes a dilemma zone within the context of traffic signals and yellow change intervals?

A Well, as I stated earlier when you first asked me about dilemma zones, a dilemma zone is simply a region that traffic engineers have defined as a region where drivers may have trouble making a decision do I go or do I stop when presented with a yellow signal.

Q And is that zone such that not only they have trouble making a decision, but in fact there is no solution to the problem if they decelerate at the rate assumed by your paper, DOT, and if they perceive and react in the time assumed by DOT for whatever purpose the average driver may be in but within that time? Are there zones to which there is no solution?

Ms. Martineau: Can I object to the form of the question?

Mr. Stam: Yes, please.

Q But you understand you go ahead and answer although she's objected.

A Yes.

Ms. Martineau: He's not saying whether or not that car is stopping or going through.

Mr. Stam: Correct.

A Good question. Yellow times are calculated from a specific point in time, not an entire zone. We can come back to that in a moment. The dilemma zones that are presented--

these were actually taken from an NCDOT publication--or a reference sheet I had. Excuse me. I wish I had pulled it out of my file and brought it for you. I mean not my file on this case, but my old file of stuff from way back when.

NCDOT got these from a professor down at Georgia Tech named Dr. Peter Parsonson. I heard he might have died a year or two ago. I'm not sure. Dr. Parsonson was an older professor. He was a great guy.

And Dr. Parsonson, through observations at inter-sections, had put together this chart. It was like in the '90s. I remember I had a fax from Lisa Moon. She sent me this chart. I don't know if you guys know Lisa.

Q Yes.

A I've known Lisa for about 20 years. And she sent me this chart---

Q (interposing) Are you talking about the chart on page 78?

A Yes, yes, as a matter of fact. I mean I've seen it in other sources. But I remember Lisa and I were having a discussion in the days before probably e-mail. We were faxing. And I just---

Q (interposing) You are old, then.

A Yeah, I know, but I just remembered that. But this chart refers to the dilemma zones that Dr. Parsonson and his grad students observed through their own observations--and I don't recall how they did their study. But they stood out in traffic and they watched where they thought people were having trouble and they made note of these distances. I can picture it.

It's a chart of all kinds of distances at different speeds. He drew like a cloud shape and said in general this is kind of the area. NCDOT used to have a very good relationship with Georgia Tech's traffic engineering program, and they used and borrowed that information to create this chart. And I was using it as a reference, trying to help the police officers understand what I was talking about.

Q Do you think you still have that chart?

A Oh, I know I do. I know I do.

Q I wonder if you could look in your file---

A (interposing) It's an ancient NCDOT sheet. It's like 1990-something.

Q All right. I'm going to ask you if you could find that chart and---

Ms. Martineau: (interposing) You can ask me.

Q I'm asking you through the lawyer for Cary if you could find that chart and get it to us.

A I'll be glad to.

Q I would appreciate that. I'd learn something. Do you or do you not know what causes dilemma zones having read the chart, read Gazis, and your own observations?

A My understanding as a traffic engineer has always been that it is an area where people seem to have trouble making a decision. When you give people a decision to make, you're going to get slightly different responses from different drivers, and that's why---
Q (interposing) Even experienced drivers?
A Absolutely.
Q Right.
A Like I said, making a correct decision hopefully gets better as we improve in our driving experience. That's why we have a graduated driver licensing program in this state and in many other states. But this area can still exist out there if we're looking at a range of drivers.
And I don't know that I ever learned how--I don't think--I mean I've talked to Dr. Parsonson many times. I don't think I ever asked him, "How did you guys go out and measure this stuff in the '60s or whenever you were doing it?"
Q But even the most experienced driver can be in that dilemma zone; is that not correct?
A The intent is to--the intent is to not have a dilemma zone through several design parameters, not just yellow lights, the yellow light timing. There's a bunch of other stuff at play at an intersection. We're trying to remove the possibility of someone having to make--having to be

uncomfortable about making decisions. They have to make decisions, but we want to remove the uncomfortableness, if you will.

Q Do you know what creates the necessity for making a decision between stop and go in the first place?

Ms. Martineau: Why people have to make a decision between stop and go?

Q Why people would have to make a decision between stop and go in the context of a yellow change interval?

A It's a result of us using technology. Back in the original days, we had police officers that directed traffic, and being an ex-cop I can testify about this. When a police officer stands out in the middle of Wake Forest Road in Raleigh directing traffic, they have two signals. We have stop, where you hold your hand up, and we have go, where you wave your hand.

They also have what we might call a you don't have to stop. The officer, as I was trained to do--watch an officer directing traffic. They will look about four or five cars back and they'll point at a driver and get their attention and go, "You get ready to stop," and they'll bring the other cars on. That's the way they transfer right of way.

When we started using electrical and mechanical devices, traffic signals, to direct traffic in place of police officers, we removed that. We removed the officer making a decision and telling people what to do and we had to transfer that decision making over to the human driver, and that's why people have to make a decision.

Q If you would turn to page 104 and 105 in the excerpt, and take a minute to remind yourself? And for the record it is Section 8.3, Red Light Running Cameras.

(Witness peruses document.)

A Okay. I took a look at it.

Q The very first sentence says, "It is undeniable that red light running contributes to intersection crashes." Does yellow light running contribute to intersection crashes? Does a person entering an intersection on a yellow light contribute to intersection crashes?

A I've never heard of one. I'm trying to remember where I took that photo. I'm sure it's in Cary. I just can't remember where.

Q On page 105?

A On 104.

Q Page 104.

A Or either one of them, for that matter.

Q All right.

A That is Maynard at Chapel Hill Road.

Q On page 104 or 105?

A Both of these. I mean the intersection has changed a lot since those days, but I'm pretty sure that's where it is.

Anyway, it's a moot point.

Q Are you familiar that around 2004, '05, '06 DOT changed the way it calculated yellow change intervals?

A Yes. It was an NCDOT ITE task force that looked at how yellow intervals--yellow and red, actually both--were being calculated in North Carolina. I was asked to be on that task force. I was already on another one, so I didn't serve on both.

Mr. Stam: Are we are at Exhibit 4?

The Reporter: Yes, sir.

(Plaintiffs Exhibits 4-7 were marked for identification.)

Q I'm going to hand you what's been marked for identification as Exhibits--I think I'll give you 4, 5, 6 and 7 together.

Ms. Martineau: While he's looking at those, can we take a brief break?

Mr. Stam: Sure.

The Reporter: Off the record. 11:01 a.m.

(A brief recess was taken.)

The Reporter: On the record. 11:19 a.m.

The Witness: Okay. I took a quick look at everything.

By Mr. Stam:

Q All right. And Exhibits 4 through 7, I understand you just saw them for the first time this morning. Is that correct?

A No. I actually--I saw these--I received at least what I think are 4, 5, and 6 of the e-mail chains from Town Council from Elizabeth late yesterday, but I didn't look at them.

Q Very recently?

A Yes.

Ms. Martineau: And also just for the record, these are not e-mails that Mr. Marceau was copied on or---

Mr. Stam: (interposing) I'm going to ask him about that.

Ms. Martineau: And of course he can't be a mind reader.

By Mr. Stam:

Q You first saw them yesterday?

Ms. Martineau: Some of them.

Q Some of them?

A Right.

Q Was that 4, 5, 6, and 7?

A I didn't even look at them. I was handed them and I promised to review them and I never did.

Q And I'm just going to ask--because you're a designated expert for the Town of Cary and this is some correspondence between the town traffic engineer for Cary, I just want to ask if you can read his mind.

Ms. Martineau: Are you a mind reader?

A No. You know, the tuner on the crystal ball is not working.

Q All right. Look at Exhibit 4 there, the first and second sentence. He's faced with a proposal apparently, writing to Pamela Alexander at DOT, that on Harrison Avenue with a 45 mile an hour speed limit somebody is talking about reducing the yellow change interval down to 3.0 or 3.3 seconds for left turns. Why would the traffic engineer say this could create a safety problem?

Ms. Martineau: Objection to the form of the question. I mean I think that's a better--if you have a question as to why Mr. Moore wrote what he wrote, you should ask Mr. Moore.

A I have no idea why Dick considered this to be a safety problem.

Q Okay. Would you consider it a safety problem, reducing the yellow change intervals where there's a 45 mile an hour speed limit on left turns from 4.5 down to 3.0 or 3.3?

A As far as this specific intersection, I want to look at it and run the numbers and check it myself. I haven't looked at this intersection. I don't know.

Q Okay. If you would go down about two thirds--halfway through the page, the paragraph that begins "The operating speeds." Would you just read that one short paragraph?

A Certainly. "The operating speeds on Harrison Avenue are higher speeds. While the left turning speed may be 20-25 miles per hour at the stopbar, the approach speed approaching the traffic signal is much greater."

Q Is that correct in your opinion, that the approach speed is much greater than 20 to 25 miles per hour?

Ms. Martineau: At Harrison Avenue?

Q At---

A (interposing) Which intersection? This was at Harrison.

Q At Harrison Avenue where there are left turns.

A Which intersection?

Q Well, in general. Is the approach speed much greater than the speed taken at the stop bar?

Ms. Martineau: In what scenario?

Mr. Stam: In any scenario.

Ms. Martineau: Well, objection to the form of the question. Go ahead and answer.

A I can't answer that question as you asked it because there are too many possible scenarios. It could be less. It could be greater. It could a little less. It could be a lot less. It could be a lot greater or it could be a little greater. It could be all over the place.

Q All right. Well, let's use our little diagram here. Here are two vehicles stopped at a red light that are in the left turn lane (indicating). They want to go that way (indicating).

A Okay.

Q So they're stopped. Do you see what I'm saying?

A Correct.

Q They're stopped at zero. So their approach speed to the stop bar would be less than 20 to 25 miles an hour; is that correct?

Ms. Martineau: In your scenario?

Q In this scenario.

A At that point in time their speed is zero.

Q All right. What about the car, the vehicle, that's free flowing for which there is no queue, a 45 mile an hour speed limit? To get through the intersection they have to decelerate; is that correct?

A I would hope so.

Q So at some point they get to 20 miles per hour or something thereabouts. Is their approach speed--is the approach speed of that vehicle, say Vehicle C, much greater than 20 miles an hour or much less?

Ms. Martineau: You're saying this is for an inter- section without a dedicated left turn lane?

Mr. Stam: No. This has a dedicated left turn lane.

Ms. Martineau: Well, then there's going to be a queue.

Mr. Stam: Did we get that on the record?

The Reporter: Yes, sir.

By Mr. Stam:

Q Is there always going to be a queue when there is a dedicated left turn lane?

A No, not at all.

Q Okay. So if there is no queue and they're starting at 45 miles an hour, what is their approach speed?

A At what point?

Q At whatever point you think is relevant for the yellow change interval used by NCDOT.

A You lost me in the question. I'm sorry.

Q Okay. Where would you--you're familiar with the ITE formula for the yellow change interval; is that correct?

A Yes, I am.

Q All right. And one of the factors is the approach speed; is that correct? It says design speed is the speed limit unless there is a speed survey, da, da, da. You're familiar with that?

A Correct.

Q All right. For a left turning vehicle, where should the approach speed be measured?

Ms. Martineau: Objection to the form of that question.

A I have no idea. We don't.

Q Okay. Where does the physics in the yellow change interval mandate that the engineer measure the approach speed?

Ms. Martineau: Objection to the form of the question.

A I have never been asked that or never considered that. I don't know.

Q Going to Exhibit 5, if you would--and these are in I guess reverse chronological order, like an e-mail chain.

A Correct.

Q But I would like to look at the one first at the bottom of the first page of Exhibit 5 that begins "Good morning Greg." Do you know who Greg is?

A Greg Fuller.

Q Do you know what his position is with DOT?

Ms. Martineau: Currently?

Q Do you know what his position was in June of 2006?

A I want to say he was in charge of signals, ITS, but I'm not positive. I mean I've seen Greg rising through the ranks over the years.

Q He deals with signals?

A Yes. His career has been in traffic engineering.

Q He's the signal engineer guy, is that right, for DOT, more or less?

A He's one of them.

Q Okay. Would you read the first paragraph of the Good morning Greg e-mail from Dick Moore, Town Traffic Engineer for the Town of Cary?

A It looks like Dick was writing to Greg and he said:

"The Town of Cary is disappointed that NCDOT by these comments will increase the number of Red light violations by Cary residents at the intersection of Walnut and Meeting Street. Because most red light camera installations have been removed across the country because of shorter yellows being installed, we can only assume that NCDOT is opposed to Red light cameras."

Q Would you comment on that?

Ms. Martineau: Objection to the form of the question. You can ask him a question.

Q Would you comment on that?

Mr. Stam: That is a question, and you objected to form.

Ms. Martineau: Objection to the form of the question.

Mr. Stam: He can now answer.

A Comment on--I mean there's a lot of stuff there. This is the first time I've ever read this--well, the second time. I read it five minutes ago.

Q Right. And I understand you haven't had a chance to analyze it or---

Ms. Martineau: (interposing) Well, it's not his words. If you have a question for him, ask him a question. I don't want him just--you know, he's here to answer your questions. So if you have a question---

Mr. Stam: (interposing) I did.

Ms. Martineau: ---for Mr. Marceau ask it.

Mr. Stam: I've asked a question.

By Mr. Stam:

Q Do you have any comment on the paragraph that you read?

A No. They are strong words. There seems to be a dispute between Greg and Dick about some signals. I don't know the whole history behind it, so I can't really offer a comment.

Q Do you know Dick Moore?

A I've worked with a Dick a few times.

Q Is he a competent traffic engineer?

A I have no idea.

Q Did you work with him on traffic issues?

A Yes.

Q Did he seem to know what he was talking about?

A No.
Q Okay. If you would go to the top of the first page of Exhibit 5?
A Where it starts out with just "Dick"?
Q "Dick," right.
A Okay.
Q "Please don't assume our comments."
A This looks like Greg's response back to Dick.
Q Right.
A Do you want me to read that?
Q If you'll read it and then I'm going to ask you a question about it.
A Okay. Sure. "Dick, Please don't assume"---
Q (interposing) Oh, I'm sorry. You don't need to read it for the record.
Ms. Martineau: Thank you.
A Oh, I'm sorry.
Ms. Martineau: You're okay.
Q Just read it to yourself and then I'm going to ask you a question about it.
(Witness peruses document.)
A Okay. I'm ready to hear questions.
Q All right. If you would go down to the sentence on the tenth line I think that begins "If the Town of Cary," and just read that one sentence, "If the Town of Cary"?

A Okay. Here we go. "If the Town of Cary believes drivers"--and this is from Greg Fuller to Dick Moore.

Ms. Martineau: You want him to read this out loud?

Mr. Stam: That sentence, yes.

Ms. Martineau: Okay.

A "If the Town of Cary believes drivers should be given additional leeway, the red light camera system can increase the time into the red clearance before a violation is recorded."

Q Okay. Do you understand what he is suggesting?

A Sure. The amnesty time could be increased.

Q All right. Does Cary have any amnesty time in its current signalization before the red light cameras record a violation?

A Well, there is no current system. It's turned off.

Q Well, I mean--I'm sorry--before it was turned off.

A Yes. The Town of Cary did use an amnesty.

Q How much?

A Two tenths of a second.

Q Two tenths of a second, okay.

A If I'm not mistaken, it's double I think what red lights use in other locations. I believe it typically is .1, but I'm not positive about that.

Q All right. Now, if you would go to number 6?

A Exhibit 6?

Q Exhibit 6. And I'm just looking at the first message on the first page because the rest of it is, you know, just the rest of that e-mail chain.

(Witness peruses document.)

A Yeah. It looks like this is Kevin Lacy's follow up to Greg's response to Dick. Boy, that's a mouthful.

Q Okay. These are two DOT employees---

Ms. Martineau: (interposing) When you say "these," do you mean Greg and Kevin?

Mr. Stam: Yeah. I was going to get to that.

Ms. Martineau: Okay.

The Witness: Kevin is Greg's boss.

By Mr. Stam:

Q He was his boss at the time or now or do you know?

A He is now, and if I'm not mistaken he was back in 2006 also.

Q And so he was suggesting that a way to solve the safety and enforcement problem was just to have a grace period into the all-red interval.

Ms. Martineau: Objection to the form of the question, mischaracterization.

Q Is that correct?

A No. It's not correct at all.

Q All right. What is he suggesting?

A Well, he doesn't--that I'm aware of here. He doesn't mention safety or anything like that. He just says he was reviewing Greg's recommendations to the town, to Dick Moore.

Q Well, Dick Moore's concern was safety, was it not?

A I'm not really sure what Dick's concern was.

Q Okay. Is that a delay time or a grace period?

Ms. Martineau: What is? What Kevin's e-mail is? You keep saying "that," but there's so much going on. Please let us know what you're talking about by "that."

A What Greg is talking about is--what we know as an amnesty time--is a delay between the onset of the phase red and the ability for the red light camera to capture a violator, capture a violator's image and then record it.

Q All right. Would you look at Exhibit 7, please?

(Witness peruses document.)

A Okay. It's another e-mail.

Q And you have not seen this before yesterday or today; is that correct?

A No, and I don't know if I even received this yesterday.

Q Well, I think actually this one is this morning, 7 and 8.

A Okay.

Q What is Exhibit 7?

A It looks like a chain of e-mails that originated with Lori Cove. Apparently there's a--I'm assuming a citizen--

someone in Cary who has received several red light citations over some time period. She has complained about them in the past and seems to be really hammering at several people.

And it looks like she got another red light ticket, and she--Lori is letting all the people who have apparently been involved in this in the past know that this woman may be talking to them, coming to see them.

And Greg mentioned in one of his follow-up e-mails that this lady had called him and she was misquoting something. And he told her, "We don't have any authority over the red light cameras that are owned by the Town of Cary," and that's the basis of it.

Q Okay. At the bottom there's a message from the Town of Cary to a group of people, other people in Cary plus--well, lots of people in Cary. You note that she did appeal. "She lost her appeal and I haven't heard from her since until today." Do you see that there?

A I'm sorry. You said a message to everybody in Cary?

Q Well, all the---

Ms. Martineau: (interposing) Well, I think the document---

Q ---people to which it was to---

Ms. Martineau: ---speaks for itself.

Q ---are apparently officials of the Town of Cary, at least the ones I can discern because their e-mail address is

@townofcary.org.

A I'm sorry. You lost me. Ask me your question again.

Q The e-mail dated December 19th, 2008, does it appear to be from an official of the Town of Cary to a lot of other officials of the Town of Cary?

Ms. Martineau: Objection to the form of the question. Answer if you know.

A No. It's from the town engineer. Officials I consider to be elected people.

Q I'm not talking about elected people. I'm talking about an employee of the Town of Cary.

Ms. Martineau: Are you asking him if he knows whether or not Lori Cove was a town employee or a town engineer on December 19, 2008?

A Lori is with the Town of Cary. She was then. And she sent it to people with the Town of Cary, also people in the DOT division office, people in DOT traffic engineering, and two people who--or at least one person. I don't know.

Q Do you read this that she had actually appealed and lost her appeal or something had happened in August of 2007?

A "She" being the citizen, Ms. Ellwood, was concerned. She had picked up apparently several or a bunch of traffic citations and was upset about it. Let's see. "She came by in August of 2007 to see me." I don't know when she got her citations and when she appealed, but it was in '07 that she came by to see Lori.

(Plaintiffs Exhibit 8 was marked for identification.)

Q Okay. Would you take a look at Exhibit 8?

A Certainly. And I will tell you I can't read this thing. Oh, there it is. It says Harrison southbound at Weston.

Q I'm going to tell you what it purports to be, and if it purports--you know, obviously whether it is that or not. Mr. Ceccarelli, sitting here with me, got the data from the Town of Cary, pushed a little button on his computer, and it put out a graph, and here's the graph. And it purports to show the number of violations per month at Harrison Avenue southbound at Weston Parkway. Are you familiar with that intersection?

A Yes. I live very close to it.

Q All right. And the spike appears to be in the months of July and August of '07. Now, here's my question to you as an engineer who teaches forensics, talks to police officers all the time. If you saw that graph of violations per month for almost anything, what would you as an engineer first hypothesize or think about if you saw a drastic spike in violations that immediately went down after the spike?

Ms. Martineau: Objection to the form of the question.

Q Did the drivers all of a sudden go wild in those two months?
A Those office people on Weston Parkway go crazy in the summer. I used to work over there. I know. They had a sale at Moe's. I don't know. No.
Q Okay. Neither of us were serious right then.
A In all seriousness---
Q (interposing) In all seriousness.
A ---as a forensic engineer, when I see a spike--and it's a dramatic spike; I won't argue that--my first question is twofold. One, I want to understand the system which is operating, and by system I mean the sphere we're working in, the globe we're working in, and two, I'm going to start looking for things that changed in there. People's behavior doesn't usually dramatically change overnight unless something causes it to change, and I want to understand what caused it to change.
Q Now, there being no spike in the summer of '05 or '06 or '08 or '09 or '10, is it likely that there was a change in driver behavior for example of Rosalind Ellwood, who was complaining?
A Well, let's define driver behavior. Driver behavior is defined by running red lights. Well, yes, quite obviously there was. Driver behavior as far as are they doing it any different in their normal approach to this intersection that

they hadn't done in the past? Maybe or maybe not.

I would want to start looking at the intersection, the signal, the geometrics. I'm going to start looking at things, as I said, the sphere and the environment of this intersection, and find out what was going on out there on the ground at that time.

(Plaintiffs Exhibit 9 was marked for identification.)

Q I'll show what's been marked for identification as Plaintiffs Deposition Exhibit 9.

A Before I look at that, let's go off the record and take a break for a few minutes.

Mr. Stam: Sure.

The Reporter: Off the record. 11:40 a.m.

(A brief recess was taken.)

The Reporter: On the record. 11:48 a.m.

By Mr. Stam:

Q Let me show you what's been marked for identification as Exhibit 9. You can see it's been an exhibit to many other depositions. Have you read any of the depositions in this case so far?

A Yes, I have.

Q Which ones?

A I read David Spencer's, Mr. Ceccarelli's, Ms. Millette's, Lisa Moon's, and Dr. George's, Elizabeth George.

It's Elizabeth I believe. I read hers.
Q All right. Mr. Fuller's?
A I did not read it. I have it. I haven't had a chance to read it.
Q And Dr. Shovlin's?
A No.
Q Have you had a chance to see this exhibit, which was an exhibit to Ms. Moon's and Dr. George's deposition?
Ms. Martineau: I don't think that we've got the exhibits back yet from the court reporter, but I don't know. I don't know if he's seen it or not.
A I want to say I saw this on your web site a long time ago, maybe possibly, but I haven't seen it with respect to an exhibit to a deposition.
Mr. Stam: Off the record.
The Reporter: Off the record. 11:49 a.m.
(Discussion off the record.)
The Reporter: On the record. 11:49 a.m.
By Mr. Stam:
Q So you've not seen this before?
A No, not with respect to an exhibit. If I have, it was on Plaintiff's web site and I just happened to glance over it.
Q Okay. Well, let me tell you what it purports to be. And that is Mr. Ceccarelli obtained data directly from the

Town of Cary to his computer about certain intersections, the number of violations per month at the intersection, and he pushed a button or whatever he does and it turned it into a graph, some program he has. I don't know what it is. And I'd just like to go over a couple of these.

The first page purports to be the intersection where Mr. Ceccarelli obtained his citation. Are you familiar with that intersection, Cary Town Boulevard and Convention Drive?

A Yes. I'm very familiar with it.

Q Going from his direction, west to east, from Maynard-- do you know where Maynard is?

A Yes.

Q ---proceeding east, what is the speed limit there?

Ms. Martineau: Objection. Answer if you can.

A It is 45 miles an hour, as best I recall. It's been about a week since I've been there.

Q All right. How long have you lived in Cary or worked in Cary?

A I've been in the general Cary area for 34 years as of today. My parents bought a house on Halloween day in '78. I've been around here for a while.

Q Okay. In November of 2009, what was the speed limit there?

Ms. Martineau: Objection. Answer if you can.

A I don't know.

Q We'll come back to that.
A Okay.
Q Assuming for the purpose of discussion that it was 45 miles per hour, as you believe it is today---
A (interposing) In 2009 it was 45 miles an hour.
Q Okay. Thank you.
A I had to think about that for a second.
Q All the witnesses have so testified.
A Well, I had to think about it. I should know that.
Q This chart purports to show a dramatic decline in citations when something happened. And I'll purport to you that what happened is they fixed the traffic signal because they goofed and they left a 35 mile an hour signal plan there for a couple of decades, even though it had been 45 miles per hour for years.
Ms. Martineau: Objection; move to strike.
Q That's our position in the case. It's also the position of all the witnesses, but it's not the position of the Town of Cary.
Ms. Martineau: Same objection. Move to strike; mischaracterization of the witnesses' testimony.
Q But assuming that that is true, what does this graph tell you as an engineer?
A The first thing I see is that there was a downward trend and Mr. Ceccarelli's citation blew that, but aside from

that I do see a drop. I do see a drop. I see other drops. I do see a drop that is centered right about the time on this graph--it's shown just after March of 2010--when, as you've told me, the yellow time for Phase 2 through moved from four seconds to four and a half seconds. I do see a drop there.

There are a couple things that caught my attention, and this is really the first time I've reviewed this. I see other up and down spikes all over the place, I mean some serious ones. That drop right there is similar to other spikes I see back in '08. These are just general comments. But yes, I do see a spike that's centered about the time that the yellow time changes.

Something that's odd to me is why doesn't that drop start when the yellow time changes, why was it already on a decline--it looks like a month and a half, maybe almost two months--before the yellow time changed. That seems odd to me.

You asked me a question before about Harrison at Weston. I'm a forensics guy. That means I'm curious. I would want to figure out why it's changed. What's bothering me too is why the change doesn't occur at the same time as the timing changed, what other factors are going on. This is what I'm asking.

Q Well, this is only counts per month. If you had a daily count, you may have a more precise---

A (interposing) Got you.
Q Let's look at the second---
A (interposing) That may answer why the decline doesn't line up with the change at the time.
Q Is a sustained change likely to be due to a change in driver behavior? Obviously you can have changes from month to month, seasonal, depending who's shopping where or the weather or whatever. But is a sustained change likely to be due to changes in driver behavior?
A Well, there again, there are two parts to driver behavior. One part is are they running red lights. And a drop would indicate a change in that behavior, eventual resulting behavior. But behavior leading up to the intersection, such as associated with decision making, there again, I don't have enough information to say yes or no or maybe.
Q All right. Turn to the second page, if you would.
(Witness complies.)
Q I'll tell you what this purports to be. One of the plaintiffs is Lori Millette, who was cited for running a red light turning left onto Cary Parkway coming off of Kildaire Farm Road northbound. Are you familiar with that intersection?
A Very much so.
Q And again, this is a chart. Mr. Ceccarelli will

testify that he took the data from the Town of Cary's records, pushed a button on his computer, produced a graph, and then he inserted the comments. So he says, "4.0 second Left Turn Yellow (should)"--that's his opinion--that it should be 4.5, but it was 4.0.

And then all of a sudden right there where the spike goes up is when the town made it a three second violation. You don't know where in the month that happened, so you can't know exactly. Then she gets a citation as part of that spike. She's convicted, and then the town turns off the camera there and it goes to zero. I don't know if it stayed turned off through 12/10, but it stayed off through the end of that graph.

Does that chart suggest to you as a forensic accident reconstructionist that driver behavior on Kildaire Farm Road suddenly changed in November/December of 2009?

Ms. Martineau: Objection; move to strike the testimony of Mr. Stam. Go ahead.

A You asked me as a crash reconstructionist and I'll testify. Yeah, as a crash reconstructionist and also as a traffic transportation engineer, there again, I better understand now why the line doesn't match up, so I won't introduce that. I understand that you can only do month by month. I know a little more about the history of this intersection.

As I said earlier when we were talking about Harrison at Weston, I want to look at the sphere. I want to look at the environment in which we're working, and then I'll look at the people operating in that.

Why are these resultant behaviors happening? What changed up front to make all this happen? And I've got to tell you I'm not surprised to see a graph like at this inter-section. I'm not shocked at all to see it. As a matter of fact, I could have predicted it.

Q Is it because drivers have dramatically changed their behavior to scoff at the law or did something else happen?

A No, not at all. When the signal plan came out--I forget who produced it--where the yellow time for that left turn, northbound left from Kildaire onto Cary Parkway, came out--what was it, late '08, '09, whenever it came out, I think it was around the end of the plan maybe, where we went from a four second yellow to a three second yellow, that plan wasn't done just to change yellow times. The phasing at that intersection changed dramatically in two very huge ways.

My mother lives not far from this intersection, and she has in all these years complained to me about only two things about traffic and they both had to do with this inter-section, not about yellow times. I promise you.

At the time that they went from four seconds to three at this particular intersection, as well as other intersections around Cary, the town was using going from a lead-lead left turning phasing operating to a lead-lag. It processes more cars per hour. But to effect that you need to have the correct technology in place. If not, you end up building what we call a yellow trap crash situation into the intersection.

And the signal heads that were in place and the phasing that was in place, a traditional late phase, using protective---

Q (interposing) That's discussed in your book, the yellow trap?

A Exactly, exactly, yellow trap crash.

Q Okay.

A What happens is if we were to try to operate lead-lag phasing with those five section left turn signal heads--we had a green ball and a green arrow--we would, a, introduce a yellow trap, or b, have to shut the whole intersection down with an all-red at inappropriate places just to bring everybody to a stop, to then restart the lighting left turns or the lighting through movements, and we don't want to do that. It's dumb and it confuses everybody.

We have to find a way to convey a message to drivers through a left turn arrow to make it happen. And the town selected using--as is being done across the state--selected using the four section signal head with a flashing yellow arrow.

The town did a great job in my opinion, publishing articles in *The Cary News*, in *The News & Observer*. They involved the media, letting people know what was coming. They'll start seeing these flashing yellow traffic signals. People got all upset. I got more complaints. My neighbors all came and complained to me. I'm like an elected official. You know. You get it.

And the fact that they changed to a different signal indication and the fact that they also changed the phasing-- all the drivers for many years at this intersection in a left turn got used to being able to travel through. And quite often they would see--for throughs and a left would see their signals expire concurrently. They no longer did.

All of a sudden we had left turns who had a green when throughs didn't and we had throughs that had a green when left turns didn't and it was a very different world. The same thing was happening at Cary Parkway and Chapel Hill Road, which is closer to my house. I had a chance to watch it quite a bit, and drivers were very upset about it.

The other part is this intersection is the reason the panel changed this type of phasing and changed these signal heads. One is for safety. The other is this intersection, especially in the p.m. peak hour, is what we call saturated flow. We've got 50 pounds of mud and we're trying to put it in a 30 pound sack. It doesn't work. There are too many cars for the roadway capacity.

And the town can by eminent domain take the buildings on either side and widen the road or they can try to utilize green interval timing to process more cars. And by doing that, they use a lead-lag. When we have saturated--my point to all that is when we have saturated traffic conditions, we have frustrated drivers.

By and large the leading cause we see people running red lights, especially those running them just a little bit past the red interval initiation, is frustrated drivers just trying to make it through all over the place.

Q Look at this chart if you've finished your answer.

A I'm not done yet.

Q Sure.

A So we have several combinations. One, we have a change in phasing. All of a sudden people are going, "Wait a minute. I should still have a green. What's this flashing yellow arrow thing?" I hear this from people. I see it myself. I actually designed one of the first intersections in the state using this, in Fayetteville.

And we have changed the phasing, so we've done something that drivers aren't used to, and then we have a whole bunch of really frustrated drivers. That turn in particular, that turning movement, has a high percentage--if we look at the right turn off of Cary Parkway onto Kildaire, a left turn, they oppose each other, and there was a high movement of vehicles there.

If you do traffic counts at that intersection, we have a lot of people trying to go through there. There's only one turn lane because we can't widen the road, and they're frustrated and they bust red lights. And so I'm not surprised that we have a spike right there. I'm sorry. That was a long-winded explanation.

Q I'm glad. Before the change you were running 50 to 100 violations per month.

Ms. Martineau: According to this exhibit.

The Witness: I'm sorry. According to?

(Ms. Martineau indicates.)

The Witness: You're correct, yes.

By Mr. Stam:

Q I hadn't actually finished my question.

A Okay.

Q Before the change you were running 50 to 100 violations per month. It appears that that went up four to fivefold after this change. Now, here's my question. The frustrated drivers going through, are they the 50 to 100 who are going through anyway or is it the next 300 or 400 people per month who just got shorted on the light?

Ms. Martineau: Objection; move to strike the testimony of Mr. Stam.

A I don't know.

Q Do you have an opinion?

A No. I've never really considered it.

Q Okay. If you'd look at the next page, Cary Parkway and Kildaire Farm Road?

A The same intersection.

Q But westbound; right?

A Correct.

Q Westbound. That's really the same issue you saw. Let's go to the next page, Walnut Street and Meeting Street. Are you familiar with that intersection?

A I received a red light citation there. I was driving my wife's car and the citation came in the mail. She was getting ready to pay it and she remembered she was out of town that day. And my daughter said, "Well, Daddy was driving your car that day," and I was very embarrassed, someone in my profession to get a red light camera citation.

Q Did you know that for years the Town of Cary on their citations would say if you weren't driving, you can only get out of it if you finger the person who did?

Ms. Glover: Objection.

Ms. Martineau: Objection; move---

A (interposing) I remember something.

Ms. Martineau: ---to strike the testimony of Mr.

Stam.

Q You remember that?

A I do remember.

Q You remember that? But they had to change it last year because we pointed out to them that that was unlawful.

Ms. Martineau: Same objection; move to strike.

Q "If you'd like to get your $50 back, talk to us."

A In a humorous fashion. I do remember that.

Q Okay.

A I got a citation there a long time ago.

Q Did you know the Town of Cary had collected $1 million of citations at that one intersection?

Ms. Martineau: Same objection; move to strike.

A I had no idea.

Q And did you know it was vastly more than most of the other intersections in town?

Ms. Martineau: Same objection; move to strike the testimony of Mr. Stam.

Q Do you have any idea why that might be?

Ms. Martineau: Same objection.

A Why the town had collected more revenue or why there were more violations there than at other intersections?

Q More violations.

A More violations?

Q And this is--I purport again this is a chart taking the town's own data, pushing a button, converting it into a graph. It looks like right before the change maybe they had to turn it off for a little bit to do the change. I don't know what happened later. But all of a sudden it goes up when you go to 3.2 seconds. You know that intersection.

A I know it very well.

Q Why would there be so many more citations at that intersection, if there are?

A I'm not surprised. Going back to my earlier discussion along that same thread, same vein, red light running quite often, if not most, typically occurs when frustrated drivers just tend to be--they want to be. It's intentional. "Maybe I can make it."

They reach the same decision point as everybody else, and they make the decision to just go ahead and go because there's an overriding desire that "Maybe I'll make it through. I'm in a hurry. I'm frustrated. I don't want to wait another second."

This particular corridor, the Walnut Street corridor through the CrossRoads area, has been studied, explored, and reviewed more times by me, by my engineering firm. There have been so many different solutions proposed to this intersection. The entire shopping center was never designed to be the way it is and the roads leading into it were never intended to be the way they were, and it's Band-Aid on top of

Band-Aid.

My point to that is there are--this is 100 pounds of mud trying to fit into a 30 pound sack. It doesn't fit, and there are very, very frustrated drivers. That might have been why I ran the red light there. I don't remember. But there are many, many frustrated drivers on that corridor.

Also a large number of those drivers just came off of an interstate, a high speed road type situation, and they're coming here just to go shopping at that shopping center. They're coming from ramp 1 and they are making a quick right and then a quick left. And my own review of coworkers one time asking---

Q (interposing) Right and left. I don't understand how you would do that, but---

A (interposing) You come off the ramp and you make a right.

Q Oh, okay.

A You come off the ramp from US 1.

Q The ones going northbound?

A Correct.

Q Okay. I've got it.

A I remember kind of polling some of my coworkers one time about some other issues. And what they brought out was when you're making that right turn and then a subsequent left to go into the shopping center, especially once the dual left turns were put in, it's very confusing because what we call the weaving distance is rather short.

And one of my coworkers said, "I got a red light citation. I didn't even know I busted the light. I mean I was so focused on traffic around me I just drove right through it. I was focused on getting in the shopping center and not hitting anybody and changing lanes." So there's a lot of stuff at play here. I'm not surprised there is a high number--that there were a high number of red light violations at this intersection.

Q Is that a complex intersection?

Ms. Martineau: Objection to the form of the question.

A The intersection itself, no, but the approach, and I don't mean to---

Q (interposing) I mean the approach.

A The general path that people take to it can--whether they're coming down Walnut or they're coming off of US 1. In either direction it can be.

Q So why in the world did they go down to three seconds for a yellow change interval at a confusing intersection where the speed limit is 45 miles an hour?

A When signal plans are being upgraded, the yellows and reds are calculated using the current practice. And if the current practice dictated three, then they would use three.

(Plaintiffs Exhibit 10 was marked for identification.)

Q I show you what's been marked for identification as Plaintiffs Exhibit 10. This is excerpts from a longer paper I have and your counsel has the longer paper, but I think you had mentioned teaching in Oregon or that there were studies from Oregon.

Ms. Martineau: That was your witness that talked about Oregon.

Q Mr. Marceau, did you talk about Oregon this morning?

A I might have. I've taught classes.

Q Yeah. I thought so.

Ms. Martineau: Okay.

A The original publisher for my book was a company called Kinetic Energy Press out of Salem, Oregon, and I taught a class at the Hillsboro County Sheriff's Department a few years ago. I've been out there working before.

Q Are you familiar with this particular paper by any chance?

A I read this. I mean it's been a long time ago. I don't know why I read it, maybe just general--I read so much stuff.

Q I'm going to particularly ask you about page--and what we have here is the title page, page 7, 8, 10, and 11. And I'm particularly going to ask you about page 8. So if you just want to take a minute to--when I say minute, take as long as you want--to just peruse it. I'm going to ask about page 8, but you look at any part you want. I want to make sure you have enough context there.

A Well, ask me a particular question and I'll look at that. There's a bunch of stuff on here, and I'll look at that particular component.

Q Okay. Well, let's look at page 8. This appears to be a summary of various brake reaction times studies for the 85th percentile and the 95th percentile for four different studies that were used here by the Transportation Research Institute of Oregon State. And my first question is this: would you explain to the court what we mean by 85th and 95th percentile?

A We're looking at the majority of drivers. That's the easiest layperson term to describe it. We're not looking at the average, the mean, in other words the 50th. We're looking at the higher percentage of drivers being covered by this time, this standard, whatever it might be.

Q Do you happen to know how many standard deviations from the mean the 85th or 95th percentile would be? I don't know.

A You know---

Q (interposing) But you know the term "standard deviations"?

A Yeah. I haven't used that in a few--I took a statistics class one time in grad school and I've never used it since.

Q Okay. But for the 85th percentile, you would get a large majority?

Mr. Ceccarelli: The standard does not apply.

Q It doesn't apply. I withdraw everything I said about standard deviation.

A Well, I would agree that it doesn't apply.

Q Okay. 85th percentile is a large majority. 95th percentile would be almost everybody but not everybody. Is that approximately correct?

A That's a good lay description of it, yes.

Q All right. So they use four studies here, and the footnotes at the bottom of page 8 give the citations to the studies. Are you familiar with these studies, any of these four studies on perception/reaction time, Gazis, Wortman, Chang, or Sivak?

A Sivak, I think I've seen that, number 4. I mean I know the names, but no, I'm not familiar with the studies. I may have seen Sivak's, but I don't really remember.

Q Okay. You are familiar with Gazis' article you said earlier?

A Yes, the article where he talks about dilemma zones and yellow time calculations.

Q All right. Now, if you would look at---

Mr. Stam: Can we go off the record for just one second?

Ms. Martineau: Sure.

The Reporter: Off the record. 12:15 p.m.

(A brief recess was taken.)

The Reporter: On the record. 12:16 p.m.

By Mr. Stam:

Q Do you see Table 1 there, Perception-Reaction Times Considering Complexity and Driver State?

A Yes.

Q Would you take a look at that, I mean take a moment to actually focus on it?

(Witness peruses document.)

A Okay. Sure.

Q Does that chart seem reasonable to you, the conclusions of the Transportation Research Institute, for the different kinds of complexity of the intersection and differences amongst drivers?

A I'm going to want to sit down and really review this before I offer an opinion on that. I'm not going to shoot from the hip on that one because I'm going to want to, you know, think about each one of these, whether it was a design or after design or how the driver is acting and think of situations where I've actually run into these myself and then offer an opinion, but I'm not going to shoot from the hip on that. It would be dumb to do that.

Q Okay. Well, going back to NCDOT and the Institute for Traffic Engineer formula for determining the yellow change interval, it's in your book that you use 1.5 seconds as perception/reaction time.

A I think I said perception/reaction times are about 1.5.

Q Right, about.

A Right.

Q And if you look at the studies there at the top of page 8 called Brake Reaction Times Studies, would it be fair to say that 1.5 is intended to be the 85th percentile calculation?

Ms. Martineau: Who intends? When you say "intended to be"--objection to the form of the question. Go ahead.

Q Mr. Marceau, you use about 1.5. And I asked you at the very beginning of our deposition whether you are intending that to be the average, mean, median, 85th, 95th or whatever, and your answer a couple hours ago was what?

A Well, first of all, let's back up. I don't use 1.5. I use whatever current practice calls for, which has changed over time.

Q Which is 1.5; correct?

A In North Carolina current practice right now is 1.5.

Q That is what we're talking about, North Carolina.
A Okay.
Q All right.
A Now, continue with the rest of your question.
Q My question is now that you have seen this paper and the results of some of the people that you have heard about, isn't it correct that when you use 1.5, you're only talking about the 85th percentile of the population so that--well, I'll stop my question there.
A No. Your question is invalid. First of all, we have no idea what these studies were about. It says brake reaction time. Reaction to what, a guy in a costume jumping out in front of a car, a red light? I don't know.
When we use a perception/reaction time for traffic engineering purposes, specifically for a yellow decision making perception/reaction, we have a known stimulus with known responses to a learning or learned audience, the drivers.
I have no idea--and that's--you know, it's a number we use. I have no idea what these studies are about. So my trying to compare a number in current practice of 1.5 by NCDOT to these would be--it's impossible. I can't do it.
Q Take a look at Table 1.
A Okay.
Q Low volume road, alert driver, low complexity. That

appears to be the simplest case, is it not, low volume, alert driver, low complexity?

A Not necessarily.

Q All right. Of the descriptions in the left column of Table 1, which is--which description most closely approximates the Lori Millette intersection, northbound on Kildaire Road intersecting with Cary Parkway? Would that be a low volume road or a two-lane, primary rural road, urban arterial, rural freeway, or urban freeway?

A It's going to fall between--and let's back up for a second. Something just dawned on me as I was reading the intro. Table 1--the table before Table 1, which doesn't even have a number to it, which is weird because that should be Table 1 and this should be Table 2, but the one on top says Brake Reaction. It sounds like they're reporting study results. This second table is not study results. These are values that some people have suggested could be used. They are not results of any validity.

So anyway, all that being said, using these type of parameters as far describing the state for Lori Millette's--when she received her citation at that intersection at 5 o'clock on a--I think it was a Friday night as a matter of fact--I would say that the driver's state would be alert, and I would say the complexity would be moderate, which I don't think falls anywhere in this chart.

Somebody who is navigating down Kildaire Farm Road has got to be alert or they just got killed. I mean it's not easy to make it down that road. But the complexity, it's not low complexity and it's not high complexity. It's somewhere in the middle.

Mr. Stam: Let's go off the record.

The Reporter: Off the record. 12:22 p.m.

(A brief recess was taken.)

The Reporter: On the record. 12:27 p.m.

(Plaintiffs Exhibit 11 was marked for identification.)

By Mr. Stam:

Q I'll show you what is marked for identification as Exhibit 11. See if you can identify that.

(Witness peruses document.)

A It looks like this is an e-mail from Buddy Murr to Greg Fuller, but I'm trying to find out why Amanda had it and why it's printed in her e-mail. But anyway, it looks like it's a--okay.

It looks like it started with an e-mail from Rob Ziemba going to Greg and Buddy, and it's links to two articles in *The News & Observer*. One is about a class action ruling article and one is about "Lawsuit doesn't stop red light." We have two newspaper articles and Rob was saying, "Hey, did you see these over the weekend?"

Q And Buddy Murr, who purports to be the state signals engineer, sends an e-mail to Greg Fuller, who is something in signals?
A He's Buddy's boss.
Q Buddy's boss--clipping page 68 from--what is the NCHRP 03-95 study?
A It's a national--it's a national highway research project. It's the National Center for Highway Research Projects, and they publish journals and studies and have meetings. They look at everything from pavement markings to roadways to signs, all kinds of stuff, in a roadway environ-ment. It's kind of a theoretical research tank kind of group.
Q Is it the kind of stuff you rely on in your work?
A I never have. It's kind of one end of the spectrum as far as research goes. I don't know that I've ever used one of their reports. I mean I've seen their reports over the years, but I've never relied on one.
Q Would you read to yourself that paragraph? And then I'm going to ask you about it.
A Okay. Buddy says, "On page 68"---
Ms. Martineau: (interposing) To yourself.
The Witness: I'm sorry. I apologize.
Q Where it starts "Speed limit" and ends "speed limit."
A Got you. Thank you.

(Witness peruses document.)

A Okay. There are words chopped off. I was trying to figure out what they probably were.

Q That's all I know. I got this from DOT.

A I think I can figure it out.

Q The "l-i" probably means in lieu of. I'm guessing. But I don't think there's anything chopped off that will affect my questions here. When you are trying to apply the ITE yellow change interval formula, the v in the formula means what?

A The approach speed.

Q Okay. Is it the 85th percentile speed if you do a speed study? I know what it says is use the speed limit unless you do a survey. Is that correct?

A That's correct.

Q All right. Now, if you use a higher speed for v, would that result--and the only change is a higher speed for v.

Ms. Martineau: Are we talking about through traffic?

Mr. Stam: Yeah.

Ms. Martineau: Okay.

Mr. Stam: Well, actually both, but let's limit it to through traffic now.

By Mr. Stam:

Q If you use a higher value for v, would that not result

in a longer yellow change interval?
A It should.
Q And if you use a lower value for v than the speed limit, then you would have a shorter yellow change interval; is that correct?
A You should.
Q Okay. But in North Carolina we normally don't do speed studies at our intersections; is that right?
A No. In all these years I think I've seen one, ever.
Q Normally not?
A No.
Q So would it not be actually more accurate then to use the speed limit plus seven miles an hour than to use the speed limit? We admit that a speed survey would be more accurate, but we don't do speed surveys. But somebody has and says the average is seven miles an hour over for straight-through. Wouldn't it be more accurate to use speed limit plus seven?
Ms. Martineau: Objection; move to strike the testimony of Mr. Stam.
A Well, first of all, your question has an inaccuracy in it. You asked me that we already know that 85th percentile speed studies are more accurate than the speed limit, and we don't know that. It could be different. It could be the same. It could be more accurate. We don't know.

In some places the 85th percentile speed could be higher than the posted. In some places it could be lower too. We don't know. So to say that one is more accurate than the other, we don't know, and that's never what ITE intended this statement to mean.

Q But if you've only seen one speed survey---

A (interposing) In all these years.

Q ---in all these years---

A (interposing) And it wasn't related to the design of a traffic signal. It was related to something else that we happened to have in place at the time.

Q Right. But if somebody else has gone to the trouble of doing speed surveys and says that the average for the 85th percentile was seven miles per hour higher, would not that be more accurate, to use---

A (interposing) I have no---

Q ---seven miles per hour?

A I have no--I'm sorry. I thought you were done.

Q All right.

A I have no idea if it's more accurate. I think it's something that we might want to look at as an industry, as a profession, and--first of all, let's back up. Traffic engineering, and I'm assuming most other branches of engineering, is constantly evolving and changing.

There's always groups of researchers--they've always got a bunch of grad students doing research project. So we're always considering new information and new ways of doing things. I doubt you'll find an engineer that's not trying to make things better all the time. We can define better in a lot of ways, but this sounds like Buddy dug up some research that somebody had done somewhere.

Q Yeah. In 2012 Buddy and Greg found the latest research---

A (interposing) Well, the study was done---

Ms. Martineau: (interposing) Objection; move to strike the testimony of Mr. Stam.

A The study was done in 1995.

Q Right.

A So it's pretty old.

Q All right. But for some reason Buddy Murr--and I can't remember. Is Greg his boss or is Buddy the boss?

A Greg's the boss.

Q All right--told his boss, "Well, this is what we got from this 1995 study." Okay. Next question, do you see my diagram?

Ms. Martineau: Objection; move to strike the testimony of Mr. Stam.

Q Do you see my diagram?

A Yes.

Q This is Lori Millette's intersection going this way (indicating), Cary Parkway.

A Got you.

Q She's going north on Kildaire.

A Okay.

Q 45 mile an hour speed limit. That's the only posted speed limit. At some point in time there are two drivers right next to each other going 45 at some point approaching the intersection.

A Okay.

Q Labeled here turning (indicating). This vehicle (indicating), Lori Millette, intends to turn left. This vehicle (indicating) intends to continue straight through. Which of those vehicles is going to need more time to proceed through the intersection without violating the law, the straight through vehicle or the left-turning vehicle?

A More time to proceed straight through?

Mr. Ceccarelli: To the intersection.

Q Proceed to the intersection to enter the intersection lawfully.

(Ms. Martineau and Ms. Glover confer.)

Ms. Martineau: Also--I'm sorry. If I could, Ms. Glover made a good point. You're representing this is Lori Millette's intersection and there are two left turn lanes in that intersection. So if we're going to do it, let's---

Ms. Glover: (interposing) You're not showing the turn bays at all.

Ms. Martineau: Right.

The Witness: It is a single left turn lane.

Ms. Glover: I'm sorry. But we're not seeing the left turn bay.

Mr. Ceccarelli: It doesn't matter.

Ms. Martineau: Well, if he is representing that he is drawing a diagram on the board, then let's be accurate. Why don't you just make your diagram not like you've done anything and just ask him your question?

By Mr. Stam:

Q At Lori Millette's intersection, how many left turn lanes are there?

A One.

Q All right.

Ms. Glover: How many through lanes?

Q How many through lanes?

A Two.

Q Two. All right. I'd better make two, then.

A One's a shared through right.

Q All right. We'll get it accurate.

Ms. Glover: Ask him do you know how long the left turn bay is.

Q We know that Walnut is like 300 or 400 feet. I don't know the one here (indicating), but this one is straight through or turn right (indicating).

A Correct.

Q The middle one is straight through.

A Correct.

Q This one is turn left (indicating).

A Correct.

Q Okay.

Ms. Glover: And you're assuming that the car in the left-turning lane is in the left--actually in the left turn bay, so the length of that left turn bay is--you're representing that on your diagram?

Mr. Stam: Right.

Ms. Martineau: Okay.

Mr. Ceccarelli: It's irrelevant. It doesn't matter.

Ms. Martineau: That's not for you to decide, Mr. Ceccarelli, okay?

Mr. Stam: Hey, this is a deposition. This ain't argument. Okay.

By Mr. Stam:

Q Let's say 300 feet back.

Ms. Martineau: I'd have to know if the left turn lane is 300 feet in length. So that's why I'm---

Q (interposing) I'll tell you what we're going to do. This is going to be Walnut Street and Meeting Place (indicating).

Ms. Martineau: Well, that does have two lanes.

A Why don't you just make it an intersection with no name?

Ms. Martineau: Right.

Q No, I'm going to use Walnut Street and Meeting Place because we know it's more than a 300 feet left turn bay.

Ms. Martineau: Then you have to redo your drawing.

Q This is Walnut Street (indicating). This is Meeting Place (indicating). And there are two left turn lanes; correct?

A Correct.

Q And two straight throughs? Is it four lanes there?

A It may have been increased to three after Lowe's came in. There was a subsequent widening after Lowe's, and it may actually be two throughs and a through right. I'm not positive.

Q There's at least two going through and at least two left turn lanes; is that right?

A Well, no. There's definitely two left turn lanes. That's a finite number. But there's at least two if not three through, and one may be a shared through right. I cannot remember if there's a right turn bay or not there. I don't think so.

Q All right. But my question is going to be about this one (indicating) versus this one (indicating).

A So a rightmost left turn versus---

Q (interposing) Left turn (indicating), through (indicating), and they are at least 300 feet back from the intersection. And the reason I say 300 is, as you know, 294 feet is the critical distance if you're going 45 miles per hour. But this left turn bay, assume for the purpose of my question, is at least 300 feet back.

So you have two vehicles. One is going to turn left. One is going to go through. Which of those two vehicles needs more time to lawfully enter the intersection?

Ms. Martineau: What's the speed of those vehicles?

Q 45 mile an hour speed limit, at least 300 feet back.

A As the question is set up--and I know you took a long time to set it up--I can't answer it and here's why. I will need to know--your question was--to me. My understanding of the ultimate question is which of the vehicles, the through or the left, needs more time to make it lawfully to the intersection or into, whichever term we wish to use.

Q Correct.

A And my response is it's going to depend on several factors. I have not considered it in this scenario. I haven't worked this through in my head already. I'd be glad to. But the information I would be asking is where--at what speed is each driver traveling and what are the traffic conditions out here in the roadway at the time, and what are the drivers going to do before they get to this point.

Q Assuming free flowing traffic.

A Okay.

Q Are you now able to answer?

A And our drivers are both traveling at what speed?

Q 45 miles an hour. Let's say it's 2:00 a.m. in the morning, no other traffic. They're each going 45 miles an hour at least 300 feet back. Which of them needs more time to lawfully enter the intersection, the vehicle that's going to make a turn, which presumably will be decelerating, or the vehicle that is not making a turn, presumably maintaining its speed?

Ms. Martineau: Objection to the form of the question.

A Because the left turning vehicle--we would hope is decelerating so they don't crash into whatever the restaurant is over there on the far left corner.

Q Bob Evans?

A Bob Evans, yeah. Because they're decelerating, their average velocity over that distance, over that 300 feet, will be less and it will take them more time to go from that 300 foot point to the stoplight. That is opposed to the driver who is holding, I'm assuming, a constant velocity of 45 miles an hour.

Q So why does Cary and/or DOT give the through driver more time than the left-turning driver?

A More---

Ms. Martineau: (interposing) Give more time?

Q Why does Cary give less time, 3.2 seconds, to the left-turning driver rather than 4.5 or whatever it is to the through driver?

Ms. Martineau: And you're talking about yellow time?

Q Yes, yellow change time.

A That was my question, because---

Q (interposing) It's an enigma.

Ms. Martineau: Objection; move to strike.

Q You can answer my question.

Mr. Stam: Are you answering the question or are you asking Mr. Marceau?

Q Go ahead and answer the question if you can answer it, Mr. Marceau.

A The reason that we give the yellow times that we do--when I say "we," I mean the traffic engineering community--is because we're using the accepted practice methods in place when we're doing the calculations to come up with the yellow time. We're using values that are accepted engineering practice for those calculations, and the time that comes out is the time that comes out.

(Plaintiffs Exhibit 12 was marked for identification.)

Q I'm showing you what's been marked for identification as Exhibit 12.

A Oh, I remember this. This is Steven's article.

Q Are you familiar with this document?

A Yes. I know the author and the document.

Q Where does the physics in the yellow change formula, which is at the bottom of the second column of the first page, to wit page 20, mandate the engineer measure the approach speed?

Ms. Martineau: Objection to the form of the question.

A You lost me. Your question was where does the physics in the yellow change formula mandate that the engineer measure the approach speed?

Q Right.

Ms. Martineau: Same objection.

A That's impossible to answer.

Q Okay. I'll represent to you that the scribbles on there are from me, my handwriting, and that they're not part of the original document.

A Well, yeah. I know that. It came out of an ITE journal.

Q Right. Is that term, though, that's---

A (interposing) Which term?

Q The term that's circled that says "yellow." Is that

the yellow change part of it, and then the second term of the equation that says "all red" the way to measure the red clearance interval, all-red clearance interval?
A It's the way to calculate it, not to measure it.
Q To calculate it, I'm sorry. You're right. Does that sound right, that that's the way to calculate the yellow change interval and the all-red clearance interval?
A When this article was written back in 2004 or 2005 when the task force originally convened, that was the current ITE method for calculating yellow and red.
Q Okay. I thought this was the new way to measure it.
A It's the way to calculate it, not to measure it.
Q To calculate it, right.
A The---
Q (interposing) And look--if you need to, look at the last page where you'll see---
A (interposing) I was trying to find a way to form my words. The formula itself didn't change. The engineering judgment around the use of their formula, in particular the caps, the high end, the low end, as well as some of the variables within the formula did change. But the general idea behind how you calculate a yellow and a red really didn't change at all.
Q Because physics doesn't change; is---
Ms. Martineau: (interposing) What did you say?

Q ---that right?
Ms. Martineau: Objection.
Mr. Stam: Because physics doesn't change.
Ms. Martineau: Objection to the form of the question; move to strike.
By Mr. Stam:
Q The laws of motion in the universe don't change.
A Not until we get near the speed of light they don't.
Q Right. Now, in this equation, there's one term that's used twice. Which is it? When I say "term," I mean one letter that's used twice.
A I understood. Velocity.
Q Velocity. When the same term is used twice in the same equation, do you use the same value for that equation or not?
A The way this is written, yes.
Q All right. Now, look at the all-red clearance interval, w plus l over v.
A Okay.
Q Earlier in your deposition I believe you told me that the v, as used for the all-red clearance interval, would be the design speed.
A Right. It's whatever--when we're designing a traffic signal, it's whatever speed we plug in.
Q Right.

A We don't use roadway design speed. That's way too high.
Q Because that vehicle that's lawfully entered the intersection and proceeding through, we have to presume it's going the speed limit.
Ms. Martineau: Objection to the form of the question; move to strike.
Q Is that correct, or it could be?
A The only discussion I've even seen on that was an ITE discussion years ago, and they said--they talked about drivers at the lawful speed, at the maximum lawful speed, and that was the--I can't remember all of it. I just remember seeing it. It was written in an ITE paper somewhere.
Q All right. Whatever it is should be the same throughout the equation; is that correct? In other words, if the same term--I've already asked that question.
A The way this equation is written--if in fact it was written v_1 and v_2, that would indicate to me that we're looking at two different velocities. The way this equation is written, it indicates v. So we use the same value to replace that variable wherever that variable shows up.
Q Okay. And you've used that document?
A Did you ask me do I use it?
Q Right. Do you use that document in your work?
A I have, certainly. Yes.

(Plaintiffs Exhibit 13 was marked for identification.)

Q All right. I show you what's been marked as Plaintiffs Deposition Exhibit 13 and ask you if you are familiar with this document.

(Witness peruses document.)

A I'm familiar with the book. It looks like several pages were copied out of it.

Q Okay. I have attached the pages that I think have something to do with the yellow change interval and the red clearance interval. And if there are other parts to that book that you think are relevant when you're reading and signing your deposition, please feel free to indicate any other pages that you think are relevant. Do you use this book in your work?

A Yes, I do.

Q All right. If you would turn to page--well, I don't have the page numbers, but it's the third sheet.

A It's page 412.

Q Is that 412?

A Yes.

Q Do you know it well?

A I've been there before. I mean someone wrote it on this copy, but I know it's page 412. I hate this page out of this particular book. It has typos and I don't like typos.

Even in my own book I find typos years later and it kills me.

Q The second full paragraph, do you find a couple of typos there?

A The second full paragraph?

Q I mean the second full paragraph from the bottom. Tell me what errors---

A (interposing) I'll read the paragraph. It's short. It's only two sentences.

Q All right.

A "As can be seen from the formula above"--and they are referring to a yellow time calculation. "As can be seen from the formula above, slower speeds result in higher values of yellow clearance time," and that is incorrect. It's inversed.

Q So it should read slower speeds result in slower values?

A Lower.

Q Lower values.

A Slower or lower.

Q All right.

A "When calculating the needed time"--the first sentence is the one that has an error in it.

Q All right. But I'm more interested in the second sentence. Would you read the second sentence?

A Sure. "When calculating the needed time, consideration should be given to the values for the 15th-percentile speed, particularly at wider intersections."

Q Now, 15 from 100 is 85, which means to me they are probably using the 85th percentile in making these calculations. Is that how you read that?

A Ask that again?

Q Well, the 15th percentile speed--in other words, 15 percent of the people going through a--coming to a light are going to be---

A (interposing) We look at the bottom 15 percent.

Q All right. So what does it mean that consideration should be given to those 15 percent people at wider intersections? What would happen if you don't consider those 15 percent people as they zip through the intersection at maybe a lower speed---

Ms. Martineau: (interposing) Objection to the form of the question.

Q ---than your formula calls for?

A I hate to bug you. Ask me that again. I was already thinking of where I had seen a reference to this when you were asking the question and I lost track. I'm sorry.

Q Intersection (indicating). You don't want cars crashing into each other. What's going to happen if you assume that everybody is going your design speed, but 15 percent of the people are going slower?

A Well, that's not what the 15th percentile refers to.
Q Okay.
A But if 15 percent were going slower--I never--I never thought about this. I'm sorry.
(Plaintiffs Exhibit 14 was marked for identification.)
Q Okay. I show you what's marked for identification as Exhibit 14 and ask if you can identify it.
(Witness peruses document.)
A This is the latest edition of the MUTCD.
Q Is that a really long document?
A Oh, yeah. It looks like these are some pages copied out of it.
Q I have copied what I--the only pages that other witnesses have said have anything to do with this question. I'd just ask you to look through those pages. Is this a volume you use in your work all the time?
A Quite frequently.
Q Frequently. And just tell me if there are parts of that book that you think I have not included. I've got Section 4D.26 - Yellow Change and Red Clearance Intervals, and then Page 512 says a little bit about it. And then at the very end is page 1, which I don't know why I have it at the end.
A Yeah. You missed two really important sections.

Q All right. Which are those?
A 4D.10.
Q 40.10?
A No. 4 letter D point 1-0, and I could be wrong. I'm shooting from the hip here.
Q Well, let's mark---
A (interposing) Is it 4D.10 or 4D.06?
Q Ms. Martineau has a copy of the whole thing here.
Mr. Stam: Ms. Martineau, could he look at that?
Ms. Martineau: I don't have the latest edition of 2009. I think I have the original 2009 edition, but he's welcome to look at it.
Mr. Stam: All right.
The Witness: I probably have it. Let's see.
By Mr. Stam:
Q I want to make sure I have all the relevant sections, or the ones that you think are relevant.
A I don't think it changed between--this is the original 2009 (indicating).
Ms. Martineau: I'll represent that the revisions of the 2009 have nothing to do with what we're talking about as far as I know.
A No, because the first inclusion of 4D.26 wasn't in 2009. I don't think there were changes there, maybe some definition changes. We'll start at the beginning of Chapter

4 or Section 4 as they call it.
Q What page? When you get to it, tell me what page it is.
A Okay. I keep mine organized by sections. It's easier.
(Pause.)
Part 4 starts on page 433.
Q Okay. What's it entitled?
A Highway Traffic Signals.
Q Okay.
A The sections you want to go to--you want to skip through all the 1 stuff, which is at the beginning.
Q And I will read it and look it up later. I just want to know where you're referring to and what it's about.
A Yeah. There are three sections in particular that you want to look at. This sounds crazy, but I never look at paper copies. I keep electronic copies and flipping through the paper here seems weird. I know that sounds dumb, but--okay. Section 4D.04. It wasn't 06. It's 4 letter D.04.
Q Entitled what?
A Meaning of Vehicular Signal Indications. This is where the MUTCD writes out for us what different signal indications mean. It talks about the meaning of a steady green signal indication and it also discusses what a yellow signal indication means, what is the meaning of a yellow

light in other words.
Q Can I just look at that for a second?
A Certainly.
(Document handed to Mr. Stam.)
Yellow light is in Section B.
Q Page 451.
(Mr. Stam peruses document.)
Q Okay. So Page 451 is relevant.
A When you're working with the MUTCD, I probably wouldn't go with page numbers. I'd go with section numbers. It's easier.
Q All right. It's 4D.04 sub--well, just all of 4D.04.
A 4D.04, section B, paragraph B, refers to yellow signals.
Q Okay. Any other sections?
A Yeah. I believe the next one is 4D.10 as in 4 David 10. Let me try to find that for you.
Q .10?
A Correct.
(Witness peruses document.)
No. I'm sorry. In 2009 they started changing some things with respect to signals. It used to be 10. I'm sorry. I'm not finding it right now. And then of course Section 26 discusses the---
Q (interposing) Which we have.

A Which you have right here, yeah. I'll just refer to your copy instead of digging through.

Q Okay.

A I know it sounds crazy, but I don't dig through paper. I keep it electronically. It's just easier.

Mr. Stam: Could we add page 451 to my exhibit there?

Ms. Martineau: Yes.

Mr. Stam: We can make a copy afterwards, or if we want to do it now while she's still here, page 451.

(Plaintiffs Exhibits 15-17 were marked for identification.)

By Mr. Stam:

Q I show you what's been marked for identification as Exhibits 15, 16, and 17, and just ask if you're familiar with these equations. I'm not asking you to do any calculations in your head, but look through them. Let's take them one by one. Exhibit 15.

(Witness peruses document.)

A Page 15, yes. I'm familiar with that--or Exhibit 15.

Q Does that appear to be a valid equation?

A Well, there are four equations, and they all appear to be valid.

Q All right. Exhibit 16, the same question.

A Exhibit 16 has eight equations on it.

Q Take your time.

Ms. Martineau: What's your question about Exhibit 16?

Q Do the eight equations appear to be valid equations?

A I don't know. I would want to work through all these. Several of them I've seen before, but a couple of them I have not, or at least not in this format. I mean there are many ways to present the same information mathematically, and I would just want to work through them to satisfy myself that I'm actually familiar with all these. There are some terms in here I'm not familiar with.

Q All right. Which terms are you not familiar with? Maybe it's a terminology question.

A I mean I'd have to go through each one. I think they are calling some things different than what I might call them, but I'll be glad to take an afternoon and work through them. It's no big deal. I mean a couple of them look familiar, but I think that things have just been rotated around. I could probably satisfy myself that they're all fine, but I'm going to do it before I say they are.

Ms. Martineau: Right.

Q Well, let's do this. Instead of taking time to do it, when you read and sign your deposition, if you have any comments on those equations, please feel free to comment.

Ms. Martineau: Well, he's here to answer your questions about it, not do math. If you have a question, ask him the question.

Mr. Stam: Okay.

Q Is Equation 1 a proper equation for determining the critical distance, if you know, velocity, time, perception time? Do you know what the a is? Is that acceleration rate, and G?

A I don't know.

Q Do you know what the term "critical distance" means?

A Yes, I do.

Q How would you define the term "critical distance"?

A In transportation engineering we respect traffic signals. And yellow time that we're talking about today is the distance where we are asking a driver to make a decision, the point in time we're asking a driver to make a decision.

Q Anything else?

A That's how I define it.

Q All right. Is Equation 2 a proper way of deriving the yellow change interval or determining the yellow change interval?

A Can you ask that question again?

Q Is Equation 2 a proper approach to determining the yellow change interval?

A I have no idea. I've never seen it presented this way. I mean I'll be glad to work through it for you, but

I've never seen it presented this way.

Q All right. I'll go directly to Exhibit 17 where c is the critical distance. Would you look at the four equations there for a moment?

A I don't see a c on this page.

Ms. Martineau: Me either.

Q Maybe we've got the wrong exhibit.

Mr. Ceccarelli: Wrong one.

Q Can you show me that again?

(Mr. Stam peruses document.)

Q Oh, that's my 15.

A Is this a restatement of 15?

Q Yeah. Let me give you a different 17.

A Yeah. This is 15 all over again.

Mr. Ceccarelli: Yeah.

Q I gave you the wrong 17. I'm sorry.

A We already have that as 15 over here.

Mr. Stam: All right. I'll throw that away. This is 17.

(Plaintiffs Exhibit 17 was re-marked for identification.)

By Mr. Stam:

Q Would you take a look at Exhibit 17 where the c is intended to mean the critical distance, and assuming you know the other abbreviations, do those four equations appear to be appropriate and valid for a 45 mile per hour speed limit and a 1.5 perception/reaction time?

A I have not used this particular format for this application, and again, I'll tell you I'll be glad to work through it. I'm an engineer. You give me an equation and I'll work through it until I understand it or I can show there's a problem with it. I'll be glad to do that. I've just never seen it presented like this, which is not uncommon in my business. I mean we just work through it.

Q You have the option when you read and sign of commenting or not. I hope you will, but---

A Okay.

(Plaintiffs Exhibits 18 and 19 were marked for identification)

Q I show you what's been marked for identification as Exhibits 18 and 19. They both show stickers from another deposition, Mr. Hennings, another engineer. Do you know John Hennings, by any chance?

A I think I've worked with him over the years. I know he's with Accident Research. I think I might have a case with him right now actually. I think we were both retained by the same counsel.

Mr. Stam: And I don't have copies. We'll make copies before we go.

Q Yesterday Mr. Hennings wrote these out as his solution to the problem for the straight through intersection and the turning radius.

Ms. Martineau: Objection to the form of the question; move to strike the testimony of Mr. Stam.

Q And my question is do you have any comment on Exhibit 18 as an approach to determining the yellow change interval at straight through intersections?

A It looks like from Exhibit 18, since this is his first calculation, that--is it Hennings?

Q John Hennings.

A Hennings is suggesting that a flat rate of 2.5 seconds, I'm assuming, be used for yellow time.

Q This is straight---

A (interposing) Yeah, for straight through.

Q For straight through.

A So he's suggesting that his entire calculation here be replaced with just 2.5 seconds, which seems really odd. I don't know if that's what he meant or--I have no idea. I have no idea what he was intending.

Q I think he's intending to use 2.5 as the perception/ reaction time that would solve the problem.

Ms. Martineau: Objection to the form of the question as to "solve the problem"; move to strike.

Q Rather than 1.5.

A I'm confused. What problem is he trying to solve?

Q Well, the problem is people get citations for red lights even though the perception/reaction time constant that is used is based on an 85th percentile in a relatively non-complex environment.

A I disagree with many elements of that statement.

Q Okay. Which ones?

A Well, first of all, at least in my deposition, we haven't established that 1.5 percent--perception/reaction time is the 85th percentile of people in a similar situation given similar responses and similar stimuli, so that kind of throws it all out the window. But I'm still confused by his equation itself.

I mean if this is an equation, what he's showing me is yellow time equals 2.5 seconds. I hear what you're saying. You think he was simply saying that he wants to replace perception/reaction with 2.5 instead of 1.5 is what I'm hearing maybe, and maybe he just didn't finish his calculation. He started it and never finished it. I don't know.

Q What about Exhibit 19?

(Witness peruses document.)

A This looks like what he is proposing to do is to take a vehicle at some initial velocity and then at some terminal velocity of 20 miles an hour and pick an average in the middle and to put that average velocity into the equation. That's what it looks like he's attempting to do in this equation here that he wrote, but he's--oh, I see what he's done.

He's gone ahead and he's written a new equation. It looks like he's proposing a new equation for yellow time that artificially increases all the yellow times is what he's done.

Q Now, when you say artificially---

A (interposing) Yeah, it sure does.

Q What do you mean by artificially?

A Well, take a look at this. I'm going to go ahead and write something out here.

Q Okay.

A If we look at the ITE formula for yellow time and we say yellow equals t plus--we'll use v. I'm going to pretend like he did that the road is flat, so we don't have any grade or gravity, any resistance calculation to worry about. So it's just v over 2a. This is ITE's base formula.

What he has done--and that's--that's what he's showing here. He's showing velocity over two times deceleration. If he in fact wants to consider an average velocity, what he should have done is replace this with the average velocity. I'll wait for Mr. Ceccarelli to get done here.

(Pause.)

By the time you go ahead and square this initial velocity and then divide it by an average velocity, we're not talking apples to apples. It's oranges to apples. And what he's doing is he's artificially jacking this up by several seconds. Now, I'm not talking about the perception/reaction time being different. Let's forget about that. That doesn't matter.

Q Put that to the side.

A Put that to the side. But what he's doing is he's--it looks like he's--is this guy a traffic engineer of some kind? It looks like he's a--like an experimental researcher traffic engineer maybe.

And he's proposing a new yellow time calculation from what I see that would indicate--it would produce yellow times that are several seconds higher than what's in current practice. That's what it looks like he's produced.

Q Yellow times?

A Yellow times, yellow interval times, that are higher than what we would do--what we would get if we used the current ITE/NCDOT methodology.

(Plaintiffs Exhibit 20 was marked for identification.)

Q I show you what's been marked as Exhibit 20 for you but was also 26 for Henning, where he actually calculates using his formula. Do you follow that?

A I see that.

Q Now, on Exhibit 18, where does the 2 come from in this formula?

A That's been a long time ago. I don't remember.

Q Okay. Well, let me refer you back to Exhibit 12.

A Are you asking me about the origin--the derivative--the derivation of this formula or are you asking me about where we recently saw it published?

Q No. I'm asking the derivation.

A Oh. It's been a long time. I was satisfied that it worked a long time ago and I haven't checked it since. I mean I turn the switch on and the lights come on. I don't check that every day either. I'm being sarcastic.

Q Let me show you Marceau 12, which has this chart on page 24. You're familiar with that chart?

A Yes.

Q Now, I believe that you testified about 20 minutes ago that if you had two vehicles at 45 miles an hour at least 300 feet away from the intersection, one intending to go straight through into the intersection lawfully, and the other intending to turn left and enter the intersection lawfully, I believe that your opinion was that the turning vehicle would need more time to do that.

A Assuming they're at same originating speed and they're at the same originating distance and that--the assumption is that the turning driver is going to slow down so as not to crash, it would take a longer time for the turning driver to go from the point of origin to the intersection.

Q And I asked you why then DOT and Cary allows about 4.5 seconds for the through driver but only 3.2 seconds for the turning driver at that intersection.

Ms. Martineau: Objection to the form of the question; move to strike as to the Town of Cary.

A I think what you asked me was why--and I forget who you said, what group--uses a shorter yellow time for a left versus a through.

Q Yeah. Do you recall what your answer was?

A My answer, as best I recall---

Q (interposing) With free flowing traffic was my summary.

A There's no free flowing traffic on Walnut Street.

Q At 2:00 a.m. in the morning?

A Yeah, okay. But my answer then and my answer would be now is that the yellow times in use are the ones that are calculated by current engineering practice.

Q Okay. Now, I would like to see if you would be able to calculate how to get the yellow change interval for the left turning driver, 45 miles an hour--hopefully they'll be at 20 miles an hour by the stop bar or less.

Using their formula, what is the value for v? Is it 20 miles an hour? Is it the average between 45 and 20? Is it 45 miles an hour, or is it something else? What is the value for v by which ITE and the NCDOT formula determines the yellow change interval in that circumstance?

A Under the current standards?

Q Yes.

A I would use 20 miles an hour.

Q Okay. But your testimony was if they're not in a queue, they'll actually be approaching at a higher speed.

A Certainly.

Q Okay.

A Let's remember if it's 2:00 a.m. and you're approaching an intersection, you're approaching a red light. At 2:00 a.m. there's no people in the queue and the light is red.

Q Assume it's green.

A It's not. That's not the way the signal works. It can't be green.

Q Why can't it be green?

A Because it rests in red.

Q On Walnut Street?

A Yes. That's a protected left turn.

Q Okay.

A Only throughs rest in green. Phases 2 and 6 rest in green at night. The left turn phase rests in red. You have to come to a stop, so it's a moot point.

Mr. Stam: Okay. If we could take five minutes?

Ms. Martineau: Sure.
The Reporter: Off the record. 1:23 p.m.
(A brief recess was taken.)
The Reporter: On the record. 1:29 p.m.
By Mr. Stam:
Q At Walnut Street and Meeting Place a car is ahead of you up in the queue and they've just got a green light and is going through, but you're 300 feet behind. Wouldn't it show a green light for an approaching vehicle?
A You know, by the fact that you're asking that question and the question you asked me before we just went on break tells me that I didn't do a good job of explaining something earlier.
Way back, an hour or so ago, you were asking me about some graphs Mr. Ceccarelli pulled together showing the increase and decrease in the number of red light camera citations at certain intersections, and I think several times I said I would want to look at the entire sphere in which we were operating. Part of what I was talking about is looking at all the possibilities.
When I say possibilities, I mean at any intersection based on how the signal is designed and how the phasing is set up, there are possibilities of how a vehicle can arrive at that intersection.
For example at this intersection you just asked me

about your previous question before we went off the record would help explain your current question. You asked me if it was 2:00 a.m. or something and the driver is arriving and the signal is red.

You just asked me now I'm 300 feet back. I'm the approaching driver. There's one car ahead of me and they just got a green light. What will happen is as soon as that car leaves the detection loop, the signal is going to gap out because I'm too far back to actuate it.

Q How far back can you actuate it?

A That has varied over the years, but the current at that intersection is only about 40 feet. It's not very far. So if that first car gaps out, if we've got between a one and three second gap time on that phase, and that car gaps out, I'm going to receive my yellow very soon after I'm in the left turn bay. Does that make sense?

Q It does.

A There's a 300 foot gap between the car ahead of me and me.

Q I understand what you're saying. Suppose in the left--the farthest left turning lane there are vehicles every 30 feet in sort of a queue.

A So we have a long stack of vehicles.

Q A long stack of vehicles---

A (interposing) Sure.

Q ---in the left lane, and I'm in the second left turning lane. By second I mean the one not---
A (interposing) You're in the rightmost left turn lane.
Q The rightmost turning lane.
A Okay.
Q So the light goes green for this queue (indicating).
A Correct.
Q Are you telling me that---
A (interposing) And you're like 300 feet back?
Q And I'm 300 feet back going 45 miles an hour.
A Got you.
Q Are you telling me that my light, the light for this lane (indicating), is going to be red, but it's going to be green for the left-ish light?
A No. Those left turns are tied together.
Q All right. So then in that situation, in free flowing traffic, 300 feet back, 45 miles an hour, having to decelerate because I'm intending to turn---
A (interposing) Sure.
Q In that case, won't the driver in the rightmost left turning lane need more time to legally enter the intersection than the driver in the third, fourth, or fifth lane who is intending to go through?
A Two separate things here. The question about which driver needs more time to enter the intersection, my answer

doesn't change. In that situation, Driver B, the one who's in a lane with no cars in front of them, may never see a yellow light, and if they do, they're going to be very close to the intersection when they do because all the cars in the leftmost lane are going to keep actuating the signal.

If they're only 30 feet apart, that means that they've only got--there's really no effective gap between them and they're going to continuously hold the green because the gap time will be between one to two or one to three seconds. So they're going to hold the green long and steady.

So by the time our parallel left turning driver, Driver B, gets to the intersection, he may never see a yellow. If he does, he's going to be very close to the stop line where, a, he's already reduced his speed to make the turn and nobody is going to have a problem making a decision about continuing or stopping. So it doesn't matter. It's a moot point.

Q Are you saying the light stays green as long as there are people in the queue?

A Who are moving over the loops, yes. That's how it was designed.

Ms. Martineau: Until it times out.

A Green lights have---

Q (interposing) Your---

A (interposing) I'm sorry.

Q Your counsel said until it times out.

A That's what I was going to explain.

Q All right.

A Green lights--well, let me back up. There are two kinds of traffic signals. There's what we call a pretimed traffic signal and we have an actuated traffic signal. A pretimed is like we used to have in the middle of downtown Apex. It went 20 seconds in green for this direction and then 30 seconds for that direction, all day and all night.

And that was a great idea until the mayor decided that he got tired of having to wait on a green light at 2:00 in the morning when he was coming home from a party. And so he got DOT to put in an actuated--that's how it works.

Q Which mayor was this?

A ---to put in an actuated traffic signal. We went from the pretimed traffic signals that are not sensitive whatso- ever to traffic to actuated traffic signals. In an actuated traffic signal we have two green times. We have a minimum and a maximum.

So for example, on a left turn I don't know what the min and max is. But I might guess that the minimum might be in the range of maybe seven to ten seconds, maybe ten seconds, and a maximum could be as high as maybe 30 or 40 seconds because there's a big turning volume.

If one car pulls up, it's 2:00 a.m. and they wait on a red and they get a green, when they pull forward, the very second that the last metal component of their vehicle passes over and leaves the detection loop back behind the stop line, the signal controller starts looking for the next car, and if doesn't see one it gives up the green. It goes to yellow and red.

Q So if it's not within 40 feet, it will go immediately to yellow?

A I said 40 because I don't know how long the loop is.

Q All right.

A Not immediately. It looks for a gap. It's looking for a gap between vehicles. We don't expect vehicles to be following bumper to bumper. So we're looking for a predetermined gap between cars. My point is if you have a queue of cars in the left-hand most left turn lane and that queue of cars keeps driving over that loop and actuating it, it's going to extend the green, as Elizabeth said, until it maxes out.

A green expires because, a, it maxes out--there's just a bunch of cars that keep actuating it--or b, because it gaps out. There's a lack of cars, and the gap time as determined is reached.

Q But if it maxes out---

A (interposing) If it maxes out.

Q ---then the car in the rightmost left turning yellow could need more time to legally enter the intersection than a through intending vehicle.

Ms. Martineau: Well, why can't that car just stop?

A The left turning car by now, as I said, I would hope is through the intersection or very close to it when they get their yellow. The whole point here is---

Q (interposing) Well, what if it's not?

A Think about this.

Q What if the reason it turned yellow was because the green maxed out?

A Then you'd have a driver in a left turn who's slowing down to make a left--in a left turn lane that's slowing down to make a left turn. If they're at full speed, say 45-ish miles an hour, I expect them to be, you know, fairly far back, unless they're trying to beat the light.

Q So they're slowing down. Maybe they're at 32.5 miles per hour.

A A nice average speed.

Q A nice average speed.

A Between 45 and 20.

Q Right. So if they're at 32.5 miles an hour at that point, why does the formula assume they're at 20 miles an hour?

A The formula doesn't assume they're at 20 miles an hour at that point in time. The formula simply uses the inputted

20 miles an hour as a design speed. There's no place in the formula where the variables are listed below that says we're using 20 miles an hour because we assume that to be a speed at this point.

Q A different question.

A Okay.

Q If a vehicle is in the straight through lane, can that vehicle still turn left by later moving into the left turn lane at the same place?

A Well, they cannot do it safely.

Q Are you saying to me that if they're 300 feet back, let's say at Lori Millette's intersection, and there are two cars there, one in the turning lane and one in the straight lane, that the one in the straight lane cannot safely move into the turning lane?

Ms. Martineau: Objection to 300 yards back in the left intersection.

A You lost me a bit. Are you saying that we've got some cars in the left turn lane and a driver in the through lane decides to cut in front of them?

Q Ms. Glover has hypothesized at Lori Millette's intersection the left turn lane doesn't go 300 feet back.

Ms. Glover: I have no idea.

Q She has no idea. So maybe---

A (interposing) It goes 200 feet.

Q Okay. So what's to keep a car 300 feet back, moving the first 100 feet during the perception/reaction time over here (indicating), and then decide to move over to the left turning lane for the final 200 feet? Is there some law that stops that?

A No.

Mr. Stam: Would you all give us just a minute? We'll step out to see if we have anything further.

Ms. Martineau: That's fine.

The Reporter: Off the record. 1:40 p.m.

(A brief recess was taken.)

The Reporter: On the record. 1:42 p.m.

Mr. Stam: No further questions.

C R O S S - E X A M I N A T I O N 1:42 p.m.

By Ms. Martineau:

Q I have a couple of questions just to follow up on something that Mr. Stam asked you about today, one of which is there was a lot of talk about the ITE formula that is on Exhibit--it's one of these exhibits.

A I think it came up in one or two of them actually.

Q Right. It also has how NCDOT recommends designing yellow times for left turns. Have you designed--you've created traffic plans; correct?

A Many hundreds.

Q Okay. Did you actually sign and seal a signal plan, a traffic signal plan that calculated yellow times for left turns as well as straight throughs?

A I would sign and seal my calculations separate from signing and sealing a signal plan.

Q Okay.

A An engineer is required to sign and seal their calculations.

Q All right. You're aware that yellow times for left turns in general are shorter than yellow times for straight throughs, let's say for example if you were designing for a 45 miles an hour road?

A The times that we use on the signal plans on generally shorter, although sometimes they may be the same, depending on protected versus permitted left turns. The pure calculated values for left turns are going to be a shorter calculated time than for through movement.

Q Okay. As a traffic signal engineer, do you feel that it is appropriate in some circumstances to have shorter yellow times for left turns?

A Absolutely.

Q Why?

A It's common practice. We use a lower speed.

Q But beyond just being common practice, do you agree or disagree that it is appropriate that dedicated left turns have shorter yellow times?

A Absolutely. Going back to---
Q (interposing) Tell him why.
A I'm sorry. I jumped the gun there. Going back to what we've just been talking about, there are only a finite number of situations in which a driver can arrive in a left turn situation for a given intersection. And as I said before, we need to look at the whole sphere, the whole big picture, if you will, or small picture around that inter-section.
And if we look at the possibilities of arrivals and what traffic conditions could be combined with how the traffic signal is operating at that moment, the calculation using 20 miles an hour, if you will, a lower speed for left turns is extremely appropriate. It's appropriate and it works. It matches the possibilities of how a driver can arrive in that left turn lane, if in fact we have a dedicated left turn.
Q You were asked some questions today about using a 2.5 perception/reaction time versus NCDOT, 1.5 perception/ reaction time. And I'll represent to you that Mr. Henning yesterday said that he felt a 2.5 perception/reaction time plugged into the ITE formula was a better idea than the practice of using 1.5. Do you agree with that?
A No, I don't agree. I'd love to see his research or what he's quoting.

Q Why don't you agree with that?
A A couple reasons. Based on research that I've been a part of over the years, something around one second-ish is perfectly fine. And number one, one second is the current ITE formula. 1.5 happens to be the North Carolina use of that same formula, and that is our current practice, but 2.5 seconds is extremely long.
2.5 seconds comes from an ASTA recommendation to ITE. 2.5 seconds has been used for many years in roadway design--which is very separate from traffic design--for roadway design, to deal with unexpected responses to unexpected stimuli, for example, stopping sight distance. It's a very different scenario. There has been talk over the years of using one uniform time for everything, but one uniform time simply doesn't fit. It just doesn't fit.
Q Do you know what the generally accepted practice among traffic signal engineers is for using perception/reaction time today?
A For yellow and red calculations?
Q Right, yellow and red.
A Well, they're using a yellow calculation when they're running the whole thing together. What I see most often is one second.
Q Do you know what North Carolina traffic signal engineers use for perception/reaction time in North Carolina

today?

A 1.5 seconds, and it has been used for a while actually in North Carolina.

Q Are you familiar with what North Carolina traffic signal engineers--what their generally accepted practice was for using perception/reaction time back in 1999?

A It was one second.

Q Are you familiar with the generally accepted engineering practice for--what calculation North Carolina traffic signal engineers use for determining yellow and red clearance times today?

A The standard ITE formula.

Q Okay. You are currently licensed in many states; correct?

A Yes.

Q Okay. Are you familiar with how other jurisdictions calculate red and yellow times?

A Yes, not just from doing design work, but because I get involved in forensic cases in other states I am reviewing signal plans. Also when I'm teaching I have my students usually bring plans from their home cities and states, so I get to see a lot of plans and designs from around the country.

Q Do you know whether or not--you've looked at Mr. Henning's proposed yellow time calculations; correct?

A Yes, if that's in fact--it looks to me like that's what he's doing. He's proposing some new yellow time calculation.

Q Is that calculation anything that you've ever seen being used by traffic signal engineers?

A Not by anybody, no.

Q And you read Mr. Ceccarelli's deposition; correct?

A Yes, I did.

Q And you saw what he proposed for yellow times; correct?

A No. I never got the exhibits.

Q Okay.

A I heard some talk about it, but I didn't actually see the exhibits.

Q Are you familiar with what MUTCD's guidances are for the length of yellow time?

A Between three and six seconds.

Q Okay. Do you think it would be proper to use a yellow time of above six seconds?

A Oh, it may be proper.

Q How about at any of the intersections at play in this case?

A No, no, no. I mean I do work in other states where they've put traffic signals on 70 mile an hour roads and 65 mile an hour roads, and you see some very high yellow times.

Ms. Martineau: Thank you. Those are the follow-up questions I have based on Mr. Stam's questions.

R E D I R E C T E X A M I N A T I O N 1:49 p.m.

By Mr. Stam:

Q Do you know what the minimum yellow time was in North Carolina as decreed by NCDOT up until 2004?

A I want to say it was four seconds simply because the controllers could--well, not the controllers. The controllers were programmed for a minimum of four, but the monitors would kick out if we ran a--if the monitor was equipped in a monitor absent of yellow or a short yellow. They were programmed from the factory at four seconds I think was the reason we went with a minimum of four.

Q You think that was the reason?

A Yeah. I'm real certain. A lot of times stuff will be tied to equipment abilities, and a lot of the monitors couldn't handle anything shorter than four seconds. I mean I'm going from memory.

Q But it was four seconds?

A It was four seconds, yes.

Q All right. Second question: you mentioned one second as the standard during your redirect, but I didn't get what you were saying one second was the standard for.

A When Elizabeth asked me that question, she was asking me, you know, what I see as accepted standard engineering practice. And I was referring to just generally, in all areas of the country, where I look over lots of plans. The most typical time I see for perception/reaction time for yellow is one second.

Q Okay. But your book says 1.5 is the---

A (interposing) I said about 1.5.

Q About 1.5. Finally, would you agree that whatever method of calculation for the yellow change interval, it must conform to the laws of motion, which is a subject of physics?

A I don't disagree with that.

Mr. Stam: No further questions.

Ms. Martineau: That's it.

Mr. Stam: Thank you very much.

(The deposition was closed at 1:51 p.m.)

STATE OF NORTH CAROLINA

COUNTY OF WAKE

C E R T I F I C A T E

I, Alexandra Hatcher, Notary Public-Reporter, do hereby certify that **Daren Marceau, P.E.** was duly sworn or affirmed by me prior to the taking of the foregoing deposition, that said deposition was taken by me and transcribed by me, and that the foregoing pages 6 through 132 constitute a true and correct transcript of the testimony of the witness to the best of my ability, and that the witness reserved the right to review his testimony.

I do further certify that I am not counsel for or in the employment of either of the parties to this action, nor am I interested in the results of this action.

In witness whereof, I have hereunto set my hand, this 1st day of December, 2012.

/s/ Alexandra Hatcher

Alexandra Hatcher, CVR
Notary No. 19931480077

S I G N A T U R E

I have read the foregoing pages 6 through 132, which contain a correct transcript of the answers made by me to the questions herein recorded. My signature is subject to corrections on the attached errata sheet, if any.

____
(Signature of Daren Marceau, P.E.)

State of _____________________
County of ____________________

I certify that the following person personally appeared before me this day and I have personal knowledge of the identity of the principal or have seen satisfactory evidence of the principal's identity in the form of a________________ or a credible witness has sworn to the identity of the principal, acknowledging to me that he or she voluntarily signed the foregoing document for the purpose stated herein and in the capacity indicated:______________________________.
(Name of Principal)

Date__________________ _______________________________
(Official signature of Notary)

(Official Seal) ___________________, Notary Public
(Notary's printed or typed name)

My commission expires_________.

****

I, Alexandra Hatcher, the officer before whom the foregoing deposition was taken on October 31, 2012, certify that the foregoing transcript was delivered to the witness either directly or through the witness' attorney or through the attorney retaining the witness on _______ and that as of this date I have not received the executed signature page.

Therefore, more than 30 days having elapsed since receipt of the transcript by the witness, the sealed original transcript was filed with attorney for Plaintiffs on ______ by means of US Priority Mail, in accordance with Rule 30(e) of the North Carolina Rules of Civil Procedure.

__________________ ________________________
Date Alexandra Hatcher, CVR
Court Reporter

PLAINTIFF'S DEPOSITION EXHIBIT 1 Marceau 10/31/12 PENGAD 800-631-6989

Curriculum Vitae
Daren E. Marceau, P.E.

President, Forensic Traffic Specialists, PLLC

Professional Summary

After several years as a police officer followed by many years in the engineering design business Daren Marceau now serves as an investigator and expert witness with a focus on traffic crash reconstruction involving traffic control devices. Mr. Marceau is a nationally recognized author and lecturer on traffic signals, signs, and pavement markings, their role in traffic crashes, and reconstructing crashes involving traffic control devices. His experience includes investigating and reconstructing passenger and commercial vehicle, bicycle, pedestrian, sport utility, and motorcycle accidents. In addition to being a court-qualified expert in traffic signal design, civil and traffic engineering, and several other areas of engineering and human factors, Mr. Marceau also possesses significant professional and personal experience in bicycling and motorcycling.

Professional Development

Pedestrian and Bicycle Accident Reconstruction, Institute of Police Technology and Management
Basic, Intermediate, and Advanced Highway Work Zone Safety, Institute for Transportation Research and Education
Work Zone Traffic Control Safety Certification, International Municipal Signal Association
Traffic Signal Technician Certification, International Municipal Signal Association
Commercial Vehicle Inspection, Accident Investigation, and Reconstruction, Institute of Police Technology and Management
Basic Law Enforcement Training, Raleigh Police Department, North Carolina
Traffic Signal Design at Local Intersections, Georgia Institute of Technology
Traffic Signal Design, North Carolina Department of Transportation
Traffic Signal Operation in Signal Systems, Institute for Transportation Research and Education
Crash Data Retrieval Tool Operator Course, Institute of Police Technology and Management

Instructor

Traffic Control Devices and Their Role in Traffic Crashes
Numerous technical sessions on traffic signal design and special topics in traffic signal operations
Low speed/soft tissue injury collisions: understanding the collision, vehicle, and occupant dynamics
Bicycle and pedestrian collisions
Accident Reconstruction at Traffic Signal Intersections, basic and advanced classes
Traffic Crashes Waiting To Happen: Traffic Control Devices That Violate Expectancy

Affiliations

National Society of Professional Engineers
International Law Enforcement Educators and Trainers Association
Institute of Transportation Engineers
Expert Witness Council, Institute of Transportation Engineers
National Association of Professional Accident Reconstructionists
National Association of Traffic Accident Reconstructionists and Investigators
International Municipal Signal Association

Authored Publications

Accident Reconstruction at Traffic Signal Intersections, © 2006 Kinetic Energy Press

Professional Experience

President, Forensic Traffic Specialists, PLLC, 2007-present

Forensics and Traffic Signal Design Practice Builder, Kimley-Horn and Associates, Inc., Raleigh, NC, 2003–2007

Associate and Project Manager, Kimley-Horn and Associates, Inc., 1995–2003

Graduate Research Assistant, North Carolina State University, 1994-1995

Survey Instrument Technician, J.Y. Phelps Surveying, 1992-1994

Police Officer, Raleigh, NC Police Department, 1986-1988

Professional Credentials

Master of Science in Civil Engineering, North Carolina State University, 1995

Bachelor of Science in Civil Engineering, North Carolina State University, 1994

Registered Professional Engineer: North Carolina #24910, Virginia #40957, South Carolina #24139, Florida #63229, and Georgia #PE030533

Certified Property and Liability Claims Instructor, North Carolina Department of Insurance

Certified Traffic Signal Technician and Signal Inspector, and Signs and Markings Technician, IMSA

113 Montauk Point Place, Cary, NC 27513 CELL 919 215 8994 dmarceau@trafficsignalexpert.com

North Carolina State University
CIVIL ENGINEERING CURRICULUM

Degree earned: B.S. in Civil Engineering

For students entering after July 2010 (Sum2 '10)

FRESHMAN YEAR

Fall Semester		Credits
CH 101	Chemistry – A Molecular Science	3
CH 102	General Chemistry Laboratory	1
E 101	Intro. to Engineering & Prob. Solving	1
E 115	Intro. to Computing Environments	1
ENG 101	Academic Writing and Research	4
MA 141	Calculus I	4
PE 10X	Fitness & Wellness Course*	1
		15

Spring Semester		Credits
CSC 112	Intro. to Computing-Fortran	3
EC 205	Economics (GEP Soc Sci Req*)	3
MA 241	Calculus II	4
PY 205	Physics for Engrs. & Sci. I	4
PE XXX	Phys. Ed/Healthy Living Elective*	1
		15

SOPHOMORE YEAR

Fall Semester		Credits
CE 214	Engr. Mechanics - Statics	3
GC 120	Foundations of Graphics	3
MA 242	Calculus III	4
PY 208	Physics Engr. & Sci. II	4
GEP Requirement*		3
		17

Spring Semester		Credits
CE313	Mechanics of Solids	3
CE 382	Hydraulics	3
MA 341	Applied Diff. Equations I **or**	3
MA 305	Elem. Linear Algebra	
MSE 200	Mech. Prop.of Structural Materia	3
GEP Requirement*		3
		15

JUNIOR YEAR

Fall Semester		Credits
CE Area Intro Elective I[1]		3
CE Area Intro Elective II[1]		3
CE Area Intro Elective III[1]		3
CE 390	Engineering Economics	1
ST 370	Prob. & Statistics for Engrs.	3
GEP Requirement*		3
		16

Spring Semester	Credits
CE Area Intro Elective IV[1]	3
CE Area Intro Elective V[1]	3
CE Elective I[2]	3
Basic Science Elective[3]	3
CE Lab if needed (CE324, CE381)	0
GEP Requirement[1]	3
	15

SENIOR YEAR

Fall Semester		Credits
CE Elective II[2]		3
CE Elective III[2]		3
CE Elective IV[2]		3
CE/MA/SCI Elective[4]		3
COM 110	Public Speaking **or**	3
ENG 331	Comm. for Engr. & Tech.	
MAE 301	Thermodynamics **or**	3
ECE 331	Principles of Electrical Engr.	
		18

Spring Semester	Credits
CE Elective V[2]	3
CE Elective VI[2]	3
CE Elective VII[2]	3
GEP Requirement*	3
GEP Requirement*	2-3
	14-15

Minimum Credit Hours Required for Graduation = 126

***GEP REQUIREMENTS** to be selected from the list approved by the College of Engineering.

[1]**CE Area Intro Elective** to be selected from the approved list (on back)

[2]**CE ELECTIVES** to be selected from the approved list (on back)

[3]**Basic Science Elective** Select one: BIO 183, MEA 101

[4]**CE/MA/SCI Elective** to be selected by student and adviser

A

10/14/10

CIVIL ENGINEERING CURRICULUM
COURSE LISTING WITH PRE- AND COREQUISITES IN PARENTHESES
For students entering after July 2010 (Sum2 '10)

FRESHMAN YEAR

Fall Semester

CH 101 (CoReq. CH 102)
CH 102 (CoReq. CH 101)
E 101
E 115
ENG 101
MA 141
PE 10X*

Spring Semester

CSC 112 (CoReq. E 115 and MA 141)
EC 205 (GEP Requirement)*
MA 241 (C- or better in MA 141)
PY 205 (C- or better in MA 141)
PE XXX Phys. Ed//Healthy Living Elective*

Matriculation Requirements:	1. C- or Better in CH 101, CH 102, E 101, MA 141, MA 241, PHY 205 2. Satisfactorily (S) in E 115

SOPHOMORE YEAR

CE 214 (GPA 2.5, C- or better in PY 205, CoReq. MA 242)
GC 120
MA 242 (C- or better in MA 241)
PY 208 (C- or better in PY 205 and MA 241)
GEP Requirement*

CE 313 (MA 242, C-or better in CE 214)
CE 382 (CE 214, CoReq. MA 341, MA 305 or ST 370)
MA 341 (MA 242) **or**
MA 305 (CoReq. MA 242)
MSE 200 (CH 101)
GEP Requirement*

JUNIOR YEAR

(All CE courses listed below also require Junior Standing in CE, CEM, or ENE)

CE Area Intro Elective I[1]
CE Area Intro Elective II[1]
CE Area Intro Elective III[1]
CE 390 (CSC 112, CoReq. MA 341 or
ST 370 (MA 241)
GEP Requirement*

CE Area Intro Elective IV[1]
CE Area Intro Elective V[1]
CE Elective I[2]
Basic Science Elective
CE Lab if needed (CE 324, CE 381)
GEP Requirement*

SENIOR YEAR

CE Elective II[2]
CE Elective III[2]
CE Elective IV[2]
CE/MA/SCI Elective[4]
COM 110 **or**
ENG 331 (Junior standing)
MAE 301 (MA 242, PY 208) **or**
ECE 331 (MA 241, PY 208)

CE Elective V[2]
CE Elective VI[2]
CE Elective VII[2]
GEP Requirement*
GEP Requirement*

*GEP Requirements to be selected from the list approved by the College of Engineering
[1]CE Area Intro Elective to selected from the approved list
[2]CE Electives to be selected from the approved list
[3]Basic Science Elective (select one): BIO 183, MEA 101
[4]CE/MA/SCI Elective to be selected by student and advisor

CE ELECTIVES

- Pick at least one CE AREA Introductory course (**I**) in five different areas for a total of five (5) courses.
- Pick an additional seven (7) courses, at least one of which must be a Capstone Design Course (**C**).
  At least one course must be an additional design course (**D**) in an area different from that of the capstone.
-Pick at least three (3) CE laboratory experiences (**L**)

				Hrs	Sem	Pre and Co-Requisites
Coastal Engineering and Water Resources						
	L	**CE 381**	**Hydraulics Sys. Meas. Lab**	1	F/S	CoReq. CE 382
I	**D**	**CE 383**	**Hydrology & Urban Water Systems**	1	F/S	C- or better in CE 382
I		**CE 487**	**Intro. To Coastal and Ocean Engineering**	3	S	Senior standing and CE 382
	D	**CE 488**	**Water Resources Engineerieng**	3	F	CE 339 or equivalent; CoReq. CE 383
C	**D**	**CE 480**	**Water Resources Engineering Project**	3	F	CE 390, C- or better in CE 382 and CE 383
Computing and Systems						
I		**CE 337**	**Civil Engineering Computing**	3	S	CSC 112, CoReq. MA 341 or MA 305
I		***CE 339**	**Civil Engineering Systems**	3	F	CSC 112, CoReq. MA 341 or MA 305
Construction Engineering and Management						
		***CE 261**	**Construction Engineering Systems**	3	S	CEM Majors; CoReq. ST 370
I	**D**	**CE 367**	**Mech. and Elec. Systems in Buildings**	3	S	CE 382
I		**CE 463**	**Construction Estimating Plan. And Control**	3	F	CE 261 (Priority to CEM)
1	**D**	**CE 466**	**Building Construction Engineering**	3	F	CoReq. CE 327 (Priority to CEM)
Environmental						
I		**CE 373**	**Fundamentals of Environmental Engineering**	3	F/S	CoReq. CHE 205 or CE 382
		CE 479	**Air Quality**	3	S	CE 373, CE 382; CoReq. ST 370
	D	**CE 476**	**Air Pollution Control**	3	F	CE 373, CE 390, MAE 301; CoReq. ST 370
	D	**CE 477**	**Principles of Solid Waste Engineering**	3	S	CE 373, CE 390, CE 382; CoReq. CE 342
	D	**CE 484**	**Water Supply and Waste Water Systems**	3	F	CE 373, CE 382
Geotechnical						
I	**L**	**CE 342**	**Engineering Behavior of Soils & Foundations**	4	F/S	C- or better in CE 313; CoReq. CE 382
		CE 435	**Engineering Geology**	3	Alt S	MEA 101 and Junior standing
	D	**CE 443**	**Seepage, Earth Embank., and Retain. Str.**	3	Alt S	CE 390, C- or better in CE 342
C	**D**	**CE 440**	**Geotech. Engineering Project (Foundations)**	3	F	CE 390, C- or better in CE 342
Structural						
	L	**CE 324**	**Structural Behavior Meas.**	1	F/S	C- or better in CE 313
I	**D**	**CE 327**	**Reinforced Concrete Design**	3	F/S	CE 332, C- or better in CE 313
		CE 325	**Structural Analysis**	3	F/S	CSC 112, C- or better in CE 313
		CE 425	**Introduction to Matrix Structural Analysis**	3	F/S	C- or better in CE 325
I	**D**	**CE 426**	**Structural Steel Design**	3	F/S	C- or better in CE 313
C	**D**	**CE 420**	**Structural Engineering Project (Buildings)**	3	S	CE 327, CE 390, CE 426, CoReq. CE 425
C	**D**	**CE 421**	**Structural Engineering Project (Bridges)**	3	F	CE 327, CE 390, CE 426, CoReq. CE 425
Transportation						
I	**D**	**CE 305**	**Traffic Engineering**	3	F/S	CE or CEM Majors, ST 370
		CE 401	**Transportation Systems Engineering**	3	F	C- or better in CE 305
	D	**CE 402**	**Traffic Operations**	3	F	C- or better in CE 305
	D	**CE 403**	**Highway Design**	3	S	C- or better in CE 305
	D	**CE 413**	**Principles of Pavement Design**	3	F	CE 332; CoReq. CE 342
C	**D**	**CE 400**	**Transportation Engineering Project**	3	S	CE 390, C- or better in CE 305; and one of the following: CE 401, CE 402, CE 403 or CE 413
Other Civil Engineering Courses						
		CE 215	**Engineering Mechanics-Dynamics**	3	F/S	Minimum GPA =/> 2.5, Grade of C- or better in CE 214 and MA 242
I	**L**	**CE 332**	**Materials of Construction**	3	F/S	MSE 200, Jr. standing in CE or CEM
	L	**CE 301**	**Civil Engineering Measurements & Surveys**	3	F/S	CEM, CE or ENE majors (Priority to CEM)

*Credit for Both CE 261 and CE 339 is not allowed.

Notes: 1. Due to departmental constraints, not every course may be taught in every semester suggested in the table above. Students should Check with the online course schedule for courses to be taught in the upcoming semester.

2. Undergraduates with a major GPA >2.5 and appropriate prerequisites may elect 500-level courses to satisfy their CE electives.

10/21/10

Accident Reconstruction At Traffic Signal Intersections

A Manual for Law Enforcement Personnel, Accident Reconstruction Professionals, Traffic Engineers, and Forensic Engineers

Daren E. Marceau, P.E., M.S.
Forensic Traffic Specialists PLLC

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Technical Book Publishing

Kinetic Energy Press

Rocklin, California

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ask if more than one max green is associated with the controller, and if so, which one was timing at the time of the accident.

4.3 Yellow Interval Timing

Traffic engineers refer to yellow intervals as the *yellow change interval.* Specific guidelines usually exist in each jurisdiction for calculating yellow times since yellow is usually expected to mean a driver needs to slow down and prepare to stop before the red signal.

Yellow change interval calculations take into consideration a normal deceleration rate of about 11 feet per second and a driver perception/reaction time of about 1.5 seconds. The yellow calculations also account for the *approach grade.* Since gravity causes downhill acceleration, more yellow time is allowed for a vehicle on a downhill, or negative grade, approach.

Some traffic signal agencies calculate standard yellow times for any given approach speed and/or grade and publish them in a table. For example, a flat 45 mph phase might use 4.0 seconds of yellow, and a flat 55 mph phase might use 5.1 seconds of yellow time. This method leads to consistency between intersections, and provides a consistent message to drivers passing through many intersections.

Other agencies prefer to calculate every yellow clearance time for every phase on every approach for every signal. This method provides custom yellow times for every intersection. It also provides the driver with consistent feelings of perceived deceleration at every intersection, but it does not provide consistent yellow times between intersections for drivers.

Understanding yellow change interval times is critical for the crash investigator. Many times, locating the vehicles in and around the intersection before the crash can be tied to yellow intervals. Yellow intervals are easily read on the signal controller screen. This is yet another instance where the local traffic engineer can help, in this case by downloading the yellow times to be used in accident analysis.

4.4 Red Interval Timing

The yellow change interval is intended to provide drivers with time to slow and to come to a stop at the intersection. In all jurisdictions of which we are aware, it is legal to enter an intersection on yellow but not on red. Thus a driver is allowed to enter the intersection at the last moment of a yellow interval before the red signal is displayed. Traffic engineers usually try to accommodate this legal driver as they proceed across the intersection by not providing a green signal to conflicting traffic until the clearing driver has sufficient time to move completely through the intersection.

In most jurisdictions the *red clearance interval* is calculated as some function of the distance from the stop line to the far side of the intersection, or the *clearance distance* a driver would navigate in going through the intersection. Typically this clearance distance is divided by the speed for the approach, and a clearance time is the resultant value. It is common to see red clearance intervals from 1 second to 3 seconds for typically sized intersections.

For example, consider an intersection where the northbound Phase 2 yellow is 4 seconds and the red interval is 2 seconds. As the Phase 2 green expires and the clearance intervals begin to time, conflicting phases have been sitting on red for some time. When Phase 2 receives a red signal, Phase 4 — a side street — has been in red and will remain in red until the Phase 2 red expires after 2 seconds. Then and only then will Phase 4 receive its green indication. As a result, the entire intersection is in red for a period — in this instance, it is timed for 2 seconds. This is called an all-red interval. Many agencies use this method. The all-red method forces all phases to sit on red for a short time while that one last driver who entered the intersection late, but legally, safely crosses through the intersection.

Returning to the previous example, by the time the Phase 4 driver starts forward — based on the all-red time and the start-up time to move forward — the Phase 2 driver is well past the far side of the intersection. It is because of this "extra clearance" from the start-up delay that some jurisdictions don't use an all-red clearance time. In some locations, as soon as the Phase 2 driver receives a red signal, the Phase 4 driver receives a green indication. With the start-up delay, some locations trust the Phase 2 vehicle should be well through the intersection.

Some agencies say the practice of no all-red time promotes less wasted time at intersections. Other agencies favor an all-red for what they claim as increased safety. This option for signals to use or not use the all-red simply means that an accident investigator must consider the all-red possibility in assessing factors in the crash. Like the yellow interval times, it is easy to obtain the red times from the controller.

Most signal agencies maintain a *logbook* in their signal cabinets or some other form of recordkeeping back at their office. Every time a technician or engineer goes into the signal cabinet to maintain, repair, or change anything a written record is made of the visit, the date, and the purpose. It is always a good idea to review the logbook to look for any changes that might have had an impact on the operations of the controller or that may have occurred after a certain accident.

Also, a monitor in the signal cabinet can send the intersection into flashing mode if abnormal operation takes place. Agencies are expected to keep records of any need to reset flashing or repair out-of-service signals. If the agency has no record of the signal at the accident needing maintenance or repair on the date of the crash, it is customary to trust that the signal was operating as designed and constructed. It is accepted to assume that the yellow and red clearance intervals programmed into the controller were being used as programmed. This line of reasoning has been used in trials. We are not aware of any jurisdictions regularly disallowing analysis and testimony based on signal controller clearance timing values. .

4.5 Pedestrian Interval Timing

Just as green, yellow, and red intervals are calculated for vehicular phases, pedestrian phase *WALK* and flashing *DON'T WALK* intervals are also calculated.

talking with the local traffic engineer to understand how delays are used in local situations.

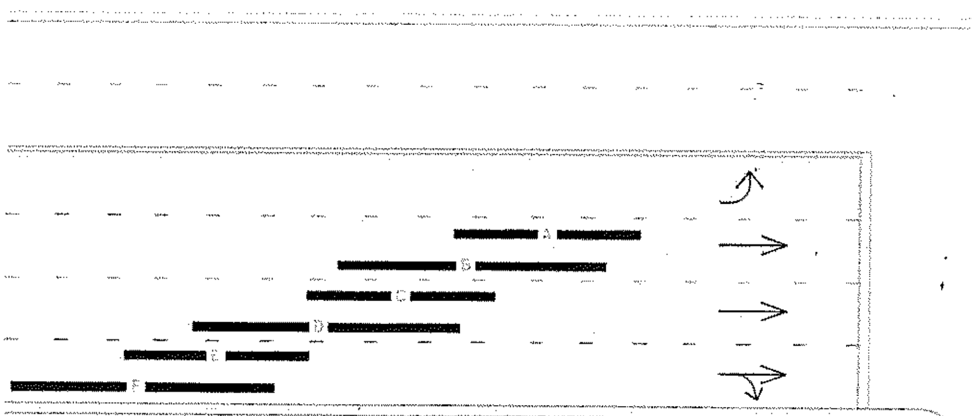
Key points about delays should be remembered during accident investigation and reconstruction:

- Delays are associated with the loop, not with the phase. For example, Phase 4, the minor street phase, might have three loops with one loop in each lane. A 15-second delay might be used on the right-turn loop, a 3-second delay might be programmed on the left-turn loop, and no delay might be programmed on the through lane loop. Phase 4 will be called from all of these loops, but after different waiting times.
- Loop detectors can fail, so during an accident investigation be sure to ask a signal technician or engineer to assist during the review of design plans and controller/detector settings, and actually observe traffic on the loop. Failed loop detectors often place a permanent call to the controller for service thus a green interval will be timed on every cycle.

5.2 Dilemma Zones

Traffic engineers understand that drivers presented with yellow signal indications at a certain distance from the stop line sometimes have trouble deciding if they should stop or move through the intersection. Traffic engineers call this distance from the stop line the *dilemma zone*. The dilemma zone is defined as the range of distance from a stop line where a driver is uncertain as to whether to slow and stop or to continue through the intersection.

There are near (downstream) and far (upstream) limits of dilemma zones for each approach speed. When determining detection loop locations, traffic engineers incorporate the desire that drivers should not receive a yellow signal when they are inside the dilemma zone. Figure 5.3 shows the distances from the stop line associated with dilemma zones for various speeds.



	SPEED (mph)	UPSTREAM BOUNDARY (ft)	DOWNSTREAM BOUNDARY (ft)
A	30	90	175
B	35	102	254
C	40	122	284
D	45	152	327
E	50	172	353
F	55	234	386

Figure 5.3 – Dilemma Zone Distances
Adapted from class notes for NCDOT's Traffic Signal Design class, circa 1999.

To limit the number of drivers being caught in the dilemma zone, it is common practice to locate an additional loop beyond the far end of the dilemma zone. When the signal controller senses a vehicle is entering the dilemma zone by this additional loop being activated, it will extend the green to allow the vehicle to get closer to the stop line before showing a yellow signal.

5.3 Detector Extension

A loop can be programmed to continue telling the signal controller that a vehicle remains on the loop even after it has left the loop. Called *detector or loop extension,* the loop continues to show a vehicle as being detected for a predetermined time after the rear bumper of the vehicle leaves the loop.

Figure 5.4 shows a car entering the near edge of the detection area provided by a 6-foot by 6-foot square loop placed 300 feet in advance of the stop line. If the car is 20-feet long and it is traveling 45 mph then it will take 0.4 seconds for the its detection capabilities. As traffic is rerouted onto new lanes, the signal technician can easily draw new detection zones on the video monitor in the signal cabinet to detect traffic in the new lanes. This can be done without disruption to traffic, and with much greater worker safety than sending a crew into traffic to install loops.

8.3 Red Light Running Cameras

It is undeniable that red light running contributes to intersection crashes. Many traffic agencies now use automated video systems to catch drivers as they violate red lights. Most *red light camera* systems use traditional loop detection to identify an offender running a red light, and then use a camera with a telephoto lens to photograph the offending vehicle's license plate.

Figure 8.2 – Red Light Camera Detection Loops

A typical red light camera system includes a series of small in-pavement loops installed near the stop line. The signal from these loops is monitored by a processor either in the traffic signal cabinet or in another cabinet, which is connected to the traditional signal cabinet with conduit and wiring. An example of a series of red light loops is shown in Figure 8.2, and a red light camera is shown in Figure 8.3.

Red light cameras are often in a tamper-resistant housing, and, as shown in Figure 8.3, may include an auxiliary strobe light to illuminate the offending vehicle at night.

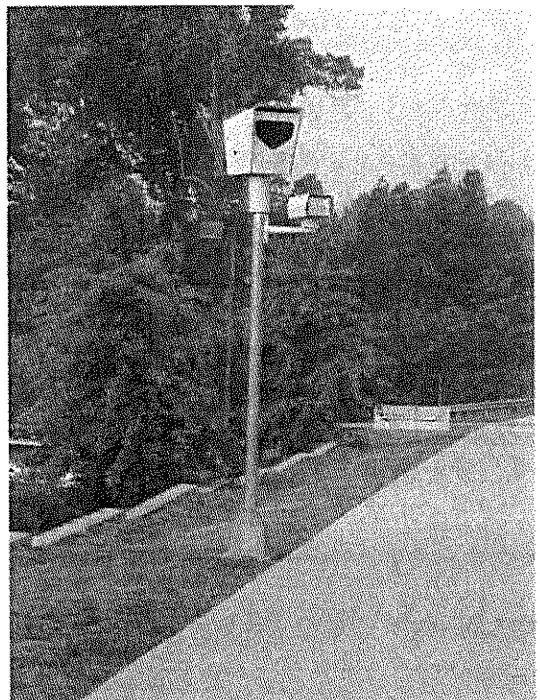


Figure 8.3 – Red Light Camera

The red light running processor senses a vehicle in motion over the loops. When this motion is concurrent with a red signal interval on the monitored phase, the red light system declares a violation situation. Systems differ slightly, but many will capture one photo of the offending vehicle across the stop line with the red signal displayed and one photo with a close-up of the license tag on the vehicle. Both photos are mailed to the registered owner of the offending vehicle and a civil penalty or fine is demanded. Some systems even capture and print on the photos the length of time that the signal had been in the red interval when the vehicle triggered the red light system, as well as the speed of the vehicle. As the offending vehicle passes over the series of detection loops, each loop acquires and then subsequently drops the presence call from the vehicle. The system is programmed to calculate, based on the rate of acquisition and drop, the vehicle's speed.

Investigators should be aware that red light cameras might be owned by a local or state agency, but they might be operated under contract by a private firm. Many traffic agencies contract services to outside vendors for red light system management and maintenance. A conversation with the local traffic engineer should identify the correct party from whom red light photos and data may be obtained.

Subject: Signal Plan Review Comments - Harrison Avenue at SAS Entrance
Date: Fri, 3 Feb 2006 09:23:00 -0500
From: Dick.Moore@TownofCary.org
To: "Pamela L. Alexander" <palexander@dot.state.nc.us>
CC: al.rager@sas.com, Bryan.Hayes@townofcary.org, Dale.Privette@TownofCary.org, Don Darity <ddarity@rameykemp.com>, "Greg A. Fuller" <gfuller@dot.state.nc.us>, Mike.Billings@TownofCary.org, "Richard E. Mullinax" <rmullinax@dot.state.nc.us>, Steve Johnson <stevejohnson@dot.state.nc.us>, Tom.Reilly@townofcary.org, Wesley.Vo@townofcary.org

Good morning Pamela,

The traffic signal plan proposes to reduce yellow times from 4.5 seconds(existing) to 3.0 to 3.3 seconds for left turns and side street phases along Harrison Avenue. With a speed limit of 45 mph for Harrison Avenue, it would appear that this major decrease in yellow time could create a safety problem.

MUTCD
Section 4D.10 Yellow Change and Red Clearance Intervals

Guidance:

A yellow change interval should have a duration of approximately 3 to 6 seconds.
The longer intervals should be reserved for use on approaches with higher speeds.

Traffic signal controller manufacturers also design controllers for a minimum of 3 seconds for all normal conditions as a safety factor.

The operating speeds on Harrison Avenue are higher speeds. While the left turning speed may be 20-25 mph at the stopbar, the approach speed approaching the traffic signal is much greater.

The Town of Cary would recommend a slow reduction in yellow time (no more than 0.5 seconds per six months), and conduct accident studies at the intersection to ensure that the accident rate does not increase.

The North Carolina section of the Instutite of Transportation Engineers (ITE) "2005 Task Force for Yellow and Red Intervals"report indicates "excessive red time ... to be greater than 3.0 seconds."
Long red clearance intervals encourages red light running.

As a result, the Town of Cary recommends all reds be no longer than 3 seconds.

We hope this information is helpful in your review of traffic signals maintained by the Town of Cary.

C. Richard(Dick) Moore
Town Traffic Engineer
Engineering Department
Town of Cary
318 North Academy Street
Cary, North Carolina 27512-8005
919-462-3937
919-460-4935 fax
dick.moore@townofcary.org (Note: new e-mail address)

"Pamela L. Alexander" <palexander@dot.state.nc.us>

02/01/2006 03:11 PM

To
Don Darity <ddarity@rameykemp.com>

cc
Dale.Privette@TownofCary.org, Steve Johnson <stevejohnson@dot.state.nc.us>, al.rager@sas.com, Dick.Moore@TownofCary.org, Wesley.Vo@townofcary.org, Tom.Reilly@townofcary.org, Mike.Billings@TownofCary.org, Bryan.Hayes@townofcary.org, "Greg A. Fuller" <gfuller@dot.state.nc.us>, "Richard E. Mullinax" <rmullinax@dot.state.nc.us>

Subject
Re: Signal Plan Review Comments

With regard to clearance calculations, unless there are mitigating circumstances at a specific intersection that would warrant changing from our standard practice, the standard practice should be followed. A personal preference is not sufficient justification to discard the recommendations of
the NCSITE Task Force. Without mitigating circumstances at this location, Ramey Kemp & Associates should follow the standard practice for calculating clearance times. If you wish to discuss further, please let me know.

Don Darity wrote:

> Dale,
>
> Thank you for the response. By copy of this e-mail, I will forawrd your
> comments to NCDOT-S&G for their input on the clearance issues. As you
> are probably aware that this intersection is on the State system and
> NCDOT dictates the way clearance times are caclulated. I am also
> requesting Steve Johnson respond to whether or not we can reuse the
> existing cabinet pad. If cable routing and splice detail designs are
> required, RKA will need approval from our client before proceeding with
> the design work. All other comments will be addressed and corrected.
>
> Don Darity, P.E.
>
> Ramey Kemp & Associates, Inc.
> 4928-A Windy Hill Drive
> Raleigh, NC 27609
> (919) 872-5115 - Phone
> (919) 872-0480 x 103 - Direct Line
> (919) 878-5416 - Fax
>
> -----Original Message-----
> From: Dale.Privette@TownofCary.org [mailto:Dale.Privette@TownofCary.org]

>
> Sent: Friday, January 13, 2006 10:01 AM
> To: Don Darity
> Cc: Dick.Moore@TownofCary.org; Wesley.Vo@townofcary.org;
> Tom.Reilly@townofcary.org; Mike.Billings@TownofCary.org;
> Bryan.Hayes@townofcary.org
> Subject: Signal Plan Review Comments
>
> Good Morning Don,
>
> Th eTown of Cary has completed its review of the preliminary signal plan
> you submitted for the intersection of Harrison Avenue and SAS Campus
> Drive
> (05-1327) on December 22, 2005. We have the following review comments
> for
> you to consider:
>
> 1. With regard to clearance calculations and timings shown in the
> timing
> chart, Dick Moore, Cary's Traffic Systems Manager, prefers that ALL
> yellow
> times in the Town of Cary be greater than or equal to 3.5 seconds. Mr.
> Moore also prefers an absolute maximum all red time of 3.0 seconds at
> ALL
> signals in Cary. Please review your total clearance time calculations
> and
> make adjustments accordingly, keeping in mind Mr. Moore's preferences.
> 2. Also, in the Timing Chart, you had indicated with an asterisk that
> the
> yellow clearance times may be field adjusted. We believe this is a
> mistake.
> 3. For proposed loop 1A, please bring the lead-in out of the forward
> end
> of this loop, then eastward across the northbound lanes and then
> trenched
> over to the signal cabinet.
> 4. The Town of Cary currently has a fiber optic drop cable that is
> spliced
> into an interconnect center in the existing signal cabinet. Are you
> proposing to reuse the existing cabinet foundation and install the new
> cabinet on it? If so, we assume you will reuse the existing fiber modem
> and cables, but there will need to be details in the specifications
> directing the contractor to re-splice the Town's fiber drop into a new
> interconnect center provided by the contractor.
> If, however, you are proposing the installation of a new cabinet
> foundation, then the Town will require you to develop cable routing
> plans
> and splice diagrams to be included in your plan set, in addition to the
> specifications language and appropriate pay items.
>
> Please consider these comments and make changes to your plans as needed.
> Let me know if you have any questions.
>
> Dale W. Privette
> Senior Engineer
> Town of Cary
> Post Office Box 8005
> Cary, NC 27512-8005
> Tel. (919) 462-3833
> FAX (919) 460-4935

--

Pamela L. Alexander, PE
S & G Special Projects Engineer
919-715-8333

Subject: Re: Walnut Street Lane Addition Project - Plan Review Comments
Date: Fri, 30 Jun 2006 07:54:18 -0400
From: "Greg A. Fuller" <gfuller@dot.state.nc.us>
Organization: North Carolina Department of Transportation
To: Dick.Moore@TownofCary.org
CC: Steve Johnson <stevejohnson@dot.state.nc.us>

PLAINTIFF'S DEPOSITION EXHIBIT 5 Marien PENGAD 800-631-6989

Dick,
Please don't assume our comments concerning the clearance intervals mean we are opposed to red light cameras. As a matter of fact, a working group of the Department's Executive Committee for Highway Safety has been seriously discussing the red light cameras as a strategy to improve intersection safety statewide. As you know, the NCSITE Task Force discussed the red light cameras and agreed the presence or absence of red light cameras would not determine how the clearance intervals would be calculated. We feel a 0.5 second reduction every 6 months of the yellow change interval is excessive. I suggest we discuss this issue with Don Darity and Steve Johnson to see if we can determine a more appropriate timeframe to reduce the yellow change interval. If the Town of Cary believes drivers should be given additional leeway, the red light camera system can increase the time into the red clearance before a violation is recorded. Once again, we will use the standard practice recommended by the NCSITE Task Force unless there are extraordinary circumstances or additional engineering data at the specific location. Our personal opinions do not meet this criteria. We can meet to discuss further if needed. Thanks

Dick.Moore@TownofCary.org wrote:

> *Good morning Greg,*
>
> *The Town of Cary is disappointed that NCDOT by these comments will increase the number of Red light violations by Cary residents at the intersection of Walnut and Meeting Street. Because most red light camera installations have been removed across the country because of shorter yellows being installed, we can only assume that NCDOT is opposed to Red light cameras.*
>
> *The Town of Cary continues to maintain:*
>
> *Red light cameras are an useful tool to make intersections safer and reduce red light violations.*
>
> *No reduction of yellows at Red light camera locations.*
>
> *The North Carolina section of the Institute of Transportation Engineers (ITE) "2005 Task Force for Yellow and Red Intervals"report indicates "excessive red time ... to be greater than 3.0 seconds. Long red clearance intervals encourages red light running and may increase accidents.*
>
> *Reduction of yellow time from 5.0 seconds to 3.0 seconds in ten(10) weeks is too short and excessive and will create an increased safety hazard. We recommend no more than 0.5 second reduction every six months.*
>
> *These issues were raised early in February in our meeting and in e-mails and remain unresolved.*
>
> *C. Richard(Dick) Moore*
> *Town Traffic Engineer*
> *Engineering Department*
> *Town of Cary*
> *318 North Academy Street*
> *Cary, North Carolina 27512-8005*

> 919-462-3937
> 919-460-4935 fax
> dick.moore@townofcary.org (Note: new e-mail address)
> ----- Forwarded by Dick Moore/Cary on 06/29/2006 08:01 AM -----
>
> "Pamela L. Alexander" <palexander@dot.state.nc.us>
> 06/28/2006 01:56 PM
>
> To
> Don Darity <ddarity@rameykemp.com>, Dale.Privette@TownofCary.org
> cc
> Hemang Surti <hsurti@rameykemp.com>, Grant Livengood <glivengood@mckimcreed.com>, Gordon Rose <GRose@mckimcreed.com>, Mike.Billings@TownofCary.org, Dick.Moore@TownofCary.org, Wesley.Vo@townofcary.org, Bryan.Hayes@townofcary.org, Jane.Stricklin@TownofCary.org, "Richard E. Mullinax" <rmullinax@dot.state.nc.us>, Steve Johnson <stevejohnson@dot.state.nc.us>, "Kelly L. Becker, PE" <kbecker@dot.state.nc.us>, "Greg A. Fuller" <gfuller@dot.state.nc.us>
> Subject
> Re: Walnut Street Lane Addition Project - Plan Review Comments
>
> Dale and Don, S&G responses in green. If you need to discuss further,
> please let me know. Pam
>
> Don Darity wrote:
> Dale, below are our responses to your comments noted in blue:
>
> Don Darity, P.E.
>
> Ramey Kemp & Associates, Inc.
> 4928-A Windy Hill Drive
> Raleigh, NC 27609
> (919) 872-5115 - Phone
> (919) 872-0480 x 103 - Direct Line
> (919) 878-5416 - Fax
> -----Original Message-----
>
> From: Dale.Privette@TownofCary.org [
> mailto:Dale.Privette@TownofCary.org]
> Sent: Friday, June 23, 2006 9:31 AM
> To: Don Darity; palexander@dot.state.nc.us
> Cc: Mike.Billings@TownofCary.org; Dick.Moore@TownofCary.org;
> Wesley.Vo@townofcary.org; Bryan.Hayes@townofcary.org;
> Jane.Stricklin@TownofCary.org
> Subject: Walnut Street Lane Addition Project - Plan Review Comments
>

> *Don,*
>
> *The Town has completed its review of your submittal dated May 31, 2006 for this Town of Cary project. This project includes the signalized intersections of Walnut Street at Dillard Drive (05-1732), Walnut Street at Meeting Street (05-1558), and Walnut Street at US1 NB Ramp (05-0270). I am providing review comments regarding the traffic signal and cable routing/splice plans only. Jane Stricklin, project manager for this project, will provide review comments for the traffic control and pavement marking plans under seperate correspondence. Our reveiw comments follow:*
>
> *Walnut at US1 Ramp (05-0270)*
>
> *1. You have provided a plan that only shows the final geometry of Walnut Street. We are concerned that the existing detection (loops and lead-ins) in the northbound lanes of Walnut Street will be damaged by the construction of the additional NB lane. How do you plan to maintain detection throughout construction? This situation occurs at all existing signalized intersections where loop detection is present. The only 2 alternatives that I know of to resolve this are 1- prepare Temporary signal designs showing recutting of loops during construction or installing video detection during construction with loops in final; or 2- negotiate with selected contractor to maintain loops w/o Temp Signal designs. The Town of Cary would be responsible with all negotiations of contract.*
>
> *2. Clearance Times - Your plan recommends a full 2 second decrease to the Yellow time for phase 4 (5 sec existing). You plan recommends a 1.3 second decrease for phase 1 (4.5 sec existing). The Town has voiced its concerns with short yellow times in the past. If these proposed times are approved by NCDOT, please consider staging the reduction of yellow times from existing to proposed over an adequate period of time to allow driveradjustment. This sounds reasonable, however RKA would not be responsible for this implementation and Iâ€™m uncertain as how to show this on the signal designs. You can add a note to the plan, such as, "Existing Yellow Change Interval for phase 2 may be decreased by 0.2 seconds per week until the required value is reached." See Design Manual 5.2.2:4.*
>
> *3. On the electrical diagram (sheet Sig.2), under note #9, please add "Channel 7, Address 3." to the end of the existing note. RKA will comply.*
>
> *Walnut at Meeting (05-1558)*
>
> *1. You have provided a plan that only shows the final geometry of Walnut Street. We are concerned that the existing detection (loops and lead-ins)in the northbound lanes of Walnut Street will be damaged by the construction of the additional NB lane. How do you plan to maintain detection throughout construction? Same as above.*
>
> *2. Please show all NEW pedestrian heads and all NEW signal heads to be*
> *provided for the entire intersection. RKA will comply.*
>
> *3. The existing signal plan of record shows the red light camera loops in the dual southbound left turn lanes, approximately where your loop 5C and 5D labels are shown. Please show the existing red light camera loops on your plan. Also, please show the existing red light camera and flash units on this plan (located in the NW quadrant). Place a note on the plans that the red light camera and*

> flash units to be relocated by others. It is my understanding that
> NCDOT does not allow showing any Red Light Camera items on NCDOT
> plans. Pam Alexander may need to elaborate on this issue. A note
> can be added concerning relocation of cameras, etc. Red Light Camera
> loops and equipment may be treated like other underground utilities
> or geometric features and shown on the plans as long as they are
> labeled "by others" or something similar. It needs to be clear that
> they are not part of the signal operation.
>
> 4. As you are aware, the signal cabinet for the intersection of
> Meeting Street at Caitboo Ave. is located in the NE quadrant
> currently. It is not shown on this plan. Are you assuming that this
> cabinet will be relocated prior to this project being let for
> construction? This cabinet needs to be accounted for. Yes, it is
> assumed this cabinet will be relocated to Caitboo Ave prior to
> widening improvements on Walnut St.
>
> 5. Clearance Times - Currently, phase 5 is monitored by a red light
> running camera. Your plan recommends reducing the yellow clearance
> time from 4.0 seconds to 3.2 seconds. We are opposed to reducing
> this yellow
> time as many jurisdictions have lost automated enforcement systems
> after motorists argued that the municipality lowered the yellow times
> without warrant. We do not want this controversy in Cary. Please
> compare existing yellow times to your proposed yellow times for
> phases 1,3,4, and 5 and consider our comments in #2 above. Pam will
> need to address this issue. The supplement to the MUTCD states in
> Section 4D.10 that "The use of redlight camera photo enforcement
> systems shall not be a consideration in determining the duration of
> yellow and red clearance intervals." Therefore, the selection of
> these times needs to be looked at separately from the red light
> camera issue. This practice was reaffirmed by the NCSITE Clearance
> Task Force. These times can also be lowered incrementaly and/or the
> Town may want to consider a grace period after the new times are
> installed.
>
> 6. The requested "Permanent Signal Easement" is labeled in the NW
> quadrant but not the NE quadrant. Please label both requested
> easements. RKA will comply.
>
> 7. The street name is "Meeting Street" on both side streets.
> Please revise your label and title block accordingly. RKA will
> comply.
>
> 8. On the electrical diagram (sheet Sig.5), under note #9, please
> add "Channel 7, Address 2." to the end of the existing note. RKA
> will comply.
>
> Walnut at Dillard (05-1732)
>
> 1. You have provided a plan that only shows the final geometry of
> Walnut Street. The existing detection is provided by Econolite Solo
> Pro video detection systems. During construction, these cameras will
> have to be adjusted as lanes are narrowed/closed. How do you plan to
> show this in this plan set? Same as above.
>
> 2. Please show all new signal and pedestrian heads to be provided
> for this entire intersection. RKA will comply.
>
> 3. Former Division Traffic Engineer John Grant had agreed to change
> the outside westbound Dillard Drive lane to a shared through and
> right whenever a detector could be placed in that existing exclusive

> right turn lane. Please change that lane on this plan to a shared
> through/right turn lane. You will need to remove the right turn
> overlap and change the signal head facing that lane, along with your
> table of operation, phasing diagram, and electrical drawings. RKA
> will comply.
>
> 4. The existing northbound Walnut Street through lanes are monitored
> by a red light camera system. The red light camera loops are
> existing near the stop bar in the existing two northbound through
> lanes. Please show these loops on this plan, and show the red light
> camera and flash units that are existing on the SE corner of the
> intersection. Place a note on the plans that the red light camera
> and flash units to be relocated by others. Again, this is not a
> NCDOT standard, however a note can be added as above. Same as above.
>
> 5. The traffic signal poles, cabinet, and loop lead-ins in the NE
> and SE quadrants are shown outside of the existing right of way. If
> you will need easements to enable the installation of the loop
> lead-ins, then show the needed easements on this plan. RKA will
> comply, however, McKim & Creed will need to acquire these easements
> and coordinate w/ TOC.
>
> 6. In the Timing Chart, we believe that the Max 1 times for phases 6
> and 7 are reversed. Please check. RKA will comply.
>
> 7. On the electrical diagram (sheet Sig.8), under note #9, please
> add "Channel 6, Address 5." to the end of the existing note. RKA
> will comply.
>
> I also have extensive comments on the cable routing and splice
> diagrams
> that are a part of this plan set. Rather than list all of the
> comments
>
> here, I would prefer that you come by and pick up a set of red lined
> plans at your earliest convenience. Please leave plans with the
> receptionist and we will have someone pick them up.
> As mentioned above, you may be receiving additional review comments
> on the traffic control and marking plans.
>
> Let me know if you have any questions.
>
> Dale W. Privette
> Senior Engineer
>
> Town of Cary
> Post Office Box 8005
> Cary, NC 27512-8005
> Tel. (919) 462-3833
> FAX (919) 460-4935
> --
> Pamela L. Alexander, PE
> S & G Special Projects Engineer
> 919-715-8333

--
Greg Fuller, PE
State ITS & Signals Engineer
phone - 919-733-8021

PLAINTIFF'S DEPOSITION EXHIBIT
PENGAD 800-631-6989
6
Marlen 10/31/1

Subject: **Re: Walnut Street Lane Addition Project - Plan Review Comments**
Date: Fri, 30 Jun 2006 13:57:23 -0400
From: Kevin Lacy <jklacy@dot.state.nc.us>
Organization: North Carolina Department of Transportation
To: "Greg A. Fuller" <gfuller@dot.state.nc.us>

Greg,
I like the option where the Town provides a grace period after the clearance intervals are changed. This approach is easily documented by the Town and it does not require any alterations to the equipment. The Town could turn off the cameras at these intersections for as long or as short of a time period they choose. This will also be a highly defensible position from the publics perspective.

I believe a three month period is plenty of time, most drivers through this corridor are everyday drivers and will adapt to the changes. Those who infrequently travel the corridor will not have a reliable basis to determine if there was a real change.

I am also supportive of setting the clearance intervals to the appropriate levels based upon the most recent standards. I am not sure what justification would be convincing enough to exempt these intersections.

Kevin

"Greg A. Fuller" wrote:

> Dick,
> Please don't assume our comments concerning the clearance intervals mean we are
> opposed to red light cameras. As a matter of fact, a working group of the
> Department's Executive Committee for Highway Safety has been seriously
> discussing the red light cameras as a strategy to improve intersection safety
> statewide. As you know, the NCSITE Task Force discussed the red light cameras
> and agreed the presence or absence of red light cameras would not determine how
> the clearance intervals would be calculated. We feel a 0.5 second reduction
> every 6 months of the yellow change interval is excessive. I suggest we discuss
> this issue with Don Darity and Steve Johnson to see if we can determine a more
> appropriate timeframe to reduce the yellow change interval. If the Town of Cary
> believes drivers should be given additional leeway, the red light camera system
> can increase the time into the red clearance before a violation is recorded.
> Once again, we will use the standard practice recommended by the NCSITE Task
> Force unless there are extraordinary circumstances or additional engineering
> data at the specific location. Our personal opinions do not meet this
> criteria. We can meet to discuss further if needed. Thanks
>
> Dick.Moore@TownofCary.org wrote:
>
> > Good morning Greg,
> >
> > The Town of Cary is disappointed that NCDOT by these comments will increase
> > the number of Red light violations by Cary residents at the intersection of
> > Walnut and Meeting Street. Because most red light camera installations have
> > been removed across the country because of shorter yellows being installed,
> > we can only assume that NCDOT is opposed to Red light cameras.
> >
> > The Town of Cary continues to maintain:
> >
> > Red light cameras are an useful tool to make intersections safer and reduce
> > red light violations.
> >
> > No reduction of yellows at Red light camera locations.
> >
> > The North Carolina section of the Institute of Transportation Engineers

Subject: [Fwd: Clearance times]
Date: Mon, 31 Oct 2005 16:13:12 -0500
From: David Naylor <DNaylor@dot.state.nc.us>
Organization: North Carolina Department of Transportation
To: "Greg A. Fuller" <gfuller@dot.state.nc.us>

FYI

--
David Naylor, P.E.
Deputy Division Traffic Engineer
NCDOT
716 W. Main Street
Albemarle, NC 28001
Office: (704) 982-0101
Fax: (704) 982-3146

Subject: Clearance times
Date: Mon, 31 Oct 2005 15:06:38 -0500
From: "Abel, Charles" <cabel@ci.charlotte.nc.us>
To: <dnaylor@dot.state.nc.us>
CC: "Babson, Liz" <ebabson@ci.charlotte.nc.us>

David,

This email is to inform you of how we are calculating and implementing clearance times within the City of Charlotte in light of the Clearance Interval Task Force's recommendations from this summer.

CALCULATION
We are using the recommendations of the Clearance Interval Task Force for calculating yellow, red and total clearance times. There is one exception, the CBD, where we will use the formula to calculate average clearance values and use them exclusively at CBD locations.

The speed that we use for left turning vehicles is found this way:
posted speed limit <= to 35 mph, use lesser of 25 mph or posted speed limit
posted speed limit >= to 40 mph, use 30 mph

This is somewhat higher than NCDOT's recommendation of 20 mph and somewhat lower than the 10 mph below the posted speed limit that CDOT was using. The speed studies that CDOT conducted for left turns found, on average, a much higher 85th percentile left turning speed than 20 mph. We felt that while 20 mph may fit widely varying conditions across the state, this low speed is not appropriate for the drivers of Charlotte. The speed studies also showed that the way CDOT calculated the left turn speed for high speed approaches was not appropriate as well and led to the modification that lowered those speeds.

IMPLEMENTATION
We are implementing the new clearance times on a case by case basis as we retime the signals. It will take approximately 2-1/2 years before all NCDOT signals will be modified.

If you want to discuss this, please give me a call at 704-336-3945.

Charles

PLAINTIFF'S DEPOSITION EXHIBIT PENGAD 800-631-6989 AA 7 Marcea 10/3/11

Gilliam, Amanda

From: Laura.Cove@townofcary.org
Sent: Monday, December 22, 2008 9:03 AM
To: Fuller, Gregory A
Subject: Re: Rosalind Ellwood complain about Red Light Cameras

Thanks Greg. I've asked Wesley to confirm what's in the field, again. You'll be happy to know that now your name is in Rosalind's little black book that she carries everywhere.

Merry Christmas to you too.

Lori Cove

From: "Fuller, Gregory A" [gfuller@ncdot.gov]
Sent: 12/22/2008 06:47 AM EST
To: Laura Cove
Subject: RE: Rosalind Ellwood complain about Red Light Cameras

This is the lady that called me. I pulled the signal plan at Harrison Avenue & Maynard Road. The Harrsion Avenue phases have yellow clearance times of 4.2 and 4.9 seconds. She kept saying it was only 3 seconds. The left turns are 3 seconds of yellow. She was looking for me to intervene but I explained that NCDOT has no authority over the red light cameras. Have a Merry Christmas.

Greg Fuller
State ITS and Signals Engineer
NCDOT - Traffic Engineering
Phone: 919-661-5800

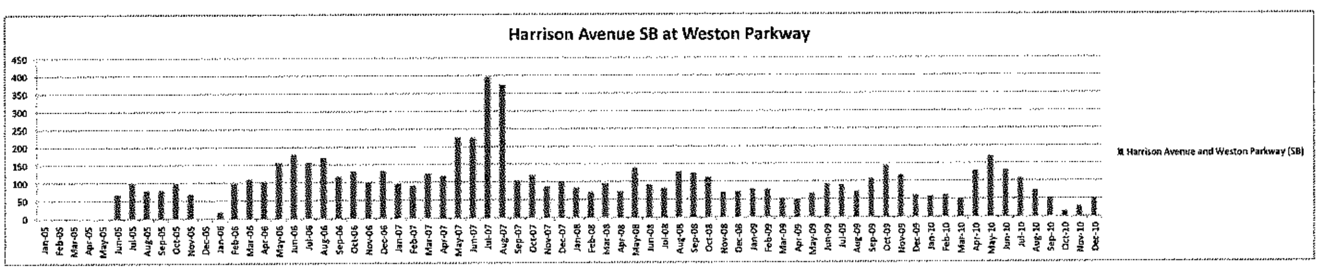
From: Laura.Cove@townofcary.org [mailto:Laura.Cove@townofcary.org]
Sent: Friday, December 19, 2008 11:04 AM
To: hudsons3@hotmail.com; Brad.Hudson@townofcary.org; Chris.Davis@TownofCary.org
Cc: David.Spencer@townofcary.org; Fuller, Gregory A; Wesley.Vo@townofcary.org; Tom.Reilly@townofcary.org; Bryan.Hayes@townofcary.org; Johnson, Steven J; Mckay, Andrew F
Subject: Rosalind Ellwood complain about Red Light Cameras

Heads up. Rosalind Ellwood has called DOT, David and me today about her strong concerns about red light cameras. I am sure that you remember her. She came by in August of 2007 to see me, called Steve at the Division and also talked to Chris in Police as well as a consultant who did the signal plans. She had received several tickets from RedFlex at that time and had finally decided to appeal. She lost her appeal and I haven't heard from her since until today.

She may have received another ticket recently or just saw the Road Warrior article this week, but she is on a mission again. She asked for the current appeal and citation data. We put that in the mail to her today (as she said she doesn't have e-mail). She also said in her message to me that she was writing me a letter stating that her previous appeal was illegal because it was supposed to be a panel of three people and only two were there. I am going to direct her to write that letter to Police since Engineering doesn't coordinate the appeal process.

Just wanted to keep everyone in loop.

Lori Cove, P.E.
Traffic Engineering Manager
Town of Cary
P.O. Box 8005
Cary, NC 27512-8005
(919)462-3937


Harrison Avenue SB at Weston Parkway
450
400
350
300
250
200
150
100
50
0
Harrison Avenue and Weston Parkway (SB)

PLAINTIFF'S DEPOSITION EXHIBIT
Hummer
11
PENGAD 800-631-6989

EXHIBIT
C

PLAINTIFF'S DEPOSITION EXHIBIT
J
Moon
PENGAD 800-631-6989

PLAINTIFF'S DEPOSITION EXHIBIT
3
George
PENGAD 800-631-6989

PLAINTIFF'S DEPOSITION EXHIBIT
9
Moreau
10/31/11
PENGAD 800-631-6989

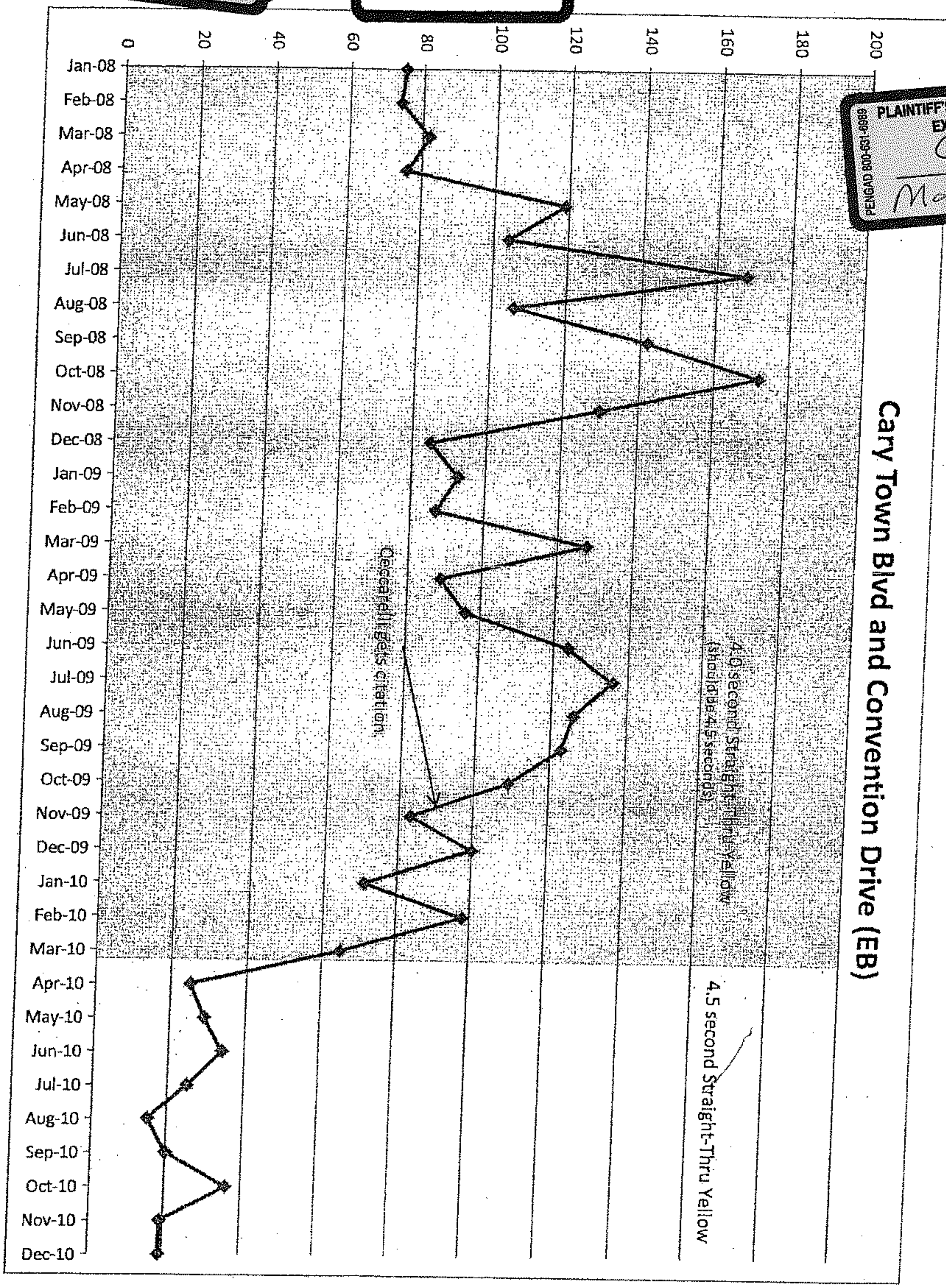
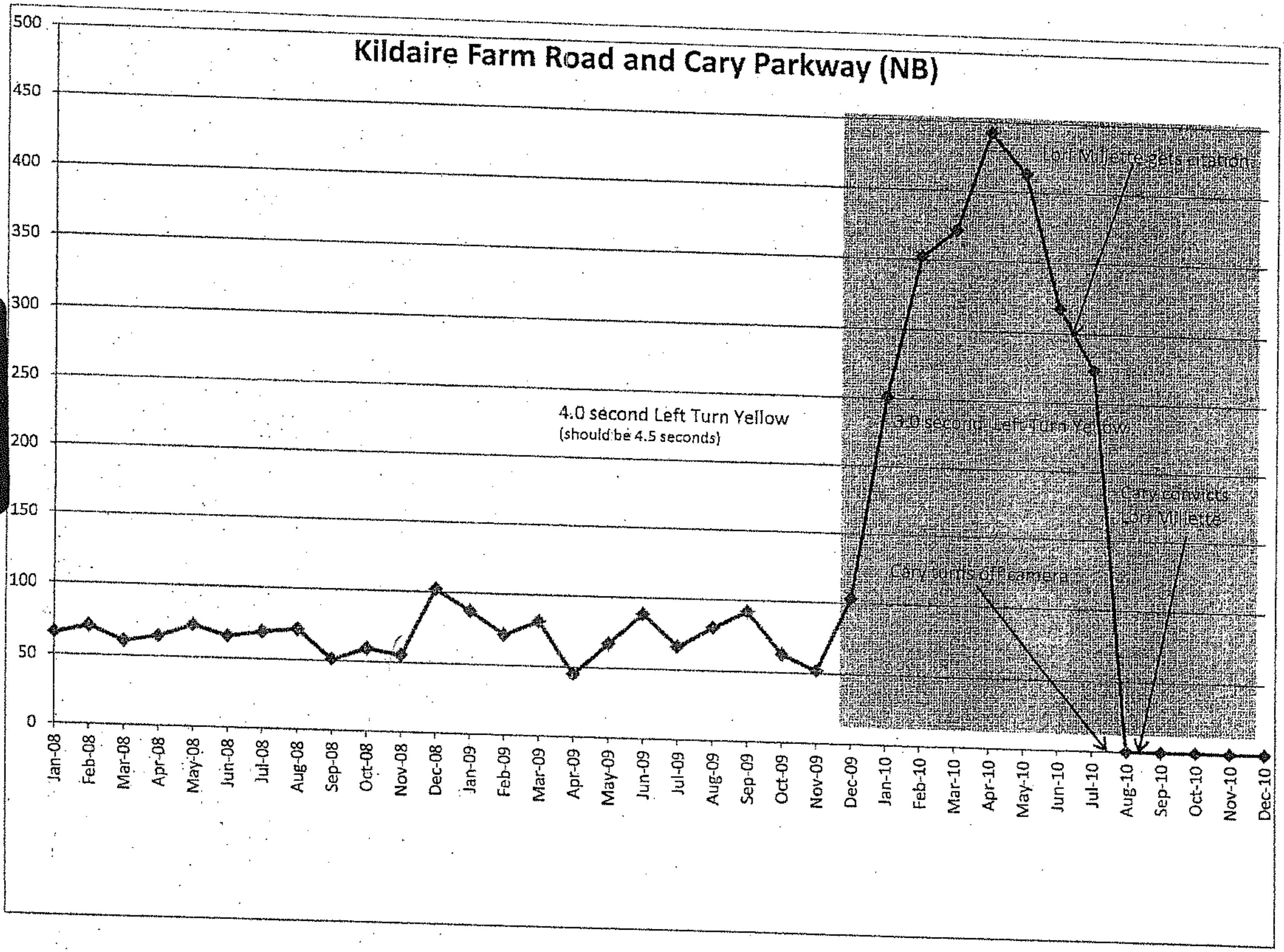


EXHIBIT
E



Kildaire Farm Road and Cary Parkway (NB)
4.0 second Left Turn Yellow
(should be 4.5 seconds)
3.0 second Left Turn Yellow
Lori Millette gets citation
Cary convicts Lori Millette
Cary turns off camera
500
450
400
350
300
250
200
150
100
50
0
Jan-08
Feb-08
Mar-08
Apr-08
May-08
Jun-08
Jul-08
Aug-08
Sep-08
Oct-08
Nov-08
Dec-08
Jan-09
Feb-09
Mar-09
Apr-09
May-09
Jun-09
Jul-09
Aug-09
Sep-09
Oct-09
Nov-09
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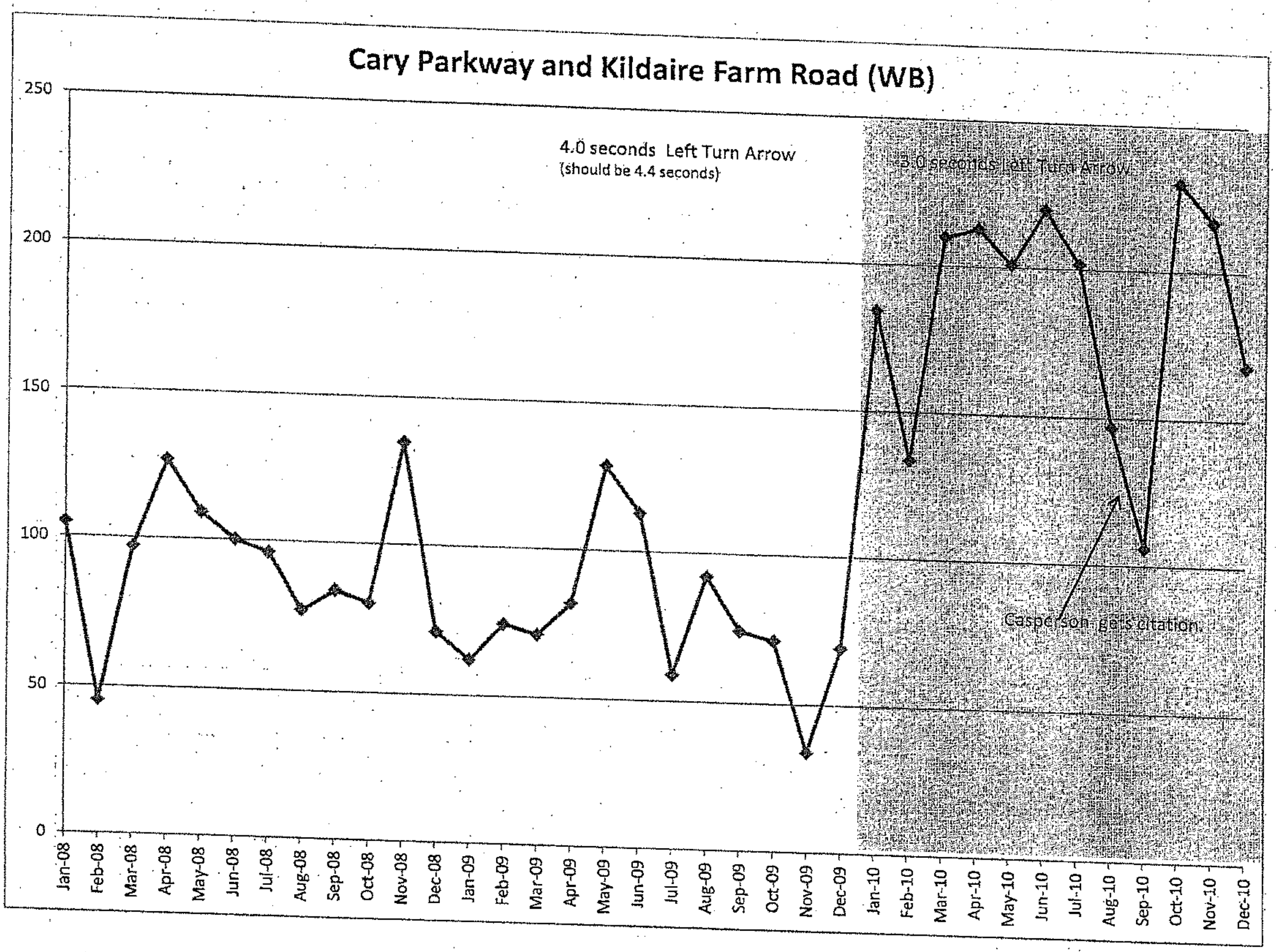
Oct-10
Nov-10
Dec-10


Cary Parkway and Kildaire Farm Road (WB)
4.0 seconds Left Turn Arrow
(should be 4.4 seconds)
3.0 seconds Left Turn Arrow
Casperson gets citation
250
200
150
100
50
0
Jan-08
Feb-08
Mar-08
Apr-08
May-08
Jun-08
Jul-08
Aug-08
Sep-08
Oct-08
Nov-08
Dec-08
Jan-09
Feb-09
Mar-09
Apr-09
May-09
Jun-09
Jul-09
Aug-09
Sep-09
Oct-09
Nov-09
Dec-09
Jan-10
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Jul-10
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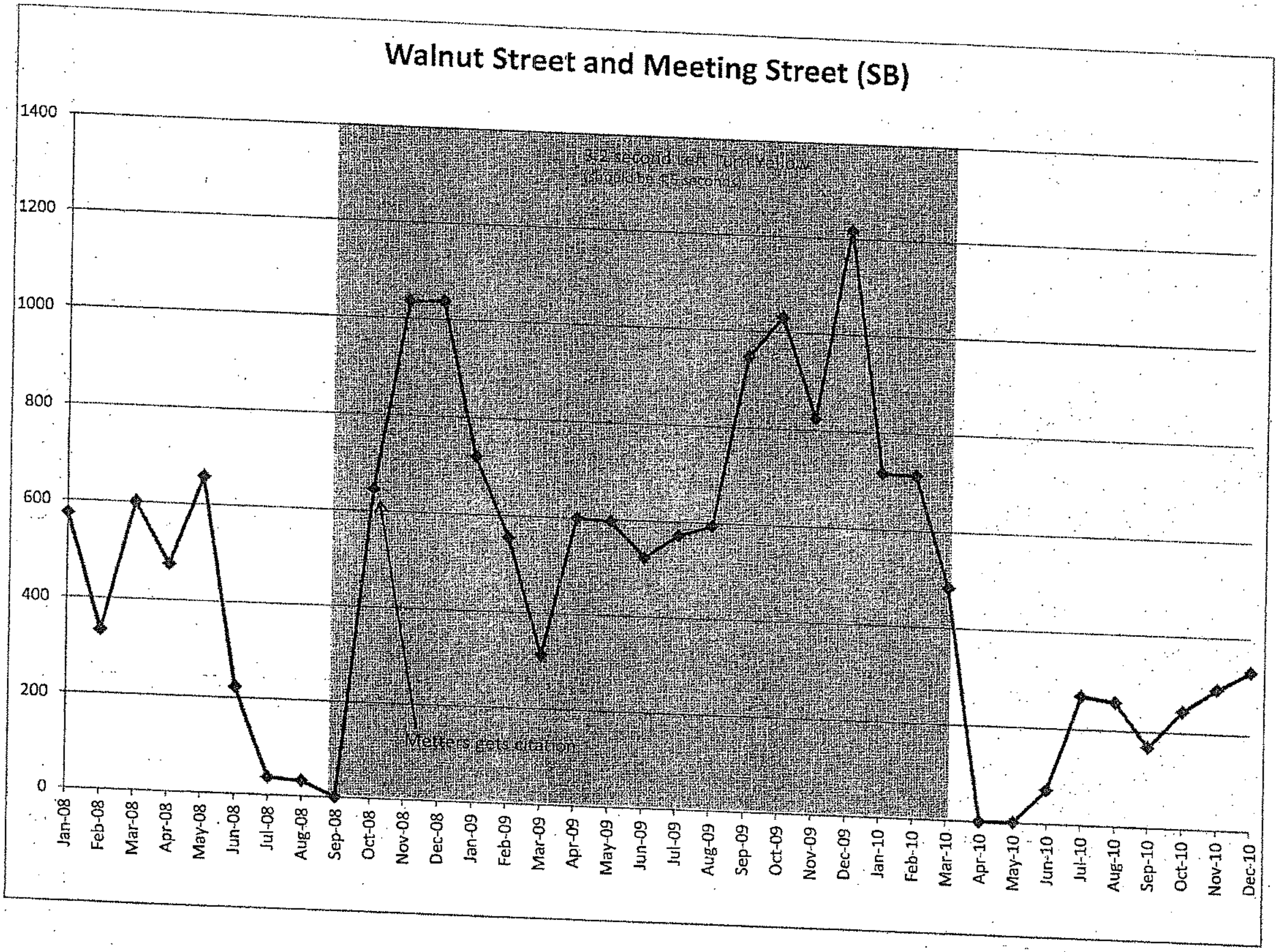
Sep-10
Oct-10
Nov-10
Dec-10



Walnut Street and Meeting Street (SB)
1400
1200
1000
800
600
400
200
0
3.2 second Left Turn Yellow
Metters gets citation
Jan-08
Feb-08
Mar-08
Apr-08
May-08
Jun-08
Jul-08
Aug-08
Sep-08
Oct-08
Nov-08
Dec-08
Jan-09
Feb-09
Mar-09
Apr-09
May-09
Jun-09
Jul-09
Aug-09
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Oct-09
Nov-09
Dec-09
Jan-10
Feb-10
Mar-10
Apr-10
May-10
Jun-10
Jul-10
Aug-10
Sep-10
Oct-10
Nov-10
Dec-10

Discussion Paper No. 8.A

STOPPING SIGHT DISTANCE AND DECISION SIGHT DISTANCE

prepared for

Oregon Department of Transportation
Salem, Oregon

by the

Transportation Research Institute
Oregon State University
Corvallis, Oregon 97331-4304

February 1997

Discussion Paper No. 8.A

STOPPING SIGHT DISTANCE AND DECISION SIGHT DISTANCE

PERCEPTION-REACTION TIMES

PIEV Process

The perception-reaction time for a driver is often broken down into the four components that are assumed to make up the perception reaction time. These are referred to as the PIEV time or process.

PIEV Process	
• Perception	the time to see or discern an object or event
• Intellection	the time to understand the implications of the object's presence or event
• Emotion	the time to decide how to react
• Volition	the time to initiate the action, for example, the time to engage the brakes

Current Design Perception-Reaction Time

Human factors research defined perception-reaction times for (1):

- design 2.5 sec
- operations/control 1.0 sec

These perception reaction times were based on observed behavior for the 85th percentile driver; that is, 85% of drivers could react in that time or less. More recent research has shown these times to be conservative for design.[2]

Wortman and Mathias (2) reported both the "surprise" and alerted 85th percentile perception reaction times. This was in an urban environment; the time was measured after the yellow indication until brake lights appeared.

The Wortman et al. research found:

- alerted 85% perception-reaction time 0.9 sec
- "surprise" 85% perception-reaction time 1.3 sec

(1) AASHTO, "Policy on Geometric Design of Streets and Highways," Washington, DC, 1984, 1990, and 1994.

(2) Wortman, R.H., and J.S. Matthaas, "Evaluation of Driver Behavior at Signalized Intersections," Transportation Research Record 904, T.R.B, Washington, D.C., 1983.

PERCEPTION-REACTION TIMES (Continued)

Perception-Reaction Time Research

Recent studies have checked the validity of 2.5 seconds as the design perception reaction time. Four recent studies have shown maximums of 1.9 seconds as the perception-reaction time for an 85th percentile time and about 2.5 seconds as the 95th percentile time.

Brake Reaction Times Studies

	85th	95th
Gazis et al. (1)	1.48	1.75
Wortman et al. (2)	1.80	2.35
Chang et al. (3)	1.90	2.50
Sivak et al. (4)	1.78	2.40

Perception-Reaction Times by Road Type

Some researchers have suggested that the perception-reaction should reflect the complexity of traffic conditions, expectancy of drivers and the driver's state. They suggest that the perception reaction times may be altered accordingly (4).

Table 1. Perception-Reaction Times Considering Complexity and Driver State

	Driver's State	Complexity	Perception-Reaction Time
Low Volume Road	Alert	Low	1.5 s
Two-Lane Primary Rural Road	Fatigued	Moderate	3.0 s
Urban Arterial	Alert	High	2.5 s
Rural Freeway	Fatigued	Low	2.5 s
Urban Freeway	Fatigued	High	3.0 s

(1) Gazis, D.R, et al, "The Problem of the Amerber Signal in Traffic Flow," Operations Research 8, March-April 1960.

(2) Wortman, R.H., and J.S. Matthaas, "Evaluation of Driver Behavior at Signalized Intersections," Transportation Research Record 904, T.R.B, Washington, D.C., 1983.

(3) Chang, M.S, et al, "Timing Traffic Signal Change Intervals Based on Driver Behavior," T.R. Record 1027, T.R.B, Washington, D.C., 1985

(4) Sivak, M., et al, "Radar Measured Reaction Times of Unalerted Drivers to Brake Signals," Perceptual Motor Skills 55, 1982.

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Discussion Paper No. 8.A

STOPPING SIGHT DISTANCE AND DECISION SIGHT DISTANCE

HUMAN FACTORS

An appreciation and understanding of human factors, behavior and abilities are needed to determine the sight distance criteria. The physical abilities and psychological limitations impact these criteria, and should be reviewed here to obtain perspective.

Visual **Acuity**The primary stimulus for operation and safe control of vehicles is eye sight. The physical composition of the eye and its functioning constitute limits that must be considered when developing sight distance criteria.

Visual Acuity

3 -4 cone	best vision – can see texture, shape, size, color, etc.
10 cone	clear vision – critical traffic control devices must be in this cone
20 cone	satisfactory vision – regulatory and warning traffic control devices should be this cone of vision
~ 90 cone	peripheral vision – only movement can be seen with this vision

Drivers focus their attention down the roadway in the cone of clear vision at 3 to 4 times the stopping distance. They then shift their vision to the right and left to keep track of traffic conditions, pedestrians and local activities. The eye movement time includes the time required for a driver to shift their eyes and to focus on an object.

Eye Movement Time

Shift to New Position	0.15-0.33 sec
Fix or Focus on Object	0.1-0.3 sec

It takes roughly 0.5 second for a driver to shift his eyes and focus. Thus, a full cycle to right and back to the left takes about 1 second. If there is glare, it takes 3 seconds to recover full visual acuity and 6 seconds to recover from bright to dim conditions.

Human Mind is Single Channel

Humans are sequential processors; that is, drivers sample, select and process information one element at a time, though very quickly. Therefore, complex situations create unsafe or inefficient operations because it takes so long for drivers to sample, select and process the information. This means that as complexity increases a longer perception-reaction time should be available. The visual acuity limitations, visibility constraints of glare/dimness recovery and complexity of traffic conditions, when taken together, require much longer perception-reaction times or decision times.

Discussion Paper No. 8.A

STOPPING SIGHT DISTANCE AND DECISION SIGHT DISTANCE

HUMAN FACTORS

Driver Expectancy

Drivers are led to expect a particular operation condition based on the information presented to them. They use both formal and informal information.

- Formal information – this includes the traffic-control devices and the geometric design features of the roadway, but does not include the roadside features such as ditch lines, guardrail, and other street furniture.

- Informal information – this includes roadside features and also land use features, such as brush lines, tree lines, fences and information signing.

Drivers develop expectations on how to drive a roadway through experience, training and habit. At times these expectations are in error because they use inappropriate informal information, or the formal information provided is not proper or gives mixed messages. Often, the information at a location is conflicting, and drivers who are familiar with the location will read traffic conditions differently than unfamiliar drivers. Traffic conditions vary dramatically on major facilities; consequently, the information that drivers receive from other vehicles is constantly changing.

Increased perception reaction time is needed to allow time for drivers to make the proper decision when information conflicts and driver expectancy may be in error.

Further, high volume and high speed conditions require longer decision times and compound any problems arising from driver expectancy.

Gilliam, Amanda

From: Murr, Buddy
Sent: Tuesday, June 26, 2012 9:09 AM
To: Fuller, Gregory A
Subject: RE: Cary Red Light Lawsuit

On page 68 of the NCHRP 03-95 study, look at the last sentence of this bullet:

- Speed limit by itself was found to be an inaccurate estimate of 85[th] percentile speed. In li of field-measured speed data to determine 85[th] percentile approach speed, the findings of study suggest it is appropriate to estimate this value for through free-flowing vehicles by adding 7 mph to the approach speed limit. For left-turning vehicles, this study suggests tl 85[th] percentile approach speed is appropriately estimated by subtracting 5 mph from the approach speed limit. When calculating the red clearance interval, the speed estimation h true for through free-flowing vehicles. However, for left-turning vehicles, this study sugg using 20 mph regardless of posted speed limit.

Buddy
G. G. Murr, Jr., PE
NCDOT - State Signals Engineer
office: 919-661-5953
main: 919-773-2800
fax: 919-771-2745
http://www.ncdot.org/doh/preconstruct/traffic/ITSS/

From: Rob Ziemba [mailto:ncsurrboy@yahoo.com]
Sent: Sunday, June 24, 2012 9:06 PM
To: Fuller, Gregory A; Murr, Buddy
Subject: Cary Red Light Lawsuit

I assume you saw these over the weekend:

http://www.newsobserver.com/2012/06/22/2154364/class-action-ruling-could-add.html

http://www.newsobserver.com/2012/06/24/2155290/lawsuit-doesnt-stop-red-light.html

Application of the ITE Change and Clearance Interval Formulas in North Carolina

DURING 2005, THE NORTH CAROLINA SECTION OF ITE CONVENED A TASK FORCE TO INVESTIGATE AND RECOMMEND A PRACTICE FOR DETERMINING YELLOW CHANGE AND RED CLEARANCE INTERVALS. THIS FEATURE BRIEFLY SUMMARIZES KEY DELIBERATIONS AND DECISIONS OF THAT TASK FORCE. THE METHODOLOGY AS IMPLEMENTED BY THE NORTH CAROLINA DEPARTMENT OF TRANSPORTATION ALSO IS PRESENTED ALONG WITH SAMPLE YELLOW AND RED TIMES RESULTING FROM ITS APPLICATION.

BY STEVEN M. CLICK, PH.D., P.E.

INTRODUCTION

In December 2004, in response to a formal request by the North Carolina Department of Transportation (NCDOT), the Traffic Engineering Council of the North Carolina Section of the Institute of Transportation Engineers (NCSITE) announced a task force to investigate and recommend a practice for determining yellow change and red clearance intervals at signalized intersections in North Carolina. The purposes of this feature are to briefly summarize key deliberations of that task force and present the resulting methodology as implemented by NCDOT.

BACKGROUND

One issue in determining appropriate yellow and red intervals is that, despite the existence of several well-recognized guidance documents, there is no national standard. The *Manual on Uniform Traffic Control Devices* (MUTCD), which typically provides prescriptions for device operation, does not stipulate the manner in which yellow or red intervals should be determined. It does, however, require the use of a yellow interval; require that the duration of the yellow and red intervals be predetermined; and suggest durations of 3 to 6 seconds for yellow and, at most, 6 seconds for red.[1]

Calculation methods are available in the *Traffic Engineering Handbook* and other sources.[2] A recent survey by ITE suggests that, by far, the most common method in use today is based on what is termed the "ITE formula," ~~shown~~ below:[3]

all red

$$Y + R = t + \frac{v}{2a + 2Gg} + \frac{w + l}{v} \quad (1)^{4}$$

yellow

where:

Y = yellow change interval (seconds [sec.])
R = red clearance interval (sec.)
t = perception-reaction time (sec.)
v = design velocity (feet/sec.)
a = deceleration rate (feet/sec.^{2})
G = acceleration due to gravity (32.2 feet/sec.^{2})
g = grade in decimal form (1 percent = 0.01)
w = clearance distance (feet)
l = vehicle length (feet)

In discussion of the yellow and red intervals, the *Traffic Engineering Handbook* goes on to suggest a typical application of the first two terms to determine the yellow and the last term to determine the red.

The ITE formula has been published, with timely revisions, since the first edition of the *Traffic Engineering Handbook* in 1941. Beginning in 1965, the formula appeared in its present form, although without the effect of grade. In this same year, ITE suggested the use of a red interval under certain conditions. The inclusion of the effect of grade on the yellow and red intervals appeared in 1982. In all, the formula has been updated eight times since 1941.[5] Still, the *Traffic Engineering Handbook* has not accrued any legal status.

Although the NCDOT documentation covers only the more recent practices for calculation of yellow and red, it gives clear evidence of its desire to provide both safe and efficient operation. One source, from February 1990, summarizes a meeting NCDOT hosted to discuss change and clearance intervals, involve traffic engineers from across the state and examine current practice. At the time of the meeting, NCDOT and most other state agencies were using the ITE formula as the foundation of their practice.[6]

More recently, NCDOT has worked to improve signal design consistency through publication of the *Traffic Management and Signal Systems Unit Design Manual*.[7] The purpose of the manual is to highlight standards of practice in signal design and operation. Although all the design manual editions have required the use of the ITE formula, specific division of the resulting total clearance into yellow and red times has not been consistent over the last 15 years and has been, at varying levels, left to the discretion of the design engineer.

The result is inconsistent yellow and red timing throughout the state.

The resulting inconsistencies, differing preferences among designers and a general consensus among NCDOT design and field personnel that these intervals are becoming too long all were factors in the decision to request a recommendation from NCSITE.

THE NCSITE TASK FORCE

In December 2004, a call went out for volunteers for the NCSITE Task Force. The NCSITE mailing list offered a representative pool of traffic engineering professionals from all over North Carolina, with a wide cross-section of relevant experience and knowledge. The resulting volunteer membership included:

- municipal engineers: 11
- consulting engineers: 10
- NCDOT engineers—central office: 7
- NCDOT engineers—field forces: 2
- non-profit organizations: 1
- research organizations: 1
- students: 1

The full NCSITE Task Force met a total of four times between January and June 2005 and divided into subcommittees to help meet the prescribed 6-month deadline. During the first task force meeting, a discussion and brainstorming session provided a list of issues to be addressed. Subcommittees held teleconferences and in-person meetings to discuss their topics and conducted data collection and reduction efforts in support of their tasks.

Issues Addressed by the Task Force

For purposes of organization, the issues tackled by the task force are presented in the sequence that they would be encountered using the methodology, beginning with text from the written recommendation and ending with summaries of key issues.

The ITE formula for the calculation of the total change plus clearance interval should be the basis for NCDOT practice. Both NCDOT's long history and the recent ITE surveys suggested the ITE formula was the logical starting point for use in the methodology.

Calculation of the yellow change and all-red clearance intervals should not vary based on the presence or absence of enforcement devices. At this time, NCDOT does not operate or intend to operate automated enforcement devices (such as red-light cameras); however, individual municipalities can petition the state legislature for the authority to install such devices. The recommended practice should result in safe and efficient intervals, independent of enforcement.

RECENTLY, NCDOT HAS WORKED TO IMPROVE SIGNAL DESIGN CONSISTENCY THROUGH PUBLICATION OF THE *TRAFFIC MANAGEMENT AND SIGNAL SYSTEMS UNIT DESIGN MANUAL.*

The NCSITE Task Force also discussed the option of including a grace period at automated enforcement locations, but it decided to leave such choices to the operating agency. NCDOT does recommend a break-in period to allow drivers to become accustomed to any changes made as a result of the new practice.

Separate practices should not exist for different regions of the state, unique vehicle streams (such as a high percentage of heavy vehicles), or left-turning vehicles versus through vehicles. Because one of the primary motivations for the task force was consistency, there was little discussion of this issue. The recommended practice should result in safe and efficient intervals, independent of region, stream, or movement.

Calculation of the yellow change interval should be performed using the first two terms of the ITE formula, with the result rounded up to the next 0.1 sec.

$$Y = t + \frac{v}{2a + 2Gg} \qquad (2)$$

The yellow and red intervals serve different functions; therefore, the calculation should be made as independently as possible. In past practices, time might be shifted from the red to yellow, but not in the new practice. Independent calculations are needed to help prevent excessive yellow time from contributing to disrespect of the yellow change interval.

The 2001 constants from the American Association of State Highway and Transportation Officials (AASHTO) for deceleration (11.2 feet/sec.^{2}) and perception/reaction time (1.5 sec.) are sound. The longer perception/reaction time responds both to the aging driver population and to the increasing number of distractions in the driving environment. At higher speeds, the higher deceleration rate does help offset the additional perception/reaction time.

The NCSITE Task Force also looked into the performance characteristics of trucks. Although no specific information could be found related to "comfortable" stops, AASHTO constants were within the expected performance capabilities of trucks.

The effect of positive grade should be factored into the yellow calculation. In past practice, NCDOT included the detrimental effects of negative grades but ignored the beneficial impacts of positive grades. None of the ITE publications suggests that positive grades should be ignored in calculations, and the Federal Highway Administration's *Signalized Intersections: Informational Guide* clearly indicates that positive grades can be used.[8]

The minimum value for yellow should be 3.0 sec. Not only does MUTCD recommend this minimum value, it also is required by the National Electrical Manufacturers Association Standards Publication.[9] Note that when the calculated yellow is less than 3.0 sec., the time difference is not shifted from red: In other words, the yellow increases without a change in the red.

Current practice in the Signals and Geometrics Section for selection of vehicle speeds, "v", was reviewed and retained in this application. For through movements, current practice uses the posted speed limit as the design speed unless a speed study has been specifically performed. When provided, the design speed will be taken as the 85th-percentile speed, up to a maximum of 10 mph above the posted limit. Because NCDOT does not signalize facilities with

Site	Left Turn Angle	Single or Dual	Collection Method*	Sample Size	Speed					
					Min	15%	Avg	StDev	85%	Max
1	125	Dual	All	39	14	15.0	18.9	3.4	21.3	30
2	110	Single	All	40	11	12.0	15.6	2.7	18.0	24
3	120	Single	All	71	12	16.0	18.4	2.9	21.0	26
4	110	Single	Sample	120	14	16.0	18.1	2.1	20.0	23
5	100	Single	Sample	120	9	11.0	13.6	2.2	16.0	20
6	100	Dual	End Car	80	14	17.0	19.0	1.8	21.0	23
7	70	Dual	End Car	160	10	13.0	14.6	1.6	16.0	20
8	115	Dual	End Car	80	13	16.0	18.7	2.3	21.0	26
9	130	Dual	End Car	156	14	17.0	19.3	2.3	22.0	25
10	85	Single	End Car	160	12	15.0	17.2	2.0	19.0	23
11	90	Dual	End Car	80	13	16.0	17.4	1.8	19.2	21
ALL	-	-	-	1106	9	14.0	17.1	2.9	20.0	30

*** Collection Methods:**
All = Speed recorded for all vehicles making the left turn
Sample = Speed recorded for an initial vehicle, a mid-queue vehicle, and an end-of-green vehicle
End Car = Speed recorded for the last vehicle using the phase each cycle

Figure 1. Left-turn speed data.

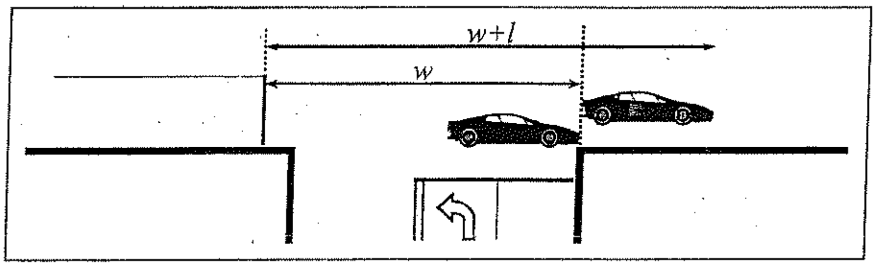

Figure 2. Effect of removing "l" from red calculations.

speed limits greater than 55 mph, the highest allowable design speed is 65 mph.

For left-turn movements, past editions of the *Traffic Management and Signal Systems Unit Design Manual* suggested a speed between 20 and 30 mph, with 20 mph the almost universal selection. Many expressed concern that 20 mph was overly conservative and led to excessive red intervals, so a field investigation was conducted. Unexpectedly, the study results, shown in Figure 1, indicated typical speeds slightly lower than 20 mph but not low enough for the task force to justify changing current practice.

Calculation of the all-red clearance interval should be based on the third term of the ITE formula, but with the following modification: The vehicle length should be removed from the all-red formula, and the result rounded up to the next 0.1 sec.

$$R = \frac{w}{v} \qquad (3)$$

Unlike MUTCD, which does not require the use of a red interval, the North Carolina Supplement to the MUTCD does.[10] As noted above, NCDOT design and field personnel shared the belief that reds were becoming too long, and NC-SITE Task Force discussions showed this sentiment was shared by both municipal and consulting engineers within the state.

The culprits: increasing intersection widths and the need to provide protected phases for left turns. The causes: increasing corner curve radii standards; the separation of crosswalks with two handicapped ramps on each corner; and increasing facility size in terms of number of lanes. To be clear, neither accident nor ticketing issues had developed to draw public attention to the problem; however, the task force members wished to correct any problems before such statistics evolved.

As modified, the red interval serves to carry the front bumper of a last-instant legal intersection entry to the far edge of the conflict zone. Originally, any vehicle equal to or shorter than the assumed length would be carried past the conflict zone. The resulting difference is shown in Figure 2.

The obvious advantage to removing the assumed vehicle length is a reduction in the red interval. Past NCDOT practice used 20 feet as the assumed vehicle length. Removing this results in a 0.7-sec. reduction at 20 mph; 0.4-sec. at 35 mph; and 0.2 sec. at 55 mph.

Despite this anticipated reduction, the formula still allows the red to increase without bound. Left-turn clearance distances of 200 ft. currently exist, resulting in red intervals of 6.9 sec., much longer than acceptable to the task force.

If the initial calculation results in an all-red clearance interval greater than 3.0 sec., the all-red clearance interval should be recalculated as follows:

$$R = \frac{1}{2}\left(\frac{w}{v} - 3\right) + 3 \qquad (4)$$

Discussion of reducing excessive red times consumed a large portion of the NC-SITE Task Force effort. The recommended method was determined to best balance competing concerns related to overly short and overly long red times. The result of this mitigation was that all of the first 3 sec. calculated for the red interval are used, but only half of the portion above that. So, if the initial calculation resulted in 4.0 sec. of red, the mitigation will reduce it to 3.5 sec. As with the other calculations, the result is rounded up to the next tenth.

The only other method receiving serious consideration was the reduction of red time based on expected time to conflict point. Although a preliminary field study looked positive, investigation of current literature, notably Muller et al., provided only minimal adjustments.[11] Faced with minimal benefits and questions about proper application, the task force discontinued its investigation into this option.

The clearance distance should be measured to the far side of an exclusive right-turn lane.

- *In the presence of a crosswalk with pedestrian signals, the clearance distance should be taken to the near side of the crosswalk*
- *A crosswalk without pedestrian signals should not be considered when determining clearance distance.*

These recommendations did not represent a change from past practice. This includes clearance distance measurements using the "straight line" method rather than a vehicle turning arc. A preliminary comparison of the straight line method to an outside wheel arc method resulted in an average difference of +2.2 feet, only +0.07 sec. at 20 mph. The task force agreed to continue using the straight-line method.

Past practice left consideration of crosswalks to the discretion of the design engineer. The task force felt it was important to always consider crosswalks with pedestrian signals when determining clearance distance. The decision to not consider crosswalks without signals was based on two factors: unsignalized crosswalks typically have insignificant pedestrian volume; and unsignalized crossings provide no guidance, so pedestrians cannot be expected to cross during any particular interval, reducing the probability of providing protection.

The *Traffic Management and Signal Systems Unit Design Manual* gives specific guidance for calculating clearance distances, shown in Figure 3.

The minimum value for all-red clearance intervals should be 1.0 sec. Prior practice suggested at least 1.0 sec., so this was not a significant change.

The proposed implementation of a yellow change interval longer than 6.0 sec. or a red clearance interval longer than 4.0 sec. is cause for a "stakeholder discussion" to provide advance notification and involvement to stakeholders and provide an opportunity to consider possible countermeasures.

Field personnel should be involved in developing and applying the practice. Stakeholder discussions help ensure these personnel are not surprised by new installation of long intervals.

Although countermeasures for reducing the yellow are difficult, typically involving the reduction in grade over the stopping distance or making geometric and enforcement changes to reduce travel speed, identification of excessive yellow at an intersection can provide an opportunity for present or future mitigation.

The opportunity for reducing the red is more likely, with lower cost solutions such as reduced median widths, positive offset left turns and channelized right-turn lanes.

For a "shared clearance" phase (when a phase serves multiple movements needing different yellow change and all-red clearance intervals), the following procedure should be applied:

- *Calculate each movement's change plus clearance intervals as if it had a dedicated phase.*
- *Use the largest yellow value; then subtract this yellow value from the largest total change plus clearance to determine red.*

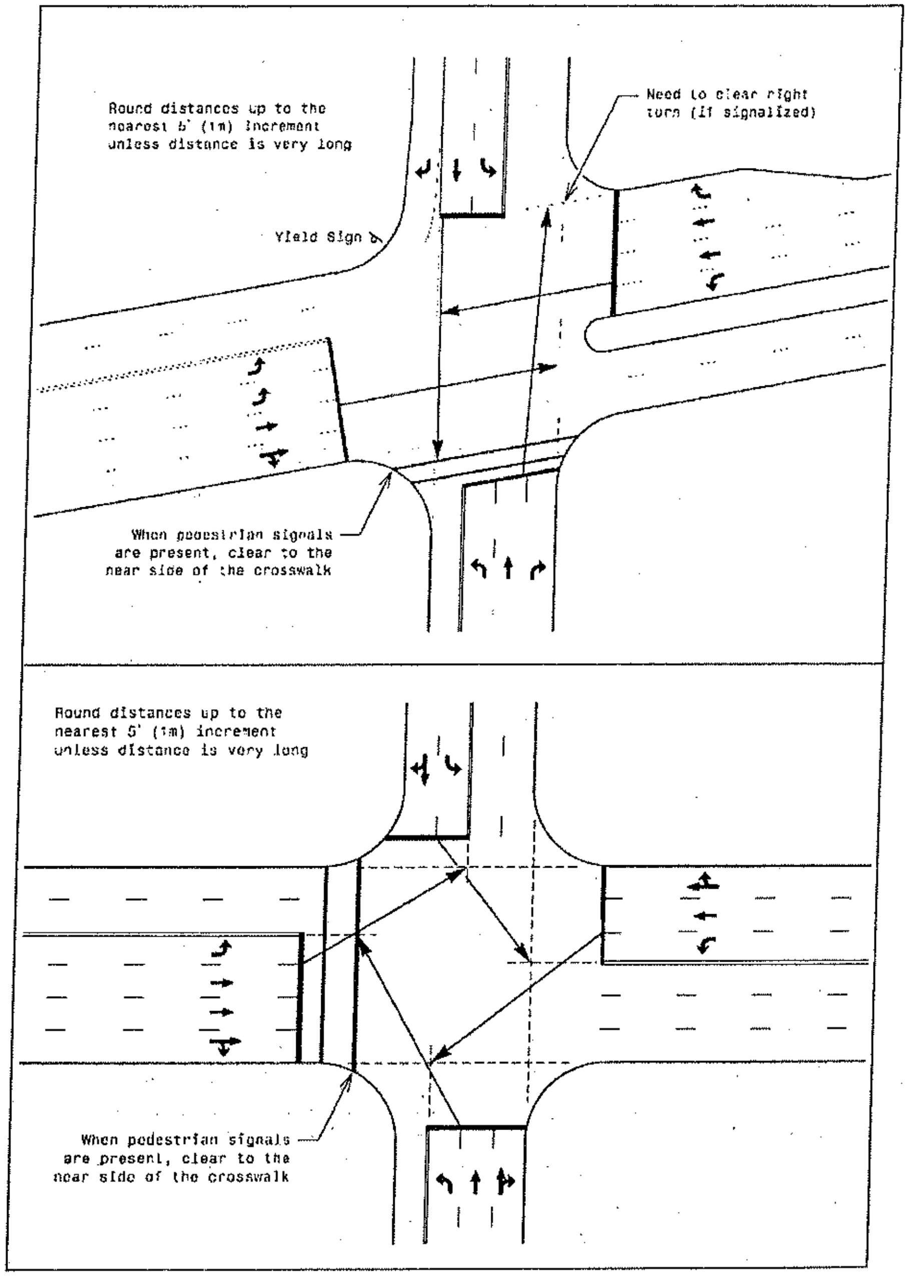

Figure 3. Measuring clearance distances.

Although this is not a change from past NCDOT practice, this confirms that mitigation of excessive red clearance intervals will take place for each movement before the shared change plus clearance is determined.

The Task Force considered but rejected both the use of the longest yellow change with the longest red clearance interval and the use of the yellow change and red clearance interval associated with the longest total clearance. The former option was rejected because it was incompatible with the goal of reducing interval length; the latter was rejected to ensure that every movement received sufficient yellow change time.

CONCLUSION

After receipt of the NCSITE Task Force recommendations, Greg A. Fuller, P.E., of the Intelligent Transportation Systems and Signals Unit of NCDOT, officially adopted the revised methodology, and the *Traffic Management and Signal Systems Unit Design Manual* was revised accordingly. The resulting methodology is presented in full in Figure 4, and a sample set of yellow and red intervals is presented in Figure 5.

Determination of Yellow Change and Red Clearance Intervals

Yellow Change Interval

Yellow interval = $t + \frac{v}{2a + 64.4g}$

t = perception reaction time, typically 1.5 seconds
v = design speed*, in ft/s
a = deceleration rate, typically 11.2 ft/s_2
g = grade

Round up to nearest 0.1 second.

Minimum yellow change interval is 3.0 seconds.

Hold stakeholder discussion** when calculated yellow change interval is longer than 6.0 seconds.

Red Clearance Interval

Red interval = $\frac{w}{v}$ w = width of intersection, in feet
v = design speed*, in ft/s

If the initial calculation results in an all red time longer than 3.0 seconds, recalculate the red time as follows:

Recalculated red interval = $\frac{1}{2}(\frac{w}{v} - 3) + 3$

Round up to nearest 0.1 second.

Minimum red clearance interval is 1.0 seconds.

Hold stakeholder discussion** when recalculated red clearance interval is longer than 4.0 seconds.

Notes

*Design speed is the speed limit unless a speed study determines that the 85th percentile speed is faster or intersection geometrics compel vehicles to traverse the intersection slower.

**The purpose of a stakeholder discussion is to provide advance notification and involvement to stakeholders and provide an opportunity to consider possible countermeasures.

For most left turn lanes, assume a speed of 20 mph (32 kph) to 30 mph (48 kph). For locations with unusual conditions a higher or lower speed may be appropriate.

For separate left turn phases, calculate yellow and red intervals.

For left turns without a separate phase, calculate yellow and red times for both the through movement and the left turn movement. Use the highest yellow and enough red to equal the highest total time.

Where existing times are higher than calculated times, use the calculated values unless there is a documented history of the need for higher times. If approach is high speed and existing times are significantly higher than the calculated times, use the calculated values but consider adding a note to the plan to direct field forces to reduce the time incrementally. Include in the note how much and how often to reduce time until the final value is reached. (Ex. Existing Yellow Change Interval for phase 2 may be decreased by 0.2 seconds per week until the required value is reached.)

Where revising a location or adding a new signal along a corridor, consider comparing clearance times at adjacent intersections to new calculations to meet driver expectations.

Sources:
Traffic Engineering Handbook, Fifth Edition, Institute of Transportation Engineers, 1999.
A Policy on Geometric Design of Highways and Streets, Fourth Edition, American Association of State Highway and Transportation Officials, 2001.

Change and Clearance Intervals
SIGNALS & GEOMETRICS SECTION
TRAFFIC ENGINEERING AND SAFETY SYSTEMS BRANCH
NORTH CAROLINA DEPARTMENT OF TRANSPORTATION

7-05

STD. NO. 5.2.2
SHEET 4 OF 4

Figure 4. The revised methodology, as adopted.

Speed mph	Speed fps	Grade -6%	-3%	0%	3%	6%
20	29.3	3.1	3.0	2.9*	2.8*	2.7*
25	36.7	3.5	3.3	3.2	3.1	2.9*
30	44.0	3.9	3.7	3.5	3.4	3.2
35	51.3	4.3	4.1	3.8	3.7	3.5
45	66.0	5.1	4.8	4.5	4.3	4.1
55	80.7	5.9	5.5	5.2	4.9	4.6
65	95.3	6.7+	6.2+	5.8	5.5	5.2

* Less than 3.0 second minimum, increase yellow time to 3.0
\+ Greater than 6.0 sec threshold, requires stakeholder meeting prior to approval

Speed mph	Speed fps	Clearance Distance (feet) 50	75	100	125	150	175	200
20	29.3	1.8	2.6	**3.3**	**3.7**	**4.1+**	**4.5+**	**5.0+**
25	36.7	1.4	2.1	2.8	**3.3**	**3.6**	**3.9**	**4.3+**
30	44.0	1.2	1.8	2.3	2.9	**3.3**	**3.5**	**3.8**
35	51.3	1.0	1.5	2.0	2.5	3.0	**3.3**	**3.5**
45	66.0	0.8*	1.2	1.6	1.9	2.3	2.7	**3.1**
55	80.7	0.7*	1.0	1.3	1.6	1.9	2.2	2.5
65	95.3	0.6*	0.8*	1.1	1.4	1.6	1.9	2.1

Shaded cells indicate mitigated red intervals
* Less than 1.0 second minimum, increase all red time to 1.0
\+ Greater than 4.0 sec threshold, requires stakeholder meeting prior to approval

Figure 5. Sample yellow and red intervals.

With the adoption of this practice, NCDOT has established a consistent method for calculating yellow and red intervals that will provide safe and efficient operation. Because of the prohibitive cost associated with an immediate statewide change, the new practice will be used for new signals and phased into existing signals as they require other revisions, with a review of closely spaced signals to help promote the desired consistency. ■

References

1. *Manual on Uniform Traffic Control Devices for Streets and Highways.* Washington, DC: Federal Highway Administration (FHWA), November, 2004.

2. *Traffic Engineering Handbook, Fifth Edition.* Pline, J.L. (ed.). Washington, DC: Institute of Transportation Engineers (ITE), 1999.

3. Tarnoff, Philip J. and J. Ordonez. *Signal Timing Practice and Procedures: State of the Practice.* Washington, DC: ITE, 2004.

4. *Traffic Engineering Handbook,* note 2 above.

5. Eccles, K.A. and H.W. McGee. *A History of the Yellow and All-Red Intervals for Traffic Signals.* Washington, DC: ITE, 2001.

6. North Carolina Statewide Stakeholder Meeting on Clearance Intervals. Unpublished Meeting Minutes, 1990.

7. *Traffic Management and Signal Systems Unit Design Manual.* North Carolina Department of Transportation (NCDOT), 2004. Note: The former Traffic Management and Signal Systems Unit since has been renamed the ITS and Signals Unit, and the manual has been renamed the accordingly.

8. *Signalized Intersections: Informational Guide* (FHWA-HRT-04-091). Washington, DC: FHWA, 2004. Accessible via www.tfhrc.gov/safety/pubs/04091.

9. *NEMA Standards Publication TS 2-1998: Traffic Controller Assemblies with NTCIP Requirements.* National Electrical Manufacturers Association, 1998.

10. *2004 North Carolina Supplement to the Manual on Uniform Traffic Control Devices.* NCDOT, 2004.

11. Muller, T.H.J., T. Dijker and P.G. Furth. "Red Clearance Intervals: Theory and Practice." *Transportation Research Record,* No. 1867 (2004): 132–143.

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TRAFFIC ENGINEERING HANDBOOK
6TH EDITION

Institute of Transportation Engineers

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a head start or the pedestrians can be held until the initial queue of vehicles has been served. However, such controller phasing may have a detrimental effect on vehicle flow and, if part of a system, on system capacity.

The goals of traffic safety and traffic capacity must be balanced when determining controller phasing for an intersection. The following section describes the various components of controller phasing. More in-depth discussion can be found in the *Manual of Traffic Signal Design* and *Signalized Intersections: Informational Guide*.[14,15]

Green Interval. Ideally, the length of the green display on each approach to an intersection will be sufficient—but not excessive—to serve all the vehicles and pedestrians queued during the red interval. Several PC-based computer programs are available to assist in determining the green interval timing.

For semi- or fully-actuated controllers, a minimum and maximum amount of green time must be determined and allocated for each phase and programmed into the controller. These values are derived from the analysis results of the timing software or other method of analysis used by the designer.

For pre-timed signal controllers, the length of the green display is based on engineering judgment. Traffic and pedestrian counts for a specific period of time are often used in determining the signal timing.

Yellow Change Interval. The purpose of the yellow change interval, which is required to be the first interval following every circular green or green arrow indication, is to warn approaching traffic of the termination of the related green interval or that a red signal indication will follow (see "Vehicle Detector Placement").

MUTCD states that yellow change intervals should have duration of 3 to 6 sec.[16] To determine the appropriate yellow time for the approach, this should be calculated using the Kinematic Model—Formula 1 found in ITE's *Determining Vehicle Signal Change and Clearance Intervals*:[17]

$$Y = t + [v/(2a+2Gg)]$$

where:
Y = yellow clearance interval (sec)
t = reaction time (typically 1 sec.)
v = design speed (ft./sec.)
a = deceleration rate (typically 10 ft./sec.^{2})
g = acceleration due to gravity (32.2 ft./sec.^{2})
G = grade of approach (percent/100, downhill is negative grade)

The equation shown above includes a reaction time, a deceleration element and an intersection clearing time. In view of the operational history of the yellow change interval and the assumptions used in the formula, applying the formula requires the exercise of engineering judgment.

Because a long yellow change interval may encourage drivers to use it as a part of the green interval, maximum care should be used when exceeding 5 sec. If the interval is too short, rear-end crashes may result. When the calculation for yellow change interval time indicates a time longer than 5 sec., a red clearance interval typically provides the additional time.

Some jurisdictions time the yellow change interval to enable a vehicle to clear the intersection before the onset of a conflicting green display. Other jurisdictions allow a conflicting green display to be shown before the intersection is cleared. Still others allow a conflicting green display to be shown after the vehicles have cleared the center line of the conflicting approach. Engineering judgment should be exercised in selecting the operation of the yellow change interval to ensure safe passage of vehicles in the intersection.

As can be seen from the formula above, slower speeds result in higher values of yellow clearance time. When calculating the needed time, consideration should be given to the values for the 15th-percentile speed, particularly at wider intersections.

The calculations for steep downgrades will yield values that some drivers may consider excessive. Simply reducing the interval times may create dangerous operating conditions. The engineer should consider lowering the approach speeds by reducing the speed limit or by the use of a warning beacon or other measures.

Red Clearance Interval. The red clearance interval is an optional interval that follows a yellow change interval and precedes the next conflicting green interval. The red clearance interval is used to provide additional time following the yellow change interval before conflicting traffic is released.

MUTCD states that the red clearance interval should not exceed 6 sec.[18] The appropriate red time for the approach should be calculated using the following formula found in ITE's *Determining Vehicle Signal Change and Clearance Intervals*:[19]

$$R = (w+L)/v$$

where
R = all red interval (sec.)
w = width of stop line to far side no-conflict point (ft.)
v = design speed (ft./sec.)
L = length of vehicle (typically 20 ft.)

For exclusive turn movements, the value of w should be measured along the vehicle turn path from the stop line to the no-conflict point.

The decision to use a red clearance interval is determined by intersection geometrics, crash experience, pedestrian activity, approach speeds, local practices and engineering judgment.

6. Left Turns

Three operational modes are available when provisions for left turns are made in the phasing of a traffic control signal:

1. **Permissive (permitted) mode only**—in which drivers may turn left after yielding to conflicting traffic or pedestrians during the circular green indication, along with the parallel through movements. A separate left-turn lane is often provided but not required. No regulatory sign is required, but an informational sign may be used.

2. **Protected (exclusive) mode only**—during which left turns are permitted only when a left green arrow is displayed. There is no conflicting vehicular or pedestrian traffic. Typically, a separate left-turn lane is provided. If the left-turn movement occurs when the adjacent through movement is shown a circular red indication, a separate left-turn lane must be provided.

   A separate left-turn signal face must be used where the signal sequence does not provide for the simultaneous movement of the parallel through traffic. The change interval display may consist of either a yellow left arrow or a circular yellow. The yellow indication must match the green indication; that is, if the separate left-turn face provides a circular green, a circular yellow is provided. If the separate left-turn signal face provides a green left arrow, the yellow indication must be a left arrow. MUTCD requires that all green arrow indications must be followed by yellow arrow indications. The red interval may use a red arrow only if a yellow arrow indication is used. Otherwise, a circular red is required.

   When a separate signal face is used, it should be positioned in line with the turning movement approach. A left-turn signal sign (R10-10) is required unless the signal face consists of arrows only or unless it is properly hooded, shielded, or louvered to ensure that conflicting circular yellow or red indications are not readily visible to motorists in the through lanes.

3. **Protected/permissive (exclusive/permitted) mode**—a combination of both the protected and the permissive modes whereby left turns may be made during the green display as defined under the respective modes. Green and yellow arrow indications are required for this type of operation.

   The controller phasing for protected/permissive mode is the most complicated of the three modes in that it combines the other two modes. Four distinct controller-phasing schemes are commonly employed:

- lead-left turn with parallel, non-conflicting through traffic;
- simultaneous lead-left turns with no parallel through traffic;
- lag-left turn with parallel, non-conflicting through traffic; and
- simultaneous lag-left turns with no parallel through traffic.

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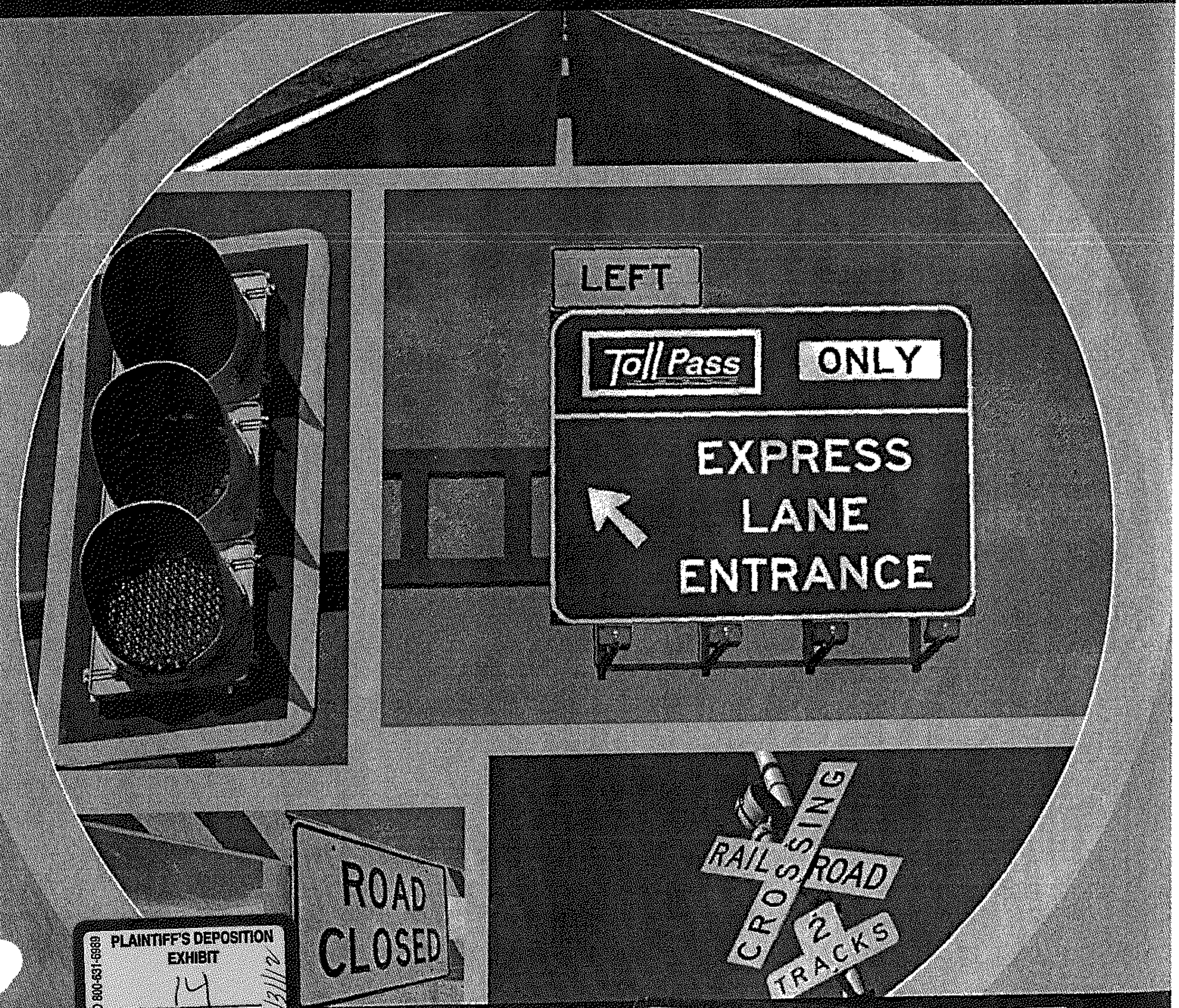

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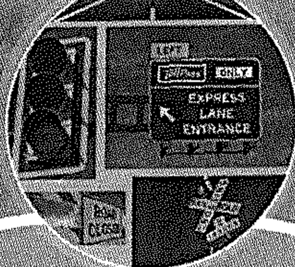

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Addresses for Publications Referenced in the MUTCD

American Automobile Association (AAA)
1000 AAA Drive
Heathrow, FL 32746
www.aaa.com
800-222-4357

American Association of State Highway and Transportation Officials (AASHTO)
444 North Capitol Street, NW, Suite 249
Washington, DC 20001
www.transportation.org
202-624-5800

American National Standards Institute (ANSI)
1819 L Street, NW, 6th Floor
Washington, DC 20036
www.ansi.org
202-293-8020

American Railway Engineering and Maintenance-of-Way Association (AREMA)
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Lanham, MD 20706
www.arema.org
301-459-3200

Federal Highway Administration Report Center
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report.center@fhwa.dot.gov

Illuminating Engineering Society (IES)
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New York, NY 10005
www.iesna.org
212-248-5000

Institute of Makers of Explosives
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www.iso.ch
011-41-22-749-0111

on the approach, the signal faces for the approach shall be as described in Items B.1 and B.2, except that flashing YELLOW ARROW signal indications shall be used in place of the GREEN ARROW signal indications for the turning movement(s) that conflicts with the signalized vehicular or pedestrian movement.

Support:

05 Figure 4D-20 illustrates application of these Standards on approaches that have only a shared left-turn/right-turn lane, and on approaches that have one or more exclusive turn lanes in addition to the shared left-turn/right-turn lane.

Option:

06 If the lane-use regulations on an approach are variable such that at certain times all of the lanes on the approach are designated as exclusive turn lanes and no lane is designated as a shared left-turn/right-turn lane:

A. During the times that no lane is designated as a shared left-turn/right-turn lane, the left-turn and right-turn movements may start and terminate independently, and the left-turn and right-turn movements may be operated in one or more of the modes of operation as described in Sections 4D.17 through 4D.24; and
B. If a protected-permissive mode is used, the shared left-turn/right-turn signal face provided in Paragraph 4 may be modified to include a dual-arrow signal section capable of displaying both a GREEN ARROW signal indication and a flashing YELLOW ARROW signal indication for a turn movement(s) in order to not exceed the maximum of five sections per signal face provided in Section 4D.08.

Section 4D.26 Yellow Change and Red Clearance Intervals

Standard:

01 **A steady yellow signal indication shall be displayed following every CIRCULAR GREEN or GREEN ARROW signal indication and following every flashing YELLOW ARROW or flashing RED ARROW signal indication displayed as a part of a steady mode operation. This requirement shall not apply when a CIRCULAR GREEN, a flashing YELLOW ARROW, or a flashing RED ARROW signal indication is followed immediately by a GREEN ARROW signal indication.**

02 **The exclusive function of the yellow change interval shall be to warn traffic of an impending change in the right-of-way assignment.**

03 **The duration of the yellow change interval shall be determined using engineering practices.**

Support:

04 Section 4D.05 contains provisions regarding the display of steady CIRCULAR YELLOW signal indications to approaches from which drivers are allowed to make permissive left turns.

Guidance:

05 *When indicated by the application of engineering practices, the yellow change interval should be followed by a red clearance interval to provide additional time before conflicting traffic movements, including pedestrians, are released.*

Standard:

06 **When used, the duration of the red clearance interval shall be determined using engineering practices.**

Support:

07 Engineering practices for determining the duration of yellow change and red clearance intervals can be found in ITE's "Traffic Control Devices Handbook" and in ITE's "Manual of Traffic Signal Design" (see Section 1A.11).

Standard:

08 **The durations of yellow change intervals and red clearance intervals shall be consistent with the determined values within the technical capabilities of the controller unit.**

09 **The duration of a yellow change interval shall not vary on a cycle-by-cycle basis within the same signal timing plan.**

10 **Except as provided in Paragraph 12, the duration of a red clearance interval shall not be decreased or omitted on a cycle-by-cycle basis within the same signal timing plan.**

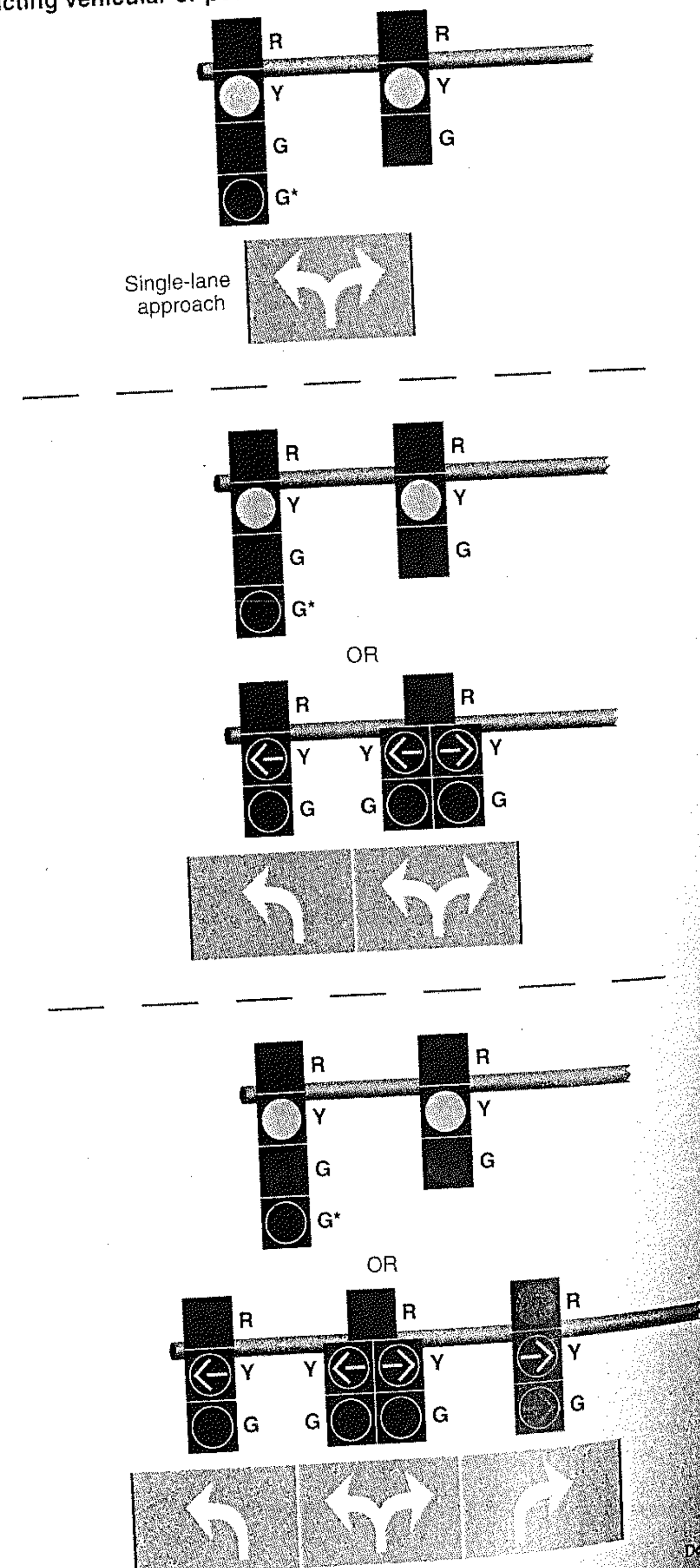
Option:

11 The duration of a red clearance interval may be extended from its predetermined value for a given cycle based upon the detection of a vehicle that is predicted to violate the red signal indication.

12 When an actuated signal sequence includes a signal phase for permissive/protected (lagging) left-turn movements in both directions, the red clearance interval may be shown during those cycles when the lagging left-turn signal phase is skipped and may be omitted during those cycles when the lagging left-turn signal phase is shown.

Figure 4D-20. Signal Indications for Approaches with a Shared Left-Turn/Right-Turn Lane and No Through Movement (Sheet 1 of 3)

A - No conflicting vehicular or pedestrian movements



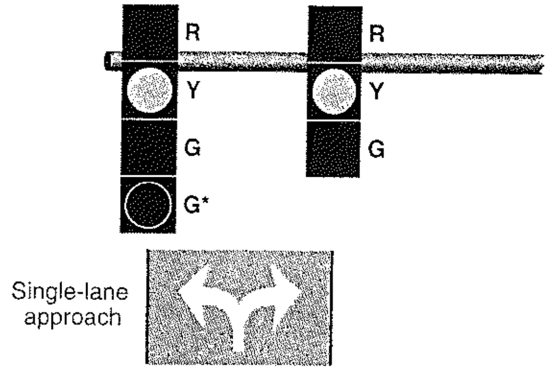
* Left-turn GREEN ARROW section shall be included if there is an opposing one-way approach and the signal phasing eliminates conflicts.

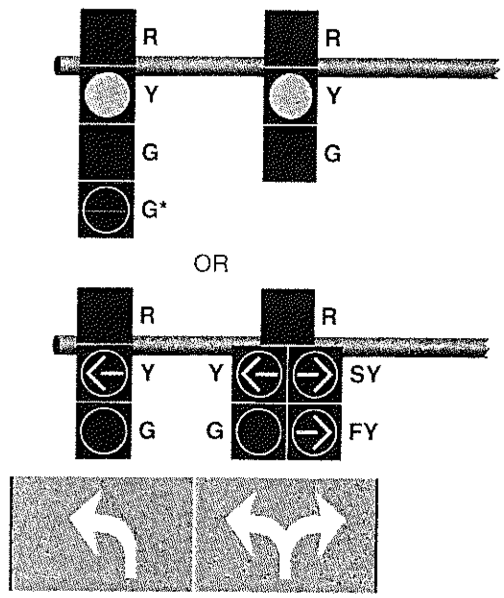
Notes:

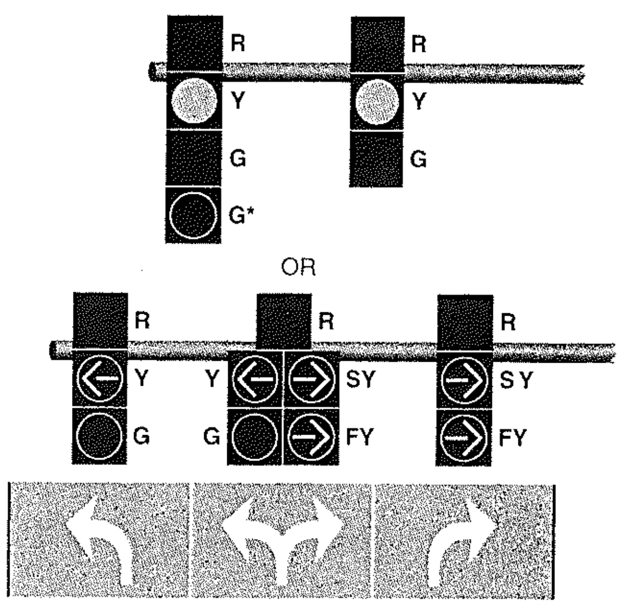
1. Horizontally-aligned signal faces may also be used.
2. Shared signal faces may also be 5 sections in a vertical straight line instead of a cluster.

Figure 4D-20. Signal Indications for Approaches with a Shared Left-Turn/Right-Turn Lane and No Through Movement (Sheet 2 of 3)

B - Pedestrian or vehicular conflict with one turn movement







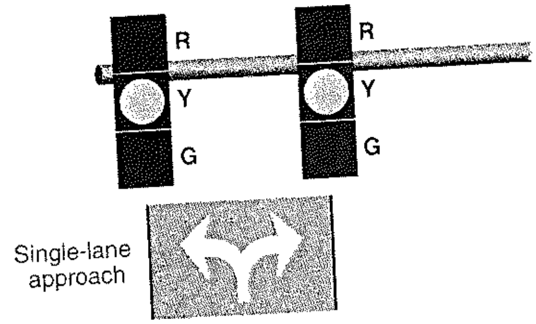
* Left-turn GREEN ARROW section shall be included if there is an opposing one-way approach and the signal phasing eliminates conflicts.

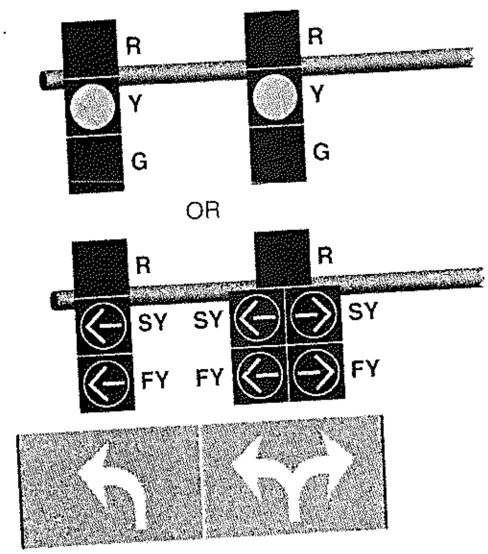
Notes:

1. A conflict with the right-turn movement is illustrated.
2. Horizontally-aligned signal faces may also be used.
3. Shared signal faces may also be 5 sections in a vertical straight line instead of a cluster.

Figure 4D-20. Signal Indications for Approaches with a Shared Left-Turn/Right-Turn Lane and No Through Movement (Sheet 3 of 3)

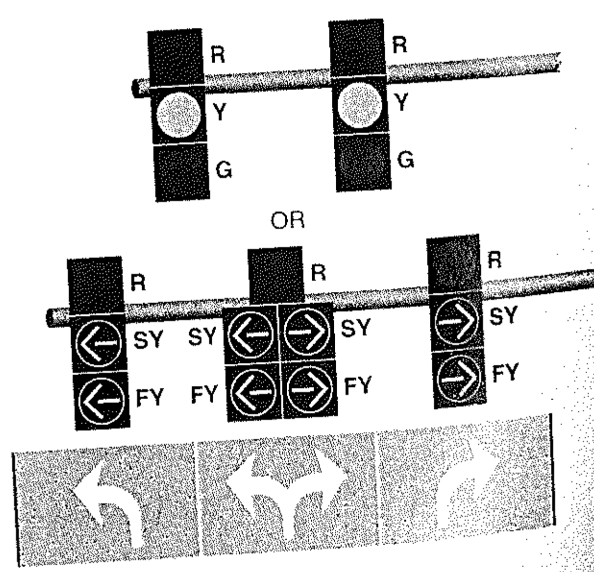
C - Pedestrian or vehicular conflicts with both turn movements





Notes:

1. Horizontally-aligned signal faces may also be used.
2. Shared signal faces may also be 5 sections in a vertical straight line instead of a cluster.



International Safety Equipment Association (ISEA)
901 North Moore Street, Suite 808
.dington, VA 22209
www.safetyequipment.org
703-525-1695

National Committee on Uniform Traffic Laws and Ordinances (NCUTLO)
107 South West Street, Suite 110
Alexandria, VA 22314
www.ncutlo.org
800-807-5290

National Electrical Manufacturers Association (NEMA)
1300 North 17th Street, Suite 1752
Rosslyn, VA 22209
www.nema.org
703-841-3200

Occupational Safety and Health Administration (OSHA)
U.S. Department of Labor
200 Constitution Avenue, NW
Washington, DC 20210
www.osha.gov
800-321-6742

Transportation Research Board (TRB)
The National Academies
500 Fifth Street, NW
Vashington, DC 20001
ww.nas.edu/trb
202-334-3072

U.S. Architectural and Transportation Barriers Compliance Board (The U.S. Access Board)
1331 F Street, NW, Suite 1000
Washington, DC 20004-1111
www.access-board.gov
202-272-0080

Acknowledgments

The Federal Highway Administration gratefully acknowledges the valuable assistance that it received from the National Committee on Uniform Traffic Control Devices and its more than 250 voluntary members in the development of this Manual.

13 The duration of a yellow change interval or a red clearance interval may be different in different signal timing plans for the same controller unit.

Guidance:

14 *A yellow change interval should have a minimum duration of 3 seconds and a maximum duration of 6 seconds. The longer intervals should be reserved for use on approaches with higher speeds.*

15 *Except when clearing a one-lane, two-way facility (see Section 4H.02) or when clearing an exceptionally wide intersection, a red clearance interval should have a duration not exceeding 6 seconds.*

Standard:

16 **Except for warning beacons mounted on advance warning signs on the approach to a signalized location (see Section 2C.36), signal displays that are intended to provide a "pre-yellow warning" interval, such as flashing green signal indications, vehicular countdown displays, or other similar displays, shall not be used at a signalized location.**

Support:

17 The use of signal displays (other than warning beacons mounted on advance warning signs) that convey a "pre-yellow warning" have been found by research to increase the frequency of crashes.

Section 4D.27 Preemption and Priority Control of Traffic Control Signals

Option:

01 Traffic control signals may be designed and operated to respond to certain classes of approaching vehicles by altering the normal signal timing and phasing plan(s) during the approach and passage of those vehicles. The alternative plan(s) may be as simple as extending a currently displayed green interval or as complex as replacing the entire set of signal phases and timing.

Support:

02 Preemption control (see definition in Section 1A.13) is typically given to trains, boats, emergency vehicles, and light rail transit.

03 Examples of preemption control include the following:

A. The prompt displaying of green signal indications at signalized locations ahead of fire vehicles, law enforcement vehicles, ambulances, and other official emergency vehicles;
B. A special sequence of signal phases and timing to expedite and/or provide additional clearance time for vehicles to clear the tracks prior to the arrival of rail traffic; and
C. A special sequence of signal phases to display a steady red indication to prohibit turning movements toward the tracks during the approach or passage of rail traffic.

04 Priority control (see definition in Section 1A.13) is typically given to certain non-emergency vehicles such as light-rail transit vehicles operating in a mixed-use alignment and buses.

05 Examples of priority control include the following:

A. The displaying of early or extended green signal indications at an intersection to assist public transit vehicles in remaining on schedule, and
B. Special phasing to assist public transit vehicles in entering the travel stream ahead of the platoon of traffic.

06 Some types or classes of vehicles supersede others when a traffic control signal responds to more than one type or class. In general, a vehicle that is more difficult to control supersedes a vehicle that is easier to control.

Option:

07 Preemption or priority control of traffic control signals may also be a means of assigning priority right-of-way to specified classes of vehicles at certain non-intersection locations such as on approaches to one-lane bridges and tunnels, movable bridges, highway maintenance and construction activities, metered freeway entrance ramps, and transit operations.

Standard:

08 **During the transition into preemption control:**

A. The yellow change interval, and any red clearance interval that follows, shall not be shortened or omitted.
B. The shortening or omission of any pedestrian walk interval and/or pedestrian change interval shall be permitted.
C. The return to the previous green signal indication shall be permitted following a steady yellow signal indication in the same signal face, omitting the red clearance interval, if any.

03 **Except as provided in Paragraph 4, the pedestrian signal heads shall continue to display a steady UPRAISED HAND (symbolizing DONT WALK) signal indication when the pedestrian hybrid beacon faces are either dark or displaying flashing or steady CIRCULAR yellow signal indications. The pedestrian signal heads shall display a WALKING PERSON (symbolizing WALK) signal indication when the pedestrian hybrid beacon faces are displaying steady CIRCULAR RED signal indications. The pedestrian signal heads shall display a flashing UPRAISED HAND (symbolizing DONT WALK) signal indication when the pedestrian hybrid beacon faces are displaying alternating flashing CIRCULAR RED signal indications. Upon termination of the pedestrian clearance interval, the pedestrian signal heads shall revert to a steady UPRAISED HAND (symbolizing DONT WALK) signal indication.**

Option:

04 Where the pedestrian hybrid beacon is installed adjacent to a roundabout to facilitate crossings by pedestrians with visual disabilities and an engineering study determines that pedestrians without visual disabilities can be allowed to cross the roadway without actuating the pedestrian hybrid beacon, the pedestrian signal heads may be dark (not illuminated) when the pedestrian hybrid beacon faces are dark.

Guidance:

05 *The duration of the flashing yellow interval should be determined by engineering judgment.*

Standard:

06 **The duration of the steady yellow change interval shall be determined using engineering practices.**

Guidance:

07 *The steady yellow interval should have a minimum duration of 3 seconds and a maximum duration of 6 seconds (see Section 4D.26). The longer intervals should be reserved for use on approaches with higher speeds.*

PART 1
GENERAL

CHAPTER 1A. GENERAL

Section 1A.01 Purpose of Traffic Control Devices

Support:

01 The purpose of traffic control devices, as well as the principles for their use, is to promote highway safety and efficiency by providing for the orderly movement of all road users on streets, highways, bikeways, and private roads open to public travel throughout the Nation.

02 Traffic control devices notify road users of regulations and provide warning and guidance needed for the uniform and efficient operation of all elements of the traffic stream in a manner intended to minimize the occurrences of crashes.

Standard:

03 **Traffic control devices or their supports shall not bear any advertising message or any other message that is not related to traffic control.**

Support:

04 Tourist-oriented directional signs and Specific Service signs are not considered advertising; rather, they are classified as motorist service signs.

Section 1A.02 Principles of Traffic Control Devices

Support:

01 This Manual contains the basic principles that govern the design and use of traffic control devices for all streets, highways, bikeways, and private roads open to public travel (see definition in Section 1A.13) regardless of type or class or the public agency, official, or owner having jurisdiction. This Manual's text specifies the restriction on the use of a device if it is intended for limited application or for a specific system. It is important that these principles be given primary consideration in the selection and application of each device.

Guidance:

02 *To be effective, a traffic control device should meet five basic requirements:*

A. Fulfill a need;
B. Command attention;
C. Convey a clear, simple meaning;
D. Command respect from road users; and
E. Give adequate time for proper response.

03 *Design, placement, operation, maintenance, and uniformity are aspects that should be carefully considered in order to maximize the ability of a traffic control device to meet the five requirements listed in the previous paragraph. Vehicle speed should be carefully considered as an element that governs the design, operation, placement, and location of various traffic control devices.*

Support:

04 The definition of the word "speed" varies depending on its use. The definitions of specific speed terms are contained in Section 1A.13.

Guidance:

05 *The actions required of road users to obey regulatory devices should be specified by State statute, or in cases not covered by State statute, by local ordinance or resolution. Such statutes, ordinances, and resolutions should be consistent with the "Uniform Vehicle Code" (see Section 1A.11).*

06 *The proper use of traffic control devices should provide the reasonable and prudent road user with the information necessary to efficiently and lawfully use the streets, highways, pedestrian facilities, and bikeways.*

Support:

07 Uniformity of the meaning of traffic control devices is vital to their effectiveness. The meanings ascribed to devices in this Manual are in general accord with the publications mentioned in Section 1A.11.

Section 1A.03 Design of Traffic Control Devices

Guidance:

01 *Devices should be designed so that features such as size, shape, color, composition, lighting or retroreflection, and contrast are combined to draw attention to the devices; that size, shape, color, and simplicity of message combine to produce a clear meaning; that legibility and size combine with placement to permit adequate time for response; and that uniformity, size, legibility, and reasonableness of the message combine to command respect.*

02 *Aspects of a device's standard design should be modified only if there is a demonstrated need.*

2. Vehicular traffic facing a GREEN ARROW signal indication, displayed alone or in combination with another signal indication, is permitted to cautiously enter the intersection only to make the movement indicated by such arrow, or such other movement as is permitted by other signal indications displayed at the same time.

   Such vehicular traffic, including vehicles turning right or left or making a U-turn movement, shall yield the right-of-way to:

   (a) Pedestrians lawfully within an associated crosswalk, and
   (b) Other vehicles lawfully within the intersection.
3. Pedestrians facing a CIRCULAR GREEN signal indication, unless otherwise directed by a pedestrian signal indication or other traffic control device, are permitted to proceed across the roadway within any marked or unmarked associated crosswalk. The pedestrian shall yield the right-of-way to vehicles lawfully within the intersection or so close as to create an immediate hazard at the time that the green signal indication is first displayed.
4. Pedestrians facing a GREEN ARROW signal indication, unless otherwise directed by a pedestrian signal indication or other traffic control device, shall not cross the roadway.

B. Steady yellow signal indications shall have the following meanings:

1. Vehicular traffic facing a steady CIRCULAR YELLOW signal indication is thereby warned that the related green movement or the related flashing arrow movement is being terminated or that a steady red signal indication will be displayed immediately thereafter when vehicular traffic shall not enter the intersection. The rules set forth concerning vehicular operation under the movement(s) being terminated shall continue to apply while the steady CIRCULAR YELLOW signal indication is displayed.
2. Vehicular traffic facing a steady YELLOW ARROW signal indication is thereby warned that the related GREEN ARROW movement or the related flashing arrow movement is being terminated. The rules set forth concerning vehicular operation under the movement(s) being terminated shall continue to apply while the steady YELLOW ARROW signal indication is displayed.
3. Pedestrians facing a steady CIRCULAR YELLOW or YELLOW ARROW signal indication, unless otherwise directed by a pedestrian signal indication or other traffic control device shall not start to cross the roadway.

C. Steady red signal indications shall have the following meanings:

1. Vehicular traffic facing a steady CIRCULAR RED signal indication, unless entering the intersection to make another movement permitted by another signal indication, shall stop at a clearly marked stop line; but if there is no stop line, traffic shall stop before entering the crosswalk on the near side of the intersection; or if there is no crosswalk, then before entering the intersection; and shall remain stopped until a signal indication to proceed is displayed, or as provided below.

   Except when a traffic control device is in place prohibiting a turn on red or a steady RED ARROW signal indication is displayed, vehicular traffic facing a steady CIRCULAR RED signal indication is permitted to enter the intersection to turn right, or to turn left from a one-way street into a one-way street, after stopping. The right to proceed with the turn shall be subject to the rules applicable after making a stop at a STOP sign.
2. Vehicular traffic facing a steady RED ARROW signal indication shall not enter the intersection to make the movement indicated by the arrow and, unless entering the intersection to make another movement permitted by another signal indication, shall stop at a clearly marked stop line; but if there is no stop line, before entering the crosswalk on the near side of the intersection; or if there is no crosswalk, then before entering the intersection; and shall remain stopped until a signal indication or other traffic control device permitting the movement indicated by such RED ARROW is displayed.

   When a traffic control device is in place permitting a turn on a steady RED ARROW signal indication, vehicular traffic facing a steady RED ARROW signal indication is permitted to enter the intersection to make the movement indicated by the arrow signal indication, after stopping. The right to proceed with the turn shall be limited to the direction indicated by the arrow and shall be subject to the rules applicable after making a stop at a STOP sign.
3. Unless otherwise directed by a pedestrian signal indication or other traffic control device, pedestrians facing a steady CIRCULAR RED or steady RED ARROW signal indication shall not enter the roadway.

D. A flashing green signal indication has no meaning and shall not be used.

Exhibit B.

The relationship between acceleration, velocity and time.

Equation 1	$$acceleration = \frac{change\ of\ velocity}{change\ of\ time}$$
Equation 2	$$a = \frac{\Delta v}{\Delta t}$$
Equation 3	$$\Delta t = \frac{\Delta v}{a}$$
Equation 4 t = time it takes for an object to stop from initial speed decelerating at constant rate a.	$$t = \frac{v}{a}$$

PLAINTIFF'S DEPOSITION EXHIBIT 15 Marcer 10/31/12 PENGAD 800-631-6989

$$a = \frac{change\ of\ velocity}{change\ of\ time}$$

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PLAINTIFF'S DEPOSITION EXHIBIT E Fuller PENGAD 800-631-6989

PLAINTIFF'S DEPOSITION EXHIBIT B Moen PENGAD 800-631-6989

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Critical Distance--also known as the Distance Required to Stop.

Equation 1	$\text{Critical Distance} = v \ \ t_p + \left[\frac{v^2}{2(a+Gg)}\right]$
Equation 2	$\text{Yellow Change Interval} = \frac{[\text{Critical Distance}]}{\text{Approach Speed}}$
Equation 3	$\text{Yellow Change Interval} = \text{Perception Time} + \frac{[\text{Safe Braking Distance}]}{\text{Approach Speed}}$
Equation 4	$Y = t_p + \frac{\left[\frac{v^2}{2(a+Gg)}\right]}{v}$
Equation 5	$Y = t_p + \frac{v}{2(a+Gg)}$
Equation 5	$Y = t_p + \frac{v}{2a + 64.4g}$
Equation 6. Grade = 0	$Y = t_p + \frac{v}{2a}$
Equation 7.	$Y - t_p = \frac{v}{2a}$
Equation 8.	$v = 2a(Y - t_p)$

A Simple Computation of Critical Distance.

	Equation
Equation 1	$c = v\ \ t_p + \left[\frac{v^2}{2(a + Gg)}\right]$
Equation 2	$c = 45 * 1.47 * 1.5 + \left[\frac{(45 * 1.47)^2}{2(11.2 + G * 0)}\right]$
Equation 3	$c = 99 + 195$
Equation 4	$c = 294$ ft
	The critical distance is 294 feet long.

Straight through

$$Y_T = PtR + \frac{V_0}{2a}$$

$$= 2.5$$

Turn

$$t_T = PtR + \frac{V_0^2}{2a(V_{avg})}$$

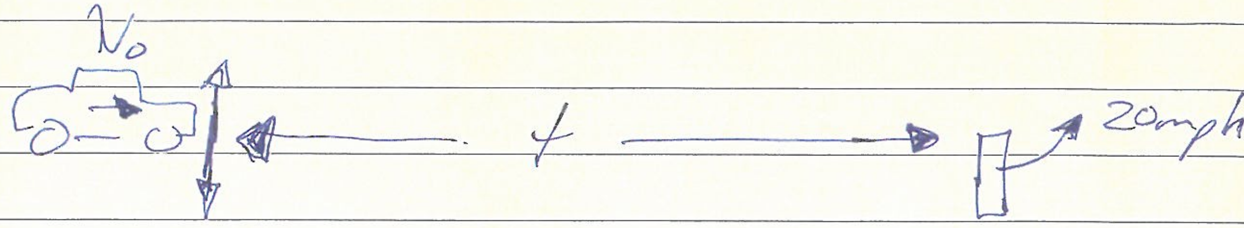

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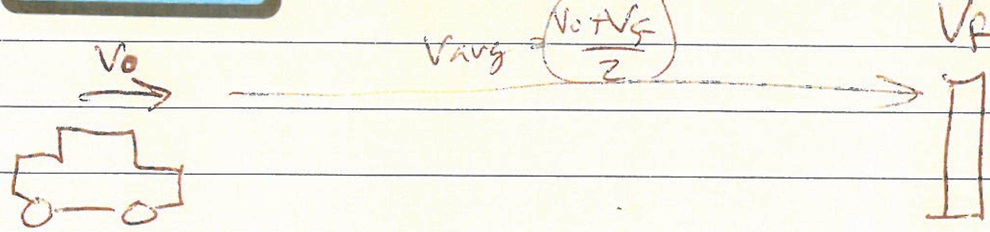
EXHIBIT
26
1

$V_f = 20\text{mph}$



$V_o = 45\text{mph}$
$V_f = 20\text{mph}$

$$Y_t = (P+R) + \frac{V_o^2}{2a(V_{avg})}$$

$$Y_t = (2.5) + \frac{(66)^2}{2(11)\left(\frac{66+29}{2}\right)} = \frac{66^2}{22(47.5)} = \frac{4356}{1045}$$

$$= 4.17$$

$$= P+R + 4.17$$
$$= 2.5 + 4.17$$
$$= 6.67$$