STATE OF NORTH CAROLINA IN THE GENERAL COURT OF JUSTICE
COUNTY OF WAKE SUPERIOR COURT DIVISION
10-CVS-019930

BRIAN CECCARELLI and LORI)
MILLETTE, individually and)
as class representatives,)
)
)
Plaintiffs,)
)
)
v.)
)
TOWN OF CARY,)
)
Defendant.)

Deposition of JOHNNIE P. HENNINGS, P.E.
(Taken by the Defendant)
Raleigh, North Carolina
Tuesday, October 30, 2012

Reported by: Marisa Munoz-Vourakis -
RMR, CRR and Notary Public

Job No. AMB201811

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Deposition of JOHNNIE P. HENNINGS, taken by the Defendant, at Accident Reconstruction Analysis, 5801 Lease Lane, Raleigh, North Carolina, on the 30th day of October, 2012 at 9:24 a.m., before Marisa Munoz-Vourakis, Registered Merit Reporter, Certified Realtime Reporter and Notary Public.

INDEX

P R O C E E D I N G S

Whereupon, JOHNNIE P. HENNINGS, having been first duly sworn, was examined and testified as follows:

EXAMINATION BY COUNSEL FOR DEFENDANT

BY MS. MARTINEAU:

Q. Mr. Hennings, my name is Elizabeth Martineau, and I'm an attorney, and I'm here to take your deposition today.

Do you understand you've been designated as an expert witness in the case brought by Mr. Ceccarelli and Ms. Millette?

A. Yes.

Q. And what were you asked to do?

A. I don't think there was a specific directive. Originally, Mr. Stam forwarded us either one or two of Mr. Ceccarelli's papers, and we were asked to review that, see if we agreed or disagreed in the general premise of the paper.

Q. And when was that one where you forwarded a copy of Mr. Ceccarelli's papers?

A. Early September of this year.

Q. And what was your assignment, to look over the papers and determine whether you agreed or disagreed?

A. Well, I think we had a discussion on the phone, and it was, you know, read over those, see if you see any faults with it. If you agree with the conclusions, you know, tell me what you see, basically is what I gathered from our conversation, was look at it, see what you take from it.

Q. And were you part of the conversation?

A. Yes.

Q. And what documents were you provided originally from Mr. Stam's office to look at?

A. The very first document we were provided was Misapplied Physics in the International Standards that Set Yellow Light Durations Forces Drivers to Run Red Lights.

Q. And is that the document you were asked to take a look at and let Mr. Stam know what you thought of it, or was there any other document that you were provided at that time?

A. I think this was the only document we were provided, but I think there was discussion that there were more documents on a website, and so we reviewed some documents on the website as well.

Q. Tell me about your -- well, tell me about your role with Accident Reconstruction Analysis, Inc. Can I just say ARAI?

A. Yeah, that's what we call it.
Q. Tell me about your role with ARAI?
A. Well, I started working here part time in the spring of '96, graduated from NC State in December of '97 and became full-time employee January of '98. I've been here since that time.
Q. And what type of engineering services do you provide?
A. The company or myself?
Q. You.
A. Myself, I generally deal with vehicular accidents and structural matters. Those are the primary things that I deal with. There are many issues that do not fall in a particular category that will require some type of engineering analysis. As an example, an exploding water tank or something that doesn't really fall into automotive or structural, it's kind of a failure analysis.
Q. Okay. And do you have a copy of your CV?
A. I do.
Q. And what I'm going to do, maybe after the deposition, I would like to get a copy of your file and materials that show what you reviewed and things like that, okay, but is it okay if I just go ahead and mark this?

A.   Sure.
MS. MARTINEAU: Let's mark it as Defendant's Exhibit 4.
(The document referred to was marked Defendant's Exhibit Number 4 for identification.)
Q.   Okay. What I've marked as, can you take a look at what's been marked as Exhibit 4?
A.   I accidentally gave you an extra page as part of my deposition list. Can I tear that off?
Q.   What is that, just to show you the list of --
A.   The list of when the Secretary of State put it together, she accidently -- I actually have a separate list for deposition. They were apparently stacked.
Q.   Okay. Take it off, if that's what you want to do.
A.   And we will staple it to that.
Q.   So take a look at Exhibit 4.
A.   I did.
Q.   Is that a copy of your resume or CV?
A.   Yes.
Q.   And tell me a little bit about your bachelor's of science in mechanical engineering you got

in 1997.

A. Well, it was a curriculum at NC State. It's generally term a four-year degree. I went part time, it took me eight years. It is a mechanical engineering degree. I'm not sure what else.

Q. What is mechanical engineering?

A. Mechanical engineering is a branch of engineering that deals with mechanics that may involve many different types of things, anything from vibrations to structures to systems control, you know, the motion of objects, things of that nature.

Q. What do you mean by system controls?

A. Well, there's a few classes that we take that are specifically geared towards controls and controls being monitoring and controlling processes, such as things such as cruise control in a car, it could be something controlling a process like we want to do this process and then when it's done, we do this process. Or if this one isn't done by a certain time this one starts, things of that nature. Those are the type of the control classes that we have. MAE435 is specifically one of those classes.

Q. And are there different types of engineering that you can specialize in?

A. Yes.

Q. What other types of engineering is there?
A. Well, there's nuclear, chemical, civil, mechanical, aerospace and each of those can be divided into subchapters.
Q. How would you characterize the type of engineering at ARAI? Is it essentially a forensic firm?
A. Well, I mean, that's kind of the general term that we use to describe what we do is forensic, yes.
Q. And how would you describe forensic?
A. Well, forensic is when, you know, many engineers do things such as design. Some engineers do testing. Generally, our job is analyzing situations, processes, materials. We look for causes to occurrences.
So forensically, you know, we look at things with an eye as to try to figure out why, in many situations.
Q. So, for example, do you do accident reconstruction?
A. Yes.
Q. So give me example of how a forensic engineer, what they would do with accident reconstruction.

A. Well, if we're talking about an accident, assumed -- are you referring to like an automobile accident?

Q. Sure.

A. Right. So an automobile accident, we deal with a lot of things. We deal with perception reaction, visibility, timelines, we deal with speed determinations, and we do a lot of what if analysis. If a car can do this, what if it did this? What if it did this? And see how those parameters affect the outcome of an accident to try to determine, in most cases, how an accident happened.

Q. So to determine what the cause of the accident was?

A. Or not only the cause of the accident but ways that it could have been avoided.

Q. Okay. And looking at your resume -- and have you ever worked as an engineer to actually -- in a capacity other than forensics?

A. No, I have not.

Q. Have you ever signed and sealed any engineering plans?

A. No.

Q. On the structural -- how would you break out like the percentage of your time with ARAI in terms of what you do with the percentage of your time?

A. Well, it varies over time. I mean, we have certain deployments, if you will, you know, a large percentage for a short period of time of my work was structural during the hurricanes of '05 and '06. In fact, several of us moved to the State of Florida to perform those investigations over the period of about a year and a half, but overall, you know, in the 14 plus years, I would say that overall it's probably about maybe 45/45 structural and vehicular, with the remaining ten being these miscellaneous cases.

Q. And so when you say structural, give me an example of what you do when you're doing forensics on a structural engineering case?

A. It could vary pretty widely. Some examples would be if a building collapsed, determining why the building collapsed. If a building is having sagging problems, analyzing why it would sag. Water intrusion problems, sometimes some people would call similar things like sick building syndrome, to determine, you know, how or why the building is having problems. It could be analysis of a building to determine if it met building code, if it meets industry standards for installation, manufacturer's standards for installation. And then, you know, if certain amount of damage to a building could have been from a particular storm, that was a large part of the job, looking at hurricane damage, things of that nature, component performance testing of windows and doors, things like that.

Q. Again, trying to determine what happened that caused the issue of the structure that you're investigating?

A. Well, it's not always a what happened. Sometimes it's, for example, someone owns a building, and they want to know if the windows meet industry standards. It may not be that they're at this time having a problem with the windows, but do they meet certain air and filtration rates, water infiltration rates, things of that nature.

Q. So in such a situation, how would you determine like what do you do to look to see whether -- what would you look to to see whether or not a window met industry standards?

A. Well, there are industry standards for testing of windows. There's ASTM standards that give testing parameters, testing the specifics of testing how to determine if a window meets a certain standard.

Windows are rated by what's called design pressure, and it varies on the wind pressure, which zone you're in. Say we have a DP40, design pressure 40 window, that's supposed to be at the coast, you know, it should be 40 PSF test, and we'll run a test to see if it has water leakage at a certain rate.

Q.   And how do you determine what the actual PSI it should be? You talked about the ASTM standards?

A.   Right.

Q.   So do you look toward outside organizations to determine what they say the standard is, or do you make up your own standard?

A.   In our job, sometimes we have many situations that don't fall specifically into a standard.

Q.   Well, I'm talking about this situation for looking to see whether or not the window meets the industry standards, and you talked about ASTM standards.

A.   Right.

Q.   So how would you determine for a window that you've been asked to come in and take a look at, how would you determine what the standard is?

A.   Sure. If, for example, the standard would be you have to look through the building code, determine what the building code says the design pressure should be for the window. Then you would go to the testing for the window, voluntary testing by the manufacturer to meet these ASTM standards. It is voluntary, however, the code requires that the window be a certain standard to be installed.

And so we would look at the methodology outlined in the ASTM standard. Now, there have been situations where something, such as a wall penetration, maybe a junction box or a vent fan or something like that, that doesn't fall under a window standard, but it's still part of the wall openings, and so then we look at that and say well, what's the intent of the standard, and the intent of the standard is to prevent water from getting in so can we, as engineers, apply that standard to another wall opening and see if it fails or passes.

Q. And when you say that standard, the ASTM standard?

A. Yeah, the specific window standard. ASTM makes probably thousands of standards.

Q. Do you know what ASTM stands for?

A. Yes, the American Society of Testing Materials.

Q. And what type of organization is that?

A. That is, it's my understanding is a volunteer organization of engineers and industry professionals who get together and agree upon a standard practice of testing.

Q. And are you aware of any other organization or group that has different standards, for example, window performance, other than ASTM, that engineers could look toward?

A. Well, over the course of years -- years ago typically the window manufacturers had their own standards, and the window manufacturer's association eventually what happened through the course of time is that enough different parties decide hey, we need to get a standard, and so they came together to become a group of people that were probably eventually employed by ASTM to produce a window standard. So over time, standard organizations come and go, sometimes they mend together.

Q. So is there another organization, other than ASTM, that has different standards for windows performance that engineers can look toward?

A. Not that I can think of right offhand. Not that I'm aware of.

Q. Sure. And in your work as a structural engineer doing forensic work, trying to determine what the standard practice is, you look toward the published ASTM standards?

A. If there is a standard that applies.
Q. And does that organization, you said it's a bunch of professionals getting together to talk about what the standards should be, and then they come up with the standard, is that fair?
A. That's typically how I envision the process.
Q. And as a forensic engineer, part of your job in structural components is to look at the standard or the practice and to see whether or not the component that you're interested in met that standard or practice?
A. If it specifically applies to that component, or if, you know, again, there are tests where we have a situation that doesn't specifically fit into the intent of the standards, so we have to make an engineering judgment as to what is the intent of the standard.
Q. When you use the word engineering judgment, what do you mean by that?
A. Well, as an engineer, we have engineering judgment. We look at things and try to determine in our opinion using our experience and knowledge as to how something should be done.
Q. Okay. And when you don't have a written

standard that you can look at, do engineers sometimes have different -- well, do engineers sometimes disagree on what the proper course should be?

A. Certainly.

Q. And can two different engineers have two different ideas that both could work?

A. That's certainly possible, yes.

Q. Now, I want to ask you a little bit about the structural services.

A. Sure.

Q. I'm sorry, I mean the vehicle accident reconstruction services. You said about 45 percent of your work is with vehicle accident reconstruction?

A. I would say that 45 percent over the course of my career, and, again, that's just an estimation. I've never added it up.

Q. I'm sure you've gotten asked that question almost in every deposition, right?

A. Certainly. And so it's difficult to quantify, but, I mean, you know, I don't want to say it's exactly 45. I just haven't counted, but I'm trying to ballpark for you.

Q. Let's say within the past, I mean, has your practice changed, like right now say within the past year or two, is your practice, percentage of time you spent different than what you just told me?

A. Yes.

Q. Tell me what you're doing now.

A. I would say over the past maybe three years, something on the order of 80 percent or greater of my work has been automobile accidents.

Q. And do you attribute any of that to the economy with construction, or is it just you're more interested in automobile accidents, or why would you say -- what do you account for the change?

A. You know, that's something that I've dealt with quite a bit trying to figure out. I'm not certain. I know there were points in times in my career where I had clients that had large class action or national cases that took up a huge amount of my time, so I was doing those cases while other engineers were doing automobile.

So it's not that the nature of the work has changed, it's just that some of my clients, those situations have resolved themselves, and now I have more time to do the automobile accidents.

Q. So have you done accident, vehicle accident reconstruction in situations where there's not an accident, where there's not an end result as an automobile accident?

A. I mean, specifically, you know, we look at things when they fail. I mean, there have been situations when maybe a tire came off, you know, things of that nature, to try to figure out how that happened. But as far as automobile, I mean, the majority of our work is automobile accidents. I'm sorry, I may have misstated that. The majority of our work related to vehicles is automobile accidents.

Q. And do you have a percentage of let's say since you've been doing 80 percent automobile accidents, what percentage of time you're working on behalf of a plaintiff versus working on behalf of a defendant?

A. Well, I mean, a lot of the cases are not specifically in litigation. I mean, we're hired by insurance companies to look at the accident to figure out how it happened.

So in that situation, I don't quantify the insurance company as a plaintiff or a defendant. But of the ones that go to litigation, are actually involved in litigation, I would say generally, again, as just a guess, probably 60 percent defense, 40 percent plaintiff.

Q. What type of -- what percentage of your automobile accident reconstruction work is doing work

pre-suit for insurance companies?
A. Pre-suit? It's just a guess, 20 percent, 25 percent.
Q. When you say just a guess, you're just pulling it out of the air, or is it based on --
A. Based on my best recollection, because I don't sit down and add them all up. I'm just trying to give you the best numbers --
Q. I don't want you to guess. You're certainly allowed to give an estimate --
A. That's an estimate. Again, I don't count these things. I don't know what the numbers are. My gut feel, when you ask me what percentage, my estimation would be 20, 25 percent.
Q. So what do you do, let's say, for a typical passenger car accident that is in litigation and you're representing one side or the other, I mean, you get a phone call, what do you do?
A. You're saying as a case that's in litigation?
Q. Correct.
A. Typically a case that's in litigation, first step is to collect whatever information we can that will be police reports, photographs. A lot of it depends on the timeline or chronology. We do get

accidents that occurred two or three years ago. At this point, the vehicles are gone.

Q. Sometimes not?

A. Sometimes not. We do get lucky, we can find them sometimes, and so that's a different situation. But if we focus for a moment on an accident that happened last week or two weeks ago and it's already in litigation, let's just say a month, those vehicles are probably still around. So I get a call, somebody says hey, my client was involved in an accident. I need you to look at it and see what happened.

So first thing I ask is where are the vehicles? Do you have an accident report? Do you have any photographs? Send me whatever information you have. Then I have to arrange to inspect the accident scene and inspect the vehicles to -- hopefully they're still there. Some vehicles have crash data on them, we download that.

So it does vary by case by case, but the outline would be look at the scene, look at the vehicles and then complete the investigation.

Q. And what are you trying to determine in your investigation? What's your role as an accident reconstruction engineer when you're investigating an accident?

A. Well, the role can vary pretty widely, depending on the type of case. For example, night time versus day time, crossing intersection versus a rear end, head on versus rear end, things of that nature, but ultimately the point is to determine how the accident happened and what events led up to the accident.

Q. And as an engineer that does accident reconstruction investigation, what principles do you apply in order to do that?

Let's say, for example, do you often measure, or does sometimes your job require you to measure the crush, the amount of crush in a vehicle?

A. Certainly.

Q. And so if you're going out to a scene measuring crush, why are you doing that? What's the purpose behind that?

A. Well, there's -- the crush vehicle can give you the determination of the energy required to crush the vehicle. If you have that energy, then you can calculate what the change in velocity is during the collision. That, combined with other scene data, you can start to put together a speed of the vehicle at impact, or the vehicles. Ideally, you would measure both. You combine that with scene evidence to determine what the speed of the vehicle was.

Q. Do engineers who practice accident reconstruction, forensic accident reconstruction, is there an organization that you can be a member of that will promulgate, I don't know, written materials or practice guidelines for accident reconstruction engineers?

A. There are many organizations, yes.

Q. Are you a member of any of them?

A. No, I'm not.

Q. Why not?

A. I've never seen the need.

Q. Well, how do you determine what types of, like if you're doing a cross-calculation, how do you determine what the practice is for such engineers to determine or to use crush data?

A. Well, you look at the original research papers. Crush data information was originally developed in Calspan in the '60s and '70s, and eventually Ray McHenry was an engineer that wrote the software. And actually, luckily, Ray lives here in Cary or Morrisville, and Ray and his colleagues wrote software that's used and wrote technical papers in how to use the software in crush analysis.

So that's one of the things I would go back on, is look at the original research as to how that analysis process came about.

Q. And is there a, like a publication or guide that promulgates the standards used in determining or standards used in making the crush data determinations?

A. Well, there are many publications out there. The Society of Automotive Engineers is a group that puts forth technical papers, and those papers get published where a person or small group of people typically will do research, and they say hey, we did a lot of research, we think you need to publish a paper on it. They submit it to SAE. SAE will review it and through a process and they will either approve it or disapprove it, and then that will become a "published" SAE paper that will be given a designation of a year and a paper number.

So those papers are written. There's probably dozens of those a year written in different forms for accident investigators or just automotive engineers, because it is truly the Society of Automotive Engineers, not specifically reconstruction.

So those papers are readily available for viewing and purchase.

Q. And do those papers promulgate accepted practices that automobile engineers use?

A. Some of them do, yes. Well, I'm sorry, your question was automobile engineers. I think all of those papers will reflect something that's interesting to the person who works in the automotive industry or someone like myself as an accident investigator.

Q. I can be more specific, because I guess I am talking about accident reconstruction.

Will the Society of Automotive Engineers, do they publish papers that promulgate traffic automobile engineers' practices for looking at things like crush data, things like that?

A. There are those out there, absolutely.

Q. And are those things that you routinely use in your practice when you're trying to determine the force of the impact in automobile crush investigations?

A. In some instances, yes.

Q. Is there more than one accepted practice for automobile forensic engineers to determine crush values?

A. To determine crush values?

Q. Yeah.

A. Like crush stiffnesses?

Q. Yeah.

A. Well, there's different tests, so you have to apply those different types of tests to the situation you have at hand.

Q. And those different tests might come out with different answers?

A. Well, they are different types of tests. For example, a full frontal impact versus a 40 percent offset or side impact or rear impact, all those give different stiffnesses for different parts of the vehicle.

Q. Do other, I mean, are there other though like competing practices out there for determining crush impacts that automobile engineers use in their practice?

A. I'm sorry, what was your question again?

Q. Sure. Other than the SAE published criteria or practice, you know, the SAE published guidelines, let's say, for how to determine crush criteria for various types of accidents, is there any other organization or publication that has like a competing theory of determining crush value that is generally accepted among the automobile reconstruction engineering -- automobile accident reconstruction practicing engineers, is probably a better way to say it?

A. Right. I think I got you. Basically

dealing specifically with crush factors, not every accident is exactly a hundred percent frontal or a hundred percent rear or 40 percent offset. Then you have accidents that are usually more often fatal. You have under rides and overrides, things of that nature.
And so there are engineers that have put forth methodology suggested to using those abstract situations that don't fall specifically in the hundred percent frontal or that type of test, and so you have to, as an engineer, look at their methodology and determine if you can apply that to your situation, or B, if you even believe that their methodology is valid.
Q. And can practicing engineers who practice in automobile accident reconstruction have -- let me try again.
Do forensic automobile accident engineers sometimes have differences of opinion regarding whether or not a certain engineering practice is useful for their application?
A. I think yes. I think that's a definite yes.
Q. You have under your -- on your CV accident reconstruction, light filament on/off analysis. What's that?
A. To determine things such as the brake

lights are on, headlights are on high or low, things like that.

Q. And that's helpful when you're investigating an accident to determine whether someone had their headlights on, for example?

A. Yeah, well, if they're on, it's very helpful, you know, like if their brake lights were on, somebody says that they weren't braking and the brake lights show that they were on. Pedestrian accident, high beams versus low beams, things like that.

Q. You have reconstruction of timeline, site distance and accident events?

A. Yes.

Q. Give me an example of what you mean by that?

A. Well, that's really something that's done in every automobile accident. We need to know what people can see, what they can do, what the timeline of events is. When we deal with those timelines, we deal with visibility, you know, the position of vehicles at points in time. So you're trying to determine how the sequence unfolded.

Q. Now, in your role, when you're doing that to determine how the sequence unfolded, do you use things such as perception reaction time?

A. Yes.
Q. How do you determine what is an acceptable perception reaction time?
A. Well, there are different numbers for perception reaction that we deal with, different studies, studies trying to determine what perception reaction time use different scenarios. So if we can, we try to apply a different scenario or the appropriate scenario, excuse me, to the scenario we have at hand.
Q. So is it fair to say --
MR. STAM: Objection, would be he was still answering.
BY MS. MARTINEAU:
Q. Go ahead.
A. I think that was really kind of just the determination I had.
MR. STAM: I apologize.
BY MS. MARTINEAU:
Q. And do you sometimes use different perception reaction times based upon a different scenario, or do you always just use the same exact perception reaction time no matter what the situation is you're facing with when you're doing an accident reconstruction analysis?
A. It does vary for situations.

Q. Can you give me an example where you might use a short perception reaction time?

A. A short perception reaction time would be a situation where someone is driving down the road and they have some warning, preconditioned warning that a car was going to pull out or a person was going to step out, and so their total perception reaction time is shortened a bit when they're preconceived that something is going to happen.

Q. In a situation such as that, where maybe you're trying to determine whether a vehicle could have avoided a pedestrian that that vehicle in reality hit, what would you look -- is there a standard that you would look at that promulgates what acceptable perception reaction time is to use in that situation?

A. Well, my practice for using perception reaction is that we know their's a wide range of perception reaction. So when giving a scenario, my practice is to say that if a person perceived and reacted in this time, this is what happened.

Q. And how do you determine what might be an acceptable time in the situation that we just described, where a vehicle is going down the road, there's a sign that indicates that it is a crosswalk coming up and there's an accident between a vehicle and a person? How would you determine, because you said there's a wide range, how would you determine what to use? What would you look at? Would you just like pull it out of the air, or would you go to a respected source to determine that value? What would you do?

A. Well, in that situation, what we have is we have a lot of different situations that can arise while you're driving. You have situations that are completely unexpected --

Q. But here we're talking --

MR. STAM: Objection.

A. I'm trying to answer your question.

Q. You can go ahead and answer, and just explain, that might just be easier. If you can't answer without first going into a narrative, then go ahead and go into a narrative.

MR. STAM: I object to the form of a question, to wit, asking the question while he's in the midst of answering another question.

MS. MARTINEAU: Okay.

Q. Go ahead.

A. To your point, it does require some explanation as to the method. You asked how do I determine what to use? And that depends on the situation.

The situations do dictate whether we use a one and a half to two and a half, whatever it is, and it varies from situation to situation. Night time is typically more than day time. Night time with multiple vehicles is more than just night time with one vehicle.

So we look at the summation of information that a person has around them to determine what's going on, and so you can have a broad daylight accident and you have a situation where witness testimony says two cars nearly hit right in front of the car, and then they moved away, and so that's another piece of information that would extend someone's perception reaction to a car stopped in front of them.

So all of that has to be taken into account as to what the perception reaction is in that situation.

Q. Can you answer my question?

A. Okay. What was the --

Q. My question was, so for an example, we can say day time, where you've got a car that there's a warning that there's a pedestrian crosswalk coming up, and eventually there's a collision at the crosswalk crossing between a car and a pedestrian, what source would you look toward to determine what the appropriate perception reaction time would be if you are trying to determine whether or not that driver could have avoided the accident?

A. Okay. Over the course of my career, I've been through dozens of perception reaction papers, and when we look at that, we look at what is the perception reaction of the average person, what's the perception reaction of 85 percent of the people or 90 or 95 percent of the people. Different studies will give you different numbers for those values, but they are all in the same ballpark.

So in a situation where that -- where we are talking about perception reaction, you asked where would I go? I would rely on my experience and the information that I've read over the years to apply an average perception reaction where that is in my situation, where I don't give an opinion in a situation where I say that Sue Smith would have perceived and reacted in one and a half seconds. I put an opinion as to if a person could perceive in one and half, it's up to a jury to determine if they believe that Sue Smith could perceive and react in a second and half.

Q. I'm actually looking -- what I'm trying to get at is what do -- you talked about looking at papers. What types of papers do accident reconstruction engineers rely on to help them determine what perception reaction time they want to plug into their investigation?

A. Right. And in my industry, for an automobile accident, for day time, attentive driver, I'm not aware of any expert that routinely uses anything other than a second and a half.

Q. Again, so you're saying that's their practice? That's what your understanding is that accident reconstructionists for, you know, attentive daylight drivers typically use one and a half seconds?

A. An average driver, and, again, other reconstructionists may do it differently, my practice is that's what the average person would do.

So I'm not sitting here saying when I use a second and a half in a reconstruction, I'm not sitting here saying that Sue Smith could have done it in a second and a half. I'm giving you, as a number for the jury to determine, that one and a half seconds is basically an average, or it's a number where the majority of the people should fall under that, but it doesn't necessarily mean that everybody falls under.

Q. I guess what I'm trying to ask you is you have not just decided, woke up one day and picked that number out of a hat, right? As a professional engineer, you've either been taught what types of perception reaction times are appropriate through studies that were done, or you may have even have participated in studies or published your own results of studies you've undertaken.

So is there something that you look at, and you may have it memorized now so you don't need to, but that engineers who want to go to the source to find out what those numbers are? Is there something that is published where you can go and look at those numbers?

MR. STAM: Objection to form.

A. There are published papers out there, and, again, there are literally dozens upon dozens of perception and reaction studies, and some of those studies do tests in one way, some of those studies do tests in another way. They measure -- you have to take all that into consideration.

Having taken all that in consideration over my career, what I see is for a given situation, I determined that the average person is going to perceive and react in about one and a half seconds in some situations. Night time is a little more, because they don't see as well night time with more cars. It's going to be a little more, because there's more information going on.

And so, again, that's the information that I use to apply perception and reaction to a situation.

Q. Have you in your practice seen other accident reconstruction engineers use different values than you?

A. Yes.

Q. And does that make -- just because two accident engineers rely on different engineering practices, does it make one engineering practice right and one engineering practice wrong?

A. Well, for example, if I have a situation where a car is driving down the road in the middle of the day, and every study I have says that a person in that situation should be able to perceive and react in one and a half seconds, and some other engineer has an opinion that it should have taken 25 seconds, clearly even just as a driver, not as an educated engineer, that's wrong for you to take you nearly half a minute to perceive that something is front of you.

So the answer is, can some engineers have opinions that I don't agree with? Yes, some of them have opinions that are so far off base that I don't find them credible at all. Then there's everything in between.

Q. And you talked about is it standard for accident reconstruction engineers, such as yourself, to rely on published studies regarding perception reaction time for different scenarios?

A. I'm not sure there is a standard.

Q. How about accepted practice? Is it an accepted practice for accident reconstruction engineers to rely on published studies that predict values for standard perception reaction time?

A. Again, there isn't an entity that approves or disproves --

Q. That wasn't my question though.

A. I'm trying to answer your question.

MR. STAM: Object to the form.

BY MS. MARTINEAU:

Q. Go ahead.

A. You're saying is it approved? There is no entity out there that approves all methodologies of what we do, and so is it acceptable? There isn't an entity out there that says this is acceptable and this isn't. Our industry doesn't have a governing body like that. And so would some engineers accept one methodology over another? Yes.

Q. When you have under vehicle accident reconstruction, proficient with reconstruction software?

A. Yes.

Q. I mean, I can read that, but, I mean, how would you explain what that means?

A. There are different software that we use. We use algorithms such as crash, SMAC, or SMAC 4, those are programs that we use to determine crush values, speeds, momentum analysis, energy analysis, and those programs also can give us visual simulations as to how an accident happened. I mean, that's what that statement is about.

Q. And speed, do these analysis for determining speed, does it depend on a number of factors, including like the type of vehicle involved? Is that one thing that you plug in?

A. Certainly.

Q. And how are these formulas developed, for example, to determine -- let's say to determine speed? How were those formulas developed of a certain vehicle?

A. Well, there isn't a formula developed to determine speed. There's a methodology given other data to determine the speed of a specific vehicle in a specific situation, and, again, that goes back to what we were talking about earlier is about the testing and research that was done at Calspan.

Q. Sorry, Calspan, what's that?

A. I don't recall what the acronym stands for.
Q. Okay. Go ahead, I'm sorry.
A. So those were methodologies that were done 30, 40 years ago. There are technical papers that promulgate how all of that research was done, validation testing, et cetera, et cetera, and so that's how those have become as reliable tools for accident reconstructionists to use in our job.
Q. When you say reliable tools, are those application, or would you consider those applications to be part of the engineering practices for accident reconstruction engineers?
A. Well, there are engineers that are accident reconstructionists. There are people that are not engineers that are accident reconstructionists.
Q. And I asked about engineers.
A. If you're talking specifically about engineers, they should rely upon those tools.
Q. And would it be acceptable in the engineering community for accident reconstruction engineers to rely on those tools, such as the programs that determine, you know, where you plug in the information regarding the crash, and then there's a program that determines, you know, things such as speed and stuff like that?

A. It's more difficult than that, because there are so many unknowns and parameters that have to be considered. So though I may be using the program that you're talking about, another engineer may think that it's inappropriate for the situation, not understanding what lengths I went to make sure that it applies to that situation.

Q. And that's part of using engineering judgment, correct?

A. That's right.

Q. But I guess I'm saying is that use of -- give me the name of one of these programs that you use?

A. SMAC.

Q. SMAC, S-M-A?

A. C.

Q. C. Okay. Your use of SMAC as an accident reconstruction engineer, would you agree that that is an accepted engineering practice to use that computer program?

A. It is to everyone that I'm a-- well, there are people that say that SMAC is not an accurate representation.

Q. But just because there might be a group of engineers or accident reconstruction engineers who don't like SMAC and who feel that SMAC is an inappropriate program to use for -- in use for accident reconstruction analysis, there's another group of engineers, including yourself, that would say that no, we like SMAC, correct?

A. Yes.

Q. And just because there's an engineering component or component of practicing engineers that don't use SMAC and feel that SMAC is not a good application, doesn't mean that your use of SMAC is unacceptable, isn't that fair to say?

A. Provided, I mean, because, again, there's so many variables. I can foresee there being a situation that an engineer could find and say well, SMAC doesn't work in this situation. If they provide adequate documentation, then I would have to accept that.

Q. But that's a little different question.

My question is more general than that, because you said that there's a group of engineers that just don't like SMAC, period, don't use it, right?

A. I believe that there are some, yes.

Q. And you use it in your practice as an accident reconstruction engineer, correct?

A. Yes.

Q. And you're aware of many others who use

SMAC in their practice as an accident reconstruction engineer?

A. Yes.

Q. And just because there's a group of engineers that have a fundamental disagreement with SMAC or use of SMAC, doesn't mean that in general, your use of SMAC in your practice is unacceptable, is that fair to say?

A. With the caveats I said before, yes.

Q. So there's a certified Vetronix/Bosch Crash Data Specialist, what's that?

A. Yes, there is a tool called the CDR tool, crash data retrieval tool, it was originally marketed by a company called Vetronix. Vetronix was ultimately or at least that branch of Vetronix was ultimately purchased and is owned by that company Bosch, and Bosch markets it as the Bosch CDR tool.

Q. And what does it do?

A. It is a tool that we can plug into the air bag module of the automobile to determine certain parameters of a vehicle when it's involved in a significant enough event to wake the module up.

Q. And you can get a bunch of data regarding -- from that download, correct?

A. Well, it varies widely from car to car, but the newer ones yes, there's a lot of data.

Q. And retrieval and interpretation of black box crash data from accident vehicles, is that somewhat similar concept?

A. It's similar, but the interpretation of the data there are many people who believe that data is exact and without flaws, but you must look for certain known flaws or certain conditions that can lead to erroneous numbers in that data.

Q. And use of downloading black box crash data, is that an accepted practice among accident reconstruction engineers?

A. Once again, I have to go back to some engineers agree with it. Some of them do not. Some of them are on the fence. So, I mean, I can't speak for everybody. I mean, it is to me. I mean, I've convinced myself through my research that that data is reliable enough to use as a tool in reconstructing an accident.

Q. Wouldn't you agree that just because a hundred percent of accident reconstructionists do not agree with a certain application, does not render that application to be unacceptable in the full engineering community?

A. Well, if some people don't accept it, then it isn't in the full engineering community. I mean, I'm saying that in principle, I think we're agreeing on the same thing.

What I'm saying is that there is a tool that I believe in, and many, many other engineers believe in, but there are, in every situation, there are some people who have valid points in certain situations that the data is unreliable.

Q. So are you unable to talk about what is an accepted engineering practice? Is that a term, something that's not familiar to you?

A. Well, when you say accepted, what I understand is that you're saying there is an entity that says this is an accepted practice, and in accident reconstruction, there is not an entity that says that.

Q. Okay. I'm sorry for the confusion, because that's not what I'm getting at. I'm not saying there's some entity out there that, you know, puts its blessing on something. Just as lawyers practice a profession, engineers practice a profession. We may not all do things the same way, but we can say yes, that's an acceptable practice. I may not do it that way, but that's an acceptable practice, because I'm familiar with the lawyering community and how they do things.

MR. STAM: Object to the form.

BY MS. MARTINEAU:
Q. And yourself, as an accident reconstruction engineer, you're familiar with -- you work with other accident reconstruction engineers, correct?
A. Yes.
Q. And you've become aware through going to things such as continuing education courses, through reviewing published research data, talking to other accident reconstruction engineers, you're generally aware of what acceptable practices in the engineering community are for accident reconstruction, correct?
A. Using the terminology that we're now agreeing upon, yes.
Q. And you may have accident reconstruction engineers that use different practices and may not fully support, you know, a different practice, but they would nonetheless say that is an acceptable practice in the community of accident reconstruction engineering, correct?
A. I mean, I agree. The problem that I'm asking is that you're saying that it's completely -- I'm not saying it's completely accepted. I'm just saying the accident reconstruction is so difficult, there are so many situations that have to be considered that in any given situation, some people will apply one

methodology and some will apply a different methodology and clearly in that situation, they're both acceptable methodologies, but we disagree upon the way it should be done.

Q. And you've been practicing accident reconstruction engineering, I forget what you said, like 15 years you said?

A. Yeah, like 15 years.

Q. And in the course of being an accident reconstruction engineer, has there been new sort of studies or ideas or theories that have developed in your tenure about how accident reconstruction engineering should be done, new ways to look at something, or has it just been stagnant and the same for your entire tenure?

A. It has changed. There have been some situations where people say this is now a tool that can be used, such as the CDR crash data tool. That information was foreign to reconstructionists before about the year 2000. Since that point, it has become widely available, widely used, but, again, every situation has to be weighed on its own merit.

Q. And we're again, I'm just talking in general, okay?

A. Right.

Q. So prior to 2000, before the CDR crash data came out -- let me change the question.
When the CDR crash data came out, how was that developed? Was there studies and task forces? I mean, is it fair to say that the theory behind the CDR crash data was looked at, studied and tested?
A. Yes.
Q. And by whom? By different types of accident reconstruction engineers?
A. Well, different types of engineers, because the air bag modules, their purpose is to fire the air bag. It just so happens that GM discovered in the '90s that they could collect some information from it.
Q. And, I mean, does that -- how do you advance engineering practice in general? Like how do engineers advance their practice? I mean, is it done through studies, research, getting together with engineers and talking out problems?
A. That can be done, yes.
Q. Have you ever been involved in any task force that looked at, you know, the validity of a new idea for any type of engineering?
A. Not in a global sense, other than my day-to-day work.
Q. So you said not in a global sense. I

missed the second part of your answer.

A. I said, but in my day-to-day work, I mean, I have to look at a situation which someone else has analyzed and either critique or accept what they've done.

Q. My question was related to a task force. Have you ever been involved in a task force that looked at, I'll make it a little bit different question, that looked at either a past engineering practice to determine whether or not that should be continued or looked at, you know, maybe a new way of doing something?

A. No, I have not.

Q. How about have you ever been involved in promulgating or determining any published standards or guidelines for use for engineers?

A. No.

Q. How about have you published any papers or provided any critique, published critique on any papers that recommended certain engineering practices for either accident reconstruction engineering or structural engineering?

A. No.

Q. Okay. We talked about this a little bit, Mr. Hennings. On the second page of your CV, under other services, it talks about litigation support -- no, I'm sorry, I jumped ahead of myself. The second -- well, the second bullet is the word, I'm looking for it, says research and testing for compliance of building codes, trade standards, ASTM standards and ANSI standards. Do you see that?

A. Yes.

Q. And what do you mean when you say -- well, let me just ask you, what do you mean by research and testing for compliance of buildings codes, trade standards ASTM standards or ANSI standards?

A. It's very similar to what we were talking about earlier with the windows. I mean, there are many situations that we come across here at our work that, you know, we have to research whether an escape ladder meets the ANSI standards, that's the A-N-S-I, things of that nature. And, I mean and it's varied and very wide the number of things that we look at to determine if something meets a certain code, trade standard, things of that nature.

Q. And you said it, but I apologize, I didn't hear it, ANSI. What does that stand for?

A. ANSI, American National Standards Institute.

Q. And what types of things does ANSI

promulgate standards for, publish standards for?
A. ANSI standards are typically safety standards related to mechanical components, such as, just as an example, ladders, walking surfaces, bath fixtures, things like that.
Q. And what is a standard?
A. Well, a standard is a means or a method that has been agreed upon, give a consistent result given, you know, testing parameters, the results of that test are considered acceptable.
Q. And who determines, like how does ANSI go about to determine whether or not a test result is acceptable?
A. There's different ways that they do that. I'm not going to say that I know how they do every one, but the general process would be they have a peer-review process for testing. Occasionally they do have revisions for those tests for unforeseen circumstances, things of that nature.
Q. And then they kind of see -- when you say peer review, is that sort of -- would that be where the proposed standard is promulgated or talked about amongst the engineering community and, you know, there's some debate back and forth about whether or not that standard is appropriate?

A.   Well, I think the process may be a little more involved than that. I mean, I'm sure there are some verbal discussions, but I think it has to be put in writing first, and then everyone has to -- well, I'm not sure of the process of how many people are tasked with reviewing and how many have to approve, I'm not sure what that is. It would be in writing, and then a certain percentage, I'm sure, would have to approve that they agree with the standard.
Q.   Have you ever been involved in the peer-review process for an ANSI standard?
A.   No.
Q.   Have you ever been involved in the peer-review process for any engineering standard?
A.   No.
Q.   So how do you know then what the peer-review process is? Is it just based -- well, how do you know what the peer-review process is?
A.   Well, the same general process goes with scientifically peer-reviewed papers. I mean, there are a certain number of people who have volunteered to review papers, and different entities use different processes that I'm aware of. I mean, that's the general process for a standard to get approved.
Q.   And you have trade standards. Well, what

is a trade standard?
A. A trade standard would be something such as if a guy is laying floor tile, you know, what is the trade standard for applying the thickness of the adhesive underneath the tile? You know, in that situation, there may not be a specific ASTM standard or an ANSI standard, and so, therefore, it would fall into a trade standard.
For example, the CTA or the Council of tile -- sorry, TCA, Tile Council of America, has their own trade standard or an industry standard that isn't an ASTM standard or isn't another type of standard and that's just an example. You know, they may have something that -- that is, they got together and said that's what the standard is, but it hasn't been reviewed or approved by ANSI or ASTM or something like that. That would be like a trade standard.
Q. Have you ever used the TCA trade standard in determining whether or not application was acceptable?
A. Yes.
Q. Give me an example of when you did that.
A. The case where there was a product that was installed underneath some tile. There was a trade standard for installing that product. Ultimately the

product was not installed per the trade standard, and they had a failure.

Q. How did you go about determining what the trade standard was?

A. Through research.

Q. So like computer research or --

A. Right. In that particular situation, I think even the tile setter had relayed that his industry standard or his trade standard was the TCA.

Q. What is an industry standard?

A. I think it's just a term. An industry standard can be a methodology that's used in the, for example, steel working industry, a standard that's used in the construction of windows or, you know, I mean, I think the trade standard or industry standard, though I have separated them, can be pretty much the same terminology.

Q. Is that sort of like what's generally accepted by the particular trade? Would that fall under industry standard?

A. Again, we're dealing with the accepted. I mean, with the understanding that I don't believe that everybody is going to agree on every situation, but there are methodologies that are, I guess, in your term, accepted in an industry by presumably more than

50 percent of the parties involved.

Q. And the last other services said litigation support and testimony in criminal matters?

A. Correct.

Q. And is that different than your role as an accident, vehicle accident reconstructionist?

A. Well, it is in the sense that there are people who investigate things only for insurance companies for the purposes of determining what happened. We do that as well as we provide support in litigation.

Q. And how much of your time is done in litigation support in the past, I don't know, three or four years?

A. I think it falls into what we said earlier, I think 80 percent of the automobile accidents are in some stage of litigation, as an estimate, I said earlier.

Q. Oh, okay. And other than the automobile accident reconstruction engineering that you do, what other types of litigation support do you provide, let's say in the past five years or so?

A. Sure. I mean, the types of things that we get involved in are --

Q. And I'm talking about you.

A. Right. I have been involved in criminal matters. I have been involved in murder trials.

Q. So when you say criminal matters and murder trials, give me an example.

A. Well, I can't really talk about -- I have one case that's ongoing that involved a shooting, and the person was killed, and I was asked to do some analysis of the dimensions of the scene and things of that nature.

Q. Why? Why did they want you to look at the scene?

A. Because no one else had done it.

Q. To determine what?

A. What were the conditions at the scene, you know, where was certain evidence in relation to other evidence, you know, in a real, physical measurement.

Q. What other type of litigation?

Well, let me ask you this, did you give testimony at the trial of that case?

A. That's still ongoing.

Q. Any other criminal matter where you've given actual trial testimony?

A. Let me think, not in a criminal matter that didn't involve a vehicle. I had my most recent criminal testimony was in -- a guy was trying to remove himself where two people were trying to beat him up, and he was in a crowded parking lot, and he ended up hitting somebody with his truck.

Q. And what was your role in that accident investigation?

A. In that role, the driver of the truck, who was trying to remove himself from this parking lot where there were two aggressors, my role was to determine how it happened, you know, what happened and to critique any problems that were put forth in the police's theory of how it happened.

Q. Did you give testimony in that case at trial?

A. Yes.

Q. Did you do so as an expert?

A. Yes.

Q. And do you know in what category you were offered as an expert?

A. I don't recall the terminology that was used to qualify me. I don't remember.

Q. When was that?

A. It was, I think November of last year. I will tell you exactly.

Q. Can we go ahead and mark that as Exhibit 20.

(The document referred to was marked Defendant's Exhibit Number 20 for identification.)

Q. And Mr. Hennings, what is Exhibit 20?

A. Exhibit 20 is a list of the trial matters that I've provided testimony.

Q. In the past forever?

A. Forever.

Q. And so this criminal case we're talking about, is it on Exhibit 20?

A. Yes. November 11, the State versus Jerry Black.

Q. All right. And so tell me what areas of engineering did you use in your testimony of Jerry Black? Was it human factors things? Was it lighting? Perception reaction?

A. That case specifically revolved around various misunderstandings by the police. It was ultimately shown to the jury that some of the evidence they were relying upon was not related to this event. It was proven to the jury that the majority of the evidence the state was relying upon was not related to this event.

Q. Are you talking about markings in the road?

A. Yes.

Q. Markings like gosh, it's been a while, scuff mark type of thing?
A. It was tire impressions.
Q. Tire impressions, okay.
So you gave the opinion of whether or not you felt, as an accident reconstruction engineer, whether the tire impressions that the police noted at the scene was related to the accident that the guy was being criminally charged with, correct?
A. That's correct.
Q. Anything else?
A. Well, it was related to the calculations surrounding his speed at impact when he hit the person, showing the errors in the police methodology in that case.
Q. What were their errors, generally?
A. Well, generally the biggest was that they said that he impacted the truck going 20 miles an hour. A, there wasn't enough space for him to accelerate to 20 miles an hour; B, the post impact trajectory suggested something along the order of three miles per hour.
The other evidence that they were relying upon was trying to put his truck which had, as I recall, something on the order of a 20-foot wheel base

and claiming that it only had 17 feet of wheel base, that his track widths was actually 65 inches, when the actual track width of the truck was 72.

So it was a combination of dimensions, physics and just very strange interpretations by the police.

Q. Is it fair to say that all those types of things, looking at scuff marks, making speed calculations, you know, looking at the length of the vehicle, the crush, any crush impressions of the vehicle, post trajectory, all those types of things, are things that automobile accident reconstruction engineers use in their day-to-day practice?

A. Well, they are things that they should be able to do. I'm not going to say that they all can, but, I mean, it was an accident reconstructionist that worked for the police.

Q. I understand. Let me ask my question again.

So the things you testified about in that trial just, you know, about the tire impressions, you know, calculations of speed impact, post impact to give opinions are all things that, in general, accident reconstructionists -- well, accident reconstruction engineers use in practicing -- in their practice?

A. Those are things that we can do. I mean, I think use and do are where we're having.

Q. What's the difference?

A. The difference is I'm not saying that they all use those things. I'm saying they should be able to do those things. It varies.

The problem that we're having, I think, is the fact that there are so many different possibilities, and so I don't know that any engineer has ever used the rotation formula to determine a speed of a car. I have, and so they should be able to do that, but I'm not going to say that that's something that anybody uses routinely at all, if ever.

So the things that I did in that trial, were unique to that trial.

Q. Okay, but I guess what I'm saying is the skills that you brought, the skill set that you brought are all things that you learned to do and are all things that are part of the practice of accident reconstruction engineering, as opposed to you didn't get up on the stand and give medical causation testimony, right? You testified about things that are in your field?

A. That's true.

Q. Now, of these litigation matters, did any of these litigation matters involve testimony that you gave regarding engineering standard of care?

A. I don't recall giving that testimony in any of those.

Q. Have you ever been hired to provide expert witness testimony in a case where well, where the question was whether or not a certain practicing engineer complied with engineering standard of care or did not comply with engineering standard of care?

A. We, as a company?

Q. I'm asking you.

A. And I have been involved in those situations where the company was tasked, and I was given the task of in an engineering review, where a complaint was filed with the board to see if an engineer followed the standard of care for an accident reconstructionist.

Q. Okay. So when you say the board, what's the board?

A. We have the licensing board that licenses engineers in North Carolina and throughout the nation.

Q. And how is your company hired -- well, give me an example of how your company -- who hires your company when they're -- in these situations when they're looking at something for the North Carolina --

I'm just going to call it I know it's the engineering surveying board, but the North Carolina engineering board?

A. Sure. And we were not hired as part of our duty as an engineer, we're asked we can agree to do that, and we provided that service at no charge.

Q. Okay. And thank you for that clarification, but who asks you? The actual board comes in and asks your company?

A. They were -- I don't know the exact role of the person, but they were like the investigative portion of the board. I don't know the exact structure of their position.

Q. How many times are you aware -- how many times have you been involved in, I will just call it a board inquiry, where your company was asked to assist in determining whether or not an accident reconstruction met the standards of care for accident reconstruction engineering in a board complaint?

A. I've only been involved once.

Q. When was that?

A. I don't recall exactly. My best estimation would be three years ago, maybe four.

Q. And what was your role in that, in that investigation from the board? What was your role to determine whether or not, you know, to give an opinion to the board whether or not that engineer in question met the professional standards or not?

A. There was an engineer that had performed an accident reconstruction. There was information, as I recall, it's been some time since I looked into that. The best of my recollection is that the engineer did not consider certain evidence in reaching his opinions and someone, I do not know who, because we were not provided the party names, someone had filed a complaint with the board that he had not followed the standard of care for engineer and reconstructionist, and ultimately there was evidence there that he did not consider or they did not. I don't even know if it was a man or a woman.

Q. What was your role in it?

A. My role was to look at the evidence that was provided and see if -- look at the information that they had submitted and to see if that engineer had or had not performed all of the tasks that he could have performed in that situation.

Q. Are you saying that your role was to determine whether or not that engineer did everything he could have done, or was it whether or not that engineer met the standards of practice for engineers in performing whatever accident reconstruction analysis he did or she did?

A. My recollection of what we were specifically asked in this situation, and I'm just going to paraphrase this as best I can, was the board who does not employ accident reconstructionists, asked a group of reconstructionists, ourselves, to look at the situation and see if what that investigator had done met methodologies that we would have used in the same situation, and ultimately the answer was no.

Q. And you said the board doesn't employ accident reconstruction engineers?

A. What I'm saying is that's not their job. Their job is licensing engineers. They do not go out and perform reconstructions. The board is responsible for administering the tests, the administration of the licensing process.

Q. Okay. And why did they -- do you know why the board came and asked an accident reconstruction -- strike that.

Do you think it would have been appropriate for the board to ask a structural engineer whether or not a practicing accident reconstruction engineer met the standard of care regarding methodology for accident reconstruction engineering?

A.   It could have been. I mean, they could have went to the highway patrol. The highway patrol has a whole team of reconstructionists, none of which are engineers. They could have went to any number of private individuals that do accident reconstruction. I don't know what the process was, why we were ultimately chosen, but there were other options.

Q.   My question though, do you think it would have been appropriate for the board to ask a structural engineer, to ask a structural engineer who does not practice in the area of accident reconstruction, whether or not an accident reconstruction engineer complied with professional standards of accident reconstruction engineering?

A.   Let's clarify. Are we talking about a structural engineer by education or structural engineer by job?

Q.   By practice.

A.   By practice? I'm not going to say that they couldn't do it, because it's just applying engineering principles. But going to an engineering firm that has done that is certainly an acceptable way.

Q.   Is there any type of engineering -- you said you've done structural and accident. Do you do any chemical engineering?

A. No.

Q. Do you think it would be appropriate for you to give opinions for standards of professional standard of care for chemical engineering, excuse me, chemical engineers?

A. I think a standard of care, as it relates to human safety, yes, but as far as what he does on a day-to-day business, no.

Q. Why not?

A. That's -- that is not any part of my training.

Q. And are there differences in different types of engineering?

I mean, is chemical engineering, the practice of chemical engineering different than the practice of accident reconstruction engineering?

A. Well, it certainly can be. I mean, there are certain parts of our engineering curriculum that all overlaps. We all take math. We all take physics. We generally take many of the same classes. At some point, we begin to diverge and take different types of classes, but the foundation of all those classes are related upon the same principles, physics and mathematics. Those are the principles of engineering.

And so your question being is -- I'm trying to remember what your question was.

Q. Just that there's different types of engineering, and that would it be appropriate for a practicing structural engineer to give standard of care testimony for an accident reconstruction engineer?

MR. STAM: Objection to form.

A. I think your question being as far as standard of care as it relates, I mean, there's so many variables in that situation as to human safety factor of safety. I mean, there are many, many variables that go into that. And your question is should a structural engineer be tasked with critiquing an accident reconstructionist? Am I understanding your question right?

Q. I guess that's part of it, sure.

A. Okay. Then what's the whole question?

Q. Well, what's your answer to that?

A. My answer is, again, it depends on what part of the standard of care we're talking about. If we're talking human safety, if we're talking about evaluating all the evidence, a structural engineer could have looked at this auto accident that we were asked to look into and go, what about this evidence here?

And so he would consider all of the

evidence. There wasn't anything to (sic) us to show that that engineer or that reconstructionist had engaged with that evidence, had used that evidence.

So standard of care, the engineer takes all of the information he has, and if some of it is being ignored, then from standard of care, he isn't performing everything he should be performing.

Q. Would you expect a structural engineer to know what the standard of care is for accident engineers as to what they need to look at to determine the cause of an accident? Isn't that, I mean, don't you have --

A. Well, I wouldn't find it unlikely that an engineer could look at a set of evidence and go well, what is this? I mean, I don't find that unlikely.

Q. Are you a member -- I think you told me before, you're not a member of any engineering organizations, is that correct?

MR. STAM: Objection to form.

A. That's correct.

Q. Do you have any? Do you hold any specialized certifications?

A. Well, I'm a licensed engineer. I have taken some education classes related to tools that we use as reconstructionists, software and methodology.

Beyond that, no.

Q. Do you know what the Institute of Traffic Engineers is?

A. I'm familiar with them, yes. I'm not intimately familiar, but I know who they are, yes.

Q. How are you familiar with them?

A. Through the course of my education, we have routinely reviewed -- excuse me -- my work experience, we have routinely reviewed DOT standard, ASHTO standards, NHTSA standards, traffic standards, stop lights, all sorts of things, which are commonly encountered in my work.

Q. And my question was, at MUTCD it was ITE, how are you familiar with ITE?

A. ITE, again, is one of the entities that has come up many, many times over the years as being involved in traffic standards.

Q. Have you ever relied on any publication from ITE for doing accident reconstruction engineering?

A. I can't answer conclusively yes or no. I mean, it's possible at some point that I've reviewed one of their standards in a case, but nothing comes to mind, I don't think.

Q. Do you know how ITE promulgates standards or guidelines or practices?

A. Not specifically, no.

Q. Is ITE, is there an ITE standard that you use on a day-to-day basis in your role, you know, within the past couple of years as an accident reconstruction engineer, forensic engineer?

A. There may be information that is contained in an ITE standard that we use for difference purposes, possibly, but from day to day, do I go and grab an ITE standard? No.

Q. Is anyone from your firm a member of ITE?

A. Not that I'm aware of.

Q. Are you familiar -- are you aware that there's a North Carolina section of ITE?

A. Generally, yes, with the North Carolina section of ITE or something -- I think I've become aware of them through this matter.

Q. Okay. Well, let me ask you about that.

Prior to being contacted by Mr. Stam or Mr. Ceccarelli or anyone associated with this case, prior to that --

A. Yes.

Q. -- had you ever been asked to determine -- well, have you ever practiced or given opinions regarding traffic signal engineering?

A. No.

Q. Have you ever, prior to your being contacted in this case, ever been asked to critique the appropriateness of a traffic signal plan for a particular intersection?

A. No.

Q. Prior to being contacted in this case, have you ever been asked to give an opinion as to what the standard of practice was for determining the length of yellow or red times for traffic signals?

MR. STAM: Objection to form.

A. I'm sorry, I lost that. Say that again?

Q. If I use the word -- well, if I use the word yellow time, what's your understanding of what a yellow time is?

A. The period of time that a traffic light shows yellow.

Q. And so my question was, prior to you being contacted for this case, had you ever been asked to, in your role as a forensic engineer, have you ever been asked to give an opinion regarding the appropriateness of the length of a yellow or red time at a traffic intersection?

A. I don't recall being asked specifically that question.

Q. So that's no?

A. No.
Q. Have you ever been -- okay, prior to your involvement in this case, were you aware of a North Carolina section of ITE task force that came together in 2004, 2005 to look at the issue of red and yellow times?
A. No.
THE WITNESS: Can we take a restroom break?
MS. MARTINEAU: Sure.
(Off the record at 10:56 a.m.)
(On the record at 11:07 a.m.)
BY MS. MARTINEAU:
Q. Prior to being contacted by Mr. Stam or anyone involved or associated with the Ceccarelli lawsuit, were you familiar with the engineering practices that were utilized in this state for determining yellow times?
A. Not as I recall.
Q. And I might have asked you this question, but because we took a break, and I don't remember exactly what I said, have you ever testified before regarding standard of care for traffic signal engineers?
A. No.

Q. Do you know if Mr. Manning, because I know he's sick today, and we're probably going to come back and take his deposition, if need be, do you know whether or not he is a member of ITE?
A. Not to my knowledge.
Q. Do you know whether or not he's ever signed and sealed traffic signal plans for traffic signals on any state or local roads?
A. Not that I'm aware of.
Q. Have you talked to him at all prior to giving your deposition today, did you talk with Dr. Manning about this case and the opinions that you hold in this case?
A. Yes.
Q. And when did you do that, yesterday?
A. It's been over the course of this month.
Q. And Mr. Stam, I know that you met with Mr. Stam yesterday, is that right?
A. Yes.
Q. And was Dr. Manning involved in that meeting?
A. Yes.
Q. And during that meeting, was it -- excuse me, did Mr. Manning mention whether or not he had ever been involved in traffic signal design?

A.   No.
Q.   And in your 15 or so years of working with ARAI, in your 15 or so years working with ARAI, have you ever come across or heard Dr. Manning indicate his -- what his level of expertise was regarding designing traffic signals?
A.   I don't recall ever having a conversation to that.
Q.   You had indicated that you weren't familiar with North Carolina section of ITE until after your involvement in this case. Do you know whether or not Mr. Manning was aware of North Carolina section of ITE's task force back in 2005, 2004 time frame prior to him being involved in this case?
A.   I do not know.
Q.   Are you aware of whether or not, you know, because you're a licensed professional engineer in North Carolina and are familiar somewhat with the North Carolina engineering board, do you know whether or not North Carolina allows individuals, other than engineers, to give opinions on engineering practices in this state in a court of law?
A.   If North Carolina does, was that your question?
Q.   Yes.

A. I am not certain what the North Carolina laws regarding that are.
Q. Are you aware what the North Carolina board of engineers' opinion is regarding nonengineers giving testimony as to engineering practices in this state?
A. I haven't specifically looked for that, so the answer is no.
Q. You don't know?
A. I don't know.
Q. Prior to your involvement in this case, had you ever reviewed any ITE publication regarding formulas for practices for traffic signal design?
A. I think we talked about this earlier. There's no question in my mind at some point in time, I've looked at something that was related to ITE, but I certainly cannot point you to a document.
Q. This is a little different question.
I'm not trying to trick you. What I'm saying is prior to you being involved in this case, had you ever looked at any ITE documents specific to a formula for determining yellow times and red times?
A. And my answer is, I very well may have. I'm not trying to be elusive. I may have. I just don't remember doing it.
Q. So you can't remember any instance prior to

being contacted in this case, where you looked at or used the ITE formula for determining yellow clearance times and red clearance times?

MR. STAM: Objection to form.

A. I do not recall before this matter ever reviewing ITE formula for yellows and reds. I may have. I just don't recall it.

Q. Okay. Prior to your involvement in this case, in your role as an engineer with ARAI, did you have a general familiarity as to whether or not traffic signal engineers in this state used practices published by ITE in traffic signal design?

A. Not specifically, no.

Q. Now, do you, in your practice here with ARAI, do you use the Manual of Uniform Traffic Control Devices?

A. Yes.

Q. In what ways?

A. There are different ways. We use MUTCD when we have to put out warning signs, things of that nature, when we're doing investigations on the side of the road. We're often tasked with MUTCD on construction zone accidents and things of that nature.

Q. Anything else?

A. Those are the first two things that come to mind. I'm sure there are other situations that we've referenced MUTCD over the years. It's one of those documents that arises fairly often.

Q. Can you think of any, prior to your involvement in this case, can you think of any time where you used the MUTCD to look at what standard or guidance MUTCD had regarding the length of yellow and red times?

A. I don't recall doing that.

Q. How about just have you had, in your role with ARAI, have you ever used the MUTCD to determine the appropriateness of a traffic signal design?

A. Not that I recall.

Q. Are you familiar with the term traffic signal engineer?

A. I've certainly heard the term, yes.

Q. Prior to your involvement in this case, had you heard the term traffic signal engineer?

A. I'm trying to recall what the terms were used when I've spoken to signal engineers over the years. I don't know if they called themselves traffic signal engineers, but that was my interpretation of who they were.

Q. So you mentioned you talked to some group called signal engineers?

A. No. No, I have talked to different people over the course of my career that my understanding is they were signal engineers. So if they called themselves a signal engineer or they were told to me they were a signal engineer, that's possible, being very specific to the term signal engineer. That's my understanding of what they were.

Q. Let me ask you this question, okay. Prior to your involvement in this case, had you heard the term, or were you familiar with the term signal engineer?

A. I'm certain that I have. I can't offer you a specific example, but --

Q. I'm not asking you for one. I'm saying before you got involved in this case, had you heard the term signal engineer?

MR. STAM: Object to form.

A. Yes.

Q. And what do you understand, again, prior to your involvement in this case, what was your understanding of what a signal engineer was?

A. It was a person tasked with orchestrating the timing of the lights at an intersection.

Q. Have you ever practiced in the area of signal engineering?

A. No.
Q. Have you ever taken any continuing education courses on signal engineering, specific to signal --
A. No.
Q. How about this, have you ever taken any engineering courses specific to signal engineering design?
A. No.
Q. Prior to this case, were you aware of North Carolina Department -- prior to your involvement in this case, have you ever reviewed, in your capacity as an engineer with ARAI, the North Carolina Department of Transportation signal systems engineer guideline for yellow and red times?
A. That specific document you have in your hand?
Q. No, the question, the question was, prior to your involvement in this case, have you ever used, in your role as an engineer with ARAI, any document promulgated by the North Carolina Department of Transportation signal engineers guidelines for determining yellow and red times?
A. Not that I recall.
Q. Okay. Is there anything you could look at

to refresh your recollection as to whether or not you have ever used these documents as an engineer with your position at ARAI?

A. In my position, I review a lot of documents over the years, and I don't want to tell you with certainty that I've never looked at it. I certainly do not recall looking at it before this case.

Q. Now, can you tell me, can you just kind of go through what documents you have with you in front, with you here?

A. Yes.

Q. Okay.

A. I have my trial and deposition lists.

Q. Yep.

A. We've already marked my CV. I have the only invoice that's been issued in this case to date.

Q. I'm not interested in the invoice. I think all I'm entitled to and all I want to ask question -- that's nice that you put it. But I mean all I'm entitled to, and all I want to get a copy of afterwards is anything you looked at and used to form the basis of your opinions today.

A. Sure. So let me rule out your subpoena.

Q. I don't think it was a subpoena, but go ahead.

A. Wasn't it?

MR. STAM: Notice of deposition.

THE WITNESS: Yes, thank you.

A. There was originally an e-mail from Mr. Stam that went to our secretary, Jennifer, that had a link to the website that there are many documents on. This is just a printout of that e-mail with the one report printed out.

In the course of this, I believe that I have read all or nearly all of the documents on that website. I do not have all of those printed out, but I have some of the documents that I specifically printed out after I reviewed them.

There is a document here that is Detailed Investigation of Crash Risk Reduction Resulting from red light cameras in small urban areas. That's done by NC A&T University.

A stopping sight distance and decision sight distance from the Oregon Department of Transportation.

There's some graphs that I'm fairly certain you're familiar with from Mr. Ceccarelli.

An excerpt from the MUTCD 2009 edition.

A 1994 ITE paper determining vehicle signal change and clearance intervals.

The 1959 Gazies' (sic) paper that's been referenced in this matter.

A stack of correspondence that appears to have e-mails and attachments that was provided to me by Mr. Stam, which from my understanding was attachment to Mr. Fuller's deposition or was given in response to his deposition.

Q. Can I interrupt you? When did you get a copy of that, just yesterday?

A. Yesterday, yes.

A timeline of the 5.32 sheet signals and geometrics section, traffic engineering and safety system branch. This was kind of a timeline that was put together by Mr. Ceccarelli.

There is the article that was published in the January 2008 ITE journal by Steven Click.

Q. Are you familiar with Mr. Click?

A. I have never -- I have no foreknowledge of Mr. Click prior to this.

This is an excerpt from the ASHTO highway design book.

Q. And did you get that yourself, or did someone supply that to you?

A. That's a book that we have here at the office.

Q. But my question is --
A. Okay, I'm sorry.
Q. Did you get this excerpt yourself, or did someone provide that to you?
A. Yes, this is mine.
Q. Okay.
A. There are -- I've got these two e-mails, which were the copies that we made before the deposition that I already had.
Q. When were you provided those e-mails yesterday?
A. Yesterday.
Another paper by Mr. Ceccarelli, and this applied physics and the international standards that set yellow light durations forces drivers to run red lights.
I have a response to Mr. Ceccarelli's derivation of yellow light equation.
I have a 1976 excerpt from the Transportation and Traffic Engineering Handbook from ITE.
Q. Where did you get that from? Is that something you copied?
A. That was provided to me, I think by e-mail from Mr. Ceccarelli.

Another paper by Mr. Ceccarelli, it's Failure Groups of Traffic Signals, Town of Cary, North Carolina.

I have a paper, the Red Light Running Crisis from the Office of the Majority Leader US House of Reps.

Q. Who provided you with that document?

A. It was referenced through -- I found it through Mr. Ceccarelli's website. I don't know if it was on his website or if it was an external reference, but that's how I got to that paper.

This is apparently a copy of Fuller Exhibit D.

Q. Prior to your involvement in this case, did you know who Greg fuller was?

A. His name sounds familiar, but I don't think I've ever met him or spoken to him.

Q. Do you know what his -- prior to your involvement in this case, did you know what his role was with NCDOT?

A. No.

Q. Do you know what his role is now?

A. I don't think I memorized his official title, but he's in the signals branch. I'm not sure exactly what he does. I know he talked about it in his deposition, but I didn't commit it to memory.

Q. What else do you have?

A. This is a research paper, Development of Guidelines for Identifying and Treating Locations with a Red Light Running Problem by Bonneson and Zimmerman. It was done for the Texas Department of Transportation. This was another document that I found through reference after going through Mr. Ceccarelli's website.

Q. Were you provided with a copy of the complaint in this lawsuit?

A. I seem to recall there's a copy of the complaint on the website. So, I mean, I was given the website and the freedom to peruse those. As I stated, I think I read every document on that website, I'm not -- I can't say with certainty that's 100 percent, but I think I read everything.

Q. I'm going to hand you, I know you may not have looked at these documents. Some of it you have and some of it -- I'm going to need that back, at least the binder back. Actually, we can probably use them all day. Okay.

So if you would, let me ask you before we jump into these documents, what is your understanding of what this lawsuit is about?

A. My understanding?

Q. Yeah.
A. Well, my understanding is that the timing of the traffic lights, it is inherent in the nature of the formulas used that the timing of the traffic lights will prevent 100 percent of the people in all situations from being able to negotiate, stop or a through maneuver or a turn maneuver without running a red light. I think that's a pretty poor way of saying that, but that's the gist.
Q. My question was, what is your understanding of the lawsuit?
A. Of the lawsuit. The lawsuit, my understanding is the lawsuit is related to the inadequateness of the formula that is used to determine light cycling.
Q. And where did you get that information from?
A. Just from reading through the website and discussions with Mr. Stam and Mr. Ceccarelli.
Q. Have you personally talked with Mr. Ceccarelli?
A. Yes.
Q. When?
A. I think he's been to my office here twice.
Q. When?

A. Once was yesterday, and then the other time, I believe, maybe two weeks ago or so. I don't have the exact date.

Q. Prior to being involved in this case, have you ever used either the NCDOT promulgated formula for determining yellow or red times or the ITE formula in determining yellow or red times in your role as an engineer with ARAI?

A. Not that I recall.

Q. Is there anything that you can look at to determine whether or not you've ever used those formulas?

A. I say that because I can't say with certainty that I haven't, but I do not recall ever doing it.

Q. If you would take a look -- well, if you would take a look at, and I'm going to mark as an exhibit to your deposition whether or not we look at them, okay.

A. Okay.

Q. Exhibit numbers 1 through 19. Okay.

(The document referred to was marked Defendant's Exhibit Number 1 for identification.)

(The document referred to was marked Defendant's Exhibit Number 2 for identification.)

(The document referred to was marked Defendant's Exhibit Number 3 for identification.)

(The document referred to was marked Defendant's Exhibit Number 5 for identification.)

(The document referred to was marked Defendant's Exhibit Number 6 for identification.)

(The document referred to was marked Defendant's Exhibit Number 7 for identification.)

(The document referred to was marked Defendant's Exhibit Number 8 for identification.)

(The document referred to was marked Defendant's Exhibit Number 9 for identification.)

(The document referred to was marked Defendant's Exhibit Number 10 for identification.)

(The document referred to was marked Defendant's Exhibit Number 11 for identification.)

(The document referred to was marked Defendant's Exhibit Number 12 for identification.)

(The document referred to was marked Defendant's Exhibit Number 13 for identification.)

(The document referred to was marked Defendant's Exhibit Number 14 for identification.)

(The document referred to was marked Defendant's Exhibit Number 15 for identification.)

(The document referred to was marked Defendant's Exhibit Number 16 for identification.)

(The document referred to was marked Defendant's Exhibit Number 17 for identification.)

(The document referred to was marked Defendant's Exhibit Number 18 for identification.)

(The document referred to was marked
Defendant's Exhibit Number 19 for
identification.)
Q. So take a look at Exhibit 8. Have you ever seen Exhibit 8 before?
A. If it's on the website, yes. I don't -- let me read it.
(Pause.)
A. This is the Lori Millette -- I think that I have, but I don't have a copy of it.
Q. I'll represent to you that Exhibit 8 is the copy of the civil citation Lori Millette received from the Town of Cary.
So have you been asked to give any opinions by either Mr. Ceccarelli or Mr. Stam in the trial of this matter regarding Exhibit 8?
A. Well, by reference, yes. I mean, the focus of my involvement in this was the ability of the formulas to accurately model what happens on the road, and so Lori Millette being one of these vehicles that was tagged at one of these lights as having run a red light, that is one of the scenarios we've analyzed.
Q. So you have analyzed Lori Millette's scenario?
A. Yes.

Q. Do you have an opinion as to whether or not Ms. Millette could have stopped her vehicle prior to entering the intersection?
(Miss Millette let back there)?
A. At what point in time?
Q. When she first saw the yellow light, could she have stopped prior to entering the intersection?
A. Well, that goes back to the criticism of the timing that's used in these lights. The timing that's used in these lights does not encompass everyone.
Q. My question is, Ms. Millette -- I'm just trying to find out what the scope of your opinion is, and my question is, have you done any calculations for Ms. Millette's situation to determine whether or not Ms. Millette could have adequately stopped her vehicle at the intersection prior to the time the light turned red?
MR. STAM: Objection to form.
A. Specific to Ms. Millette? No. To her situation, yes.
Q. Have you read Ms. Millette's deposition?
A. No.
Q. What about Redflex? Have you ever been involved as an engineer with ARAI in examining the

interplay between red light cameras and traffic signals?
A. Not that I recall, no. And that was before this matter?
Q. Correct.
A. No.
Q. How about since this matter, have you done any investigation -- have you been asked to look at the interplay between the red light cameras and the traffic signals at the intersections in question?
A. Well, my understanding is that the red light cameras are there for traffic violations. As far as the actual interaction between the light and the camera, I mean, I have not been asked to look into the technology behind that or anything of that nature.
Q. And if you would take a look at what's behind tab nine. Have you seen, and I'll represent to you this is a copy of Brian Ceccarelli's civil citation that he received from the Town of Cary. Have you seen this before?
A. Yes.
Q. When?
A. It's one of the documents that I reviewed. Exactly which time, I don't know.
Q. Were you asked -- again, I'm trying to find

out the scope of what opinions you're going to have.
Were you asked to look at this citation specifically and make a determination of whether or not Mr. Ceccarelli could have safely stopped his vehicle at the time when he first would have seen the yellow indication in his direction of travel?
MR. STAM: Object to form.
A. Specifically, again, to Mr. Ceccarelli, no, but to his situation, yes.
Q. Is it fair to say that the opinion -- well, let me ask you, I don't want to necessarily know what your opinions are, but is it fair to say what you intend to talk about at the trial of this matter is whether or not the formula that is utilized or that was utilized on the traffic signal plans in question was an appropriate formula?
A. I think that is a good summary of what my opinions to be.
Q. And prior to your, again, you know, I'm just trying to make sure that I understand, you know, what you have done in the past and what your areas of expertise are.
Prior to being contacted for this case, had you ever testified about or studied the appropriateness of either the ITE published formula for determining

yellow and red times, or the North Carolina Department of Transportation signal design sections formula for determining yellow and red times?

A. Was your question if I ever -- what was the beginning of that question, just the beginning part of it?

Q. I don't know if I can say it exactly, so I will just re-- prior to being contacted in this case, had you ever been asked in your role as an engineer with ARAI to give an opinion about the appropriateness of using the ITE published formula for determining yellow and/or red times?

A. No.

Q. Prior to you being contacted in this case, had you ever been asked in your role as an engineer for ARAI to give an opinion about the appropriateness of using the North Carolina Department of Transportation signal section standard for determining yellow and red times?

A. No.

Q. Do you know, Mr. Hennings, what intersections are at issue in this lawsuit?

A. Specifically, I know that Mr. Ceccarelli's is over off of Cary Town Boulevard and Commercial Drive or something of that nature, and I think Ms. Millette was at Walnut and Meeting, I believe. If I remember correctly, that's where it was.

Q.   Have you looked at the signal plan that was in play for Mr. Ceccarelli's intersection?

A.   I have, yes.

Q.   And where is it?

A.   It's one of the documents on his website. I mean, there are thousands of documents on that website and referenced, and I certainly have not printed all of them off.

Q.   Do you have an opinion whether or not Mr. Ceccarelli is a North Carolina professional engineer?

MR. STAM: Objection to form.

A.   My understanding he is not.

Q.   Do you know whether Mr. Ceccarelli has ever been involved in determining standards for traffic signal engineers?

A.   I'm not aware of what his full experience is. I'm not aware of him having any involvement in that.

Q.   Do you know what he has done professionally as a physicist?

A.   As a physicist? No.

Q.   Other than Mr. Ceccarelli and

Ms. Millette's intersection, are you aware of what other intersections are involved in this case?

A. I've read over them, but, again, that was not the focus of what I was doing. I'm aware that there are other intersections. I can't cite to you all of those intersections off the top of my head.

Q. So your role, as you understand it, was to give a more broader opinion as to the appropriateness of the ITE formula that's used by North Carolina traffic engineers and the appropriateness of the North Carolina Department of Transportation's formula for yellow and red times as used by North Carolina engineers?

A. Well, I guess the appropriateness is a good word, but the, I think I like the word the inadequacies of the methodology, I think is a better way to describe it.

Q. Prior to your involvement in this case, what undertakings did you have to determine what would be adequate methodologies for determining yellow and red times?

A. I have never been tasked with looking into the situation before.

Q. So prior to your involvement in this case, what undertakings did you take to determine for yourself whether the methods used for determining yellow and red times by traffic signal engineers were adequate or inadequate?

MR. STAM: Objection to form.

A. If I understand your question, I have not been -- I have not looked into the methodologies used by those engineers until becoming involved in this matter.

Q. And you've never practiced in the area of traffic signal engineering, is that right?

A. No.

Q. And you've not -- other than possibly seeing signal plans on Mr. Ceccarelli's website, do you know -- have you analyzed the yellow times used by the signal engineers on each of the plans?

A. I mean, I've certainly looked at them, and, again, I didn't commit the entire plan to memory, but that, again, is not the focus of my opinions.

Q. Okay. You understand, right, you have been designated as an expert witness by Mr. Stam?

A. Yes.

Q. And you understood that your deposition has been scheduled today for some time?

A. Yes.

Q. And you understood that I would be coming in here and asking you questions about the opinions that you hold?

A. Yes.

Q. And you are prepared to give me the opinions that you intend to give at trial today, correct?

A. Yes.

Q. Are you -- do you purport or do you intend to give any opinions as to what constitutes the charter of the Town of Cary?

A. No.

Q. You're not -- you don't purport to be an expert at all in the North Carolina general assembly versus general laws, local laws or anything like that?

MR. STAM: Objection to form.

A. No.

Q. Have you reviewed any of the traffic laws regarding traffic signals in preparation for your testimony today?

A. No.

Q. Take a look, if you would, at Exhibit 5, and I'll purport to you that Exhibit 5 is portions of both the 2009 and 2003 MUTCD. Most of it is unrelated, I think, to the issue at this case.

MR. STAM: It's about 500 pages.

BY MS. MARTINEAU:
Q. But I have it here.
Did you review the MUTCD in preparation or in the research that you did to give opinions in this case?
A. Yes.
Q. What did you look at?
A. Well, specifically to the sections regarding yellow timing.
Q. Okay. Anything else?
A. Not that I recall right offhand.
Q. And the section of the MUTCD that you brought with you this morning or today, were those sections that were given to you by either Mr. Ceccarelli or Mr. Stam, or were those sections that you copied?
A. There were the copies that I received from the website.
Q. Now, are you familiar, or did you review any of the North Carolina statutes that either authorize or forbid the Town of Cary from utilizing red light cameras?
A. No.
Q. Do you know what the statute requirements are that set forth when the Town of Cary can use red

light cameras?
A. No.
Q. So that's not at all the scope of your -- the testimony that you were asked to give as an expert today?
A. No.
Q. You have -- okay.
Do you have any -- do you hold an opinion that -- well, let me ask it this way.
You're not here today to give an opinion that any of the engineers who signed and sealed the signal plans at issue in this case were not licensed professional engineers, are you?
A. That is not something I've looked at or plan to testify to.
Q. Okay. Do you know whether or not the intersections at question are state owned roads or Town of Cary owned roads?
A. The road or the intersection?
Q. Um-hum.
A. I mean, I've seen some text in the documents I reviewed of there being some transition from the Cary controlling those roads. I'm not sure of the full nature of what their control is.
Q. So that's nothing that you're going to give

an expert opinion on as to who owned the road, who didn't own the road, correct?

A. That is not something I've looked into.

Q. And you have no information to refute the testimony of Greg Fuller from the Department of Transportation, where he said that these are state-owned intersections? You have no information that these are anything but state-owned intersections, is that fair?

A. I may have glazed over some documents, but that, again is not something that I've looked at.

Q. If you would take a look at Exhibit 7.

Mr. Hennings, do you know what Exhibit 7 is? Have you ever seen this before?

A. This may be in the references on Mr. Ceccarelli's website, but I was not involved in reading the laws or the section of the general statutes.

Q. Okay. And my question was, have you ever seen this before?

A. I think I glanced at it, but it's not something that I consumed for information.

Q. And I will represent to you that Exhibit A is a copy of a local, a general and a local law regarding the use of red light cameras in Wake County for towns such as the Town of Cary that was in place in 2004 and beyond, okay?

A. Yes.

Q. I know you have not seen this before. If you take a look at Section B, again, it says any traffic control photographic system or any device which is part of that system as described in subsection A of this section, installed on a street or highway, which is a part of the state highway system, shall meet requirements established by the NCDOT.

Do you see that?

A. Yes.

Q. And you're not here today to give any opinions that are contrary to that statement, are you?

A. I mean, other than related to the timing of the lights, no. I mean, I can see how loosely that could be inferred to be covered in that, but, I mean, no.

Q. Okay. We'll come back to that in a second. And I didn't think you were. I'm just making sure.

Now, when you looked at the MUTCD for this case, what -- well, let me back up a little bit.

You said that in your role as an accident reconstructionist for -- excuse me, an accident -- excuse me. In your role as an engineer for ARAI you sometimes utilize the MUTCD?

A. That's right.

Q. So are you familiar with the portion of the MUTCD that talks about the difference between a standard and a guidance and an option?

A. Yes, I mean, more so from what I've read in this case.

Q. So prior -- and I appreciate that.

So prior to your involvement in this case, was that anything that you studied or reviewed as part of your job as an engineer of ARAI, the difference between MUTCD standards, guidance and options?

A. I would say probably so, I mean, in our use of the MUTCD for things that we do at work. As far as what is required, what's a guide, what's a standard, that wasn't something that I would say that I have studied, but it is something to take into consideration when we've had to use the MUTCD.

Q. So one of the examples that you gave to me earlier today where you or your company may use the MUTCD is when you've doing an accident investigation and you have to put out safety devices?

A. That's right.

Q. So when you have done that, what is your understanding in that role of the difference between a

standard and a guidance and an option?
A. Well, it's just my interpretation of the words themselves; standard, guidance, option. Standard, means it is the standard. Guidance means here's some suggestions of which it could be done. Options are here it could be done A, it could be done B. I mean, all of those are variable ways of accomplishing the end result of having a safe set of traffic devices.
Q. And are those your -- do you know whether or not that standard guidance and option are defined by the MUTCD?
A. I think they are. I don't know where that definition is, but I believe they are.
Q. Did you review any of that in preparation for giving an opinion here today?
A. No, not specifically.
Q. So you would then go back, and I think it's Exhibit 7, if you would take a look at 7E, excuse me, I'm sorry, section E.
MR. STAM: Of which law?
MS. MARTINEAU: Of Exhibit 7.
MR. STAM: There are two.
MS. MARTINEAU: Of the first one.
MR. STAM: On the second sheet?

MS. MARTINEAU: Yes.
Q. And, again, have you reviewed Section E in relation to the testimony or the opinions that you are prepared to give today?
A. Not until just now. Okay.
Q. Do you have an opinion of whether or not the duration of the yellow light change intervals at the intersections in play in this case are any less than the yellow light change interval duration that is on the traffic signal plan of record?
A. I don't believe so. I know there is issue of -- I'm aware of the issue that the signal light timing was changed in Mr. Ceccarelli's intersection, and as far as was it different than what was on the plan at the time, I think, from my understanding, that may be somewhat contested as to which plan applies and when, but specifically, no.
Q. So just so I'm clear, and okay, so my question was regarding -- is this -- and we can go through the intersection, each one. We might do something like that later.
But in general, was it part of your role today -- let me ask it this way.
You do not have an opinion as to whether or not the yellow light change interval, which is shown

on -- strike that.

You do not have an opinion as to whether or not the yellow light change interval at the intersections in question is less than the yellow light change interval shown on the traffic signal plans of record in this case?

A. The only one that I can specifically think of is Mr. Ceccarelli's, and my understanding is there is some disagreement as to what the actual speed limit is supposed to be in that section, and that the signal plan may reflect a difference in speed limit than what Mr. Ceccarelli and other people believe is on the ground. Beyond that, no.

Q. But that's a different -- I mean, you're answering something different than I'm asking. So let's just go with, Mr. Ceccarelli, and I'm not trying to confuse you, okay, so if I am, let me know.

The intersection of Mr. Ceccarelli, okay, that intersection, in fact, we can take a look at it, if you want. Let's see, okay, I'm going to mark this as Exhibit 21.

(The document referred to was marked Defendant's Exhibit Number 21 for identification.)

Q. And I know this is a small copy, but have you seen -- have you examined Exhibit 21 in relation to the testimony you're going to give today?

A. I have definitely seen this, yes.

Q. Okay. So I will represent to you -- well, do you know whether or not this is the signal plan of record at Mr. Ceccarelli's intersection?

A. It is definitely, from my understanding, a signal plan from 1991. I think ultimately the names of Western Boulevard Extension changed over the course of time.

Q. Listen again. My question is, I will represent to you that North Carolina Department of Transportation provided this document as the official signal plan of record at Mr. Ceccarelli's intersection, at the time Mr. Ceccarelli went through the red light, okay?

A. Okay.

Q. Do you have any information different than that?

A. I do not.

Q. Okay. All right, so --

MR. STAM: I thought two days before he got his intersection, they approved a different signal plan. They just hadn't fixed it on the ground yet, but since you are representing something, I thought we should get out on the record --

MS. MARTINEAU: This is the signal plan of record that NCDOT gave to us as the official signal plan for that intersection in question at the time.

MR. STAM: Okay. I think you'll find that they actually had approved a different one two days before he got his ticket, but the town and the DOT had just not fixed it yet. But perhaps I'm wrong.

MS. MARTINEAU: It had not been implemented.

MR. GLOVER: We understand the history.

MR. STAM: The question is, you say representing to him that this is the signal plan of record. What is the signal plan of record when DOT has already said change it but it just hadn't been changed yet?

MR. GLOVER: DOT said this was the plan of record. That's what she represented.

MR. STAM: Proceed on.

BY MS. MARTINEAU:
Q. Okay, so all right.
So do you know what is your understanding of, if any, of what is required to have a -- to change a speed limit on a state-owned road that is located in a municipality? Do you know what's required under the law?
A. Not verbatim, no. There is clearly some process, but verbatim, I do not know what it is.
Q. Do you have a general understanding of what the process is?
A. No.
Q. So do you know what the yellow time -- what is the yellow time reflected on this signal plan, Exhibit 21, for Mr. Ceccarelli's intersection?
A. It is four seconds.
Q. Do you have any opinion that -- or okay, so four seconds?
A. Yes.
Q. Do you know whether or not the yellow time at Mr. Ceccarelli's intersection at the time he received his -- or excuse me -- do you know whether or not the yellow time at Mr. Ceccarelli's intersection at the time he allegedly ran the red light was any less than is shown on Exhibit 21?

A. I'm not aware that it was.
Q. Okay. And, again, you indicated earlier you're not, you don't intend to give a -- you don't have an opinion that Mr. Peoples, who signed and sealed this plan, was something other than a licensed professional engineer?
A. I don't have any information otherwise.
Q. Do you know Mr. Peoples?
A. No.
Q. Do you know what his experience is in designing traffic signals?
A. No.
Q. Do you know whether or not he has more experience than you do in designing traffic signals?
A. No.
Q. Do you have any experience in designing traffic signals?
A. No.
Q. Okay. Do you know whether or not -- well, back in 1991, do you know what the requirements of the Manual on Uniform Traffic Control Devices was for yellow times?
A. In '91?
Q. Yes.
A. I don't think I have a copy of that. I do

not have a copy of that. I don't recall specifically if I have seen that document or not.

Q. Okay. Do you know whether or not the yellow time that is on -- that is reflected on 21 was done in accordance with the requirements of the Manual of Uniform Traffic Control Devices?

A. I would have to see that document to make that determination.

Q. How about looking at the document that you do have, which manual do you have that you've looked at?

Well, let me ask you this. In relation to your opinions today, have you looked at -- are you prepared, or were you asked to give an opinion of whether or not the traffic, the yellow time reflected on the traffic signal plan of record, was in full conformance with the requirements of the manual on Uniform Traffic Control Devices?

MR. STAM: Since it's a 500-page document, can you direct him to pages?

MS. MARTINEAU: I can do it later. You understand I'm taking his deposition. He's been designated as an expert in this case. I'm trying to determine what his knowledge is, what the basis of his opinions are going to be.

MR. STAM: I understand all that, but when you ask somebody about a 500-page document, it's common to refer him to the right page.

BY MS. MARTINEAU:

Q. My question though is different from that. My question is, do you have an opinion, or were you asked to give an opinion as to whether or not the traffic signal plan reflected on Exhibit 1 was in full conformance with the requirements of the Manual on Uniform Traffic Control Devices?

A. That is not what I was asked to do.

Q. Okay. And I'm going to mark as Exhibit 22 to your deposition, and I will represent to you that Exhibit 22 is a copy of the clearance time sheet used by Mr. Peoples in calculating the yellow times that are shown and that are on Exhibit 21.

(The document referred to was marked Defendant's Exhibit Number 22 for identification.)

Q. Have you ever seen Exhibit 22 before?

A. No.

Q. In your role as an engineer with ARAI, have you ever utilized clearance time sheets, such as that

shown on Exhibit 22?
A. Not as Exhibit 22, no.
Q. Do you know whether or not the clearance time sheet that was shown on Exhibit 22 was commonly used by traffic signal engineers in determining yellow times?
A. I do not know.
Q. Do you know whether or not back in 1991, it was a common practice of traffic signal engineers to use clearance time sheets, such as that shown on 22 for determining yellow times?
A. I do not know.
Q. And as far as the other intersections that are in play in this case, Walnut and Kildaire, Maynard and Kildaire, Cary and High House or Cary and Kildaire, and, again, I'm just trying to find out what your opinions are today, do you have an opinion as to whether or not the yellow light change intervals at these intersections are less than what is shown on the traffic signal plans and records that have been provided by NCDOT?
A. I'm not aware that they are.
Q. And, again, we can -- I mean, your role today is not to provide an opinion that the engineers that signed and sealed these plans are not licensed

professional engineers, is that right?
A. I'm not making any allegations to that effect.
Q. I do want to show you though -- I'm going to mark as Exhibit 23 to your deposition, and I'll represent to you that Exhibit 23 is a clearance time calculation sheet that is -- that was used by NCDOT at sometime after 1991. It's the newer version.
(The document referred to was marked Defendant's Exhibit Number 23 for identification.)
Q. Have you ever seen Exhibit 23 before?
A. No.
Q. Okay. Have you ever used clearance -- the clearance time calculation sheet, as shown on Exhibit 23, in your role as an engineer with ARAI?
A. No.
Q. Do you know whether or not the clearance time sheet that is reflected on Exhibit 23 is commonly used by traffic engineers in this state back in 2006 forward for calculating yellow times for traffic signal intersections in North Carolina?
A. I'm not aware of that.
Q. I think I already asked you this question, but just in case I didn't, do you have an opinion as to

whether or not the other intersections that play in this case, whether the yellow times on those signal plans were done in accordance with the Manual of Uniform Traffic Control Devices?

A. That -- again, that's a little outside of what my involvement in this is.

Q. So let me just ask the question again.

Do you have an opinion as to whether or not any of these other intersections at play, and, again, it's Maynard and Kildaire, Cary and High House, Walnut and Kildaire and Kildaire and Cary and actually then the other direction Cary and Kildaire, do you have an opinion as to whether or not the yellow times reflected on those signal plans that are at issue in this case, whether they are in full conformance with the Manual of Uniform Traffic Control Devices?

A. That is not something that I've gone into detail to investigate.

Q. So, again, so is the answer no?

A. No, I do not know. I do not know if they are or are not in complete agreement.

Q. So as far as what you were asked to do today, so you don't have an opinion as to whether or not the yellow times at the signal plans in question in this case, whether they were done in full conformance

with the Manual of Uniform Traffic Control Devices?
A. No, I have not investigated. I do not know if they are in full conformance.
Q. Would you take a look at -- okay, take a look at Exhibit 10.
Have you seen Exhibit 10 before?
A. Yes.
Q. And prior to you being contacted in this case, had you ever used Exhibit 10 in your role as an engineer with ARAI?
A. No.
Q. And after being contacted in this case, what, if anything, did you do to undertake for yourself to learn and understand what the North Carolina section of ITE did that resulted in Exhibit 10?
A. I'm sorry, I lost part of that question. What was that?
Q. After you were contacted in this case, what did you do or what investigation did you undertake for yourself to learn about what the North Carolina section of ITE did that resulted in the document that's identified as Exhibit 10?
A. I did not go further than reading this summary.
Q. And when you say this summary, you mean the

paper that was published by ITE entitled application of the ITE change and clearance interval formulas in North Carolina?

A. That's right.

Q. Do you have an opinion, or do you know what the task force did as back up to its recommendations that are set forth in Exhibit 10?

A. Not in debt, no. I mean, they clearly had some type of meeting, but other than that, I don't have any specific knowledge.

Q. If you would take a look at Exhibit 18, and I will represent to you Exhibit 18 was produced by NCDOT in response to a subpoena issued by Mr. Ceccarelli. And Exhibit 18 is entitled yellow and red clearance time task force kickoff meeting.

A. Okay.

Q. Do you see that?

A. Yes.

Q. And there's a list of a bunch of people?

A. Yes.

Q. And along with their organization and title?

A. Yes.

Q. And are you familiar with any of these people?

A. I have spoken to Pam Alexander on a few occasions, and then some of the names I recognize from the e-mail strings and things of that nature, but Pam Alexander is the only person that I can say with certainty that I recognize their name before involvement in this.

Q. How do you know Pam Alexander?

A. On occasion, we have to obtain signal diagrams doing an intersection accident.

Q. And do accident reconstruction engineers like yourself use signal plans in conducting accident reconstruction to determine, you know, when the light was yellow, when the light was red, how long the light had been yellow and things like that?

A. Yeah, that's kind of the process we go through on some occasions.

Q. Okay. And do you know, either now or before being involved in this case, what Pam Alexander's role was in the North Carolina section of ITE task force related to looking into red and yellow times?

A. Other than what's on this paper, no.

Q. Do you have an opinion whether or not Pam Alexander is a good traffic signal engineer?

A. I have no idea.

Q. Do you know whether she is a traffic signal engineer?
A. I do not know what her role is.
Q. So other than Pam Alexander, is there any other name that you are familiar with?
A. Again, earlier I said I thought Greg Fuller's name sounds familiar, but I have no recollection of ever meeting him or having interaction, but the name sounds familiar.
Q. Do you have any opinion whether or not any of these folks that are listed on 18 were qualified to be part of the North Carolina section of the ITE task force that looked into making recommendations for yellow and red time?
A. No, I don't have any opinion on that.
Q. Do you have an opinion that your qualifications are better than the qualifications listed at tab Exhibit 18 regarding traffic signal engineering?
MR. STAM: Objection to form.
A. Could you repeat that?
Q. Sure. I mean, I understand that you've not practiced as a traffic signal engineer, right?
A. That's correct.
Q. And do you have an opinion that your

experience in traffic signal engineering is greater than the experience of those individuals listed on Exhibit 18?

A. I'm not aware of what all their experience is. I can only assume that some of them have some experience. As you've already stated, I don't have any traffic engineering experience, so whether I have equal or less than any of these people, I'm uncertain.

Q. Going back to -- so do you have an understanding that the North Carolina section of traffic signal engineer task force that looked into red and yellow times in North Carolina in 2004, 2005 was comprised of traffic signal engineers from both NCDOT, local government as well as private engineering firms?

A. That's my understanding of what it was comprised of.

Q. And do you know what they did that led to their recommendations?

A. On day to day, no.

Q. Back prior to the task force being organized, do you know what the engineering practice was for traffic signal engineers for determining yellow times for traffic signals?

A. I know there were some documents, the chart or sheet 5.2.3 or 5.2.2, that was in the North Carolina traffic signal text, gave some guidelines for yellow and red. I mean, I've seen some historical copies for that.

Q. Okay. And do you have an opinion that those documents were either used by traffic signal engineers in the practice of traffic signal engineering in North Carolina or not used by traffic signal engineers?

A. It's my understanding that it was used.

Q. Let's take a look at Exhibit 13, and I'll represent to you Exhibit 13 was an exhibit used in Dr. Hummer's deposition by Mr. Stam, and it's various portions of the North Carolina Department of Transportation change signal section clearance interval sheets?

A. Yes.

Q. And have you seen these before, what's behind Exhibit 13?

A. Those appear to be copies of what I've seen before.

Q. Okay. And do you know how, or do you know what the purpose of this document was when published by -- or strike that.

Do you know whether this is an internal document of NCDOT to be used by their engineers, or if

this is a published document to be used by any engineer or whether this is something that is to be used by the general public? Do you know what the purpose behind the documents in Exhibit 13 are?
A. I did not read the scope and purpose of the text that this comes from.
Q. And do you have an understanding that -- well, let's look at the first page, for example, it says it's a sheet, 5.3.2. Do you see that?
A. Yes.
Q. And on the left, far left it says 1099. Do you see that?
A. Yes.
Q. So is it your understanding that this is sheet 5.3.2 of this design manual that was in effect of 10-99, October of 1999?
A. That's what I would infer from this, yes.
Q. And so then the next page shows May 1, correct?
A. Well, May of '01.
Q. And then 3 of '02?
A. Yes.
Q. And 7 of '05?
A. Yes.
Q. 7 of '09?

A. Yes.
Q. All right. And do you know whether or not the documents that are reflected behind tab 13 were promulgated or -- strike that -- were published standards or practices used by traffic signal engineers in North Carolina during the time reflected on each particular sheet?
A. It's my understanding these are the guidelines by the signals and geometrics section. As far as who used them to fully answer your question, I'm not sure who used these documents.
Q. Okay. Do you know whether or not traffic signal engineers who were designing traffic signals in the State of North Carolina, whether it was their practice to use the documents behind tab 13?
A. If it was whose practice?
Q. The engineers, if it was the traffic signal engineers' practice to use the documents behind tab 13 in determining yellow and red times?
A. I mean, my understanding is this document is produced by the DOT. These are at least guidelines at a minimum of how to signal those lights. Which engineers used those or did engineers actually use them, I don't know.
Q. You don't know.

If you would take a look at -- do you know when the North Carolina Department of Transportation -- excuse me, the North Carolina Department of Transportation signal section first published their -- a design manual showing, giving a guideline or a practice on how to determine yellow times for traffic signals in North Carolina?

A. No.

Q. So if you would take a look at what's behind 14. I'll represent to you -- well, I'll represent to you that this is a 1997 version of the NCDOT. I'll just call it signal design manual.

And do you know whether or not this is the recommended practice reflected behind Exhibit 14, was the practice that was used back in 1991?

A. I would not anticipate that, given that this is a -- dated '95.

Q. Okay. Do you know what the practice was for traffic signal engineers back in 1991 for determining the length of yellow times for traffic signals in North Carolina?

A. I have not seen -- I don't believe I've seen a document of that vintage.

Q. So my question was though do you know --

A. No.

Q. If you would take a look at Exhibit 16.
Have you seen Exhibit 16 before?
A. It looks familiar. I know I've seen several of these IT traffic engineering handbook excerpts. I think I've seen the '10 version, but I'm not positive.
Q. Do you know if the 6th Edition, I know this says published in '10, but do you know if whether or not the 6th Edition was originally published in 2009?
A. I don't know. I don't know.
Q. Okay. And, again, and I'm not trying to -- if I have asked you this before, I do apologize, but as far as the particular document behind Exhibit 16, is this a document that you have used within the last five years, let's say, in your role as an engineer at ARAI prior to your involvement in this case?
A. The document as a whole?
Q. Yeah, let's talk about the document as a whole.
A. As a whole, I'm certain that at some point in time, and I can't point you to a reference, but at some point in time, I have been involved in a calculation or some type of analysis that would involve ITE standards.
Q. Okay. So have you used in your practice an

ITE published calculation?

A. It is probable, but I cannot say that for certain that I have.

Q. And in your -- when you say probable, in what subset of what you do for ARAI do you believe you would have used a calculation published by ITE's traffic engineering handbook, 6th Edition?

A. In the course of my job, I mean, the situations that I encounter are wide and varied. We deal quite often with cross-slopes of highways, banking, super elevation, roadway design, site lines, intersection design, I mean, there are many, many things that we consider, and I'm just saying that it's very, very probable that a formula or some reference from ITE has been across my desk in one of those cases, and, again, I can't point to a specific one.

Q. In your experience, is ITE publications generally accepted and relied on by engineers?

A. In my experience, any document that I receive, I question the validity of it. Every formula I look at it critically to try to figure out where it came from and is it applicable.

And so in all instances, I can't give a blanket statement that it's acceptable in all instances. It is a technical handbook. It's put together by transportation engineers. It gives it some value of credibility, but that does not make me immediately assume that everything in it is 100 percent correct.

Q. My question was, in your experience as an engineer, are IT -- is -- are formulas that are published by ITE relied on by engineers in the practice of engineering?

MR. STAM: Objection to form.

A. I think that's an awfully broad question. Engineers practice in engineering. Certainly ITE doesn't apply to nuclear engineering.

Q. Let's make it to you in your practice of engineering. In your practice of engineering, are the formulas in -- that have been published by ITE in the traffic engineering handbook generally relied on by traffic -- excuse me, generally relied on by accident reconstruction engineering?

A. I can tell you that we have many, many reference books. I don't know what other accident reconstructionists rely upon. I have heard of ITE before, and I have very likely reviewed something, some publication of theirs. So what other engineers do, I don't know.

My experience, if I've ever even seen an

ITE document before, I would question it before I would use that and apply that in a situation.

Q. So you testified a moment ago that you do not know what other accident reconstructionists or publications other accident reconstructionists rely on?

A. Not every publication that they rely on.

Q. Do you know what traffic signal engineers, what publications from ITE that traffic signal engineers in this state rely on?

A. Not every document.

Q. Do you know any that they rely on?

A. I know there's a lot of reference to the ITE formula in this case, and the ITE is the yellow phasing formula that's put forth in the traffic engineering handbook.

Q. And, again, do you know, I mean, do you know because -- do you know what North Carolina traffic signal engineers in this state, what documents -- let's be specific, whether or not they rely on the ITE formula that's been published by ITE in the traffic engineering handbooks?

MR. STAM: Objection to form.

BY MS. MARTINEAU:

Q. In determining yellow and red times?

MR. STAM: Objection to form.

A. That was an awfully long question, but as I understand it, my understanding is that on or about the 2005 time frame, the recommended practice by the signals division began suggesting the ITE formula.

Q. Let's talk about before that. Before 2005, do you know, do you have an opinion as to what traffic signal engineers in this state -- whether or not traffic signal engineers in this state prior to 2005 relied on the ITE formula published in the traffic engineering handbooks to determine yellow and red times?

A. I do not know every document that they relied upon.

Q. I didn't ask you about every document. I asked you about this document.

A. I mean, I'm trying to answer, but I can't answer a yes or no because I don't know what --

Q. Yes, you can. I mean, that's an answer --

MR. STAM: Ms. Martineau, I object to form, and the objection is if you ask a question while he's still answering any question is objectionable.

MS. MARTINEAU: Okay.

Q. Listen to my question, okay.

Do you know prior to 2005, do you know

whether or not traffic signal engineers in this state relied on the ITE formula promulgated by the traffic handbook, excuse me, the Traffic Engineering Handbook, to determine yellow and red times?

A. I do not know.

Q. Do you know what the practice, what the engineering practices were of traffic signal engineers in this state prior to 2005 for determining yellow and red times?

A. Other than the document that we were just looking at, the document under Exhibit 13, that's the only information that I have as to what was the practice prior to about 2004, 2005.

Q. After 2000 -- after, let's see, after the North Carolina section of ITE, the task force for yellow and red times came out with its recommendation and published the document behind Exhibit 10, do you have an understanding of what the task force recommended for traffic signal engineers for designing yellow and red times?

A. After the task force?

Q. Yes.

A. The only information that I have is in Exhibit 13, the 302 -- 3 of 2002 version has one methodology. The July of '05 has a methodology that's consistent with the ITE formula outlined in Exhibit 10.

Q. So other than documents that you were provided in this case, either through Mr. Ceccarelli's website or given to you by either Mr. Ceccarelli or Mr. Stam, what have you done to determine what the practice was of traffic signal engineers for determining yellow and red times in North Carolina after 2005?

A. The other information that I have -- well, I do have, again, this Exhibit 10, Exhibit 13 and in Ms. Moon and Mr. Fuller's deposition, there was some mention of using the ITE formula.

Q. But do you have, have you, through your investigation in this case, do you have an opinion as to what the engineering practice was, what the traffic signal engineering practice was after publication of Exhibit 10 for traffic signal engineers in this state for determining yellow times?

MR. STAM: Object to form. Go ahead.

A. The only information I have as far as a timeline and what their guidelines were are obtained in Exhibit 13.

Q. Okay. But my question is a little bit different.

Do you have an opinion as to what the

practice was of traffic signal engineers after 2005 for determining yellow times?
A. Yes.
Q. Okay. What was that practice?
A. My understanding is in July of '05, this clearance interval sheet, 5.2.2, was put forth that outlines the, in general, the methodologies of the ITE formula.
Q. And is it your understanding -- what sheet is that again, 13?
A. Exhibit 13, July '05.
Q. So it's your understanding, or you have an opinion that the formula shown on Exhibit 13, dated 7/05 reflects what the engineering practice was for traffic signal engineers in North Carolina to determine yellow times after 7/05?
A. It is my understanding that that is the suggestion by the signals and geometrics section.
Q. Okay, but my question --
A. Well, I'm saying as far as whether all engineers from NCDOT complied with this or they used some other formula, I do not know.
Q. Okay. But that's a different question too.
I'm asking you, do you know in general what the -- after 2005, after the task force came out, do

you know in general what the engineering practice was for determining yellow times that was used by traffic signal engineers in this state for signals?
A. And I think my earlier answer is my understanding was the ITE formula.
Q. That is shown on 7/05?
A. Yes, that portion of Exhibit 13.
Q. Okay. And do you know whether or not the traffic signal -- the traffic -- excuse me. Do you know whether or not the engineers who signed and sealed the traffic signals in question that are dated after 7/05 used the formula reflected in the 7/05 document to determine the length of yellow times?
A. Do I know for a fact that's what they did? No.
Q. Okay. Now, what on 7/05 -- do you know what the recommended -- all right. Do you know on 7/05 that it recommended that traffic signal engineers for most left-turn lanes assume a speed of 20 miles an hour to 30 miles an hour when using the yellow change interval formula?
A. That's my understanding as to what they do, yes.
Q. And do you know whether or not the traffic signal engineers whose name appear on the traffic

signal plans of record in this case after 7/05 used an assumed speed of 20 miles an hour when determining or calculating what the yellow change interval should be for left turn signals?

A. I do not know that they did in fact use that formula.

Q. So you don't know if they did or not?

A. That's correct.

Q. Okay. Do you know whether or not traffic signal engineers today, whether it's generally accepted by traffic signal engineers today to use 20 miles an hour in the ITE formula when determining how long yellow times should be for dedicated left turn signals?

MR. STAM: Objection to the form, and let me state what my objection is so you can --

MS. MARTINEAU: You don't need to.

MR. STAM: I feel I do need to. Where? The question does not include where the 20 miles an hour is measured.

MS. MARTINEAU: I didn't ask him where it was measured.

MR. STAM: Well, unless a vehicle is always at the same speed, then to determine its speed limit, you got to know at what point --

MS. MARTINEAU: I'm not asking him about where to determine the speed limit. I'm asking him what he understands the practice is, okay?

MR. STAM: I have made my objection.

MS. MARTINEAU: Okay.

Q. Do you know whether or not -- well, do you know today whether it is the practice of traffic signal engineers when determining the length of the yellow change interval at left turn lanes, whether it's their practice to use 20 miles an hour and plug it into the ITE formula shown on Exhibit 13, dated 7/05?

A. That is my understanding, yes.

Q. And where do you get that understanding from?

A. My understanding is from the depositions of Moon and Fuller. I think it was mentioned in at least one of those, of that 20 mile per hour suggestion, and then in addition to the documents here in Exhibit 13.

Q. Have you in either -- in your investigation into this case after being contacted about it or even before being involved in this case, have you undertaken any investigation to learn whether there's an alternative practice being employed by traffic signal engineers in this state when they design yellow change intervals for dedicated left turn lanes?

A. I have not.

Q. Now, are you familiar with the traffic laws of this state regarding vehicle control sign and signals?

A. Specifically which --

Q. Sure, Section 21 5.8, vehicle control signs and signals.

A. Other than my general knowledge as a driver, I mean, I've never looked up that statute or section of law, whatever that is.

Q. This is just -- I'll represent to you this is just a general Chapter 20 driving statute.

A. Okay.

Q. Okay. And do you know what North Carolina law is in their general statutes regarding whether or not it is legal to enter an intersection on a yellow light?

A. My experience is that it is legal, yes.

Q. And is that your experience as a driver, or is that your experience from looking up the law, or is that your experience from your work as an engineer with ARAI?

A. Probably a combination of all of those. I know that I have several friends that are police officers, and I have specifically asked that question years ago actually, way before this was ever an issue.

Q. So it's your understanding that in North Carolina, as long as you enter the intersection before the light turns red, it's -- you're safe? It's legal?

A. That is my understanding, yes.

Q. And you have not heard anything in this case to make you think otherwise, right?

A. No.

Q. Okay. Do you know under North Carolina General Statute 20-158, if the state legislature has promulgated that it is the Department of Transportation with reference to state highways and -- that it's -- excuse me. That it's the Department of Transportation that's authorized to control vehicles at intersections where there are traffic signals?

A. I'm not sure I understand that question.

Q. Well, do you know, I mean, are you familiar with the law, Section 2058 (sic) that says the Department of Transportation with reference to state highways are hereby authorized to control vehicles at intersections and other appropriate places by erecting or installing steady beam traffic signals and other traffic control devices?

A. I've never read that statute, so I'm not familiar with it.
Q. Okay. Do you know, according to that statute, what the purpose of a yellow -- what the purpose of a yellow light is?
A. In how it's defined in that statute? I do not.
Q. How about did you look to see -- do you know what the purpose of the yellow light is, according to the Uniform Manual of Traffic Control Devices?
A. Well, there are different but similar definitions, both given forth in MUTCD. I think there's a definition of ITE. Mr. Fuller I believe gave a definition, maybe Ms. Moon.
The yellow provides you a visual cue that your right-of-way is going to end and that a red light is forthcoming, and that some opposing traffic or crossing traffic is going to receive a red -- a green excuse me.
Q. And you got that from just looking at material and reading depositions?
A. Well, that's common knowledge as well.
Q. Common knowledge, the purpose of the yellow light?
A. Yes.

Q. Do you know what the guidance is for the length of yellow times promulgated by the Manual of Uniform Traffic Control Devices either in 2003 or 2009, MUTCD?

A. If I recall correctly, the guidance was yellows typically between three and six.

Q. And is it your understanding that the signal plans in question in this case, all have yellow times between three and six?

A. I believe that they are, yes.

Q. Now, I know we've been here a long time, and I appreciate your patience with me. And, again, you know, this is my one chance to talk with you, so it's my job to explore sort of what your background is, what you did, you know, what things you know, don't know.

Now, I want to ask you specifically about what opinions you do intend to give in this case if you were called to the stand and asked by Mr. Stam to talk to the jury about your opinions. And what are those opinions?

THE WITNESS: Can we take a restroom break?

MS. MARTINEAU: Sure.

(Off the record at 12:45 p.m.)

(On the record at 12:51 p.m.)

BY MS. MARTINEAU:

Q. Okay, Mr. Hennings, we're back on the record, and as I indicated before we went off, you've been very patient and allowed me to ask my questions that enabled me to kind of find out your background related to this case and information you have regarding the opinions you're about to give. You know, you've been designated as an expert witness, and what are the opinions that you have or the engineering opinions that you have in this case that you intend to give at the trial of this matter?

A. Okay. They are somewhat intermixed. They are a couple of opinions.

I guess the overlying opinion is that the yellow timing of the lights do not afford everyone or even a very high percentage of people, does not afford them the time to act appropriately to prevent themselves from running a red light.

Q. Anything else?

A. Yes. The manner with which the formula has been used for left turning vehicles is inappropriate. The inputs placed within those formulas are inappropriate, and the end result of those errors results in a certain percentage of people that will end up running a red light, if they come upon an intersection under just the right conditions because of the timing of the light.

Q. Anything else?

A. I mean, those all probably need to be expanded on, but that's the overlying opinions.

Q. So you have that the yellow timing -- is it the yellow timing formula shown where?

A. The ITE type formula, and the formula that's shown in Exhibit is it 13 that had the cut sheets?

Q. Just so we know, the formula that's been promulgated by ITE for determining yellow and red times?

A. Yes.

Q. As well as the formula that's been promulgated by North Carolina DOT, the signal section for formulating yellow and red times, in your opinion, does not afford drivers enough time to act appropriately in order to prevent them from running a red light?

A. The time that results from that formula, yes.

Q. And you also are of the opinion that the manner of the formula is inappropriate, and the inputs that you use in the formula are inappropriate, and that those resulting errors cause a certain percentage of people to run red lights?

A. Yeah, and I think you may have missed part of the manner with which the formula is applied to left turning vehicles was inappropriate.

Q. Okay. Now, prior to your involvement in this case, what understanding, if any, or what research were you involved in or interested in, if any, regarding the purpose behind the length of yellow times versus red times?

A. The research into the purpose of the yellow, was that your question?

Q. Yes.

A. I don't recall having done any research into the purpose of the yellow prior to this.

Q. Now, you're familiar a little bit with the Manual of Uniform Traffic Control Devices?

A. Yes.

Q. Do you know whether the Manual of Uniform Traffic Control Devices gives, as one of its options, to use the ITE formula found in the 6th Edition of the Traffic Engineering Handbook?

A. I think, depending on time, I think there was -- there may have been a point in time where the

MUTCD -- I don't recall if the MUTCD has always recommended ITE formula. I think it uses it as a suggestion, and it suggests that yellow lights should be three and six, between three and six.

Q. Okay. So let's take a look at that. Do you have that?

A. Yes, which exhibit was it in?

Q. It's the big one. I brought with me the whole --

A. Number 5?

Q. -- the whole chapter. I have the introduction chapter of the 2009 and the 2003, as well as the chapters related to signal times for 2009 and 2003, and I can point you somewhere.

A. If you don't mind, direct me, because it's a rather large document.

Q. Did you review this document though in looking at your opinions during this case?

A. During the course of this case, I have seen multiple copies of MUTCD. I don't recall all which versions were printed when.

Q. Okay. Let's look at, I think it's like page 475. If we get there, I can probably see.

A. I think that's roughly where I was at.

MR. STAM: Is it 485?

MS. MARTINEAU: Yes, thank you.

Q. Take a look starting around page --

A. 4D.26.

Q. On page 485, under Section 4D.26 yellow change and red clearance intervals. Is it your understanding that this is the portion of the MUTCD, 2009 version, that talks about specifically timing of yellow change intervals?

A. That's what I read on this page, and there's a section yellow and change rate intervals -- clearance intervals, excuse me.

Q. Are you aware, I mean, I'm not, are you aware of some other section?

A. Not in this document. Not that I recall.

Q. And do you recall earlier how we talked about how MUTCD has different levels of authority, such as standard, guidance, option?

A. Right.

Q. And standard, the standard promulgated in 2009 MUTCD for yellow change intervals says that a steady yellow signal indication shall be displayed following every circular green or green arrow signal indication and follow every flashing yellow arrow or flashing red arrow?

A. Yes.

Q. And you see where it says, the exclusive function of the yellow change interval shall be to warn traffic of an impending change in the right-of-way assignment?

A. Yes.

Q. And that's consistent with what your recollection was as a driver, as an engineer and from review of this as what the purpose of the yellow change interval is?

A. Yes, that's right.

Q. And then for standard, it says, the duration of the yellow change interval shall be determined using engineering practices?

A. Right.

Q. And that's the standard, is that right?

A. Yes. No, I'm sorry -- yeah, that's all still under the standard.

Q. Okay. And then under -- a couple of pages over, you would take a look at page 489, there's something in parenthesis, it says guidance?

A. You mean in italicizes?

Q. Yes. Thank you. May the record reflect in italics it says guidance. Do you see that?

A. Yes.

Q. And what is a guidance as far as MUTCD is concerned?

A. As I recall it, it's a suggestion.

Q. And the suggestion is what for yellow change intervals?

A. Well, it says, should have a duration between three and six.

Q. And, again, you testified that as far as you understand, all the signal plans at issue in this case have yellow times between three and six, correct?

A. That's my recollection, yes. I will let the documents speak for themselves, but I don't recall seeing anything outside of that.

Q. And is there anything in here that gives a formula that must be followed by traffic signal engineers in determining yellow times?

A. In determining yellow? No. Well, there is if you look further down on page 485, it seems to be a little -- it seems to be a little confusing, because under the standard, it says the duration of the red shall be determined using engineering practices, and then for support, it says for the determination of yellow and red, you can use the ITE book. But regardless, I mean, it's under the red clearance, and ITE formula does both yellow and red, so.

Q. Where are you on page 485?

A. That's line 07 underneath Section 4D.26.
Q. On page 485?
A. Yes.
Q. So under -- on page 485, under support, it says, engineering practices for determining the duration of yellow change and red change intervals can be found in ITE's traffic control devices handbook and ITE's manual of traffic signal design?
A. Yes.
Q. And that's under support?
A. That's correct.
Q. And what is support? Again, for the purposes of MUTCD, what does that mean in terms of level of requirement?
A. My understanding is here is a place you can look for a practice.
Q. Okay. And are you aware of what the ITE formula that's outlined in either traffic control devices handbook from ITE or manual of traffic signal design from ITE?
A. I'm familiar with the formula, yes.
Q. And is that the formula that you feel that you're here to give opinions about today?
A. Yes.
Q. But you do acknowledge that the 2009

version of the Manual of Uniform Traffic Control Devices, as support, states engineering practices for determining the duration of yellow change and red clearance intervals can be found in ITE publications?
A. That's correct.
Q. Okay. Now, do you know, do you have -- do you know what Mr. Ceccarelli's opinion is as to how long the yellow change interval should be?
A. I'm familiar with the papers he wrote, yes, and, obviously, the yellow change interval is a function of grade and speed and all of that.
So, I mean, it's a value that's dependent upon a couple of other inputs.
Q. Right. Do you know if he is promulgating long yellow times, longer than that allowed in the Manual of Uniform Traffic Control Devices?
A. I'm not going to say in all situations is it more than the three to six. I think he may have some cycles that are longer than six.
Q. And those cycles would be in violation of the current Manual of Uniform Traffic Control Devices, correct?
A. By their definition, yes.
Q. Do you feel, do you have an opinion as to whether or not the longer yellow times supported by

Ceccarelli in the circumstances where he supports those, and we can look at his paper if you want, do you have an opinion as to whether or not those longer yellow times over six seconds is a good engineering practice or not?

A. There are situations where times of six or more would be warranted.

Q. Even though it's in violation of the Manual of Uniform Traffic Control Devices?

A. Yes.

Q. Do you know what you have to do in order to -- do you know what the manual requires if engineers want to test theories or practices that are outside of the scope or what is authorized in the manual?

A. No, I'm not familiar with that.

Q. Are you familiar that there's a whole section in the MUTCD that talks about what someone should do if they have a new idea or a new theory in order to get it tested, to see if there's support for it in the engineering community?

A. I have not seen that.

Q. Have you ever in your role as an engineer, ever attempted to promulgate a new idea or a new way of doing an engineering practice that's not allowed by the Manual of Uniform Traffic Control Devices?

A. Sorry, say that again?

Q. Sure. Have you, as an engineer, ever utilized the steps that are outlined in the MUTCD for either testing or implementing an engineering idea that's currently not allowed by MUTCD?

A. In the course of my investigation in this matter, you know, I've come to be at odds with the guidelines from the traffic engineers and the MUTCD.

Q. Okay. I understand that. But my question is, have you ever in the course of your role as an engineer, used the policy or the guidelines outlined by the Manual of Uniform Traffic Control Devices for implementing or testing a new idea that is currently prohibited in the MUTCD?

A. No.

Q. Do you agree that engineering new ideas in engineering should be tested prior to implementation?

A. Yes.

Q. Do you have -- have you come up with a formula that you believe should be adopted by ITE and/or the North Carolina Department of Transportation signals section for use in determining the length of yellow times?

A. Yes.

Q. What is that formula?

A. Well, the formula is not that different from the ITE formula.

The problem that I have seen is that there seems to be a misunderstanding of what the effects of putting erroneous inputs into the formula and a misunderstanding of what the formula really does. That seems to be the overlying problem, is that one thing I know is vehicle motion. There's one thing that I know very well. It is clear when I read through this formula and I read through these depositions and I read through these explanations, that some people do not have a full appreciation for what the effects of this formula are.

Q. Okay. My question is what is your formula?

A. For a formula, for a straight-through turn, the formula would be essentially the same, but they're putting the wrong inputs in. So the formula is the P and R plus V over 2A. It's the same formula, but they're putting in the wrong perception and reaction.

Q. Okay. If you would write what your formula would be, what you think for straight-throughs?

A. Yeah, let's make sure these are handled two completely different ways straight-throughs and turns.

Q. Why don't you write straight-through on that?

A. Okay. Let's do that. (Witness complying.) Now, IT formula --

Q. No, I want to know what your formula is.

A. Let me finish my answer, please.

Q. Go ahead.

A. I said IT formula and my formula equals perception reaction plus V0 over 2A, okay. The problem is --

Q. Can I mark that as an? I think we're on 24.

(The document referred to was marked Defendant's Exhibit Number 24 for identification.)

A. Now, here's the problem. This formula only givers you exactly the amount of time that the average driver needs to go straight through the yellow light.

If there is any variation, if the car slows slightly, or if that person has a higher perception reaction than the standard driver, then that person ends up running the light.

So my adjustment to the straight-through formula would be simply very simple. You use the ASHTO recommended two and a half seconds for perception and reaction, and if we do that, we take care of 80 percent of the red light runners. It is just that simple.

Q. Do you know what -- do you know whether or not traffic signal engineers -- strike that.
Are you familiar in your role, prior to being contacted for this case, were you familiar with the concerns that traffic signal engineers have with long yellows?
A. Not prior to this case. I've never heard that concern prior to this case.
Q. And do you know whether or not it is the practice of traffic signal engineers to use a perception and reaction time of 1.5 for when they use the ITE formula?
A. That's the guidance given in the DOT pages that are in Exhibit, I think it's 13. Let me check that. Yes, Exhibit 13.
Q. Okay. And are you aware of other traffic signal design -- well, are you aware of other traffic signal design engineering practices that automate traffic sequences or phase sequences?
A. That automate the phase sequences? Yes.
Q. Are you aware that some traffic signals have minimum and maximum green?
A. Yes.
Q. And maximum green, is it your understanding, as long as cars are hitting the loops,

it will stay green until the maximum green time runs out?

A. Yes, I mean, I know there are phases like that, yes.

Q. Okay, all right. And do you know, I mean, are you familiar with studies that have been done by ITE and other traffic signal engineering -- and other traffic signal engineers to determine what they feel is the appropriate perception reaction time?

A. There have been many studies to that effect, yes.

Q. And for use and what perception reaction time to use when designing traffic signals?

A. Well, perception reaction is not specific to traffic signals, but some are specifically monitored at traffic signals. There are many other P&R tests, and studies have been done in different situations.

Q. Have you done any studies regarding perception reaction time related to how long a yellow change interval should be?

A. I have not.

Q. Have you read any that recommend using something other than 1.5?

A. Well, I can tell you there are many studies that says that in a situation like that, their perception reaction is greater than 1.5. ASHTO recommends using two and a half for design. There are many studies and even in Gazies' paper from '59, there's other studies here in my stack that show that the average perception reaction is longer than one and a half. And we're not talking about average. We want to get as many people as possible. So we need to really look at something at more like a 95 or 95 percentile perception reaction. Because if we don't consider those other people, then we've shorted them on yellow, and that's the problem. Because they've done these studies and found out what average perception reactions are, when they need to be considered what's a 90 or 95th percentile person.

Q. Well, where have you seen that traffic signal engineers have stated that traffic signals need to be designed for 90 to 95 percent of the traveling public?

A. I have not seen that. Well, sorry, let me restate that. The MUTC -- not the MUTC, the ASHTO guidelines suggest for design that a two and a half second perception reaction should be used.

Q. Where is that?

A. Here's one copy from the '94 Edition.

Q. Is that for use in determining yellow times?

A. It specifically says a reaction time of two and a half seconds is considered adequate for more complex conditions than those in the use of these other studies, but it is not adequate for the most complex conditions encountered by the driver. Additional consideration of the most complex conditions, such as those found at multiphase, at grade intersections.

So what they're saying is two and a half does not consider multiphase intersections. At a minimum, we're talking two and a half, according to ASHTO.

Q. Okay. Well, what does, do you -- what does the North Carolina statute that authorizes municipalities, such as the Town of Cary, require them to follow?

A. I don't know.

Q. Have you in the course -- are you -- have you in the course of your work on this case or any other case, have you written any proposed new guidelines or spoken to any ITE engineers about your idea of using ASHTO's 2.5 second perception reaction time?

A. I have not.

Q. Do you know how long the ITE formula has been used by traffic signal engineers in North Carolina?

A. Well, I know that -- I'm not aware of it being suggested by the DOT until about '05. Now, if somebody was using it before that, I'm not aware of that.

Q. Do you know what is taught by North Carolina engineering, traffic engineering professors, what they teach students to use as perception reaction time in determining yellow change intervals?

A. I do not.

Q. Do you know whether or not the North Carolina section of the Institute of Traffic Engineers considered using longer reaction -- perception reaction times and rejected that idea when they conducted their task force?

A. I seem to recall something to that effect in one of the papers that I read, but I'm not positive on that.

Q. Any other criticism you have of the ITE formula for straight-through drivers?

A. I think that's the overlying, I mean, could it be done better? Yes, it could be. This is a method that is very easy, that we know from the traffic studies that 80 percent of the red light runners are within the first second. If we just add that one second to the two and a half perception reaction time, which is suggested by ASHTO, then we take care of 80 percent of the people that were caught running red lights.

Q. What do you base that on?

A. These traffic studies in my file, I mean --

Q. What traffic studies?

A. Well, there's one by the Texas Transportation Institute, and I read over many more. These just happened to be the ones that I printed.

Q. Okay.

A. Where's that other one at?

You had asked earlier about other engineers suggesting two and a half seconds. I forgot about this paper that was written for the Oregon Department of Transportation, where they found that the drivers stayed alert for the complexity situation of high, such as outlined in ASHTO. The P&R time should be two and a half seconds. I forgot about that.

Q. What deceleration rate do you think should be used in the formula?

A. I don't disagree with a third of a G that's being used.

Q. Do you agree that cars can stop faster than that?

A. Oh, yes.

Q. What is, I mean, typically in your -- in your role as an accident reconstruction engineer, what is the typical stopping distance of the average vehicle?

A. Well, that depends on the speed. I mean, that's --

Q. Or deceleration rate? Maybe that's a better way to ask the question.

A. There isn't a typical deceleration rate. There are what studies show what people are comfortable, what people feel uncomfortable, what is emergency braking, the third of a G that's put forth by the DOT. I think that is a good number for a comfortable deceleration rate.

Q. What's the range of comfortable deceleration rates that you have seen in your role as an accident reconstruction --

A. The numbers I've seen are generally around a quarter of a G to a third of a G.

Q. How is that to a person who doesn't know what a G is, what is that?

A. Oh, okay, so basically the 11.2 that DOT uses, or the 10.6 that's been put forth in some of the other documents, those are right at a third of a G. A third of a G is going to be right at 10.8 maybe feet per second squared.

Q. What about ten feet per second squared?

A. That's just slightly less than a third of a G. That's going to be right at .3 Gs.

Q. Is that a comfortable stopping? Have you used that? Have you seen 10.00 feet per second in the range of comfortable stopping distance as an accident reconstruction engineer?

A. Yes. Like I said earlier, we're talking quarter of a G, which is going to fall out at about right around -- right at eight feet per second squared, up to about a third of a G, which is around 11 feet per second.

MR. STAM: Is that squared.

THE WITNESS: Feet per second squared.

Q. Using 11.2 feet per second square that's on the, I mean, is a conservative deceleration rate, wouldn't you agree, in the comfortable zone?

A. No, that's on the high end of the comfortable zone.

MR. STAM: Objection to form. I don't know what conservative means in that context.

MS. MARTINEAU: Me either.
Q. So you've seen it anywhere from eight feet per second up to eleven what?
A. Yeah, in the ball -- I do it in Gs, not in feet per second. So I'm trying to convert it for you on the fly here. But, you know, a quarter of a G is roughly eight feet per second squared. A third of a G is roughly eleven feet per second squared. There isn't a lot of difference in that.
Q. Now, you would agree when you come up to an intersection, it's pretty clear that there's traffic signals?
A. Yes.
Q. And do you have any understanding of the human factor component of traffic signal engineering as to what traffic signal engineers are trying to condition drivers to do?
A. That's a question, why are they conditioning drivers when drivers are already conditioned? There's studies out there that show what drivers do.
So if they are attempting to condition drivers, then they're doing something they already know people are going to fail.
Q. Well, I'm asking you regarding what you

understand traffic signal engineers, what you understand that they are trying to do?

A. Well, traffic signal engineers, their primary purpose is safety. That's above and beyond everything else.

Q. Well, let me ask you about that.

Do you have any information that the formula that ITE is using has increased crashes?

A. Has it increased crashes? Using that formula increases vehicles entering the intersection on a red cycle, and that certainly has a very good probability of creating more crashes.

Q. Are you aware of any crash studies related to any of the intersections in this case or any intersections in North Carolina that attribute, that attribute crashes to the yellow times used in IT formulas?

A. I can tell you this, in these studies, when they add time to the yellow time, they put time above the ITE formula, crashes go down. So that's a study you. You asked if there was a study --

Q. North Carolina -- go ahead.

A. This is North Carolina, it's right here, The Urban Transit Institute at North Carolina A&T. They found that when they increased the yellow time, the crashes go down.

Q. Was that study published?

A. It's on the internet, July 2004. It was done for the US Department of Transportation.

Q. Do you know if it was published by NCDOT?

A. By NCDOT, no.

Q. Do you know if it was peer reviewed?

A. There was some type of peer review of original copy of this report. This was the more -- it was a revisit to the original report.

Q. Do you know whether or not any practicing traffic signal engineer in North Carolina uses 2.5 deceleration rate when determining yellow times in North Carolina?

A. I'm not aware of any.

MR. STAM: I'm sorry, objection to form. Did you say 2.5 deceleration rate?

MS. MARTINEAU: I don't know what I said.

A. I understood the question to be 2.5 perception reaction.

MR. STAM: I think both of you all are meaning the same thing, but you said something different.

MS. MARTINEAU: Maybe.

Q. Let me ask, are you aware of any practicing signal engineer who uses 2.5 perception reaction time in determining yellow times using either the ITE formula or the North Carolina DOT signal manual formula in North Carolina?

A. I'm not aware of any.

Q. Do you know whether or not using 2.5 perception reaction time is an accepted engineering practice in North Carolina for using -- for determining yellow times?

A. I'm not aware of anyone using two and a half.

Q. Let's talk a little bit about the left turn yellow time formula. Do you have an opinion as to what the left turn yellow time formula should be?

A. Definitely.

Q. And what is that?

A. Again, the formula is very similar to the ITE formula, however with slight modification. The yellow time should equal to the P&R time and, again, I'm going to say two and a half seconds, plus V0 squared over 2A times V average over the approach distance.

Q. So what's the difference? I'm going to mark this as Exhibit 25.

(The document referred to was marked Defendant's Exhibit Number 25 for identification.)

Q. What's the difference?

A. Well, here's the difference. It stems from what the yellow does, what the red does and what this formula does and basic physics.

So if we look at basic physics and, excuse me a second, so I can get a formula, okay, we have a car moving down the road. I'm going to draw it on here. The car is traveling down the road. The car is traveling at sum V0, velocity 0. He's approaching a left-hand turn. Now, by the DOT standards, they say everybody makes that turn on average of 20 miles per hour, not DOT, but DO, but it's the DOT studies that are outlined in the documents. They say 20 miles per hour is what people are making the turn at. They are basing that yellow time on that 20 miles per hour. The yellow is not related to the time in the curve whatsoever. The yellow is related to the speed of a car approaching the light.

So if we take a car that's approaching at the speed limit, and they are going to slow at 20 miles per hour using 20 miles per hour as the V, as they've been doing is inappropriate. It does not afford the approaching driver the time they need to enter the intersection comfortably before it turns red.

Q. Can they stop?

A. In some situations they may be put in a situation that they could not stop.

Q. In what situation?

A. Well, when you have a high rate of speed and a short yellow, if they short the yellow too much, then it will be very difficult for them to stop. They may be able to stop under emergency braking, but it will be difficult.

Q. So what are you saying they need to do when you say average, what would that require?

A. Well, it's very simple, they just take the posted speed limit, add it to the 20 miles per hour, divide by two, and that's V average. And what this does is this takes account the time needed for the car to reach the stop bar. They're not taking that into account with the ITE formula.

Q. Well, is the purpose of the ITE formula to give drivers enough time to reach the stop bar on yellow?

A. Yeah, that is the purpose.

Q. Where do you get that from?

A. Okay. I have the basic formula for vehicle motion. What we know is that if a car is in just the right position when that light turns red, they're going to spend some time perceiving and reacting.

Q. You mean yellow?

A. When the light turns yellow, thank you. They are going to spend some period of time perceiving and reacting. Then they are at a distance from the stop bar. At the end of that P&R, they decide if they're going to go or if they're going to stop.

Now, we know if that car is going to a certain speed of V0, the distance required for that car to stop is VO squared over 2A equals X. That's the distance. Now, we want to know, okay, the light turned yellow here, we want to know how long does it take that car to go that distance and enter the intersection legally before it turns red.

So we divide that distance by A velocity to get time, and that's the time that's in the yellow formula.

If we divide by the wrong velocity, we get the wrong time. Now they've omitted this part. They apparently do not realize the implication of this formula, how it was derived.

So if you divide it by V, if you haven't slowed down at all, then it's just V0, and that formula equates to V0 over 2A, and that's perfect. That's what the IT formula is already V0 over 2A. But if you have a car decelerating, then this formula goes down to V0 squared divided by 2A, and the 2A is multiplied times the V average over that distance to find out how long it takes them to go that distance. That is when you get the correct time for a car decelerating over that distance who can still legally enter the intersection.

Q. Well, I mean, why do you believe that traffic signal engineers are trying to design yellow times to allow decelerating vehicles to enter the intersection versus to stop?

A. Well, they're not giving them the opportunity. If they wanted them to just stop, then they would just go red, stop. But we can't do that. People can't react immediately. There has to be a period of time. Reading through this information, their design should be focused on safety. We're talking about safety. We're talking about people being safe on the road, people not being forced to enter an intersection, people not being forced to do emergency stops in crowded streets. We're talking about safety. We want people to decelerate comfortably. The formula and the way that they use it now does not afford people that opportunity.

Q. It's your belief that they should be able to decelerate and stop during the length of the yellow time?

A. No, they will decelerate and stop before or, excuse me, after the yellow is gone, we're talking about cars that go through.

Q. Do you understand that it is -- that traffic signal engineers design yellow times for those cars to continue at the velocity speed or greater, that's the purpose of the formula?

MR. STAM: Objection to the form of the question.

A. This is what I can tell you. If they want people to go above the speed limit, I find that shocking, because that's dangerous.

Secondly, if they want people to travel and have a perception and reaction, which everybody does, and they give somebody the opportunity to either slow down or go, now, if they want them to stop, then they need to just put a red light, but they can't do that, because people take time to perceive and react, and this goes back to a fundamental misunderstanding of what the formula does and the timing related to a car coming down the road who is either going to stop or a car that is going to continue in legally.

Q. Do you think that it's possible that you have a fundamental misunderstanding of what traffic signal engineers intend by the ITE formula and the North Carolina Department of Transportation's signal manual formula?

A. When I take it as a whole, they understand --

Q. My question was about you.

MR. STAM: Objection to the form.

BY MS. MARTINEAU:

Q. You know how to answer the question and then explain your answer. And what's happening is I'm not getting answers. I'm just getting explanations.

MR. STAM: Ms. Martineau, he starts, and then he continues and you start --

MS. MARTINEAU: You know that a judge would say sir, please answer the question, if you need to explain it, go ahead.

MR. STAM: I object to any question that is propounded while he's in the middle of an answer.

A. Can you restate your question?

Q. I don't recall what it was.

Oh, you have made statements several times that traffic engineers misunderstand the purpose behind

the ITE formula, is that right?
A. From everything that I have read, they don't show any understanding of what the formula does.
Q. And you have not used this formula in your practice as an engineer prior to being contacted by Mr. Stam or Mr. Ceccarelli in this case, correct?
A. That is correct.
Q. And so my question was, do you think it's possible that you misunderstand the purpose of the ITE formula and the North Carolina Department of Transportation's signal design unit formula for determining yellow times?
A. It is possible that I am misunderstanding what their purpose is. I will agree to that.
Q. Now, for left turns, you indicated that they need to use the average, right?
A. Yes.
Q. And you did say what you thought it was, but I'm a little bit, I think I misunderstood you.
When you say average, are you saying that traffic studies need to be done at every intersection to determine what the average speed of approaching drivers are when making a left-hand turn?
A. Okay. I'll explain that we know that there have been traffic studies by the DOT that say that cars

make this turn at 20 to 30 miles per hour, and I think that the actual average by the DOT study was it came out at 18 miles per hour.

So I don't really have an issue with them using that 20-mile per hour speed as the turning velocity. That seems to be validated in their study. That's not at issue.

What's at issue is the way that they've performed this equation does not account for a car approaching at the speed limit and having to slow down.

Q. Do you agree that cars cannot make dedicated left turns -- that most cars cannot safely maneuver dedicated left turns at 45 miles an hour?

A. Most turns, yes, I agree.

Q. And do you know what the design speed is for most, and I'm not talking about yellow times, just when you're designing -- have you ever built or designed an intersection?

A. I have not.

Q. Do you know what ASHTO recommends, or let me ask a different question.

Do you know what North Carolina civil engineers, what their practice is, what speed they design for when designing left turns?

A. I mean, I can theorize, but I don't know.

Q. Okay. Okay. Do you have a problem with traffic signal engineers using or plugging into their yellow time formula a speed lower than the posted speed limit?
A. For a left turn?
Q. Yes, for a left turn.
A. No, I believe that the speed should be less than the posted speed limit, but it has --
Q. Do you agree with left turns, that there's just a large variety of scenarios for left turn drivers in dedicated left turn lanes?
A. Sure. There can definitely be different scenarios.
Q. So you might have someone who is stopped at a red light and there be multiple cars stopped at that red light. You might have a situation where there are multiple cars approaching as the light goes from green to yellow, right?
A. Yes.
Q. You may have no one in the cue and the single car approaching as the light turns green to yellow?
A. Correct.
Q. And that traffic signal engineers -- do you disagree that traffic signal engineers have to use

their engineering judgment to determine what they believe an appropriate number would be when determining -- when using the ITE formula for determining yellow times on left turns?

A. My concern is that they are measuring -- by the information I read, they are measuring the speed of the vehicles as they cross the stop bar, as they enter the intersection. That is not necessarily the approach speed. The approach speed may be as high as the velocity, the speed limit, and they slow down to the 20 miles per hour that's measured. The formula, as used, does not account for that.

Now, notwithstanding that, if they also, as I stated earlier, add a proper perception and reaction of two and a half seconds, then they have fully encompassed all of the situations that they should be encountering, and we should greatly, by the studies that I have seen, greatly reduce the dangerous situation of people entering on red.

Q. Do traffic signal engineers use other measures to improve intersection safety?

A. There are many ways they do that, yes.

Q. They use like, for example, using all red phases?

A. But don't forget now, the all red is a completely different issue than the yellow.

Q. But isn't part of the purpose of having all red to advance safety for motorists?

A. The purpose -- it is in a way. The purpose of the all red is to clear any vehicles that legally entered the intersection before another crossing traffic gets green.

Q. Where do you get that from?

A. Well, that's what all of the numbers are. They measure how far the car is going and its speed, that's time.

Q. Well, where -- have you seen in the MUTCD a definition of all red clearance?

A. I've certainly read it in several places. I'm not sure that I can pull them up right now.

Q. Isn't the purpose of the all red to clear traffic that is in the intersection before --

A. If that isn't the purpose, then they're creating dangerous situations.

Q. Well, you said legally. But the purpose of all red is to clear out vehicles who are in the intersection before the light in the opposite direction turns green, correct?

A. That's right, it is, because if it isn't that situation, then they're allowing cars to enter while there's still cars that are in the intersection. We don't want that. Nobody wants that.

Q. Are you aware of some traffic signal engineers that do allow, in some circumstances, vehicles to enter an intersection while vehicles are clearing an intersection at the other end? Are you aware of that?

A. At the other end? Sure, but I'm talking about crossing traffic.

Q. Now, have you, your idea of a new way to use -- or strike that.

Your idea of a new way to determine yellow times for left turn signals where there's a dedicated left turn, have you done, have you promulgated that idea to ITE?

A. This is something that I had never researched until the last few weeks.

Q. Are you aware that there are traffic signal engineers who spend their entire career researching and determining the effectiveness of traffic signal engineering practices, including the lengthy yellow times?

A. I'm not aware of anybody that has done that.

Q. Do you know what traffic signal

engineers -- strike that.

Do you know what professors at North Carolina State, for example, who teach traffic signal engineering, do you know what they teach their students to use for perception reaction time when determining left turn signals?

A. I do not.

Q. How about do you know what North Carolina engineering professors, for example, at NC State teach their traffic signal engineering students for -- do you know what North Carolina engineering professors who teach traffic signal engineering students, what they teach their students to use for the approach speed when designing left turn yellow times?

A. I do not.

Q. Do you know what the process was for the various North Carolina traffic signal engineers who were part of the left turn yellow time task force, what they did, what they reviewed and why they made the recommendation they made?

A. I read something that I had not seen until yesterday that was, seemed to be a different summary.

In general, yes, but I do not know the details. I guess that's the appropriate answer.

Q. And so you feel that you have an

alternative way that would make -- you feel that you have an alternative way for designing yellow times for through as well as left turn -- I'm sorry, as well as left turns that comport -- that would make up a good traffic signal engineering practice, is that right?
A. The answer is yes.
Q. And you feel that your way is better than the way that's currently being practiced by traffic signal engineers in this state?
A. I think that the methodology that I suggest will provide a safer traveling environment, and that's the key.
Q. Do you know whether or not the Town of Cary's use of red light cameras at the intersections in question violate the rules set out by the North Carolina legislature for enacting such a program?
A. That being, you know, a general statute law, that isn't something I didn't look into that.
Q. Have you discussed your ideas with any traffic signal engineer?
A. I have not.
Q. Do you intend -- do any of your -- do you promulgate use of yellow times -- would your formula produce yellow times greater than six seconds?
A. I think in a few situations, yes, when the

timing of it worked out, such as on the higher speeds.
Q. Would that be where -- would your formula for where the speed limit was 45 miles an hour on such a road, would your formula for straight-through yellow times produce a yellow time greater than six seconds?
A. Let's see, at 45 miles per hour, no, on a 45, it would be about five and a half seconds.
Q. What do you mean by about?
A. I did it in my head. I mean, you're talking 45 miles per hour, 66 feet per second divided by 22 equals three seconds, plus two and a half P&R, so that's 5.5 seconds.
Q. What about for left turns?
A. Left turns would depend on the approach speed and the time, but on a 45 left turn, assuming they enter at 20, 66 plus 29, that one would end up at somewhere around seven and a half seconds.
Q. So that would be your yellow time for left turns, using your formula and using an approach speed of 20 miles an hour --
A. No.
Q. Using what I thought you said?
A. Entering speed of 20 miles per hour, an approach speed of 45.
Q. So you would -- in your formula, you would

use an approach speed of 45 and an entering speed of 20 miles an hour?

A. Sorry, let me redo that.

It would be about 6.7 seconds.

Q. Can you show me so that I know? I'm going to give you a piece of paper. We'll mark it, I think we're at Exhibit 26, just so I know.

(The document referred to was marked Defendant's Exhibit Number 26 for identification.)

Q. Go ahead and again, if you would, put your left turn yellow time formula down and then again show me what typically values you would put in for that formula. Does that make sense?

A. Absolutely. First, I'm going to draw a picture, a car approaching at V0. This is yellow time, and you want me to do a hypothetical?

Q. Yes, a typical 90-degree yellow, excuse me, 90-degree turn, and how you would determine yellow time when the speed limit is 45.

MR. STAM: With zero grade?

MS. MARTINEAU: Sure, zero grade.

A. Let's be clear now, the turn speed has been found by DOT to be -- sorry, mislabeled this, 20-mile per hour, okay.

Q. So what is the yellow time in that scenario?
A. Essentially 6.7 seconds.
Q. And so the 6.7 seconds, you would agree that that is above the guidance set forth in the MUTCD, correct?
A. I agree.
Q. And do you know what the consensus and recommendation was by the North Carolina section of ITE as far as what perception reaction time to use when determining yellow times?
A. I've read so many documents. I believe it came out as one and a half, but if you have a document you can point me to.
Q. We can take a look at it. Where was it, it's behind --
MR. STAM: What were you looking for?
MS. MARTINEAU: I was looking for Exhibit 10.
MR. STAM: It's got the 1.5, it's 13, the last page.
A. Yes.
Q. Where are you looking?
A. The top of page 24 in the chart, figure four, it's the revised methodology as adopted.

Q. So you understand that that was the recommendation and consensus of the North Carolina section of ITE?

A. I can't say consensus, but definitely the recommendation. I don't know if it was concluded or agreed upon by everybody, but that is the final result.

Q. And the consensus to you doesn't mean agreed to by everyone, correct?

A. Or a majority. It may have been that the principles -- I don't know what factors were in play. I mean, it may have been the person in charge said no, we're going to use 1.5. I don't know. The end result is they produced a document that said 1.5. And I just want to clarify one thing that we talked about.

Q. Sure.

A. In all of these formulas that we've been looking at, these calculations that I've put forward, these are assuming zero grade to simplify the equation. The inclusion or exclusion of grade in my formulas would be the same as in the ITE.

Q. So you have no criticism of ITE and CDOT signal manual including or accounting for grade when determining yellow times?

A. When we're only talking about grade, yes, their inclusion of grade, I think, is appropriate. For my purposes of making Exhibit 26 and any other, whenever we talk about these formulas, I am purposely at this point excluding grade for simplicity.

Q. Okay. And we talked about this before, but you're aware that ITE recommends using 1.5 perception reaction time?

A. Yes.

Q. When you use the Manual of Uniform Traffic Control Devices in your role as an accident reconstruction engineer or just as an engineer for ARAI, what is your policy regarding following guidances?

A. Well, things such as building code or MUTCD, they cannot account for every possible situation in the world. That's why there's revisions, occasionally. Oh, we didn't include this.

So whenever we come across a situation if we're doing MUTCD to check signage compliance at an accident site or whatever, we have to make sure that the document is clear on the situation at hand. It is possible that we will come across a situation that is not completely outlined in the MUTCD. And so we have to look at the intent of the MUTCD and make our decision as to does this situation comply with the intent of the MUTCD.

Q. And you saw there where the guidelines of the MUTCD for yellow times said they should between three and six seconds?

A. Yes.

Q. Are there any other opinions that you intend to give in this case that we have not covered?

A. Well, the overlying opinions -- maybe I'll just restate them to be clear. Is that first and foremost, for both through vehicles and turning vehicles, the perception and reaction time should be two and a half seconds. They need to add that extra second over what they're doing now.

Secondly, for straight-through vehicles, the formula, as is, if they include the perception and reaction time, as I suggest, they could continue to use the formula but add a proper perception and reaction, and they would do away with nearly 80 percent of red light runners.

So it's clear, just from that snippet of information, that people are not adequately being given time to prevent running that red light.

If we can only add a second and prevent 80 percent of the red light runners, then I think we've done a tremendous benefit for safety, that we know that increasing that time, it's a factor of safety.

Thirdly, on the turning vehicles, it is inappropriate, in my opinion, to use 20 miles per hour as the V squared or the V in the yellow timing formula, because the yellow timing formula addresses only maneuvers before the stop bar, but they should be considering the average between the approaching velocity and the 20 so they get an accurate count for the amount of time it takes a car to travel that critical distance.

Q. How do they determine the average? I mean, in real -- are you saying that a speed study has to be done to determine what the average approach speed is?

A. No, no. What I'm saying is they should average this 20 miles per hour they're already using, which is the actual turn speed. They should average that speed with the approach speed, which should be the speed limit or very close thereof, and so what we're doing is we're accounting for a car that comes in, in this example, is coming in at 45 miles per hour. They get a yellow light. They determine they're going to go, but they begin to slow down to enter the intersection at 20 miles per hour. So to figure out what that time is, we have to take the average of those two velocities.

Q. Do you know whether or not it's accurate to say that vehicles at these intersections who get in the cue and are approaching the intersections are actually going the speed limit?

A. Well, in that scenario, we're not talking about the ones in the cue. We're talking about a car that's approaching at the speed limit.

Now, if we account for that car, we will have already accounted for all the cars in the cue. As they're doing it now, they are not A, accounting for the approaching car at speed; and B, not affording enough perception and reaction.

Q. Do you know whether traffic signal engineers who are using the ITE formula or the North Carolina Department of Transportation's signal sections formula intend to account for a driver approaching the intersection at 45 miles an hour when their intent is to make a left turn?

A. I think you lost me on that question.

Q. Sure. Do you know whether or not they want to -- that it's part of their engineering practice to account for a driver who's going to make a left turn in these dedicated lanes approaching at 45 miles an hour?

MR. STAM: Objection to form.

A. If I understand what you're saying, do I think that they are purposely accounting for the approaching driver at the speed limit?

Q. Not accounting for.

A. Do I think they are purposely not accounting for? I don't think purposely. I don't think they are doing it purposely. I think the problem is is that they have this formula that they don't -- are not appreciating how the formula was derived and what it means. They're basing the movements of a car before it enters the intersection on a speed at the time it enters the intersection, and that's inappropriate, in my opinion.

Q. Anything else?

A. Again, both in the through and the turn perception reaction needs to be increased to the ASHTO standard. They need to adjust turning formula to account for slowing vehicles.

At an absolute minimum, at an absolute minimum, they need to include one more second perception reaction. We know from traffic studies that one second accounts for 80 percent of red light runners, and this is a matter -- I can't stress this enough -- it's a matter of safety. We want these intersections to be safe, and if you can do something by just adding merely one second to prevent cars from entering on red, then that's making the intersection more safe, and the formula, as they are using it, does not allow a car to decelerate at the rate that they suggest of 11.2 feet per second and avoid running a red light, given just the right conditions. That's why it only happens occasionally. It's not happening at every light. You have just the right driver at just the right point in time, and they are, for lack of a better way to say it, forced by the timing to run into the red.

Q.   So what type of driver? Is it the driver that is in the zone of indecision at the very right time and makes a decision to go, or is it the diver who's in the zone of indecision that makes a decision to slow and go, or is it the driver who's in the zone of indecision that makes the decision to stop?

A.   Is which driver, I'm sorry?

Q.   The small subset of drivers that are at the right place at the right time, that can't avoid running a red light?

A.   Okay. That falls into the perception and reaction. Once again, we're talking about only a second, one second, and we're saying that for a straight-through driver, if they add that one second, if this driver, for whatever reason, this driver, their perception and reaction falls in the 90 or 95th percentile, as opposed to the one and a half second, which is the, whatever it is, 80 percentile, if we have a driver that has a longer perception and reaction and they begin to decelerate at the end of their perception and reaction, they are going to run the red light, because their perception and reaction is longer than afforded by the one and a half that the DOT uses now.

Q. Can they stop?

A. Can they physically stop?

Q. Yeah.

A. Yes.

Q. Could they continue at the -- for straight-through drivers, could they continue at the speed limit and enter the intersection before the light turns red?

A. Yes.

Q. But they can't decelerate and then decide to enter the intersection when the light -- before the light turns red?

A. If they decelerate, they have to come to a stop, because then they're going to get caught at the light, if they change their mind to go.

Q. And those drivers can stop?

A. They can physically stop, yes. They cannot stop in the manner outlined by the DOT.

Q. Now, have you discussed the formulas and the data that should be inputted into those formulas that you talked about today, and that is your opinion as to what North Carolina traffic signal engineers should use when designing yellow times for both through and left turns?

A. Okay.

Q. Are those the formulas that Dr. Manning would also opine that he believes should be used in this case?

A. Yes.

Q. For the same reasons that you've just talked about?

A. Yes.

Q. And have you ever been asked to address traffic signal engineers regarding to your theories of how to determine an input data for determining the time of yellow times for both through and left turn signals?

A. At this point, no.

Q. Is there anything that you've been asked to do in this case that you've not yet done?

MR. STAM: Objection to form.

BY MS. MARTINEAU:

Q. Let me clarify. Anything that you've been asked to do by Mr. Stam or any attorney that's

representing Mr. Ceccarelli that you've not yet done?
A. Not that I recall. I mean, again, I just kind of stress that the original question to me was do I agree that the yellow light cycles are improper, and through the course of this investigation, I've come to believe that they are improper, and that I've come to offer forward what I believe is a proper solution.
Q. And in terms of any of the data that you've looked at that's been compiled by Mr. Ceccarelli, do you know how many of those drivers were in an indecision zone at the time the yellow light in their direction of travel first turned yellow?
MR. STAM: Objection.
A. The only answer I can have for that is no, I don't know each and every individual circumstance. But what I do know is that traffic studies show if we add one second, we take care of 80 percent. And so it would be my opinion that 80 percent or more were caught in an indecision zone because the yellow was too short.
Q. And you base that on studies that show increased yellow times reduce red light runners?
A. Yes.
Q. And so because of that, you say that that supports that 80 percent of the red light runners that are in Ceccarelli's data were in an indecision zone?

A. What it supports is it goes back to the fundamental understanding of there are a certain percentage of people that are not going to be able to perceive and react as used in the DOT guidelines.

The ASHTO guidelines say two and a half percent for design. They're clear on that. And so there is a large percentage of people that simply cannot perceive and react and brake in the manner that the DOT is trying to make them do it. Therefore, they are entering the intersection because of the timing of the yellow.

Q. Okay. But you understood what my question was? You made the statement that -- my question originally was, do you know how many of the drivers that were documented in Ceccarelli's data were in an indecision zone, were in an indecision zone at the time the yellow light in their direction of travel first turned yellow?

MR. STAM: Objection to form, because I don't know what you mean by the drivers in Mr. Ceccarelli's data. Maybe the witness knows.

A. As I interpret your question --

Q. Well, no, if you don't understand it, please let me know, and I know you've given plenty of depositions, so I'm sure you know that if you don't understand the question --

A. Right. As I understand it, if I could rephrase, do I know what the exact conditions were for all of the people that received tickets, red light tickets represented in the data?

Q. Well, that's a little different question than my question. Do you understand what an indecision zone is?

A. Yes.

Q. And you understand that Mr. Ceccarelli --

A. Well, I assume -- sorry to interrupt -- you're talking about the dilemma zone? I think different people use different terminology; indecision zone, dilemma zone, that's my understanding of what your question is.

Q. Okay. Well, I think -- okay. Well, an indecision zone is a zone where a driver has to make a decision of whether to stop or go, and sometimes they make the wrong decision?

A. And sometimes they're presented with a situation that doesn't have an answer per the guidelines of DOT, and so the indecision zone, it's important to note that indecision zone does not exist if the yellow is long enough. It only exists when the yellow is too short.

Q. Well, it certainly can exist if you may have a longer yellow, you can have folks who make the decision to go and they don't have enough time to get into the intersection prior to the light turning red?

A. There are many circumstances that can play into that, yes, but what I'm saying is if the yellow is long enough, people have time to perceive, react and come to a controlled stop or continue on with their speed.

Q. Okay. And even using ITE's formula and the 1.5 perception reaction time, drivers who are in the indecision or the dilemma zone can either choose to stop or -- and have enough distance to stop before the light turns red, or can choose to go at the rate of travel of the speed that they're going or the speed limit and get into the intersection before the light turns red?

A. There are situations when that is the case, you're right.

Q. And so what Mr. Ceccarelli is complaining about now, because he's changed his, you know, now and what I think what my understanding from your testimony is what you are concerned about is that driver that makes a decision to decelerate but continues through the intersection, correct?

A. No. It's more than that. It's far more than that. The situation is that we're talking drivers that don't perceive and react in that second and a half. We're talking about drivers that perceive and react in two seconds.

Q. Okay, but those drivers --

MR. STAM: I object to any question before he finishes his current sentence.

MS. MARTINEAU: I object to him not answering my question before and not answering my question.

Q. But even those drivers who take longer than 1.5 seconds to perceive and react to something can still stop, correct?

A. Okay. That's a good point. That's a very good point. That's exactly what we need to talk about.

Q. Yes or no?

A. Yes, but let me explain why that's important.

Q. Okay.

A. No, I'm sorry the answer to that is not in all situations. So we're talking about a left turn driver, the DOT puts in 20 miles per hour. So they have a yellow time. When you equate the yellow time, it comes out to 2.8. But they say no, we can't do anything less than three seconds, okay.

Q. Is that what the practice is?

A. That is, yes. Their practice is no less than three seconds. If you use the ITE formula, it comes out to 2.8, flat ground, 20 miles per hour. So they bump it up to three seconds.

Now if, if we have a driver, a 95th percentile driver, that's coming along at 20 miles an hour, they were in the cue, and they have a two and a half second perception and reaction, the ASHTO 95th percentile person, two and a half seconds of perception and reaction, they cannot physically stop under emergency braking in the half second that's left for them.

Q. Well, where are they at the time the light first turns yellow?

A. They're at the point, at this perfect inflection point. If they were just slightly ahead of that, they would be okay. If they were slightly behind it, they would be okay. But they're at the perfect point in time, what you may be terming the dilemma zone or indecision zone, but if they're there, that's what I'm saying, this only happens occasionally. You have a two and a half second perception reaction person, who is only afforded three seconds of yellow, so, therefore, they only have a half a second to stop from 20 miles an hour, and they physically cannot do it. That is why I'm saying they need two and a half seconds of perception and reaction.

Q. Okay. For the -- in a situation where you have a three second yellow left turn, would the all red be longer? The total clearance time is the same, correct?

A. No, that's the misunderstanding of the formula. The problem is that the red time is only related to the car clearing the intersection. It has nothing to do with the yellow. That's the whole misunderstanding with the formula, and the way they're using it is they do not understand what they're doing, but regardless, if you only have half a second, you can't stop from 20 miles an hour in half a second.

Q. Do you believe that it is the practice of traffic signal engineers in North Carolina to design signals for 95 percent of the drivers out there?

A. If they're designing for safety, yes. That's what it should be.

Q. What's their practice?

A. Their practice is apparently one and a half, at least two of the light signals. I haven't looked at everything else.

MS. MARTINEAU: Thank you, Mr. Hennings, those are the questions I have for you.

(Off the record at 2:20 p.m.)

(On the record at 2:23 p.m.)

MR. STAM: I just have a few questions.

EXAMINATION BY COUNSEL FOR PLAINTIFFS

BY MR. STAM:

Q. Mr. Hennings, if you turn to Exhibit 8.

A. Yes.

Q. And ask you if you can take a look at that violation.

What intersection is that?

A. Kildaire and Cary Parkway.

Q. Is that a left turn, Kildaire left on Cary Parkway?

A. Yes.

Q. You had mentioned earlier Walnut Street turning left at Meeting Place. Are you familiar with that intersection as well?

A. Yes.

Q. Is it the same issue, whether it's a left turn onto Cary Parkway or left turn at the Meeting

Place that you previously described?

A. My criticism is that it is the same with the left turn, and that any times that are generally the same as equated by the ITE formula, as used by NCDOT, any of those times, whether they were equated with ITE formula or not, if the times are approximately the same, they are too short.

Q. Looking at either Exhibit 10 or the last page of 13, referring to that part of Exhibit 10, which is in bigger print later on?

A. Yes, sir.

Q. And I guess this is actually the whatever the legal status it has is the official DOT formula. Do you see where it says the yellow change interval V equals design speed in feet per second, top left?

A. Yes.

Q. And do you see the asterisk there to the notes? It may be easier to read on the last page of 13.

Is the same chart?

A. Okay. And your question?

Q. V equals design speed in feet per second?

A. Yes.

Q. Do you see the note for that V? What is design speed?

A. Oh, it's -- design speed is speed limit unless speed study determines 85th percentile is faster.

Q. Look at the third note there. For most left turns, assume a speed of 20 miles per hour to 30 miles per hour. Is it your understanding that they use 20 miles an hour usually their designs for at the stop bar?

MS. MARTINEAU: Objection to the form of that question.

BY MS. MARTINEAU:

Q. From your reading of the depositions of Lisa Moon, Greg Fuller and the other depositions, is it your understanding from your previous discussion that they're using the speed at the stop bar to plug in that 20 miles an hour?

MS. MARTINEAU: Same objection. Go ahead.

A. That is my understanding.

Q. Does this document actually say to do that?

A. It does not.

Q. If you turn to, I believe, it's Exhibit 7, and I believe it's page 485 -- it's not 7, it's Exhibit 5.

A. Sorry, you said page 487?

Q.   I think it was 485.
A.   Correct. Okay, I'm finally there.
Q.   Where is the page that talks about between three and six seconds?
MS. MARTINEAU: It's after.
MR. STAM: Is that 489?
MS. MARTINEAU: Yeah.
BY MR. STAM:
Q.   Page 489.
A.   Yes.
Q.   Is 4.5 seconds between three seconds and six seconds?
A.   Yes.
Q.   So if you would take a look at Exhibit 21 and 22, which were -- they're not in the book, they were handed to you earlier.
A.   Oh, yes.
Q.   I don't think we addressed this earlier.
Mr. Ceccarelli's claim is that although the actual speed limit was 45 miles per hour, the assumed speed for purposes of signal was 35 miles per hour. What is the effect of the formula in plugging in the wrong speed limit?
A.   Can I restate your question?
Q.   Yes, you can.

A. If you use the ITE formula, and you plug in a speed that is below the speed limit, the traveling speed, speed limit, if you plug in a number that's below the speed limit, you will get a yellow time that is shorter than you need.

Q. Have you seen studies that indicate how much in excess of the speed limit the typical approach speed is in North Carolina? In other words, the ITE formula says use the speed limit unless you've done a speed study?

A. Yes.

Q. If you did a speed study at a typical intersection that is posted at 45 miles per hour, do you know about what you would get?

MS. MARTINEAU: Objection to the form of the question, lack of foundation.

BY MR. STAM:

Q. Do you know what average speed you would get at the approach speed would be?

MS. MARTINEAU: Same objection.

A. The only reference that I recall seeing to that effect in review for this and right offhand, I don't recall what it was, I apologize, but that particular study found, I think, the average speed was seven miles per hour over the speed limit.

Q. Whatever that figure is, if it's higher than the speed limit?
A. Yes.
Q. If you plug that value into the ITE formula, V, for the approach speed, would the yellow light be longer or shorter if you used the speed study instead of the speed limit?
MS. MARTINEAU: The speed study that showed the speed was faster?
BY MR. STAM:
Q. If a speed study showed a higher approach speed than the speed limit, then would the yellow change interval be longer or shorter, according to the ITE formula?
A. It would be longer.
MR. STAM: Give me a second, I think I'm through.
MS. MARTINEAU: Sure.
BY MR. STAM:
Q. Hypothetically, Mr. Hennings, at a particular intersection, if the proper, by whatever formula, yellow change interval was X, and the proper all red clearance interval was Y, plug in whatever numbers you want.
A. Okay.

Q. If you were to short the yellow change interval by a second but increase the all red interval by a second, what would the effect be on safety of the ability to clear the intersection of conflicting cars?

MS. MARTINEAU: Objection to the form of the question, lack of foundation for this witness.

A. If when we add in your example X and Y, you're talking about the total clearance formula, that is the full ITE formula is the X and Y are the yellow and red. And your question, if I'm correct, was what if we took hypothetically one second off of yellow and added it to red?

Q. Correct.

A. What that would do is if we reduce the yellow time by what's required, which is kind of the whole argument I have been making this afternoon, that some cars are going to enter the intersection, but they are still going to clear, but they are going to go in on red.

Q. So the effect on safety would be a wash, is that correct?

A. It would be a wash, with the exception that as far as safety goes, it would be a wash, but some cars would be forced to enter a red.

Q. So for safety, it's a wash, but as far as people getting ticketed, a whole lot more people would be ticketed for a technical violation?

A. By reducing the required yellow time, it would definitely increase the probability of cars entering the intersection on red.

MR. STAM: No further questions.

MS. MARTINEAU: I have no questions.

(Whereupon the deposition was concluded at 2:35 p.m.)

(Signature reserved.)

SIGNATURE PAGE

____

JOHNNIE P. HENNINGS

SUBSCRIBED AND SWORN to before me this ______

day of______________________________, 2012

____

NOTARY PUBLIC

My Commission expires:___________________________

TRANSCRIPTION

MMV

CASE NAME: Ceccarelli vs. Town of Cary

WITNESS NAME: JOHNNIE P. HENNINGS

DATE: October 30, 2012

PAGE	LINE	READS	SHOULD READ

C E R T I F I C A T E

I, Marisa Munoz-Vourakis, RMR, CRR and Notary Public, the officer before whom the foregoing proceeding was conducted, do hereby certify that the witness(es) whose testimony appears in the foregoing proceeding were duly sworn by me; that the testimony of said witness(es) were taken by me to the best of my ability and thereafter transcribed under my supervision; and that the foregoing pages, inclusive, constitute a true and accurate transcription of the testimony of the witness(es).

I do further certify that I am neither counsel for, related to, nor employed by any of the parties to this action in which this proceeding was conducted, and further, that I am not a relative or employee of any attorney or counsel employed by the parties thereof, nor financially or otherwise interested in the outcome of the action.

IN WITNESS WHEREOF, I have hereunto subscribed my name this of , 2012.

MARISA MUNOZ-VOURAKIS

Notary #20032900127

b

n

p

VERITEXT
LEGAL SOLUTIONS

25B Vreeland Road, Suite 301, Florham Park, New Jersey 07932
(800) 567-8658 (office) (973) 629-1287 (fax)
Email: Litsup-nj@veritext.com

JAN 8 ~~2012~~, 2012

To: Elizabeth A. Martineau, Esq.

In Re: Ceccarelli vs. Town of Cary

Veritext reference number: amb201811

Witness: Johnnie P. Hennings   Deposition Date: 10/30/2012

Enclosed is the sealed original transcript.

________ I certify that original transcript was requested prior to the statutory time required for review and signature had elapsed.

________ I certify that the witness was given the statutory allowable time within which to read and sign the deposition, and the witness failed to appear for such reading and signing.

___x___ I certify that transcript has been reviewed by the witness and:

___ No corrections/changes were made

_x_ Attached are the corrections/changes

___ Corrections were previously forwarded to counsel

Sincerely,
Production Department

Encl.

CC: Paul Stam, Esq.

Q. If you were to short the yellow change interval by a second but increase the all red interval by a second, what would the effect be on safety of the ability to clear the intersection of conflicting cars?

MS. MARTINEAU: Objection to the form of the question, lack of foundation for this witness.

A. If when we add in your example X and Y, you're talking about the total clearance formula, that is the full ITE formula is the X and Y are the yellow and red. And your question, if I'm correct, was what if we took hypothetically one second off of yellow and added it to red?

Q. Correct.

A. What that would do is if we reduce the yellow time by what's required, which is kind of the whole argument I have been making this afternoon, that some cars are going to enter the intersection, but they are still going to clear, but they are going to go in on red.

Q. So the effect on safety would be a wash, is that correct?

A. It would be a wash, with the exception that as far as safety goes, it would be a wash, but some cars would be forced to enter a red.

Q. So for safety, it's a wash, but as far as people getting ticketed, a whole lot more people would be ticketed for a technical violation?

A. By reducing the required yellow time, it would definitely increase the probability of cars entering the intersection on red.

MR. STAM: No further questions.

MS. MARTINEAU: I have no questions.

(Whereupon the deposition was concluded at 2:35 p.m.)

(Signature reserved.)

SIGNATURE PAGE

JOHNNIE P. HENNINGS

SUBSCRIBED AND SWORN to before me this 17th day of December, 2012

NOTARY PUBLIC

My Commission expires: 5-25-13

JENNIFER METZ
NOTARY
PUBLIC
WAKE COUNTY, N.C

TRANSCRIPTION

MMV

CASE NAME: Ceccarelli vs. Town of Cary

WITNESS NAME: JOHNNIE P. HENNINGS

DATE: October 30, 2012

PAGE LINE READS SHOULD READ

Errata Sheet

Page	Line	Reads	Should Read
100	20	No	Yes, briefly.
101	23	No	Yes, briefly.
119	8	debt	depth
153	15	"straight-through turn"	"straight-through"
164	23-24		This is a study from Texas
191	16	Yes	Depending on several factors, yes.
195	24		important to note that the dilemma zone is minimized
195	25		if the yellow is properly timed.
196	1	yellow is too shot	-------

FILED
2012 APR 26 PM 2:54
WAKE COUNTY, C.S.C.
BY________

STATE OF NORTH CAROLINA

COUNTY OF WAKE

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

BRIAN CECCARELLI and LORI MILLETTE,

individually and as class representatives,

Plaintiffs,

v.

TOWN OF CARY,

Defendant.

AMENDED COMPLAINT

Plaintiffs, complaining of Defendant, allege and say:

1. All Plaintiffs are residents of Wake County, North Carolina.

2. Defendant, Town of Cary, is a political subdivision of the state of North Carolina, organized and operating as a municipal corporation, pursuant to North Carolina General Statute 160A with the capacity to be sued. Defendant's principal offices are located in Wake County, North Carolina.

3. Pursuant to S.L. 2001-286 (as amended by S.L. 2003-380), the Town of Cary adopted ordinance Sec. 34-303 entitled "offenses" (hereinafter "the Ordinance") as part of Article X of the Cary Town Ordinances entitled "Automated Traffic Controls Systems" (hereinafter "Article X") on May 26, 2005. A copy of Article X is attached hereto as Exhibit A.

4. On March 11, 2004, the Town of Cary adopted ordinance Sec. 34-303 entitled "offenses" (hereinafter "the Ordinance") as part of Article X of the Cary Town Ordinances entitled "Automated Traffic Control Systems" (hereinafter "Article X"). A copy of Article X is attached hereto as Exhibit A.

5. On April 27, 2006, the Town of Cary adopted ordinance TC 06-007 entitled "Ordinance Adopting Revisions to the Town Charter of the Town of Cary, North Carolina" (hereinafter "the Charter").

6. Article VIII, Section 8.15 of the Charter mandates that any traffic control photographic system operated by the Town of Cary meet requirements established by the North Carolina Department of Transportation. Section 8.15(e) states:

The duration of the yellow light change interval at intersections where traffic

DEFENDANT'S EXHIBIT
NO. 1 10/30/12
MMV

control photographic systems are in use may be no less than the yellow light interval duration specified in the Design Manual [hereinafter "the Manual"] developed by the Signals and Geometrics Section of the North Carolina Department of Transportation [hereinafter "the NCDOT"].

7. The Ordinance makes it unlawful for a vehicle to cross the stop line into an intersection toward which a red light camera is in operation when the traffic signal for that vehicle's direction of travel is emitting a steady red light.

8. Any violation of the Ordinance is a civil violation for which a civil penalty of $50 is assessed by the Town of Cary.

9. The Town of Cary operates 18 Automated Traffic Control photographic systems, a list of which is attached as Exhibit C.

FIRST CLAIM FOR RELIEF

10. Paragraphs 1-9 of this Complaint are incorporated into this First claim for Relief as if fully set out herein.

11. On November 6, 2009 at 09:27 PM Plaintiff Ceccarelli drove his vehicle east bound on Cary Towne Blvd Crossing its intersection with Convention Drive.

12. The speed limit on the relevant portion of Cary Towne Blvd is 45 mph and has been since prior to February 2004.

13. However, from the beginning of operation of the Automated Traffic Controls System at this intersection in February 2004 until the NCDOT Traffic Signal Plan for the intersection of Cary Towne Blvd and Convention Drive was superseded by a plan dated March 19, 2010, the plan of record for this intersection was based on a speed limit of 35 mph on the relevant portion of Cary Towne Blvd, rather than the actual speed limit of 45 mph.

14. Prior to March 19, 2010, the NCDOT Traffic Signal Plan for the intersection of Cary Towne Blvd and Convention Drive calculated the yellow light duration based on a speed limit that was 10 mph less than the actual speed limit on the relevant portion of Cary Towne Blvd.

15. The duration of the yellow light change interval at the intersection of Cary Towne Blvd and Convention Drive was shorter than required by the Manual from the beginning of operation of the Automated Traffic Controls System at this intersection in February 2004 until the NCDOT Traffic Signal Plan was superseded on March 19, 2010.

16. The operation of the Automated Traffic Control system and the enforcement of the Ordinance by the Defendant with respect to this intersection was conducted in an arbitrary and capricious manner and in violation of the law from February 2004 until March 19, 2010.

17. The Plaintiff is not afforded the same protections of a yellow light duration as other

drivers at comparable intersections.

18. Plaintiff Ceccarelli was unable to safely stop his vehicle before the traffic signal turned red in his path of travel.

19. Plaintiff Ceccarelli was issued a Notice of Violation of Cary Town Code 34-303 on November 10, 2009 by the Town of Cary.

20. Plaintiff Ceccarelli paid the civil penalty of $50 demanded by the Town of Cary.

21. Plaintiff Ceccarelli appealed this violation on December 2, 2009 and appeared before a panel established by the Town of Cary on January 20, 2010 which found that Plaintiff did violate Cary Town Code 34-303.

22. Plaintiff Ceccarelli has exhausted his administrative appeals.

SECOND CLAIM FOR RELIEF

23. Paragraphs 1 through 22 of this Complaint are incorporated into this Second Claim for Relief as if fully set out herein.

24. On May 7, 2010 at 05:18 PM Plaintiff Millette was traveling North on Kildaire Farm Road and turned left at the intersection of Kildaire Farm Road and Cary Parkway.

25. The speed limit at all relevant times and on the relevant portions of Kildaire Farm Road at all relevant times was 45 mph.

26. The left turn yellow light arrow durations are determined using the assumption that vehicles turning left will be traveling 20 to 30 mph.

27. Plaintiff Millette was unable to safely stop her vehicle before the traffic signal turned red in her respective path of travel.

28. Plaintiff Millette was issued a Notice of Violation of Cary Town Code 34-303 subsequent to the date of her respective violations alleged by the Town of Cary.

29. Plaintiff Millette paid the civil penalty of $50 demanded by the Town of Cary.

30. Plaintiff Millette appealed this violation and appeared before a panel established by the Town of Cary on August 18, 2010 which found that Plaintiff did violate Cary Town Code 34-303.

31. Plaintiff Millette has exhausted her administrative appeals.

32. The Defendant uses the NCDOT's methodology and plans, which in the case of these left turns is arbitrary and capricious for the yellow light duration for left turning drivers where there is a yellow turn arrow.

The following paragraphs apply to both Claims for Relief:

33. Plaintiffs bring this claim for relief pursuant to N.C.G.S. § 1-253 *et. seq.*, and Rule 57 of the North Carolina Rules of Civil Procedure for a judgment awarding a refund for all sums paid by Plaintiff under the Ordinance to the date of judgment.

34. There exists a class which includes the above-named Plaintiffs and all others similarly situated who were issued similar notices of violation and paid the civil penalty of $50 and are subject to the Ordinance and the penalties imposed thereby. The named and unnamed members of the class have an interest in the same issues of fact and law, and these issues predominate over issues affecting only individual class members.

35. The named Plaintiffs exhausted their administrative remedies and the unnamed class members are not required to exhaust available administrative remedies. The unnamed class members are not required to exhaust their remedies because either:

(a) The named Plaintiffs in this action who have exhausted available administrative remedies may represent the other unnamed plaintiffs who have not exhausted the same available administrative remedies independently.

(b) Alternatively, the administrative remedy is inadequate. First, Plaintiffs' challenge is not based on the individual circumstances of their respective citations, but on the allegation that the signal plans that apply to intersections of a certain type are arbitrary and capricious. Second, the town employees designated as the decision makers are not administrative law judges and are not qualified to rule on whether a signal plan is arbitrary and capricious.

36. The named Plaintiffs and the unnamed class members have an actual controversy with the Town of Cary.

37. The named Plaintiffs and the unnamed class members have a genuine personal interest in the outcome of this litigation in that each is subject to the Ordinance and the penalties imposed thereby. The named Plaintiffs and the unnamed class members will have to pay and have paid the penalty.

38. The Town of Cary has and will unlawfully obtain the penalties from the named Plaintiff and the unnamed class members through the operation of its Ordinance. The Town of Cary is obligated to refund fully all of the penalties to the named Plaintiffs and unnamed class members with interest. The named Plaintiff and the unnamed class members are entitled to a refund of any penalties as in an action for money had and received or other action for return of unlawfully obtained or collected moneys.

39. The named Plaintiffs will fairly and adequately represent the interest of all potential class members in that the named Plaintiffs have a genuine, personal, substantial and direct interest in successfully pursuing this case and they are situated similarly to the unnamed

class members with respect to application of the Ordinance. The named Plaintiffs will adequately represent members of the class located outside of North Carolina as well, if any exist.

40. There is no conflict of interest existing between the named Plaintiffs and any potential class members as to the issues raised in this action.

41. There are many potential class members and therefore, the class is so numerous that it is impractical to bring them all before the Court except pursuant to a class action designation or certification under Rule 23 of the Rules of Civil Procedure.

42. Proceeding as a class action will provide a fair and efficient adjudication of this controversy without the need for a multiplicity of lawsuits. This matter should proceed as a class action. See Perry v. Union Camp Corporation, 100 N.C. App. 168 (1990); Crowe v. Citicorp, 319 N.C. 275 (1986).

43. The named and unnamed members of the class do hereby protest payment of the civil penalties and any payments made are paid under protest.

44. The Town of Cary is not immune from this suit for a permanent injunction or for return of unlawfully collected fees or the relief sought hereunder by any claim of governmental immunity.

45. In the alternative, assuming *arguendo* that governmental immunity might apply, Defendant has waived its governmental immunity from civil liability by obtaining liability insurance as provided by N.C.G.S. § 153A-435 or by participation in a local government risk pool. The aforesaid policy or participation in the government risk pool was in full force and effect at all times material to the matters described herein.

WHEREFORE, Plaintiffs prays that the Court:

1. Certify this matter as a class action pursuant to Rule 23 of the North Carolina Rules of Civil Procedure;

2. Enter a judgment declaring that the application of the Ordinance to these named Plaintiffs and the unnamed Plainitff similarly situated and the penalties imposed thereunder are void and unenforceable in that they are beyond the scope of and violative of the Town of Cary's enabling authority under the General Statutes, its charter, or other law as applied to the Plaintiff and the Plaintiff class;

3. Enter a judgment awarding as damages a full refund to the named Plaintiffs and the unnamed class members, in a sum to be determined at trial, of all monies collected pursuant to the Ordinance, plus interest as allowed by law;

4. Award Plaintiffs' attorneys reasonable attorneys fees from the common fund created for the Plaintiff class;

5. Award the named Plaintiff and unnamed class members any and all other and further relief that the Court deems just and proper; and

6. That the costs of the action be taxed against Defendant.

This is the 25th day of April, 2012.

WILLIAM W. PEASLEE,
ATTORNEY AT LAW PLLC

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William Peaslee by Pl Stam
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EXHIBIT A

CODE OF ORDINANCES

TOWN OF

CARY, NORTH CAROLINA

Published by Order of the Town Council

Adopted: May 26, 2005
Effective: May 26, 2005

Current through local ordinance 2010-Code-08, passed 10-14-2010 and effective 11-15-2010

AMERICAN LEGAL PUBLISHING CORPORATION

432 Walnut Street   Cincinnati, Ohio 45202-3909   (513) 421-4248

PREFACE

This Code constitutes a recodification of the general and permanent ordinances of the Town of Cary, North Carolina.

Source materials used in the preparation of the Code were the 1982 Code and ordinances adopted by the Town Council. The source of each section is included in the history note appearing in parentheses at the end thereof. The absence of such a note indicates that the section is new and was adopted for the first time with the adoption of the Code. By use of the comparative tables appearing in the back of this Code, the reader can locate any code section or ordinance included herein.

The chapters of the Code have been conveniently arranged in alphabetical order, and the various sections within each chapter have been catchlined to facilitate usage. Notes which tie related sections of the Code together and which refer to relevant state law have been included. A table listing the state law citations and setting forth their location within the Code is included at the back of this Code.

Chapter and Section Numbering System

The chapter and section numbering system used in this Code is the same system used in many state and local government codes. Each section number consists of two parts separated by a dash. The figure before the dash refers to the chapter number, and the figure after the dash refers to the position of the section within the chapter. Thus, the second section of chapter 1 is numbered 1-2, and the first section of chapter 6 is 6-1. Under this system, each section is identified with its chapter, and at the same time new sections can be inserted in their proper place by using the decimal system for amendments. For example, if new material consisting of one section that would logically come between sections 6-1 and 6-2 is desired to be added, such new section would be numbered 6-1.5. New articles and new divisions may be included in the same way or, in the case of articles, may be placed at the end of the chapter embracing the subject, and, in the case of divisions, may be placed at the end of the article embracing the subject. The next successive number shall be assigned to the new article or division. New chapters may be included by using one of the reserved chapter numbers. Care should be taken that the alphabetical arrangement of chapters is maintained when including new chapters.

Page Numbering System

The page numbering system used in this Code is a prefix system. The letters to the left of the colon are an abbreviation which represents a certain portion of the volume. The number to the right of the colon represents the number of the page in that portion. In the case of a chapter of the Code, the number to the left of the colon indicates the number of the chapter. In the case of an appendix to the Code, the letter immediately to the left of the colon indicates the letter of the appendix. The following are typical parts of codes of ordinances, which may or may not appear in this Code at this time, and their corresponding prefixes:

EXHIBIT A

Sec. 34-281. Enforcement.

Violation of this article shall be an infraction, the maximum penalty for which shall be $50.00, provided however, that operating a golf cart under the influence of an impairing substance (i.e., alcohol or drugs) on a public road or highway is not a violation of this article, but a violation of state law, and is punishable as provided therein.

(Code 1982, § 12-234; Ord. No. 02-008, § 1, 3-14-2002; Ord. No. 06-003, 2-9-2006)

Note—Formerly § 24-280.

Sec. 34-282. Liability disclaimer.

This article is adopted to address the interest of public safety. Golf carts are not designed or manufactured to be used on the public streets, and the town in no way advocates or endorses their operation on public streets or roads. The town, by regulating such operation is merely trying to address obvious safety issues, and adoption of this article is not to be relied upon as a determination that operation on public streets is safe or advisable if done in accordance with this article. All persons who operate or ride upon golf carts on public streets or roads do so at their own risk and peril, and must be observant of, and attentive to the safety of themselves and others, including their passengers, other motorists, bicyclists, and pedestrians. The town has no liability under any theory of liability and the town assumes no liability, for permitting golf carts to be operated on the public streets and roads under the special legislation granted by the state's legislature. Any person who operates a golf cart is responsible for procuring liability insurance sufficient to cover the risk involved in using a golf cart on the public streets and roads.

(Code 1982, § 12-235; Ord. No. 02-008, § 1, 3-14-2002; Ord. No. 06-003, 2-9-2006)

Note—Formerly § 24-281.

Secs. 34-283—34-300. Reserved.

ARTICLE X. AUTOMATED TRAFFIC CONTROL SYSTEMS

Sec. 34-301. Definitions.

The following words, terms and phrases, when used in this article, shall have the meanings ascribed to them in this section, except where the context clearly indicates a different meaning:

Automated traffic control system is an automated system consisting of a photographic, video or electronic camera and a vehicle sensor installed to work in conjunction with an official traffic control signal and to automatically produce photographs, automated or digital images of each vehicle violating a standard traffic control.

In operation means operating in good working condition.

System location is the approach to an intersection toward which a photographic, video, or electronic camera is directed and in operation.

Vehicle owner is the person identified by the North Carolina division of motor vehicles as the registered owner of a vehicle.
(Code 1982, § 12-241; Ord. No. 02-004, § 1, 2-14-2002)

Sec. 34-302. Generally.

(a) The town shall maintain a list of system locations where automated traffic control systems are located.

(b) If a violation of G.S. 20-158 is detected by both a law enforcement officer and a traffic control photographic system, the officer may charge the offender with an infraction. If the officer charges the offender with an infraction, a civil penalty issued by the municipality for the same offense is void and unenforceable.

(c) The citation shall clearly state the manner in which the civil violation may be appealed. The citation shall be processed by officials or agents of the town and shall be forwarded by personal service or first-class mail to the owner's address as given on the motor vehicle registration.
(Code 1982, § 12-242; Ord. No. 02-004, § 1, 2-14-2002; Ord. No. 04-002, § 1, 3-11-2004)

Sec. 34-303. Offense.

(a) It shall be unlawful for a vehicle to cross the stop line at a system location when the traffic signal for that vehicle's direction of travel is emitting a steady red light.

(b) The owner of a vehicle shall be responsible for a civil violation under this section, except when said owner can provide evidence that the vehicle was in the care, custody, or control of another person at the time of the violation, as described in subsection (c).

(c) Notwithstanding subsection (b), the owner of the vehicle shall not be responsible for the violation if, within 30 calendar days after notification of the violation, said owner furnishes the officials or agents of the town:

(1) The name and address of the person or company who leased, rented, or otherwise had the care, custody, or control of the vehicle; or

(2) An affidavit stating that, at the time of the violation, the vehicle involved was stolen or was in the care, custody, or control of some person who did not have permission of the owner to use the vehicle; or

(3) A statement that the person who received the citation is not the owner or driver of the vehicle, or that the person who received the citation was not driving a vehicle at the time and location designated in the citation.

(Code 1982, § 12-243; Ord. No. 02-004, § 1, 2-14-2002; Ord. No. 04-002, § 2, 3-11-2004)

Sec. 34-304. Penalty.

Any violation of section 34-303 shall be deemed a noncriminal violation for which a civil penalty of $50.00 shall be assessed. Failure to pay the civil penalty or to file an appeal within 30 calendar

days of the mailing date of notification of the violation shall result in an additional penalty of $50.00. The town may establish procedures for the collection of the civil penalties and may enforce the penalties by a civil action in the nature of a debt.
(Code 1982, § 12-244; Ord. No. 02-004, § 1, 2-14-2002)

Sec. 34-305. Appeal.

A notice of appeal shall be filed within 30 calendar days after the mailing date of the notification of the violation. The failure to give notice of appeal within this time period shall constitute a waiver of the right to contest the violation. Appeals shall be heard through a nonjudicial administrative hearing process by a panel established by the town.
(Code 1982, § 12-245; Ord. No. 02-004, § 1, 2-14-2002)

Secs. 34-306—34-320. Reserved.

ARTICLE XI. SCHEDULES

Secs. 34-321—34-334. Reserved.

Editor's note—Traffic schedules are maintained in the Town Clerk's Office.

EXHIBIT B

THE CHARTER OF THE TOWN OF CARY*

*Editor's note—Printed herein is Ord. No. 06-007, as adopted on April 27, 2006 and effective on such date. Amendments are indicated by parenthetical history notes following amended provisions. The absence of a history note indicates that the provision remains unchanged from the original. Obvious misspellings have been corrected without notation. For stylistic purposes, headings and catchlines have been made uniform citations to state statutes, and expression of numbers in text as appears in the City Code has been used. A consistent scheme of capitalization has also been used. Additions for clarity are indicated by brackets. The preamble to such ordinance reads as follows:

State law reference—Cities and towns, G.S. § 160A-1 et seq.

Article VI. Street and Sidewalk Improvements

Article VII. Water and Sewer Improvements

Article VIII. Regulatory, Police and Miscellaneous Powers measured from the outside boundary of any property, including property zoned for residential and nonresidential use. The purpose of such ordinances shall be to protect existing trees and shrubs for use as future buffers.

(b) Ordinances adopted pursuant to this section shall be limited to situations where undeveloped property is planned or zoned for residential or nonresidential use in accordance with adopted Town plans and zoning regulations. Such ordinances shall include reasonable provisions for access onto and within the subject property.

(c) Notwithstanding any limitations contained in subsection (a) of this section, the Town may adopt ordinances to regulate the preservation and removal of significant specimen or "champion" trees on sites being planned for new development. Specific standards for identifying and designating such trees, including species and size, shall be incorporated as part of any such ordinance.

(d) Any ordinance adopted pursuant to this section shall exclude normal forestry activities on property taxed under the present-use value standard or conducted pursuant to a forestry management plan prepared or approved by a forester registered pursuant to Chapter 89B of the General Statutes. However, for such properties, a municipality may deny a building permit or refuse to approve a site or subdivision plan for a period of five years following harvest if all or substantially all of the perimeter buffer trees which should have been protected were removed from the tract of land for which the permit or plan approval is sought.

(e) Before adopting an ordinance authorized by this section, the Council shall hold a public hearing on the proposed ordinance. Notice of the public hearing shall be given in accordance with G.S. 160A-364.

(f) Nothing in this section shall be construed to limit or be limited by any provisions of Section 8.12 of this Charter or any other existing laws or ordinances.
(N.C.S.L. Ch. 2001-191; Ord. No. 06-001, § 9, 2-9-2006)

Sec. 8.15. Traffic control photographic system (red light cameras).

(a) A traffic control photographic system is an electronic system consisting of a photographic, video, or electronic camera and a vehicle sensor installed to work in conjunction with an official traffic control device to automatically produce photographs, video, or digital images of each vehicle violating a standard traffic control statute or ordinance.

(b) Any traffic control photographic system or any device which is a part of that system, as described in subsection (a) of this section, installed on a street or highway which is a part of the state highway system shall meet requirements established by the North Carolina Department of Transportation. Any traffic control system installed on a street within the Town of Cary shall meet standards established by the Town of Cary and shall be consistent with any standards set by the Department of Transportation.

(c) Any traffic control photographic system installed on a street or highway shall be identified by appropriate advance warning signs conspicuously posted not more than three hundred (300) feet from the location of the traffic control photographic system. All advance warning signs shall be consistent with a statewide standard adopted by the Department of Transportation in conjunction with the Town of Cary.

(d) The Town of Cary may adopt ordinances for the civil enforcement of G.S. 20-158 by means of a traffic control photographic system, as described in subsection (a) of this section. If the Town of Cary adopts an ordinance pursuant to this section then, notwithstanding G.S. 20-176, a violation of G.S. 20-158 detected only by a traffic control photographic system shall not be an infraction. If a violation of G.S. 20-158 is detected by both a law enforcement officer and a traffic control photographic system, the officer may charge the offender with an infraction. If the officer charges the offender with an infraction, a civil penalty issued by the Town of Cary for the same offense is void and unenforceable. An ordinance authorized by this subsection shall provide that:

(1) The owner of a vehicle shall be responsible for a violation unless the owner can furnish evidence that the vehicle was, at the time of the violation, in the care, custody, or control of another person. The owner of the vehicle shall not be responsible for the violation if the owner of the vehicle, within thirty (30) days after receiving notification of the violation, furnishes the office of the mayor any one of the following:

a. An affidavit stating the name and address of the person or company who had the care, custody, and control of the vehicle at the time of the violation.

b. An affidavit stating that the vehicle involved was, at the time, stolen. The affidavit must be supported with evidence that supports the affidavit, including insurance or police report information.

c. An affidavit stating that the person who received the citation is not the owner or driver of the vehicle, or that the person who received the citation was not driving a vehicle at the time and location designated in the citation.

(2) Subdivision (1) of this subsection shall not apply, and the registered owner of the vehicle shall not be responsible for the violation, if notice of the violation is given to the registered owner of the vehicle more than 90 days after the date of the violation.

(3) A violation detected by a traffic control photographic system shall be deemed a noncriminal violation for which a civil penalty of fifty dollars ($50.00) shall be assessed and for which no points authorized by G.S. 20-16(c) shall be assigned to the owner or driver of the vehicle nor insurance points as authorized by G.S. 58-36-65.

(4) The owner of the vehicle shall be issued a citation that shall be attached to photographic evidence of the violation that identifies the vehicle involved. The citation shall clearly state the manner in which the violation may be challenged. The owner of the vehicle shall comply with the directions on the citation. The citation shall be processed by officials or agents of the Town of Cary and shall be forwarded by personal service or first-class mail to the address given on the motor vehicle registration. If the owner fails to pay the civil penalty or to respond to the citation within the time period specified on the citation, the owner shall

have waived the right to contest responsibility for the violation and shall be subject to a civil penalty not to exceed one hundred dollars ($100.00). The Town of Cary may establish procedures for the collection of these penalties and may enforce the penalties by civil action in the nature of debt.

(5) The Town of Cary shall establish a nonjudicial administrative hearing process to review objections to citations or penalties issued or assessed under this section. The Town of Cary may establish an appeals panel composed of town employees to review objections. If the Town of Cary does not establish an appeals panel composed of town employees, the mayor shall review and make a final decision on all objections.

(e) The duration of the yellow light change interval at intersections where traffic control photographic systems are in use shall be no less than the yellow light change interval duration specified in the Design Manual developed by the Signals and Geometrics Section of the North Carolina Department of Transportation.

(f) The Town of Cary upon enacting an ordinance implementing a traffic control photographic system may enter into a contract with a contractor for the lease, lease-purchase, or purchase of the system. The Town of Cary may enter into only one contract for the lease, lease-purchase, or purchase of the system and the duration of the contract may be for no more than sixty (60) months. After the period specified in the contract has expired, the system shall either be the property of the Town of Cary or the system shall be removed and returned to the contractor.

(g) The clear proceeds from the citations issued pursuant to the ordinance authorized by this section shall be paid to the Wake County school fund. The clear proceeds from the citations shall mean the funds remaining after paying for the lease, lease-purchase, or purchase of the traffic control photographic system; paying a contractor for operating the system; and paying any administrative costs incurred by the Town of Cary related to the use of the system.
(N.C.S.L. Ch. 2001-286; N.C.S.L. Ch. 2003-380; Ord. No. 05-001, § 11, 2-9-2005)

Section 8.16. Issuing licenses for closing-out sales. In accordance with N.C. General Statutes Article 17, Chapter 66.

(a) The town council is authorized to designate an officer other than the town clerk to issue closing-out sale licenses.
(Ord. No. 2007-17, § 1, 10-11-07)
(N.C.S.L. 2007-22; N.C.S.L. 2002-33; G.S. 66-77)

Section 8.17. Allowing the Town of Cary to adopt ordinances regulating demolition of historic structures in their historic districts.

(a) In order to preserve and enhance one of the most valuable and unique natural resources of the community, and to preserve the property values and promote the general welfare of its citizens, a municipality may adopt ordinances to regulate the demolition of historic structures within its municipal corporate limits and extraterritorial jurisdiction. For purposes of this act, the term "historic structures" means:

(1) Any designated local, State, or national landmark; or,

EXHIBIT C

Intersection
Cary Town Blvd and Convention (EB)
Kildaire Farm Road and High Meadow Drive (SB)
High House Road and Prestonwood Drive (WB)
NW Maynard Road and Chapel Hill Road (NB)
Maynard Road and Walnut Street (SB)
Tryon Road and Crescent Green Way (EB)
Tryon Road and Regency Parkway (WB)
Walnut Street and Dillard Drive (NB)
Maynard Road and Kildaire Farm Road (WB)
Kildaire Farm Road and Maynard Road (SB)
Cary Parkway and Kildaire Farm Road (WB)
Kildaire Farm Road and Cary Parkway (NB)
Cary Parkway and High House Road (NB)
Harrison Avenue and Maynard Road (SB)
Harrison Avenue and Weston Parkway (SB)
Walnut Street and Meeting Street (SB)
Ten-Ten Road and Kildaire Farm Road (EB)
Cary Parkway and High Meadow (WB)

STATE OF NORTH CAROLINA

COUNTY OF WAKE

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

BRIAN CECCARELLI and LORI MILLETTE,

individually and as class representative,

Plaintiffs,

v.

TOWN OF CARY

Defendant.

CERTIFICATE OF SERVICE

The undersigned hereby certifies that a copy of the foregoing AMENDED COMPLAINT was served on the defendant's counsel in this action by faxing, emailing and depositing a copy of the same in the United States Mail, first-class postage prepaid, and addressed as follows:

X Depositing a copy hereof, postage prepaid, in the United States Mail, addressed to the attorney for each said party as follows:

Martineau King PLLC
Elizabeth A. Martineau
Attorney for Defendant
P.O. Box 31188
Charlotte, NC 28231
Phone: 704-247-8520

This the 25 day of April, 2012

~~Caroline E. Nickel~~ PAUL STAM
Stam & Danchi, PLLC
Attorneys for Plaintiff

FILED

2012 JUN 19 [illegible]

WAKE COUNTY, C.S.C.

NORTH CAROLINA

WAKE COUNTY

IN THE GENERAL COURT OF JUSTICE
SUPERIOR COURT DIVISION
10-CVS-19903

BRIAN CECCARELLI and LORI MILLETTE individually and as class representatives,

Plaintiffs,

v.

TOWN OF CARY,

Defendant.

ORDER GRANTING PLAINTIFFS' MOTION FOR CLASS CERTIFICATION

This Cause came on before the undersigned Judge at the December 12, 2011 Session of Wake County Civil Superior Court on Plaintiffs' Motion for Class Certification. The hearing on this matter was held over to the January 10, 2012 motions session, and additional materials and argument were taken by the Court at that time. The Court took the motion under advisement and considered all of the materials produced by the parties for and against the Motion for Summary Judgment and with respect to Class Certification – including pleadings, affidavits, answers to interrogatories, exhibits, memoranda of law submitted by the parties, and arguments from both counsel for the Plaintiffs and counsel for the Defendant. Separate orders have previously been issued by the Court regarding other motions before the Court at the December 12, 2011 and January 10, 2012 hearings. Having reviewed the arguments of counsel and all matters of record, the Court makes the following findings and conclusions:

1. Plaintiffs, in their Complaint, challenge the application, at certain street intersections, of Defendant Town of Cary's ordinance making it unlawful for a vehicle to cross the stop line into an intersection toward which an automated traffic control photographic system (a.k.a. "red light camera") is in operation when the traffic signal for that vehicle's

DEFENDANT'S EXHIBIT NO. 2 10/30/12 MMV

direction of travel is emitting a steady red light. Cary Code of Ord. § 34-303. Any violation of this ordinance is a civil violation for which a civil penalty of $50 is assessed by the Town of Cary. *Id.* at § 34-303,

2. Plaintiffs allege that the Town of Cary operates or has operated eighteen automated traffic control photographic systems. Plaintiffs assert that from 2004 to 2010, in order to operate a red light camera, the Town of Cary Charter required that the yellow light duration of the traffic signal where such a camera was installed be no less than the interval specified in the N.C. Department of Transportation Design Manual.
3. Plaintiff Ceccarelli alleges that on November 6, 2009, he drove his vehicle eastbound on Cary Towne Boulevard crossing its intersection with Convention Drive. This intersection has an automated traffic control photographic system installed by the Defendant. Plaintiff Ceccarelli alleges that the speed limit on the relevant portion of Cary Towne Boulevard was 45 mph. He further alleges that the NCDOT traffic signal plan of record was based on an incorrect speed limit of 35 mph, and that the yellow light duration for the intersection's traffic signal was less than that which would have been required by an accurate calculation of clearance time. Plaintiff Ceccarelli, therefore, asserts that he was unable to safely stop his vehicle before the traffic signal turned red in his respective path of travel.
4. Plaintiff Ceccarelli was issued Notice of Violation of Cary Town Code § 34-303 on November 10, 2009 and appeared before an appeal panel established by the Town of Cary. On January 20, 2010, the panel found Plaintiff Ceccarelli had violated Cary Town Code § 34-303. Plaintiff Ceccarelli has exhausted his administrative appeals.
5. Plaintiff Ceccarelli asserts that the traffic plan that he contends was inaccurate was used

until March 2010, and that this inaccuracy caused the duration of the yellow light to be less than the interval specified by the N.C. Department of Transportation and/or the Town Charter, and therefore, the utilization of automated traffic control photographic system by the Defendant at the intersection of Cary Towne Boulevard and Convention Center Drive was unlawful.

6. Plaintiffs, in their first claim for relief, seek to have a class certified of all drivers who were assessed a civil penalty for violations of Cary Town Code § 34-303 at the same type of intersection complained of by Plaintiff Ceccarelli – namely where the yellow light duration of the traffic signal at an intersection with an automated traffic control photographic system installed was set at a lower speed limit than the posted speed limit on the relevant roadway.

7. Plaintiffs, in their second claim for relief, claim that on May 7, 2010, Plaintiff Millette was traveling north on Kildaire Farm Road and turned left at the intersection of Kildaire Farm Road and Cary Parkway. This intersection has an automated traffic control photographic system installed by the Defendant. Plaintiffs assert that the posted speed limit for the relevant portion of Kildaire Farm Road was 45 mph.

8. Plaintiffs further assert that the duration of the left turn yellow light arrow for the above-described intersection was determined using the assumption that vehicles turning left would be traveling 20 to 30 mph. Plaintiffs contend that this assumption is not consistent with sound engineering principles and that it is not consistent with the interval specified in the NCDOT Design Manual, and that therefore, the utilization of automated traffic control photographic system by the Defendant at the intersection of Kildaire Farm Road and Cary Parkway, and other similar intersections, was unlawful.

9. Plaintiff Millette, after seeing the yellow light, contends that she was unable to safely stop her vehicle before the traffic signal turned red in her respective path of travel. She was issued a Notice of Violation of Cary Town Code §34-303 on May 21, 2010 by the Town of Cary. Plaintiff Millette paid the civil penalty of $50, appealed the violation, and on August 18, 2010 appeared before an appeal panel established by the Town of Cary. The panel found she had violated § 34-303. Plaintiff Millette has exhausted her administrative appeals.

10. Plaintiffs, in their second claim for relief, seek to have a class certified of all drivers who were assessed a civil penalty for violations of Cary Town Code § 34-303 at the same type of intersection complained of by Plaintiff Millette – namely where the yellow light duration at an intersection with an automated traffic control photographic system was calculated under what the Plaintiffs contend was an arbitrary and capricious formula that assumed motorists would be going much slower than the posted speed limit before making a left turn.

11. The Court finds that the proposed classes (hereinafter referred to as the "Ceccarelli Class" and the "Millette Class") are each so numerous that joinder of all members is impractical. While the record does not yet establish the actual number of potential plaintiffs for each class, the parties have provided estimates in their arguments and memoranda ranging from hundreds to tens of thousands, depending upon how narrowly the classes are defined. The Court finds that joinder of even the lowest of these estimates, namely hundreds of plaintiffs, would be impractical.

12. The Court finds that the members of the proposed classes share common questions of law and fact, namely whether the traffic control signals at intersections where automated

traffic control photographic systems were installed provided yellow light duration periods consistent with NCDOT Design Manuals and/or the Cary Town Charter and, if not, whether the failure to provide sufficient yellow light durations at such intersections provides a legal remedy for those class members who received and paid a Notice of Violation of § 34-303.

13. The Court further finds that the claims of the proposed class representatives are typical of absent class members.

14. The Court finds that the representative parties will fairly and adequately protect the interest of the classes. In making this determination, the Court finds that the named plaintiffs and their counsel do not have any conflicts of interest with other class members and the named plaintiffs and their counsel have demonstrated that they will prosecute the action vigorously on behalf of the classes. The Court is satisfied that the law firm of Stam & Danchie, PLLC has experience in class action litigation and complex litigation and that this firm, in conjunction with the firm of William W. Peaslee, Attorney at Law, PLLC, will be able to adequately litigate the class action.

15. The Court finds that questions of law and fact common to these classes predominate over questions affecting only individual members and that a class action is superior to other available methods for fairly and efficiently adjudicating the controversy. Each of the proposed classes is sufficiently cohesive to warrant adjudication by representation. Adjudication of common issues will help achieve judicial economy.

16. While individualized issues exist within the classes, these issues do not predominate. One such individualized issue is whether the failure of some absent class members to exhaust their administrative remedies by appealing their citation deprives the Court of

subject matter jurisdiction. The Court concludes that the failure of absent class members (other than named plaintiffs) to exhaust their administrative remedies does not deprive the Court of subject matter jurisdiction because once Plaintiffs Ceccarelli and Millette gave their notices of appeal protesting the Defendant's actions, the Defendant was on notice that it could be facing similar claims in the future.

17. The Court finds that adequate notice can and will be given to all members of the classes through publication.

Based on the foregoing, the Court concludes that:

1. The Plaintiffs' Motion for Class Certification of Plaintiffs' First (Ceccarelli) and Second (Millette) Claim for Relief is ALLOWED.
2. The class for the First Claim for Relief (Ceccarelli) shall be those persons who were assessed a civil penalty for violation of Cary Ord. § 34-303 at the intersection of Cary Towne Boulevard and Convention Drive from December 2, 2009 through March 19, 2010. The inclusive dates are on or after the date that Ceccarelli gave notice of appeal of his citation until the yellow light interval duration at that intersection was changed.
3. The class for the Second Claim for Relief shall be those persons who were assessed a civil penalty for violation of Cary Ord. § 34-303 between August 1, 2010 through the date of trial while making a left turn maneuver at the same type of intersection complained of by Plaintiff Millette, specifically:

   (i) traveling westbound on Maynard Road & turning left onto Kildaire Farm Road;

   (ii) traveling westbound on Cary Parkway & turning left onto Kildaire Farm Road;

   (iii) traveling northbound on Kildaire Farm Road & turning left onto Cary Parkway;

(iv) traveling northbound on Cary Parkway & turning left onto High House Road; and

(v) traveling southbound on Walnut Street & turning left onto Meeting Street.

The inclusive dates are August 1, 2010 through the date of trial. The inclusive date commences are on or after the date that Millette gave notice of appeal of her citation.

4. The Court is not ruling on the applicability of statute of limitations or statutes of repose defenses asserted by the Defendant. This order does not preclude the Defendant from raising these issues at a later time.

SO ORDERED, this the 19 day of June, ~~2012.~~

Honorable Paul C. Ridgeway
Wake County Superior Court

Served upon:

Counsel for the Plaintiffs:

Paul Stam
Caroline Nickel
Stam & Danchi, PLLC
P.O. Box 1600
Apex, NC 27502

William Peaslee
102 Commonwealth Court
Cary, NC 27511

Counsel for the Defendant:

Elizabeth A. Martineau
Martineau King, PLLC
P.O. Box 31188
Charlotte, NC 28231

CHARLES R. MANNING, JR.

President

ACCIDENT RECONSTRUCTION ANALYSIS, INC.

An engineering consulting firm with a full-scale metallurgical laboratory and testing facility to investigate all aspects of failure analysis and accident reconstruction.

PROFESSIONAL ENGINEER				NC State University
North Carolina	Virginia	South Carolina	Florida	Mechanical Engineering
8559	00513	22888	62859	Adjunct Professor

ADDRESS

5801 Lease Lane
Raleigh, North Carolina 27617

Business Phone: (919) 787-9675

EDUCATION

General Electric Apprentice School (1947-1950)
Worked on machinery, maintenance, set-up and planning.
Attended night school in areas of math, physics, shop theory and machine design.

UNITED STATES AIR FORCE (1950-1954)

1950-1951	Aircraft and Engine School, Sheppard Field, Texas
1951	Advanced Jet School
1951-1954	Active Service in Korea - Aircraft Crew Chief Flight Chief - in charge of maintenance on flight of aircraft Hangar Chief - in charge of all major maintenance on Squadron of Aircraft
1952-1953	Aircraft Accident Investigation Team (Korean War)

BS **Florida State University**, 1955-1958, Mathematics and Geology

Massachusetts Institute of Technology, 1960, Electron Microprobe School - short course

University of Wisconsin, 1961, Biomedical Engineering - short course

MS **Virginia Polytechnic Institute**, 1962, Metallurgical Engineering, Minor in Physics

Lehigh University, 1964, Fracture Mechanics - short course

PhD **North Carolina State University**, 1967, Materials Engineering (Metallurgy and Ceramics), Minor in Mechanical Engineering

Massachusetts Institute of Technology, 1990, Cardiovascular Pathophysiology for Engineers and Physical Scientists - short course

HONORS

NASA Outstanding Performance Award on Apollo Program in 1965
NASA Superior Achievement Award
USAF Soldier's Medal for Valor
ASM Award for Top Thesis in 1962 entitled:
"Study of Nitrogen Diffusion in Austenitic Stainless Steel"
U.S. Patent Development of New Materials for Crown and Bridges
Distinguished Alumni Award for 2006 from North Carolina State University

DEFENDANT'S EXHIBIT
NO. 3 10/30/12 mm

MAJOR INVESTIGATIONS

- SPACE SHUTTLE CHALLENGER, Cape Kennedy, Florida
- THUNDERBIRD CRASH, Indian Wells, Nevada
- APOLLO FIRE, Cape Kennedy, Florida
- LOWE'S MOTOR SPEEDWAY BRIDGE COLLAPSE
- DALE EARNHARDT ACCIDENT

PROFESSIONAL SERVICES

Metallurgical Testing
Mechanical Testing of Metals
Fracture Analysis
Mechanical Testing of Nonmetals (plastics, fiberglass, wood, elastomers)
Microscopy and Electron Microscopy
Micro-Chemical Analysis
Materials Studies (metals, ceramics and polymers)
Metallurgy
Strain Gage Studies
Stress Analysis / Finite Element Analysis
Chemical Analysis
Computer-Aided Modeling and Auto Accident Simulation
Corrosion Testing/Studies and Corrosion Design
Flammability Testing
Vibration Technology
Welding Studies/Microstructural Correlation of Weld Procedure and Welder Certification
Scanning Electron Microscopy for high magnification analysis

1979-present

President and Founder, Accident Reconstruction Analysis, Inc.

Performing consulting services in the following areas:

- Metallurgical Analysis and Testing of Materials
- Stress Analysis and Design of Systems, Strain Gage Testing and Thermal Testing
- Technical Investigation of Machinery and Machinery Accidents Including Electrical Shock and Bum
- Motor Vehicle
    - . computer-aided modeling and auto accident simulation, accident reconstruction, failure analysis
- Aircraft and Flight Test Studies
    - . aircraft accident reconstruction and analysis
    - . helicopter accident reconstruction and analysis
    - . stress testing and studies
    - . mechanical design testing and analysis
- Railroad Accident Reconstruction, Accident Analysis, System Analysis, G-force Measurements
- Maritime Accident Reconstruction and Marine Fires and Explosions
- Fires, Commercial and Residential
    - . Reconstruction of fires and explosions including industrial explosions and chemical reactors to determine cause and origin
    - . Fire seminars for the IAAI (International Association of Arson Investigators) which include electrical studies, case histories and cause and origin studies, as well as studies on all types of appliances as they relate to fires
- Gas Explosions and Oil Fires
- Structures and Failure Analysis of All Materials Construction Industry
    - . Study housing and buildings (residential, commercial and industrial) for structural problems or damages related to construction or tornado, wind and hurricane destruction
- Elevators
    - . Reconstruction analysis, dynamic testing including measuring "G" loading. Correlate "G" loading to injury level.

- Ladders
  . Aluminum and fiberglass; structural studies; fiberglass studies and analysis
- Testing
  . Mechanical, thermal and metallurgical

1967-1979
Manning and Associates
Performing consulting in the following areas:
- Failure Analysis of All Materials
- Accident Reconstruction of:
  . Aircraft, Motor Vehicle and Machinery Accidents
  . Fires and Explosions (including natural and propane gas explosions and oil fires
- Stress Analysis Performed on:
  . Engines, air frames, large structures such as Cape Hatteras National Lighthouse, pump storage turbine stations for power companies, building collapses, pipeline fire failures
  . Computer-aided auto reconstruction
  . Developed/designed new high temperature processing technology

1969
Scientific Exchange Program
Visits to Soviet Union & Europe (first to visit certain remote areas of Soviet Union)

- Studied melting technology (Electro Slag Remelting/Vacuum Arc Remelting) and high precision tube mills
- Ran experimental plant producing high precision tubing (steel, nickel base, copper, titanium and zircaloy materials)

1970-1980
Professor of Materials Engineering
North Carolina State University
Taught courses in:
- Physical Examination of Materials
- X-Ray Diffraction
- Mechanical Behavior of Materials, Stress Analysis
- Welding Engineering
- Corrosion Control and Engineering
- Physical Ceramics
- Glass Technology
- Materials Factors in Design (Failure Analysis, Accident Reconstruction and Product Design)
- Structure and Properties of Thermal Behavior/Materials

University of North Carolina
- Dental School Visiting Lecturer

1967-1970
Associate Professor of Materials Engineering
North Carolina State University

1966-1967
Langley Air Force Base
Propulsion Manager on Apollo Propulsion Tanks, Douglas S-4V, Service and Command Module, Lunar Lander
Group Leader of Failure Analysis and Reconstruction Laboratory
Developed United States Patent on Shot Peening Equipment and Processing

1962-1965
National Aeronautics and Space Administration (NASA)
Group Leader of Failure Analysis and Reconstruction Laboratory
Member of Pressure Vessel and Safety Committee

1958-1961
National Aeronautics and Space Administration (NASA)
Research Engineer
- Performed materials testing, evaluation, predictions of materials life, high temperature testing, joint processes, failure analysis and reconstruction.
- Developed metallurgy and materials laboratory for the above.

Group Leader of Failure Analysis and Reconstruction Laboratory

1958
National Advisory Committee for Aeronautics

RESEARCH

NASA Performed erosion studies on materials including testing for Army Aviation Laboratory at Fort Eustis on helicopter blades and high temperature material development for rocket nozzles. Obtained two U.S. patents in this area.

NATIONAL INSTITUTE OF HEALTH
Developed biomedical materials for implants.
Developed model for crack propagation in brittle materials.
Performed surface energy studies to determine bonding of metal and ceramic materials.

NORTH CAROLINA STATE UNIVERSITY
Crack initiation and propagation studies in cast iron.
Advisor for MS students (1968 - 1981)
Advisor for PhD students (1968 - 1981)

PUBLICATIONS

Published over 40 technical papers.
Co-authored three technical publications.
(Listing of above available upon request)

SPEECHES

American Society of Metals
American Ceramic Society
American Society of Mechanical Engineers
American Society of Safety Engineers
National Association of Legal Assistants, Inc.
North Carolina Bar Association
Seminars on Failure Analysis and Accident Reconstruction
NC/SC Construction Law Seminar
Various Conferences

PROFESSIONAL MEMBERSHIPS AND AFFILIATIONS

AMERICAN CERAMIC SOCIETY
AMERICAN SOCIETY FOR ENGINEERING EDUCATION
AMERICAN SOCIETY FOR METALS
AMERICAN WELDING SOCIETY
INTERNATIONAL SOCIETIES OF AIRCRAFT AND SAFETY INVESTIGATION
NATIONAL FIRE PROTECTION ASSOCIATION
NATIONAL SAFETY COUNCIL
SOCIETY OF AUTOMOTIVE ENGINEERS
SOUTHERN BUILDING CODE CONGRESS INTERNATIONAL

CHARLES R. MANNING, JR.

BIBLIOGRAPHY

SELECTED TECHNICAL PAPERS

1. Application of Rate-Temperature Parameters to Tensile Data for Magnesium Alloys and a Relation Between the Larson-Miller constant and the Activation Energy. NASA TN D-172; May, 1960. Charles R. Manning, Jr.

2. An Evaluation of Some Current Practices for Short-Time Elevated-Temperature Tensile Tests of Metals. NASA TN D-420; September, 1960. Charles R. Manning, Jr and George J. Heimerl

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3. "Factors Affecting the Thermal Shock Behavior of Yetria Stabilized Hafnia Based Graphite and Tungsten Composites." Published in the Ceramics in Severe Environments. Materials Science Research, Volume 5, pp. 137-147, Plenum Press 1971. Lynn Lineback and Charles R. Manning, Jr.

4. "Ceramic Metal Composites for Surgical Implants." Published in Bioceramics; Engineering in Medicine; pp. 443-467; Wiley-Interscience Press, 1971. (Supported by NIH Institutional Grant 8-0198 to Charles R. Manning, Jr. at North Carolina State University.) W. E. Cook, Charles R. Manning, Jr., J. C. Hurt and D. F. Taylor (W. E. Cook is C. R. Manning, Jr. Graduate Student)

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NGR-34-002-108 National Aeronautics and Space Administration
1970-1974 Langley Research Center, Hampton, Virginia
Second Grant on Hypersonic Vehicles
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Administration, Langley Research Center, Hampton, Virginia
PROGRESS REPORT:
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August, 1971.
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Charles R. Manning, Jr. and Lynn Lineback, 1973.
PROGRESS REPORT:
"X-Ray Analysis of Hafnia-Tungsten Rocket Nozzles to Study Destabilization"
Charles R. Manning, Jr. and Leroy Honeycutt, October 1 - December 31, 1973.
PROGRESS REPORT:
"Test Firing of Hafnia-Tungsten Rocket Nozzle Insert on Scout Vehicle"
Charles R. Manning, Jr. and Lynn Lineback (12th Quarterly Report)
INVENTION:
U. S. PATENT NO. 3,706,583 - December 19, 1973:
"Thermal Shock Resistant Hafnia Ceramic Materials"
Inventors - Lynn Lineback and Charles R. Manning, Jr.
PROGRESS REPORT:
"Erosion and Thermal Shock Resistance of Hot Pressed Tantalum Carbide, Hafnium Carbide and Zirconium Carbide Containing Free Carbon and Refractory Fibers"
Charles R. Manning, Jr. and Leroy Honeycutt III

3. "A Mechanistic Model for Prediction of Ductile Erosion"
USAAMRDL-TR-75-30 to Charles R. Manning, Jr.
U. S. Army Air Mobility Research and Development Laboratory, Fort Eustes, Virginia 23604
North Carolina State University, Department of Materials Engineering, Raleigh, North Carolina 27607
William Jenning, Charles R. Manning, Jr. and W. J. Head
December 31, 1974

4. National Institute of Health - Institutional Grant 8-0198
North Carolina State University
National Institute of Health - Institutional Grant R01-DE03262-01 (Investigators: Charles R. Manning, Jr., (NCSU) and Duane Taylor (UNC)
"Fabrication of Phosphate Bonded Aluminum by Hot Pressing"

James P. Mathers and Charles R. Manning, Jr.
1974
"Ceramic Composites for Biomedical Applications"
James P. Mathers and Charles R. Manning, Jr., 1975
"Ceramic Composites for Biomedical Applications"
David E. Ramsey, Jr., Charles R. Manning, Jr. and D. F. Taylor

5. Research Grant: North Carolina Brick and Tile Association
"Study of North Carolina Clays and Shales"
(Charles R. Manning, Jr. - Grant)
Kirankumar Delal and Charles R. Manning, Jr.
INVENTION:
Dental Alloy 3,914,867 - October 28, 1975
Inventors:
Charles R. Manning, Jr. and Mitchell W. Haller
Assignee: Dentsply Research and Development Corporation,
Milford, Delaware

Selected Presentations

1. "Effect of Rapid Loading on Mechanical Properties Molybdenum Sheet" Charles R. Manning, Jr. Presented at Conference on Evaluation of Reprocessed Molybdenum Sheet, Langley Research Center, NASA, May, 1961.

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13. "Advances in Electroslag Melting and Welding"
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Presented at the American Society of Mechanical Engineers
Conference in 1978.

14. "Accident Reconstruction"
Charles R. Manning, Jr.
Seminar Presented at the American Society of Metals in Richmond, Virginia in 1981.

Selected Doctoral Dissertations Done Under Direction of
Professor Charles R. Manning, Jr.

1. Sodium-Iron-Silica Glasses and Steel
"Systems-Wetting, Adherence and Mossbauer Effect
Spectroscopic Studies," Vasanth Kumar Bhat, 1970.

2. "Thermocechanical and Thermochemical Behavior of a Hafnium-20 Percent Tantalum Alloy," James Preston Howell, 1971.

3. "Model for Thermal Stress Resistance of Truly Elastic Materials Containing More Than One Crack," Lynn David Lineback, 1973.

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1. "Wettability of Binary Alloys of Aluminum on Coated and Uncoated Graphite," Thomas Burl Gurganus, May, 1970.

2. "Effects of Processing Parameters on Microconstituents in Solid-Solution Strengthened Nickel-Base Superalloy-Nickelvac-HX," Rafiz Abedin Bandukwala, 1970.

3. "Wetting and Interfacial Behavior of Nickel Binary Alloys with Al, Cr, and Ti Additions on Stabilized Zirconia," John William Vorberger, Jr., 1970.

4. "Factors Affecting the Thermal Shock Resistance of Several Hafnia Based Composites Containing Graphite or Tungsten," Lynn David Lineback, 1971.

5. "Study of North Carolina Clays and Shales," Kirankumar Hiralal Dalal, 1972.

6. "A Texture Study of Zircaloy Tubing," Stephen Stanley Koszewski, Jr., 1973.

7. "Hot Pressing and Thermal Shock Parameters Governing Zirconia-Tungsten Composites," Leroy Honeycutt, III, May, 1973.

8. "Fabrication of Phosphate Bonded Alumina by Hog Pressing," James Patrick Mathers, 1974.

9. "Mechanical Erosion of Metallic Materials as a Function of Material Parameters," William H. Jennings, August, 1975.

10. "Ceramic Composites for Biomedical Applications," David Earl Ramsey, Jr., 1976.

11. "Metal Reinforced Ceramic," Francisco Erasmo Iannetti, June, 1977.

12. "The Effect of Porosity on the Strength of Aluminum Diecasting," Robert L. Edwards, North Carolina State University, 1981.

Selected Patents

1. U. S. PATENT NO. 3,706,583 - December 19, 1973:
"Thermal Shock Resistant Hafnia Ceramic Materials"
Inventors - Lynn Lineback and Charles R. Manning, Jr.

2. Dental Alloy 3,914,867 - October 28, 1975
Inventors: Charles R. Manning, Jr. and Mitchell W. Hallar
Assignee: Dentsply Research and Development Corporation, Milford, Delaware

3. Controlled Shot Peening to Alleviate Stress Corrosion - 1968
Assignee: Unites States NASA
Inventors: Charles R. Manning, Jr., M. Seiford, B. Lisagor and T. Bales

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EDUCATION

NORTH CAROLINA STATE UNIVERSITY RALEIGH, NC
Bachelor of Science Mechanical Engineering
December, 1997

CENTRAL CAROLINA COMMUNITY COLLEGE SANFORD, NC
Courses in mathematics and physics

EXPERIENCE

Accident Reconstruction Analysis, Inc. RALEIGH, NC
Staff Engineer:
January 1998 to Present

Structural Services
- Water intrusion cause and origin
- Structural integrity and damage
- Mold causation
- Code violations
- Failure investigations
- Structural load calculations
- Retaining wall failure
- Hurricane and storm damage
- Remedial repair plans

Vehicle Accident Reconstruction
- Investigation of single vehicle, multi-vehicle and heavy vehicle accidents
- Investigation of motorcycle, bicycle and pedestrian accidents
- Light filament on/off analysis
- Hydroplaning accidents
- Roadway surface defects
- Stoplight/intersection accidents
- Scene surveys with laser surveying equipment
- Reconstruction of time lines, sight distance and accident events
- Proficient with reconstruction software
- Certified Vetronix/Bosch Crash Data Specialist
- Retrieval and interpretation of "Black Box" crash data from accident vehicles
- Retrieval and interpretation of Engine Control Module data from heavy vehicles

Other Services

- General mechanical and component analysis
- Research and testing for compliance of building codes, trade standards, ASTM standards or ANSI standards
- Investigations related to failure of mechanical components and assemblies
- Reconstruction and testing of failed mechanical and structural components
- Investigation of industrial machinery failures
- Litigation support and testimony in criminal matters

Testimony Experience

- Deposition Testimony
- Arbitration Testimony
- Civil Trial Testimony
- Criminal Trial Testimony

Employment Experience

Accident Reconstruction Analysis, Inc. RALEIGH, NC
Assistant Engineer:
April 1996 to December 1997
Assist staff engineers with inspection and documentation of accident and fire scenes; Design and implement testing procedures and fixtures; Research and collect information for reports; Prepare exhibits for court trials; assisted in documentation of physical evidence in criminal, civil and insurance cases.

Walnut Creek Amphitheater RALEIGH, NC
Operations
March to September, 1993 and 1995
Full-time position for general maintenance of facility; Oversee redesign projects; Facility modification and preparation for upcoming events.

Certifications
North Carolina State Board of Registration for Professional Engineers and Land Surveyors:
Engineer in Training, 2001, Registered Professional Engineer 2012

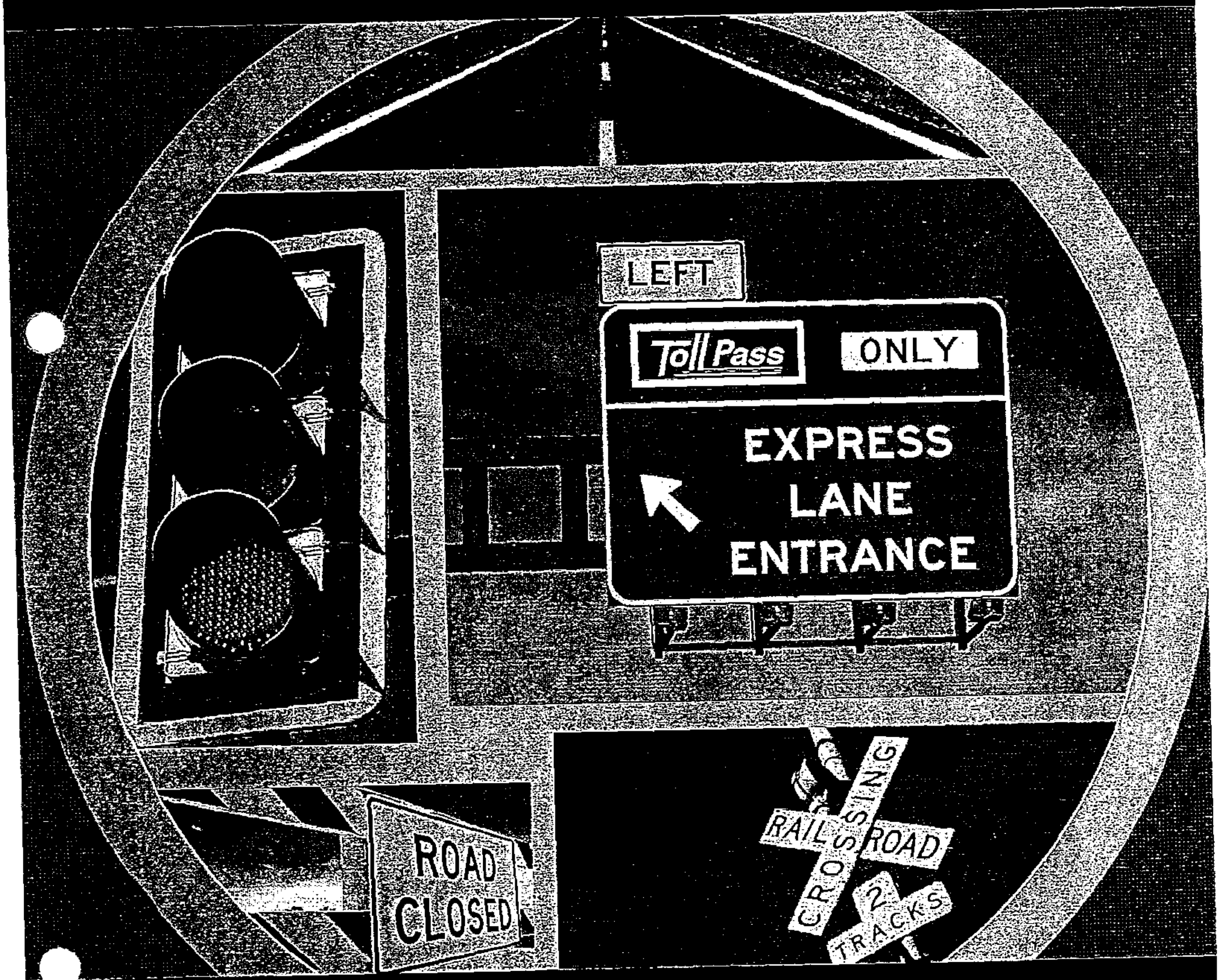
Honors

Nazemi Award for Thermal Systems Design
First Place NCSU Senior Engineering Design

Manual on Uniform Traffic Control Devices

for Streets and Highways

2009 Edition



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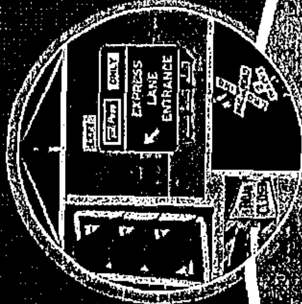
Federal Highway Administration



Manual on Uniform Traffic Control Devices

2009 Edition

The Manual on Uniform Traffic Control Devices (MUTCD) is approved by the Federal Highway Administrator as the National Standard in accordance with Title 23 U.S. Code, Sections 109(d), 114(a), 217, 315, and 402(a), 23 CFR 655, and 49 CFR 1.48(b)(8), 1.48(b)(33), and 1.48(c)(2).

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)
10003 Derekwood Lane, Suite 210
Lanham, MD 20706
www.arema.org
301-459-3200

Federal Highway Administration Report Center
Facsimile number: 814-239-2156
report.center@fhwa.dot.gov

Illuminating Engineering Society (IES)
120 Wall Street, Floor 17
New York, NY 10005
www.iesna.org
212-248-5000

Institute of Makers of Explosives
1120 19th Street, NW, Suite 310
Washington, DC 20036-3605
www.ime.org
202-429-9280

Institute of Transportation Engineers (ITE)
1099 14th Street, NW, Suite 300 West
Washington, DC 20005-3438
www.ite.org
202-289-0222

International Organization for Standardization
1, ch. de la Voie-Creuse
Case Postale 56
CH-1211
Geneva 20, Switzerland
www.iso.ch
011-41-22-749-0111

International Safety Equipment Association (ISEA)
1901 North Moore Street, Suite 808
Arlington, 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
Washington, DC 20001
www.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.

MANUAL ON UNIFORM TRAFFIC CONTROL DEVICES
TABLE OF CONTENTS

CHAPTER 2B. REGULATORY SIGNS, BARRICADES, AND GATES

CHAPTER 2J. SPECIFIC SERVICE SIGNS

CHAPTER 2K. TOURIST-ORIENTED DIRECTIONAL SIGNS

CHAPTER 2L. CHANGEABLE MESSAGE SIGNS

CHAPTER 2M. RECREATIONAL AND CULTURAL INTEREST AREA SIGNS

CHAPTER 2N. EMERGENCY MANAGEMENT SIGNING

PART 3. MARKINGS

CHAPTER 3A. GENERAL

CHAPTER 3B. PAVEMENT AND CURB MARKINGS

CHAPTER 3C. ROUNDABOUT MARKINGS

CHAPTER 3D MARKINGS FOR PREFERENTIAL LANES

CHAPTER 3E. MARKINGS FOR TOLL PLAZAS

CHAPTER 4E PEDESTRIAN CONTROL FEATURES

CHAPTER 4F PEDESTRIAN HYBRID BEACONS

PART 6 TEMPORARY TRAFFIC CONTROL

CHAPTER 6A GENERAL

CHAPTER 6B FUNDAMENTAL PRINCIPLES

CHAPTER 6C TEMPORARY TRAFFIC CONTROL ELEMENTS

CHAPTER 6D PEDESTRIAN AND WORKER SAFETY

CHAPTER 6E FLAGGER CONTROL

CHAPTER 6F TEMPORARY TRAFFIC CONTROL ZONE DEVICES

PART 7 TRAFFIC CONTROL FOR SCHOOL AREAS

CHAPTER 7A GENERAL

CHAPTER 7B SIGNS

CHAPTER 7C MARKINGS

CHAPTER 7D CROSSING SUPERVISION

PART 8 TRAFFIC CONTROL FOR RAILROAD AND LIGHT RAIL TRANSIT GRADE CROSSINGS

CHAPTER 8A GENERAL

CHAPTER 8B SIGNS AND MARKINGS

CHAPTER 8C FLASHING-LIGHT SIGNALS, GATES, AND TRAFFIC CONTROL SIGNALS

CHAPTER 8D PATHWAY GRADE CROSSINGS

PART 9 TRAFFIC CONTROL FOR BICYCLE FACILITIES

CHAPTER 9A GENERAL

CHAPTER 9B SIGNS

CHAPTER 9C MARKINGS

CHAPTER 9D SIGNALS

FIGURES

Page

TABLES

Page

MANUAL ON UNIFORM TRAFFIC CONTROL DEVICES
INTRODUCTION

Standard:

01 **Traffic control devices sball be defined as all signs, signals, markings, and other devices used to regulate, warn, or guide traffic, placed on, over, or adjacent to a street, higbway, pedestrian facility, bikeway, or private road open to public travel (see definition in Section 1A.13) by authority of a public agency or official having jurisdiction, or, in tbe case of a private road, by autbority of the private owner or private official baving jurisdiction.**

02 **Tbe Manual on Uniform Traffic Control Devices (MUTCD) is incorporated by reference in 23 Code of Federal Regulations (CFR), Part 655, Subpart F and sball be recognized as tbe national standard for all traffic control devices installed on any street, highway, bikeway, or private road open to public travel (see definition in Section 1A.13) in accordance with 23 U.S.C. 109(d) and 402(a). The policies and procedures of the Federal Higbway Administration (FHWA) to obtain basic uniformity of traffic control devices shall be as described in 23 CFR 655, Subpart F.**

03 **In accordance with 23 CFR 655.603(a), for the purposes of applicability of the MUTCD:**

A. Toll roads under tbe jurisdiction of public agencies or authorities or public-private partnerships shall be considered to be public highways;
B. Private roads open to public travel shall be as defined in Section 1A.13; and
C. Parking areas, including the driving aisles witbin those parking areas, that are either publicly or privately owned shall not be considered to be "open to public travel" for purposes of MUTCD applicability.

04 **Any traffic control device design or application provision contained in this Manual shall be considered to be in the public domain. Traffic control devices contained in this Manual shall not be protected by a patent, trademark, or copyright, except for the Interstate Shield and any items owned by FHWA.**

Support:

05 Pictographs, as defined in Section 1A.13, are embedded in traffic control devices but the pictographs themselves are not considered traffic control devices for the purposes of Paragraph 4.

06 The need for uniform standards was recognized long ago. The American Association of State Highway Officials (AASHO), now known as the American Association of State Highway and Transportation Officials (AASHTO), published a manual for rural highways in 1927, and the National Conference on Street and Highway Safety (NCSHS) published a manual for urban streets in 1930. In the early years, the necessity for unification of the standards applicable to the different classes of road and street systems was obvious. To meet this need, a joint committee of AASHO and NCSHS developed and published the original edition of this Manual on Uniform Traffic Control Devices (MUTCD) in 1935. That committee, now called the National Committee on Uniform Traffic Control Devices (NCUTCD), though changed from time to time in name, organization, and personnel, has been in continuous existence and has contributed to periodic revisions of this Manual. The FHWA has administered the MUTCD since the 1971 edition. The FHWA and its predecessor organizations have participated in the development and publishing of the previous editions. There were nine previous editions of the MUTCD, and several of those editions were revised one or more times. Table I-1 traces the evolution of the MUTCD, including the two manuals developed by AASHO and NCSHS.

Standard:

07 **The U.S. Secretary of Transportation, under authority granted by the Highway Safety Act of 1966, decreed that traffic control devices on all streets and highways open to public travel in accordance with 23 U.S.C. 109(d) and 402(a) in each State shall be in substantial conformance with the Standards issued or endorsed by the FHWA.**

Support:

08 The "Uniform Vehicle Code (UVC)" is one of the publications referenced in the MUTCD. The UVC contains a model set of motor vehicle codes and traffic laws for use throughout the United States.

Guidance:

09 *The States should adopt Section 15-116 of the UVC, which states that, "No person shall install or maintain in any area of private property used by the public any sign, signal, marking, or other device intended to regulate, warn, or guide traffic unless it conforms with the State manual and specifications adopted under Section 15-104."*

Table I-1. Evolution of the MUTCD

Year	Name	Month / Year Revised
1927	Manual and Specifications for the Manufacture, Display, and Erection of U.S. Standard Road Markers and Signs (for rural roads)	4/29, 12/31
1930	Manual on Street Traffic Signs, Signals, and Markings (for urban streets)	No revisions
1935	Manual on Uniform Traffic Control Devices for Streets and Highways (MUTCD)	2/39
1942	Manual on Uniform Traffic Control Devices for Streets and Highways — War Emergency Edition	No revisions
1948	Manual on Uniform Traffic Control Devices for Streets and Highways	9/54
1961	Manual on Uniform Traffic Control Devices for Streets and Highways	No revisions
1971	Manual on Uniform Traffic Control Devices for Streets and Highways	11/71, 4/72, 3/73, 10/73, 6/74, 6/75, 9/76, 12/77
1978	Manual on Uniform Traffic Control Devices for Streets and Highways	12/79, 12/83, 9/84, 3/86
1988	Manual on Uniform Traffic Control Devices for Streets and Highways	1/90, 3/92, 9/93, 11/94, 12/96, 6/98, 1/00
2000	Manual on Uniform Traffic Control Devices for Streets and Highways — Millennium Edition	7/02
2003	Manual on Uniform Traffic Control Devices for Streets and Highways	11/04, 12/07
2009	Manual on Uniform Traffic Control Devices for Streets and Highways	

Support:

10 The Standard, Guidance, Option, and Support material described in this edition of the MUTCD provide the transportation professional with the information needed to make appropriate decisions regarding the use of traffic control devices on streets, highways, bikeways, and private roads open to public travel (see definition in Section 1A.13).

11 Throughout this Manual the headings Standard, Guidance, Option, and Support are used to classify the nature of the text that follows. Figures and tables, including the notes contained therein, supplement the text and might constitute a Standard, Guidance, Option, or Support. The user needs to refer to the appropriate text to classify the nature of the figure, table, or note contained therein.

Standard:

12 **When used in this Manual, the text headings of Standard, Guidance, Option, and Support shall be as defined in Paragraph 1 of Section 1A.13.**

Support:

13 Throughout this Manual all dimensions and distances are provided in English units. Appendix A2 contains tables for converting each of the English unit numerical values that are used in this Manual to the equivalent Metric (International System of Units) values.

Guidance:

14 *If Metric units are to be used in laying out distances or determining sizes of devices, such units should be specified on plan drawings and made known to those responsible for designing, installing, or maintaining traffic control devices.*

15 *Except when a specific numeral is required or recommended by the text of a Section of this Manual, numerals displayed on the images of devices in the figures that specify quantities such as times, distances, speed limits, and weights should be regarded as examples only. When installing any of these devices, the numerals should be appropriately altered to fit the specific situation.*

Support:

16 The following information will be useful when reference is being made to a specific portion of text in this Manual.

17 There are nine Parts in this Manual and each Part is comprised of one or more Chapters. Each Chapter is comprised of one or more Sections. Parts are given a numerical identification, such as Part 2 – Signs. Chapters are identified by the Part number and a letter, such as Chapter 2B – Regulatory Signs, Barricades, and Gates. Sections are identified by the Chapter number and letter followed by a decimal point and a number, such as Section 2B.03 – Size of Regulatory Signs.

18 Each Section is comprised of one or more paragraphs. The paragraphs are indented and are identified by a number. Paragraphs are counted from the beginning of each Section without regard to the intervening text headings (Standard, Guidance, Option, or Support). Some paragraphs have lettered or numbered items. As an example of how to cite this Manual, the phrase "Not less than 40 feet beyond the stop line" that appears in Section 4D.14 of this Manual would be referenced in writing as "Section 4D.14, P1, A.1," and would be verbally referenced as "Item A.1 of Paragraph 1 of Section 4D.14."

Standard:

19 **In accordance with 23 CFR 655.603(b)(3), States or other Federal agencies that have their own MUTCDs or Supplements shall revise these MUTCDs or Supplements to be in substantial conformance with changes to the National MUTCD within 2 years of the effective date of the Final Rule for the changes. Substantial conformance of such State or other Federal agency MUTCDs or Supplements shall be as defined in 23 CFR 655.603(b)(1).**

20 **After the effective date of a new edition of the MUTCD or a revision thereto, or after the adoption thereof by the State, whichever occurs later, new or reconstructed devices installed shall be in compliance with the new edition or revision.**

21 **In cases involving Federal-aid projects for new highway or bikeway construction or reconstruction, the traffic control devices installed (temporary or permanent) shall be in conformance with the most recent edition of the National MUTCD before that highway is opened or re-opened to the public for unrestricted travel [23 CFR 655.603(d)(2) and (d)(3)].**

22 **Unless a particular device is no longer serviceable, non-compliant devices on existing highways and bikeways shall be brought into compliance with the current edition of the National MUTCD as part of the systematic upgrading of substandard traffic control devices (and installation of new required traffic control devices) required pursuant to the Highway Safety Program, 23 U.S.C. §402(a). The FHWA has the authority to establish other target compliance dates for implementation of particular changes to the MUTCD [23 CFR 655.603(d)(1)]. These target compliance dates established by the FHWA shall be as shown in Table I-2.**

23 **Except as provided in Paragraph 24, when a non-compliant traffic control device is being replaced or refurbished because it is damaged, missing, or no longer serviceable for any reason, it shall be replaced with a compliant device.**

Option:

24 A damaged, missing, or otherwise non-serviceable device that is non-compliant may be replaced in kind if engineering judgment indicates that:

A. One compliant device in the midst of a series of adjacent non-compliant devices would be confusing to road users; and/or
B. The schedule for replacement of the whole series of non-compliant devices will result in achieving timely compliance with the MUTCD.

Table I-2. Target Compliance Dates Established by the FHWA (Sheet 1 of 3)

2009 MUTCD Section Number(s)	2009 MUTCD Section Title	Specific Provision	Compliance Date
2A.08	Minimum Retroreflectivity Levels	Implementation and continued use of an assessment or management method that is designed to maintain traffic sign retroreflectivity at or above the established minimum levels	January 22, 2012 (c)
2A.08	Minimum Retroreflectivity Levels	Replacement of regulatory, warning, and post-mounted guide (except street name) signs that are identified using the assessment or management method as failing to meet the established minimum levels	January 22, 2015 (c)
2A.08	Minimum Retroreflectivity Levels	Replacement of street name signs and overhead guide signs that are identified using the assessment or management method as failing to meet the established minimum levels	January 22, 2018 (c)
2A.19	Lateral Offset	Crashworthiness of sign supports on roads with posted speed limit of 50 mph or higher	January 17, 2013 (a)
2B.03	Size of Regulatory Signs	Increased sign sizes and other 2003 MUTCD revisions to Table 2B-1 (*)	December 22, 2013 (b)
2B.09	YIELD Sign Applications	Changes in YIELD sign application criteria from the 1988 MUTCD to the 2003 MUTCD (*)	January 17, 2011 (a)
2B.10	STOP Sign or YIELD Sign Placement	Signs mounted on the back of STOP or YIELD signs should not obscure shape of STOP sign, with exception for DO NOT ENTER signs (2003 MUTCD Sections 2B.06 and 2B.10) (*)	December 22, 2013 (b)
2B.11	Yield Here To Pedestrians Signs and Stop Here For Pedestrians Signs (R1-5 Series)	New Section 2B.11 in the 2003 MUTCD (*)	December 22, 2013 (b)
2B.13	Speed Limit Sign (R2-1)	Color of changeable message legend of YOUR SPEED legend	December 22, 2013 (b)
2B.26	Reversible Lane Control Signs (R3-9e through R3-9i)	Removal of the R3-9c and R3-9e signs that had been included in the 2000 MUTCD (2003 MUTCD Section 2B.25)	December 22, 2013 (b)
2B.40	ONE WAY Signs (R6-1, R6-2)	New requirement in the 2009 MUTCD for the number and locations of ONE WAY signs	December 31, 2019
2B.55	Photo Enforced Signs and Plaques (R10-18, R10-19P, R10-19aP)	New signs (2003 MUTCD Section 2B.46) (*)	December 22, 2013 (b)
2C.04	Size of Warning Signs	New sizes in the 2003 MUTCD for the W1 Series arrow signs, the W12-2a low clearance signs, the W7 Series runaway truck signs, and the W10-1 advance grade crossing sign (*)	December 22, 2013 (b)
2C.06 thru 2C.14	Horizontal Alignment Warning Signs	Revised requirements in the 2009 MUTCD regarding the use of various horizontal alignment signs	December 31, 2019
2C.13	Truck Rollover Warning Sign (W1-13)	New W1-13 sign (2003 MUTCD Section 2C.11)	December 22, 2013 (b)
2C.20	NARROW BRIDGE Sign (W5-2)	Elimination of symbol sign (2003 MUTCD Section 2C.16)	December 22, 2013 (b)
2C.30	PAVEMENT ENDS Sign (W8-3)	Removal of symbol sign (2000 MUTCD Section 2C.23)	January 17, 2011 (a)
2C.38	Reduced Speed Limit Ahead Signs (W3-5, W3-5a)	Removal of R2-5 Series Reduced Speed Ahead signs and use of W3-5 or W3-5a warning signs instead (2003 MUTCD Section 2C.30)	December 22, 2018 (b)
2C.40	Merge Signs (W4-1, W4-5)	New Entering Roadway Merge sign (W4-5) (2003 MUTCD Section 2C.31)	December 22, 2013 (b)
2C.41	Added Lane Signs (W4-3, W4-6)	New Entering Roadway Added Lane sign (W4-6) (2003 MUTCD Section 2C.32)	December 22, 2013 (b)
2C.42	Lane Ends Signs (W4-2, W9-1, W9-2)	New design of W4-2 sign (2003 MUTCD Section 2C.33)	December 22, 2013 (b)
2C.46	Intersection Warning Signs (W2-1 through W2-8)	New design of Circular Intersection (W2-6) sign (2003 MUTCD Section 2C.37)	December 22, 2013 (b)
2C.49	Vehicular Traffic Warning Signs	New symbol signs W11-1, W11-5, W11-5a, W11-6, W11-11, and W11-14 (2003 MUTCD Section 2C.40)	December 22, 2013 (b)

Table I-2. Target Compliance Dates Established by the FHWA (Sheet 2 of 3)

2009 MUTCD Section Number(s)	2009 MUTCD Section Title	Specific Provision	Compliance Date
2C.50	Non-Vehicular Warning Signs	Elimination of crosswalk lines from crossing signs and use of diagonal downward pointing arrow (W16-7P) supplemental plaque if at the crossing (2003 MUTCD Section 2C.41)	January 17, 2011 (a)(b)
2C.61	PHOTO ENFORCED Plaque (W16-10P)	New plaque (2003 MUTCD Section 2C.53) (*)	December 22, 2013 (b)
2C.63	Object Marker Design and Placement Height	Width of stripes on Type 3 striped marker (2003 MUTCD Section 3C.01)	December 22, 2013 (b)
2D.43	Street Name Signs (D3-1 or D3-1a)	6-inch letter height for lettering on post-mounted Street Name signs (except on multi-lane streets with speed limits greater than 40 mph) (2000 MUTCD Section 2D.38)	January 9, 2012 (a)
2D.43	Street Name Signs (D3-1 or D3-1a)	8-inch letter height on post-mounted signs on multi-lane streets with speed limits greater than 40 mph and 12-inch letter height on overhead signs (2003 MUTCD Section 2D.38)	December 22, 2018 (b)
2D.44	Advance Street Name Signs (D3-2)	Requirements of new Section 2D.39 in the 2003 MUTCD	December 22, 2018 (b)
2D.45	Signing on Conventional Roads on Approaches to Interchanges	New requirement in the 2009 MUTCD for multi-lane approaches to interchanges to have guide signs to identify which direction of turn is to be made for access to each direction of the freeway or expressway	December 31, 2019
2E.31, 2E.33, and 2E.36	Plaques for Left-Hand Exits	New requirement in the 2009 MUTCD to use E1-5aP and E1-5bP plaques for left-hand exits	December 31, 2014
2G.01 through 2G.07	Regulatory Signs for Preferential Lanes	Requirements for regulatory signs for preferential lanes (2003 MUTCD Sections 2B.26 through 2B.28) (*)	December 22, 2013 (b)
2G.11 through 2G.15	Preferential Lane Guide Signs	New Section 2E.59 in the 2003 MUTCD (*)	December 22, 2013 (b)
2H.02, 2H.03	Reference Location Signs, Intermediate Reference Location Signs, and Enhanced Reference Location Signs	Location and spacing of Reference Location Signs and design of Intermediate Reference Location signs (2003 MUTCD Sections 2D.46 and 2E.54)	December 22, 2013 (b)
2I.07	Radio Information Signing	New Channel 9 Monitored (D12-3) sign (2003 MUTCD Section 2D.45)	December 22, 2013 (b)
2I.08	TRAVEL INFO CALL 511 Signs (D12-5 and D12-5a)	New TRAVEL INFO CALL 511 Sign (D12-5) (2003 MUTCD Section 2D.45)	December 22, 2013 (b)
2J.05	Size of Lettering	Minimum height of letters and numerals on Specific Service signs (2000 MUTCD Section 2F.05)	January 17, 2011 (a)
2N.03	Evacuation Route Signs (EM-1 and EM-1a)	New design and size of EM-1 sign (2003 MUTCD Section 2I.03)	December 22, 2018 (b)
3B.04, 3B.05	White Longitudinal Pavement Markings	New requirement in the 2009 MUTCD for dotted lane lines for dropped lanes and for acceleration, deceleration, and auxiliary lanes	December 31, 2016 or resurfacing, whichever occurs first
3B.18	Crosswalk Markings	Gap between transverse lines of a crosswalk (2003 MUTCD Section 3B.17)	December 22, 2013 (b)
4D.01	General	Location of signalized midblock crosswalks	December 22, 2013 (b)
4D.26	Yellow Change and Red Clearance Intervals	New requirement in the 2009 MUTCD that durations of yellow change and red clearance intervals shall be determined using engineering practices	December 31, 2014, or when timing adjustments are made to the individual intersection and/or corridor, whichever occurs first
4D.31	Flashing Operation—Transition Out of Flashing Mode	Duration of steady red clearance interval in change from red-red flashing mode to steady (stop-and-go) mode (2003 MUTCD Section 4D.12)	December 22, 2013 (b)
4E.06	Pedestrian Intervals and Signal Phases	New requirement in the 2009 MUTCD that the pedestrian change interval shall not extend into the red clearance interval and shall be followed by a buffer interval of at least 3 seconds	December 31, 2014, or when timing adjustments are made to the individual intersection and/or corridor, whichever occurs first
4E.07	Countdown Pedestrian Signals	Pedestrian countdown hardware requirements	December 22, 2013 (b)

Table I-2. Target Compliance Dates Established by the FHWA (Sheet 3 of 3)

2009 MUTCD Section Number(s)	2009 MUTCD Section Title	Specific Provision	Compliance Date
5C.05	NARROW BRIDGE Sign (W5-2)	Elimination of symbol signs	December 22, 2013 (b)
6D.03	Worker Safety Considerations	New requirement in the 2009 MUTCD that all workers within the right-of-way shall wear high-visibility apparel	December 31, 2011
6E.02	High-Visibility Safety Apparel	New requirement in the 2009 MUTCD that all flaggers within the right-of-way shall wear high-visibility apparel	December 31, 2011
7B.11	School Advance Crossing Assembly	Use of AHEAD (W16-9P) plaque or distance plaque (W16-2P or W16-2aP) (2000 MUTCD Section 7B.08)	January 17, 2011 (a)
7B.12	School Crossing Assembly	Elimination of crosswalk lines from crossing signs and use of diagonal downward pointing arrow (W16-7P) supplemental plaque (2000 MUTCD Sections 7B.08 and 7B.09)	January 17, 2011 (a)
7B.16	Reduced Schoool Speed Limit Ahead Sign (S4-5, S4-5a)	Removal of R2-5 Series Reduced Speed Ahead signs and use of S4-5 or S4-5a warning signs instead (2003 MUTCD Section 7B.12)	December 22, 2018 (b)
7D.04	Uniform of Adult Crossing Guards	New requirement in the 2009 MUTCD for high-visibility apparel for adult crossing guards	December 31, 2011
8B.03	Grade Crossing (Crossbuck) Sign (R15-1) and Number of Tracks Plaque (R15-2P) at Active and Passive Grade Crossings	Retroreflective strip on crossbuck support (2000 MUTCD Section 8B.02) (*)	January 17, 2011 (a)
8B.04	Crossbuck Assemblies with YIELD or STOP Signs at Passive Grade Crossings	New requirement in the 2009 MUTCD for the use of STOP or YIELD signs with Crossbuck signs at passive grade crossings	December 31, 2019
8B.19 and 8C.02 through 8C.05	LRT Approaching-Activated Blank-Out Warning Sign, Flashing Light Signals, and Automatic Gates	Automatic gates, flashing-light signals, and blank-out signs at highway-LRT crossings per Part 10 of the 2000 MUTCD (*)	January 17, 2011 (a)
8C.09	Traffic Control Signals at or Near Highway-Rail Grade Crossings	Pre-signals (2003 MUTCD Section 8D.07)	December 22, 2013 (b)
8C.12	Grade Crossings Within or In Close Proximity to Circular Intersections	New requirement in the 2009 MUTCD for study of grade crossings near roundabouts	December 31, 2014
9B.18	Bicycle Warning and Combined Bicycle/Pedestrian Signs (W11-1 and W11-15)	Elimination of crosswalk lines from crossing signs and use of diagonal downward pointing arrow (W16-7P) supplemental plaque if at the crossing (2000 MUTCD Section 9B.15)	January 17, 2011 (a)

Notes: Unless otherwise noted, dates are as established in the Final Rule for the 2009 MUTCD.
(a) Date established in the Final Rule for the 2000 MUTCD
(b) Date established in the Final Rule for the 2003 MUTCD
(c) Date established in the Final Rule for Revision 2 of the 2003 MUTCD
(*) Provisions may have been revised in the 2009 MUTCD

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.*

Support:

03 An example of modifying a device's design would be to modify the Combination Horizontal Alignment/Intersection (W1-10) sign to show intersecting side roads on both sides rather than on just one side of the major road within the curve.

Option:

04 With the exception of symbols and colors, minor modifications in the specific design elements of a device may be made provided the essential appearance characteristics are preserved.

Section 1A.04 Placement and Operation of Traffic Control Devices

Guidance:

01 *Placement of a traffic control device should be within the road user's view so that adequate visibility is provided. To aid in conveying the proper meaning, the traffic control device should be appropriately positioned with respect to the location, object, or situation to which it applies. The location and legibility of the traffic control device should be such that a road user has adequate time to make the proper response in both day and night conditions.*

02 *Traffic control devices should be placed and operated in a uniform and consistent manner.*

03 *Unnecessary traffic control devices should be removed. The fact that a device is in good physical condition should not be a basis for deferring needed removal or change.*

Section 1A.05 Maintenance of Traffic Control Devices

Guidance:

01 *Functional maintenance of traffic control devices should be used to determine if certain devices need to be changed to meet current traffic conditions.*

02 *Physical maintenance of traffic control devices should be performed to retain the legibility and visibility of the device, and to retain the proper functioning of the device.*

Support:

03 Clean, legible, properly mounted devices in good working condition command the respect of road users.

Section 1A.06 Uniformity of Traffic Control Devices

Support:

01 Uniformity of devices simplifies the task of the road user because it aids in recognition and understanding, thereby reducing perception/reaction time. Uniformity assists road users, law enforcement officers, and traffic courts by giving everyone the same interpretation. Uniformity assists public highway officials through efficiency in manufacture, installation, maintenance, and administration. Uniformity means treating similar situations in a similar way. The use of uniform traffic control devices does not, in itself, constitute uniformity. A standard device used where it is not appropriate is as objectionable as a non-standard device; in fact, this might be worse, because such misuse might result in disrespect at those locations where the device is needed and appropriate.

Section 1A.07 Responsibility for Traffic Control Devices

Standard:

01 **The responsibility for the design, placement, operation, maintenance, and uniformity of traffic control devices shall rest with the public agency or the official having jurisdiction, or, in the case of private roads open to public travel, with the private owner or private official having jurisdiction. 23 CFR 655.603 adopts the MUTCD as the national standard for all traffic control devices installed on any street, highway, bikeway, or private road open to public travel (see definition in Section 1A.13). When a State or other Federal agency manual or supplement is required, that manual or supplement shall be in substantial conformance with the National MUTCD.**

02 **23 CFR 655.603 also states that traffic control devices on all streets, highways, bikeways, and private roads open to public travel in each State shall be in substantial conformance with standards issued or endorsed by the Federal Highway Administrator.**

Support:

03 The Introduction of this Manual contains information regarding the meaning of substantial conformance and the applicability of the MUTCD to private roads open to public travel.

04 The "Uniform Vehicle Code" (see Section 1A.11) has the following provision in Section 15-104 for the adoption of a uniform manual:

"(a) The [State Highway Agency] shall adopt a manual and specification for a uniform system of traffic control devices consistent with the provisions of this code for use upon highways within this State. Such uniform system shall correlate with and so far as possible conform to the system set forth in the most recent edition of the Manual on Uniform Traffic Control Devices for Streets and Highways, and other standards issued or endorsed by the Federal Highway Administrator."

"(b) The Manual adopted pursuant to subsection (a) shall have the force and effect of law."

05 All States have officially adopted the National MUTCD either in its entirety, with supplemental provisions, or as a separate published document.

Guidance:

06 *These individual State manuals or supplements should be reviewed for specific provisions relating to that State.*

Support:

07 The National MUTCD has also been adopted by the National Park Service, the U.S. Forest Service, the U.S. Military Command, the Bureau of Indian Affairs, the Bureau of Land Management, and the U.S. Fish and Wildlife Service.

Guidance:

08 *States should adopt Section 15-116 of the "Uniform Vehicle Code," which states that, "No person shall install or maintain in any area of private property used by the public any sign, signal, marking, or other device intended to regulate, warn, or guide traffic unless it conforms with the State manual and specifications adopted under Section 15-104."*

Section 1A.08 Authority for Placement of Traffic Control Devices

Standard:

01 **Traffic control devices, advertisements, announcements, and other signs or messages within the highway right-of-way shall be placed only as authorized by a public authority or the official having jurisdiction, or, in the case of private roads open to public travel, by the private owner or private official having jurisdiction, for the purpose of regulating, warning, or guiding traffic.**

02 **When the public agency or the official having jurisdiction over a street or highway or, in the case of private roads open to public travel, the private owner or private official having jurisdiction, has granted proper authority, others such as contractors and public utility companies shall be permitted to install temporary traffic control devices in temporary traffic control zones. Such traffic control devices shall conform with the Standards of this Manual.**

03 **All regulatory traffic control devices shall be supported by laws, ordinances, or regulations.**

Support:

04 Provisions of this Manual are based upon the concept that effective traffic control depends upon both appropriate application of the devices and reasonable enforcement of the regulations.

05 Although some highway design features, such as curbs, median barriers, guardrails, speed humps or tables, and textured pavement, have a significant impact on traffic operations and safety, they are not considered to be traffic control devices and provisions regarding their design and use are generally not included in this Manual.

06 Certain types of signs and other devices that do not have any traffic control purpose are sometimes placed within the highway right-of-way by or with the permission of the public agency or the official having jurisdiction over the street or highway. Most of these signs and other devices are not intended for use by road users in general, and their message is only important to individuals who have been instructed in their meanings. These signs and other devices are not considered to be traffic control devices and provisions regarding their design and use are not included in this Manual. Among these signs and other devices are the following:

A. Devices whose purpose is to assist highway maintenance personnel. Examples include markers to guide snowplow operators, devices that identify culvert and drop inlet locations, and devices that precisely identify highway locations for maintenance or mowing purposes.
B. Devices whose purpose is to assist fire or law enforcement personnel. Examples include markers that identify fire hydrant locations, signs that identify fire or water district boundaries, speed measurement pavement markings, small indicator lights to assist in enforcement of red light violations, and photo enforcement systems.
C. Devices whose purpose is to assist utility company personnel and highway contractors, such as markers that identify underground utility locations.
D. Signs posting local non-traffic ordinances.
E. Signs giving civic organization meeting information.

Standard:

07 **Signs and other devices that do not have any traffic control purpose that are placed within the highway right-of-way shall not be located where they will interfere with, or detract from, traffic control devices.**

Guidance:

08 *Any unauthorized traffic control device or other sign or message placed on the highway right-of-way by a private organization or individual constitutes a public nuisance and should be removed. All unofficial or non-essential traffic control devices, signs, or messages should be removed.*

Section 1A.09 Engineering Study and Engineering Judgment

Support:

01 Definitions of an engineering study and engineering judgment are contained in Section 1A.13.

Standard:

02 **This Manual describes the application of traffic control devices, but shall not be a legal requirement for their installation.**

Guidance:

03 *Early in the processes of location and design of roads and streets, engineers should coordinate such location and design with the design and placement of the traffic control devices to be used with such roads and streets.*

04 *Jurisdictions, or owners of private roads open to public travel, with responsibility for traffic control that do not have engineers on their staffs who are trained and/or experienced in traffic control devices should seek engineering assistance from others, such as the State transportation agency, their county, a nearby large city, or a traffic engineering consultant.*

Support:

05 As part of the Federal-aid Program, each State is required to have a Local Technology Assistance Program (LTAP) and to provide technical assistance to local highway agencies. Requisite technical training in the application of the principles of the MUTCD is available from the State's Local Technology Assistance Program for needed engineering guidance and assistance.

Section 1A.10 Interpretations, Experimentations, Changes, and Interim Approvals

Standard:

01 **Design, application, and placement of traffic control devices other than those adopted in this Manual shall be prohibited unless the provisions of this Section are followed.**

Support:

02 Continuing advances in technology will produce changes in the highway, vehicle, and road user proficiency; therefore, portions of the system of traffic control devices in this Manual will require updating. In addition, unique situations often arise for device applications that might require interpretation or clarification of this Manual. It is important to have a procedure for recognizing these developments and for introducing new ideas and modifications into the system.

Standard:

03 **Except as provided in Paragraph 4, requests for any interpretation, permission to experiment, interim approval, or change shall be submitted electronically to the Federal Highway Administration (FHWA), Office of Transportation Operations, MUTCD team, at the following e-mail address: MUTCDofficialrequest@dot.gov.**

Option:

04 If electronic submittal is not possible, requests for interpretations, permission to experiment, interim approvals, or changes may instead be mailed to the Office of Transportation Operations, HOTO-1, Federal Highway Administration, 1200 New Jersey Avenue, SE, Washington, DC 20590.

Support:

05 Communications regarding other MUTCD matters that are not related to official requests will receive quicker attention if they are submitted electronically to the MUTCD Team Leader or to the appropriate individual MUTCD team member. Their e-mail addresses are available through the links contained on the "Who's Who" page on the MUTCD website at http://mutcd.fhwa.dot.gov/team.htm.

06 An interpretation includes a consideration of the application and operation of standard traffic control devices, official meanings of standard traffic control devices, or the variations from standard device designs.

Guidance:

07 *Requests for an interpretation of this Manual should contain the following information:*

A. *A concise statement of the interpretation being sought;*
B. *A description of the condition that provoked the need for an interpretation;*
C. *Any illustration that would be helpful to understand the request; and*
D. *Any supporting research data that is pertinent to the item to be interpreted.*

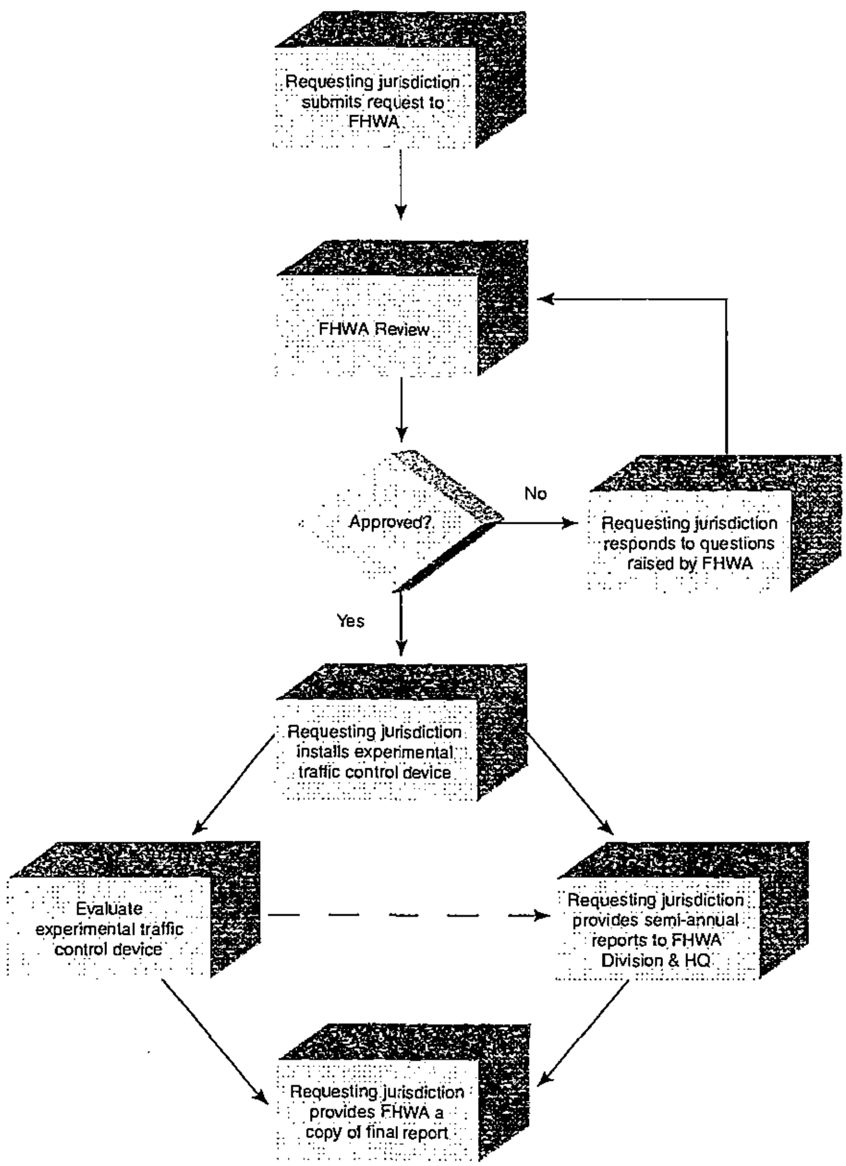
Support:

08 Requests to experiment include consideration of field deployment for the purpose of testing or evaluating a new traffic control device, its application or manner of use, or a provision not specifically described in this Manual.

09 A request for permission to experiment will be considered only when submitted by the public agency or toll facility operator responsible for the operation of the road or street on which the experiment is to take place. For a private road open to public travel, the request will be considered only if it is submitted by the private owner or private official having jurisdiction.

10 A diagram indicating the process for experimenting with traffic control devices is shown in Figure 1A-1.

Figure 1A-1. Process for Requesting and Conducting Experimentations for New Traffic Control Devices



Guidance:

11 *The request for permission to experiment should contain the following:*

A. A statement indicating the nature of the problem.
B. A description of the proposed change to the traffic control device or application of the traffic control device, how it was developed, the manner in which it deviates from the standard, and how it is expected to be an improvement over existing standards.
C. Any illustration that would be helpful to understand the traffic control device or use of the traffic control device.
D. Any supporting data explaining how the traffic control device was developed, if it has been tried, in what ways it was found to be adequate or inadequate, and how this choice of device or application was derived.
E. A legally binding statement certifying that the concept of the traffic control device is not protected by a patent or copyright. (An example of a traffic control device concept would be countdown pedestrian signals in general. Ordinarily an entire general concept would not be patented or copyrighted, but if it were it would not be acceptable for experimentation unless the patent or copyright owner signs a waiver of rights acceptable to the FHWA. An example of a patented or copyrighted specific device within the general concept of countdown pedestrian signals would be a manufacturer's design for its specific brand of countdown signal, including the design details of the housing or electronics that are unique to that manufacturer's product. As long as the general concept is not patented or copyrighted, it is acceptable for experimentation to incorporate the use of one or more patented devices of one or several manufacturers.)
F. The time period and location(s) of the experiment.
G. A detailed research or evaluation plan that must provide for close monitoring of the experimentation, especially in the early stages of its field implementation. The evaluation plan should include before and after studies as well as quantitative data describing the performance of the experimental device.
H. An agreement to restore the site of the experiment to a condition that complies with the provisions of this Manual within 3 months following the end of the time period of the experiment. This agreement must also provide that the agency sponsoring the experimentation will terminate the experimentation at any time that it determines significant safety concerns are directly or indirectly attributable to the experimentation. The FHWA's Office of Transportation Operations has the right to terminate approval of the experimentation at any time if there is an indication of safety concerns. If, as a result of the experimentation, a request is made that this Manual be changed to include the device or application being experimented with, the device or application will be permitted to remain in place until an official rulemaking action has occurred.
I. An agreement to provide semi-annual progress reports for the duration of the experimentation, and an agreement to provide a copy of the final results of the experimentation to the FHWA's Office of Transportation Operations within 3 months following completion of the experimentation. The FHWA's Office of Transportation Operations has the right to terminate approval of the experimentation if reports are not provided in accordance with this schedule.

Support:

12 A change includes consideration of a new device to replace a present standard device, an additional device to be added to the list of standard devices, or a revision to a traffic control device application or placement criteria.

Guidance:

13 *Requests for a change to this Manual should contain the following information:*

A. A statement indicating what change is proposed;
B. Any illustration that would be helpful to understand the request; and
C. Any supporting research data that is pertinent to the item to be reviewed.

Support:

14 Interim approval allows interim use, pending official rulemaking, of a new traffic control device, a revision to the application or manner of use of an existing traffic control device, or a provision not specifically described in this Manual. The FHWA issues an Interim Approval by official memorandum signed by the Associate Administrator for Operations and posts this memorandum on the MUTCD website. the issuance by FHWA of an interim approval will typically result in the traffic control device or application being placed into the next scheduled rulemaking process for revisions to this Manual.

15 Interim approval is considered based on the results of successful experimentation, results of analytical or laboratory studies, and/or review of non-U.S. experience with a traffic control device or application. Interim approval considerations include an assessment of relative risks, benefits, costs, impacts, and other factors.

16 Interim approval allows for optional use of a traffic control device or application and does not create a new mandate or recommendation for use. Interim approval includes conditions that jurisdictions agree to comply with in order to use the traffic control device or application until an official rulemaking action has occurred.

Standard:

17 **A jurisdiction, toll facility operator, or owner of a private road open to public travel that desires to use a traffic control device for which FHWA has issued an interim approval shall request permission from FHWA.**

Guidance:

18 *The request for permission to place a traffic control device under an interim approval should contain the following:*

- A. *A description of where the device will be used, such as a list of specific locations or highway segments or types of situations, or a statement of the intent to use the device jurisdiction-wide;*
- B. *An agreement to abide by the specific conditions for use of the device as contained in the FHWA's interim approval document;*
- C. *An agreement to maintain and continually update a list of locations where the device has been installed; and*
- D. *An agreement to:*
  1. *Restore the site(s) of the interim approval to a condition that complies with the provisions in this Manual within 3 months following the issuance of a Final Rule on this traffic control device; and*
  2. *Terminate use of the device or application installed under the interim approval at any time that it determines significant safety concerns are directly or indirectly attributable to the device or application. The FHWA's Office of Transportation Operations has the right to terminate the interim approval at any time if there is an indication of safety concerns.*

Option:

19 A State may submit a request for the use of a device under interim approval for all jurisdictions in that State, as long as the request contains the information listed in Paragraph 18.

Guidance:

20 *A local jurisdiction, toll facility operator, or owner of a private road open to public travel using a traffic control device or application under an interim approval that was granted by FHWA either directly or on a statewide basis based on the State's request should inform the State of the locations of such use.*

21 *A local jurisdiction, toll facility operator, or owner of a private road open to public travel that is requesting permission to experiment or permission to use a device or application under an interim approval should first check for any State laws and/or directives covering the application of the MUTCD provisions that might exist in their State.*

Option:

22 A device or application installed under an interim approval may remain in place, under the conditions established in the interim approval, until an official rulemaking action has occurred.

Support:

23 A diagram indicating the process for incorporating new traffic control devices into this Manual is shown in Figure 1A-2.

24 For additional information concerning interpretations, experimentation, changes, or interim approvals, visit the MUTCD website at http://mutcd.fhwa.dot.gov.

Section 1A.11 Relation to Other Publications

Standard:

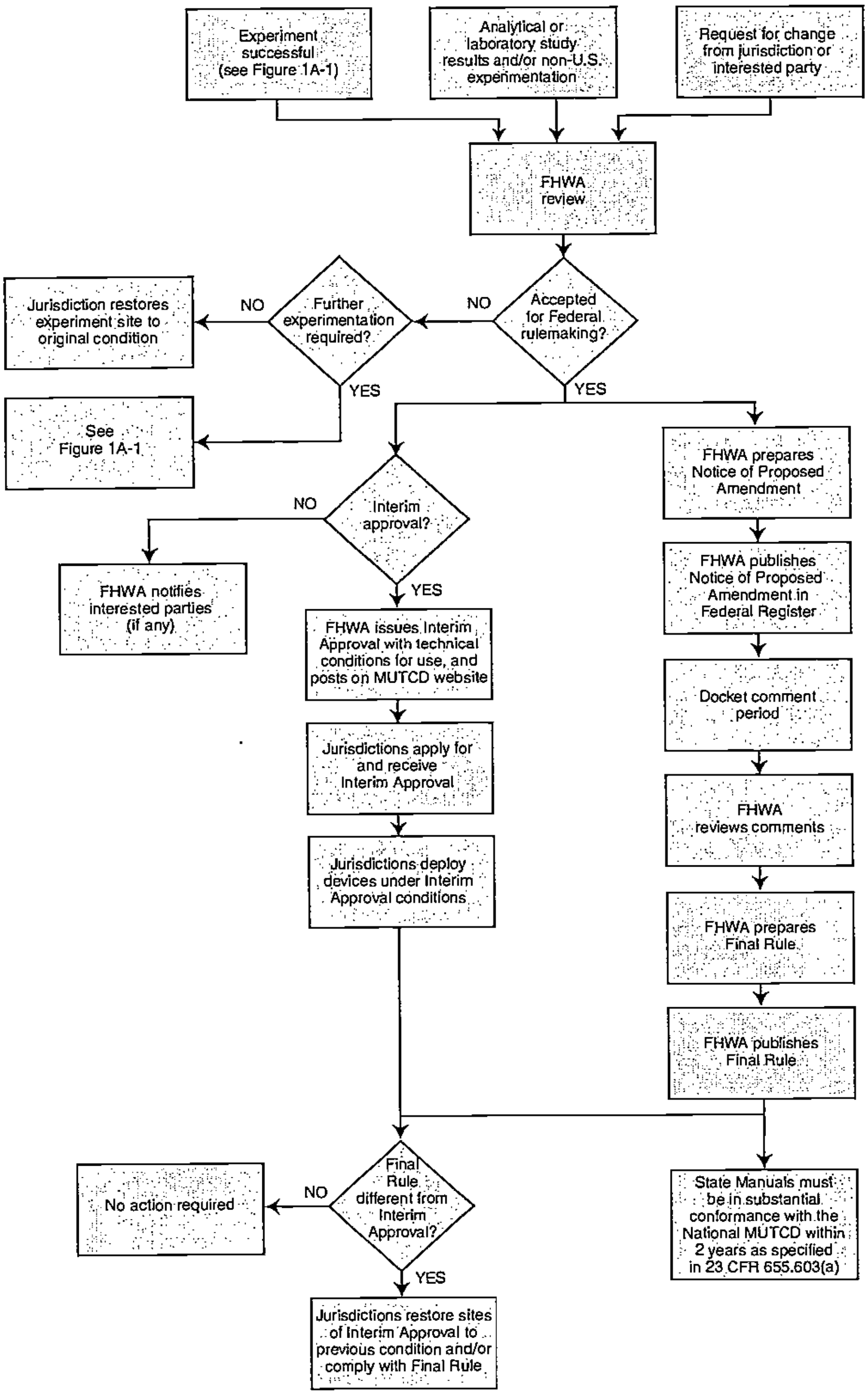
01 **To the extent that they are incorporated by specific reference, the latest editions of the following publications, or those editions specifically noted, shall be a part of this Manual: "Standard Highway Signs and Markings" book (FHWA); and "Color Specifications for Retroreflective Sign and Pavement Marking Materials" (appendix to subpart F of Part 655 of Title 23 of the Code of Federal Regulations).**

Support:

02 The "Standard Highway Signs and Markings" book includes standard alphabets and symbols and arrows for signs and pavement markings.

03 For information about the publications mentioned in Paragraph 1, visit the Federal Highway Administration's MUTCD website at http://mutcd.fhwa.dot.gov, or write to the FHWA, 1200 New Jersey Avenue, SE, HOTO, Washington, DC 20590.

Figure 1A-2. Process for Incorporating New Traffic Control Devices into the MUTCD



04 Other publications that are useful sources of information with respect to the use of this Manual are listed in this paragraph. See Page i of this Manual for ordering information for the following publications (later editions might also be available as useful sources of information):

1. "AAA School Safety Patrol Operations Manual," 2006 Edition (American Automobile Association—AAA)
2. "A Policy on Geometric Design of Highways and Streets," 2004 Edition (American Association of State Highway and Transportation Officials—AASHTO)
3. "Guide for the Development of Bicycle Facilities," 1999 Edition (AASHTO)
4. "Guide for the Planning, Design, and Operation of Pedestrian Facilities," 2004 Edition (AASHTO)
5. "Guide to Metric Conversion," 1993 Edition (AASHTO)
6. "Guidelines for the Selection of Supplemental Guide Signs for Traffic Generators Adjacent to Freeways," 4th Edition/Guide Signs, Part II: Guidelines for Airport Guide Signing/Guide Signs, Part III: List of Control Cities for Use in Guide Signs on Interstate Highways," Item Code: GSGLC-4, 2001 Edition (AASHTO)
7. "Roadside Design Guide," 2006 Edition (AASHTO)
8. "Standard Specifications for Movable Highway Bridges," 1988 Edition (AASHTO)
9. "Traffic Engineering Metric Conversion Folders—Addendum to the Guide to Metric Conversion," 1993 Edition (AASHTO)
10. "2009 AREMA Communications & Signals Manual," (American Railway Engineering & Maintenance-of-Way Association—AREMA)
11. "Changeable Message Sign Operation and Messaging Handbook (FHWA-OP-03-070)," 2004 Edition (Federal Highway Administration—FHWA)
12. "Designing Sidewalks and Trails for Access—Part 2—Best Practices Design Guide (FHWA-EP-01-027)," 2001 Edition (FHWA)
13. "Federal-Aid Highway Program Guidance on High Occupancy Vehicle (HOV) Lanes," 2001 (FHWA)
14. "Maintaining Traffic Sign Retroreflectivity," 2007 Edition (FHWA)
15. "Railroad-Highway Grade Crossing Handbook—Revised Second Edition (FHWA-SA-07-010)," 2007 Edition (FHWA)
16. "Ramp Management and Control Handbook (FHWA-HOP-06-001)," 2006 Edition (FHWA)
17. "Roundabouts-An Informational Guide (FHWA-RD-00-067)," 2000 Edition (FHWA)
18. "Signal Timing Manual (FHWA-HOP-08-024)," 2008 Edition (FHWA)
19. "Signalized Intersections: an Informational Guide (FHWA-HRT-04-091)," 2004 Edition (FHWA)
20. "Travel Better, Travel Longer: A Pocket Guide to Improving Traffic Control and Mobility for Our Older Population (FHWA-OP-03-098)," 2003 Edition (FHWA)
21. "Practice for Roadway Lighting," RP-8, 2001 (Illuminating Engineering Society—IES)
22. "Safety Guide for the Prevention of Radio Frequency Radiation Hazards in the Use of Commercial Electric Detonators (Blasting Caps)," Safety Library Publication No. 20, July 2001 Edition (Institute of Makers of Explosives)
23. "American National Standard for High-Visibility Public Safety Vests," (ANSI/ISEA 207-2006), 2006 Edition (International Safety Equipment Association—ISEA)
24. "American National Standard for High-Visibility Safety Apparel and Headwear," (ANSI/ISEA 107-2004), 2004 Edition (ISEA)
25. "Manual of Traffic Signal Design," 1998 Edition (Institute of Transportation Engineers—ITE)
26. "Manual of Transportation Engineering Studies," 1994 Edition (ITE)
27. "Pedestrian Traffic Control Signal Indications," Part 1—1985 Edition; Part 2 (LED Pedestrian Traffic Signal Modules)—2004 Edition (ITE)
28. "Preemption of Traffic Signals Near Railroad Crossings," 2006 Edition (ITE)
29. "Purchase Specification for Flashing and Steady Burn Warning Lights," 1981 Edition (ITE)
30. "Traffic Control Devices Handbook," 2001 Edition (ITE)
31. "Traffic Detector Handbook," 1991 Edition (ITE)
32. "Traffic Engineering Handbook," 2009 Edition (ITE)
33. "Traffic Signal Lamps," 1980 Edition (ITE)
34. "Vehicle Traffic Control Signal Heads," Part 1—1985 Edition; Part 2 (LED Circular Signal Supplement)—2005 Edition; Part 3 (LED Vehicular Arrow Traffic Signal Supplement)—2004 Edition (ITE)
35. "Uniform Vehicle Code (UVC) and Model Traffic Ordinance," 2000 Edition (National Committee on Uniform Traffic Laws and Ordinances—NCUTLO)
36. "NEMA Standards Publication TS 4-2005 Hardware Standards for Dynamic Message Signs (DMS) With NTCIP Requirements," 2005 Edition (National Electrical Manufacturers Association—NEMA)
37. "Occupational Safety and Health Administration Regulations (Standards - 29 CFR), General Safety and Health Provisions - 1926.20," amended June 30, 1993 (Occupational Safety and Health Administration—OSHA)
38. "Accessible Pedestrian Signals—A Guide to Best Practices (NCHRP Web-Only Document 117A)," 2008 Edition (Transportation Research Board—TRB)

39. "Guidelines for Accessible Pedestrian Signals (NCHRP Web-Only Document 117B)," 2008 Edition (TRB)
40. "Highway Capacity Manual," 2000 Edition (TRB)
41. "Recommended Procedures for the Safety Performance Evaluation of Highway Features," (NCHRP Report 350), 1993 Edition (TRB)
42. "The Americans with Disabilities Act Accessibility Guidelines for Buildings and Facilities (ADAAG)," July 1998 Edition (The U.S. Access Board)

Section 1A.12 Color Code

Support:

01 The following color code establishes general meanings for 11 colors of a total of 13 colors that have been identified as being appropriate for use in conveying traffic control information. tolerance limits for each color are contained in 23 CFR Part 655, Appendix to Subpart F and are available at the Federal Highway Administration's MUTCD website at http://mutcd.fhwa.dot.gov or by writing to the FHWA, Office of Safety Research and Development (HRD-T-301), 6300 Georgetown Pike, McLean, VA 22101.

02 The two colors for which general meanings have not yet been assigned are being reserved for future applications that will be determined only by FHWA after consultation with the States, the engineering community, and the general public. The meanings described in this Section are of a general nature. More specific assignments of colors are given in the individual Parts of this Manual relating to each class of devices.

Standard:

03 **The general meaning of the 13 colors shall be as follows:**

A. Black—regulation
B. Blue—road user services guidance, tourist information, and evacuation route
C. Brown—recreational and cultural interest area guidance
D. Coral—unassigned
E. Fluorescent Pink—incident management
F. Fluorescent Yellow-Green—pedestrian warning, bicycle warning, playground warning, school bus and school warning
G. Green—indicated movements permitted, direction guidance
H. Light Blue—unassigned
I. Orange—temporary traffic control
J. Purple—lanes restricted to use only by vehicles with registered electronic toll collection (ETC) accounts
K. Red—stop or prohibition
L. White—regulation
M. Yellow—warning

Section 1A.13 Definitions of Headings, Words, and Phrases in this Manual

Standard:

01 **When used in this Manual, the text headings of Standard, Guidance, Option, and Support shall be defined as follows:**

A. Standard—a statement of required, mandatory, or specifically prohibitive practice regarding a traffic control device. All Standard statements are labeled, and the text appears in bold type. The verb "shall" is typically used. The verbs "should" and "may" are not used in Standard statements. Standard statements are sometimes modified by Options. Standard statements shall not be modified or compromised based on engineering judgment or engineering study.

B. Guidance—a statement of recommended, but not mandatory, practice in typical situations, with deviations allowed if engineering judgment or engineering study indicates the deviation to be appropriate. All Guidance statements are labeled, and the text appears in unbold type. The verb "should" is typically used. The verbs "shall" and "may" are not used in Guidance statements. Guidance statements are sometimes modified by Options.

C. Option—a statement of practice that is a permissive condition and carries no requirement or recommendation. Option statements sometime contain allowable modifications to a Standard or Guidance statement. All Option statements are labeled, and the text appears in unbold type. The verb "may" is typically used. The verbs "shall" and "should" are not used in Option statements.

D. Support—an informational statement that does not convey any degree of mandate, recommendation, authorization, prohibition, or enforceable condition. Support statements are labeled, and the text appears in unbold type. The verbs "shall," "should," and "may" are not used in Support statements.

02 Unless otherwise defined in this Section, or in other Parts of this Manual, words or phrases shall have the meaning(s) as defined in the most recent editions of the "Uniform Vehicle Code," "AASHTO Transportation Glossary (Highway Definitions)," and other publications mentioned in Section 1A.11.

03 The following words and phrases, when used in this Manual, shall have the following meanings:

1. Accessible Pedestrian Signal—a device that communicates information about pedestrian signal timing in non-visual format such as audible tones, speech messages, and/or vibrating surfaces.
2. Accessible Pedestrian Signal Detector—a device designated to assist the pedestrian who has visual or physical disabilities in activating the pedestrian phase.
3. Active Grade Crossing Warning System—the flashing-light signals, with or without warning gates, together with the necessary control equipment used to inform road users of the approach or presence of rail traffic at grade crossings.
4. Actuated Operation—a type of traffic control signal operation in which some or all signal phases are operated on the basis of actuation.
5. Actuation—initiation of a change in or extension of a traffic signal phase through the operation of any type of detector.
6. Advance Preemption—the notification of approaching rail traffic that is forwarded to the highway traffic signal controller unit or assembly by the railroad or light rail transit equipment in advance of the activation of the railroad or light rail transit warning devices.
7. Advance Preemption Time—the period of time that is the difference between the required maximum highway traffic signal preemption time and the activation of the railroad or light rail transit warning devices.
8. Advisory Speed—a recommended speed for all vehicles operating on a section of highway and based on the highway design, operating characteristics, and conditions.
9. Alley—a street or highway intended to provide access to the rear or side of lots or buildings in urban areas and not intended for the purpose of through vehicular traffic.
10. Altered Speed Zone—a speed limit, other than a statutory speed limit, that is based upon an engineering study.
11. Approach—all lanes of traffic moving toward an intersection or a midblock location from one direction, including any adjacent parking lane(s).
12. Arterial Highway (Street)—a general term denoting a highway primarily used by through traffic, usually on a continuous route or a highway designated as part of an arterial system.
13. Attended Lane (Manual Lane)—a toll lane adjacent to a toll booth occupied by a human toll collector who makes change, issues receipts, and perform other toll-related functions. Attended lanes at toll plazas typically require vehicles to stop to pay the toll.
14. Automatic Lane—see Exact Change Lane.
15. Average Annual Daily Traffic (AADT)—the total volume of traffic passing a point or segment of a highway facility in both directions for one year divided by the number of days in the year. Normally, periodic daily traffic volumes are adjusted for hours of the day counted, days of the week, and seasons of the year to arrive at average annual daily traffic.
16. Average Daily Traffic (ADT)—the average 24 hour volume, being the total volume during a stated period divided by the number of days in that period. Normally, this would be periodic daily traffic volumes over several days, not adjusted for days of the week or seasons of the year.
17. Average Day—a day representing traffic volumes normally and repeatedly found at a location, typically a weekday when volumes are influenced by employment or a weekend day when volumes are influenced by entertainment or recreation.
18. Backplate—see Signal Backplate.
19. Barrier-Separated Lane—a preferential lane or other special purpose lane that is separated from the adjacent general-purpose lane(s) by a physical barrier.
20. Beacon—a highway traffic signal with one or more signal sections that operates in a flashing mode.
21. Bicycle—a pedal-powered vehicle upon which the human operator sits.
22. Bicycle Facilities—a general term denoting improvements and provisions that accommodate or encourage bicycling, including parking and storage facilities, and shared roadways not specifically defined for bicycle use.
23. Bicycle Lane—a portion of a roadway that has been designated for preferential or exclusive use by bicyclists by pavement markings and, if used, signs.
24. Bikeway—a generic term for any road, street, path, or way that in some manner is specifically designated for bicycle travel, regardless of whether such facilities are designated for the exclusive use of bicycles or are to be shared with other transportation modes.

25. Buffer-Separated Lane—a preferential lane or other special purpose lane that is separated from the adjacent general-purpose lane(s) by a pattern of standard longitudinal pavement markings that is wider than a normal or wide lane line marking. The buffer area might include rumble strips, textured pavement, or channelizing devices such as tubular markers or traversable curbs, but does not include a physical barrier.
26. Cantilevered Signal Structure—a structure, also referred to as a mast arm, that is rigidly attached to a vertical pole and is used to provide overhead support of highway traffic signal faces or grade crossing signal units.
27. Center Line Markings—the yellow pavement marking line(s) that delineates the separation of traffic lanes that have opposite directions of travel on a roadway. These markings need not be at the geometrical center of the pavement.
28. Changeable Message Sign—a sign that is capable of displaying more than one message (one of which might be a "blank" display), changeable manually, by remote control, or by automatic control. Electronic-display changeable message signs are referred to as Dynamic Message Signs in the National Intelligent Transportation Systems (ITS) Architecture and are referred to as Variable Message Signs in the National Electrical Manufacturers Association (NEMA) standards publication.
29. Channelizing Line Markings—a wide or double solid white line used to form islands where traffic in the same direction of travel is permitted on both sides of the island.
30. Circular Intersection—an intersection that has an island, generally circular in design, located in the center of the intersection where traffic passes to the right of the island. Circular intersections include roundabouts, rotaries, and traffic circles.
31. Circulatory Roadway—the roadway within a circular intersection on which traffic travels in a counterclockwise direction around an island in the center of the circular intersection.
32. Clear Storage Distance—when used in Part 8, the distance available for vehicle storage measured between 6 feet from the rail nearest the intersection to the intersection stop line or the normal stopping point on the highway. At skewed grade crossings and intersections, the 6-foot distance shall be measured perpendicular to the nearest rail either along the center line or edge line of the highway, as appropriate, to obtain the shorter distance. Where exit gates are used, the distance available for vehicle storage is measured from the point where the rear of the vehicle would be clear of the exit gate arm. In cases where the exit gate arm is parallel to the track(s) and is not perpendicular to the highway, the distance is measured either along the center line or edge line of the highway, as appropriate, to obtain the shorter distance.
33. Clear Zone—the total roadside border area, starting at the edge of the traveled way, that is available for an errant driver to stop or regain control of a vehicle. This area might consist of a shoulder, a recoverable slope, and/or a non-recoverable, traversable slope with a clear run-out area at its toe.
34. Collector Highway—a term denoting a highway that in rural areas connects small towns and local highways to arterial highways, and in urban areas provides land access and traffic circulation within residential, commercial, and business areas and connects local highways to the arterial highways.
35. Concurrent Flow Preferential Lane—a preferential lane that is operated in the same direction as the adjacent mixed flow lanes, separated from the adjacent general-purpose freeway lanes by a standard lane stripe, painted buffer, or barrier.
36. Conflict Monitor—a device used to detect and respond to improper or conflicting signal indications and improper operating voltages in a traffic controller assembly.
37. Constant Warning Time Detection—a means of detecting rail traffic that provides relatively uniform warning time for the approach of trains or light rail transit traffic that are not accelerating or decelerating after being detected.
38. Contiguous Lane—a lane, preferential or otherwise, that is separated from the adjacent lane(s) only by a normal or wide lane line marking.
39. Controller Assembly—a complete electrical device mounted in a cabinet for controlling the operation of a highway traffic signal.
40. Controller Unit—that part of a controller assembly that is devoted to the selection and timing of the display of signal indications.
41. Conventional Road—a street or highway other than a low-volume road (as defined in Section 5A.01), expressway, or freeway.
42. Counter-Flow Lane—a lane operating in a direction opposite to the normal flow of traffic designated for peak direction of travel during at least a portion of the day. Counter-flow lanes are usually separated from the off-peak direction lanes by tubular markers or other flexible channelizing devices, temporary lane separators, or movable or permanent barrier.

43. Crasbworthy—a cbaracteristic of a roadside appurtenance that bas been successfully crasb tested in accordance with a national standard such as the National Cooperative Highway Research Program Report 350, "Recommended Procedures for the Safety Performance Evaluation of Higbway Features."
44. Crosswalk—(a) that part of a roadway at an intersection included witbin the connections of tbe lateral lines of tbe sidewalks on opposite sides of tbe highway measured from the curbs or in the absence of curbs, from the edges of the traversable roadway, and in the absence of a sidewalk on one side of the roadway, the part of a roadway included witbin the extension of the lateral lines of tbe sidewalk at rigbt angles to the center line; (b) any portion of a roadway at an intersection or elsewhere distinctly indicated as a pedestrian crossing by pavement marking lines on the surface, wbich might be supplemented by contrasting pavement texture, style, or color.
45. Crosswalk Lines—white pavement marking lines that identify a crosswalk.
46. Cycle Length—the time required for one complete sequence of signal indications.
47. Dark Mode—the lack of all signal indications at a signalized location. (The dark mode is most commonly associated with power failures, ramp meters, hybrid beacons, beacons, and some movable bridge signals.)
48. Delineator—a retroreflective device mounted on the roadway surface or at the side of the roadway in a series to indicate the alignment of the roadway, especially at night or in adverse weather.
49. Design Vehicle—the longest vehicle permitted by statute of the road authority (State or other) on tbat roadway.
50. Designated Bicycle Route—a system of bikeways designated by the jurisdiction having authority with appropriate directional and informational route signs, with or without specific bicycle route numbers.
51. Detectable—having a continuous edge within 6 inches of the surface so that pedestrians who have visual disabilities can sense its presence and receive usable guidance information.
52. Detector—a device used for determining the presence or passage of vehicles or pedestrians.
53. Downstream—a term that refers to a location that is encountered by traffic subsequent to an upstream location as it flows in an "upstream to downstream" direction. For example, "the downstream end of a lane line separating tbe turn lane from a through lane on the approach to an intersection" is the end of the lane line that is closest to the intersection.
54. Dropped Lane—a through lane that becomes a mandatory turn lane on a conventional roadway, or a through lane that becomes a mandatory exit lane on a freeway or expressway. The end of an acceleration lane and reductions in the number of through lanes that do not involve a mandatory turn or exit are not considered dropped lanes.
55. Dual-Arrow Signal Section—a type of signal section designed to include both a yellow arrow and a green arrow.
56. Dynamic Envelope—the clearance required for light rail transit traffic or a train and its cargo overhang due to any combination of loading, lateral motion, or suspension failure (see Figure 8B-8).
57. Dynamic Exit Gate Operating Mode—a mode of operation where the exit gate operation is based on the presence of vehicles within the minimum track clearance distance.
58. Edge Line Markings—white or yellow pavement marking lines that delineate the right or left edge(s) of a traveled way.
59. Electronic Toll Collection (ETC)—a system for automated collection of tolls from moving or stopped vehicles through wireless tecbnologies such as radio-frequency communication or optical scanning. ETC systems are classified as one of the following: (1) systems that require users to have registered toll accounts, with the use of equipment inside or on the exterior of vehicles, such as a transponder or barcode decal, tbat communicates with or is detected by roadside or overhead receiving equipment, or with the use of license plate optical scanning, to automatically deduct the toll from the registered user account, or (2) systems that do not require users to have registered toll accounts because vehicle license plates are optically scanned and invoices for the toll amount are sent through postal mail to the address of the vehicle owner.
60. Electronic Toll Collection (ETC) Account-Only Lane—a non-attended toll lane that is restricted to use only by vehicles with a registered toll payment account.
61. Emergency-Vehicle Hybrid Beacon—a special type of hybrid beacon used to warn and control traffic at an unsignalized location to assist authorized emergency vehicles in entering or crossing a street or highway.
62. Emergency-Vehicle Traffic Control Signal—a special traffic control signal that assigns the right-of-way to an authorized emergency vehicle.
63. End-of-Roadway Marker—a device used to warn and alert road users of the end of a roadway in other than temporary traffic control zones.

64. Engineering Judgment—the evaluation of available pertinent information, and the application of appropriate principles, provisions, and practices as contained in this Manual and other sources, for the purpose of deciding upon the applicability, design, operation, or installation of a traffic control device. Engineering judgment shall be exercised by an engineer, or by an individual working under the supervision of an engineer, through the application of procedures and criteria established by the engineer. Documentation of engineering judgment is not required.
65. Engineering Study—the comprehensive analysis and evaluation of available pertinent information, and the application of appropriate principles, provisions, and practices as contained in this Manual and other sources, for the purpose of deciding upon the applicability, design, operation, or installation of a traffic control device. An engineering study shall be performed by an engineer, or by an individual working under the supervision of an engineer, through the application of procedures and criteria established by the engineer. An engineering study shall be documented.
66. Entrance Gate—an automatic gate that can be lowered across the lanes approaching a grade crossing to block road users from entering the grade crossing.
67. Exact Change Lane (Automatic Lane)—a non-attended toll lane that has a receptacle into which road users deposit coins totaling the exact amount of the toll. Exact Change lanes at toll plazas typically require vehicles to stop to pay the toll.
68. Exit Gate—an automatic gate that can be lowered across the lanes departing a grade crossing to block road users from entering the grade crossing by driving in the opposing traffic lanes.
69. Exit Gate Clearance Time—for Four-Quadrant Gate systems at grade crossings, the amount of time provided to delay the descent of the exit gate arm(s) after entrance gate arm(s) begin to descend.
70. Exit Gate Operating Mode—for Four-Quadrant Gate systems at grade crossings, the mode of control used to govern the operation of the exit gate arms.
71. Expressway—a divided highway with partial control of access.
72. Flagger—a person who actively controls the flow of vehicular traffic into and/or through a temporary traffic control zone using hand-signaling devices or an Automated Flagger Assistance Device (AFAD).
73. Flasher—a device used to turn highway traffic signal indications on and off at a repetitive rate of approximately once per second.
74. Flashing—an operation in which a light source, such as a traffic signal indication, is turned on and off repetitively.
75. Flashing-Light Signals—a warning device consisting of two red signal indications arranged horizontally that are activated to flash alternately when rail traffic is approaching or present at a grade crossing.
76. Flashing Mode—a mode of operation in which at least one traffic signal indication in each vehicular signal face of a highway traffic signal is turned on and off repetitively.
77. Freeway—a divided highway with full control of access.
78. Full-Actuated Operation—a type of traffic control signal operation in which all signal phases function on the basis of actuation.
79. Gate—an automatically-operated or manually-operated traffic control device that is used to physically obstruct road users such that they are discouraged from proceeding past a particular point on a roadway or pathway, or such that they are discouraged from entering a particular grade crossing, ramp, lane, roadway, or facility.
80. Grade Crossing—the general area where a highway and a railroad and/or light rail transit route cross at the same level, within which are included the tracks, highway, and traffic control devices for traffic traversing that area.
81. Guide Sign—a sign that shows route designations, destinations, directions, distances, services, points of interest, or other geographical, recreational, or cultural information.
82. High-Occupancy Vehicle (HOV)—a motor vehicle carrying at least two or more persons, including carpools, vanpools, and buses.
83. Highway—a general term for denoting a public way for purposes of vehicular travel, including the entire area within the right-of-way.
84. Highway-Light Rail Transit Grade Crossing—the general area where a highway and a light rail transit route cross at the same level, within which are included the light rail transit tracks, highway, and traffic control devices for traffic traversing that area.
85. Highway-Rail Grade Crossing—the general area where a highway and a railroad cross at the same level, within which are included the railroad tracks, highway, and traffic control devices for highway traffic traversing that area.

86. Highway Traffic Signal—a power-operated traffic control device by which traffic is warned or directed to take some specific action. These devices do not include power-operated signs, steadily-illuminated pavement markers, warning lights (see Section 6F.83), or steady burning electric lamps.
87. HOV Lane—any preferential lane designated for exclusive use by high-occupancy vehicles for all or part of a day—including a designated lane on a freeway, other highway, street, or independent roadway on a separate right-of-way.
88. Hybrid Beacon—a special type of beacon that is intentionally placed in a dark mode (no indications displayed) between periods of operation and, when operated, displays both steady and flashing traffic control signal indications.
89. Inherently Low Emission Vehicle (ILEV)—any kind of vehicle that, because of inherent properties of the fuel system design, will not have significant evaporative emissions, even if its evaporative emission control system has failed.
90. In-Roadway Lights—a special type of highway traffic signal installed in the roadway surface to warn road users that they are approaching a condition on or adjacent to the roadway that might not be readily apparent and might require the road users to slow down and/or come to a stop.
91. Interchange—a system of interconnecting roadways providing for traffic movement between two or more highways that do not intersect at grade.
92. Interconnection—when used in Part 8, the electrical connection between the railroad or light rail transit active warning system and the highway traffic signal controller assembly for the purpose of preemption.
93. Intermediate Interchange—an interchange with an urban or rural route that is not a major or minor interchange as defined in this Section.
94. Intersection—intersection is defined as follows:
    (a) The area embraced within the prolongation or connection of the lateral curb lines, or if none, the lateral boundary lines of the roadways of two highways that join one another at, or approximately at, right angles, or the area within which vehicles traveling on different highways that join at any other angle might come into conflict.
    (b) The junction of an alley or driveway with a roadway or highway shall not constitute an intersection, unless the roadway or highway at said junction is controlled by a traffic control device.
    (c) If a highway includes two roadways that are 30 feet or more apart (see definition of Median), then every crossing of each roadway of such divided highway by an intersecting highway shall be a separate intersection.
    (d) If both intersecting highways include two roadways that are 30 feet or more apart, then every crossing of any two roadways of such highways shall be a separate intersection.
    (e) At a location controlled by a traffic control signal, regardless of the distance between the separate intersections as defined in (c) and (d) above:
        (1) If a stop line, yield line, or crosswalk has not been designated on the roadway (within the median) between the separate intersections, the two intersections and the roadway (median) between them shall be considered as one intersection;
        (2) Where a stop line, yield line, or crosswalk is designated on the roadway on the intersection approach, the area within the crosswalk and/or beyond the designated stop line or yield line shall be part of the intersection; and
        (3) Where a crosswalk is designated on a roadway on the departure from the intersection, the intersection shall include the area extending to the far side of such crosswalk.
95. Intersection Control Beacon—a beacon used only at an intersection to control two or more directions of travel.
96. Interval—the part of a signal cycle during which signal indications do not change.
97. Interval Sequence—the order of appearance of signal indications during successive intervals of a signal cycle.
98. Island—a defined area between traffic lanes for control of vehicular movements, for toll collection, or for pedestrian refuge. It includes all end protection and approach treatments. Within an intersection area, a median or an outer separation is considered to be an island.
99. Lane Drop—see Dropped Lane.
100. Lane Line Markings—white pavement marking lines that delineate the separation of traffic lanes that have the same direction of travel on a roadway.
101. Lane-Use Control Signal—a signal face displaying indications to permit or prohibit the use of specific lanes of a roadway or to indicate the impending prohibition of such use.

102. Legend—see Sign Legend.
103. Lens—see Signal Lens.
104. Light Rail Transit Traffic (Light Rail Transit Equipment)—every device in, upon, or by which any person or property can be transported on light rail transit tracks, including single-unit light rail transit cars (such at streetcars and trolleys) and assemblies of multiple light rail transit cars coupled together.
105. Locomotive Horn—an air horn, steam whistle, or similar audible warning device (see 49 CFR Part 229.129) mounted on a locomotive or control cab car. The terms "locomotive horn," "train whistle," "locomotive whistle," and "train horn" are used interchangeably in the railroad industry.
106. Logo—a distinctive emblem or trademark that identifies a commercial business and/or the product or service offered by the business.
107. Longitudinal Markings—pavement markings that are generally placed parallel and adjacent to the flow of traffic such as lane lines, center lines, edge lines, channelizing lines, and others.
108. Louver—see Signal Louver.
109. Major Interchange—an interchange with another freeway or expressway, or an interchange with a high-volume multi-lane highway, principal urban arterial, or major rural route where the interchanging traffic is heavy or includes many road users unfamiliar with the area.
110. Major Street—the street normally carrying the higher volume of vehicular traffic.
111. Malfunction Management Unit—same as Conflict Monitor.
112. Managed Lane—a highway lane or set of lanes, or a highway facility, for which variable operational strategies such as direction of travel, tolling, pricing, and/or vehicle type or occupancy requirements are implemented and managed in real-time in response to changing conditions. Managed lanes are typically buffer- or barrier-separated lanes parallel to the general-purpose lanes of a highway in which access is restricted to designated locations. There are also some highways on which all lanes are managed.
113. Manual Lane—see Attended Lane.
114. Maximum Highway Traffic Signal Preemption Time—the maximum amount of time needed following initiation of the preemption sequence for the highway traffic signals to complete the timing of the right-of-way transfer time, queue clearance time, and separation time.
115. Median—the area between two roadways of a divided highway measured from edge of traveled way to edge of traveled way. The median excludes turn lanes. The median width might be different between intersections, interchanges, and at opposite approaches of the same intersection.
116. Minimum Track Clearance Distance—for standard two-quadrant warning devices, the minimum track clearance distance is the length along a highway at one or more railroad or light rail transit tracks, measured from the highway stop line, warning device, or 12 feet perpendicular to the track center line, to 6 feet beyond the track(s) measured perpendicular to the far rail, along the center line or edge line of the highway, as appropriate, to obtain the longer distance. For Four-Quadrant Gate systems, the minimum track clearance distance is the length along a highway at one or more railroad or light rail transit tracks, measured either from the highway stop line or entrance warning device, to the point where the rear of the vehicle would be clear of the exit gate arm. In cases where the exit gate arm is parallel to the track(s) and is not perpendicular to the highway, the distance is measured either along the center line or edge line of the highway, as appropriate, to obtain the longer distance.
117. Minimum Warning Time—when used in Part 8, the least amount of time active warning devices shall operate prior to the arrival of rail traffic at a grade crossing.
118. Minor Interchange—an interchange where traffic is local and very light, such as interchanges with land service access roads. Where the sum of the exit volumes is estimated to be lower than 100 vehicles per day in the design year, the interchange is classified as local.
119. Minor Street—the street normally carrying the lower volume of vehicular traffic.
120. Movable Bridge Resistance Gate—a type of traffic gate, which is located downstream of the movable bridge warning gate, that provides a physical deterrent to vehicle and/or pedestrian traffic when placed in the appropriate position.
121. Movable Bridge Signal—a highway traffic signal installed at a movable bridge to notify traffic to stop during periods when the roadway is closed to allow the bridge to open.
122. Movable Bridge Warning Gate—a type of traffic gate designed to warn, but not primarily to block, vehicle and/or pedestrian traffic when placed in the appropriate position.
123. Multi-Lane—more than one lane moving in the same direction. A multi-lane street, highway, or roadway has a basic cross-section comprised of two or more through lanes in one or both directions. A multi-lane approach has two or more lanes moving toward the intersection, including turning lanes.

124. Neutral Area—the paved area between the channelizing lines separating an entrance or exit ramp or a channelized turn lane or channelized entering lane from the adjacent through lane(s).
125. Object Marker—a device used to mark obstructions within or adjacent to the roadway.
126. Occupancy Requirement—any restriction that regulates the use of a facility or one or more lanes of a facility for any period of the day based on a specified number of persons in a vehicle.
127. Occupant—a person driving or riding in a car, truck, bus, or other vehicle.
128. Open-Road ETC Lane—a non-attended lane that is designed to allow toll payments to be electronically collected from vehicles traveling at normal highway speeds. Open-Road ETC lanes are typically physically separated from the toll plaza, often following the alignment of the mainline lanes, with toll plaza lanes for cash toll payments being on a different alignment after diverging from the mainline lanes or a subset thereof.
129. Open-Road Tolling—a system designed to allow electronic toll collection (ETC) from vehicles traveling at normal highway speeds. Open-Road Tolling might be used on toll roads or toll facilities in conjunction with toll plazas. Open-Road Tolling is also typically used on managed lanes and on toll facilities that only accept payment by ETC.
130. Open-Road Tolling Point—the location along an Open-Road ETC lane at which roadside or overhead detection and receiving equipment are placed and vehicles are electronically assessed a toll.
131. Opposing Traffic—vehicles that are traveling in the opposite direction. At an intersection, vehicles entering from an approach that is approximately straight ahead would be considered to be opposing traffic, but vehicles entering from approaches on the left or right would not be considered to be opposing traffic.
132. Overhead Sign—a sign that is placed such that a portion or the entirety of the sign or its support is directly above the roadway or shoulder such that vehicles travel below it. Typical installations include signs placed on cantilever arms that extend over the roadway or shoulder, on sign support structures that span the entire width of the pavement, on mast arms or span wires that also support traffic control signals, and on highway bridges that cross over the roadway.
133. Parking Area—a parking lot or parking garage that is separated from a roadway. Parallel or angle parking spaces along a roadway are not considered a parking area.
134. Passive Grade Crossing—a grade crossing where none of the automatic traffic control devices associated with an Active Grade Crossing Warning System are present and at which the traffic control devices consist entirely of signs and/or markings.
135. Pathway—a general term denoting a public way for purposes of travel by authorized users outside the traveled way and physically separated from the roadway by an open space or barrier and either within the highway right-of-way or within an independent alignment. Pathways include shared-use paths, but do not include sidewalks.
136. Pathway Grade Crossing—the general area where a pathway and railroad or light rail transit tracks cross at the same level, within which are included the tracks, pathway, and traffic control devices for pathway traffic traversing that area.
137. Paved—a bituminous surface treatment, mixed bituminous concrete, or Portland cement concrete roadway surface that has both a structural (weight bearing) and a sealing purpose for the roadway.
138. Pedestrian—a person on foot, in a wheelchair, on skates, or on a skateboard.
139. Pedestrian Change Interval—an interval during which the flashing UPRAISED HAND (symbolizing DONT WALK) signal indication is displayed.
140. Pedestrian Clearance Time—the time provided for a pedestrian crossing in a crosswalk, after leaving the curb or shoulder, to travel to the far side of the traveled way or to a median.
141. Pedestrian Facilities—a general term denoting improvements and provisions made to accommodate or encourage walking.
142. Pedestrian Hybrid Beacon— a special type of hybrid beacon used to warn and control traffic at an unsignalized location to assist pedestrians in crossing a street or highway at a marked crosswalk.
143. Pedestrian Signal Head—a signal head, which contains the symbols WALKING PERSON (symbolizing WALK) and UPRAISED HAND (symbolizing DONT WALK), that is installed to direct pedestrian traffic at a traffic control signal.
144. Permissive Mode—a mode of traffic control signal operation in which left or right turns are permitted to be made after yielding to pedestrians, if any, and/or opposing traffic, if any. When a CIRCULAR GREEN signal indication is displayed, both left and right turns are permitted unless otherwise prohibited by another traffic control device. When a flashing YELLOW ARROW or flashing RED ARROW signal indication is displayed, the turn indicated by the arrow is permitted.

145. Physical Gore—a longitudinal point where a physical barrier or the lack of a paved surface inhibits road users from crossing from a ramp or channelized turn lane or channelized entering lane to the adjacent through lane(s) or vice versa.
146. Pictograph—a pictorial representation used to identify a governmental jurisdiction, an area of jurisdiction, a governmental agency, a military base or branch of service, a governmental-approved university or college, a toll payment system, or a government-approved institution.
147. Plaque—a traffic control device intended to communicate specific information to road users through a word, symbol, or arrow legend that is placed immediately adjacent to a sign to supplement the message on the sign. The difference between a plaque and a sign is that a plaque cannot be used alone. The designation for a plaque includes a "P" suffix.
148. Platoon—a group of vehicles or pedestrians traveling together as a group, either voluntarily or involuntarily, because of traffic signal controls, geometrics, or other factors.
149. Portable Traffic Control Signal—a temporary traffic control signal that is designed so that it can be easily transported and reused at different locations.
150. Post-Mounted Sign—a sign that is placed to the side of the roadway such that no portion of the sign or its support is directly above the roadway or shoulder.
151. Posted Speed Limit—a speed limit determined by law or regulation and displayed on Speed Limit signs.
152. Preemption—the transfer of normal operation of a traffic control signal to a special control mode of operation.
153. Preferential Laue—a highway lane reserved for the exclusive use of one or more specific types of vehicles or vehicles with at least a specific number of occupants.
154. Pre-Signal—traffic control signal faces that control traffic approaching a grade crossing in conjunction with the traffic control signal faces that control traffic approaching a highway-highway intersection beyond the tracks. Supplemental near-side traffic control signal faces for the highway-highway intersection are not considered pre-signals. Pre-signals are typically used where the clear storage distance is insufficient to store one or more design vehicles.
155. Pretimed Operation—a type of traffic control signal operation in which none of the signal phases function on the basis of actuation.
156. Primary Signal Facc—onc of thc rcquircd or rccommcndcd minimum number of signal faces for a given approach or separate turning movement, but not including near-side signal faces required as a result of the far-side signal faces exceeding the maximum distance from the stop line.
157. Principal Legend—place names, street names, and route numbers placed on guide signs.
158. Priority Control—a means by which the assignment of right-of-way is obtained or modified.
159. Private Road Open to Public Travel—private toll roads and roads (including any adjacent sidewalks that generally run parallel to the road) within shopping centers, airports, sports arenas, and other similar business and/or recreation facilities that are privately owned, but where the public is allowed to travel without access restrictions. Roads within private gated properties (except for gated toll roads) where access is restricted at all times, parking areas, driving aisles within parking areas, and private grade crossings shall not be included in this definition.
160. Protected Mode—a mode of traffic control signal operation in which left or right turns are permitted to be made when a left or right GREEN ARROW signal indication is displayed.
161. Public Road—any road, street, or similar facility under tbe jurisdiction of and maintained by a public agency and open to public travel.
162. Pushbutton—a button to activate a device or signal timing for pedestrians, bicyclists, or other road users.
163. Pushbutton Information Message—a recorded message that can be actuated by pressing a pushbutton when the walk interval is not timing and that provides the name of the street that the crosswalk associated with that particular pushbutton crosses and can also provide other information about the intersection signalization or geometry.
164. Pushbutton Locator Tone—a repeating sound that informs approaching pedestrians that a pusbbutton exists to actuate pedestrian timing or receive additional information and that enables pedestrians who have visual disabilities to locate the pushbutton.
165. Queue Clearance Time—when used in Part 8, the time required for the design vehicle of maximum length stopped just inside the minimum track clearance distance to start up and move through and clear the entire minimum track clearance distance. If pre-signals are present, this time shall be long enough to allow the vehicle to move through the intersection, or to clear the tracks if there is sufficient clear storage distance. If a Four-Quadrant Gate system is present, this time shall be long enough to permit the exit gate arm to lower after the design vehicle is clear of the minimum track clearance distance.

166. Quiet Zone—a segment of a rail line, witb one or a number of consecutive public highway-rail grade crossings at wbich locomotive horns are not routinely sounded per 49 CFR Part 222.
167. Rail Traffic—every device in, upon, or by whicb any person or property can be transported on rails or tracks and to which all otber traffic must yield tbe right-of-way by law at grade crossings, including trains, one or more locomotives coupled (witb or without cars), other railroad equipment, and light rail transit operating in exclusive or semi-exclusive alignments. Light rail transit operating in a mixed-use alignment, to whicb other traffic is not required to yield tbe rigbt-of-way by law, is a vehicle and is not considered to be rail traffic.
168. Raised Pavement Marker—a device mounted on or in a road surface that has a beight generally not exceeding approximately 1 inch above the road surface for a permanent marker, or not exceeding approximately 2 incbes above tbe road surface for a temporary flexible marker, and that is intended to be used as a positioning guide and/or to supplement or substitute for pavement markings.
169. Ramp Control Signal—a higbway traffic signal installed to control tbe flow of traffic onto a freeway at an entrance ramp or at a freeway-to-freeway ramp connection.
170. Ramp Meter—see Ramp Control Signal.
171. Red Clearance Interval—an interval that follows a yellow cbange interval and precedes the next conflicting green interval.
172. Regulatory Sign—a sign that gives notice to road users of traffic laws or regulations.
173. Retroreflectivity—a property of a surface that allows a large portion of the light coming from a point source to be returned directly back to a point near its origin.
174. Right-of-Way [Assignment]—the permitting of vehicles and/or pedestrians to proceed in a lawful manner in preference to other vehicles or pedestrians by the display of a sign or signal indications.
175. Right-of-Way Transfer Time—when used in Part 8, tbe maximum amount of time needed for the worst case condition, prior to display of the track clearance green interval. Tbis includes any railroad or ligbt rail transit or highway traffic signal control equipment time to react to a preemption call, and any traffic control signal green, pedestrian walk and clearance, yellow change, and red clearance intervals for conflicting traffic.
176. Road—see Roadway.
177. Road User—a vehicle operator, bicyclist, or pedestrian, including persons with disabilities, within tbe highway or on a private road open to public travel.
178. Roadway—tbat portion of a bigbway improved, designed, or ordinarily used for vebicular travel and parking lanes, but exclusive of the sidewalk, berm, or shoulder even though such sidewalk, berm, or shoulder is used by persons riding bicycles or other human-powered vehicles. In the event a higbway includes two or more separate roadways, tbe term roadway as used in tbis Manual shall refer to any such roadway separately, but not to all such roadways collectively.
179. Roadway Network—a geographical arrangement of intersecting roadways.
180. Roundabout—a circular intersection with yield control at entry, which permits a vehicle on the circulatory roadway to proceed, and with deflection of the approaching vehicle counter-clockwise around a central island.
181. Rumble Strip—a series of intermittent, narrow, transverse areas of rough-textured, slightly raised, or depressed road surface that extend across the travel lane to alert road users to unusual traffic conditions or are located along the sboulder, along the roadway center line, or within islands formed by pavement markings to alert road users that they are leaving the travel lanes.
182. Rural Highway—a type of roadway normally characterized by lower volumes, higher speeds, fewer turning conflicts, and less conflict with pedestrians.
183. Safe-Positioned—the positioning of emergency vehicles at an incident in a manner that attempts to protect both the responders performing their duties and road users traveling through tbe incident scene, while minimizing, to the extent practical, disruption of the adjacent traffic flow.
184. School—a public or private educational institution recognized by the State education authority for one or more grades K tbrough 12 or as otherwise defined by the State.
185. School Zone—a designated roadway segment approaching, adjacent to, and beyond school buildings or grounds, or along wbich school related activities occur.
186. Semi-Actuated Operation—a type of traffic control signal operation in whicb at least one, but not all, signal phases function on the basis of actuation.
187. Separate Turn Signal Face—a signal face that exclusively controls a turn movement and that displays signal indications that are applicable only to the turn movement.
188. Separation Time—the component of maximum highway traffic signal preemption time during which the minimum track clearance distance is clear of vehicular traffic prior to the arrival of rail traffic.

189. Shared Roadway—a roadway that is officially designated and marked as a bicycle route, but which is open to motor vehicle travel and upon which no bicycle lane is designated.
190. Shared Turn Signal Face—a signal face, for controlling both a turn movement and the adjacent through movement, that always displays the same color of circular signal indication that the adjacent through signal face or faces display.
191. Shared-Use Path—a bikeway outside the traveled way and physically separated from motorized vehicular traffic by an open space or barrier and either within the highway right-of-way or within an independent alignment. Shared-use paths are also used by pedestrians (including skaters, users of manual and motorized wheelchairs, and joggers) and other authorized motorized and non-motorized users.
192. Sidewalk—that portion of a street between the curb line, or the lateral line of a roadway, and the adjacent property line or on easements of private property that is paved or improved and intended for use by pedestrians.
193. Sign—any traffic control device that is intended to communicate specific information to road users through a word, symbol, and/or arrow legend. Signs do not include highway traffic signals, pavement markings, delineators, or channelization devices.
194. Sign Assembly—a group of signs, located on the same support(s), that supplement one another in conveying information to road users.
195. Sign Illumination—either internal or external lighting that shows similar color by day or night. Street or highway lighting shall not be considered as meeting this definition.
196. Sign Legend—all word messages, logos, pictographs, and symbol and arrow designs that are intended to convey specific meanings. The border, if any, on a sign is not considered to be a part of the legend.
197. Sign Panel—a separate panel or piece of material containing a word, symbol, and/or arrow legend that is affixed to the face of a sign.
198. Signal Backplate—a thin strip of material that extends outward from and parallel to a signal face on all sides of a signal housing to provide a background for improved visibility of the signal indications.
199. Signal Coordination—the establishment of timed relationships between adjacent traffic control signals.
200. Signal Face—an assembly of one or more signal sections that is provided for controlling one or more traffic movements on a single approach.
201. Signal Head—an assembly of one or more signal faces that is provided for controlling traffic movements on one or more approaches.
202. Signal Housing—that part of a signal section that protects the light source and other required components.
203. Signal Indication—the illumination of a signal lens or equivalent device.
204. Signal Lens—that part of the signal section that redirects the light coming directly from the light source and its reflector, if any.
205. Signal Louver—a device that can be mounted inside a signal visor to restrict visibility of a signal indication from the side or to limit the visibility of the signal indication to a certain lane or lanes, or to a certain distance from the stop line.
206. Signal Phase—the right-of-way, yellow change, and red clearance intervals in a cycle that are assigned to an independent traffic movement or combination of movements.
207. Signal Section—the assembly of a signal housing, signal lens, if any, and light source with necessary components to be used for displaying one signal indication.
208. Signal System—two or more traffic control signals operating in signal coordination.
209. Signal Timing—the amount of time allocated for the display of a signal indication.
210. Signal Visor—that part of a signal section that directs the signal indication specifically to approaching traffic and reduces the effect of direct external light entering the signal lens.
211. Signing—individual signs or a group of signs, not necessarily on the same support(s), that supplement one another in conveying information to road users.
212. Simultaneous Preemption—notification of approaching rail traffic is forwarded to the highway traffic signal controller unit or assembly and railroad or light rail transit active warning devices at the same time.
213. Special Purpose Road—a low-volume, low-speed road that serves recreational areas or resource development activities.

214. Speed—speed is defined based on the following classifications:
    (a) Average Speed—the summation of the instantaneous or spot-measured speeds at a specific location of vehicles divided by the number of vehicles observed.
    (b) Design Speed—a selected speed used to determine the various geometric design features of a roadway.
    (c) 85th-Percentile Speed—the speed at or below which 85 percent of the motor vehicles travel.
    (d) Operating Speed—a speed at which a typical vehicle or the overall traffic operates. Operating speed might be defined with speed values such as the average, pace, or 85th-percentile speeds.
    (e) Pace—the 10 mph speed range representing the speeds of the largest percentage of vehicles in the traffic stream.
215. Speed Limit—the maximum (or minimum) speed applicable to a section of highway as established by law or regulation.
216. Speed Limit Sign Beacon—a beacon used to supplement a SPEED LIMIT sign.
217. Speed Measurement Markings—a white transverse pavement marking placed on the roadway to assist the enforcement of speed regulations.
218. Speed Zone—a section of highway with a speed limit that is established by law or regulation, but which might be different from a legislatively specified statutory speed limit.
219. Splitter Island—a median island used to separate opposing directions of traffic entering and exiting a roundabout.
220. Station Crossing—a pathway grade crossing that is associated with a station platform.
221. Statutory Speed Limit—a speed limit established by legislative action that typically is applicable for a particular class of highways with specified design, functional, jurisdictional and/or location characteristics and that is not necessarily displayed on Speed Limit signs.
222. Steady (Steady Mode)—the continuous display of a signal indication for the duration of an interval, signal phase, or consecutive signal phases.
223. Stop Beacon—a beacon used to supplement a STOP sign, a DO NOT ENTER sign, or a WRONG WAY sign.
224. Stop Line—a solid white pavement marking line extending across approach lanes to indicate the point at which a stop is intended or required to be made.
225. Street—see Highway.
226. Supplemental Signal Face—a signal face that is not a primary signal face but which is provided for a given approach or separate turning movement to enhance visibility or conspicuity.
227. Symbol—the approved design of a pictorial representation of a specific traffic control message for signs, pavement markings, traffic control signals, or other traffic control devices, as shown in the MUTCD.
228. Temporary Traffic Control Signal—a traffic control signal that is installed for a limited time period.
229. Temporary Traffic Control Zone—an area of a highway where road user conditions are changed because of a work zone or incident by the use of temporary traffic control devices, flaggers, uniformed law enforcement officers, or other authorized personnel.
230. Theoretical Gore—a longitudinal point at the upstream end of a neutral area at an exit ramp or channelized turn lane where the channelizing lines that separate the ramp or channelized turn lane from the adjacent through lane(s) begin to diverge, or a longitudinal point at the downstream end of a neutral area at an entrance ramp or channelized entering lane where the channelizing lines that separate the ramp or channelized entering lane from the adjacent through lane(s) intersect each other.
231. Timed Exit Gate Operating Mode—a mode of operation where the exit gate descent at a grade crossing is based on a predetermined time interval.
232. Toll Booth—a shelter where a toll attendant is stationed to collect tolls or issue toll tickets. A toll booth is located adjacent to a toll lane and is typically set on a toll island.
233. Toll Island—a raised island on which a toll booth or other toll collection and related equipment are located.
234. Toll Lane—an individual lane located within a toll plaza in which a toll payment is collected or, for toll-ticket systems, a toll ticket is issued.
235. Toll Plaza—the location at which tolls are collected consisting of a grouping of toll booths, toll islands, toll lanes, and, typically, a canopy. Toll plazas might be located on highway mainlines or on interchange ramps. A mainline toll plaza is sometimes referred to as a barrier toll plaza because it interrupts the traffic flow.

236. Toll-Ticket System—a system in which the user of a toll road receives a ticket from a machine or toll booth attendant upon entering a toll system. The ticket denotes the user's point of entry and, upon exiting the toll system, the user surrenders the ticket and is charged a toll based on the distance traveled between the points of entry and exit.
237. Traffic—pedestrians, bicyclists, ridden or herded animals, vehicles, streetcars, and other conveyances either singularly or together while using for purposes of travel any highway or private road open to public travel.
238. Traffic Control Device—a sign, signal, marking, or other device used to regulate, warn, or guide traffic, placed on, over, or adjacent to a street, highway, private road open to public travel, pedestrian facility, or shared-use path by authority of a public agency or official having jurisdiction, or, in the case of a private road open to public travel, by authority of the private owner or private official having jurisdiction.
239. Traffic Control Signal (Traffic Signal)—any highway traffic signal by which traffic is alternately directed to stop and permitted to proceed.
240. Train—one or more locomotives coupled, with or without cars, that operates on rails or tracks and to which all other traffic must yield the right-of-way by law at highway-rail grade crossings.
241. Transverse Markings—pavement markings that are generally placed perpendicular and across the flow of traffic such as shoulder markings; word, symbol, and arrow markings; stop lines; crosswalk lines; speed measurement markings; parking space markings; and others.
242. Traveled Way—the portion of the roadway for the movement of vehicles, exclusive of the shoulders, berms, sidewalks, and parking lanes.
243. Turn Bay—a lane for the exclusive use of turning vehicles that is formed on the approach to the location where the turn is to be made. In most cases where turn bays are provided, drivers who desire to turn must move out of a through lane into the newly formed turn bay in order to turn. A through lane that becomes a turn lane is considered to be a dropped lane rather than a turn bay.
244. Upstream—a term that refers to a location that is encountered by traffic prior to a downstream location as it flows in an "upstream to downstream" direction. For example, "the upstream end of a lane line separating the turn lane from a through lane on the approach to an intersection" is the end of the line that is furthest from the intersection.
245. Urban Street—a type of street normally characterized by relatively low speeds, wide ranges of traffic volumes, narrower lanes, frequent intersections and driveways, significant pedestrian traffic, and more businesses and houses.
246. Vehicle—every device in, upon, or by which any person or property can be transported or drawn upon a highway, except trains and light rail transit operating in exclusive or semi-exclusive alignments. Light rail transit equipment operating in a mixed-use alignment, to which other traffic is not required to yield the right-of-way by law, is a vehicle.
247. Vibrotactile Pedestrian Device—an accessible pedestrian signal feature that communicates, by touch, information about pedestrian timing using a vibrating surface.
248. Visibility-Limited Signal Face or Visibility-Limited Signal Section—a type of signal face or signal section designed (or shielded, hooded, or louvered) to restrict the visibility of a signal indication from the side, to a certain lane or lanes, or to a certain distance from the stop line.
249. Walk Interval—an interval during which the WALKING PERSON (symbolizing WALK) signal indication is displayed.
250. Warning Beacon—a beacon used only to supplement an appropriate warning or regulatory sign or marker.
251. Warning Light—a portable, powered, yellow, lens-directed, enclosed light that is used in a temporary traffic control zone in either a steady burn or a flashing mode.
252. Warning Sign—a sign that gives notice to road users of a situation that might not be readily apparent.
253. Warrant—a warrant describes a threshold condition based upon average or normal conditious that, if found to be satisfied as part of an engineering study, shall result in analysis of other traffic conditions or factors to determine whether a traffic control device or other improvement is justified. Warrants are not a substitute for engineering judgment. The fact that a warrant for a particular traffic control device is met is not conclusive justification for the installation of the device.
254. Wayside Equipment—the signals, switches, and/or control devices for railroad or light rail transit operations housed within one or more enclosures located along the railroad or light rail transit right-of-way and/or on railroad or light rail transit property.
255. Wayside Horn System—a stationary horn (or series of horns) located at a grade crossing that is used in conjunction with train-activated or light rail transit-activated warning systems to provide audible warning of approaching rail traffic to road users on the highway or pathway approaches to a grade crossing, either as a supplement or alternative to the sounding of a locomotive horn.

256. Worker—a person on foot whose duties place him or her within the right-of-way of a street, highway, or pathway, such as street, highway, or pathway construction and maintenance forces, survey crews, utility crews, responders to incidents within the street, highway, or pathway right-of-way, and law enforcement personnel when directing traffic, investigating crashes, and handling lane closures, obstructed roadways, and disasters within the right-of-way of a street, highway, or pathway.
257. Wrong-Way Arrow—a slender, elongated, white pavement marking arrow placed upstream from the ramp terminus to indicate the correct direction of traffic flow. Wrong-way arrows are intended primarily to warn wrong-way road users that they are going in the wrong direction.
258. Yellow Change Interval—the first interval following the green or flashing arrow interval during which the steady yellow signal indication is displayed.
259. Yield Line—a row of solid white isosceles triangles pointing toward approaching vehicles extending across approach lanes to indicate the point at which the yield is intended or required to be made.

Section 1A.14 Meanings of Acronyms and Abbreviations in this Manual

Standard:

01 The following acronyms and abbreviations, when used in this Manual, shall have the following meanings:

1. AADT—annual average daily traffic
2. AASHTO—American Association of State Highway and Transportation Officials
3. ADA—Americans with Disabilities Act
4. ADAAG—Americans with Disabilities Accessibility Guidelines
5. ADT—average daily traffic
6. AFAD—Automated Flagger Assistance Device
7. ANSI—American National Standards Institute
8. CFR—Code of Federal Regulations
9. CMS—changeable message sign
10. dBA—A-weighted decibels
11. EPA—Environmental Protection Agency
12. ETC—electronic toll collection
13. EV—electric vehicle
14. FHWA—Federal Highway Administration
15. FRA—Federal Railroad Administration
16. FTA—Federal Transit Administration
17. HOT—high occupancy tolls
18. HOTM—FHWA's Office of Transportation Management
19. HOTO—FHWA's Office of Transportation Operations
20. HOV—high-occupancy vehicle
21. ILEV—inherently low emission vehicle
22. ISEA—International Safety Equipment Association
23. ITE—Institute of Transportation Engineers
24. ITS—intelligent transportation systems
25. LED—light emitting diode
26. LP—liquid petroleum
27. MPH or mph—miles per hour
28. MUTCD—Manual on Uniform Traffic Control Devices
29. NCHRP—National Cooperative Highway Research Program
30. ORT—open-road tolling
31. PCMS—portable changeable message sign
32. PRT—perception-response time
33. RPM—raised pavement marker
34. RRPM—raised retroreflective pavement marker
35. RV—recreational vehicle
36. TDD—telecommunication devices for the deaf
37. TRB—Transportation Research Board
38. TTC—temporary traffic control
39. U.S.—United States
40. U.S.C.—United States Code
41. USDOT—United States Department of Transportation
42. UVC—Uniform Vehicle Code
43. VPH or vph—vehicles per hour

Section 1A.15 Abbreviations Used on Traffic Control Devices

Standard:

01 **When the word messages shown in Table 1A-1 need to be abbreviated in connection with traffic control devices, the abbreviations shown in Table 1A-1 shall be used.**

02 **When the word messages shown in Table 1A-2 need to be abbreviated on a portable changeable message sign, the abbreviations shown in Table 1A-2 shall be used. Unless indicated by an asterisk, these abbreviations shall only be used on portable changeable message signs.**

Guidance:

03 *The abbreviations for the words listed in Table 1A-2 that also show a prompt word should not be used on a portable changeable message sign unless the prompt word shown in Table 1A-2 either precedes or follows the abbreviation, as applicable.*

Standard:

04 **The abbreviations shown in Table 1A-3 shall not be used in connection with traffic control devices because of their potential to be misinterpreted by road users.**

Guidance:

05 *If multiple abbreviations are permitted in Table 1A-1 or 1A-2, the same abbreviation should be used throughout a single jurisdiction.*

06 *Except as otherwise provided in Table 1A-1 or 1A-2 or unless necessary to avoid confusion, periods, commas, apostrophes, question marks, ampersands, and other punctuation marks or characters that are not letters or numerals should not be used in any abbreviation.*

Table 1A-1. Acceptable Abbreviations

Word Message	Standard Abbreviation
Afternoon / Evening	PM
Alternate	ALT
AM Radio	AM
Avenue	AVE, AV
Bicycle	BIKE
Boulevard	BLVD*
Bridge	(See Table 1A-2)
CB Radio	CB
Center (as part of a place name)	CTR
Circle	CIR*
Civil Defense	CD
Compressed Natural Gas	CNG
Court	CT*
Crossing (other than highway-rail)	X-ING
Drive	DR*
East	E
Electric Vehicle	EV
Expressway	EXPWY*
Feet	FT
FM Radio	FM
Freeway	FRWY, FWY*
Friday	FRI
Hazardous Material	HAZMAT
High Occupancy Vehicle	HOV
Highway	HWY*
Hospital	HOSP
Hour(s)	HR, HRS
Information	INFO
Inherently Low Emission Vehicle	ILEV
International	INTL
Interstate	(See Table 1A-2)
Junction / Intersection	JCT
Lane	(See Table 1A-2)
Liquid Propane Gas	LP-GAS
Maximum	MAX
Mile(s)	MI
Miles Per Hour	MPH
Minimum	MIN
Minute(s)	MIN
Monday	MON
Morning / Late Night	AM
Mount	MT
Mountain	MTN
National	NATL
North	N
Parkway	PKWY*
Pedestrian	PED
Place	PL*
Pounds	LBS
Road	RD*
Saint	ST
Saturday	SAT
South	S
State, county, or other non-US or non-Interstate numbered route	(See Table 1A-2)
Street	ST*
Sunday	SUN
Telephone	PHONE
Temporary	TEMP
Terrace	TER*
Thursday	THURS
Thruway	THWY*
Tons of Weight	T
Trail	TR*
Tuesday	TUES
Turnpike	TPK*
Two-Way Intersection	2-WAY
US Numbered Route	US
Wednesday	WED
West	W

*This abbreviation shall not be used for any application other than the name of a roadway.

Table 1A-2. Abbreviations That Shall be Used Only on Portable Changeable Message Signs

Word Message	Standard Abbreviation	Prompt Word That Should Precede the Abbreviation	Prompt Word That Should Follow the Abbreviation
Access	ACCS	—	Road
Ahead	AHD	Fog	—
Blocked	BLKD	Lane	—
Bridge	BR*	[Name]	—
Cannot	CANT	—	—
Center	CNTR	—	Lane
Chemical	CHEM	—	Spill
Condition	COND	Traffic	—
Congested	CONG	Traffic	—
Construction	CONST	—	Ahead
Crossing	XING	—	—
Do Not	DONT	—	—
Downtown	DWNTN	—	Traffic
Eastbound	E-BND	—	—
Emergency	EMER	—	—
Entrance, Enter	ENT	—	—
Exit	EX	Next	—
Express	EXP	—	Lane
Frontage	FRNTG	—	Road
Hazardous	HAZ	—	Driving
Highway-Rail Grade Crossing	RR XING	—	—
Interstate	I-*	—	[Number]
It Is	ITS	—	—
Lane	LN	[Roadway Name]*, Right, Left, Center	—
Left	LFT	—	—
Local	LOC	—	Traffic
Lower	LWR	—	Level
Maintenance	MAINT	—	—
Major	MAJ	—	Accident
Minor	MNR	—	Accident
Normal	NORM	—	—
Northbound	N-BND	—	—
Oversized	OVRSZ	—	Load
Parking	PKING	—	—
Pavement	PVMT	Wet	—
Prepare	PREP	—	To Stop
Quality	QLTY	Air	—
Right	RT	Keep, Next	—
Right	RT	—	Lane
Roadwork	RDWK	—	Ahead, [Distance]
Route	RT, RTE	Best	—
Service	SERV	—	—
Shoulder	SHLDR	—	—
Slippery	SLIP	—	—
Southbound	S-BND	—	—
Speed	SPD	—	—
State, county, or other non-US or non-Interstate numbered route	[Route Abbreviation determined by highway agency]**	—	[Number]
Tires With Lugs	LUGS	—	—
Traffic	TRAF	—	—
Travelers	TRVLRS	—	—
Two-Wheeled Vehicles	CYCLES	—	—
Upper	UPR	—	Level
Vehicle(s)	VEH, VEHS	—	—
Warning	WARN	—	—
Westbound	W-BND	—	—
Will Not	WONT	—	—

* This abbreviation, when accompanied by the prompt word, may be used on traffic control devices other than portable changeable message signs.

** A space and no dash shall be placed between the abbreviation and the number of the route.

Table 1A-3. Unacceptable Abbreviations

Abbreviation	Intended Word	Common Misinterpretation
ACC	Accident	Access (Road)
CLRS	Clears	Colors
DLY	Delay	Daily
FDR	Feeder	Federal
L	Left	Lane (Merge)
LT	Light (Traffic)	Left
PARK	Parking	Park
POLL	Pollution (Index)	Poll
RED	Reduce	Red
STAD	Stadium	Standard
WRNG	Warning	Wrong

PART 4
HIGHWAY TRAFFIC SIGNALS

CHAPTER 4A. GENERAL

Section 4A.01 Types

Support:

01 The following types and uses of highway traffic signals are discussed in Part 4: traffic control signals; pedestrian signals; hybrid beacons; emergency-vehicle signals; traffic control signals for one-lane, two-way facilities; traffic control signals for freeway entrance ramps; traffic control signals for movable bridges; toll plaza traffic signals; flashing beacons; lane-use control signals; and in-roadway lights.

Section 4A.02 Definitions Relating to Highway Traffic Signals

Support:

01 Definitions and acronyms pertaining to Part 4 are provided in Sections 1A.13 and 1A.14.

CHAPTER 4B. TRAFFIC CONTROL SIGNALS—GENERAL

Section 4B.01 General

Support:

01 Words such as pedestrians and bicyclists are used redundantly in selected Sections of Part 4 to encourage sensitivity to these elements of "traffic."

02 Standards for traffic control signals are important because traffic control signals need to attract the attention of a variety of road users, including those who are older, those with impaired vision, as well as those who are fatigued or distracted, or who are not expecting to encounter a signal at a particular location.

Section 4B.02 Basis of Installation or Removal of Traffic Control Signals

Guidance:

01 *The selection and use of traffic control signals should be based on an engineering study of roadway, traffic, and other conditions.*

Support:

02 A careful analysis of traffic operations, pedestrian and bicyclist needs, and other factors at a large number of signalized and unsignalized locations, coupled with engineering judgment, has provided a series of signal warrants, described in Chapter 4C, that define the minimum conditions under which installing traffic control signals might be justified.

Guidance:

03 *Engineering judgment should be applied in the review of operating traffic control signals to determine whether the type of installation and the timing program meet the current requirements of all forms of traffic.*

04 *If changes in traffic patterns eliminate the need for a traffic control signal, consideration should be given to removing it and replacing it with appropriate alternative traffic control devices, if any are needed.*

05 *If the engineering study indicates that the traffic control signal is no longer justified, and a decision is made to remove the signal, removal should be accomplished using the following steps:*

A. *Determine the appropriate traffic control to be used after removal of the signal.*
B. *Remove any sight-distance restrictions as necessary.*
C. *Inform the public of the removal study.*
D. *Flash or cover the signal heads for a minimum of 90 days, and install the appropriate stop control or other traffic control devices.*
E. *Remove the signal if the engineering data collected during the removal study period confirms that the signal is no longer needed.*

Option:

06 Because Items C, D, and E in Paragraph 5 are not relevant when a temporary traffic control signal (see Section 4D.32) is removed, a temporary traffic control signal may be removed immediately after Items A and B are completed.

07 Instead of total removal of a traffic control signal, the poles, controller cabinet, and cables may remain in place after removal of the signal heads for continued analysis.

Section 4B.03 Advantages and Disadvantages of Traffic Control Signals

Support:

01 When properly used, traffic control signals are valuable devices for the control of vehicular and pedestrian traffic. They assign the right-of-way to the various traffic movements and thereby profoundly influence traffic flow.

02 Traffic control signals that are properly designed, located, operated, and maintained will have one or more of the following advantages:

A. They provide for the orderly movement of traffic.
B. They increase the traffic-handling capacity of the intersection if:
   1. Proper physical layouts and control measures are used, and
   2. The signal operational parameters are reviewed and updated (if needed) on a regular basis (as engineering judgment determines that significant traffic flow and/or land use changes have occurred) to maximize the ability of the traffic control signal to satisfy current traffic demands.
C. They reduce the frequency and severity of certain types of crashes, especially right-angle collisions.
D. They are coordinated to provide for continuous or nearly continuous movement of traffic at a definite speed along a given route under favorable conditions.
E. They are used to interrupt heavy traffic at intervals to permit other traffic, vehicular or pedestrian, to cross.

03 Traffic control signals are often considered a panacea for all traffic problems at intersections. This belief has led to traffic control signals being installed at many locations where they are not needed, adversely affecting the safety and efficiency of vehicular, bicycle, and pedestrian traffic.

04 Traffic control signals, even when justified by traffic and roadway conditions, can be ill-designed, ineffectively placed, improperly operated, or poorly maintained. Improper or unjustified traffic control signals can result in one or more of the following disadvantages:

A. Excessive delay,
B. Excessive disobedience of the signal indications,
C. Increased use of less adequate routes as road users attempt to avoid the traffic control signals, and
D. Significant increases in the frequency of collisions (especially rear-end collisions).

Section 4B.04 Alternatives to Traffic Control Signals

Guidance:

01 *Since vehicular delay and the frequency of some types of crashes are sometimes greater under traffic signal control than under STOP sign control, consideration should be given to providing alternatives to traffic control signals even if one or more of the signal warrants has been satisfied.*

Option:

02 These alternatives may include, but are not limited to, the following:

A. Installing signs along the major street to warn road users approaching the intersection;
B. Relocating the stop line(s) and making other changes to improve the sight distance at the intersection;
C. Installing measures designed to reduce speeds on the approaches;
D. Installing a flashing beacon at the intersection to supplement STOP sign control;
E. Installing flashing beacons on warning signs in advance of a STOP sign controlled intersection on major- and/or minor-street approaches;
F. Adding one or more lanes on a minor-street approach to reduce the number of vehicles per lane on the approach;
G. Revising the geometrics at the intersection to channelize vehicular movements and reduce the time required for a vehicle to complete a movement, which could also assist pedestrians;
H. Revising the geometrics at the intersection to add pedestrian median refuge islands and/or curb extensions;
I. Installing roadway lighting if a disproportionate number of crashes occur at night;
J. Restricting one or more turning movements, perhaps on a time-of-day basis, if alternate routes are available;
K. If the warrant is satisfied, installing multi-way STOP sign control;
L. Installing a pedestrian hybrid beacon (see Chapter 4F) or In-Roadway Warning Lights (see Chapter 4N) if pedestrian safety is the major concern;
M. Installing a roundabout; and
N. Employing other alternatives, depending on conditions at the intersection.

Section 4B.05 Adequate Roadway Capacity

Support:

01 The delays inherent in the alternating assignment of right-of-way at intersections controlled by traffic control signals can frequently be reduced by widening the major roadway, the minor roadway, or both roadways. Widening the minor roadway often benefits the operations on the major roadway, because it reduces the green time that must be assigned to minor-roadway traffic. In urban areas, the effect of widening can be achieved by eliminating parking on intersection approaches. It is desirable to have at least two lanes for moving traffic on each approach to a signalized location. Additional width on the departure side of the intersection, as well as on the approach side, will sometimes be needed to clear traffic through the intersection effectively.

Guidance:

02 *Adequate roadway capacity should be provided at a signalized location. Before an intersection is widened, the additional green time pedestrians need to cross the widened roadways should be considered to determine if it will exceed the green time saved through improved vehicular flow.*

03 *Other methods of increasing the roadway capacity at signalized locations that do not involve roadway widening, such as revisions to the pavement markings and the careful evaluation of proper lane-use assignments (including varying the lane use by time of day), should be considered where appropriate. Such consideration should include evaluation of any impacts that changes to pavement markings and lane assignments will have on bicycle travel.*

CHAPTER 4C. TRAFFIC CONTROL SIGNAL NEEDS STUDIES

Section 4C.01 Studies and Factors for Justifying Traffic Control Signals

Standard:

01 **An engineering study of traffic conditions, pedestrian characteristics, and physical characteristics of the location shall be performed to determine whether installation of a traffic control signal is justified at a particular location.**

02 **The investigation of the need for a traffic control signal shall include an analysis of factors related to the existing operation and safety at the study location and the potential to improve these conditions, and the applicable factors contained in the following traffic signal warrants:**

Warrant 1, Eight-Hour Vehicular Volume
Warrant 2, Four-Hour Vehicular Volume
Warrant 3, Peak Hour
Warrant 4, Pedestrian Volume
Warrant 5, School Crossing
Warrant 6, Coordinated Signal System
Warrant 7, Crash Experience
Warrant 8, Roadway Network
Warrant 9, Intersection Near a Grade Crossing

03 **The satisfaction of a traffic signal warrant or warrants shall not in itself require the installation of a traffic control signal.**

Support:

04 Sections 8C.09 and 8C.10 contain information regarding the use of traffic control signals instead of gates and/ or flashing-light signals at highway-rail grade crossings and highway-light rail transit grade crossings, respectively.

Guidance:

05 *A traffic control signal should not be installed unless one or more of the factors described in this Chapter are met.*

06 *A traffic control signal should not be installed unless an engineering study indicates that installing a traffic control signal will improve the overall safety and/or operation of the intersection.*

07 *A traffic control signal should not be installed if it will seriously disrupt progressive traffic flow.*

08 *The study should consider the effects of the right-turn vehicles from the minor-street approaches. Engineering judgment should be used to determine what, if any, portion of the right-turn traffic is subtracted from the minor-street traffic count when evaluating the count against the signal warrants listed in Paragraph 2.*

09 *Engineering judgment should also be used in applying various traffic signal warrants to cases where approaches consist of one lane plus one left-turn or right-turn lane. The site-specific traffic characteristics should dictate whether an approach is considered as one lane or two lanes. For example, for an approach with one lane for through and right-turning traffic plus a left-turn lane, if engineering judgment indicates that it should be considered a one-lane approach because the traffic using the left-turn lane is minor, the total traffic volume approaching the intersection should be applied against the signal warrants as a one-lane approach. The approach should be considered two lanes if approximately half of the traffic on the approach turns left and the left-turn lane is of sufficient length to accommodate all left-turn vehicles.*

10 *Similar engineering judgment and rationale should be applied to a street approach with one through/left-turn lane plus a right-turn lane. In this case, the degree of conflict of minor-street right-turn traffic with traffic on the major street should be considered. Thus, right-turn traffic should not be included in the minor-street volume if the movement enters the major street with minimal conflict. The approach should be evaluated as a one-lane approach with only the traffic volume in the through/left-turn lane considered.*

11 *At a location that is under development or construction and where it is not possible to obtain a traffic count that would represent future traffic conditions, hourly volumes should be estimated as part of an engineering study for comparison with traffic signal warrants. Except for locations where the engineering study uses the satisfaction of Warrant 8 to justify a signal, a traffic control signal installed under projected conditions should have an engineering study done within 1 year of putting the signal into stop-and-go operation to determine if the signal is justified. If not justified, the signal should be taken out of stop-and-go operation or removed.*

12 *For signal warrant analysis, a location with a wide median, even if the median width is greater than 30 feet, should be considered as one intersection.*

Option:

13 At an intersection with a high volume of left-turn traffic from the major street, the signal warrant analysis may be performed in a manner that considers the higher of the major-street left-turn volumes as the "minor-street" volume and the corresponding single direction of opposing traffic on the major street as the "major-street" volume.

14 For signal warrants requiring conditions to be present for a certain number of hours in order to be satisfied, any four sequential 15-minute periods may be considered as 1 hour if the separate 1-hour periods used in the warrant analysis do not overlap each other and both the major-street volume and the minor-street volume are for the same specific one-hour periods.

15 For signal warrant analysis, bicyclists may be counted as either vehicles or pedestrians.

Support:

16 When performing a signal warrant analysis, bicyclists riding in the street with other vehicular traffic are usually counted as vehicles and bicyclists who are clearly using pedestrian facilities are usually counted as pedestrians.

Option:

17 Engineering study data may include the following:

A. The number of vehicles entering the intersection in each hour from each approach during 12 hours of an average day. It is desirable that the hours selected contain the greatest percentage of the 24-hour traffic volume.
B. Vehicular volumes for each traffic movement from each approach, classified by vehicle type (heavy trucks, passenger cars and light trucks, public-transit vehicles, and, in some locations, bicycles), during each 15-minute period of the 2 hours in the morning and 2 hours in the afternoon during which total traffic entering the intersection is greatest.
C. Pedestrian volume counts on each crosswalk during the same periods as the vehicular counts in Item B and during hours of highest pedestrian volume. Where young, elderly, and/or persons with physical or visual disabilities need special consideration, the pedestrians and their crossing times may be classified by general observation.
D. Information about nearby facilities and activity centers that serve the young, elderly, and/or persons with disabilities, including requests from persons with disabilities for accessible crossing improvements at the location under study. These persons might not be adequately reflected in the pedestrian volume count if the absence of a signal restrains their mobility.
E. The posted or statutory speed limit or the 85^{th}-percentile speed on the uncontrolled approaches to the location.
F. A condition diagram showing details of the physical layout, including such features as intersection geometrics, channelization, grades, sight-distance restrictions, transit stops and routes, parking conditions, pavement markings, roadway lighting, driveways, nearby railroad crossings, distance to nearest traffic control signals, utility poles and fixtures, and adjacent land use.
G. A collision diagram showing crash experience by type, location, direction of movement, severity, weather, time of day, date, and day of week for at least 1 year.

18 The following data, which are desirable for a more precise understanding of the operation of the intersection, may be obtained during the periods described in Item B of Paragraph 17:

A. Vehicle-hours of stopped time delay determined separately for each approach.
B. The number and distribution of acceptable gaps in vehicular traffic on the major street for entrance from the minor street.
C. The posted or statutory speed limit or the 85^{th}-percentile speed on controlled approaches at a point near to the intersection but unaffected by the control.
D. Pedestrian delay time for at least two 30-minute peak pedestrian delay periods of an average weekday or like periods of a Saturday or Sunday.
E. Queue length on stop-controlled approaches.

Section 4C.02 Warrant 1, Eight-Hour Vehicular Volume

Support:

01 The Minimum Vehicular Volume, Condition A, is intended for application at locations where a large volume of intersecting traffic is the principal reason to consider installing a traffic control signal.

02 The Interruption of Continuous Traffic, Condition B, is intended for application at locations where Condition A is not satisfied and where the traffic volume on a major street is so heavy that traffic on a minor intersecting street suffers excessive delay or conflict in entering or crossing the major street.

03 It is intended that Warrant 1 be treated as a single warrant. If Condition A is satisfied, then Warrant 1 is satisfied and analyses of Condition B and the combination of Conditions A and B are not needed. Similarly, if Condition B is satisfied, then Warrant 1 is satisfied and an analysis of the combination of Conditions A and B is not needed.

Standard:

04 **The need for a traffic control signal shall be considered if an engineering study finds that one of the following conditions exist for each of any 8 hours of an average day:**

A. The vehicles per hour given in both of the 100 percent columns of Condition A in Table 4C-1 exist on the major-street and the higher-volume minor-street approaches, respectively, to the intersection; or

B. The vehicles per hour given in both of the 100 percent columns of Condition B in Table 4C-1 exist on the major-street and the higher-volume minor-street approaches, respectively, to the intersection.

In applying each condition the major-street and minor-street volumes shall be for the same 8 hours. On the minor street, the higher volume shall not be required to be on the same approach during each of these 8 hours.

Option:

05 If the posted or statutory speed limit or the 85th-percentile speed on the major street exceeds 40 mph, or if the intersection lies within the built-up area of an isolated community having a population of less than 10,000, the traffic volumes in the 70 percent columns in Table 4C-1 may be used in place of the 100 percent columns.

Guidance:

06 *The combination of Conditions A and B is intended for application at locations where Condition A is not satisfied and Condition B is not satisfied and should be applied only after an adequate trial of other alternatives that could cause less delay and inconvenience to traffic has failed to solve the traffic problems.*

Standard:

07 **The need for a traffic control signal shall be considered if an engineering study finds that both of the following conditions exist for each of any 8 hours of an average day:**

A. The vehicles per hour given in both of the 80 percent columns of Condition A in Table 4C-1 exist on the major-street and the higher-volume minor-street approaches, respectively, to the intersection; and

B. The vehicles per hour given in both of the 80 percent columns of Condition B in Table 4C-1 exist on the major-street and the higher-volume minor-street approaches, respectively, to the intersection.

These major-street and minor-street volumes shall be for the same 8 hours for each condition; however, the 8 hours satisfied in Condition A shall not be required to be the same 8 hours satisfied in Condition B. On the minor street, the higher volume shall not be required to be on the same approach during each of the 8 hours.

Table 4C-1. Warrant 1, Eight-Hour Vehicular Volume

Condition A—Minimum Vehicular Volume

Number of lanes for moving traffic on each approach		Vehicles per hour on major street (total of both approaches)				Vehicles per hour on higher-volume minor-street approach (one direction only)			
Major Street	Minor Street	100%[a]	80%[b]	70%[c]	56%[d]	100%[a]	80%[b]	70%[c]	56%[d]
1	1	500	400	350	280	150	120	105	84
2 or more	1	600	480	420	336	150	120	105	84
2 or more	2 or more	600	480	420	336	200	160	140	112
1	2 or more	500	400	350	280	200	160	140	112

Condition B—Interruption of Continuous Traffic

Number of lanes for moving traffic on each approach		Vehicles per hour on major street (total of both approaches)				Vehicles per hour on higher-volume minor-street approach (one direction only)			
Major Street	Minor Street	100%[a]	80%[b]	70%[c]	56%[d]	100%[a]	80%[b]	70%[c]	56%[d]
1	1	750	600	525	420	75	60	53	42
2 or more	1	900	720	630	504	75	60	53	42
2 or more	2 or more	900	720	630	504	100	80	70	56
1	2 or more	750	600	525	420	100	80	70	56

[a] Basic minimum hourly volume

[b] Used for combination of Conditions A and B after adequate trial of other remedial measures

[c] May be used when the major-street speed exceeds 40 mph or in an isolated community with a population of less than 10,000

[d] May be used for combination of Conditions A and B after adequate trial of other remedial measures when the major-street speed exceeds 40 mph or in an isolated community with a population of less than 10,000

Option:

08 If the posted or statutory speed limit or the 85th-percentile speed on the major street exceeds 40 mph, or if the intersection lies within the built-up area of an isolated community having a population of less than 10,000, the traffic volumes in the 56 percent columns in Table 4C-1 may be used in place of the 80 percent columns.

Section 4C.03 Warrant 2, Four-Hour Vehicular Volume

Support:

01 The Four-Hour Vehicular Volume signal warrant conditions are intended to be applied where the volume of intersecting traffic is the principal reason to consider installing a traffic control signal.

Standard:

02 **The need for a traffic control signal shall be considered if an engineering study finds that, for each of any 4 hours of an average day, the plotted points representing the vehicles per hour on the major street (total of both approaches) and the corresponding vehicles per hour on the higher-volume minor-street approach (one direction only) all fall above the applicable curve in Figure 4C-1 for the existing combination of approach lanes. On the minor street, the higher volume shall not be required to be on the same approach during each of these 4 hours.**

Option:

03 If the posted or statutory speed limit or the 85th-percentile speed on the major street exceeds 40 mph, or if the intersection lies within the built-up area of an isolated community having a population of less than 10,000, Figure 4C-2 may be used in place of Figure 4C-1.

Section 4C.04 Warrant 3, Peak Hour

Support:

01 The Peak Hour signal warrant is intended for use at a location where traffic conditions are such that for a minimum of 1 hour of an average day, the minor-street traffic suffers undue delay when entering or crossing the major street.

Standard:

02 **This signal warrant shall be applied only in unusual cases, such as office complexes, manufacturing plants, industrial complexes, or high-occupancy vehicle facilities that attract or discharge large numbers of vehicles over a short time.**

03 **The need for a traffic control signal shall be considered if an engineering study finds that the criteria in either of the following two categories are met:**

A. If all three of the following conditions exist for the same 1 hour (any four consecutive 15-minute periods) of an average day:

1. The total stopped time delay experienced by the traffic on one minor-street approach (one direction only) controlled by a STOP sign equals or exceeds: 4 vehicle-hours for a one-lane approach or 5 vehicle-hours for a two-lane approach; and

2. The volume on the same minor-street approach (one direction only) equals or exceeds 100 vehicles per hour for one moving lane of traffic or 150 vehicles per hour for two moving lanes; and

3. The total entering volume serviced during the hour equals or exceeds 650 vehicles per hour for intersections with three approaches or 800 vehicles per hour for intersections with four or more approaches.

B. The plotted point representing the vehicles per hour on the major street (total of both approaches) and the corresponding vehicles per hour on the higher-volume minor-street approach (one direction only) for 1 hour (any four consecutive 15-minute periods) of an average day falls above the applicable curve in Figure 4C-3 for the existing combination of approach lanes.

Option:

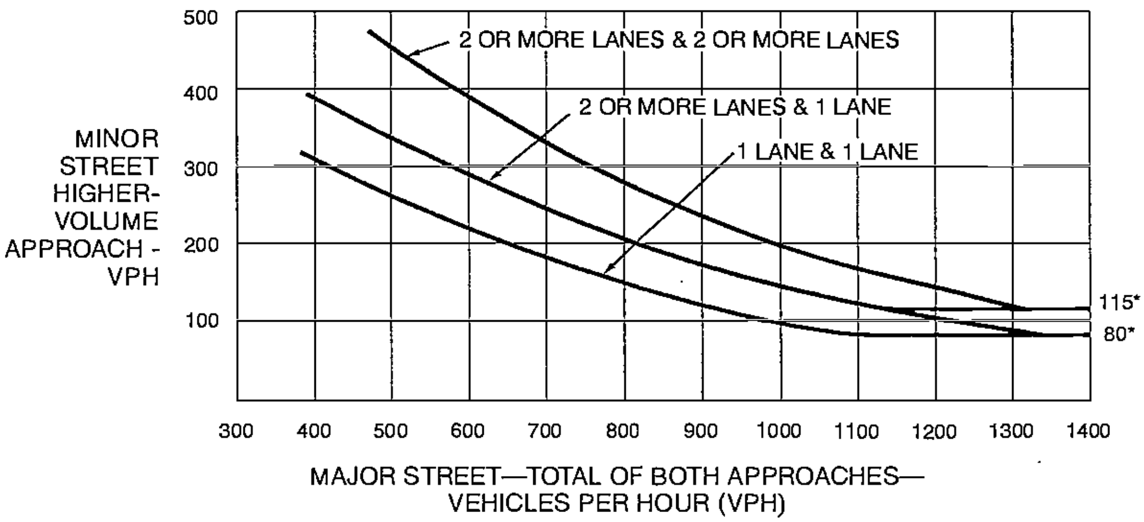
04 If the posted or statutory speed limit or the 85th-percentile speed on the major street exceeds 40 mph, or if the intersection lies within the built-up area of an isolated community having a population of less than 10,000, Figure 4C-4 may be used in place of Figure 4C-3 to evaluate the criteria in the second category of the Standard.

05 If this warrant is the only warrant met and a traffic control signal is justified by an engineering study, the traffic control signal may be operated in the flashing mode during the hours that the volume criteria of this warrant are not met.

Guidance:

06 *If this warrant is the only warrant met and a traffic control signal is justified by an engineering study, the traffic control signal should be traffic-actuated.*

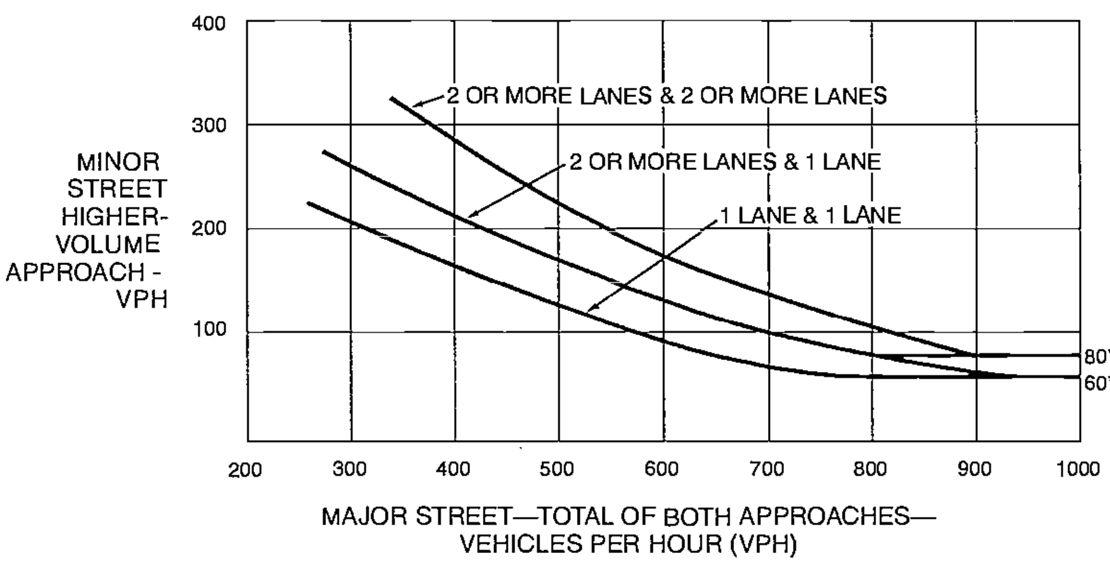
Figure 4C-1. Warrant 2, Four-Hour Vehicular Volume



*Note: 115 vph applies as the lower threshold volume for a minor-street approach with two or more lanes and 80 vph applies as the lower threshold volume for a minor-street approach with one lane.

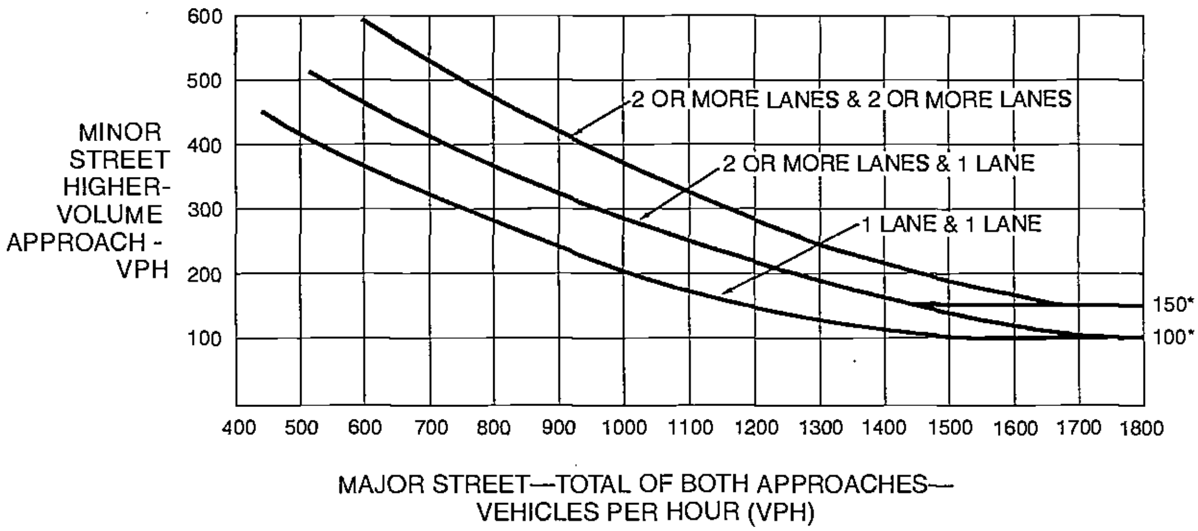
Figure 4C-2. Warrant 2, Four-Hour Vehicular Volume (70% Factor)

(COMMUNITY LESS THAN 10,000 POPULATION OR ABOVE 40 MPH ON MAJOR STREET)



*Note: 80 vph applies as the lower threshold volume for a minor-street approach with two or more lanes and 60 vph applies as the lower threshold volume for a minor-street approach with one lane.

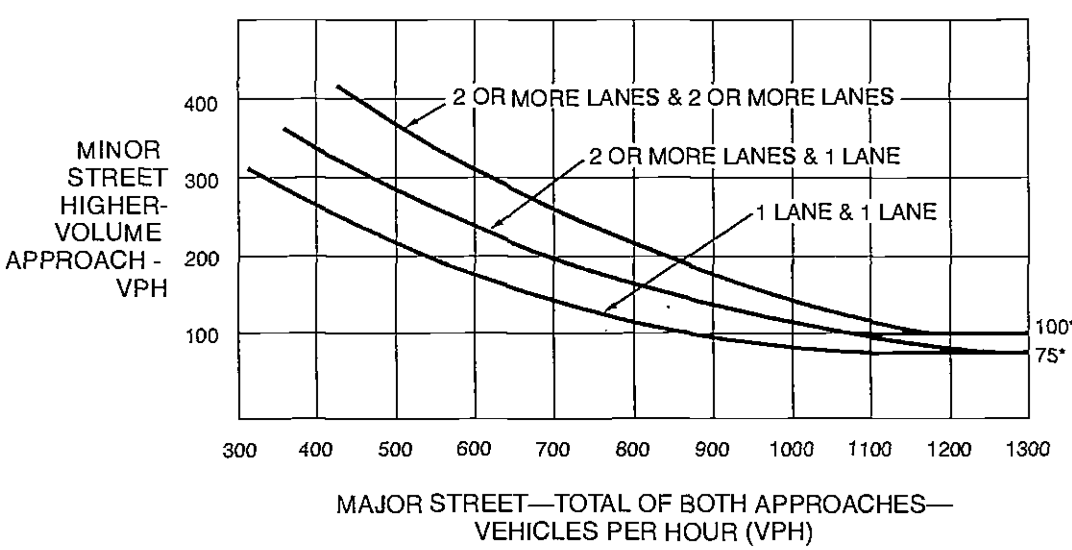
Figure 4C-3. Warrant 3, Peak Hour



*Note: 150 vph applies as the lower threshold volume for a minor-street approach with two or more lanes and 100 vph applies as the lower threshold volume for a minor-street approach with one lane.

Figure 4C-4. Warrant 3, Peak Hour (70% Factor)

(COMMUNITY LESS THAN 10,000 POPULATION OR ABOVE 40 MPH ON MAJOR STREET)



*Note: 100 vph applies as the lower threshold volume for a minor-street approach with two or more lanes and 75 vph applies as the lower threshold volume for a minor-street approach with one lane.

Section 4C.05 Warrant 4, Pedestrian Volume

Support:

01 The Pedestrian Volume signal warrant is intended for application where the traffic volume on a major street is so heavy that pedestrians experience excessive delay in crossing the major street.

Standard:

02 **The need for a traffic control signal at an intersection or midblock crossing shall be considered if an engineering study finds that one of the following criteria is met:**

- **A. For each of any 4 hours of an average day, the plotted points representing the vehicles per hour on the major street (total of both approaches) and the corresponding pedestrians per hour crossing the major street (total of all crossings) all fall above the curve in Figure 4C-5; or**
- **B. For 1 hour (any four consecutive 15-minute periods) of an average day, the plotted point representing the vehicles per hour on the major street (total of both approaches) and the corresponding pedestrians per hour crossing the major street (total of all crossings) falls above the curve in Figure 4C-7.**

Option:

03 If the posted or statutory speed limit or the 85th-percentile speed on the major street exceeds 35 mph, or if the intersection lies within the built-up area of an isolated community having a population of less than 10,000, Figure 4C-6 may be used in place of Figure 4C-5 to evaluate Criterion A in Paragraph 2, and Figure 4C-8 may be used in place of Figure 4C-7 to evaluate Criterion B in Paragraph 2.

Standard:

04 **The Pedestrian Volume signal warrant shall not be applied at locations where the distance to the nearest traffic control signal or STOP sign controlling the street that pedestrians desire to cross is less than 300 feet, unless the proposed traffic control signal will not restrict the progressive movement of traffic.**

05 **If this warrant is met and a traffic control signal is justified by an engineering study, the traffic control signal shall be equipped with pedestrian signal heads complying with the provisions set forth in Chapter 4E.**

Guidance:

06 *If this warrant is met and a traffic control signal is justified by an engineering study, then:*

- *A. If it is installed at an intersection or major driveway location, the traffic control signal should also control the minor-street or driveway traffic, should be traffic-actuated, and should include pedestrian detection.*
- *B. If it is installed at a non-intersection crossing, the traffic control signal should be installed at least 100 feet from side streets or driveways that are controlled by STOP or YIELD signs, and should be pedestrian-actuated. If the traffic control signal is installed at a non-intersection crossing, at least one of the signal faces should be over the traveled way for each approach, parking and other sight obstructions should be prohibited for at least 100 feet in advance of and at least 20 feet beyond the crosswalk or site accommodations should be made through curb extensions or other techniques to provide adequate sight distance, and the installation should include suitable standard signs and pavement markings.*
- *C. Furthermore, if it is installed within a signal system, the traffic control signal should be coordinated.*

Option:

07 The criterion for the pedestrian volume crossing the major street may be reduced as much as 50 percent if the 15th-percentile crossing speed of pedestrians is less than 3.5 feet per second.

08 A traffic control signal may not be needed at the study location if adjacent coordinated traffic control signals consistently provide gaps of adequate length for pedestrians to cross the street.

Section 4C.06 Warrant 5, School Crossing

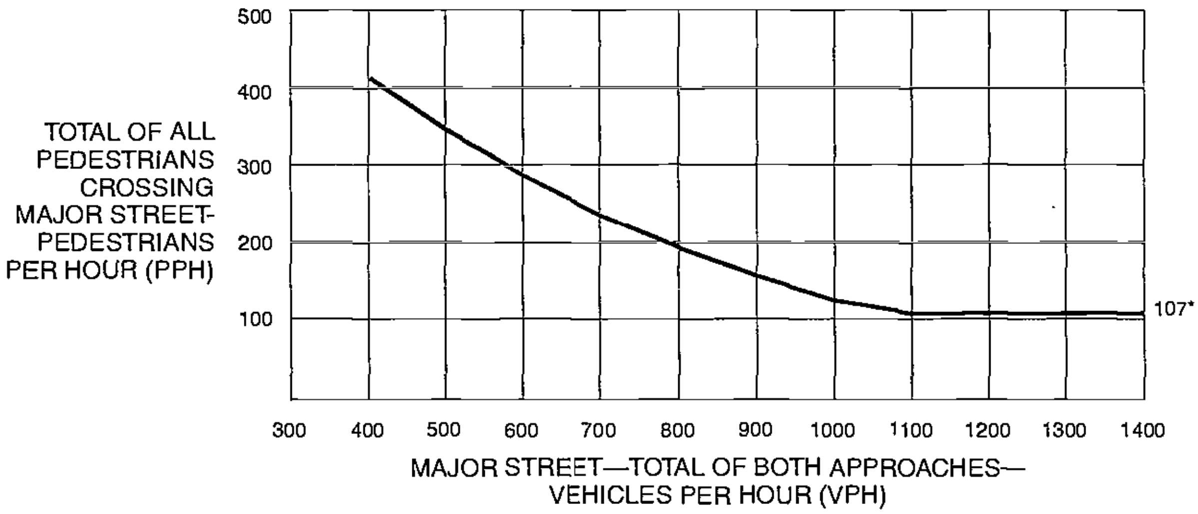
Support:

01 The School Crossing signal warrant is intended for application where the fact that schoolchildren cross the major street is the principal reason to consider installing a traffic control signal. For the purposes of this warrant, the word "schoolchildren" includes elementary through high school students.

Standard:

02 **The need for a traffic control signal shall be considered when an engineering study of the frequency and adequacy of gaps in the vehicular traffic stream as related to the number and size of groups of schoolchildren at an established school crossing across the major street shows that the number of adequate gaps in the traffic stream during the period when the schoolchildren are using the crossing is less than the number of minutes in the same period (see Section 7A.03) and there are a minimum of 20 schoolchildren during the highest crossing hour.**

Figure 4C-5. Warrant 4, Pedestrian Four-Hour Volume

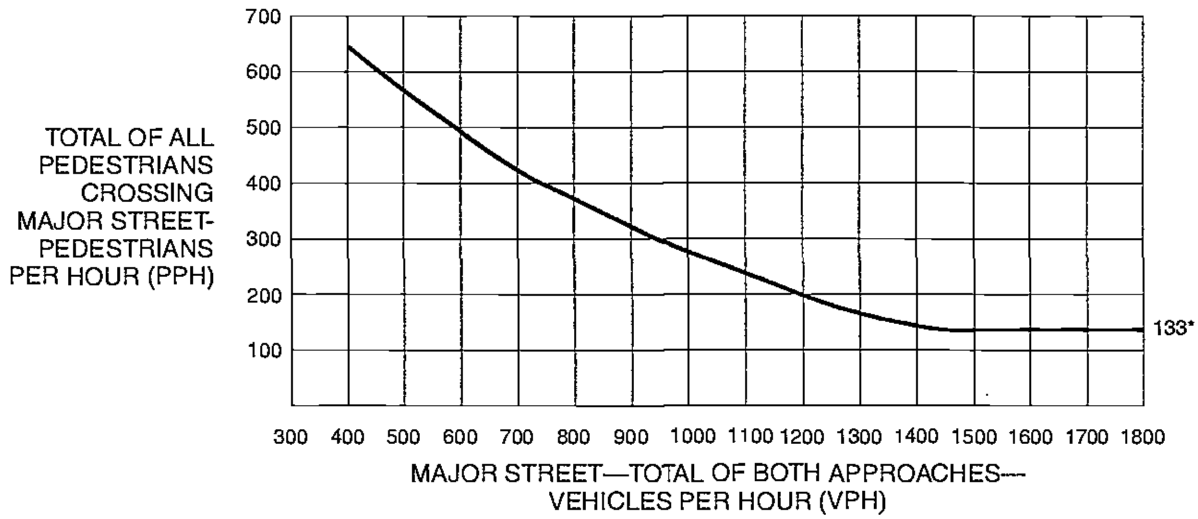


*Note: 107 pph applies as the lower threshold volume.

Figure 4C-6. Warrant 4, Pedestrian Four-Hour Volume (70% Factor)

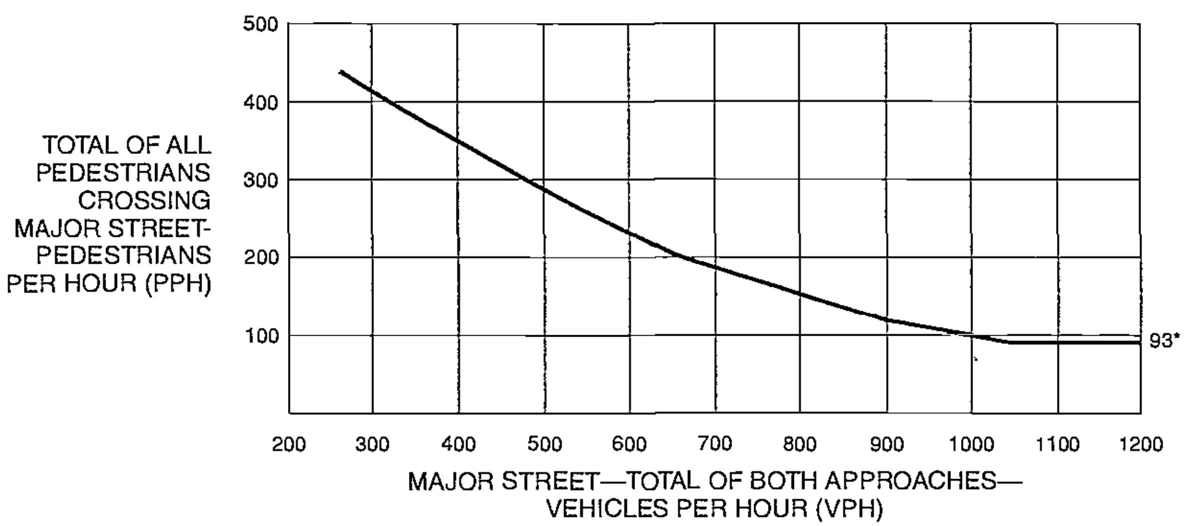
*Note: 75 pph applies as the lower threshold volume.

Figure 4C-7. Warrant 4, Pedestrian Peak Hour



*Note: 133 pph applies as the lower threshold volume.

Figure 4C-8. Warrant 4, Pedestrian Peak Hour (70% Factor)



*Note: 93 pph applies as the lower threshold volume.

03 **Before a decision is made to install a traffic control signal, consideration shall be given to the implementation of other remedial measures, such as warning signs and flashers, school speed zones, school crossing guards, or a grade-separated crossing.**

04 **The School Crossing signal warrant shall not be applied at locations where the distance to the nearest traffic control signal along the major street is less than 300 feet, unless the proposed traffic control signal will not restrict the progressive movement of traffic.**

Guidance:

05 *If this warrant is met and a traffic control signal is justified by an engineering study, then:*

A. *If it is installed at an intersection or major driveway location, the traffic control signal should also control the minor-street or driveway traffic, should be traffic-actuated, and should include pedestrian detection.*
B. *If it is installed at a non-intersection crossing, the traffic control signal should be installed at least 100 feet from side streets or driveways that are controlled by STOP or YIELD signs, and should be pedestrian-actuated. If the traffic control signal is installed at a non-intersection crossing, at least one of the signal faces should be over the traveled way for each approach, parking and other sight obstructions should be prohibited for at least 100 feet in advance of and at least 20 feet beyond the crosswalk or site accommodations should be made through curb extensions or other techniques to provide adequate sight distance, and the installation should include suitable standard signs and pavement markings.*
C. *Furthermore, if it is installed within a signal system, the traffic control signal should be coordinated.*

Section 4C.07 Warrant 6, Coordinated Signal System

Support:

01 Progressive movement in a coordinated signal system sometimes necessitates installing traffic control signals at intersections where they would not otherwise be needed in order to maintain proper platooning of vehicles.

Standard:

02 **The need for a traffic control signal shall be considered if an engineering study finds that one of the following criteria is met:**

A. **On a one-way street or a street that has traffic predominantly in one direction, the adjacent traffic control signals are so far apart that they do not provide the necessary degree of vehicular platooning.**
B. **On a two-way street, adjacent traffic control signals do not provide the necessary degree of platooning and the proposed and adjacent traffic control signals will collectively provide a progressive operation.**

Guidance:

03 *The Coordinated Signal System signal warrant should not be applied where the resultant spacing of traffic control signals would be less than 1,000 feet.*

Section 4C.08 Warrant 7, Crash Experience

Support:

01 The Crash Experience signal warrant conditions are intended for application where the severity and frequency of crashes are the principal reasons to consider installing a traffic control signal.

Standard:

02 **The need for a traffic control signal shall be considered if an engineering study finds that all of the following criteria are met:**

A. **Adequate trial of alternatives with satisfactory observance and enforcement has failed to reduce the crash frequency; and**
B. **Five or more reported crashes, of types susceptible to correction by a traffic control signal, have occurred within a 12-month period, each crash involving personal injury or property damage apparently exceeding the applicable requirements for a reportable crash; and**
C. **For each of any 8 hours of an average day, the vehicles per hour (vph) given in both of the 80 percent columns of Condition A in Table 4C-1 (see Section 4C.02), or the vph in both of the 80 percent columns of Condition B in Table 4C-1 exists on the major-street and the higher-volume minor-street approach, respectively, to the intersection, or the volume of pedestrian traffic is not less than 80 percent of the requirements specified in the Pedestrian Volume warrant. These major-street and minor-street volumes shall be for the same 8 hours. On the minor street, the higher volume shall not be required to be on the same approach during each of the 8 hours.**

Option:

03 If the posted or statutory speed limit or the 85th-percentile speed on the major street exceeds 40 mph, or if the intersection lies within the built-up area of an isolated community having a population of less than 10,000, the traffic volumes in the 56 percent columns in Table 4C-1 may be used in place of the 80 percent columns.

Section 4C.09 Warrant 8, Roadway Network

Support:

01 Installing a traffic control signal at some intersections might be justified to encourage concentration and organization of traffic flow on a roadway network.

Standard:

02 **The need for a traffic control signal shall be considered if an engineering study finds that the common intersection of two or more major routes meets one or both of the following criteria:**

A. The intersection has a total existing, or immediately projected, entering volume of at least 1,000 vehicles per hour during the peak hour of a typical weekday and has 5-year projected traffic volumes, based on an engineering study, that meet one or more of Warrants 1, 2, and 3 during an average weekday; or

B. The intersection has a total existing or immediately projected entering volume of at least 1,000 vehicles per hour for each of any 5 hours of a non-normal business day (Saturday or Sunday).

03 **A major route as used in this signal warrant shall have at least one of the following characteristics:**

A. It is part of the street or highway system that serves as the principal roadway network for through traffic flow.

B. It includes rural or suburban highways outside, entering, or traversing a city.

C. It appears as a major route on an official plan, such as a major street plan in an urban area traffic and transportation study.

Section 4C.10 Warrant 9, Intersection Near a Grade Crossing

Support:

01 The Intersection Near a Grade Crossing signal warrant is intended for use at a location where none of the conditions described in the other eight traffic signal warrants are met, but the proximity to the intersection of a grade crossing on an intersection approach controlled by a STOP or YIELD sign is the principal reason to consider installing a traffic control signal.

Guidance:

02 *This signal warrant should be applied only after adequate consideration has been given to other alternatives or after a trial of an alternative has failed to alleviate the safety concerns associated with the grade crossing. Among the alternatives that should be considered or tried are:*

A. Providing additional pavement that would enable vehicles to clear the track or that would provide space for an evasive maneuver, or

B. Reassigning the stop controls at the intersection to make the approach across the track a non-stopping approach.

Standard:

03 **The need for a traffic control signal shall be considered if an engineering study finds that both of the following criteria are met:**

A. A grade crossing exists on an approach controlled by a STOP or YIELD sign and the center of the track nearest to the intersection is within 140 feet of the stop line or yield line on the approach; and

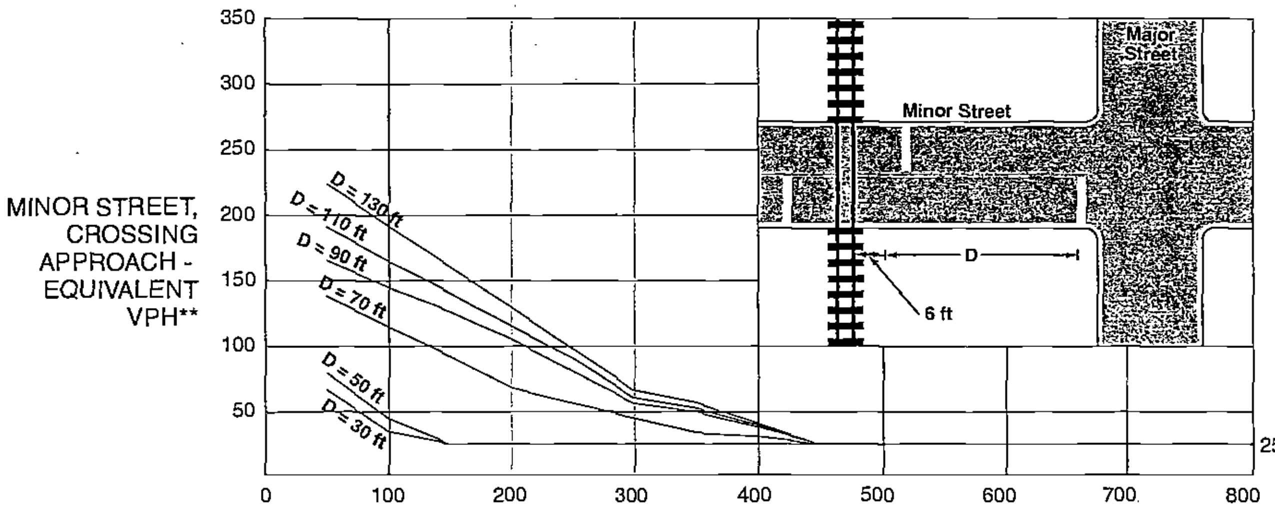
B. During the highest traffic volume hour during which rail traffic uses the crossing, the plotted point representing the vehicles per hour on the major street (total of both approaches) and the corresponding vehicles per hour on the minor-street approach that crosses the track (one direction only, approaching the intersection) falls above the applicable curve in Figure 4C-9 or 4C-10 for the existing combination of approach lanes over the track and the distance D, which is the clear storage distance as defined in Section 1A.13.

Guidance:

04 *The following considerations apply when plotting the traffic volume data on Figure 4C-9 or 4C-10:*

A. Figure 4C-9 should be used if there is only one lane approaching the intersection at the track crossing location and Figure 4C-10 should be used if there are two or more lanes approaching the intersection at the track crossing location.

Figure 4C-9. Warrant 9, Intersection Near a Grade Crossing (One Approach Lane at the Track Crossing)



* 25 vph applies as the lower threshold volume

** VPH after applying the adjustment factors in Tables 4C-2, 4C-3, and/or 4C-4, if appropriate

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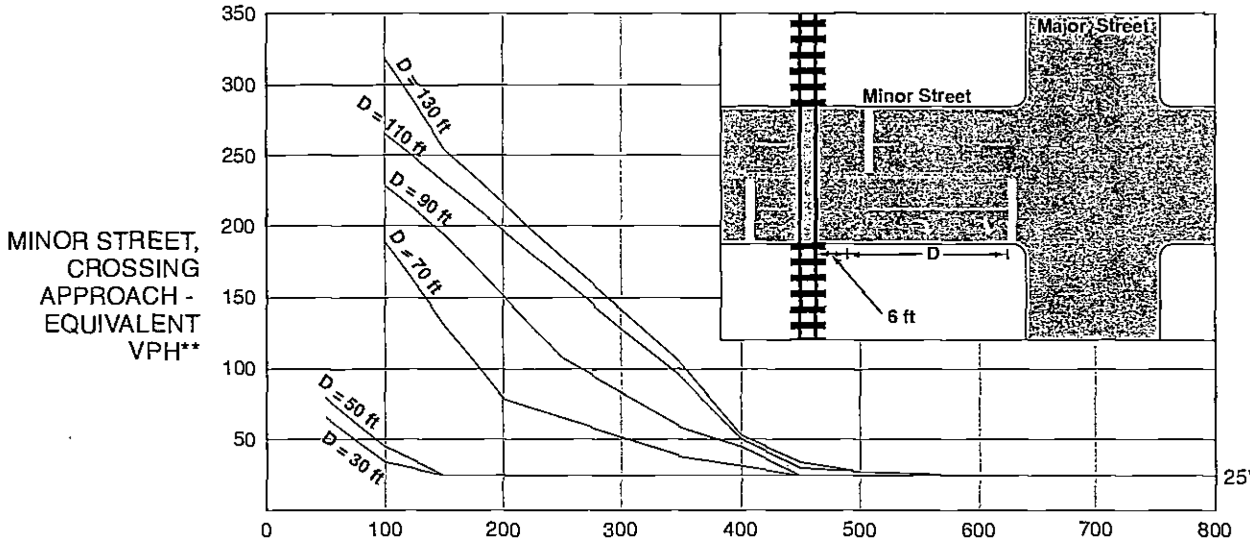
Figure 4C-10. Warrant 9, Intersection Near a Grade Crossing (Two or More Approach Lanes at the Track Crossing)



* 25 vph applies as the lower threshold volume

** VPH after applying the adjustment factors in Tables 4C-2, 4C-3, and/or 4C-4, if appropriate

B. *After determining the actual distance D, the curve for the distance D that is nearest to the actual distance D should be used. For example, if the actual distance D is 95 feet, the plotted point should be compared to the curve for D = 90 feet.*

C. *If the rail traffic arrival times are unknown, the highest traffic volume hour of the day should be used.*

Option:

05 The minor-street approach volume may be multiplied by up to three adjustment factors as provided in Paragraphs 6 through 8.

06 Because the curves are based on an average of four occurrences of rail traffic per day, the vehicles per hour on the minor-street approach may be multiplied by the adjustment factor shown in Table 4C-2 for the appropriate number of occurrences of rail traffic per day.

07 Because the curves are based on typical vehicle occupancy, if at least 2% of the vehicles crossing the track are buses carrying at least 20 people, the vehicles per hour on the minor-street approach may be multiplied by the adjustment factor shown in Table 4C-3 for the appropriate percentage of high-occupancy buses.

08 Because the curves are based on tractor-trailer trucks comprising 10% of the vehicles crossing the track, the vehicles per hour on the minor-street approach may be multiplied by the adjustment factor shown in Table 4C-4 for the appropriate distance and percentage of tractor-trailer trucks.

Standard:

09 **If this warrant is met and a traffic control signal at the intersection is justified by an engineering study, then:**

A. **The traffic control signal shall have actuation on the minor street;**

B. **Preemption control shall be provided in accordance with Sections 4D.27, 8C.09, and 8C.10; and**

C. **The grade crossing shall have flashing-light signals (see Chapter 8C).**

Guidance:

10 *If this warrant is met and a traffic control signal at the intersection is justified by an engineering study, the grade crossing should have automatic gates (see Chapter 8C).*

Table 4C-2. Warrant 9, Adjustment Factor for Daily Frequency of Rail Traffic

Rail Traffic per Day	Adjustment Factor
1	0.67
2	0.91
3 to 5	1.00
6 to 8	1.18
9 to 11	1.25
12 or more	1.33

Table 4C-3. Warrant 9, Adjustment Factor for Percentage of High-Occupancy Buses

% of High-Occupancy Buses* on Minor-Street Approach	Adjustment Factor
0%	1.00
2%	1.09
4%	1.19
6% or more	1.32

* A high-occupancy bus is defined as a bus occupied by at least 20 people.

Table 4C-4. Warrant 9, Adjustment Factor for Percentage of Tractor-Trailer Trucks

% of Tractor-Trailer Trucks on Minor-Street Approach	Adjustment Factor	
	D less than 70 feet	D of 70 feet or more
0% to 2.5%	0.50	0.50
2.6% to 7.5%	0.75	0.75
7.6% to 12.5%	1.00	1.00
12.6% to 17.5%	2.30	1.15
17.6% to 22.5%	2.70	1.35
22.6% to 27.5%	3.28	1.64
More than 27.5%	4.18	2.09

CHAPTER 4D. TRAFFIC CONTROL SIGNAL FEATURES

Section 4D.01 General

Support:

01 The features of traffic control signals of interest to road users are the location, design, and meaning of the signal indications. Uniformity in the design features that affect the traffic to be controlled, as set forth in this Manual, is especially important for the safety and efficiency of operations.

02 Traffic control signals can be operated in pretimed, semi-actuated, or full-actuated modes. For isolated (non-interconnected) signalized locations on rural high-speed highways, full-actuated mode with advance vehicle detection on the high-speed approaches is typically used. These features are designed to reduce the frequency with which the onset of the yellow change interval is displayed when high-speed approaching vehicles are in the "dilemma zone" such that the drivers of these high-speed vehicles find it difficult to decide whether to stop or proceed.

Standard:

03 **When a traffic control signal is not in operation, such as before it is placed in service, during seasonal shutdowns, or when it is not desirable to operate the traffic control signal, the signal faces shall be covered, turned, or taken down to clearly indicate that the traffic control signal is not in operation.**

Support:

04 Seasonal shutdown is a condition in which a permanent traffic signal is turned off or otherwise made non-operational during a particular season when its operation is not justified. This might be applied in a community where tourist traffic during most of the year justifies the permanent signalization, but a seasonal shutdown of the signal during an annual period of lower tourist traffic would reduce delays; or where a major traffic generator, such as a large factory, justifies the permanent signalization, but the large factory is shut down for an annual factory vacation for a few weeks in the summer.

Standard:

05 **A traffic control signal shall control traffic only at the intersection or midblock location where the signal faces are placed.**

06 **Midblock crosswalks shall not be signalized if they are located within 300 feet from the nearest traffic control signal, unless the proposed traffic control signal will not restrict the progressive movement of traffic.**

Guidance:

07 *A midblock crosswalk location should not be controlled by a traffic control signal if the crosswalk is located within 100 feet from side streets or driveways that are controlled by STOP signs or YIELD signs.*

08 *Engineering judgment should be used to determine the proper phasing and timing for a traffic control signal. Since traffic flows and patterns change, phasing and timing should be reevaluated regularly and updated if needed.*

09 *Traffic control signals within 1/2 mile of one another along a major route or in a network of intersecting major routes should be coordinated, preferably with interconnected controller units. Where traffic control signals that are within 1/2 mile of one another along a major route have a jurisdictional boundary or a boundary between different signal systems between them, coordination across the boundary should be considered.*

Support:

10 Signal coordination need not be maintained between control sections that operate on different cycle lengths.

11 For coordination with grade crossing signals and movable bridge signals, see Sections 4D.27, 4J.03, 8C.09, and 8C.10.

Section 4D.02 Responsibility for Operation and Maintenance

Guidance:

01 *Prior to installing any traffic control signal, the responsibility for the maintenance of the signal and all of the appurtenances, hardware, software, and the timing plan(s) should be clearly established. The responsible agency should provide for the maintenance of the traffic control signal and all of its appurtenances in a competent manner.*

02 *To this end the agency should:*

- *A. Keep every controller assembly in effective operation in accordance with its predetermined timing schedule; check the operation of the controller assembly frequently enough to verify that it is operating in accordance with the predetermined timing schedule; and establish a policy to maintain a record of all timing changes and that only authorized persons are permitted to make timing changes;*

B. *Clean the optical system of the signal sections and replace the light sources as frequently as experience proves necessary;*
C. *Clean and service equipment and other appurtenances as frequently as experience proves necessary;*
D. *Provide for alternate operation of the traffic control signal during a period of failure, using flashing mode or manual control, or manual traffic direction by proper authorities as might be required by traffic volumes or congestion, or by erecting other traffic control devices;*
E. *Have properly skilled maintenance personnel available without undue delay for all signal malfunctions and signal indication failures;*
F. *Provide spare equipment to minimize the interruption of traffic control signal operation as a result of equipment failure;*
G. *Provide for the availability of properly skilled maintenance personnel for the repair of all components; and*
H. *Maintain the appearance of the signal displays and equipment.*

Section 4D.03 Provisions for Pedestrians

Support:

01 Chapter 4E contains additional information regarding pedestrian signals and Chapter 4F contains additional information regarding pedestrian hybrid beacons.

Standard:

02 **The design and operation of traffic control signals shall take into consideration the needs of pedestrian as well as vehicular traffic.**

03 **If engineering judgment indicates the need for provisions for a given pedestrian movement, signal faces conveniently visible to pedestrians shall be provided by pedestrian signal heads (see Chapter 4E) or a vehicular signal face(s) for a concurrent vehicular movement.**

Guidance:

04 *Accessible pedestrian signals (see Sections 4E.09 through 4E.13) that provide information in non-visual formats (such as audible tones, speech messages, and/or vibrating surfaces) should be provided where determined appropriate by engineering judgment.*

05 *Where pedestrian movements regularly occur, pedestrians should be provided with sufficient time to cross the roadway by adjusting the traffic control signal operation and timing to provide sufficient crossing time every cycle or by providing pedestrian detectors.*

06 *If it is necessary or desirable to prohibit certain pedestrian movements at a traffic control signal location, No Pedestrian Crossing (R9-3) signs (see Section 2B.51) should be used if it is not practical to provide a barrier or other physical feature to physically prevent the pedestrian movements.*

Section 4D.04 Meaning of Vehicular Signal Indications

Support:

01 The "Uniform Vehicle Code" (see Section 1A.11) is the primary source for the standards for the meaning of vehicular signal indications to both vehicle operators and pedestrians as provided in this Section, and the standards for the meaning of separate pedestrian signal head indications as provided in Section 4E.02.

02 The physical area that is defined as being "within the intersection" is dependent upon the conditions that are described in the definition of intersection in Section 1A.13.

Standard:

03 **The following meanings shall be given to highway traffic signal indications for vehicles and pedestrians:**

A. Steady green signal indications shall have the following meanings:

1. Vehicular traffic facing a CIRCULAR GREEN signal indication is permitted to proceed straight through or turn right or left or make a U-turn movement except as such movement is modified by lane-use signs, turn prohibition signs, lane markings, roadway design, separate turn signal indications, or other traffic control devices.

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.

In addition, vehicular traffic turning left or making a U-turn movement to the left shall yield the right-of-way to other vehicles approaching from the opposite direction so closely as to constitute an immediate hazard during the time when such turning vehicle is moving across or within the intersection.

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 greeu 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.

E. Flashing yellow signal indications shall have the following meanings:
   1. Vehicular traffic, on an approach to an intersection, facing a flashing CIRCULAR YELLOW signal indication is permitted to cautiously enter the intersection to proceed straight through or turn right or left or make a U-turn except as such movement is modified by lane-use signs, turn prohibition signs, lane markings, roadway design, separate turn signal indications, or other traffic control devices.

      Such vehicular traffic, including vehicles turning right or left or making a U-turn, shall yield the right-of-way to:

      (a) Pedestrians lawfully within an associated crosswalk, and
      (b) Other vehicles lawfully within the intersection.

      In addition, vehicular traffic turning left or making a U-turn to the left shall yield the right-of-way to other vehicles approaching from the opposite direction so closely as to constitute an immediate hazard during the time when such turning vehicle is moving across or within the intersection.
   2. Vehicular traffic, on an approach to an intersection, facing a flashing YELLOW 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 other such 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, shall yield the right-of-way to:

      (a) Pedestrians lawfully within an associated crosswalk, and
      (b) Other vehicles lawfully within the intersection.

      In addition, vehicular traffic turning left or making a U-turn to the left shall yield the right-of-way to other vehicles approaching from the opposite direction so closely as to constitute an immediate hazard during the time when such turning vehicle is moving across or within the intersection.
   3. Pedestrians facing any flashing yellow signal indication at an intersection, 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. Pedestrians shall yield the right-of-way to vehicles lawfully within the intersection at the time that the flashing yellow signal indication is first displayed.
   4. When a flashing CIRCULAR YELLOW signal indication(s) is displayed as a beacon (see Chapter 4L) to supplement another traffic control device, road users are notified that there is a need to pay extra attention to the message contained thereon or that the regulatory or warning requirements of the other traffic control device, which might not be applicable at all times, are currently applicable.

F. Flashing red signal indications shall have the following meanings:
   1. Vehicular traffic, on an approach to an intersection, facing a flashing CIRCULAR RED 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, at the point nearest the intersecting roadway where the driver has a view of approaching traffic on the intersecting roadway before entering the intersection. The right to proceed shall be subject to the rules applicable after making a stop at a STOP sign.
   2. Vehicular traffic, on an approach to an intersection, facing a flashing RED ARROW signal indication if intending to turn in the direction indicated by the arrow 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, at the point nearest the intersecting roadway where the driver has a view of approaching traffic on the intersecting roadway before entering the intersection. 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. Pedestrians facing any flashing red signal indication at an intersection, 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. Pedestrians shall yield the right-of-way to vehicles lawfully within the intersection at the time that the flashing red signal indication is first displayed.
   4. When a flashing CIRCULAR RED signal indication(s) is displayed as a beacon (see Chapter 4L) to supplement another traffic control device, road users are notified that there is a need to pay extra attention to the message contained thereon or that the regulatory requirements of the other traffic control device, which might not be applicable at all times, are currently applicable. Use of this signal indication shall be limited to supplementing STOP (R1-1), DO NOT ENTER (R5-1), or WRONG WAY (R5-1a) signs, and to applications where compliance with the supplemented traffic control device requires a stop at a designated point.

Section 4D.05 Application of Steady Signal Indications

Standard:

01 **When a traffic control signal is being operated in a steady (stop-and-go) mode, at least one indication in each signal face shall be displayed at any given time.**

02 **A signal face(s) that controls a particular vehicular movement during any interval of a cycle shall control that same movement during all intervals of the cycle.**

03 **Steady signal indications shall be applied as follows:**

A. A steady CIRCULAR RED signal indication:

1. **Shall be displayed when it is intended to prohibit traffic, except pedestrians directed by a pedestrian signal head, from entering the intersection or other controlled area. Turning after stopping is permitted as stated in Item C.1 in Paragraph 3 of Section 4D.04.**
2. **Shall be displayed with the appropriate GREEN ARROW signal indications when it is intended to permit traffic to make a specified turn or turns, and to prohibit traffic from proceeding straight ahead through the intersection or other controlled area, except in protected only mode operation (see Sections 4D.19 and 4D.23), or in protected/permissive mode operation with separate turn signal faces (see Sections 4D.20 and 4D.24).**

B. A steady CIRCULAR YELLOW signal indication:

1. **Shall be displayed following a CIRCULAR GREEN or straight-through GREEN ARROW signal indication in the same signal face.**
2. **Shall not be displayed in conjunction with the change from the CIRCULAR RED signal indication to the CIRCULAR GREEN signal indication.**
3. **Shall be followed by a CIRCULAR RED signal indication except that, when entering preemption operation, the return to the previous CIRCULAR GREEN signal indication shall be permitted following a steady CIRCULAR YELLOW signal indication (see Section 4D.27).**
4. **Shall not be displayed to an approach from which drivers are turning left permissively or making a U-turn to the left permissively unless one of the following conditions exists:**
   - **(a) A steady CIRCULAR YELLOW signal indication is also simultaneously being displayed to the opposing approach;**
   - **(b) An engineering study has determined that, because of unique intersection conditions, the condition described in Item (a) cannot reasonably be implemented without causing significant operational or safety problems and that the volume of impacted left-turning or U-turning traffic is relatively low, and those left-turning or U-turning drivers are advised that a steady CIRCULAR YELLOW signal indication is not simultaneously being displayed to the opposing traffic if this operation occurs continuously by the installation near the left-most signal head of a W25-1 sign (see Section 2C.48) with the legend ONCOMING TRAFFIC HAS EXTENDED GREEN; or**
   - **(c) Drivers are advised of the operation if it occurs only occasionally, such as during a preemption sequence, by the installation near the left-most signal head of a W25-2 sign (see Section 2C.48) with the legend ONCOMING TRAFFIC MAY HAVE EXTENDED GREEN.**

C. A steady CIRCULAR GREEN signal indication shall be displayed only when it is intended to permit traffic to proceed in any direction that is lawful and practical.

D. A steady RED ARROW signal indication shall be displayed when it is intended to prohibit traffic, except pedestrians directed by a pedestrian signal head, from entering the intersection or other controlled area to make the indicated turn. Except as described in Item C.2 in Paragraph 3 of Section 4D.04, turning on a steady RED ARROW signal indication shall not be permitted.

E. A steady YELLOW ARROW signal indication:

1. **Shall be displayed in the same direction as a GREEN ARROW signal indication following a GREEN ARROW signal indication in the same signal face, unless:**
   - **(a) The GREEN ARROW signal indication and a CIRCULAR GREEN (or straight-through GREEN ARROW) signal indication terminate simultaneously in the same signal face, or**
   - **(b) The green arrow is a straight-through GREEN ARROW (see Item B.1).**
2. **Shall be displayed in the same direction as a flashing YELLOW ARROW signal indication or flashing RED ARROW signal indication following a flashing YELLOW ARROW signal indication or flashing RED ARROW signal indication in the same signal face, when the flashing arrow indication is displayed as part of a steady mode operation, if the signal face will subsequently display a steady red signal indication.**

3. Shall not be displayed in conjunction with the change from a steady RED ARROW, flashing RED ARROW, or flashing YELLOW ARROW signal indication to a GREEN ARROW signal indication, except when entering preemption operation as provided in Item 5(a).
4. Shall not be displayed when any conflicting vehicular movement has a green or yellow signal indication (except for the situation regarding U-turns to the left provided in Paragraph 4) or any conflicting pedestrian movement has a WALKING PERSON (symbolizing WALK) or flashing UPRAISED HAND (symbolizing DONT WALK) signal indication, except that a steady left-turn (or U-turn to the left) YELLOW ARROW signal indication used to terminate a flashing left-turn (or U-turn to the left) YELLOW ARROW or a flashing left-turn (or U-turn to the left) RED ARROW signal indication in a signal face controlling a permissive left-turn (or U-turn to the left) movement as described in Sections 4D.18 and 4D.20 shall be permitted to be displayed when a CIRCULAR YELLOW signal indication is displayed for the opposing through movement. Vehicles departing in the same direction shall not be considered in conflict if, for each turn lane with moving traffic, there is a separate departing lane, and pavement markings or raised channelization clearly indicate which departure lane to use.
5. Shall not be displayed to terminate a flashing arrow signal indication on an approach from which drivers are turning left permissively or making a U-turn to the left permissively unless one of the following conditions exists:
   (a) A steady CIRCULAR YELLOW signal indication is also simultaneously being displayed to the opposing approach;
   (b) An engineering study has determined that, because of unique intersection conditions, the condition described in Item (a) cannot reasonably be implemented without causing significant operational or safety problems and that the volume of impacted left-turning or U-turning traffic is relatively low, and those left-turning or U-turning drivers are advised that a steady CIRCULAR YELLOW signal indication is not simultaneously being displayed to the opposing traffic if this operation occurs continuously by the installation near the left-most signal head of a W25-1 sign (see Section 2C.48) with the legend ONCOMING TRAFFIC HAS EXTENDED GREEN; or
   (c) Drivers are advised of the operation if it occurs only occasionally, such as during a preemption sequence, by the installation near the left-most signal head of a W25-2 sign (see Section 2C.48) with the legend ONCOMING TRAFFIC MAY HAVE EXTENDED GREEN.
6. Shall be terminated by a RED ARROW signal indication for the same direction or a CIRCULAR RED signal indication except:
   (a) When entering preemption operation, the display of a GREEN ARROW signal indication or a flashing arrow signal indication shall be permitted following a steady YELLOW ARROW signal indication.
   (b) When the movement controlled by the arrow is to continue on a permissive mode basis during an immediately following CIRCULAR GREEN or flashing YELLOW ARROW signal indication.

F. A steady GREEN ARROW signal indication:
1. Shall be displayed only to allow vehicular movements, in the direction indicated, that are not in conflict with other vehicles moving on a green or yellow signal indication and are not in conflict with pedestrians crossing in compliance with a WALKING PERSON (symbolizing WALK) or flashing UPRAISED HAND (symbolizing DONT WALK) signal indication. Vehicles departing in the same direction shall not be considered in conflict if, for each turn lane with moving traffic, there is a separate departing lane, and pavement markings or raised channelization clearly indicate which departure lane to use.
2. Shall be displayed on a signal face that controls a left-turn movement when said movement is not in conflict with other vehicles moving on a green or yellow signal indication (except for the situation regarding U-turns provided in Paragraph 4) and is not in conflict with pedestrians crossing in compliance with a WALKING PERSON (symbolizing WALK) or flashing UPRAISED HAND (symbolizing DONT WALK) signal indication. Vehicles departing in the same direction shall not be considered in conflict if, for each turn lane with moving traffic, there is a separate departing lane, and pavement markings or raised channelization clearly indicate which departure lane to use.
3. Shall not be required on the stem of a T-intersection or for turns from a one-way street.

Option:

04 If U-turns are permitted from the approach and a right-turn GREEN ARROW signal indication is simultaneously being displayed to road users making a right turn from the conflicting approach to the left, road users making a U-turn may be advised of the operation by the installation near the left-turn signal face of a U-TURN YIELD TO RIGHT TURN (R10-16) sign (see Section 2B.53).

05 If not otherwise prohibited, a steady straight-through green arrow signal indication may be used instead of a circular green signal indication in a signal face on an approach intersecting a one-way street to discourage wrong-way turns.

06 If not otherwise prohibited, steady red, yellow, and green turn arrow signal indications may be used instead of steady circular red, yellow, and green signal indications in a signal face on an approach where all traffic is required to turn or where the straight-through movement is not physically possible.

Support:

07 Section 4D.25 contains information regarding the signalization of approaches that have a shared left-turn/right-turn lane and no through movement.

Standard:

08 **If supplemental signal faces are used, the following limitations shall apply:**

A. Left-turn arrows and U-turn arrows to the left shall not be used in near-right signal faces.
B. Right-turn arrows and U-turn arrows to the right shall not be used in far-left signal faces. A far-side median-mounted signal face shall be considered a far-left signal for this application.

09 **A straight-through RED ARROW signal indication or a straight-through YELLOW ARROW signal indication shall not be displayed on any signal face, either alone or in combination with any other signal indication.**

10 **The following combinations of signal indications shall not be simultaneously displayed on any one signal face:**

A. CIRCULAR RED with CIRCULAR YELLOW;
B. CIRCULAR GREEN with CIRCULAR RED; or
C. Straight-through GREEN ARROW with CIRCULAR RED;

11 **Additionally, the above combinations shall not be simultaneously displayed on an approach as a result of the combination of displays from multiple signal faces unless the display is created by a signal face(s) devoted exclusively to the control of a right-turning movement and:**

A. The signal face(s) controlling the right-turning movement is visibility-limited from the adjacent through movement or positioned to minimize potential confusion to approaching road users, or
B. A RIGHT TURN SIGNAL (R10-10) sign (see Sections 4D.21 through 4D.24) is mounted adjacent to the signal face(s) controlling the right-turning movement.

12 **The following combinations of signal indications shall not be simultaneously displayed on any one signal face or as a result of the combination of displays from multiple signal faces on an approach:**

A. CIRCULAR GREEN with CIRCULAR YELLOW;
B. Straight-through GREEN ARROW with CIRCULAR YELLOW;
C. GREEN ARROW with YELLOW ARROW pointing in the same direction;
D. RED ARROW with YELLOW ARROW pointing in the same direction; or
E. GREEN ARROW with RED ARROW pointing in the same direction.

13 **Except as otherwise provided in Sections 4F.03 and 4G.04, the same signal section shall not be used to display both a flashing yellow and a steady yellow indication during steady mode operation. Except as otherwise provided in Sections 4D.18, 4D.20, 4D.22, and 4D.24, the same signal section shall not be used to display both a flashing red and a steady red indication during steady mode operation.**

Guidance:

14 *No movement that creates an unexpected crossing of pathways of moving vehicles or pedestrians should be allowed during any green or yellow interval, except when all three of the following conditions are met:*

A. The movement involves only slight conflict, and
B. Serious traffic delays are substantially reduced by permitting the conflicting movement, and
C. Drivers and pedestrians subjected to the unexpected conflict are effectively warned thereof by a sign.

Section 4D.06 Signal Indications – Design, Illumination, Color, and Shape

Standard:

01 **Eacb signal indication, except tbose used for pedestrian signal heads and lane-use control signals, shall be circular or arrow.**

02 **Letters or numbers (including those associated with countdown displays) shall not be displayed as part of a vehicular signal indication.**

03 **Strobes shall not be used within or adjacent to any signal indication.**

04 **Except for the flashing signal indications and tbe pre-emption confirmation ligbts that are expressly allowed by the provisions of this Chapter, flasbing displays sball not be used witbin or adjacent to any signal indications.**

05 **Each circular signal indication shall emit a single color: red, yellow, or green.**

06 **Each arrow signal indication sball emit a single color: red, yellow, or green except that tbe alternate display (dual-arrow signal section) of a GREEN ARROW and a YELLOW ARROW signal indication, both pointing in the same direction, shall be permitted, provided that tbey are not displayed simultaneously.**

07 **Tbe arrow, which shall show only one direction, shall be the only illuminated part of an arrow signal indication.**

08 **Arrows shall be pointed:**

A. Vertically upward to indicate a straight-through movement, or
B. Horizontally in the direction of the turn to indicate a turn at approximately or greater tban a right angle, or
C. Upward with a slope at an angle approximately equal to that of the turn if the angle of the turn is substantially less than a right angle, or
D. In a manner that directs the driver through the turn if a U-turn arrow is used (see Figure 4D-1).

Figure 4D-1. Example of U-Turn Signal Face

09 **Except as provided in Paragraph 10, the requirements of the publication entitled "Vehicle Traffic Control Signal Heads" (see Section 1A.11) tbat pertain to tbe aspects of the signal head design that affect the display of the signal indications shall be met.**

Guidance:

10 *The intensity and distribution of light from each illuminated signal lens should comply with the publications entitled "Vehicle Traffic Control Signal Heads" and "Traffic Signal Lamps" (see Section 1A.11).*

Standard:

11 **References to signal lenses in this section shall not be used to limit signal optical units to incandescent lamps within optical assemblies that include lenses.**

Support:

12 Research has resulted in signal optical units that are not lenses, such as, but not limited to, light emitting diode (LED) traffic signal modules. Some units are practical for all signal indications, and some are practical for specific types such as visibility-limited signal indications.

Guidance:

13 *If a signal indication is so bright that it causes excessive glare during nighttime conditions, some form of automatic dimming should be used to reduce the brilliance of the signal indication.*

Section 4D.07 Size of Vehicular Signal Indications

Standard:

01 **There shall be two nominal diameter sizes for vehicular signal indications: 8 inches and 12 inches.**

02 **Except as provided in Paragraph 3 below, 12-inch signal indications shall be used for all signal sections in all new signal faces.**

Option:

03 Eight-inch circular signal indications may be used in new signal faces only for:

A. The green or flashing yellow signal indications in an emergency-vehicle traffic control signal (see Section 4G.02);
B. The circular indications in signal faces controlling the approach to the downstream location where two adjacent signalized locations are close to each other and it is not practical because of factors such as high approach speeds, horizontal or vertical curves, or other geometric factors to install visibility-limited signal faces for the downstream approach;

C. The circular indications in a signal face that is located less than 120 feet from the stop line on a roadway with a posted or statutory speed limit of 30 mph or less;
D. The circular indications in a supplemental near-side signal face:
E. The circular indications in a supplemental signal face installed for the sole purpose of controlling pedestrian movements (see Section 4D.03) rather than vehicular movements; and
F. The circular indications in a signal face installed for the sole purpose of controlling a bikeway or a bicycle movement.

04 Existing 8-inch circular signal indications that are not included in Items A through F in Paragraph 3 may be retained for the remainder of their useful service life.

Section 4D.08 Positions of Signal Indications Within a Signal Face – General

Support:

01 Standardization of the number and arrangements of signal sections in vehicular traffic control signal faces enables road users who are color vision deficient to identify the illuminated color by its position relative to other signal sections.

Standard:

02 **Unless otherwise provided in this Manual for a particular application, each signal face at a signalized location shall have three, four, or five signal sections. Unless otherwise provided in this Manual for a particular application, if a vertical signal face includes a cluster (see Section 4D.09), the signal face shall have at least three vertical positions.**

03 **A single-section signal face shall be permitted at a traffic control signal if it consists of a continuously-displayed GREEN ARROW signal indication that is being used to indicate a continuous movement.**

04 **The signal sections in a signal face shall be arranged in a vertical or horizontal straight line, except as otherwise provided in Section 4D.09.**

05 **The arrangement of adjacent signal sections in a signal face shall follow the relative positions listed in Sections 4D.09 or 4D.10, as applicable.**

06 **If a signal section that displays a CIRCULAR YELLOW signal indication is used, it shall be located between the signal section that displays the red signal indication and all other signal sections.**

07 **If a U-turn arrow signal section is used in a signal face for a U-turn to the left, its position in the signal face shall be the same as stated in Sections 4D.09 and 4D.10 for a left-turn arrow signal section of the same color. If a U-turn arrow signal section is used in a signal face for a U-turn to the right, its position in the signal face shall be the same as stated in Sections 4D.09 and 4D.10 for a right-turn arrow signal section of the same color.**

08 **A U-turn arrow signal indication pointing to the left shall not be used in a signal face that also contains a left-turn arrow signal indication. A U-turn arrow signal indication pointing to the right shall not be used in a signal face that also contains a right-turn arrow signal indication.**

Option:

09 Within a signal face, two identical CIRCULAR RED or RED ARROW signal indications may be displayed immediately horizontally adjacent to each other in a vertical or horizontal signal face (see Figure 4D-2) for emphasis.

10 Horizontally-arranged and vertically-arranged signal faces may be used on the same approach provided they are separated to meet the lateral separation spacing required in Section 4D.13.

Support:

11 Figure 4D-2 illustrates some of the typical arrangements of signal sections in signal faces that do not control separate turning movements. Figures 4D-6 through 4D-12 illustrate the typical arrangements of signal sections in left-turn signal faces. Figures 4D-13 through 4D-19 illustrate the typical arrangements of signal sections in right-turn signal faces.

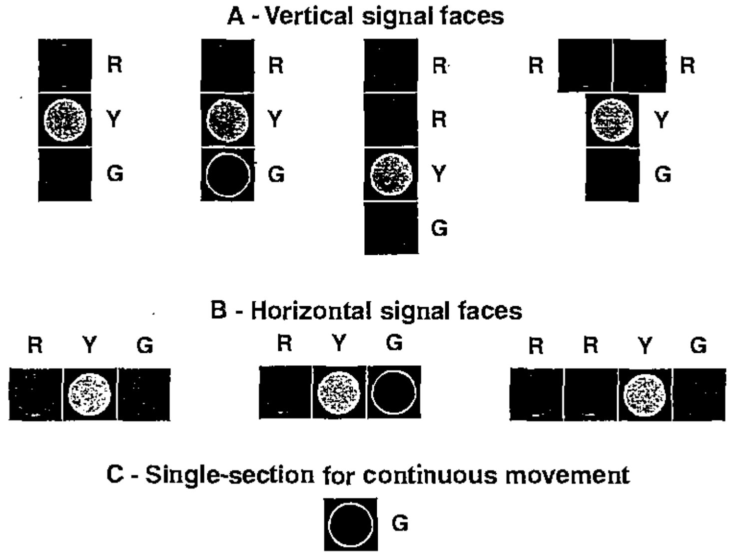
Section 4D.09 Positions of Signal Indications Within a Vertical Signal Face

Standard:

01 **In each vertically-arranged signal face, all signal sections that display red signal indications shall be located above all signal sections that display yellow and green signal indications.**

02 **In vertically-arranged signal faces, each signal section that displays a YELLOW ARROW signal indication shall be located above the signal section that displays the GREEN ARROW signal indication to which it applies.**

Figure 4D-2. Typical Arrangements of Signal Sections in Signal Faces That Do Not Control Turning Movements



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03 **The relative positions of signal sections in a vertically-arranged signal face, from top to bottom, shall be as follows:**

CIRCULAR RED
Steady and/or flashing left-turn RED ARROW
Steady and/or flashing right-turn RED ARROW
CIRCULAR YELLOW
CIRCULAR GREEN
Straight-through GREEN ARROW
Steady left-turn YELLOW ARROW
Flashing left-turn YELLOW ARROW
Left-turn GREEN ARROW
Steady right-turn YELLOW ARROW
Flashing right-turn YELLOW ARROW
Right-turn GREEN ARROW

04 **If a dual-arrow signal section (capable of alternating between the display of a GREEN ARROW and a YELLOW ARROW signal indication) is used in a vertically-arranged signal face, the dual-arrow signal section shall occupy the same position relative to the other sections as the signal section that displays the GREEN ARROW signal indication in a vertically-arranged signal face would occupy.**

Option:

05 In a vertically-arranged signal face, signal sections that display signal indications of the same color may be arranged horizontally adjacent to each other at right angles to the basic straight line arrangement to form a clustered signal face (see Figures 4D-2, 4D-9, 4D-11, 4D-16, and 4D-18).

Standard:

06 **Such clusters shall be limited to the following:**

A. Two identical signal sections,
B. Two or three different signal sections that display signal indications of the same color, or
C. For only the specific case described in Section 4D.25 (see Drawing B of Figure 4D-20), two signal sections, one of which displays a GREEN ARROW signal indication and the other of which displays a flashing YELLOW ARROW signal indication.

07 **The signal section that displays a flashing yellow signal indication during steady mode operation:**

A. Shall not be placed in the same vertical position as the signal section that displays a steady yellow signal indication, and
B. Shall be placed below the signal section that displays a steady yellow signal indication.

Support:

08 Sections 4F.02 and 4G.04 contain exceptions to the provisions of this Section that are applicable to hybrid beacons.

Section 4D.10 Positions of Signal Indications Within a Horizontal Signal Face

Standard:

01 **In each horizontally-arranged signal face, all signal sections that display red signal indications shall be located to the left of all signal sections that display yellow and green signal indications.**

02 **In horizontally-arranged signal faces, each signal section that displays a YELLOW ARROW signal indication shall be located to the left of the signal section that displays the GREEN ARROW signal indication to which it applies.**

03 **The relative positions of signal sections in a horizontally-arranged signal face, from left to right, shall be as follows:**

CIRCULAR RED
Steady and/or flashing left-turn RED ARROW
Steady and/or flashing right-turn RED ARROW
CIRCULAR YELLOW
Steady left-turn YELLOW ARROW
Flashing left-turn YELLOW ARROW
Left-turn GREEN ARROW
CIRCULAR GREEN
Straight-through GREEN ARROW
Steady right-turn YELLOW ARROW
Flashing right-turn YELLOW ARROW
Right-turn GREEN ARROW

04 **If a dual-arrow signal section (capable of alternating between the display of a GREEN ARROW and a YELLOW ARROW signal indication) is used in a horizontally-arranged signal face, the signal section that displays the dual left-turn arrow signal indication shall be located immediately to the right of the signal section that displays the CIRCULAR YELLOW signal indication, the signal section that displays the straight-through GREEN ARROW signal indication shall be located immediately to the right of the signal section that displays the CIRCULAR GREEN signal indication, and the signal section that displays the dual right-turn arrow signal indication shall be located to the right of all other signal sections.**

05 **The signal section that displays a flashing yellow signal indication during steady mode operation:**

A. Shall not be placed in the same horizontal position as the signal section that displays a steady yellow signal indication, and

B. Shall be placed to the right of the signal section that displays a steady yellow signal indication.

Section 4D.11 Number of Signal Faces on an Approach

Standard:

01 **The signal faces for each approach to an intersection or a midblock location shall be provided as follows:**

A. If a signalized through movement exists on an approach, a minimum of two primary signal faces shall be provided for the through movement. If a signalized through movement does not exist on an approach, a minimum of two primary signal faces shall be provided for the signalized turning movement that is considered to be the major movement from the approach (also see Section 4D.25).

B. See Sections 4D.17 through 4D.20 for left-turn (and U-turn to the left) signal faces.

C. See Sections 4D.21 through 4D.24 for right-turn (and U-turn to the right) signal faces.

Option:

02 Where a movement (or a certain lane or lanes) at the intersection never conflicts with any other signalized vehicular or pedestrian movement, a continuously-displayed single-section GREEN ARROW signal indication may be used to inform road users that the movement is free-flow and does not need to stop.

Support:

03 In some circumstances where the through movement never conflicts with any other signalized vehicular or pedestrian movement at the intersection, such as at T-intersections with appropriate geometrics and/or pavement markings and signing, an engineering study might determine that the through movement (or certain lanes of the through movement) can be free-flow and not signalized.

Guidance:

04 *If two or more left-turn lanes are provided for a separately controlled protected only mode left-turn movement, or if a left-turn movement represents the major movement from an approach, two or more primary left-turn signal faces should be provided.*

05 *If two or more right-turn lanes are provided for a separately controlled right-turn movement, or if a right-turn movement represents the major movement from an approach, two or more primary right-turn signal faces should be provided.*

Support:

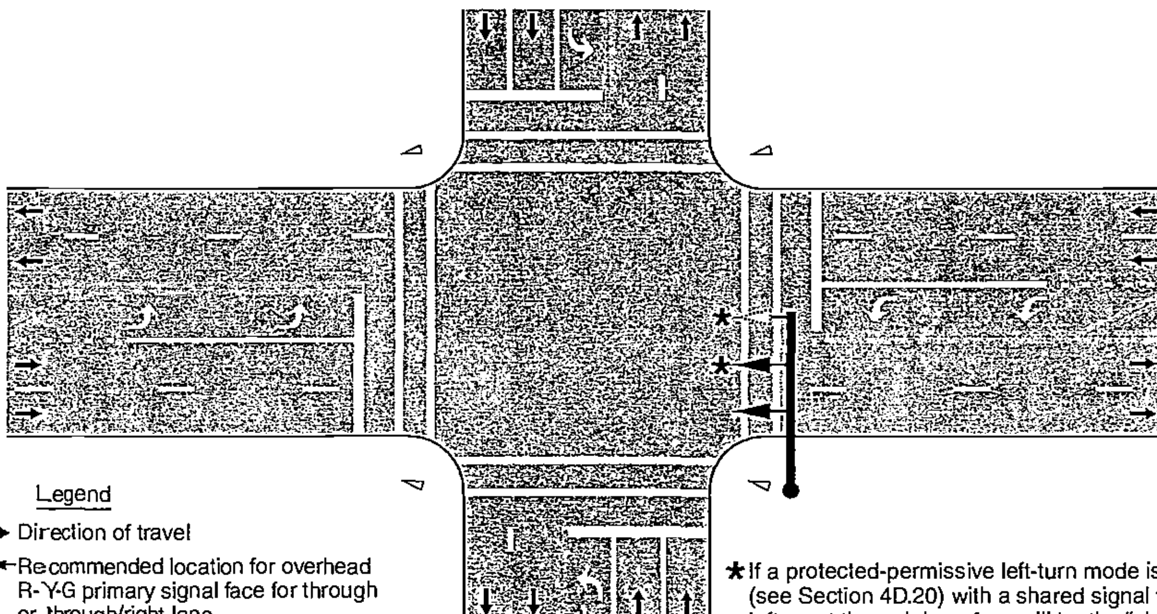
06 Locating primary signal faces overhead on the far side of the intersection has been shown to provide safer operation by reducing intersection entries late in the yellow interval and by reducing red signal violations, as compared to post-mounting signal faces at the roadside or locating signal faces overhead within the intersection on a diagonally-oriented mast arm or span wire. On approaches with two or more lanes for the through movement, one signal face per through lane, centered over each through lane, has also been shown to provide safer operation.

Guidance:

07 *If the posted or statutory speed limit or the 85th-percentile speed on an approach to a signalized location is 45 mph or higher, signal faces should be provided as follows for all new or reconstructed signal installations (see Figure 4D-3):*

A. The minimum number and location of primary (non-supplemental) signal faces for through traffic should be provided in accordance with Table 4D-1.

Figure 4D-3. Recommended Vehicular Signal Faces for Approaches with Posted, Statutory, or 85th-Percentile Speed of 45 mph or Higher



Legend

→ Direction of travel

← Recommended location for overhead R-Y-G primary signal face for through or through/right lane

◁ Overhead primary left-turn signal face as determined by selected mode of left-turn operation

◁ Possible location for a supplemental R-Y-G signal face

* If a protected-permissive left-turn mode is used (see Section 4D.20) with a shared signal face, the left-most through lane face will be the "shared" signal face, will contain appropriate left-turn arrow indications in addition to circular R-Y-G, and will be located over the projection of the lane line between the left-turn and through lanes.

Notes:

1. Signal faces for only one direction and only one possible set of geometrics (number of lanes, etc.) are illustrated. If there are fewer or more than two through lanes on the approach, see Table 4D-2.
2. Any primary left-turn and/or right-turn signal faces, as determined by Sections 4D.17 through 4D.24, should be overhead for each exclusive turn lane.
3. One or more pole-mounted or overhead supplemental faces should be considered, based on the geometrics of the approach, to maximize visibility for approaching traffic.
4. All signal faces should have backplates.

Table 4D-1. Recommended Minimum Number of Primary Signal Faces for Through Traffic on Approaches with Posted, Statutory, or 85th-Percentile Speed of 45 mph or Higher

Number of Through Lanes on Approach	Total Number of Primary Through Signal Faces for Approach*	Minimum Number of Overhead-Mounted Primary Through Signal Faces for Approach
1	2	1
2	2	1
3	3	2
4 or more	4 or more	3**

NOTES: * A minimum of two through signal faces is always required (See Section 4D.11). These recommended numbers of through signal faces may be exceeded. Also, see cone of vision requirements otherwise indicated in Section 4D.13.

** If practical, all of the recommended number of primary through signal faces should be located overhead.

B. If the number of overhead primary signal faces for through traffic is equal to the number of through lanes on an approach, one overhead signal face should be located approximately over the center of each through lane.

C. Except for shared left-turn and right-turn signal faces, any primary signal face required by Sections 4D.17 through 4D.25 for an exclusive turn lane should be located overhead approximately over the center of each exclusive turn lane.

D. All primary signal faces should be located on the far side of the intersection.

E. In addition to the primary signal faces, one or more supplemental pole-mounted or overhead signal faces should be considered to provide added visibility for approaching traffic that is traveling behind large vehicles.

F. All signal faces should have backplates.

08 *This layout of signal faces should also be considered for any major urban or suburban arterial street with four or more lanes and for other approaches with speeds of less than 45 mph.*

Section 4D.12 Visibility, Aiming, and Shielding of Signal Faces

Standard:

01 **The primary consideration in signal face placement, aiming, and adjustment shall be to optimize the visibility of signal indications to approaching traffic.**

02 **Road users approaching a signalized intersection or other signalized area, such as a midblock crosswalk, shall be given a clear and unmistakable indication of their right-of-way assignment.**

03 **The geometry of each intersection to be signalized, including vertical grades, horizontal curves, and obstructions as well as the lateral and vertical angles of sight toward a signal face, as determined by typical driver-eye position, shall be considered in determining the vertical, longitudinal, and lateral position of the signal face.**

Guidance:

04 *The two primary signal faces required as a minimum for each approach should be continuously visible to traffic approaching the traffic control signal, from a point at least the minimum sight distance provided in Table 4D-2 in advance of and measured to the stop line. This range of continuous visibility should be provided unless precluded by a physical obstruction or unless another signalized location is within this range.*

Table 4D-2. Minimum Sight Distance for Signal Visibility

85th-Percentile Speed	Minimum Sight Distance
20 mph	175 feet
25 mph	215 feet
30 mph	270 feet
35 mph	325 feet
40 mph	390 feet
45 mph	460 feet
50 mph	540 feet
55 mph	625 feet
60 mph	715 feet

Note: Distances in this table are derived from stopping sight distance plus an assumed queue length for shorter cycle lengths (60 to 75 seconds).

05 *There should be legal authority to prohibit the display of any unauthorized sign, signal, marking, or device that interferes with the effectiveness of any official traffic control device (see Section 11-205 of the "Uniform Vehicle Code").*

06 *At signalized midblock crosswalks, at least one of the signal faces should be over the traveled way for each approach.*

Standard:

07 **If approaching traffic does not have a continuous view of at least two signal faces for at least the minimum sight distance shown in Table 4D-2, a sign (see Section 2C.36) shall be installed to warn approaching traffic of the traffic control signal.**

Option:

08 If a sign is installed to warn approaching road users of the traffic control signal, the sign may be supplemented by a Warning Beacon (see Section 4L.03).

09 A Warning Beacon used in this manner may be interconnected with the traffic signal controller assembly in such a manner as to flash yellow during the period when road users passing this beacon at the legal speed for the roadway might encounter a red signal indication (or a queue resulting from the display of the red signal indication) upon arrival at the signalized location.

10 If the sight distance to the signal faces for an approach is limited by horizontal or vertical alignment, supplemental signal faces aimed at a point on the approach at which the signal indications first become visible may be used.

Guidance:

11 *Supplemental signal faces should be used if engineering judgment has shown that they are needed to achieve intersection visibility both in advance and immediately before the signalized location.*

12 *If supplemental signal faces are used, they should be located to provide optimum visibility for the movement to be controlled.*

Standard:

13 **In cases where irregular street design necessitates placing signal faces for different street approaches with a comparatively small angle between their respective signal indications, each signal indication shall, to the extent practical, be visibility-limited by signal visors, signal louvers, or other means so that an approaching road user's view of the signal indication(s) controlling movements on other approaches is minimized.**

14 **Signal visors exceeding 12 inches in length shall not be used on free-swinging signal faces.**

Guidance:

15 *Signal visors should be used on signal faces to aid in directing the signal indication specifically to approaching traffic, as well as to reduce "sun phantom," which can result when external light enters the lens.*

16 *The use of signal visors, or the use of signal faces or devices that direct the light without a reduction in intensity, should be considered as an alternative to signal louvers because of the reduction in light output caused by signal louvers.*

Option:

17 Special signal faces, such as visibility-limited signal faces, may be used such that the road user does not see signal indications intended for other approaches before seeing the signal indications for their own approach, if simultaneous viewing of both signal indications could cause the road user to be misdirected.

Guidance:

18 *If the posted or statutory speed limit or the 85th-percentile speed on an approach to a signalized location is 45 mph or higher, signal backplates should be used on all of the signal faces that face the approach. Signal backplates should also be considered for use on signal faces on approaches with posted or statutory speed limits or 85th-percentile speeds of less than 45 mph where sun glare, bright sky, and/or complex or confusing backgrounds indicate a need for enhanced signal face target value.*

Support:

19 The use of backplates enhances the contrast between the traffic signal indications and their surroundings for both day and night conditions, which is also helpful to older drivers.

Standard:

20 **The inside of signal visors (hoods), the entire surface of louvers and fins, and the front surface of backplates shall have a dull black finish to minimize light reflection and to increase contrast between the signal indication and its background.**

Option:

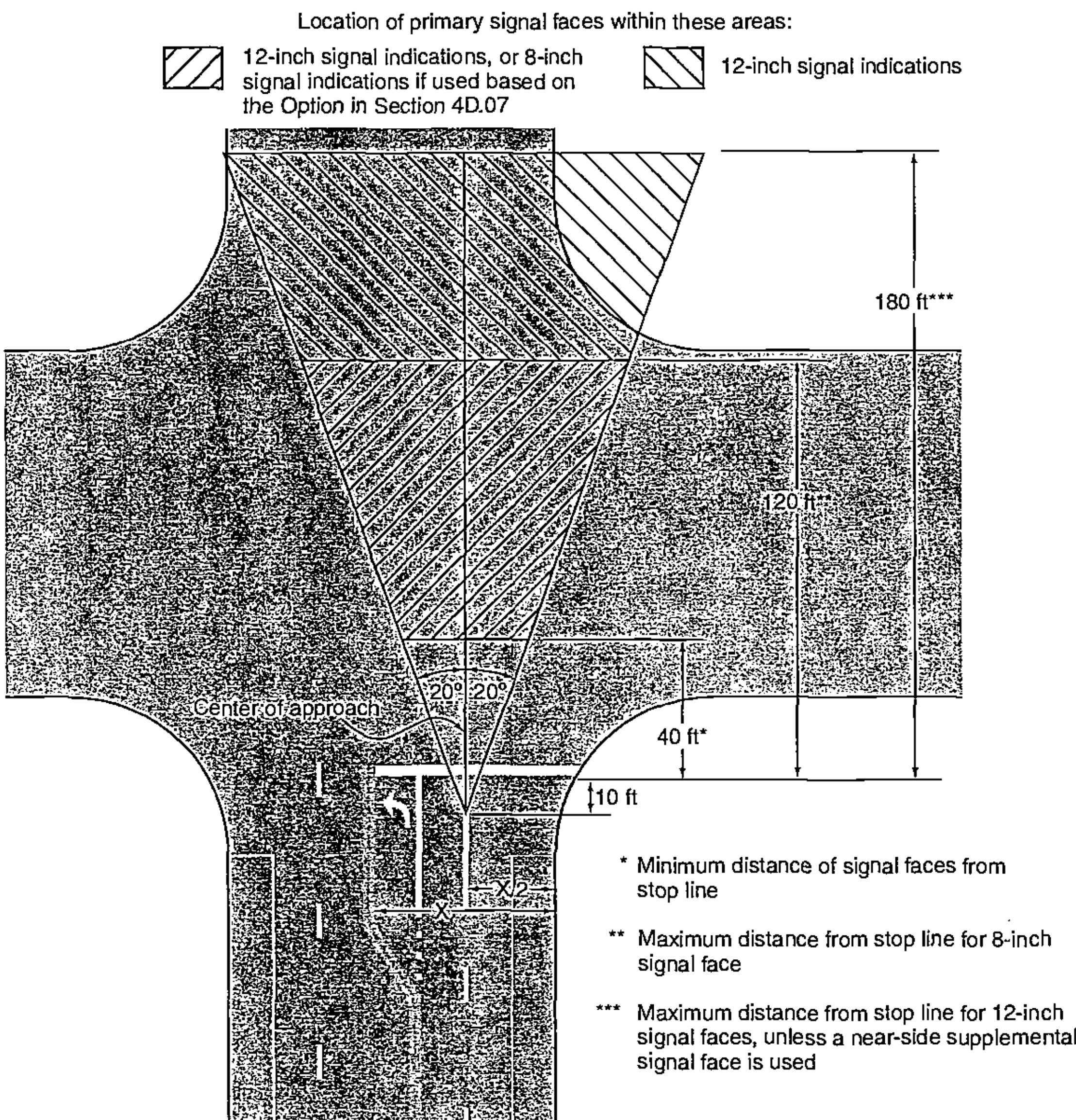
21 A yellow retroreflective strip with a minimum width of 1 inch and a maximum width of 3 inches may be placed along the perimeter of the face of a signal backplate to project a rectangular appearance at night.

Section 4D.13 Lateral Positioning of Signal Faces

Standard:

01 **At least one and preferably both of the minimum of two primary signal faces required for the through movement (or the major turning movement if there is no through movement) on the approach shall be located between two lines intersecting with the center of the approach at a point 10 feet behind the stop line, one making an angle of approximately 20 degrees to the right of the center of the approach extended, and the other making an angle of approximately 20 degrees to the left of the center of the approach extended. The signal face that satisfies this requirement shall simultaneously satisfy the longitudinal placement requirement described in Section 4D.14 (see Figure 4D-4).**

Figure 4D-4. Lateral and Longitudinal Location of Primary Signal Faces



Notes:

1. See Section 4D.11 for approaches with posted, statutory, or 85th-percentile speeds of 45 mph or higher
2. See Section 4D.13 regarding location of signal faces that display a CIRCULAR GREEN signal indication for a permissive left-turn movement on approaches with an exclusive left-turn lane or lanes

02 **If both of the minimum of two primary signal faces required for the through movement (or the major turning movement if there is no through movement) on the approach are post-mounted, they shall both be on the far side of the intersection, one on the right and one on the left of the approach lane(s).**

03 **The required signal faces for through traffic on an approach shall be located not less than 8 feet apart measured horizontally perpendicular to the approach between the centers of the signal faces.**

04 **If more than one separate turn signal face is provided for a turning movement and if one or both of the separate turn signal faces are located over the roadway, the signal faces shall be located not less than 8 feet apart measured horizontally perpendicular to the approach between the centers of the signal faces.**

Guidance:

05 *If a signal face controls a specific lane or lanes of an approach, its position should make it readily visible to road users making that movement.*

Support:

06 Section 4D.11 contains additional provisions regarding lateral positioning of signal faces for approaches having a posted or statutory speed limit or an 85th-percentile speed of 45 mph or higher.

Standard:

07 **If an exclusive left-turn, right-turn, or U-turn lane is present on an approach and if a primary separate turn signal face controlling that lane is mounted over the roadway, the primary separate turn signal face shall not be positioned any further to the right than the extension of the right-hand edge of the exclusive turn lane or any further to the left than the extension of the left-hand edge of the exclusive turn lane.**

08 **Supplemental turn signal faces mounted over the roadway shall not be subject to the positioning requirements in the previous paragraph.**

Guidance:

09 *For new or reconstructed signal installations, on an approach with an exclusive turn lane(s) for a left-turn (or U-turn to the left) movement and with opposing vehicular traffic, signal faces that display a CIRCULAR GREEN signal indication should not be post-mounted on the far-side median or mounted overhead above the exclusive turn lane(s) or the extension of the lane(s).*

Standard:

10 **If supplemental post-mounted signal faces are used, the following limitations shall apply:**

A. Left-turn arrows and U-turn arrows to the left shall not be used in near-right signal faces.

B. Right-turn arrows and U-turn arrows to the right shall not be used in far-left signal faces. A far-side median-mounted signal face shall be considered a far-left signal for this application.

Section 4D.14 Longitudinal Positioning of Signal Faces

Standard:

01 **Except where the width of an intersecting roadway or other conditions make it physically impractical, the signal faces for each approach to an intersection or a midblock location shall be provided as follows:**

A. A signal face installed to satisfy the requirements for primary left-turn signal faces (see Sections 4D.17 through 4D.20) and primary right-turn signal faces (see Sections 4D.21 through 4D.24), and at least one and preferably both of the minimum of two primary signal faces required for the through movement (or the major turning movement if there is no through movement) on the approach shall be located:

1. No less than 40 feet beyond the stop line,

2. No more than 180 feet beyond the stop line unless a supplemental near-side signal face is provided, and

3. As near as practical to the line of the driver's normal view, if mounted over the roadway.

The primary signal face that satisfies this requirement shall simultaneously satisfy the lateral placement requirement described in Section 4D.13 (see Figure 4D-4).

B. Where the nearest signal face is located between 150 and 180 feet beyond the stop line, engineering judgment of the conditions, including the worst-case visibility conditions, shall be used to determine if the provision of a supplemental near-side signal face would be beneficial.

Support:

02 Section 4D.11 contains additional provisions regarding longitudinal positioning of signal faces for approaches having a posted or 85th-percentile speed of 45 mph or higher.

Guidance:

03 *Supplemental near-side signal faces should be located as near as practical to the stop line.*

Section 4D.15 Mounting Height of Signal Faces

Standard:

01 **The top of the signal housing of a vehicular signal face located over any portion of a highway that can be used by motor vehicles shall not be more than 25.6 feet above the pavement.**

02 **For viewing distances between 40 and 53 feet from the stop line, the maximum mounting height to the top of the signal housing shall be as shown in Figure 4D-5.**

03 **The bottom of the signal housing and any related attachments to a vehicular signal face located over any portion of a highway that can be used by motor vehicles shall be at least 15 feet above the pavement.**

04 **The bottom of the signal housing (including brackets) of a vehicular signal face that is vertically arranged and not located over a roadway:**

A. Shall be a minimum of 8 feet and a maximum of 19 feet above the sidewalk or, if there is no sidewalk, above the pavement grade at the center of the roadway.
B. Shall be a minimum of 4.5 feet and a maximum of 19 feet above the median island grade of a center median island if located on the near side of the intersection.

05 **The bottom of the signal housing (including brackets) of a vehicular signal face that is horizontally arranged and not located over a roadway:**

A. Shall be a minimum of 8 feet and a maximum of 22 feet above the sidewalk or, if there is no sidewalk, above the pavement grade at the center of the roadway.
B. Shall be a minimum of 4.5 feet and a maximum of 22 feet above the median island grade of a center median island if located on the near side of the intersection.

Section 4D.16 Lateral Offset (Clearance) of Signal Faces

Standard:

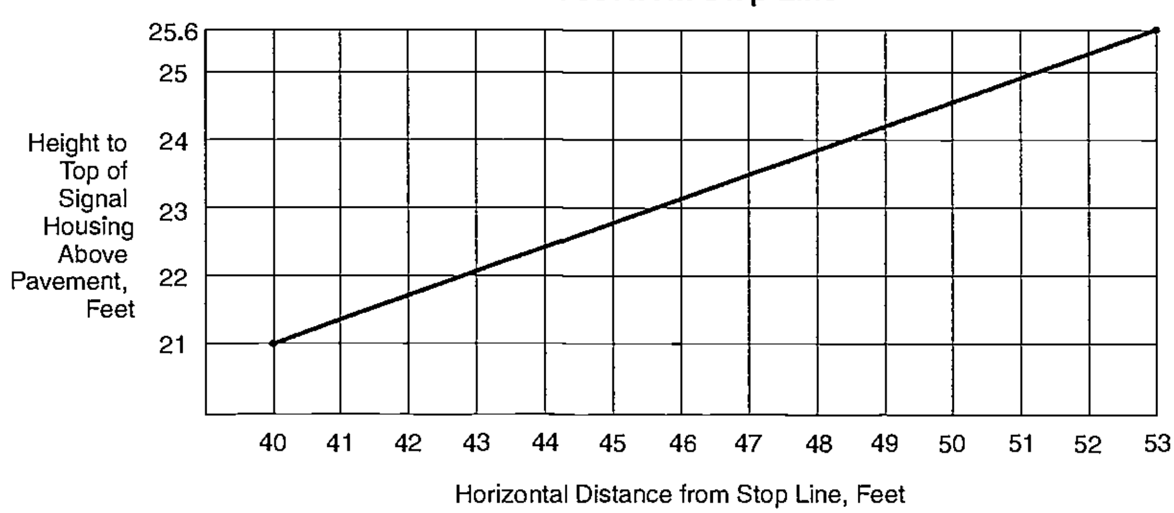
01 **Signal faces mounted at the side of a roadway with curbs at less than 15 feet from the bottom of the housing and any related attachments shall have a horizontal offset of not less than 2 feet from the face of a vertical curb, or if there is no curb, not less than 2 feet from the edge of a shoulder.**

Section 4D.17 Signal Indications for Left-Turn Movements – General

Standard:

01 **In Sections 4D.17 through 4D.20, provisions applicable to left-turn movements and left-turn lanes shall also apply to signal indications for U-turus to the left that are provided at locations where left turns are prohibited or not geometrically possible.**

Figure 4D-5. Maximum Mounting Height of Signal Faces Located Between 40 Feet and 53 Feet from Stop Line



Support:

02 Left-turning traffic is controlled by one of four modes as follows:

A. Permissive Only Mode—turns made on a CIRCULAR GREEN signal indication, a flashing left-turn YELLOW ARROW signal indication, or a flashing left-turn RED ARROW signal indication after yielding to pedestrians, if any, and/or opposing traffic, if any.
B. Protected Only Mode—turns made only when a left-turn GREEN ARROW signal indication is displayed.
C. Protected/Permissive Mode—both modes can occur on an approach during the same cycle.
D. Variable Left-Turn Mode—the operating mode changes among the protected only mode and/or the protected/permissive mode and/or the permissive only mode during different periods of the day or as traffic conditions change.

Option:

03 In areas having a high percentage of older drivers, special consideration may be given to the use of protected only mode left-turn phasing, when appropriate.

Standard:

04 **During a permissive left-turn movement, the signal faces for through traffic on the opposing approach shall simultaneously display green or steady yellow signal indications. If pedestrians crossing the lane or lanes used by the permissive left-turn movement to depart the intersection are controlled by pedestrian signal heads, the signal indications displayed by those pedestrian signal heads shall not be limited to any particular display during the permissive left-turn movement.**

05 **During a protected left-turn movement, the signal faces for through traffic on the opposing approach shall simultaneously display steady CIRCULAR RED signal indications. If pedestrians crossing the lane or lanes used by the protected left-turn movement to depart the intersection are controlled by pedestrian signal heads, the pedestrian signal heads shall display a steady UPRAISED HAND (symbolizing DONT WALK) signal indication during the protected left-turn movement.**

06 **A protected only mode left-turn movement that does not begin and terminate at the same time as the adjacent through movement shall not be provided on an approach unless an exclusive left-turn lane exists.**

07 **A yellow change interval for the left-turn movement shall not be displayed when the status of the left-turn operation is changing from permissive to protected within any given signal sequence.**

08 **If the operating mode changes among the protected only mode and/or the protected/permissive mode and/or the permissive only mode during different periods of the day or as traffic conditions change, the requirements in Sections 4D.18 through 4D.20 that are appropriate to that mode of operation shall be met, subject to the following:**

A. The CIRCULAR GREEN and CIRCULAR YELLOW signal indications shall not be displayed when operating in the protected only mode.
B. The left-turn GREEN ARROW and left-turn YELLOW ARROW signal indications shall not be displayed when operating in the permissive only mode.

Option:

09 Additional static signs or changeable message signs may be used to meet the requirements for the variable left-turn mode or to inform drivers that left-turn green arrows will not be available during certain times of the day.

Support:

10 Sections 4D.17 through 4D.20 describe the use of the following two types of signal faces for controlling left-turn movements:

A. Shared signal face – This type of signal face controls both the left-turn movement and the adjacent movement (usually the through movement) and can serve as one of the two required primary signal faces for the adjacent movement. A shared signal face always displays the same color of circular indication that is displayed by the signal face or faces for the adjacent movement. If a shared signal face that provides protected/permissive mode left turns is mounted overhead at the intersection, it is usually positioned over or slightly to the right of the extension of the lane line separating the left-turn lane from the adjacent lane.
B. Separate left-turn signal face – This type of signal face controls only the left-turn movement and cannot serve as one of the two required primary signal faces for the adjacent movement (usually the through movement) because it displays signal indications that are applicable only to the left-turn movement. If a separate left-turn signal face is mounted overhead at the intersection, it is positioned over the extension of the left-turn lane. In a separate left-turn signal face, a flashing left-turn YELLOW ARROW signal indication or a flashing left-turn RED ARROW signal indication is used to control permissive left-turning movements.

11 Section 4D.13 contains provisions regarding the lateral positioning of signal faces that control left-turn movements.

12 It is not necessary that the same mode of left-turn operation or same type of left-turn signal face be used on every approach to a signalized location. Selecting different modes and types of left-turn signal faces for the various approaches to the same signalized location is acceptable.

Option:

13 A signal face that is shared by left-turning and right-turning traffic may be provided for a shared left-turn/right-turn lane on an approach that has no through traffic (see Section 4D.25).

Section 4D.18 Signal Indications for Permissive Only Mode Left-Turn Movements

Standard:

01 **If a shared signal face is provided for a permissive only mode left turn, it shall meet the following requirements (see Figure 4D-6):**

A. It shall be capable of displaying the following signal indications: steady CIRCULAR RED, steady CIRCULAR YELLOW, and CIRCULAR GREEN. Only one of the three indications shall be displayed at any given time.

B. During the permissive left-turn movement, a CIRCULAR GREEN signal indication shall be displayed.

C. A permissive only shared signal face, regardless of where it is positioned and regardless of how many adjacent through signal faces are provided, shall always simultaneously display the same color of circular indication that the adjacent through signal face or faces display.

D. If the permissive only mode is not the only left-turn mode used for the approach, the signal face shall be the same shared signal face that is used for the protected/permissive mode (see Section 4D.20) except that the left-turn GREEN ARROW and left-turn YELLOW ARROW signal indications shall not be displayed when operating in the permissive only mode.

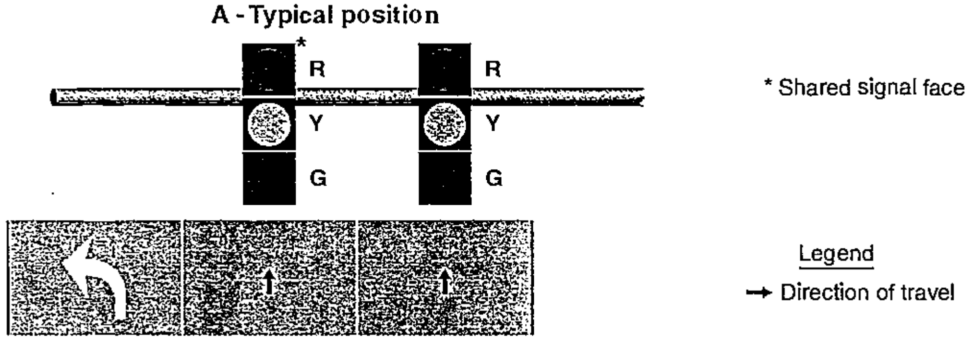
02 **If a separate left-turn signal face is being operated in a permissive only left-turns mode, a CIRCULAR GREEN signal indication shall not be used in that face.**

03 **If a separate left-turn signal face is being operated in a permissive only left-turn mode and a flashing left-turn YELLOW ARROW signal indication is provided, it shall meet the following requirements (see Figure 4D-7):**

A. It shall be capable of displaying the following signal indications: steady left-turn RED ARROW, steady left-turn YELLOW ARROW, and flashing left-turn YELLOW ARROW. Only one of the three indications shall be displayed at any given time.

Figure 4D-6. Typical Position and Arrangements of Shared Signal Faces for Permissive Only Mode Left Turns

A - Typical position



B - Typical arrangements

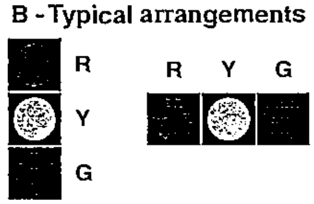
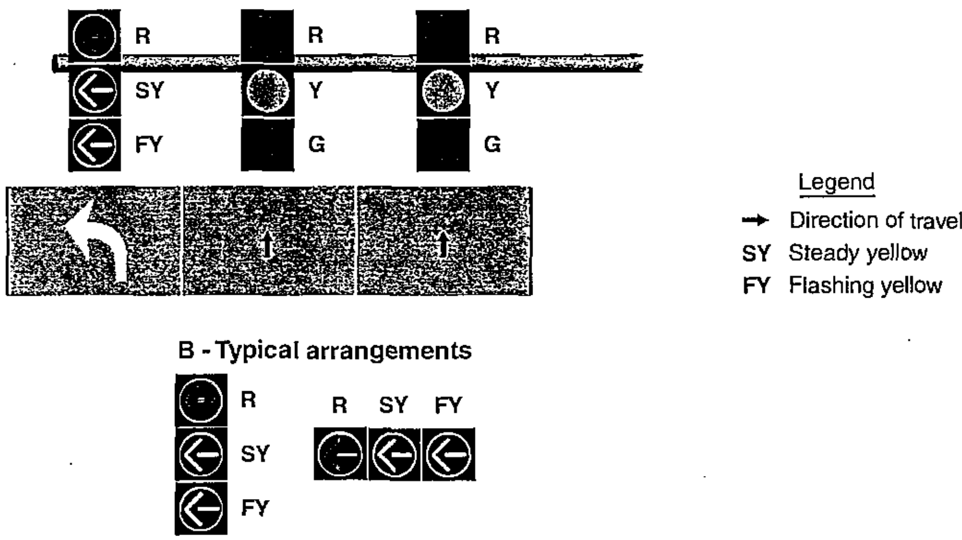


Figure 4D-7. Typical Position and Arrangements of Separate Signal Faces with Flashing Yellow Arrow for Permissive Only Mode Left Turns



B. During the permissive left-turn movement, a flashing left-turn YELLOW ARROW signal indication shall be displayed.
C. A steady left-turn YELLOW ARROW signal indication shall be displayed following the flashing left-turn YELLOW ARROW signal indication.
D. It shall be permitted to display a flashing left-turn YELLOW ARROW signal indication for a permissive left-turn movement while the signal faces for the adjacent through movement display steady CIRCULAR RED signal indications and the opposing left-turn signal faces display left-turn GREEN ARROW signal indications for a protected left-turn movement.
E. During steady mode (stop-and-go) operation, the signal section that displays the steady left-turn YELLOW ARROW signal indication during change intervals shall not be used to display the flashing left-turn YELLOW ARROW signal indication for permissive left turns.
F. During flashing mode operation (see Section 4D.30), the display of a flashing left-turn YELLOW ARROW signal indication shall be only from the signal section that displays a steady left-turn YELLOW ARROW signal indication during steady mode (stop-and-go) operation.
G. If the permissive only mode is not the only left-turn mode used for the approach, the signal face shall be the same separate left-turn signal face with a flashing YELLOW ARROW signal indication that is used for the protected/permissive mode (see Section 4D.20) except that the left-turn GREEN ARROW signal indication shall not be displayed when operating in the permissive only mode.

Option:

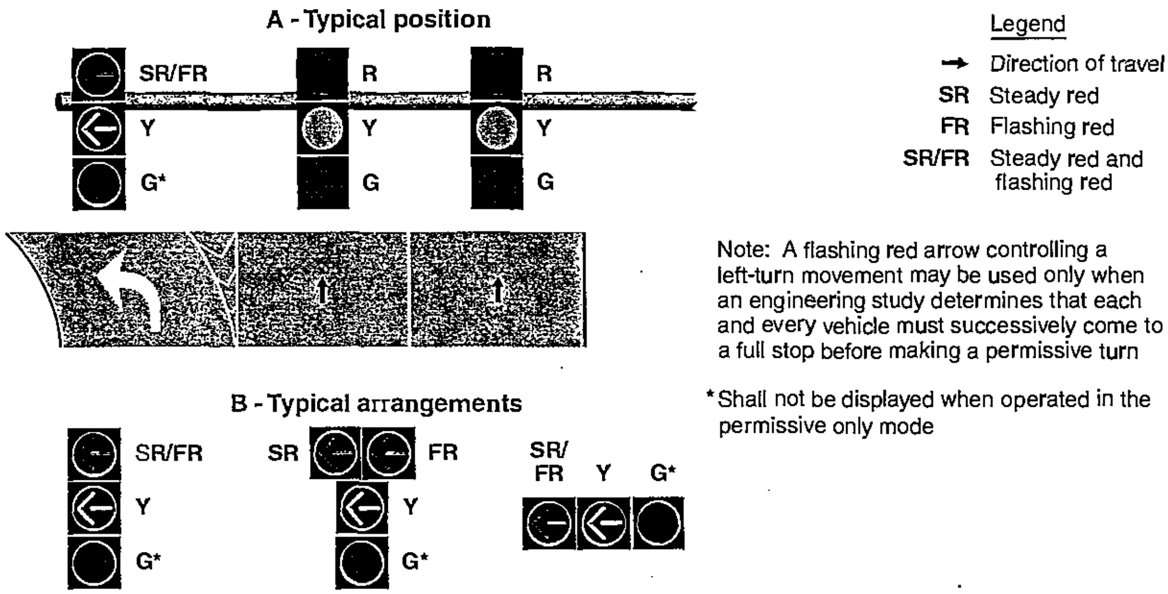
04 A separate left-turn signal face with a flashing left-turn RED ARROW signal indication during the permissive left-turn movement may be used for unusual geometric conditions, such as wide medians with offset left-turn lanes, but only when an engineering study determines that each and every vehicle must successively come to a full stop before making a permissive left turn.

Standard:

05 If a separate left-turn signal face is being operated in a permissive only left-turn mode and a flashing left-turn RED ARROW signal indication is provided, it shall meet the following requirements (see Figure 4D-8):

A. It shall be capable of displaying the following signal indications: steady or flashing left-turn RED ARROW, steady left-turn YELLOW ARROW, and left-turn GREEN ARROW. Only one of the three indications shall be displayed at any given time. The GREEN ARROW indication is required in order to provide a three-section signal face, but shall not be displayed during the permissive only mode.
B. During the permissive left-turn movement, a flashing left-turn RED ARROW signal indication shall be displayed, thus indicating that each and every vehicle must successively come to a full stop before making a permissive left turn.

Figure 4D-8. Typical Position and Arrangements of Separate Signal Faces with Flashing Red Arrow for Permissive Only Mode and Protected/Permissive Mode Left Turns



C. A steady left-turn YELLOW ARROW signal indication shall be displayed following the flashing left-turn RED ARROW signal indication.

D. It sball be permitted to display a flashing left-turn RED ARROW signal indication for a permissive left-turn movement while the signal faces for the adjacent through movement display steady CIRCULAR RED signal indications and the opposing left-turn signal faces display left-turn GREEN ARROW signal indications for a protected left-turn movement.

E. A supplementary sign shall not be required. If used, it shall be a LEFT TURN YIELD ON FLASHING RED ARROW AFTER STOP (R10-27) sign (see Figure 2B-27).

Option:

06 The requirements of Item A in Paragraph 5 may be met by a vertically-arranged signal face with a horizontal cluster of two left-turn RED ARROW signal indications, the left-most of which displays a steady indication and the right-most of which displays a flashing indication (see Figure 4D-8).

Section 4D.19 Signal Indications for Protected Only Mode Left-Turn Movements

Standard:

01 **A shared signal face shall not be used for protected only mode left turns unless the CIRCULAR GREEN and left-turn GREEN ARROW signal indications always begin and terminate together. If a shared signal face is provided for a protected only mode left turn, it shall meet the following requirements (see Figure 4D-9):**

A. It sball be capable of displaying the following signal indications: steady CIRCULAR RED, steady CIRCULAR YELLOW, CIRCULAR GREEN, and left-turn GREEN ARROW. Only one of the three colors shall be displayed at any given time.

B. During the protected left-turn movement, the shared signal face shall simultaneously display both a CIRCULAR GREEN signal indication and a left-turn GREEN ARROW signal indication.

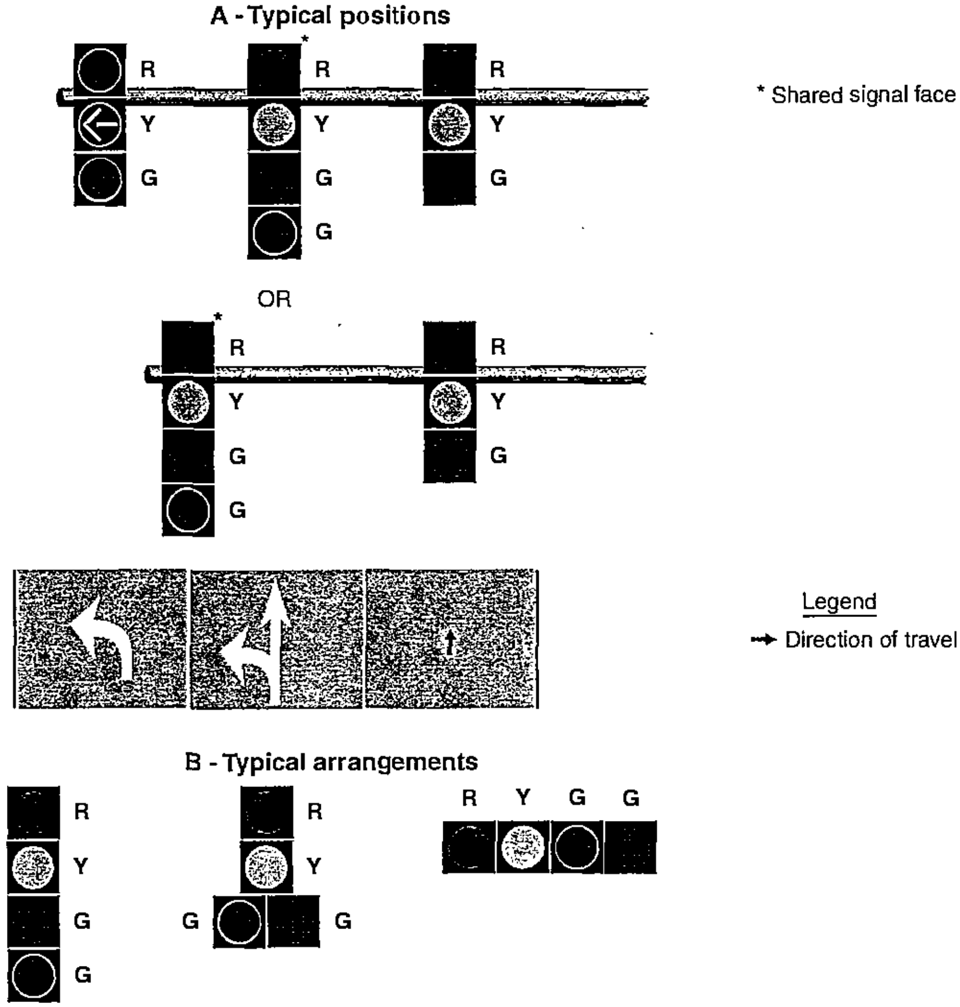
C. The sbared signal face shall always simultaneously display the same color of circular indication that tbe adjacent through signal face or faces display.

D. If tbe protected only mode is not the only left-turn mode used for the approach, tbe signal face shall be the same shared signal face that is used for the protected/permissive mode (see Section 4D.20).

Option:

02 A straight-through GREEN ARROW signal indication may be used instead of the CIRCULAR GREEN signal indication in Items A and B in Paragraph 1 on an approach where right turns are prohibited and a straight-through GREEN ARROW signal indication is also used instead of a CIRCULAR GREEN signal indication in the other signal face(s) for through traffic.

Figure 4D-9. Typical Positions and Arrangements of Shared Signal Faces for Protected Only Mode Left Turns



Note: Shared signal faces shall only be used for a protected-only mode left turn if the circular green and green left-turn arrow indications always begin and terminate together

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Standard:

03 **If a separate left-turn signal face is provided for a protected only mode left turn, it shall meet the following requirements (see Figure 4D-10):**

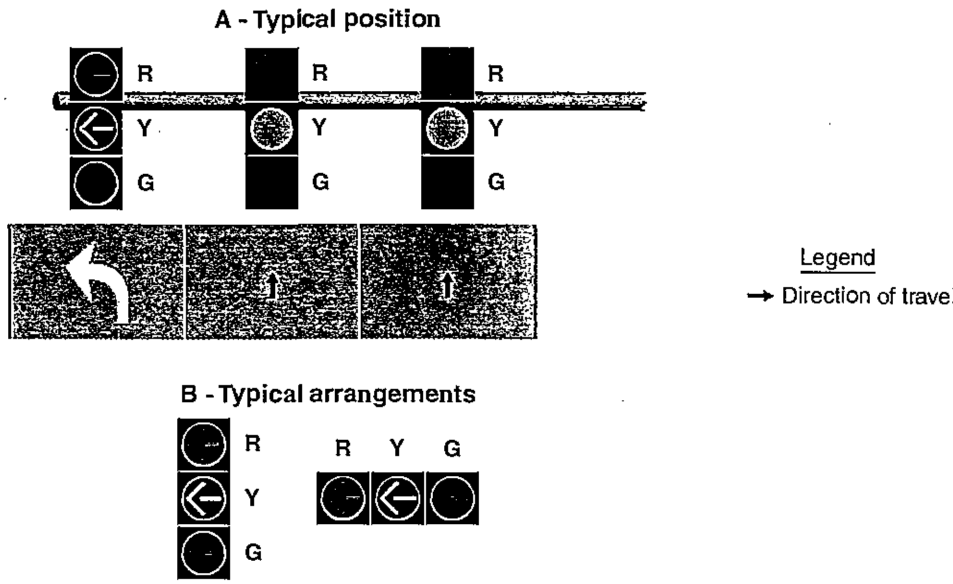
A. **It shall be capable of displaying, the following signal indications: steady left-turn RED ARROW, steady left-turn YELLOW ARROW, and left-turn GREEN ARROW. Only one of the three indications shall be displayed at any given time. A signal instruction sign shall not be required with this set of signal indications. If used, it shall be a LEFT ON GREEN ARROW ONLY (R10-5) sign (see Figure 2B-27).**

B. **During the protected left-turn movement, a left-turn GREEN ARROW signal indication shall be displayed.**

C. **A steady left-turn YELLOW ARROW signal indication shall be displayed following the left-turn GREEN ARROW signal indication.**

D. **If the protected only mode is not the only left-turn mode used for the approach, the signal face shall be the same separate left-turn signal face that is used for the protected/permissive mode (see Section 4D.20 and Figures 4D-8 and 4D-12) except that the flashing left-turn YELLOW ARROW or flashing left-turn RED ARROW signal indication shall not be displayed when operating in the protected only mode.**

Figure 4D-10. Typical Position and Arrangements of Separate Signal Faces for Protected Only Mode Left Turns



Section 4D.20 Signal Indications for Protected/Permissive Mode Left-Turn Movements

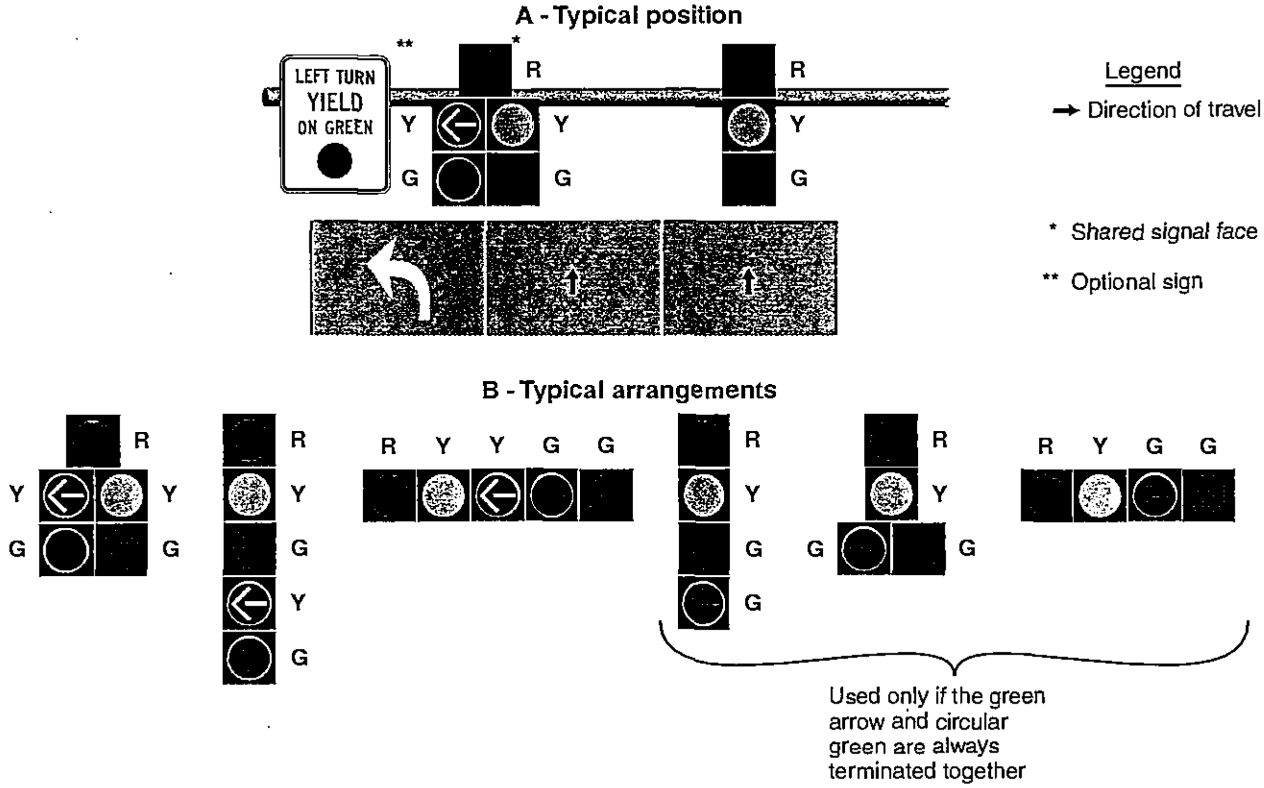
Standard:

01 **If a shared signal face is provided for a protected/permissive mode left turn, it shall meet the following requirements (see Figure 4D-11):**

- **A. It shall be capable of displaying the following signal indications: steady CIRCULAR RED, steady CIRCULAR YELLOW, CIRCULAR green, steady left-turn YELLOW ARROW, and left-turn GREEN ARROW. Only one of the three circular indications shall be displayed at any given time. Only one of the two arrow indications shall be displayed at any given time. If the left-turn GREEN ARROW signal indication and the CIRCULAR GREEN signal indication(s) for the adjacent through movement are always terminated together, the steady left-turn YELLOW ARROW signal indication shall not be required.**
- **B. During the protected left-turn movement, the shared signal face shall simultaneously display a left-turn GREEN ARROW signal indication and a circular signal indication that is the same color as the signal indication for the adjacent through lane on the same approach as the protected left turn.**
- **C. A steady left-turn YELLOW ARROW signal indication shall be displayed following the left-turn GREEN ARROW signal indication, unless the left-turn GREEN ARROW signal indication and the CIRCULAR GREEN signal indication(s) for the adjacent through movement are being terminated together. When the left-turn GREEN ARROW and CIRCULAR GREEN signal indications are being terminated together, the required display following the left-turn GREEN ARROW signal indication shall be either the display of a CIRCULAR YELLOW signal indication alone or the simultaneous display of the CIRCULAR YELLOW and left-turn YELLOW ARROW signal indications.**
- **D. During the permissive left-turn movement, the shared signal face shall display only a CIRCULAR GREEN signal indication.**
- **E. A protected/permissive shared signal face, regardless of where it is positioned and regardless of how many adjacent through signal faces are provided, shall always simultaneously display the same color of circular indication that the adjacent through signal face or faces display.**
- **F. A supplementary sign shall not be required. If used, it shall be a LEFT TURN YIELD ON GREEN (symbolic circular green) (R10-12) sign (see Figure 2B-27).**

02 **If a separate left-turn signal face is being operated in a protected/permissive left-turn mode, a CIRCULAR GREEN signal indication shall not be used in that face.**

Figure 4D-11. Typical Position and Arrangements of Shared Signal Faces for Protected/Permissive Mode Left Turns



03 **If a separate left-turn signal face is being operated in a protected/permissive left-turn mode and a flashing left-turn yellow arrow signal indication is provided, it shall meet the following requirements (see Figure 4D-12):**

A. It shall be capable of displaying the following signal indications: steady left-turn RED ARROW, steady left-turn YELLOW ARROW, flashing left-turn YELLOW ARROW, and left-turn GREEN ARROW. Only one of the four indications shall be displayed at any given time.

B. During the protected left-turn movement, a left-turn GREEN ARROW signal indication shall be displayed.

C. A steady left-turn YELLOW ARROW signal indication shall be displayed following the left-turn GREEN ARROW signal indication.

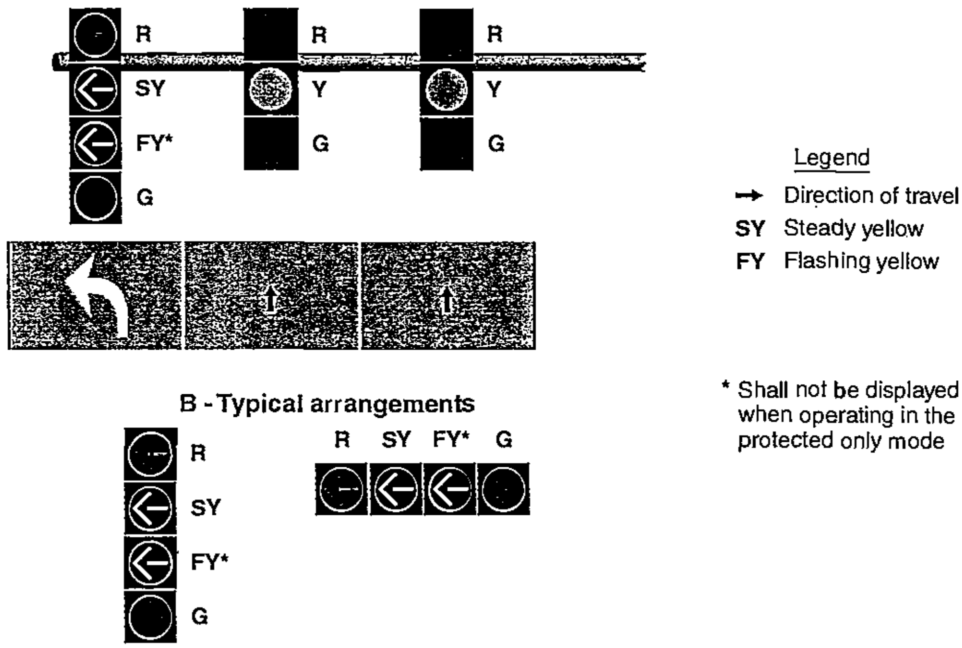
D. During the permissive left-turn movement, a flashing left-turn YELLOW ARROW signal indication shall be displayed.

E. A steady left-turn YELLOW ARROW signal indication shall be displayed following the flashing left-turn YELLOW ARROW signal indication if the permissive left-turn movement is being terminated and the separate left-turn signal face will subsequently display a steady left-turn RED ARROW indication.

F. It shall be permitted to display a flashing left-turn YELLOW ARROW signal indication for a permissive left-turn movement while the signal faces for the adjacent through movement display steady CIRCULAR RED signal indications and the opposing left-turn signal faces display left-turn GREEN ARROW signal indications for a protected left-turn movement.

G. When a permissive left-turn movement is changing to a protected left-turn movement, a left-turn GREEN ARROW signal indication shall be displayed immediately upon the termination of the flashing left-turn YELLOW ARROW signal indication. A steady left-turn YELLOW ARROW signal indication shall not be displayed between the display of the flashing left-turn YELLOW ARROW signal indication and the display of the steady left-turn GREEN ARROW signal indication.

Figure 4D-12. Typical Position and Arrangements of Separate Signal Faces with Flashing Yellow Arrow for Protected/Permissive Mode and Protected Only Mode Left Turns



H. The display sball be a four-section signal face except that a three-section signal face contaiuing a dual-arrow signal section sball be permitted where signal head height limitations (or lateral positioning limitations for a horizontally-mounted signal face) will not permit the use of a four-section signal face. The dual-arrow signal section, where used, shall display a GREEN ARROW for the protected left-turn movement and a flashing YELLOW ARROW for the permissive left-turn movement.
I. During steady mode (stop-and-go) operation, the signal section that displays the steady left-turn YELLOW ARROW signal indication during change intervals shall not be used to display the flasbing left-turn YELLOW ARROW signal indication for permissive left turns.
J. During flashing mode operation (see Section 4D.30), the display of a flashing left-turn YELLOW ARROW signal indication shall be only from the signal section tbat displays a steady left-turn YELLOW ARROW signal indication during steady mode (stop-and-go) operation.

Option:

04 A separate left-turn signal face with a flashing left-turn RED ARROW signal indication during the permissive left-turn movement may be used for unusual geometric conditions, such as wide medians with offset left-turn lanes, but only when an engiueering study determines that each and every vehicle must successively come to a full stop before making a permissive left turn.

Standard:

05 If a separate left-turn signal face is being operated in a protected/permissive left-turn mode and a flashing left-turn RED arrow signal indication is provided, it shall meet the following requirements (see Fignre 4D-8):

A. It shall be capable of displaying the following signal indications: steady or flashing left-turn RED ARROW, steady left-turn YELLOW ARROW, and left-turn GREEN ARROW. Only one of the three indications shall be displayed at any given time.
B. During the protected left-turn movement, a left-turn GREEN ARROW signal indication shall be displayed.
C. A steady left-turn YELLOW ARROW signal indication shall be displayed following the left-turn GREEN ARROW signal indication.
D. During the permissive left-turn movement, a flashing left-turn RED ARROW signal indication shall be displayed.

E. **A steady left-turn YELLOW ARROW signal indication shall be displayed following the flashing left-turn RED ARROW signal indication if the permissive left-turn movement is being terminated and the separate left-turn signal face will subsequently display a steady left-turn RED ARROW indication.**
F. **When a permissive left-turn movement is changing to a protected left-turn movement, a left-turn GREEN ARROW signal indication shall be displayed immediately upon the termination of the flashing left-turn RED ARROW signal indication. A steady left-turn YELLOW ARROW signal indication shall not be displayed between the display of the flashing left-turn RED ARROW signal indication and the display of the steady left-turn GREEN ARROW signal indication.**
G. **It shall be permitted to display a flashing left-turn RED ARROW signal indication for a permissive left-turn movement while the signal faces for the adjacent through movement display steady CIRCULAR RED signal indications and the opposing left-turn signal faces display left-turn GREEN ARROW signal indications for a protected left-turn movement.**
H. **A supplementary sign shall not be required. If used, it shall be a LEFT TURN YIELD ON FLASHING RED ARROW AFTER STOP (R10-27) sign (see Figure 2B-27).**

Option:

06 The requirements of Item A in Paragraph 5 may be met by a vertically-arranged signal face with a horizontal cluster of two left-turn RED ARROW signal indications, the left-most of which displays a steady indication and the right-most of which displays a flashing indication (see Figure 4D-8).

Section 4D.21 Signal Indications for Right-Turn Movements – General

Standard:

01 **In Sections 4D.21 through 4D.24, provisions applicable to right-turn movements and right-turn lanes shall also apply to signal indications for U-turns to the right that are provided at locations where right turns are prohibited or not geometrically possible.**

Support:

02 Right-turning traffic is controlled by one of four modes as follows:

A. Permissive Only Mode—turns made on a CIRCULAR GREEN signal indication, a flashing right-turn YELLOW ARROW signal indication, or a flashing right-turn RED ARROW signal indication after yielding to pedestrians, if any.
B. Protected Only Mode—turns made only when a right-turn GREEN ARROW signal indication is displayed.
C. Protected/Permissive Mode—both modes occur on an approach during the same cycle.
D. Variable Right-Turn Mode—the operating mode changes among the protected only mode and/or the protected/permissive mode and/or the permissive only mode during different periods of the day or as traffic conditions change.

Standard:

03 **During a permissive right-turn movement, the signal faces, if any, that exclusively control U-turn traffic that conflicts with the permissive right-turn movement (see Item F.1 in Section 4D.05) shall simultaneously display steady U-turn RED ARROW signal indications. If pedestrians crossing the lane or lanes used by the permissive right-turn movement to depart the intersection are controlled by pedestrian signal heads, the signal indications displayed by those pedestrian signal heads shall not be limited to any particular display during the permissive right-turn movement.**

04 **During a protected right-turn movement, the signal faces for left-turn traffic, if any, on the opposing approach shall not simultaneously display a steady left-turn GREEN ARROW or steady left-turn YELLOW ARROW signal indication, and signal faces, if any, that exclusively control U-turn traffic that conflicts with the protected right-turn movement (see Item F.1 in Section 4D.05) shall simultaneously display steady U-turn RED ARROW signal indications. If pedestrians crossing the lane or lanes used by the protected right-turn movement to depart the intersection are controlled by pedestrian signal heads, the pedestrian signal heads shall display a steady UPRAISED HAND (symbolizing DONT WALK) signal indication during the protected right-turn movement.**

05 **A protected only mode right-turn movement that does not begin and terminate at the same time as the adjacent through movement shall not be provided on an approach unless an exclusive right-turn lane exists.**

06 **A yellow change interval for the right-turn movement shall not be displayed when the status of the right-turn operation is changing from permissive to protected within any given signal sequence.**

07 If the operating mode changes among the protected only mode and/or the protected/permissive mode and/or the permissive only mode during different periods of the day or as traffic conditions change, the requirements in Sections 4D.22 through 4D.24 that are appropriate to that mode of operation shall be met, subject to the following:

A. The CIRCULAR GREEN and CIRCULAR YELLOW signal indications shall not be displayed when operating in the protected only mode.

B. The right-turn GREEN ARROW and right-turn YELLOW ARROW signal indications shall not be displayed when operating in the permissive only mode.

Option:

08 Additional static signs or changeable message signs may be used to meet the requirements for the variable right-turn mode or to inform drivers that right-turn green arrows will not be available during certain times of the day.

Support:

09 Sections 4D.21 through 4D.24 describe the use of the following two types of signal faces for controlling right-turn movements:

A. Shared signal face – This type of signal face controls both the right-turn movement and the adjacent movement (usually the through movement) and can serve as one of the two required primary signal faces for the adjacent movement. A shared signal face always displays the same color of circular indication that is displayed by the signal face or faces for the adjacent movement.

B. Separate right-turn signal face – This type of signal face controls only the right-turn movement and cannot serve as one of the two required primary signal faces for the adjacent movement (usually the through movement) because it displays signal indications that are applicable only to the right-turn movement. If a separate right-turn signal face is mounted overhead at the intersection, it is positioned over the extension of the right-turn lane. In a separate right-turn signal face, a flashing right-turn YELLOW ARROW signal indication or a flashing right-turn RED ARROW signal indication is used to control permissive right-turning movements.

10 Section 4D.13 contains provisions regarding the lateral positioning of signal faces that control right-turn movements.

11 It is not necessary that the same mode of right-turn operation or same type of right-turn signal face be used on every approach to a signalized location. Selecting different modes and types of right-turn signal faces for the various approaches to the same signalized location is acceptable.

Option:

12 A signal face that is shared by left-turning and right-turning traffic may be provided for a shared left-turn/right-turn lane on an approach that has no through traffic (see Section 4D.25).

Section 4D.22 Signal Indications for Permissive Only Mode Right-Turn Movements

Standard:

01 If a shared signal face is provided for a permissive only mode right turn, it shall meet the following requirements (see Figure 4D-13):

A. It shall be capable of displaying the following signal indications: steady CIRCULAR RED, steady CIRCULAR YELLOW, and CIRCULAR GREEN. Only one of the three indications shall be displayed at any given time.

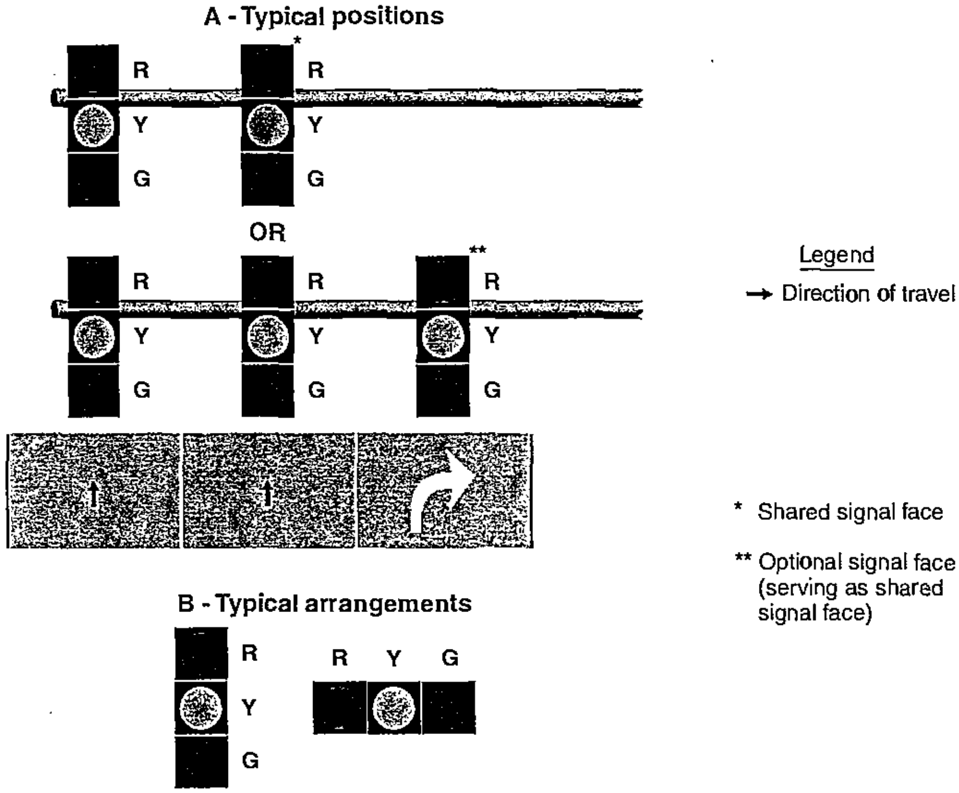
B. During the permissive right-turn movement, a CIRCULAR GREEN signal indication shall be displayed.

C. A permissive only shared signal face, regardless of where it is positioned and regardless of how many adjacent through signal faces are provided, shall always simultaneously display the same color of circular indication that the adjacent through signal face or faces display.

D. If the permissive only mode is not the only right-turn mode used for the approach, the signal face shall be the same shared signal face that is used for the protected/permissive mode (see Section 4D.24) except that the right-turn GREEN ARROW and right-turn YELLOW ARROW signal indications shall not be displayed when operating in the permissive only mode.

02 If a separate right-turn signal face is being operated in a permissive only right-turn mode, a CIRCULAR GREEN signal indication shall not be used in that face.

Figure 4D-13. Typical Positions and Arrangements of Shared Signal Faces for Permissive Only Mode Right Turns



03 If a separate right-turn signal face is being operated in a permissive only right-turn mode and a flashing right-turn yellow arrow signal indication is provided, it shall meet the following requirements (see Figure 4D-14):

A. It shall be capable of displaying one of the following sets of signal indications:
   1. Steady right-turn RED ARROW, steady right-turn YELLOW ARROW, and flashing right-turn YELLOW ARROW. Only one of the three indications shall be displayed at any given time.
   2. Steady CIRCULAR RED, steady right-turn YELLOW ARROW, and flashing right-turn YELLOW ARROW. Only one of the three indications shall be displayed at any given time. If the CIRCULAR RED signal indication is sometimes displayed when the signal faces for the adjacent through lane(s) are not displaying a CIRCULAR RED signal indication, a RIGHT TURN SIGNAL (R10-10R) sign (see Figure 2B-27) shall be used unless the CIRCULAR RED signal indication in the separate right-turn signal face is shielded, hooded, louvered, positioned, or designed such that it is not readily visible to drivers in the through lane(s).

B. During the permissive right-turn movement, a flashing right-turn YELLOW ARROW signal indication shall be displayed.

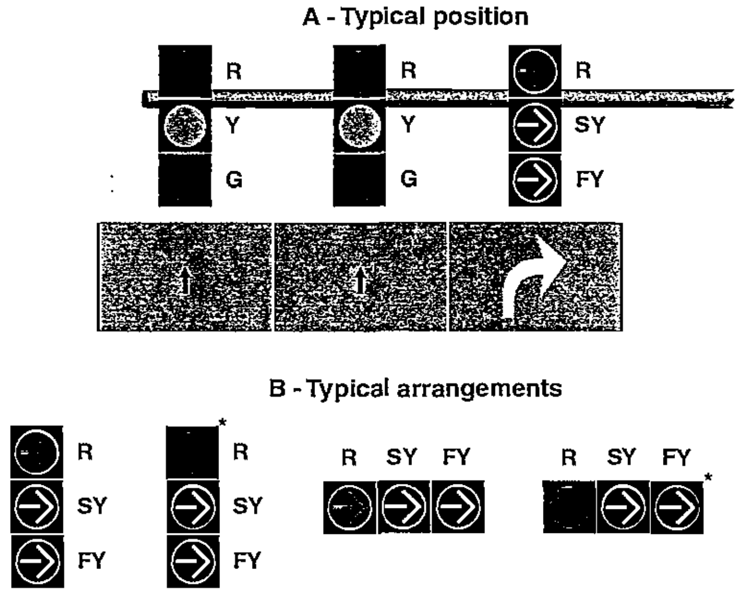
C. A steady right-turn YELLOW ARROW signal indication shall be displayed following the flashing right-turn YELLOW ARROW signal indication.

D. When the separate right-turn signal face is providing a message to stop and remain stopped, a steady right-turn RED ARROW signal indication shall be displayed if it is intended that right turns on red not be permitted (except when a traffic control device is in place permitting a turn on a steady RED ARROW signal indication) or a steady CIRCULAR RED signal indication shall be displayed if it is intended that right turns on red be permitted.

E. It shall be permitted to display a flashing right-turn YELLOW ARROW signal indication for a permissive right-turn movement while the signal faces for the adjacent through movement display steady CIRCULAR RED signal indications.

F. During steady mode (stop-and-go) operation, the signal section that displays the steady right-turn YELLOW ARROW signal indication during change intervals shall not be used to display the flashing right-turn YELLOW ARROW signal indication for permissive right turns.

Figure 4D-14. Typical Position and Arrangements of Separate Signal Faces with Flashing Yellow Arrow for Permissive Only Mode Right Turns



Legend

→ Direction of travel

SY Steady yellow

FY Flashing yellow

* These faces would be used if it is intended that a right turn on red after stop be permitted; a RIGHT TURN SIGNAL (R10-10R) sign shall be used with these faces if the red indication is sometimes displayed when the signal faces for the adjacent through lane(s) are not displaying a red indication and the red indication in the right-turn signal face is not visibility limited

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G. During flashing mode operation (see Section 4D.30), the display of a flashing right-turn YELLOW ARROW signal indication shall be only from the signal section that displays a steady right-turn YELLOW ARROW signal indication during steady mode (stop-and-go) operation.

H. If the permissive only mode is not the only right-turn mode used for the approach, the signal face shall be the same separate right-turn signal face with a flashing YELLOW ARROW signal indication that is used for the protected/permissive mode (see Section 4D.24) except that the right-turn GREEN ARROW signal indication shall not be displayed when operating in the permissive only mode.

Option:

04 When an engineering study determines that each and every vehicle must successively come to a full stop before making a permissive right turn, a separate right-turn signal face with a flashing right-turn RED ARROW signal indication during the permissive right-turn movement may be used.

Standard:

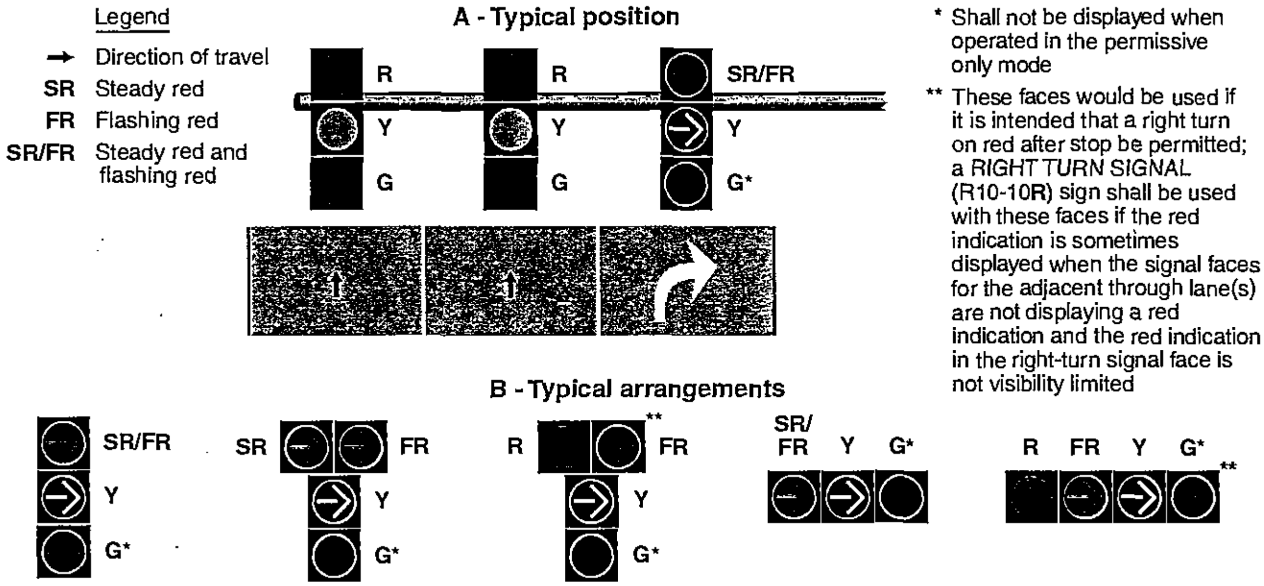
05 **If a separate right-turn signal face is being operated in a permissive only right-turn mode and a flashing right-turn RED arrow signal indication is provided, it shall meet the following requirements (see Figure 4D-15):**

A. It shall be capable of displaying one of the following sets of signal indications:

1. **Steady or flashing right-turn RED ARROW, steady right-turn YELLOW ARROW, and right-turn GREEN ARROW. Only one of the three indications shall be displayed at any given time. The GREEN ARROW indication is required in order to provide a three-section signal face, but shall not be displayed during permissive only mode.**
2. **Steady CIRCULAR RED on the left and steady right-turn RED ARROW on the right of the top position, steady right-turn YELLOW ARROW in the middle position, and right-turn GREEN ARROW in the bottom position. Only one of the four indications shall be displayed at any given time. The GREEN ARROW indication is required in order to provide three vertical positions, but shall not be displayed during permissive only mode. If the CIRCULAR RED signal indication is sometimes displayed when the signal faces for the adjacent through lane(s) are not displaying a CIRCULAR RED signal indication, a RIGHT TURN SIGNAL (R10-10R) sign (see Figure 2B-27) shall be used unless the CIRCULAR RED signal indication in the separate right-turn signal face is shielded, hooded, louvered, positioned, or designed such that it is not readily visible to drivers in the through lane(s).**

B. During the permissive right-turn movement, a flashing right-turn RED ARROW signal indication shall be displayed, thus indicating that each and every vehicle must successively come to a full stop before making a permissive right turn.

Figure 4D-15. Typical Position and Arrangements of Separate Signal Faces with Flashing Red Arrow for Permissive Only Mode and Protected/Permissive Mode Right Turns



Note: A flashing red arrow controlling a right-turn movement may be used only when an engineering study determines that each and every vehicle must successively come to a full stop before making a permissive turn

C. A steady right-turn YELLOW ARROW signal indication shall be displayed following the flashing right-turn RED ARROW signal indication.

D. When the separate right-turn signal face is providing a message to stop and remain stopped, a steady right-turn RED ARROW signal indication shall be displayed if it is intended that right turns on red not be permitted (except when a traffic control device is in place permitting a turn on a steady RED ARROW signal indication) or a steady CIRCULAR RED signal indication shall be displayed if it is intended that right turns on red be permitted.

E. The display of a flashing right-turn RED ARROW signal indication for a permissive right-turn movement while the signal faces for the adjacent through movement display steady CIRCULAR RED signal indications and the opposing left-turn signal faces display left-turn GREEN ARROW signal indications for a protected left-turn movement shall be permitted.

F. A supplementary sign shall not be required. If used, it shall be a RIGHT TURN YIELD ON FLASHING RED ARROW AFTER STOP (R10-27) sign (see Figure 2B-27).

Option:

06 The requirements of Item A.1 in Paragraph 5 may be met by a vertically-arranged signal face with a horizontal cluster of two right-turn RED ARROW signal indications, the left-most of which displays a steady indication and the right-most of which displays a flashing indication (see Figure 4D-15).

Section 4D.23 Signal Indications for Protected Only Mode Right-Turn Movements

Standard:

01 **A shared signal face shall not be used for protected only mode right turns unless the CIRCULAR GREEN and right-turn GREEN ARROW signal indications always begin and terminate together. If a shared signal face is provided for a protected only right turn, it shall meet the following requirements (see Figure 4D-16):**

A. It shall be capable of displaying the following signal indications: steady CIRCULAR RED, steady CIRCULAR YELLOW, CIRCULAR GREEN, and right-turn GREEN ARROW. Only one of the three colors shall be displayed at any given time.

B. During the protected right-turn movement, the shared signal face shall simultaneously display both a CIRCULAR GREEN signal indication and a right-turn GREEN ARROW signal indication.

C. The shared signal face shall always simultaneously display the same color of circular indication that the adjacent through signal face or faces display.

D. If the protected only mode is not the only right-turn mode used for the approach, the signal face shall he the same shared signal face that is used for the protected/permissive mode (see Section 4D.24).

Option:

02 A straight-through GREEN ARROW signal indication may be used instead of the CIRCULAR GREEN signal indication in Items A and B in Paragraph 1 on an approach where left turns are prohibited and a straight-through GREEN ARROW signal indication is also used instead of a CIRCULAR GREEN signal indication in the other signal face(s) for through traffic.

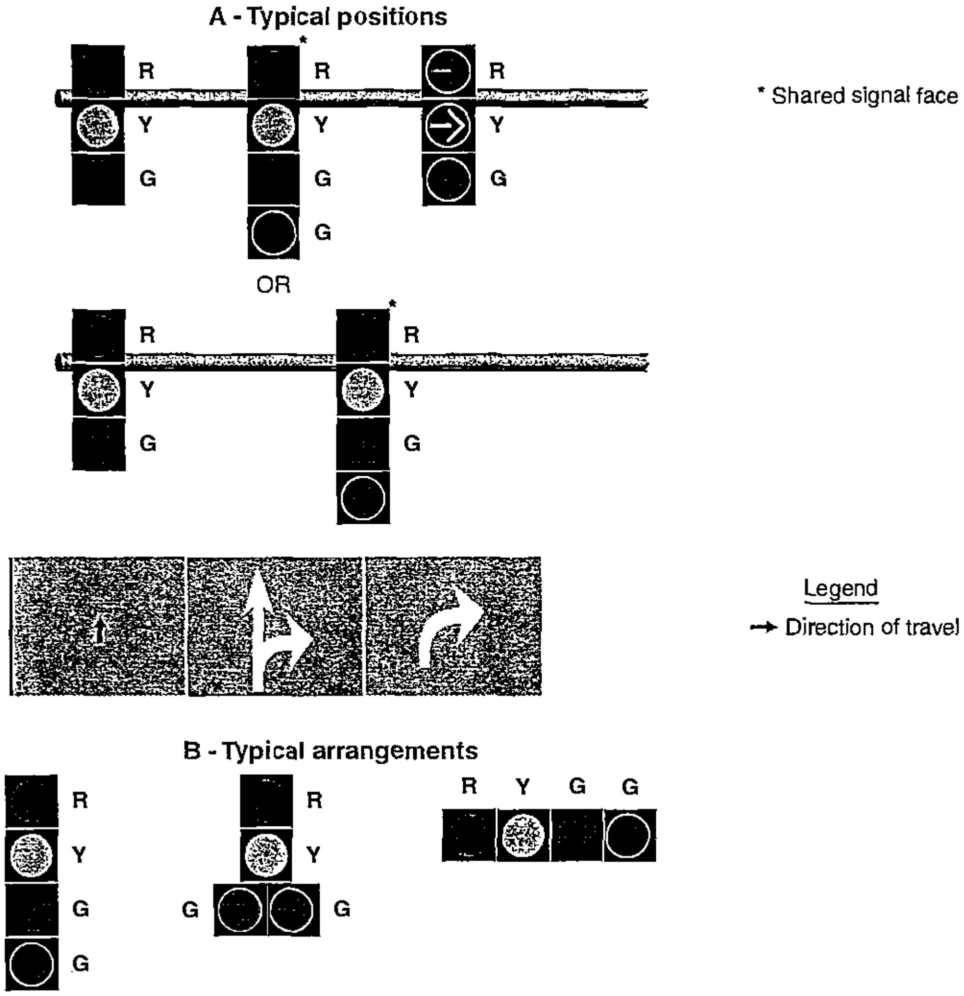
Standard:

03 If a separate right-turn signal face is provided for a protected only mode right turn, it shall meet the following requirements (see Figure 4D-17):

A. It shall be capable of displaying one of the following sets of signal indications:

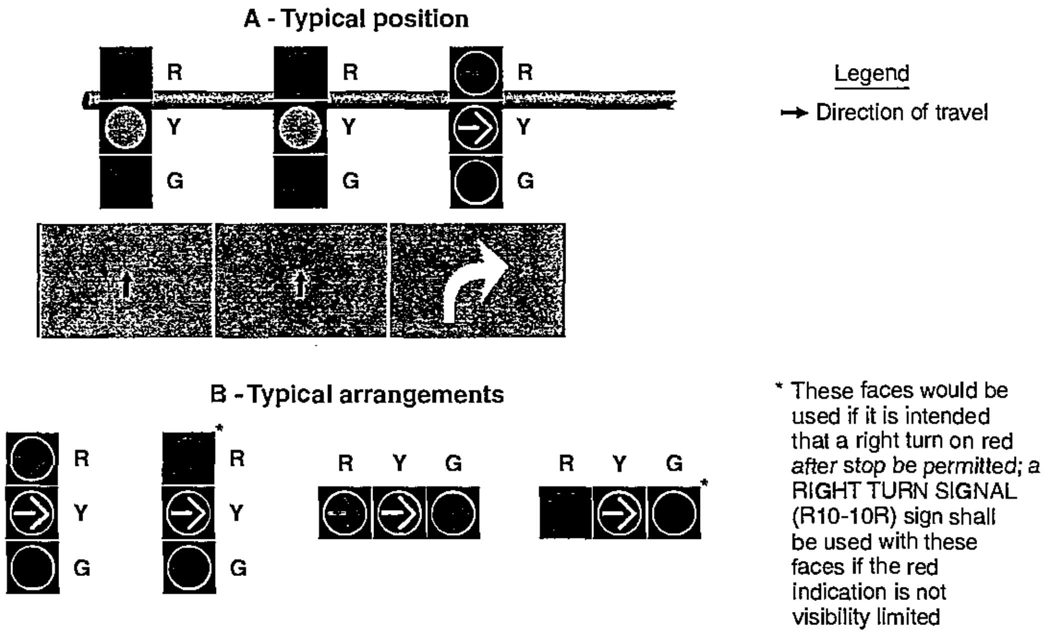
1. Steady right-turn RED ARROW, steady right-turn YELLOW ARROW, and right-turn GREEN ARROW. Only one of the three indications shall be displayed at any given time. A signal instruction sign shall not be required with this set of signal indications. If used, it shall be a RIGHT ON GREEN ARROW ONLY (R10-5a) sign (see Figure 2B-27).

Figure 4D-16. Typical Positions and Arrangements of Shared Signal Faces for Protected Only Mode Right Turns



Note: Shared signal faces shall only be used for a protected-only mode right turn if the circular green and green right-turn arrow indications always begin and terminate together

Figure 4D-17. Typical Position and Arrangements of Separate Signal Faces for Protected Only Mode Right Turns



2. Steady CIRCULAR RED, steady right-turn YELLOW ARROW, and right-turn GREEN ARROW. Only one of three indications shall be displayed at any given time. If the CIRCULAR RED signal indication is sometimes displayed when the signal faces for the adjacent through lane(s) are not displaying a CIRCULAR RED signal indication, a RIGHT TURN SIGNAL (R10-10R) sign (see Figure 2B-27) shall be used unless the CIRCULAR RED signal indication is shielded, hooded, louvered, positioned, or designed such that it is not readily visible to drivers in the through lane(s).

B. During the protected right-turn movement, a right-turn GREEN ARROW signal indication shall be displayed.

C. A steady right-turn YELLOW ARROW signal indication shall be displayed following the right-turn GREEN ARROW signal indication.

D. When the separate signal face is providing a message to stop and remain stopped, a steady right-turn RED ARROW signal indication shall he displayed if it is intended that right turns on red not be permitted (except when a traffic control device is in place permitting a turn on a steady RED ARROW signal indication) or a steady CIRCULAR RED signal indication shall be displayed if it is intended that right turns on red be permitted.

E. If the protected only mode is not the only right-turn mode used for the approach, the signal face shall be the same separate right-turn signal face that is used for the protected/permissive mode (see Section 4D.24 and Figure 4D-19) except that a flashing right-turn YELLOW ARROW or flashing right-turn RED ARROW signal indication shall not be displayed when operating in the protected only mode.

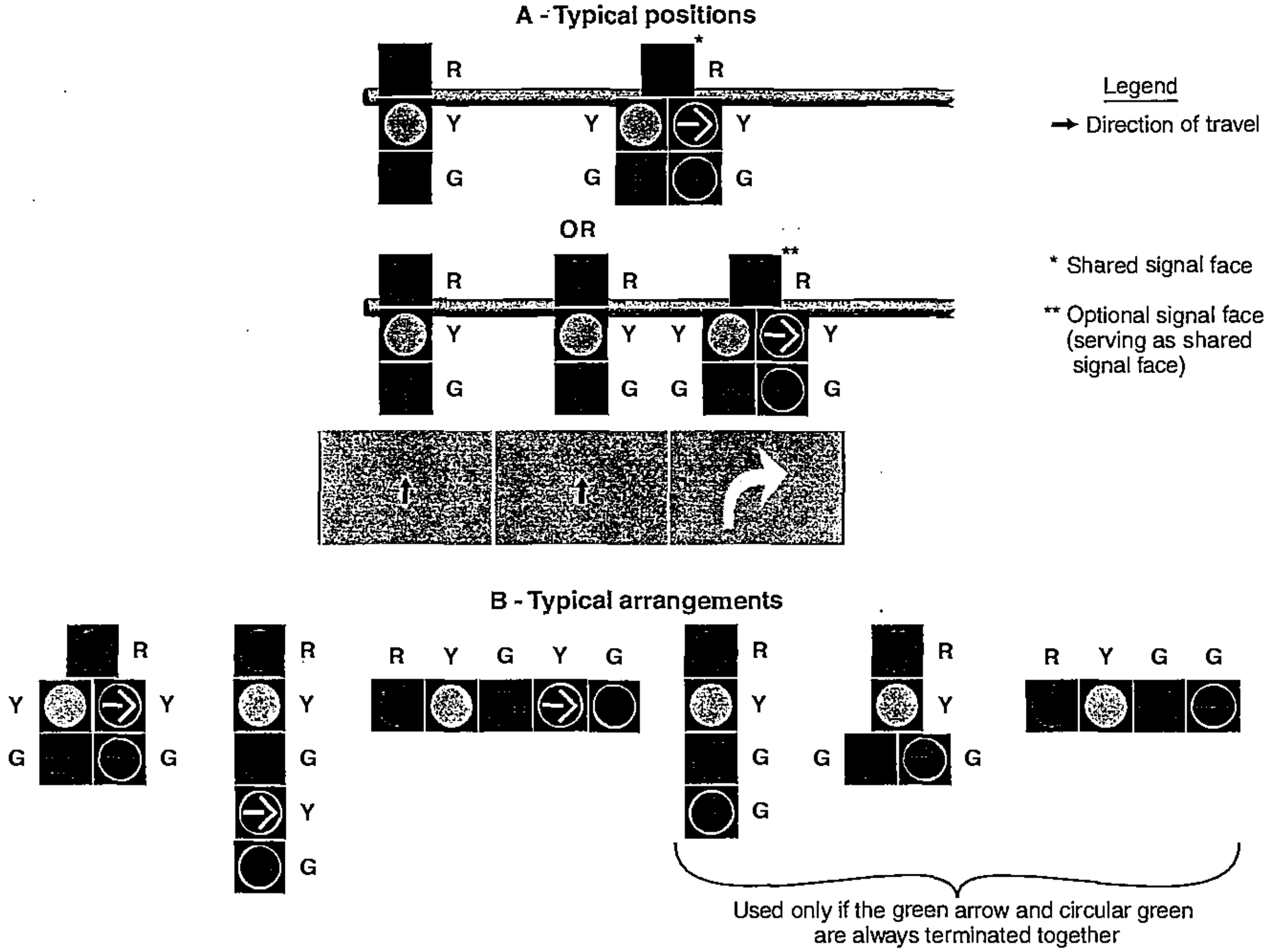
Section 4D.24 Signal Indications for Protected/Permissive Mode Right-Turn Movements

Standard:

01 If a shared signal face is provided for a protected/permissive mode right turn, it shall meet the following requirements (see Figure 4D-18):

A. It shall be capable of displaying the following signal indications: steady CIRCULAR RED, steady CIRCULAR YELLOW, CIRCULAR green, steady right-turn YELLOW ARROW, and right-turn GREEN ARROW. Only one of the three circular indications shall be displayed at any given time. Only one of the two arrow indications shall be displayed at any given time. If the right-turn GREEN ARROW signal indication and the CIRCULAR GREEN signal indication(s) for the adjacent through movement are always terminated together, the steady right-turn YELLOW ARROW signal indication shall not be required.

Figure 4D-18. Typical Positions and Arrangements of Shared Signal Faces for Protected/Permissive Mode Right Turns



B. During the protected right-turn movement, the shared signal face shall simultaneously display a right-turn GREEN ARROW signal indication and a circular signal indication that is the same color as the signal indication for the adjacent through lane on the same approach as the protected right turn.

C. A steady right-turn YELLOW ARROW signal indication shall be displayed following the right-turn GREEN ARROW signal indication, unless the right-turn GREEN ARROW signal indication and the CIRCULAR GREEN signal indication(s) for the adjacent through movement are being terminated together. When the right-turn GREEN ARROW and CIRCULAR GREEN signal indications are being terminated together, the required display following the right-turn GREEN ARROW signal indication shall be either the display of a CIRCULAR YELLOW signal indication alone or the simultaneous display of the CIRCULAR YELLOW and right-turn YELLOW ARROW signal indications.

D. During the permissive right-turn movement, the shared signal face shall display only a CIRCULAR GREEN signal indication.

E. A protected/permissive shared signal face, regardless of where it is positioned and regardless of how many adjacent through signal faces are provided, shall always simultaneously display the same color of circular indication that the adjacent through signal face or faces display.

02 If a separate right-turn signal face is being operated in a protected/permissive right-turn mode, a CIRCULAR GREEN signal indication shall not be used in that face.

03 **If a separate right-turn signal face is being operated in a protected/permissive right-turn mode and a flashing right-turn yellow arrow signal indication is provided, it shall meet the following requirements (see Figure 4D-19):**

A. It shall be capable of displaying one of the following sets of signal indications:

1. Steady right-turn RED ARROW, steady right-turn YELLOW ARROW, flashing right-turn YELLOW ARROW, and right-turn GREEN ARROW. Only one of the four indications shall be displayed at any given time.

2. Steady CIRCULAR RED, steady right-turn YELLOW ARROW, flashing right-turn YELLOW ARROW, and right-turn GREEN ARROW. Only one of the four indications shall be displayed at any given time. If the CIRCULAR RED signal indication is sometimes displayed when the signal faces for the adjacent through lane(s) are not displaying a CIRCULAR RED signal indication, a RIGHT TURN SIGNAL (R10-10R) sign (see Figure 2B-27) shall be used unless the CIRCULAR RED signal indication in the separate right-turn signal face is shielded, hooded, louvered, positioned, or designed such that it is not readily visible to drivers in the through lane(s).

B. During the protected right-turn movement, a right-turn GREEN ARROW signal indication shall be displayed.

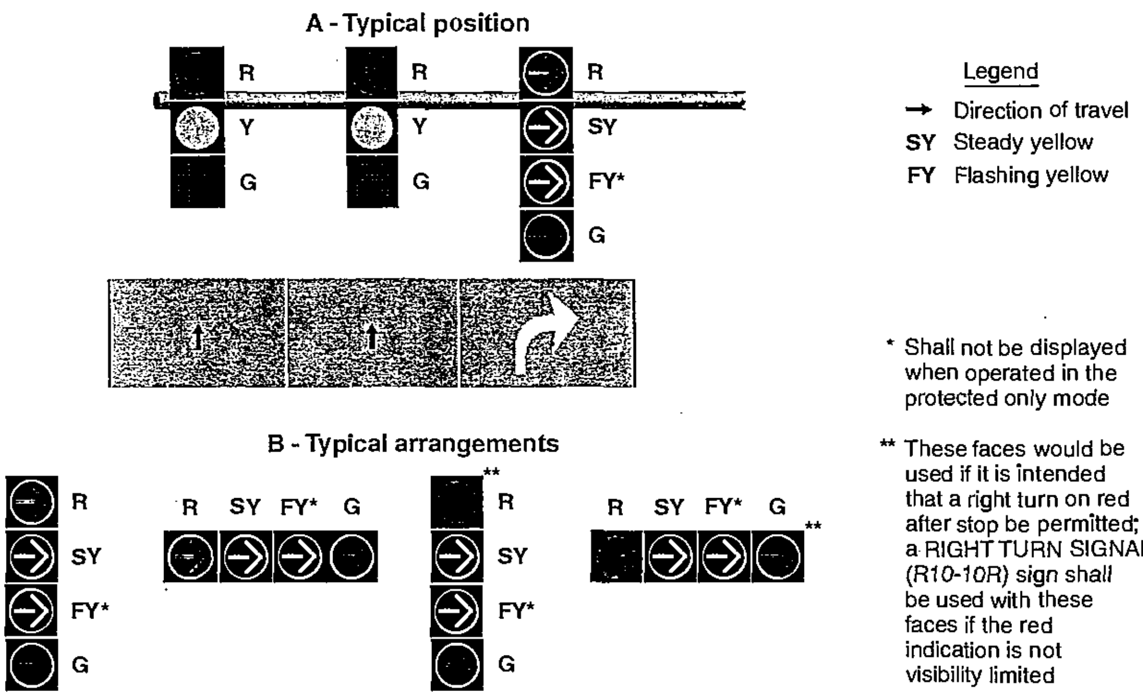
C. A steady right-turn YELLOW ARROW signal indication shall be displayed following the right-turn GREEN ARROW signal indication.

D. During the permissive right-turn movement, a flashing right-turn YELLOW ARROW signal indication shall be displayed.

E. A steady right-turn YELLOW ARROW signal indication shall be displayed following the flashing right-turn YELLOW ARROW signal indication if the permissive right-turn movement is being terminated and the separate right-turn signal face will subsequently display a steady red indication.

F. When a permissive right-turn movement is changing to a protected right-turn movement, a right-turn GREEN ARROW signal indication shall be displayed immediately upon the termination of the flashing right-turn YELLOW ARROW signal indication. A steady right-turn YELLOW ARROW signal indication shall not be displayed between the display of the flashing right-turn YELLOW ARROW signal indication and the display of the steady right-turn GREEN ARROW signal indication.

Figure 4D-19. Typical Position and Arrangements of Separate Signal Faces with Flashing Yellow Arrow for Protected/Permissive Mode and Protected Only Mode Right Turns



G. When the separate right-turn signal face is providing a message to stop and remain stopped, a steady right-turn RED ARROW signal indication shall be displayed if it is intended that right turns on red not be permitted (except when a traffic control device is in place permitting a turn on a steady RED ARROW signal indication) or a steady CIRCULAR RED signal indication shall be displayed if it is intended that right turns on red be permitted.

H. It shall be permitted to display a flashing right-turn YELLOW ARROW signal indication for a permissive right-turn movement while the signal faces for the adjacent through movement display steady CIRCULAR RED signal indications.

I. A signal face containing a dual-arrow signal section in place of separate flashing right-turn YELLOW ARROW and right-turn GREEN ARROW signal sections shall be permitted where signal head height limitations (or lateral positioning limitations for a horizontally-mounted signal face) are a concern. The dual-arrow signal section, where used, shall display a GREEN ARROW for the protected right-turn movement and a flashing YELLOW ARROW for the permissive right-turn movement.

J. During steady mode (stop-and-go) operation, the signal section that displays the steady right-turn YELLOW ARROW signal indication during change intervals shall not be used to display the flashing right-turn YELLOW ARROW signal indication for permissive right turns.

K. During flashing mode operation (see Section 4D.30), the display of a flashing right-turn YELLOW ARROW signal indication shall be only from the signal section that displays a steady right-turn YELLOW ARROW signal indication during steady mode (stop-and-go) operation.

Option:

04 When an engineering study determines that each and every vehicle must successively come to a full stop before making a permissive right turn, a separate signal face that has a flashing right-turn RED ARROW signal indication during the permissive right-turn movement may be used.

Standard:

05 If a separate right-turn signal face is being operated in a protected/permissive right-turn mode and a flashing right-turn RED arrow signal indication is provided, it shall meet the following requirements (see Figure 4D-15):

A. It shall be capable of displaying one of the following sets of signal indications:
   1. Steady or flashing right-turn RED ARROW, steady right-turn YELLOW ARROW, and right-turn GREEN ARROW. Only one of the three indications shall be displayed at any given time.
   2. Steady CIRCULAR RED on the left and steady or flashing right-turn RED ARROW on the right of the top position, steady right-turn YELLOW ARROW in the middle position, and right-turn GREEN ARROW in the bottom position. Only one of the four indications shall be displayed at any given time. If the CIRCULAR RED signal indication is sometimes displayed when the signal faces for the adjacent through lane(s) are not displaying a CIRCULAR RED signal indication, a RIGHT TURN SIGNAL (R10-10R) sign (see Figure 2B-27) shall be used unless the CIRCULAR RED signal indication in the separate right-turn signal face is shielded, hooded, louvered, positioned, or designed such that it is not readily visible to drivers in the through lane(s).

B. During the protected right-turn movement, a right-turn GREEN ARROW signal indication shall be displayed.

C. A steady right-turn YELLOW ARROW signal indication shall be displayed following the right-turn GREEN ARROW signal indication.

D. During the permissive right-turn movement, the separate right-turn signal face shall display a flashing right-turn RED ARROW signal indication.

E. A steady right-turn YELLOW ARROW signal indication shall be displayed following the flashing right-turn RED ARROW signal indication if the permissive right-turn movement is being terminated and the separate right-turn signal face will subsequently display a steady red indication.

F. When a permissive right-turn movement is changing to a protected right-turn movement, a right-turn GREEN ARROW signal indication shall be displayed immediately upon the termination of the flashing right-turn RED ARROW signal indication. A steady right-turn YELLOW ARROW signal indication shall not be displayed between the display of the flashing right-turn RED ARROW signal indication and the display of the steady right-turn GREEN ARROW signal indication.

G. When the separate right-turn signal face is providing a message to stop and remain stopped, a steady right-turn RED ARROW signal indication shall be displayed if it is intended that right turns on red not be permitted (except when a traffic control device is in place permitting a turn on a steady RED ARROW signal indication) or a steady CIRCULAR RED signal indication shall be displayed if it is intended that right turns on red be permitted.

H. It shall be permitted to display a flashing right-turn RED ARROW signal indication for a permissive right-turn movement while the signal faces for the adjacent through movement display steady CIRCULAR RED signal indications and the opposing left-turn signal faces display left-turn GREEN ARROW signal indications for a protected left-turn movement.

I. A supplementary sign shall not be required. If used, it shall be a RIGHT TURN YIELD ON FLASHING RED ARROW AFTER STOP (R10-27) sign (see Figure 2B-27).

Option:

06 The requirements of Item A.1 in Paragraph 5 may be met by a vertically-arranged signal face with a horizontal cluster of two right-turn RED ARROW signal indications, the left-most of which displays a steady indication and the right-most of which displays a flashing indication (see Figure 4D-15).

Section 4D.25 Signal Indications for Approaches With Shared Left-Turn/Right-Turn Lanes and No Through Movement

Support:

01 A lane that is shared by left-turn and right-turn movements is sometimes provided on an approach that has no through movement, such as the stem of a T-intersection or where the opposite approach is a one-way roadway in the opposing direction.

Standard:

02 **When a shared left-turn/right-turn lane exists on a signalized approach, the left-turn and right-turn movements shall start and terminate simultaneously and the red signal indication used in each of the signal faces on the approach shall be a CIRCULAR RED.**

Support:

03 This requirement for the use of CIRCULAR RED signal indications in signal faces for approaches having a shared lane for left-turn and right-turn movements is a specific exception to other provisions in this Chapter that would otherwise require the use of RED ARROW signal indications.

Standard:

04 **The signal faces provided for an approach with a shared left-turn/right-turn lane and no through movement shall be one of the following:**

A. Two or more signal faces, each capable of displaying CIRCULAR RED, CIRCULAR YELLOW, and CIRCULAR GREEN signal indications, shall be provided for the approach. This display shall be permissible regardless of number of exclusive left-turn and/or right-turn lanes that exist on the approach in addition to the shared left-turn/right-turn lane and regardless of whether or not there are pedestrian or opposing vehicular movements that conflict with the left-turn or right-turn movements. However, if there is an opposing approach and the signal phasing protects the left-turn movement on the approach with the shared left-turn/right-turn lane from conflicts with the opposing vehicular movements and any signalized pedestrian movements, a left-turn GREEN ARROW signal indication shall also be included in the left-most signal face and shall be displayed simultaneously with the CIRCULAR GREEN signal indication.

B. If the approach has one or more exclusive turn lanes in addition to the shared left-turn/right-turn lane and there is no conflict with a signalized vehicular or pedestrian movement, and GREEN ARROW signal indications are used in place of CIRCULAR GREEN signal indications on the approach, the signal faces for the approach shall be:

1. A signal face(s) capable of displaying CIRCULAR RED, YELLOW ARROW, and GREEN ARROW signal indications for the exclusive turn lane(s), with the arrows pointing in the direction of the turn, and

2. A shared left-turn/right-turn signal face capable of displaying CIRCULAR RED, left-turn YELLOW ARROW, left-turn GREEN ARROW, right-turn YELLOW ARROW, and right-turn GREEN ARROW signal indications, in an arrangement of signal sections that complies with the provisions of Section 4D.09 or 4D.10.

C. If the approach has one or more exclusive turn lanes in addition to the shared left-turn/right-turn lane and there is a conflict with a signalized vehicular or pedestrian movement, and flashing YELLOW ARROW signal indications are used in place of CIRCULAR GREEN signal indications

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.**

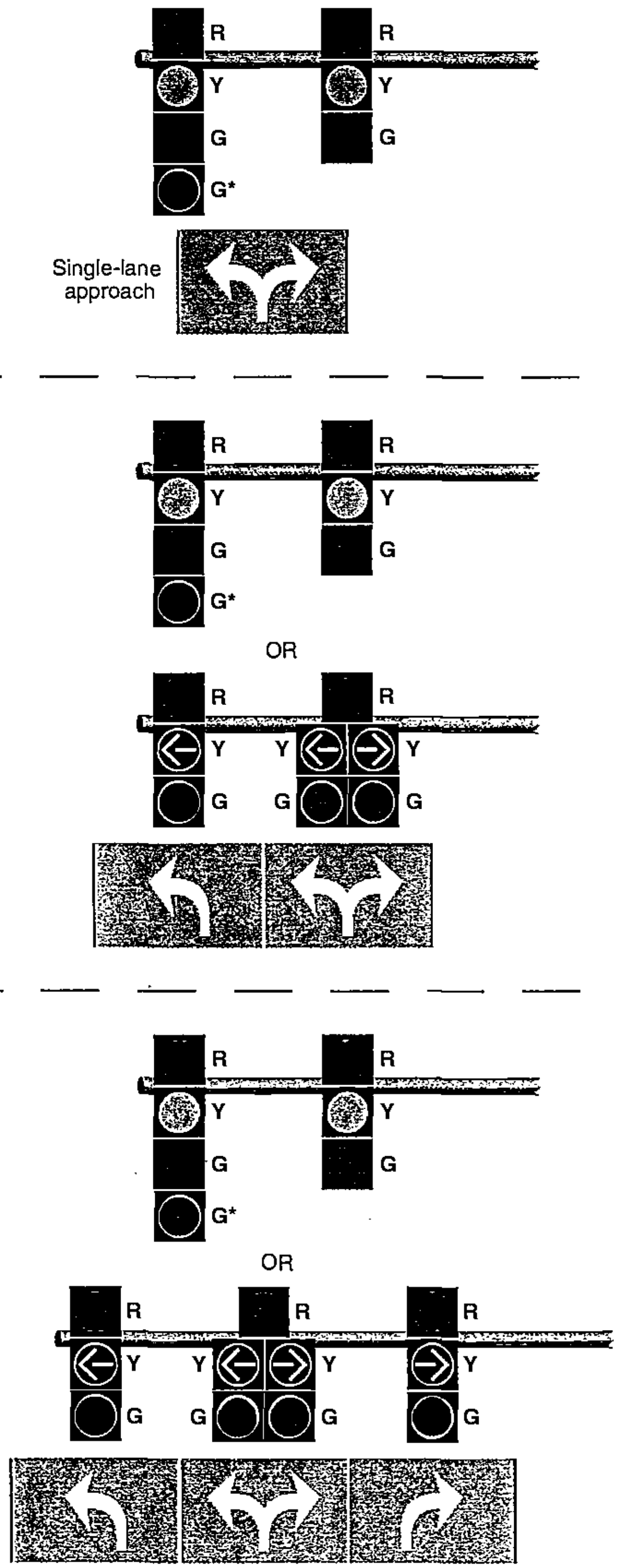
Option:

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



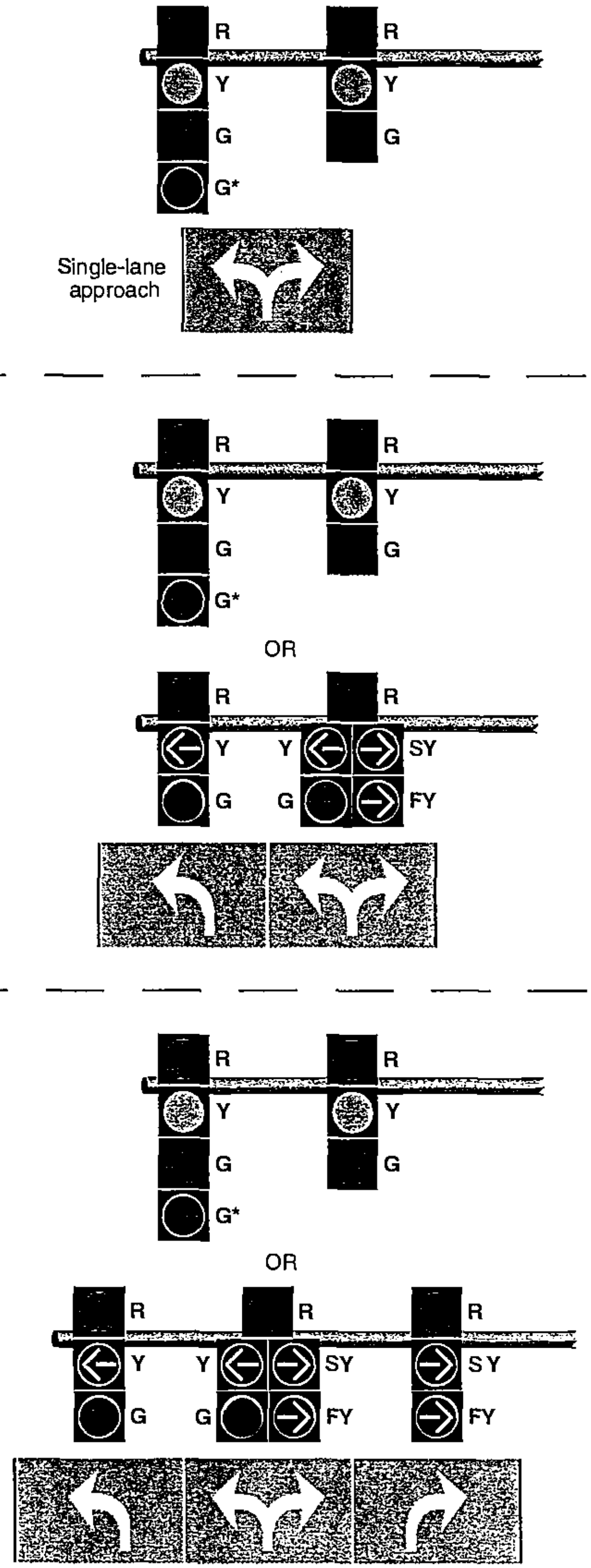
* Left-turn GREEN ARROW section shall be included if there is an opposing one-way approach and the signal phasing eliminates conflicts.

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



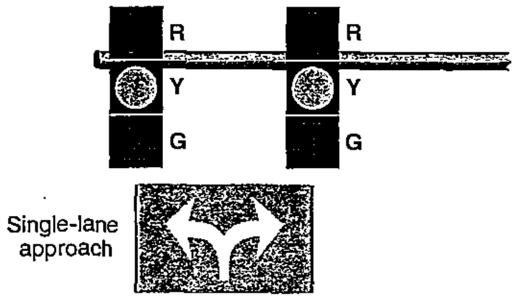
* Left-turn GREEN ARROW section shall be included if there is an opposing one-way approach and the signal phasing eliminates conflicts.

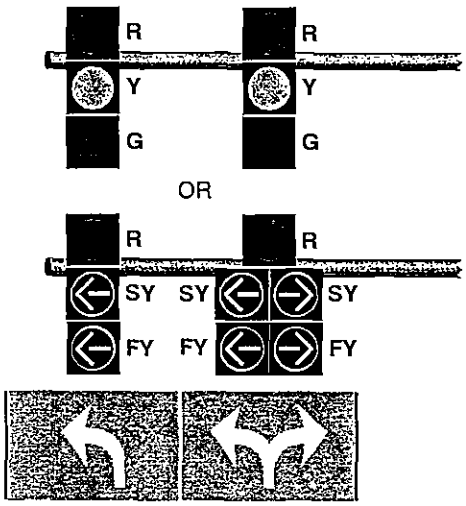
Notes:

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)

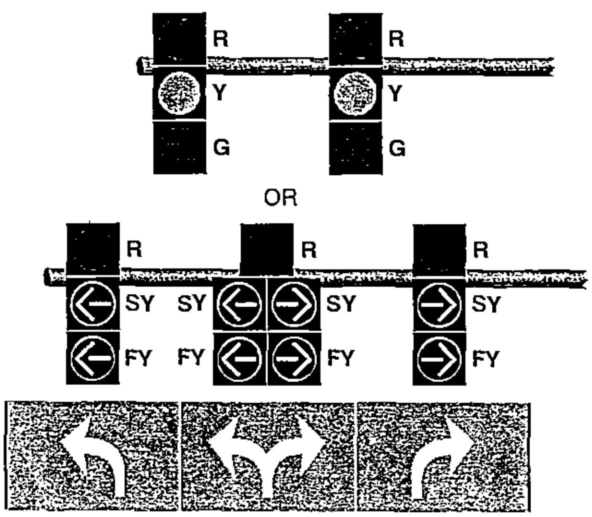
C - Pedestrian or vehicular conflicts with both turn movements





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.



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.

09 **During preemption control and during the transition out of preemption control:**

A. The shortening or omission of any yellow change interval, and of any red clearance interval that follows, shall not be permitted.

B. A signal indication sequence from a steady yellow signal indication to a green signal indication shall not be permitted.

10 **During priority control and during the transition into or out of priority control:**

A. The shortening or omission of any yellow change interval, and of any red clearance interval that follows, shall not be permitted.

B. The shortening of any pedestrian walk interval below that time described in Section 4E.06 shall not be permitted.

C. The omission of a pedestrian walk interval and its associated change interval shall not be permitted unless the associated vehicular phase is also omitted or the pedestrian phase is exclusive.

D. The shortening or omission of any pedestrian change interval shall not be permitted.

E. A signal indication sequence from a steady yellow signal indication to a green signal indication shall not be permitted.

Guidance:

11 *Except for traffic control signals interconnected with light rail transit systems, traffic control signals with railroad preemption or coordinated with flashing-light signal systems should be provided with a back-up power supply.*

12 *When a traffic control signal that is returning to a steady mode from a dark mode (typically upon restoration from a power failure) receives a preemption or priority request, care should be exercised to minimize the possibility of vehicles or pedestrians being misdirected into a conflict with the vehicle making the request.*

Option:

13 During the change from a dark mode to a steady mode under a preemption or priority request, the display of signal indications that could misdirect road users may be prevented by one or more of the following methods:

A. Having the traffic control signal remain in the dark mode,

B. Having the traffic control signal remain in the flashing mode,

C. Altering the flashing mode,

D. Executing the normal start-up routine before responding, or

E. Responding directly to initial or dwell period.

Guidance:

14 *If a traffic control signal is installed near or within a grade crossing or if a grade crossing with active traffic control devices is within or near a signalized highway intersection, Chapter 8C should be consulted.*

15 *Traffic control signals operating under preemption control or under priority control should be operated in a manner designed to keep traffic moving.*

16 *Traffic control signals that are designed to respond under preemption or priority control to more than one type or class of vehicle should be designed to respond in the relative order of importance or difficulty in stopping the type or class of vehicle. The order of priority should be: train, boat, heavy vehicle (fire vehicle, emergency medical service), light vehicle (law enforcement), light rail transit, rubber-tired transit.*

Option:

17 A distinctive indication may be provided at the intersection to show that an emergency vehicle has been given control of the traffic control signal (see Section 11-106 of the "Uniform Vehicle Code"). In order to assist in the understanding of the control of the traffic signal, a common distinctive indication may be used where drivers from different agencies travel through the same intersection when responding to emergencies.

18 If engineering judgment indicates that light rail transit signal indications would reduce road user confusion that might otherwise occur if standard traffic signal indications were used to control these movements, light rail transit signal indications complying with Section 8C.11 and as illustrated in Figure 8C-3 may be used for preemption or priority control of the following exclusive movements at signalized intersections:

A. Public transit buses in "queue jumper" lanes, and

B. Bus rapid transit in semi-exclusive or mixed-use alignments.

Section 4D.28 Flashing Operation of Traffic Control Signals – General

Standard:

01 **The light source of a flashing signal indication shall be flashed continuously at a rate of not less than 50 or more than 60 times per minute.**

02 **The displayed period of each flash shall be a minimum of 1/2 and a maximum of 2/3 of the total flash cycle.**

03 **Flashing signal indications shall comply with the requirements of other Sections of this Manual regarding visibility-limiting or positioning of conflicting signal indications, except that flashing yellow signal indications for through traffic shall not be required to be visibility-limited or positioned to minimize visual conflict for road users in separately controlled turn lanes.**

04 **Each traffic control signal shall be provided with an independent flasher mechanism that operates in compliance with this Section.**

05 **The flashing operation shall not be terminated by removal or turn off of the controller unit or of the conflict monitor (malfunction management unit) or both.**

06 **A manual switch, a conflict monitor (malfunction management unit) circuit, and, if appropriate, automatic means shall be provided to initiate the flashing mode.**

Option:

07 Based on engineering study or engineering judgment, traffic control signals may be operated in the flashing mode on a scheduled basis during one or more periods of the day rather than operated continuously in the steady (stop-and-go) mode.

Support:

08 Sections 4E.06 and 4E.09 contain information regarding the operation of pedestrian signal heads and accessible pedestrian signal detector pushbutton locator tones, respectively, during flashing operation.

Section 4D.29 Flashing Operation – Transition Into Flashing Mode

Standard:

01 **The transition from steady (stop-and-go) mode to flashing mode, if initiated by a conflict monitor (malfunction management unit) or by a manual switch, shall be permitted to be made at any time.**

02 **Programmed changes from steady (stop-and-go) mode to flashing mode shall be made under either of the following circumstances:**

A. At the end of the common major-street red interval (such as just prior to the start of the green in both directions on the major street), or

B. Directly from a CIRCULAR GREEN signal indication to a flashing CIRCULAR YELLOW signal indication, or from a GREEN ARROW signal indication to a flashing YELLOW ARROW signal indication, or from a flashing YELLOW ARROW signal indication (see Sections 4D.17 to 4D.24) to a flashing YELLOW ARROW signal indication in a different signal section.

03 **During programmed changes into flashing mode, no green signal indication or flashing yellow signal indication shall be terminated and immediately followed by a steady red or flashing red signal indication without first displaying the steady yellow signal indication.**

Section 4D.30 Flashing Operation – Signal Indications During Flashing Mode

Guidance:

01 *When a traffic control signal is operated in the flashing mode, a flashing yellow signal indication should be used for the major street and a flashing red signal indication should be used for the other approaches unless flashing red signal indications are used on all approaches.*

Standard:

02 **When a traffic control signal is operated in the flashing mode, all of the green signal indications at the signalized location shall be dark (non-illuminated) and shall not be displayed in either a steady or flashing manner, except for single-section GREEN ARROW signal indications as provided elsewhere in this Section.**

03 **Flashing yellow signal indications shall be used on more than one approach to a signalized location only if those approaches do not conflict with each other.**

04 **Except as provided in Paragraph 5, when a traffic control signal is operated in the flashing mode, one and only one signal indication in every signal face at the signalized location shall be flashed.**

Option:

05 If a signal face has two identical CIRCULAR RED or RED ARROW signal indications (see Section 4D.08), both of those identical signal indications may be flashed simultaneously.

Standard:

06 **No steady indications, other than a single-section signal face consisting of a continuously-displayed GREEN ARROW signal indication that is used alone to indicate a continuous movement in the steady (stop-and-go) mode, shall be displayed at the signalized location during the flashing mode. A single-section GREEN ARROW signal indication shall remain continuously-displayed when the traffic control signal is operated in the flashing mode.**

07 **If a signal face includes both circular and arrow signal indications of the color that is to be flashed, only the circular signal indication shall be flashed.**

08 **All signal faces that are flashed on an approach shall flash the same color, either yellow or red, except that separate turn signal faces (see Sections 4D.17 and 4D.21) shall be permitted to flash a RED ARROW signal indication when the adjacent through movement signal indications are flashed yellow. Shared signal faces (see Sections 4D.17 and 4D.21) for turn movements shall not be permitted to flash a CIRCULAR RED signal indication when the adjacent through movement signal indications are flashed yellow.**

09 **The appropriate RED ARROW or YELLOW ARROW signal indication shall be flashed when a signal face consists entirely of arrow indications. A signal face that consists entirely of arrow indications and that provides a protected only turn movement during the steady (stop-and-go) mode or that provides a flashing yellow arrow or flashing red arrow signal indication for a permissive turn movement during the steady (stop-and-go) mode shall be permitted to flash the YELLOW ARROW signal indication during the flashing mode if the adjacent through movement signal indications are flashed yellow and if it is intended that a permissive turn movement not requiring a full stop by each turning vehicle be provided during the flashing mode.**

Section 4D.31 Flashing Operation – Transition Out of Flashing Mode

Standard:

01 **All changes from flashing mode to steady (stop-and-go) mode shall be made under one of the following procedures:**

A. Yellow-red flashing mode: Changes from flashing mode to steady (stop-and-go) mode shall be made at the beginning of the major-street green interval (when a green signal indication is displayed to through traffic in both directions on the major street), or if there is no common major-street green interval, at the beginning of the green interval for the major traffic movement on the major street.

B. Red-red flashing mode: Changes from flashing mode to steady (stop-and-go) mode shall be made by changing the flashing red indications to steady red indications followed by appropriate green indications to begin the steady mode cycle. These green indications shall be the beginning of the major-street green interval (when a green signal indication is displayed to through traffic in both directions on the major street) or if there is no common major-street green interval, at the beginning of the green interval for the major traffic movement on the major street.

Guidance:

02 *The steady red clearance interval provided during the change from red-red flashing mode to steady (stop-and-go) mode should have a duration of 6 seconds.*

03 *When changing from the yellow-red flashing mode to steady (stop-and-go) mode, if there is no common major-street green interval, the provision of a steady red clearance interval for the other approaches before changing from a flashing yellow or a flashing red signal indication to a green signal indication on the major approach should be considered.*

Standard:

04 **During programmed changes out of flashing mode, no flashing yellow signal indication shall be terminated and immediately followed by a steady red or flashing red signal indication without first displaying the steady yellow signal indication.**

Option:

05 Because special midblock signals that rest in flashing circular yellow in the position normally occupied by the green signal indication do not have a green signal indication in the signal face, these signals may go directly from flashing circular yellow (in the position normally occupied by the green signal indication) to steady yellow without going first to a green signal indication.

Section 4D.32 Temporary and Portable Traffic Control Signals

Support:

01 A temporary traffic control signal is generally installed using methods that minimize the costs of installation, relocation, and/or removal. Typical temporary traffic control signals are for specific purposes, such as for one-lane, two-way facilities in temporary traffic control zones (see Chapter 4H), for a haul-road intersection, or for access to a site that will have a permanent access point developed at another location in the near future.

Standard:

02 **Advance signing shall be used when employing a temporary traffic control signal.**

03 **A temporary traffic control signal shall:**

- **A. Meet the physical display and operational requirements of a conventional traffic control signal.**
- **B. Be removed when no longer needed.**
- **C. Be placed in the flashing mode when not being used if it will be operated in the steady mode within 5 working days; otherwise, it shall be removed.**
- **D. Be placed in the flashing mode during periods when it is not desirable to operate the signal, or the signal heads shall be covered, turned, or taken down to indicate that the signal is not in operation.**

Guidance:

04 *A temporary traffic control signal should be used only if engineering judgment indicates that installing the signal will improve the overall safety and/or operation of the location.*

05 *The use of temporary traffic control signals by a work crew on a regular basis in their work area should be subject to the approval of the jurisdiction having authority over the roadway.*

06 *A temporary traffic control signal should not operate longer than 30 days unless associated with a longer-term temporary traffic control zone project.*

07 *For use of temporary traffic control signals in temporary traffic control zones, reference should be made to Section 6F.84.*

Section 4D.33 Lateral Offset of Signal Supports and Cabinets

Guidance:

01 *The following items should be considered when placing signal supports and cabinets:*

- *A. Reference should be made to the American Association of State Highway and Transportation Officials (AASHTO) "Roadside Design Guide" (see Section 1A.11) and to the "Americans with Disabilities Act Accessibility Guidelines for Buildings and Facilities (ADAAG)" (see Section 1A.11).*
- *B. Signal supports should be placed as far as practical from the edge of the traveled way without adversely affecting the visibility of the signal indications.*
- *C. Where supports cannot be located based on the recommended AASHTO clearances, consideration should be given to the use of appropriate safety devices.*
- *D. No part of a concrete base for a signal support should extend more than 4 inches above the ground level at any point. This limitation does not apply to the concrete base for a rigid support.*
- *E. In order to minimize hindrance to the passage of persons with physical disabilities, a signal support or controller cabinet should not obstruct the sidewalk, or access from the sidewalk to the crosswalk.*
- *F. Controller cabinets should be located as far as practical from the edge of the roadway.*
- *G. On medians, the minimum clearances provided in Items A through E for signal supports should be obtained if practical.*

Section 4D.34 Use of Signs at Signalized Locations

Support:

01 Traffic signal signs are sometimes used at highway traffic signal locations to instruct or guide pedestrians, bicyclists, or motorists. Among the signs typically used at or on the approaches to signalized locations are movement prohibition signs (see Section 2B.18), lane control signs (see Sections 2B.19 to 2B.22), pedestrian crossing signs (see Section 2B.51), pedestrian actuation signs (see Section 2B.52), traffic signal signs (see Sections 2B.53 and 2C.48), Signal Ahead warning signs (see Section 2C.36), Street Name signs (see Section 2D.43), and Advance Street Name signs (see Section 2D.44).

Guidance:

02 *Regulatory, warning, and guide signs should be used at traffic control signal locations as provided in Part 2 and as specifically provided elsewhere in Part 4.*

03 *Traffic signal signs should be located adjacent to the signal face to which they apply.*

Support:

04 Section 2B.19 contains information regarding the use of overhead lane control signs on signalized approaches where lane drops, multiple-lane turns involving shared through-and-turn lanes, or other lane-use regulations that would be unexpected by unfamiliar road users are present.

Standard:

05 **If used, illuminated traffic signal signs shall be designed and mounted in such a manner as to avoid glare and reflections that seriously detract from the signal indications. Traffic control signal faces shall be given dominant position and brightness to maximize their priority in the overall display.**

06 **The minimum vertical clearance and horizontal offset of the total assembly of traffic signal signs (see Section 2B.53) shall comply with the provisions of Sections 4D.15 and 4D.16.**

07 **STOP signs shall not be used in conjunction with any traffic control signal operation, except in either of the following cases:**

A. If the signal indication for an approach is a flashing red at all times, or

B. If a minor street or driveway is located within or adjacent to the area controlled by the traffic control signal, but does not require separate traffic signal control because an extremely low potential for conflict exists.

Section 4D.35 Use of Pavement Markings at Signalized Locations

Support:

01 Pavement markings (see Part 3) that clearly communicate the operational plan of an intersection to road users play an important role in the effective operation of traffic control signals. By designating the number of lanes, the use of each lane, the length of additional lanes on the approach to an intersection, and the proper stopping points, the engineer can design the signal phasing and timing to best match the goals of the operational plan.

Guidance:

02 *Pavement markings should be used at traffic control signal locations as provided in Part 3. If the road surface will not retain pavement markings, signs should be installed to provide the needed road user information.*

CHAPTER 4E. PEDESTRIAN CONTROL FEATURES

Section 4E.01 Pedestrian Signal Heads

Support:

01 Pedestrian signal heads provide special types of traffic signal indications exclusively intended for controlling pedestrian traffic. These signal indications consist of the illuminated symbols of a WALKING PERSON (symbolizing WALK) and an UPRAISED HAND (symbolizing DONT WALK).

Guidance:

02 *Engineering judgment should determine the need for separate pedestrian signal heads (see Section 4D.03) and accessible pedestrian signals (see Section 4E.09).*

Support:

03 Chapter 4F contains information regarding the use of pedestrian hybrid beacons and Chapter 4N contains information regarding the use of In-Roadway Warning Lights at unsignalized marked crosswalks.

Section 4E.02 Meaning of Pedestrian Signal Head Indications

Standard:

01 **Pedestrian signal head indications shall have the following meanings:**

A. A steady WALKING PERSON (symbolizing WALK) signal indication means that a pedestrian facing the signal indication is permitted to start to cross the roadway in the direction of the signal indication, possibly in conflict with turning vehicles. The pedestrian shall yield the rigbt-of-way to vehicles lawfully within tbe intersection at the time tbat the WALKING PERSON (symbolizing WALK) signal indication is first shown.

B. A flashing UPRAISED HAND (symbolizing DONT WALK) signal indication means that a pedestrian shall not start to cross the roadway in the direction of the signal indication, but tbat any pedestrian who has already started to cross on a steady WALKING PERSON (symbolizing WALK) signal indication shall proceed to the far side of the traveled way of the street or higbway, unless otherwise directed by a traffic control device to proceed only to the median of a divided bighway or only to some otber island or pedestrian refuge area.

C. A steady UPRAISED HAND (symbolizing DONT WALK) signal indication means that a pedestrian shall not enter the roadway in the direction of the signal indication.

D. A flashing WALKING PERSON (symbolizing WALK) signal indication has no meaning and shall not be used.

Section 4E.03 Application of Pedestrian Signal Heads

Standard:

01 **Pedestrian signal heads shall be used in conjunction with vehicular traffic control signals under any of the following conditions:**

A. If a traffic control signal is justified by an engineering study and meets either Warrant 4, Pedestrian Volume or Warrant 5, School Crossing (see Chapter 4C);

B. If an exclusive signal phase is provided or made available for pedestrian movements in one or more directions, with all conflicting vehicular movements being stopped;

C. At an established school crossing at any signalized location; or

D. Where engineering judgment determines that multi-phase signal indications (as with split-pbase timing) would tend to confuse or cause conflicts with pedestrians using a crosswalk guided only by vehicular signal indications.

Guidance:

02 *Pedestrian signal heads should be used under any of the following conditions:*

A. If it is necessary to assist pedestrians in deciding when to begin crossing the roadway in the chosen direction or if engineering judgment determines that pedestrian signal heads are justified to minimize vehicle-pedestrian conflicts;

B. If pedestrians are permitted to cross a portion of a street, such as to or from a median of sufficient width for pedestrians to wait, during a particular interval but are not permitted to cross the remainder of the street during any part of the same interval; and/or

C. If no vehicular signal indications are visible to pedestrians, or if the vehicular signal indications that are visible to pedestrians starting a crossing provide insufficient guidance for them to decide when to begin crossing the roadway in the chosen direction, such as on one-way streets, at T-intersections, or at multi-phase signal operations.

Option:

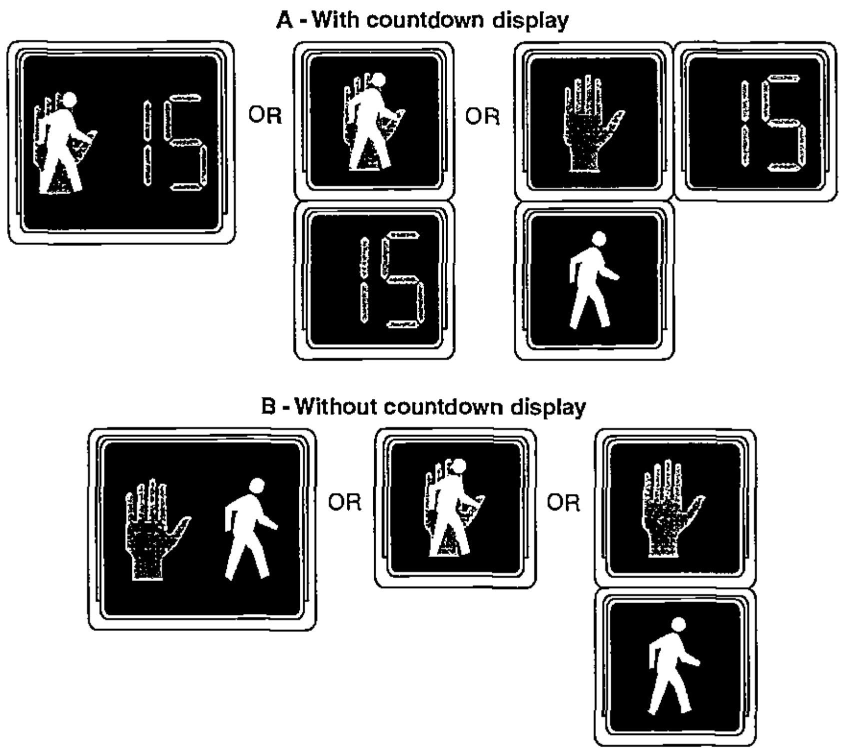
03 Pedestrian signal heads may be used under other conditions based on engineering judgment.

Section 4E.04 Size, Design, and Illumination of Pedestrian Signal Head Indications

Standard:

01 All new pedestrian signal head indications shall be displayed within a rectangular background and shall consist of symbolized messages (see Figure 4E-1), except that existing pedestrian signal head indications with lettered or outline style symbol messages shall be permitted to be retained for the remainder of their useful service life. The symbol designs that are set forth in the "Standard Highway Signs and Markings" book (see Section 1A.11) shall be used. Each pedestrian signal head indication shall be independently displayed and emit a single color.

Figure 4E-1. Typical Pedestrian Signal Indications



02 If a two-section pedestrian signal head is used, the UPRAISED HAND (symbolizing DONT WALK) signal section shall be mounted directly above the WALKING PERSON (symbolizing WALK) signal section. If a one-section pedestrian signal head is used, the symbols shall be either overlaid upon each other or arranged side-by-side with the UPRAISED HAND symbol to the left of the WALKING PERSON symbol, and a light source that can display each symbol independently shall be used.

03 The WALKING PERSON (symbolizing WALK) signal indication shall be white, conforming to the publication entitled "Pedestrian Traffic Control Signal Indications" (see Section 1A.11), with all except the symbol obscured by an opaque material.

04 The UPRAISED HAND (symbolizing DONT WALK) signal indication shall be Portland orange, conforming to the publication entitled "Pedestrian Traffic Control Signal Indications" (see Section 1A.11), with all except the symbol obscured by an opaque material.

05 When not illuminated, the WALKING PERSON (symbolizing WALK) and UPRAISED HAND (symbolizing DONT WALK) symbols shall not be readily visible to pedestrians at the far end of the crosswalk that the pedestrian signal head indications control.

06 For pedestrian signal head indications, the symbols shall be at least 6 inches high.

07 The light source of a flashing UPRAISED HAND (symbolizing DONT WALK) signal indication shall be flashed continuously at a rate of not less than 50 or more than 60 times per minute. The displayed period of each flash shall be a minimum of 1/2 and a maximum of 2/3 of the total flash cycle.

Guidance:

08 *Pedestrian signal head indications should be conspicuous and recognizable to pedestrians at all distances from the beginning of the controlled crosswalk to a point 10 feet from the end of the controlled crosswalk during both day and night.*

09 *For crosswalks where the pedestrian enters the crosswalk more than 100 feet from the pedestrian signal head indications, the symbols should be at least 9 inches high.*

10 *If the pedestrian signal indication is so bright that it causes excessive glare in nighttime conditions, some form of automatic dimming should be used to reduce the brilliance of the signal indication.*

Option:

11 An animated eyes symbol may be added to a pedestrian signal head in order to prompt pedestrians to look for vehicles in the intersection during the time that the WALKING PERSON (symbolizing WALK) signal indication is displayed.

Standard:

12 **If used, the animated eyes symbol shall consist of an outline of a pair of white steadily-illuminated eyes with white eyeballs that scan from side to side at a rate of approximately once per second. The animated eyes symbol shall be at least 12 inches wide with each eye having a width of at least 5 inches and a height of at least 2.5 inches. The animated eyes symbol shall be illuminated at the start of the walk interval and shall terminate at the end of the walk interval.**

Section 4E.05 <u>Location and Height of Pedestrian Signal Heads</u>

Standard:

01 **Pedestrian signal heads shall be mounted with the bottom of the signal housing including brackets not less than 7 feet or more than 10 feet above sidewalk level, and shall be positioned and adjusted to provide maximum visibility at the beginning of the controlled crosswalk.**

02 **If pedestrian signal heads are mounted on the same support as vehicular signal heads, there shall be a physical separation between them.**

Section 4E.06 <u>Pedestrian Intervals and Signal Phases</u>

Standard:

01 **At intersections equipped with pedestrian signal heads, the pedestrian signal indications shall be displayed except when the vehicular traffic control signal is being operated in the flashing mode. At those times, the pedestrian signal indications shall not be displayed.**

02 **When the pedestrian signal heads associated with a crosswalk are displaying either a steady WALKING PERSON (symbolizing WALK) or a flashing UPRAISED HAND (symbolizing DONT WALK) signal indication, a steady or a flashing red signal indication shall be shown to any conflicting vehicular movement that is approaching the intersection or midblock location perpendicular or nearly perpendicular to the crosswalk.**

03 **When pedestrian signal heads are used, a WALKING PERSON (symbolizing WALK) signal indication shall be displayed only when pedestrians are permitted to leave the curb or shoulder.**

04 **A pedestrian change interval consisting of a flashing UPRAISED HAND (symbolizing DONT WALK) signal indication shall begin immediately following the WALKING PERSON (symbolizing WALK) signal indication. Following the pedestrian change interval, a buffer interval consisting of a steady UPRAISED HAND (symbolizing DONT WALK) signal indication shall be displayed for at least 3 seconds prior to the release of any conflicting vehicular movement. The sum of the time of the pedestrian change interval and the buffer interval shall not be less than the calculated pedestrian clearance time (see Paragraphs 7 through 16). The buffer interval shall not begin later than the beginning of the red clearance interval, if used.**

Option:

05 During the yellow change interval, the UPRAISED HAND (symbolizing DON'T WALK) signal indication may be displayed as either a flashing indication, a steady indication, or a flashing indication for an initial portion of the yellow change interval and a steady indication for the remainder of the interval.

Support:

06 Figure 4E-2 illustrates the pedestrian intervals and their possible relationships with associated vehicular signal phase intervals.

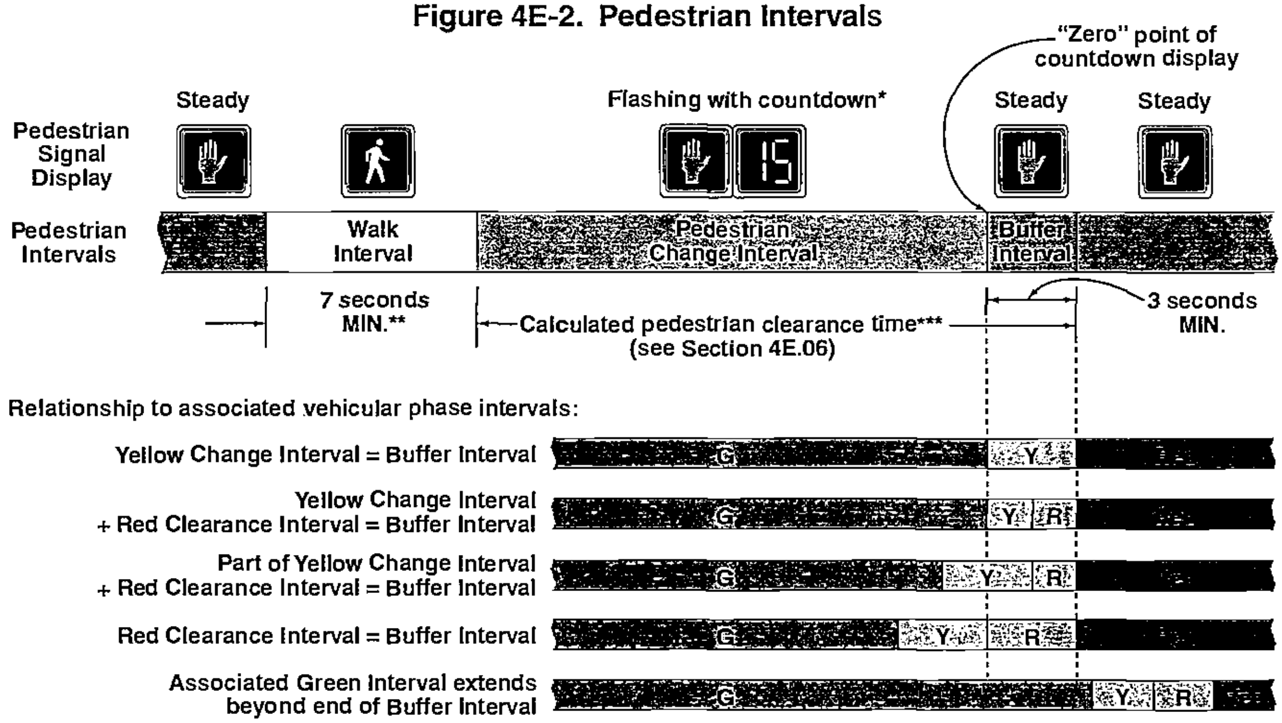
Guidance:

07 *Except as provided in Paragraph 8, the pedestrian clearance time should be sufficient to allow a pedestrian crossing in the crosswalk who left the curb or shoulder at the end of the WALKING PERSON (symbolizing WALK) signal indication to travel at a walking speed of 3.5 feet per second to at least the far side of the traveled way or to a median of sufficient width for pedestrians to wait.*

Option:

08 A walking speed of up to 4 feet per second may be used to evaluate the sufficiency of the pedestrian clearance time at locations where an extended pushbutton press function has been installed to provide slower pedestrians an opportunity to request and receive a longer pedestrian clearance time. Passive pedestrian detection may also be used to automatically adjust the pedestrian clearance time based on the pedestrian's actual walking speed or actual clearance of the crosswalk.

Figure 4E-2. Pedestrian Intervals



* The countdown display is optional for Pedestrian Change Intervals of 7 seconds or less.

** The Walk Interval may be reduced under some conditions (see Section 4E.06).

*** The Buffer Interval, which shall always be provided and displayed, may be used to help satisfy the calculated pedestrian clearance time, or may begin after the calculated pedestrian clearance time has ended.

Legend

G = Green Interval
Y = Yellow Change Interval (of at least 3 seconds)
R = Red Clearance Interval
Red = Red because conflicting traffic has been released

09 The additional time provided by an extended pushbutton press to satisfy pedestrian clearance time needs may be added to either the walk interval or the pedestrian change interval.

Guidance:

10 *Where pedestrians who walk slower than 3.5 feet per second, or pedestrians who use wheelchairs, routinely use the crosswalk, a walking speed of less than 3.5 feet per second should be considered in determining the pedestrian clearance time.*

11 *Except as provided in Paragraph 12, the walk interval should be at least 7 seconds in length so that pedestrians will have adequate opportunity to leave the curb or shoulder before the pedestrian clearance time begins.*

Option:

12 If pedestrian volumes and characteristics do not require a 7-second walk interval, walk intervals as short as 4 seconds may be used.

Support:

13 The walk interval is intended for pedestrians to start their crossing. The pedestrian clearance time is intended to allow pedestrians who started crossing during the walk interval to complete their crossing. Longer walk intervals are often used when the duration of the vehicular green phase associated with the pedestrian crossing is long enough to allow it.

Guidance:

14 *The total of the walk interval and pedestrian clearance time should be sufficient to allow a pedestrian crossing in the crosswalk who left the pedestrian detector (or, if no pedestrian detector is present, a location 6 feet from the face of the curb or from the edge of the pavement) at the beginning of the WALKING PERSON (symbolizing WALK) signal indication to travel at a walking speed of 3 feet per second to the far side of the traveled way being crossed or to the median if a two-stage pedestrian crossing sequence is used. Any additional time that is required to satisfy the conditions of this paragraph should be added to the walk interval.*

Option:

15 On a street with a median of sufficient width for pedestrians to wait, a pedestrian clearance time that allows the pedestrian to cross only from the curb or shoulder to the median may be provided.

Standard:

16 **Where the pedestrian clearance time is sufficient only for crossing from the curb or shoulder to a median of sufficient width for pedestrians to wait, median-mounted pedestrian signals (with pedestrian detectors if actuated operation is used) shall be provided (see Sections 4E.08 and 4E.09) and signing such as the R10-3d sign (see Section 2B.52) shall be provided to notify pedestrians to cross only to the median to await the next WALKING PERSON (symbolizing WALK) signal indication.**

Guidance:

17 *Where median-mounted pedestrian signals and detectors are provided, the use of accessible pedestrian signals (see Sections 4E.09 through 4E.13) should be considered.*

Option:

18 During the transition into preemption, the walk interval and the pedestrian change interval may be shortened or omitted as described in Section 4D.27.

19 At intersections with high pedestrian volumes and high conflicting turning vehicle volumes, a brief leading pedestrian interval, during which an advance WALKING PERSON (symbolizing WALK) indication is displayed for the crosswalk while red indications continue to be displayed to parallel through and/or turning traffic, may be used to reduce conflicts between pedestrians and turning vehicles.

Guidance:

20 *If a leading pedestrian interval is used, the use of accessible pedestrian signals (see Sections 4E.09 through 4E.13) should be considered.*

Support:

21 If a leading pedestrian interval is used without accessible features, pedestrians who are visually impaired can be expected to begin crossing at the onset of the vehicular movement when drivers are not expecting them to begin crossing.

Guidance:

22 *If a leading pedestrian interval is used, it should be at least 3 seconds in duration and should be timed to allow pedestrians to cross at least one lane of traffic or, in the case of a large corner radius, to travel far enough for pedestrians to establish their position ahead of the turning traffic before the turning traffic is released.*

23 *If a leading pedestrian interval is used, consideration should be given to prohibiting turns across the crosswalk during the leading pedestrian interval.*

Support:

24 At intersections with pedestrian volumes that are so high that drivers have difficulty finding an opportunity to turn across the crosswalk, the duration of the green interval for a parallel concurrent vehicular movement is sometimes intentionally set to extend beyond the pedestrian clearance time to provide turning drivers additional green time to make their turns while the pedestrian signal head is displaying a steady UPRAISED HAND (symbolizing DONT WALK) signal indication after pedestrians have had time to complete their crossings.

Section 4E.07 Countdown Pedestrian Signals

Standard:

01 **All pedestrian signal heads used at crosswalks where the pedestrian change interval is more than 7 seconds shall include a pedestrian change interval countdown display in order to inform pedestrians of the number of seconds remaining in the pedestrian change interval.**

Option:

02 Pedestrian signal heads used at crosswalks where the pedestrian change interval is 7 seconds or less may include a pedestrian change interval countdown display in order to inform pedestrians of the number of seconds remaining in the pedestrian change interval.

Standard:

03 **Where countdown pedestrian signals are used, the countdown shall always be displayed simultaneously with the flashing UPRAISED HAND (symbolizing DONT WALK) signal indication displayed for that crosswalk.**

04 **Countdown pedestrian signals shall consist of Portland orange numbers that are at least 6 inches in height on a black opaque background. The countdown pedestrian signal shall be located immediately adjacent to the associated UPRAISED HAND (symbolizing DONT WALK) pedestrian signal head indication (see Figure 4E-1).**

05 **The display of the number of remaining seconds shall begin only at the beginning of the pedestrian change interval (flashing UPRAISED HAND). After the countdown displays zero, the display shall remain dark until the beginning of the next countdown.**

06 **The countdown pedestrian signal shall display the number of seconds remaining until the termination of the pedestrian change interval (flashing UPRAISED HAND). Countdown displays shall not be used during the walk interval or during the red clearance interval of a concurrent vehicular phase.**

Guidance:

07 *If used with a pedestrian signal head that does not have a concurrent vehicular phase, the pedestrian change interval (flashing UPRAISED HAND) should be set to be approximately 4 seconds less than the required pedestrian clearance time (see Section 4E.06) and an additional clearance interval (during which a steady UPRAISED HAND is displayed) should be provided prior to the start of the conflicting vehicular phase.*

08 *For crosswalks where the pedestrian enters the crosswalk more than 100 feet from the countdown pedestrian signal display, the numbers should be at least 9 inches in height.*

09 *Because some technology includes the countdown pedestrian signal logic in a separate timing device that is independent of the timing in the traffic signal controller, care should be exercised by the engineer when timing changes are made to pedestrian change intervals.*

10 *If the pedestrian change interval is interrupted or shortened as a part of a transition into a preemption sequence (see Section 4E.06), the countdown pedestrian signal display should be discontinued and go dark immediately upon activation of the preemption transition.*

Section 4E.08 Pedestrian Detectors

Option:

01 Pedestrian detectors may be pushbuttons or passive detection devices.

Support:

02 Passive detection devices register the presence of a pedestrian in a position indicative of a desire to cross, without requiring the pedestrian to push a button. Some passive detection devices are capable of tracking the progress of a pedestrian as the pedestrian crosses the roadway for the purpose of extending or shortening the duration of certain pedestrian timing intervals.

03 The provisions in this Section place pedestrian pushbuttons within easy reach of pedestrians who are intending to cross each crosswalk and make it obvious which pushbutton is associated with each crosswalk. These provisions also position pushbutton poles in optimal locations for installation of accessible pedestrian signals (see Sections 4E.09 through 4E.13). Information regarding reach ranges can be found in the "Americans with Disabilities Act Accessibility Guidelines for Buildings and Facilities (ADAAG)" (see Section 1A.11).

Guidance:

04 *If pedestrian pushbuttons are used, they should be capable of easy activation and conveniently located near each end of the crosswalks. Except as provided in Paragraphs 5 and 6, pedestrian pushbuttons should be located to meet all of the following criteria (see Figure 4E-3):*

- A. *Unobstructed and adjacent to a level all-weather surface to provide access from a wheelchair;*
- B. *Where there is an all-weather surface, a wheelchair accessible route from the pushbutton to the ramp;*
- C. *Between the edge of the crosswalk line (extended) farthest from the center of the intersection and the side of a curb ramp (if present), but not greater than 5 feet from said crosswalk line;*
- D. *Between 1.5 and 6 feet from the edge of the curb, shoulder, or pavement;*
- E. *With the face of the pushbutton parallel to the crosswalk to be used; and*
- F. *At a mounting height of approximately 3.5 feet, but no more than 4 feet, above the sidewalk.*

05 *Where there are physical constraints that make it impractical to place the pedestrian pushbutton adjacent to a level all-weather surface, the surface should be as level as feasible.*

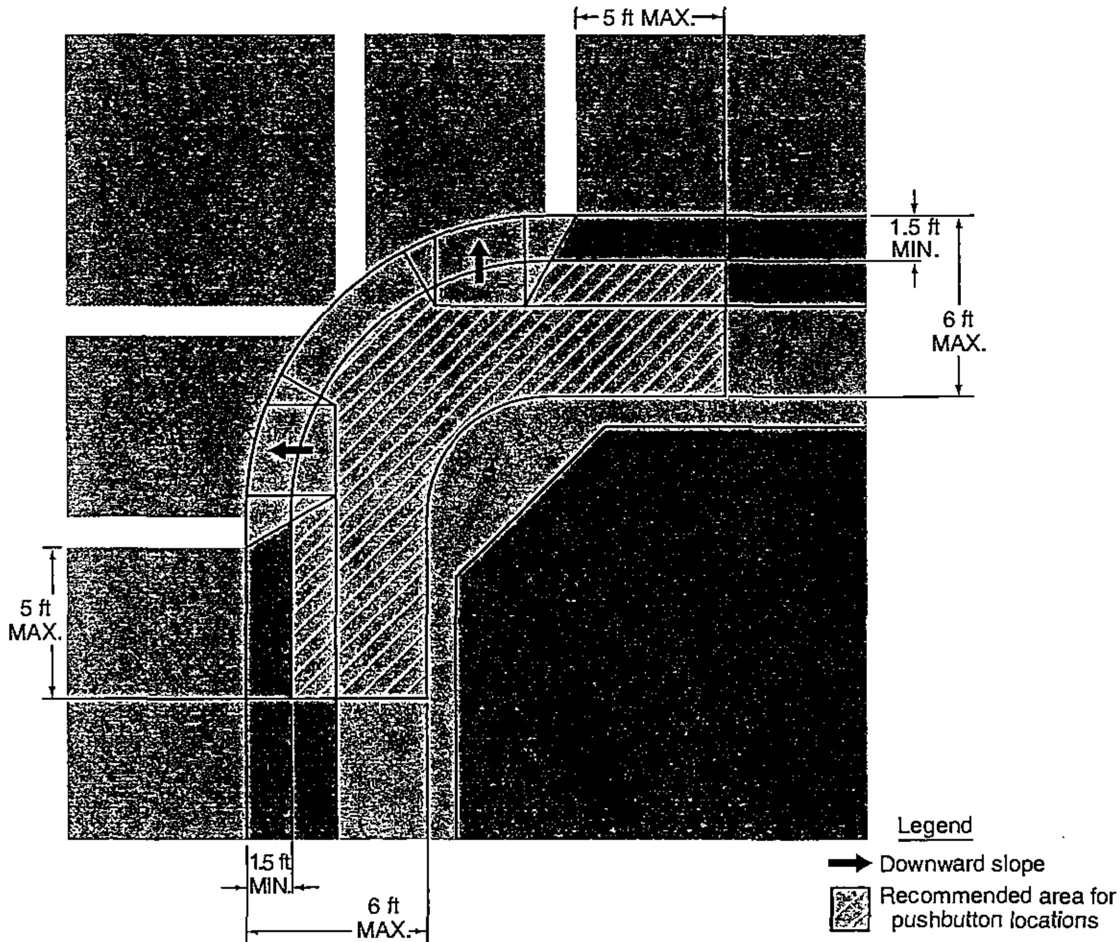
06 *Where there are physical constraints that make it impractical to place the pedestrian pushbutton between 1.5 and 6 feet from the edge of the curb, shoulder, or pavement, it should not be farther than 10 feet from the edge of curb, shoulder, or pavement.*

07 *Except as provided in Paragraph 8, where two pedestrian pushbuttons are provided on the same corner of a signalized location, the pushbuttons should be separated by a distance of at least 10 feet.*

Option:

08 Where there are physical constraints on a particular corner that make it impractical to provide the 10-foot separation between the two pedestrian pushbuttons, the pushbuttons may be placed closer together or on the same pole.

Figure 4E-3. Pushbutton Location Area



Notes:

1. Where there are constraints that make it impractical to place the pedestrian pushbutton between 1.5 feet and 6 feet from the edge of the curb, shoulder, or pavement, it should not be further than 10 feet from the edge of curb, shoulder, or pavement.
2. Two pedestrian pushbuttons on a corner should be separated by 10 feet.
3. This figure is not drawn to scale.
4. Figure 4E-4 shows typical pushbutton locations.

Support:

09 Figure 4E-4 shows typical pedestrian pushbutton locations for a variety of situations.

Standard:

10 **Signs (see Section 2B.52) shall be mounted adjacent to or integral with pedestrian pushbuttons, explaining their purpose and use.**

Option:

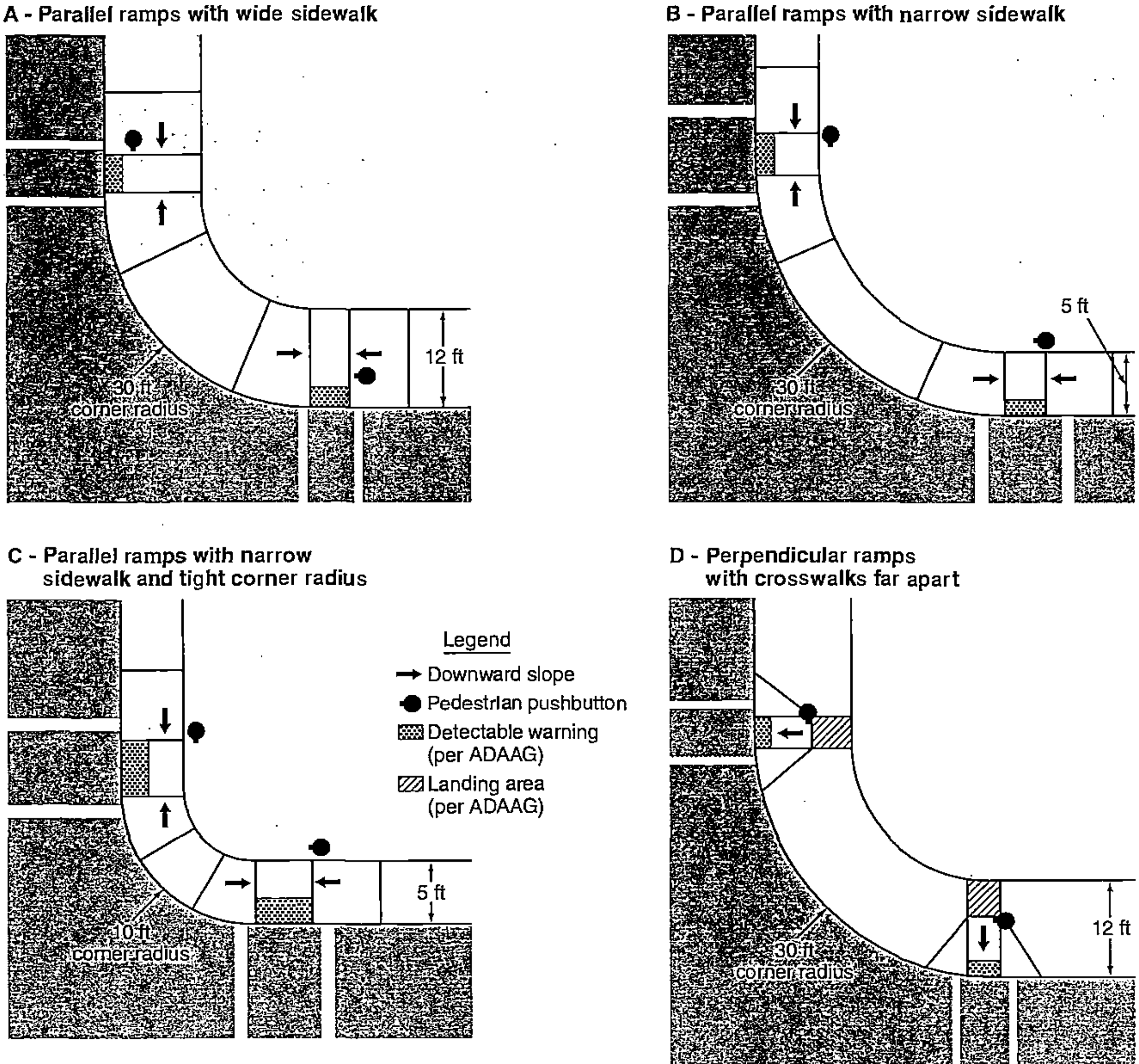
11 At certain locations, a supplemental sign in a more visible location may be used to call attention to the pedestrian pushbutton.

Standard:

12 **The positioning of pedestrian pusbbuttons and the legends on the pedestrian pushbutton signs shall clearly indicate which crosswalk signal is actuated by each pedestrian pushbutton.**

13 **If tbe pedestrian clearance time is sufficient only to cross from the curb or shoulder to a median of sufficient width for pedestrians to wait and the signals are pedestrian actuated, an additional pedestrian detector sball be provided in the median.**

Figure 4E-4. Typical Pushbutton Locations (Sheet 1 of 2)



Notes:

1. This figure is not drawn to scale.
2. These drawings are intended to describe the typical locations for pedestrian pushbutton installations. They are not intended to be a guide for the design of curb cut ramps.
3. Figure 4E-3 shows the recommended area for pushbutton locations.

Guidance:

14 *The use of additional pedestrian detectors on islands or medians where a pedestrian might become stranded should be considered.*

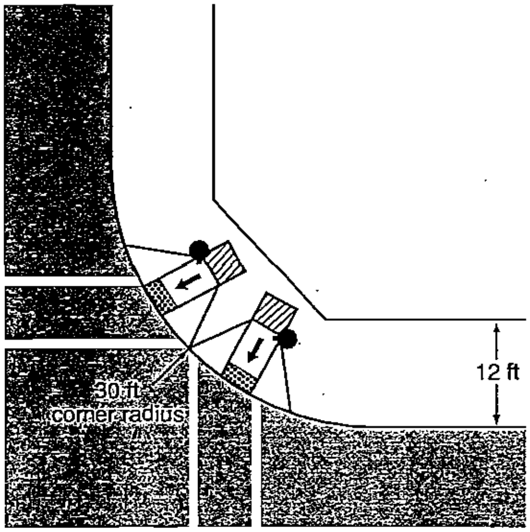
15 *If used, special purpose pushbuttons (to be operated only by authorized persons) should include a housing capable of being locked to prevent access by the general public and do not need an instructional sign.*

Standard:

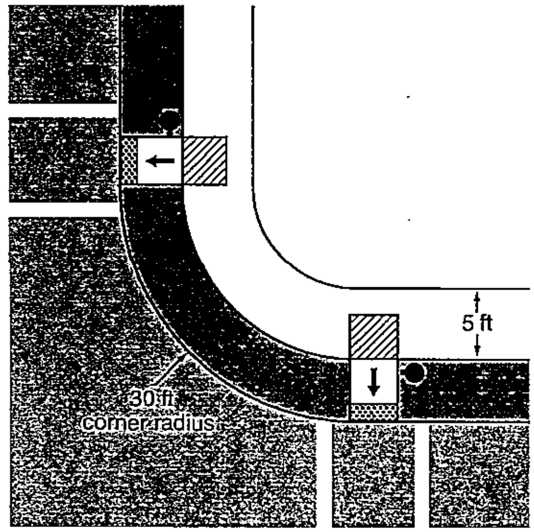
16 **If used, a pilot light or other means of indication installed with a pedestrian pushbutton shall not be illuminated until actuation. Once it is actuated, the pilot light shall remain illuminated until the pedestrian's green or WALKING PERSON (symbolizing WALK) signal indication is displayed.**

Figure 4E-4. Typical Pushbutton Locations (Sheet 2 of 2)

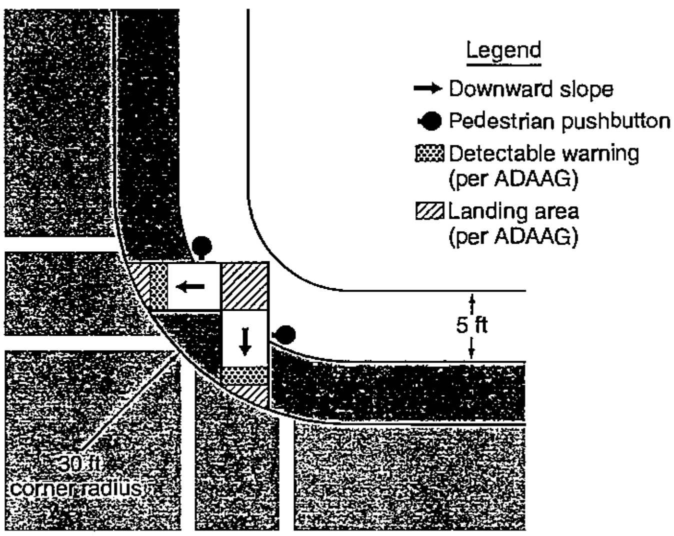
E - Perpendicular ramps with crosswalks close together



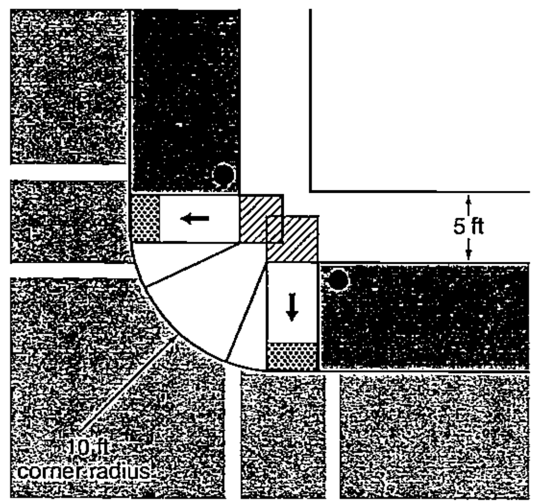
F - Perpendicular ramps with sidewalk set back from road with crosswalks far apart



G - Perpendicular ramps with sidewalk set back from road with crosswalks close together



H - Perpendicular ramps with sidewalk set back from road with continuous sidewalk between ramps



Notes:

1. This figure is not drawn to scale.
2. Tese drawings are intended to describe the typical locations for pedestrian pushbutton installations. They are not intended to be a guide for the design of curb cut ramps.
3. Figure 4E-3 shows the recommended area for pushbutton locations.

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17 **If a pilot light is used at an accessible pedestrian signal location (see Sections 4E.09 through 4E.13), each actuation shall be accompanied by the speech message "wait."**

Option:

18 At signalized locations with a demonstrated need and subject to equipment capabilities, pedestrians with special needs may be provided with additional crossing time by means of an extended pushbutton press.

Standard:

19 **If additional crossing time is provided by means of an extended pushbutton press, a PUSH BUTTON FOR 2 SECONDS FOR EXTRA CROSSING TIME (R10-32P) plaque (see Figure 2B-26) shall be mounted adjacent to or integral with the pedestrian pushbutton.**

Section 4E.09 Accessible Pedestrian Signals and Detectors – General

Support:

01 Accessible pedestrian signals and detectors provide information in non-visual formats (such as audible tones, speech messages, and/or vibrating surfaces).

02 The primary technique that pedestrians who have visual disabilities use to cross streets at signalized locations is to initiate their crossing when they hear the traffic in front of them stop and the traffic alongside them begin to move, which often corresponds to the onset of the green interval. The existing environment is often not sufficient to provide the information that pedestrians who have visual disabilities need to cross a roadway at a signalized location.

Guidance:

03 *If a particular signalized location presents difficulties for pedestrians who have visual disabilities to cross the roadway, an engineering study should be conducted that considers the needs of pedestrians in general, as well as the information needs of pedestrians with visual disabilities. The engineering study should consider the following factors:*

A. Potential demand for accessible pedestrian signals;
B. A request for accessible pedestrian signals;
C. Traffic volumes during times when pedestrians might be present, including periods of low traffic volumes or high turn-on-red volumes;
D. The complexity of traffic signal phasing (such as split phases, protected turn phases, leading pedestrian intervals, and exclusive pedestrian phases); and
E. The complexity of intersection geometry.

Support:

04 The factors that make crossing at a signalized location difficult for pedestrians who have visual disabilities include: increasingly quiet cars, right turn on red (which masks the beginning of the through phase), continuous right-turn movements, complex signal operations, traffic circles, and wide streets. Furthermore, low traffic volumes might make it difficult for pedestrians who have visual disabilities to discern signal phase changes.

05 Local organizations, providing support services to pedestrians who have visual and/or hearing disabilities, can often act as important advisors to the traffic engineer when consideration is being given to the installation of devices to assist such pedestrians. Additionally, orientation and mobility specialists or similar staff also might be able to provide a wide range of advice. The U.S. Access Board (www.access-board.gov) provides technical assistance for making pedestrian signal information available to persons with visual disabilities (see Page i for the address for the U.S. Access Board).

Standard:

06 **When used, accessible pedestrian signals shall be used in combination with pedestrian signal timing. The information provided by an accessible pedestrian signal shall clearly indicate which pedestrian crossing is served by each device.**

07 **Under stop-and-go operation, accessible pedestrian signals shall not be limited in operation by the time of day or day of week.**

Option:

08 Accessible pedestrian signal detectors may be pushbuttons or passive detection devices.

09 At locations with pretimed traffic control signals or non-actuated approaches, pedestrian pushbuttons may be used to activate the accessible pedestrian signals.

Support:

10 Accessible pedestrian signals are typically integrated into the pedestrian detector (pushbutton), so the audible tones and/or messages come from the pushbutton housing. They have a pushbutton locator tone and tactile arrow, and can include audible beaconing and other special features.

Option:

11 The name of the street to be crossed may also be provided in accessible format, such as Braille or raised print. Tactile maps of crosswalks may also be provided.

Support:

12 Specifications regarding the use of Braille or raised print for traffic control devices can be found in the "Americans with Disabilities Act Accessibility Guidelines for Buildings and Facilities (ADAAG)" (see Section 1A.11).

Standard:

13 **At accessible pedestrian signal locations where pedestrian pushbuttons are used, each pushbutton shall activate both the walk interval and the accessible pedestrian signals.**

Section 4E.10 Accessible Pedestrian Signals and Detectors – Location

Support:

01 Accessible pedestrian signals that are located as close as possible to pedestrians waiting to cross the street provide the clearest and least ambiguous indication of which pedestrian crossing is served by a device.

Guidance:

02 *Pushbuttons for accessible pedestrian signals should be located in accordance with the provisions of Section 4E.08 and should be located as close as possible to the crosswalk line furthest from the center of the intersection and as close as possible to the curb ramp.*

Standard:

03 **If two accessible pedestrian pushbuttons are placed less than 10 feet apart or on the same pole, each accessible pedestrian pushbutton shall be provided with the following features (see Sections 4E.11 through 4E.13):**

- **A. A pushbutton locator tone,**
- **B. A tactile arrow,**
- **C. A speech walk message for the WALKING PERSON (symbolizing WALK) indication, and**
- **D. A speech pushbutton information message.**

04 **If the pedestrian clearance time is sufficient only to cross from the curb or shoulder to a median of sufficient width for pedestrians to wait and accessible pedestrian detectors are used, an additional accessible pedestrian detector shall be provided in the median.**

Section 4E.11 Accessible Pedestrian Signals and Detectors – Walk Indications

Support:

01 Technology that provides different sounds for each non-concurrent signal phase has frequently been found to provide ambiguous information. Research indicates that a rapid tick tone for each crossing coming from accessible pedestrian signal devices on separated poles located close to each crosswalk provides unambiguous information to pedestrians who are blind or visually impaired. Vibrotactile indications provide information to pedestrians who are blind and deaf and are also used by pedestrians who are blind or who have low vision to confirm the walk signal in noisy situations.

Standard:

02 **Accessible pedestrian signals shall have both audible and vibrotactile walk indications.**

03 **Vibrotactile walk indications shall be provided by a tactile arrow on the pushbutton (see Section 4E.12) that vibrates during the walk interval.**

04 **Accessible pedestrian signals shall have an audible walk indication during the walk interval only. The audible walk indication shall be audible from the beginning of the associated crosswalk.**

05 **The accessible walk indication shall have the same duration as the pedestrian walk signal except when the pedestrian signal rests in walk.**

Guidance:

06 *If the pedestrian signal rests in walk, the accessible walk indication should be limited to the first 7 seconds of the walk interval. The accessible walk indication should be recalled by a button press during the walk interval provided that the crossing time remaining is greater than the pedestrian change interval.*

Standard:

07 **Where two accessible pedestrian signals are separated by a distance of at least 10 feet, the audible walk indication shall be a percussive tone. Where two accessible pedestrian signals on one corner are not separated by a distance of at least 10 feet, the audible walk indication shall be a speech walk message.**

08 **Audible tone walk indications shall repeat at eight to ten ticks per second. Audible tones used as walk indications shall consist of multiple frequencies with a dominant component at 880 Hz.**

Guidance:

09 *The volume of audible walk indications and pushbutton locator tones (see Section 4E.12) should be set to be a maximum of 5 dBA louder than ambient sound, except when audible beaconing is provided in response to an extended pushbutton press.*

Standard:

10 **Automatic volume adjustment in response to ambient traffic sound level shall be provided up to a maximum volume of 100 dBA.**

Guidance:

11 *The sound level of audible walk indications and pushbutton locator tones should be adjusted to be low enough to avoid misleading pedestrians who have visual disabilities when the following conditions exist:*

A. Where there is an island that allows unsignalized right turns across a crosswalk between the island and the sidewalk.

B. Where multi-leg approaches or complex signal phasing require more than two pedestrian phases, such that it might be unclear which crosswalk is served by each audible tone.

C. At intersections where a diagonal pedestrian crossing is allowed, or where one street receives a WALKING PERSON (symbolizing WALK) signal indication simultaneously with another street.

Option:

12 An alert tone, which is a very brief burst of high-frequency sound at the beginning of the audible walk indication that rapidly decays to the frequency of the walk tone, may be used to alert pedestrians to the beginning of the walk interval.

Support:

13 An alert tone can be particularly useful if the walk tone is not easily audible in some traffic conditions.

14 Speech walk messages communicate to pedestrians which street has the walk interval. Speech messages might be either directly audible or transmitted, requiring a personal receiver to hear the message. To be a useful system, the words and their meaning need to be correctly understood by all users in the context of the street environment where they are used. Because of this, tones are the preferred means of providing audible walk indications except where two accessible pedestrian signals on one corner are not separated by a distance of at least 10 feet.

15 If speech walk messages are used, pedestrians have to know the names of the streets that they are crossing in order for the speech walk messages to be unambiguous. In getting directions to travel to a new location, pedestrians with visual disabilities do not always get the name of each street to be crossed. Therefore, it is desirable to give users of accessible pedestrian signals the name of the street controlled by the pushbutton. This can be done by means of a speech pushbutton information message (see Section 4D.13) during the flashing or steady UPRAISED HAND intervals, or by raised print and Braille labels on the pushbutton housing.

16 By combining the information from the pushbutton message or Braille label, the tactile arrow aligned in the direction of travel on the relevant crosswalk, and the speech walk message, pedestrians with visual disabilities are able to correctly respond to speech walk messages even if there are two pushbuttons on the same pole.

Standard:

17 **If speech walk messages are used to communicate the walk interval, they shall provide a clear message that the walk interval is in effect, as well as to which crossing it applies. Speech walk messages shall be used only at intersections where it is technically infeasible to install two accessible pedestrian signals at one corner separated by a distance of at least 10 feet.**

18 **Speech walk messages that are used at intersections having pedestrian phasing that is concurrent with vehicular phasing shall be patterned after the model: "Broadway. Walk sign is on to cross Broadway."**

19 **Speech walk messages that are used at intersections having exclusive pedestrian phasing shall be patterned after the model: "Walk sign is on for all crossings."**

20 **Speech walk messages shall not contain any additional information, except they shall include designations such as "Street" or "Avenue" where this information is necessary to avoid ambiguity at a particular location.**

Guidance:

21 *Speech walk messages should not state or imply a command to the pedestrian, such as "Cross Broadway now." Speech walk messages should not tell pedestrians that it is "safe to cross," because it is always the pedestrian's responsibility to check actual traffic conditions.*

Standard:

22 **A speech walk message is not required at times when the walk interval is not timing, but, if provided:**

A. It shall begin with the term "wait."

B. It need not be repeated for the entire time that the walk interval is not timing.

23 **If a pilot light (see Section 4E.08) is used at an accessible pedestrian signal location, each actuation shall be accompanied by the speech message "wait."**

Option:

24 Accessible pedestrian signals that provide speech walk messages may provide similar messages in languages other than English, if needed, except for the terms "walk sign" and "wait."

Standard:

25 **Following the audible walk indication, accessible pedestrian signals shall revert to the pushbutton locator tone (see Section 4E.12) during the pedestrian change interval.**

Section 4E.12 Accessible Pedestrian Signals and Detectors – Tactile Arrows and Locator Tones

Standard:

01 **To enable pedestrians who have visual disabilities to distingnish and locate the appropriate pushbutton at an accessible pedestrian signal location, pushbuttons shall clearly indicate by means of tactile arrows which crosswalk signal is actuated by each pushbutton. Tactile arrows shall be located on the pushbutton, have bigh visual contrast (light on dark or dark on light), and shall be aligned parallel to the direction of travel on the associated crosswalk.**

02 **An accessible pedestrian pushbutton shall incorporate a locator tone.**

Support:

03 A pushbutton locator tone is a repeating sound that informs approaching pedestrians that a pushbutton to actuate pedestrian timing or receive additional information exists, and that enables pedestrians with visual disabilities to locate the pushbutton.

Standard:

04 **Pushbutton locator tones shall have a duration of 0.15 seconds or less, and shall repeat at 1-second intervals.**

05 **Pushbutton locator tones shall be deactivated when the traffic control signal is operating in a flashing mode. This requirement shall not apply to traffic control signals or pedestrian bybrid beacons that are activated from a flashing or dark mode to a stop-and-go mode by pedestrian actuations.**

06 **Pushbutton locator tones shall be intensity responsive to ambient sound, and be audible 6 to 12 feet from the pushbutton, or to the building line, whichever is less.**

Support:

07 Section 4E.11 contains additional provisions regarding the volume and sound level of pushbutton locator tones.

Section 4E.13 Accessible Pedestrian Signals and Detectors – Extended Pushbutton Press Features

Option:

01 Pedestrians may be provided with additional features such as increased crossing time, audible beaconing, or a speech pushbutton information message as a result of an extended pushbutton press.

Standard:

02 **If an extended pushbutton press is used to provide any additional feature(s), a pushbutton press of less than one second shall actuate only the pedestrian timing and any associated accessible walk indication, and a pushbutton press of one second or more shall actuate the pedestrian timing, any associated accessible walk indication, and any additional feature(s).**

03 **If additional crossing time is provided by means of an extended pushbutton press, a PUSH BUTTON FOR 2 SECONDS FOR EXTRA CROSSING TIME (R10-32P) plaque (see Figure 2B-26) shall be mounted adjacent to or integral with the pedestrian pushbutton.**

Support:

04 Audible beaconing is the use of an audible signal in such a way that pedestrians with visual disabilities can home in on the signal that is located on the far end of the crosswalk as they cross the street.

05 Not all crosswalks at an intersection need audible beaconing; audible beaconing can actually cause confusion if used at all crosswalks at some intersections. Audible beaconing is not appropriate at locations with channelized turns or split phasing, because of the possibility of confusion.

Guidance:

06 *Audible beaconing should only be considered following an engineering study at:*

A. *Crosswalks longer than 70 feet, unless they are divided by a median that has another accessible pedestrian signal with a locator tone;*
B. *Crosswalks that are skewed;*
C. *Intersections with irregular geometry, such as more than four legs;*
D. *Crosswalks where audible beaconing is requested by an individual with visual disabilities; or*
E. *Other locations where a study indicates audible beaconing would be beneficial.*

Option:

07 Audible beaconing may be provided in several ways, any of which are initiated by an extended pushbutton press.

Standard:

08 **If audible beaconing is used, the volume of tbe pusbbutton locator tone during tbe pedestrian change interval of the called pedestrian phase shall be increased and operated in one of tbe following ways:**

- **A. Tbe louder audible walk indication and louder locator tone comes from the far end of the crosswalk, as pedestrians cross the street,**
- **B. Tbe louder locator tone comes from both ends of tbe crosswalk, or**
- **C. Tbe louder locator tone comes from an additional speaker tbat is aimed at tbe center of the crosswalk and that is mounted on a pedestrian signal bead.**

Option:

09 Speech pushbutton information messages may provide intersection identification, as well as information about unusual intersection signalization and geometry, such as notification regarding exclusive pedestrian phasing, leading pedestrian intervals, split phasing, diagonal crosswalks, and medians or islands.

Standard:

10 **If speech pushbutton information messages are made available by actuating tbe accessible pedestrian signal detector, they sball only be actuated when the walk interval is not timing. Tbey shall begin witb tbe term "Wait," followed by intersection identification information modeled after: "Wait to cross Broadway at Grand." If information on intersection signalization or geometry is also given, it shall follow the intersection identification information.**

Guidance:

11 *Speech pushbutton information messages should not be used to provide landmark information or to inform pedestrians with visual disabilities about detours or temporary traffic control situations.*

Support:

12 Additional information on the structure and wording of speech pushbutton information messages is included in ITE's "Electronic Toolbox for Making Intersections More Accessible for Pedestrians Who Are Blind or Visually Impaired," which is available at ITE's website (see Page i).

CHAPTER 4F. PEDESTRIAN HYBRID BEACONS

Section 4F.01 Application of Pedestrian Hybrid Beacons

Support:

01 A pedestrian hybrid beacon is a special type of hybrid beacon used to warn and control traffic at an unsignalized location to assist pedestrians in crossing a street or highway at a marked crosswalk.

Option:

02 A pedestrian hybrid beacon may be considered for installation to facilitate pedestrian crossings at a location that does not meet traffic signal warrants (see Chapter 4C), or at a location that meets traffic signal warrants under Sections 4C.05 and/or 4C.06 but a decision is made to not install a traffic control signal.

Standard:

03 **If used, pedestrian hybrid beacons shall be used in conjunction with signs and pavement markings to warn and control traffic at locations where pedestrians enter or cross a street or highway. A pedestrian hybrid beacon shall only be installed at a marked crosswalk.**

Guidance:

04 *If one of the signal warrants of Chapter 4C is met and a traffic control signal is justified by an engineering study, and if a decision is made to install a traffic control signal, it should be installed based upon the provisions of Chapters 4D and 4E.*

05 *If a traffic control signal is not justified under the signal warrants of Chapter 4C and if gaps in traffic are not adequate to permit pedestrians to cross, or if the speed for vehicles approaching on the major street is too high to permit pedestrians to cross, or if pedestrian delay is excessive, the need for a pedestrian hybrid beacon should be considered on the basis of an engineering study that considers major-street volumes, speeds, widths, and gaps in conjunction with pedestrian volumes, walking speeds, and delay.*

06 *For a major street where the posted or statutory speed limit or the 85th-percentile speed is 35 mph or less, the need for a pedestrian hybrid beacon should be considered if the engineering study finds that the plotted point representing the vehicles per hour on the major street (total of both approaches) and the corresponding total of all pedestrians crossing the major street for 1 hour (any four consecutive 15-minute periods) of an average day falls above the applicable curve in Figure 4F-1 for the length of the crosswalk.*

07 *For a major street where the posted or statutory speed limit or the 85th-percentile speed exceeds 35 mph, the need for a pedestrian hybrid beacon should be considered if the engineering study finds that the plotted point representing the vehicles per hour on the major street (total of both approaches) and the corresponding total of all pedestrians crossing the major street for 1 hour (any four consecutive 15-minute periods) of an average day falls above the applicable curve in Figure 4F-2 for the length of the crosswalk.*

08 *For crosswalks that have lengths other than the four that are specifically shown in Figures 4F-1 and 4F-2, the values should be interpolated between the curves.*

Section 4F.02 Design of Pedestrian Hybrid Beacons

Standard:

01 **Except as otherwise provided in this Section, a pedestrian hybrid beacon shall meet the provisions of Chapters 4D and 4E.**

02 **A pedestrian hybrid beacon face shall consist of three signal sections, with a CIRCULAR YELLOW signal indication centered below two horizontally aligned CIRCULAR RED signal indications (see Figure 4F-3).**

03 **When an engineering study finds that installation of a pedestrian hybrid beacon is justified, then:**

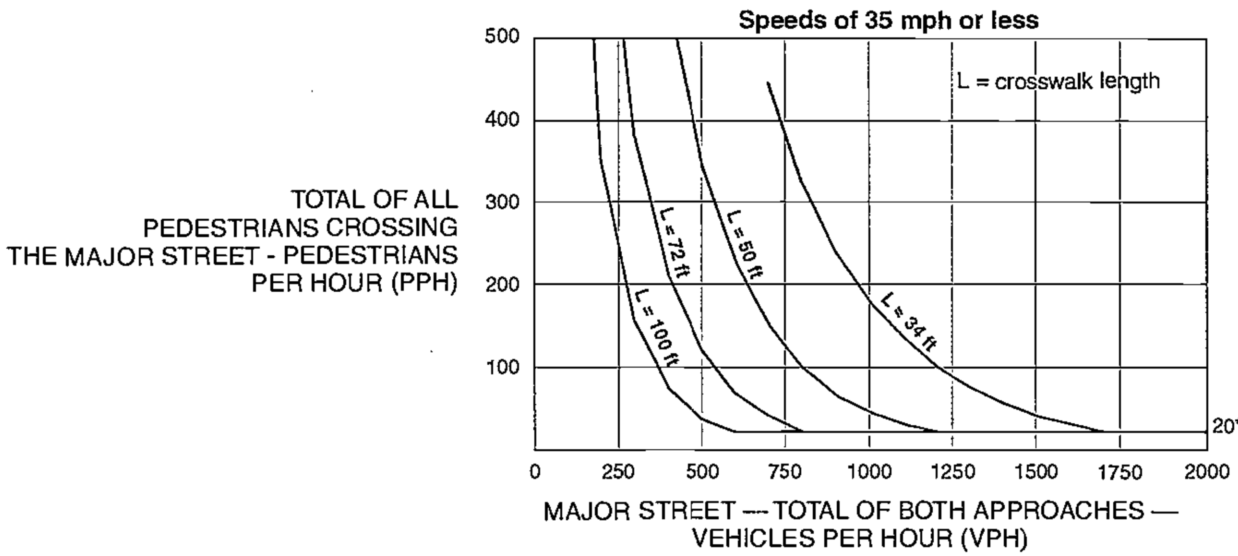
A. At least two pedestrian hybrid beacon faces shall be installed for each approach of the major street,
B. A stop line shall be installed for each approach to the crosswalk,
C. A pedestrian signal head conforming to the provisions set forth in Chapter 4E shall be installed at each end of the marked crosswalk, and
D. The pedestrian hybrid beacon shall be pedestrian actuated.

Guidance:

04 *When an engineering study finds that installation of a pedestrian hybrid beacon is justified, then:*

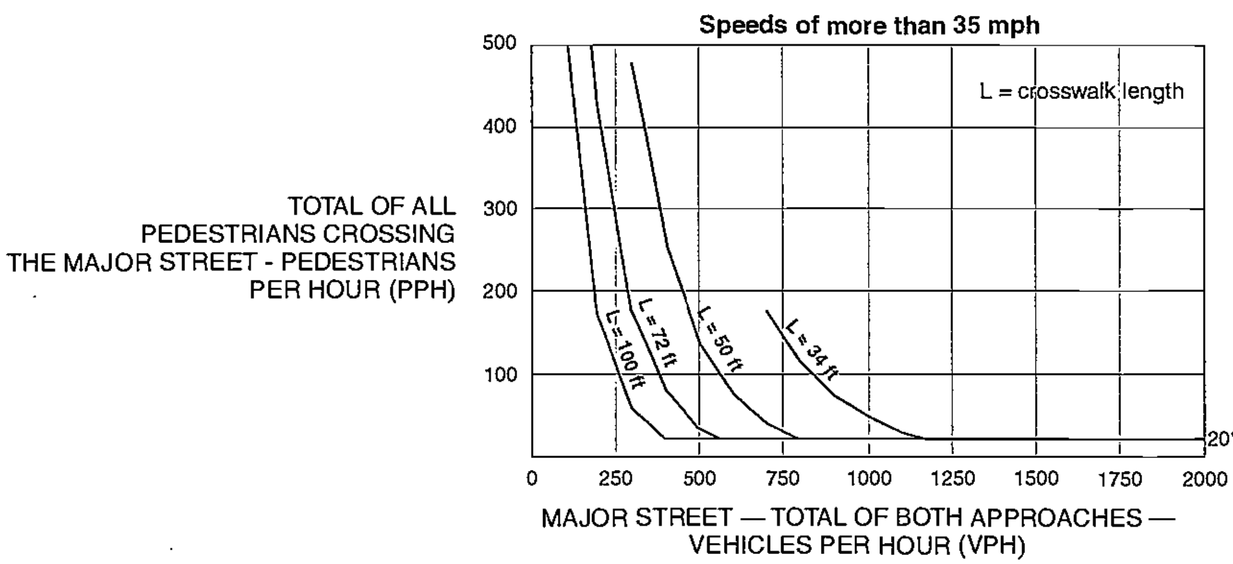
A. The pedestrian hybrid beacon should be installed at least 100 feet from side streets or driveways that are controlled by STOP or YIELD signs,

Figure 4F-1. Guidelines for the Installation of Pedestrian Hybrid Beacons on Low-Speed Roadways



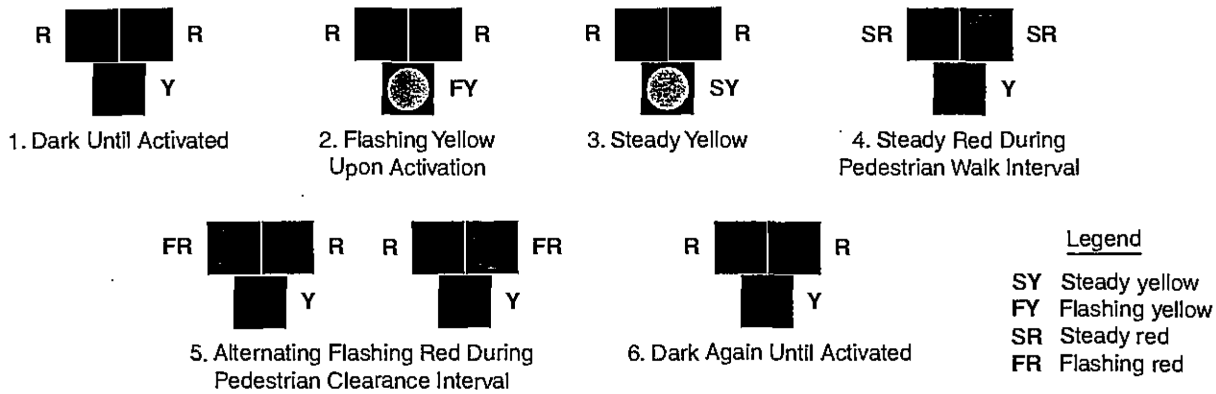
* Note: 20 pph applies as the lower threshold volume

Figure 4F-2. Guidelines for the Installation of Pedestrian Hybrid Beacons on High-Speed Roadways



* Note: 20 pph applies as the lower threshold volume

Figure 4F-3. Sequence for a Pedestrian Hybrid Beacon



B. Parking and other sight obstructions should be prohibited for at least 100 feet in advance of and at least 20 feet beyond the marked crosswalk, or site accommodations should be made through curb extensions or other techniques to provide adequate sight distance,

C. The installation should include suitable standard signs and pavement markings, and

D. If installed within a signal system, the pedestrian hybrid beacon should be coordinated.

05 *On approaches having posted or statutory speed limits or 85th-percentile speeds in excess of 35 mph and on approaches having traffic or operating conditions that would tend to obscure visibility of roadside hybrid beacon face locations, both of the minimum of two pedestrian hybrid beacon faces should be installed over the roadway.*

06 *On multi-lane approaches having a posted or statutory speed limits or 85th-percentile speeds of 35 mph or less, either a pedestrian hybrid beacon face should be installed on each side of the approach (if a median of sufficient width exists) or at least one of the pedestrian hybrid beacon faces should be installed over the roadway.*

07 *A pedestrian hybrid beacon should comply with the signal face location provisions described in Sections 4D.11 through 4D.16.*

Standard:

08 **A CROSSWALK STOP ON RED (symbolic circular red) (R10-23) sign (see Section 2B.53) shall be mounted adjacent to a pedestrian hybrid beacon face on each major street approach. If an overhead pedestrian hybrid beacon face is provided, the sign shall be mounted adjacent to the overhead signal face.**

Option:

09 A Pedestrian (W11-2) warning sign (see Section 2C.50) with an AHEAD (W16-9P) supplemental plaque may be placed in advance of a pedestrian hybrid beacon. A warning beacon may be installed to supplement the W11-2 sign.

Guidance:

10 *If a warning beacon supplements a W11-2 sign in advance of a pedestrian hybrid beacon, it should be programmed to flash only when the pedestrian hybrid beacon is not in the dark mode.*

Standard:

11 **If a warning beacon is installed to supplement the W11-2 sign, the design and location of the warning beacon shall comply with the provisions of Sections 4L.01 and 4L.03.**

Section 4F.03 Operation of Pedestrian Hybrid Beacons

Standard:

01 **Pedestrian hybrid beacon indications shall be dark (not illuminated) during periods between actuations.**

02 **Upon actuation by a pedestrian, a pedestrian hybrid beacon face shall display a flashing CIRCULAR yellow signal indication, followed by a steady CIRCULAR yellow signal indication, followed by both steady CIRCULAR RED signal indications during the pedestrian walk interval, followed by alternating flashing CIRCULAR RED signal indications during the pedestrian clearance interval (see Figure 4F-3). Upon termination of the pedestrian clearance interval, the pedestrian hybrid beacon faces shall revert to a dark (not illuminated) condition.**

03 **Except as provided in Paragrapb 4, tbe pedestrian signal beads shall continue to display a steady UPRAISED HAND (symbolizing DONT WALK) signal indication when tbe pedestrian bybrid beacon faces are either dark or displaying flashing or steady CIRCULAR yellow signal indications. Tbe pedestrian signal heads sball display a WALKING PERSON (symbolizing WALK) signal indication when the pedestrian bybrid beacon faces are displaying steady CIRCULAR RED signal indications. The pedestrian signal heads sball display a flasbing UPRAISED HAND (symbolizing DONT WALK) signal indication when the pedestrian hybrid beacon faces are displaying alternating flasbing 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.*

CHAPTER 4G. TRAFFIC CONTROL SIGNALS AND HYBRID BEACONS FOR EMERGENCY-VEHICLE ACCESS

Section 4G.01 Application of Emergency-Vehicle Traffic Control Signals and Hybrid Beacons

Support:

01 An emergency-vehicle traffic control signal is a special traffic control signal that assigns the right-of-way to an authorized emergency vehicle.

Option:

02 An emergency-vehicle traffic control signal may be installed at a location that does not meet other traffic signal warrants such as at an intersection or other location to permit direct access from a building housing the emergency vehicle.

03 An emergency-vehicle hybrid beacon may be installed instead of an emergency-vehicle traffic control signal under conditions described in Section 4G.04.

Guidance:

04 *If a traffic control signal is not justified under the signal warrants of Chapter 4C and if gaps in traffic are not adequate to permit the timely entrance of emergency vehicles, or the stopping sight distance for vehicles approaching on the major street is insufficient for emergency vehicles, installing an emergency-vehicle traffic control signal should be considered. If one of the signal warrants of Chapter 4C is met and a traffic control signal is justified by an engineering study, and if a decision is made to install a traffic control signal, it should be installed based upon the provisions of Chapter 4D.*

05 *The sight distance determination should be based on the location of the visibility obstruction for the critical approach lane for each street or drive and the posted or statutory speed limit or 85th-percentile speed on the major street, whichever is higher.*

Section 4G.02 Design of Emergency-Vehicle Traffic Control Signals

Standard:

01 **Except as otherwise provided in this Section, an emergency-vehicle traffic control signal shall meet the requirements of this Manual.**

02 **An Emergency Vehicle (W11-8) sign (see Section 2C.49) with an EMERGENCY SIGNAL AHEAD (W11-12P) supplemental plaque shall be placed in advance of all emergency-vehicle traffic control signals. If a warning beacon is installed to supplement the W11-8 sign, the design and location of the beacon shall comply with the Standards of Sections 4L.01 and 4L.03.**

Guidance:

03 *At least one of the two required signal faces for each approach on the major street should be located over the roadway.*

04 *The following size signal indications should be used for emergency-vehicle traffic control signals: 12-inch diameter for steady red and steady yellow circular signal indications and any arrow indications, and 8-inch diameter for green or flashing yellow circular signal indications.*

Standard:

05 **An EMERGENCY SIGNAL (R10-13) sign shall be mounted adjacent to a signal face on each major street approach (see Section 2B.53). If an overhead signal face is provided, the EMERGENCY SIGNAL sign shall be mounted adjacent to the overhead signal face.**

Option:

06 An approach that only serves emergency vehicles may be provided with only one signal face consisting of one or more signal sections.

07 Besides using an 8-inch diameter signal indication, other appropriate means to reduce the flashing yellow light output may be used.

Section 4G.03 Operation of Emergency-Vehicle Traffic Control Signals

Standard:

01 **Right-of-way for emergency vehicles at signalized locations operating in the steady (stop-and-go) mode shall be obtained as provided in Section 4D.27.**

02 **As a minimum, the signal indications, sequence, and manner of operation of an emergency-vehicle traffic control signal installed at a midblock location shall be as follows:**

A. **The signal indication, between emergency-vehicle actuations, shall be either green or flashing yellow. If the flashing yellow signal indication is used instead of the green signal indication, it shall be displayed in the normal position of the green signal indication, while the steady red and steady yellow signal indications shall be displayed in their normal positions.**
B. **When an emergency-vehicle actuation occurs, a steady yellow change interval followed by a steady red interval shall be displayed to traffic on the major street.**
C. **A yellow change interval is not required following the green interval for the emergency-vehicle driveway.**

03 **Emergency-vehicle traffic control signals located at intersections shall either be operated in the flashing mode between emergency-vehicle actuations (see Sections 4D.28 and 4D.30) or be full-actuated or semi-actuated to accommodate normal vehicular and pedestrian traffic on the streets.**

04 **Warning beacons, if used with an emergency-vehicle traffic control signal, shall be flashed only:**

A. **For an appropriate time in advance of and during the steady yellow change interval for the major street; and**
B. **During the steady red interval for the major street.**

Guidance:

05 *The duration of the steady red interval for traffic on the major street should be determined by on-site test-run time studies, but should not exceed 1.5 times the time required for the emergency vehicle to clear the path of conflicting vehicles.*

Option:

06 An emergency-vehicle traffic control signal sequence may be initiated manually from a local control point such as a fire station or law enforcement headquarters or from an emergency vehicle equipped for remote operation of the signal.

Section 4G.04 Emergency-Vehicle Hybrid Beacons

Standard:

01 **Emergency-vehicle hybrid beacons shall be used only in conjunction with signs to warn and control traffic at an unsignalized location where emergency vehicles enter or cross a street or highway. Emergency-vehicle hybrid beacons shall be actuated only by authorized emergency or maintenance personnel.**

Guidance:

02 *Emergency-vehicle hybrid beacons should only be used when all of the following criteria are satisfied:*

A. *The conditions justifying an emergency-vehicle traffic control signal (see Section 4G.01) are met; and*
B. *An engineering study, considering the road width, approach speeds, and other pertinent factors, determines that emergency-vehicle hybrid beacons can be designed and located in compliance with the requirements contained in this Section and in Section 4L.01, such that they effectively warn and control traffic at the location; and*
C. *The location is not at or within 100 feet from an intersection or driveway where the side road or driveway is controlled by a STOP or YIELD sign.*

Standard:

03 **Except as otherwise provided in this Section, an emergency-vehicle hybrid beacon shall meet the requirements of this Manual.**

04 **An emergency-vehicle hybrid beacon face shall consist of three signal sections, with a CIRCULAR YELLOW signal indication centered below two horizontally aligned CIRCULAR RED signal indications (see Figure 4G-1).**

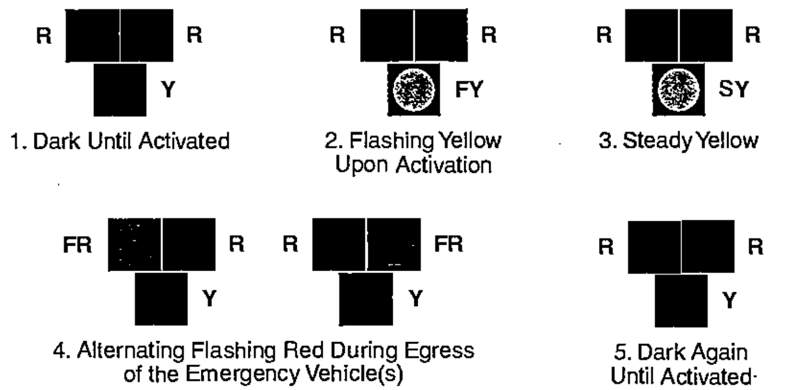
05 **Emergency-vehicle hybrid beacons shall be placed in a dark mode (no indications displayed) during periods between actuations.**

06 **Upon actuation by authorized emergency personnel, the emergency-vehicle hybrid beacon faces shall each display a flashing yellow signal indication, followed by a steady yellow change interval, prior to displaying two CIRCULAR RED signal indications in an alternating flashing array for a duration of time adequate for egress of the emergency vehicles. The alternating flashing red signal indications shall only be displayed when it is required that drivers on the major street stop and then proceed subject to the rules applicable after making a stop at a STOP sign. Upon termination of the flashing red signal indications, the emergency-vehicle hybrid beacons shall revert to a dark mode (no indications displayed) condition.**

Guidance:

07 *The duration of the flashing yellow interval should be determined by engineering judgment.*

Figure 4G-1. Sequence for an Emergency-Vehicle Hybrid Beacon



Legend

SY Steady yellow
FY Flashing yellow
FR Flashing red

Note: An optional steady red clearance interval may be used after Interval 3 and before Interval 4.

Standard:

08 **The duration of the steady yellow change interval shall be determined using engineering practices.**

Guidance:

09 *The steady yellow change 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.*

Option:

10 A steady red clearance interval may be used after the steady yellow change interval.

11 Emergency-vehicle hybrid beacons may be equipped with a light or other display visible to the operator of the egressing emergency vehicle to provide confirmation that the beacons are operating.

12 Emergency-vehicle hybrid beacons may be supplemented with an advance warning sign, which may also be supplemented with a Warning Beacon (see Section 4L.03).

Guidance:

13 *If a Warning Beacon is used to supplement the advance warning sign, it should be programmed to flash only when the emergency-vehicle hybrid beacon is not in the dark mode.*

Standard:

14 **At least two emergency-vehicle hybrid beacon faces shall be installed for each approach of the major street and a stop line shall be installed for each approach of the major street.**

Guidance:

15 *On approaches having posted or statutory speed limits or 85th-percentile speeds in excess of 40 mph, and on approaches having traffic or operating conditions that would tend to obscure visibility of roadside beacon faces, both of the minimum of two emergency-vehicle hybrid beacon faces should be installed over the roadway.*

16 *On multi-lane approaches having posted or statutory speed limits or 85th-percentile speeds of 40 mph or less, either an emergency-vehicle hybrid beacon face should be installed on each side of the approach (if a median of sufficient width exists) or at least one of the emergency-vehicle hybrid beacon faces should be installed over the roadway.*

17 *An emergency-vehicle hybrid beacon should comply with the signal face location provisions described in Sections 4D.11 through 4D.16.*

Standard:

18 **Stop lines and EMERGENCY SIGNAL—STOP WHEN FLASHING RED (R10-14 or R10-14a) signs (see Section 2B.53) shall be used with emergency-vehicle hybrid beacons.**

Option:

19 If needed for extra emphasis, a STOP HERE ON FLASHING RED (R10-14b) sign (see Section 2B.53) may be installed with an emergency-vehicle hybrid beacon.

CHAPTER 4H. TRAFFIC CONTROL SIGNALS FOR ONE-LANE, TWO-WAY FACILITIES

Section 4H.01 Application of Traffic Control Signals for One-Lane, Two-Way Facilities

Support:

01 A traffic control signal at a narrow bridge, tunnel, or roadway section is a special signal that assigns the right-of-way for vehicles passing over a bridge or through a tunnel or roadway section that is not of sufficient width for two opposing vehicles to pass.

02 Temporary traffic control signals (see Sections 4D.32 and 6F.84) are the most frequent application of one-lane, two-way facilities.

Guidance:

03 *Sight distance across or through the one-lane, two-way facility should be considered as well as the approach speed and sight distance approaching the facility when determining whether traffic control signals should be installed.*

Option:

04 At a narrow bridge, tunnel, or roadway section where a traffic control signal is not justified under the conditions of Chapter 4C, a traffic control signal may be used if gaps in opposing traffic do not permit the flow of traffic through the one-lane section of roadway.

Section 4H.02 Design of Traffic Control Signals for One-Lane, Two-Way Facilities

Standard:

01 **The provisions of Chapter 4D shall apply to traffic control signals for one-lane, two-way facilities, except that:**

A. Durations of red clearance intervals shall be adequate to clear the one-lane section of conflicting vehicles.

B. Adequate means, such as interconnection, shall be provided to prevent conflicting signal indications, such as green and green, at opposite ends of the section.

Section 4H.03 Operation of Traffic Control Signals for One-Lane, Two-Way Facilities

Standard:

01 **Traffic control signals at one-lane, two-way facilities shall operate in a manner consistent with traffic requirements.**

02 **When in the flashing mode, the signal indications shall flash red.**

Guidance:

03 *Adequate time should be provided to allow traffic to clear the narrow facility before opposing traffic is allowed to move. Engineering judgment should be used to determine the proper timing for the signal.*

CHAPTER 4I. TRAFFIC CONTROL SIGNALS FOR FREEWAY ENTRANCE RAMPS

Section 4I.01 Application of Freeway Entrance Ramp Control Signals

Support:

01 Ramp control signals are traffic control signals that control the flow of traffic entering the freeway facility. This is often referred to as "ramp metering."

02 Freeway entrance ramp control signals are sometimes used if controlling traffic entering the freeway could reduce the total expected delay to traffic in the freeway corridor, including freeway ramps and local streets.

Guidance:

03 *The installation of ramp control signals should be preceded by an engineering study of the physical and traffic conditions on the highway facilities likely to be affected. The study should include the ramps and ramp connections and the surface streets that would be affected by the ramp control, as well as the freeway section concerned.*

Support:

04 Information on conditions that might justify freeway entrance ramp control signals, factors to be evaluated in traffic engineering studies for ramp control signals, design of ramp control signals, and operation of ramp control signals can be found in the FHWA's "Ramp Management and Control Handbook" (see Section 1A.11).

Section 4I.02 Design of Freeway Entrance Ramp Control Signals

Standard:

01 **Ramp control signals shall meet all of the standard design specifications for traffic control signals, except as otherwise provided in this Section.**

02 **The signal face for freeway entrance ramp control signals shall be either a two-section signal face containing red and green signal indications or a three-section signal face containing red, yellow, and green signal indications.**

03 **If only one lane is present on an entrance ramp or if more than one lane is present on an entrance ramp and the ramp control signals are operated such that green signal indications are always displayed simultaneously to all of the lanes on the ramp, then a minimum of two signal faces per ramp shall face entering traffic.**

04 **If more than one lane is present on an entrance ramp and the ramp control signals are operated such that green signal indications are not always displayed simultaneously to all of the lanes on the ramp, then one signal face shall be provided over the approximate center of each separately-controlled lane.**

Guidance:

05 *Additional side-mounted signal faces should be considered for ramps with two or more separately-controlled lanes.*

Standard:

06 **Ramp control signals shall be located and designed to minimize their viewing by mainline freeway traffic.**

Option:

07 Ramp control signals may be placed in the dark mode (no indications displayed) when not in use.

08 Ramp control signals may be used to control some, but not all, lanes on a ramp, such as when non-metered HOV bypass lanes are provided on a ramp.

09 The required signal faces, if located at the side of the ramp roadway, may be mounted such that the height above the pavement grade at the center of the ramp roadway to the bottom of the signal housing of the lowest signal face is between 4.5 and 6 feet.

10 For entrance ramps with only one controlled lane, the two required signal faces may both be mounted at the side of the roadway on a single pole, with one face at the normal mounting height and one face mounted lower as provided in Paragraph 9, as a specific exception to the normal 8-foot minimum lateral separation of signal faces required by Section 4D.13.

Guidance:

11 *Regulatory signs with legends appropriate to the control, such as XX VEHICLE(S) PER GREEN or XX VEHICLE(S) PER GREEN EACH LANE (see Section 2B.56), should be installed adjacent to the ramp control signal faces. When ramp control signals are installed on a freeway-to-freeway ramp, special consideration should be given to assuring adequate visibility of the ramp control signals, and multiple advance warning signs with flashing warning beacons should be installed to warn road users of the metered operation.*

Section 4I.03 Operation of Freeway Entrance Ramp Control Signals

Guidance:

01 *Operational strategies for ramp control signals, such as periods of operation, metering rates and algorithms, and queue management, should be determined by the operating agency prior to the installation of the ramp control signals and should be closely monitored and adjusted as needed thereafter.*

02 *When the ramp control signals are operated only during certain periods of the day, a RAMP METERED WHEN FLASHING (W3-8) sign (see Section 2C.37) should be installed in advance of the ramp control signal near the entrance to the ramp, or on the arterial on the approach to the ramp, to alert road users to the presence and operation of ramp meters.*

Standard:

03 **The RAMP METERED WHEN FLASHING sign shall be supplemented with a warning beacon (see Section 4L.03) that flashes when the ramp control signal is in operation.**

CHAPTER 4J. TRAFFIC CONTROL FOR MOVABLE BRIDGES

Section 4J.01 Application of Traffic Control for Movable Bridges

Support:

01 Traffic control signals for movable bridges are a special type of highway traffic signal installed at movable bridges to notify road users to stop because of a road closure rather than alternately giving the right-of-way to conflicting traffic movements. The signals are operated in coordination with the opening and closing of the movable bridge, and with the operation of movable bridge warning and resistance gates, or other devices and features used to warn, control, and stop traffic.

02 Movable bridge warning gates installed at movable bridges decrease the likelihood of vehicles and pedestrians passing the stop line and entering an area where potential hazards exist because of bridge operations.

03 A movable bridge resistance gate is sometimes used at movable bridges and located downstream of the movable bridge warning gate. A movable bridge resistance gate provides a physical deterrent to road users when placed in the appropriate position. The movable bridge resistance gates are considered a design feature and not a traffic control device; requirements for them are contained in AASHTO's "Standard Specifications for Movable Highway Bridges" (see Page i for AASHTO's address).

Standard:

04 **Traffic control at movable bridges shall include both signals and gates, except in the following cases:**

- **A. Neither is required if other traffic control devices or measures considered appropriate are used under either of the following conditions:**
  - **1. On low-volume roads (roads of less than 400 vehicles average daily traffic), or**
  - **2. At manually operated bridges if electric power is not available.**
- **B. Only signals are required in urban areas if intersecting streets or driveways make gates ineffective.**
- **C. Only movable bridge warning gates are required if a traffic control signal that is controlled as part of the bridge operations exists within 500 feet of the movable bridge resistance gates and no intervening traffic entrances exist.**

Section 4J.02 Design and Location of Movable Bridge Signals and Gates

Standard:

01 **The signal faces and mountings of movable bridge signals shall comply with the provisions of Chapter 4D except as provided in this Section.**

02 **Signal faces with 12-inch diameter signal indications shall be used for all new movable bridge signals.**

Option:

03 Existing signal faces with 8-inch diameter lenses may be retained for the remainder of their useful service life.

Standard:

04 **Since movable bridge operations cover a variable range of time periods between opeuings, the signal faces shall be one of the following types:**

- **A. Three-section signal faces with red, yellow, and green signal indications; or**
- **B. Two one-section signal faces with red signal indications in a vertical array separated by a STOP HERE ON RED (R10-6) sign (see Section 2B.53).**

05 **Regardless of which signal type is selected, at least two signal faces shall be provided for each approach to the movable span and a stop line (see Section 3B.16) shall be installed to indicate the point behind which vehicles are required to stop.**

Guidance:

06 *If movable bridge operation is frequent, the use of three-section signal faces should be considered.*

07 *Insofar as practical, the height and lateral placement of signal faces should comply with the requirements for other traffic control signals in accordance with Chapter 4D. They should be located no more than 50 feet in advance of the movable bridge warning gate.*

Option:

08 Movable bridge signals may be supplemented with audible warning devices to provide additional warning to drivers and pedestrians.

Standard:

09 **A DRAW BRIDGE (W3-6) sign (see Section 2C.39) shall be used in advance of movable bridge signals and gates to give warning to road users, except in urban conditions where such signing would not be practical.**

10 **If physical conditions prevent a road user from having a continuous view of at least two signal indications for the distance specified in Table 4D-2, an auxiliary device (either a supplemental signal face or the mandatory DRAW BRIDGE (W3-6) sign to which has been added a warning beacon that is interconnected with the movable bridge controller unit) shall be provided in advance of movable bridge signals and gates.**

Option:

11 The DRAW BRIDGE (W3-6) sign may be supplemented by a Warning Beacon (see Section 4L.03).

Standard:

12 **If two sets of gates (both a warning and a resistance gate) are used for a single direction, highway traffic signals shall not be required to accompany the resistance gate nearest the span opening.**

13 **Movable bridge warning gates, if used, shall be at least standard railroad size, striped with 16-inch alternate vertical, fully reflectorized red and white stripes. Flashing red lights in accordance with the Standards for those on railroad gates (see Section 8C.04) shall be included on the gate arm and they shall only be operated if the gate is closed or in the process of being opened or closed. In the horizontal position, the top of the gate shall be approximately 4 feet above the pavement.**

Guidance:

14 *Movable bridge warning gates should be of lightweight construction. In its normal upright position, the gate arm should provide adequate lateral clearance.*

Option:

15 The movable bridge resistance gates may be delineated, if practical, in a manner similar to the movable bridge warning gate.

Standard:

16 **Movable bridge warning gates, if used, shall extend at least across the full width of the approach lanes if movable bridge resistance gates are used. On divided highways in which the roadways are separated by a barrier median, movable bridge warning gates, if used, shall extend across all roadway lanes approaching the span openings.**

Guidance:

17 *If movable bridge resistance gates are not used on undivided highways, movable bridge warning gates, if used, should extend across the full width of the roadway.*

Option:

18 A single full-width gate or two half-width gates may be used.

Support:

19 The locations of movable bridge signals and gates are determined by the location of the movable bridge resistance gate (if used) rather than by the location of the movable spans. The movable bridge resistance gates for high-speed highways are preferably located 50 feet or more from the span opening except for bascule and lift bridges, where they are often attached to, or are a part of, the structure.

Standard:

20 **Except where physical conditions make it impractical, movable bridge warning gates shall be located 100 feet or more from the movable bridge resistance gates or, if movable bridge resistance gates are not used, 100 feet or more from the movable span.**

Guidance:

21 *On bridges or causeways that cross a long reach of water and that might be hit by large marine vessels, within the limits of practicality, traffic should not be halted on a section of the bridge or causeway that is subject to impact.*

22 *In cases where it is not practical to halt traffic on a span that is not subject to impact, traffic should be halted at least one span from the opening. If traffic is halted by signals and gates more than 330 feet from the movable bridge warning gates (or from the span opening if movable bridge warning gates are not used), a second set of gates should be installed approximately 100 feet from the gate or span opening.*

23 *If the movable bridge is close to a grade crossing and traffic might possibly be stopped on the crossing as a result of the bridge opening, a traffic control device should notify the road users to not stop on the railroad tracks.*

Section 4J.03 Operation of Movable Bridge Signals and Gates

Standard:

01 **Traffic control devices at movable bridges shall be coordinated witb the movable spans, so that tbe signals, gates, and movable spans are controlled by the bridge tender tbrougb an interlocked control.**

02 **If tbe tbree-section type of signal face is used, tbe green signal indication shall be displayed at all times between bridge openings, except that if the bridge is not expected to open during continuous periods in excess of 5 hours, a flasbing yellow signal indication sball be permitted to be used. Tbe signal sball display a steady red signal indication when traffic is required to stop. The duration of the yellow change interval between the display of tbe green and steady red signal indications, or flasbing yellow and steady red signal indications, shall be determined using engineering practices (see Section 4D.26).**

03 **If tbe vertical array of red signal indications is the type of signal face selected, the red signal indications shall flash alternately only when traffic is required to stop.**

Guidance:

04 *The 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.*

05 *Traffic control signals on adjacent streets and highways should be interconnected with the drawbridge control if indicated by engineering judgment. When such interconnection is provided, the traffic control signals at adjacent intersections should be preempted by the operation of the movable bridge in the manner described in Section 4D.27.*

CHAPTER 4K. HIGHWAY TRAFFIC SIGNALS AT TOLL PLAZAS

Section 4K.01 Traffic Signals at Toll Plazas

Standard:

01 **Traffic control signals or devices that closely resemble traffic control signals that use red or green circular indications shall not be used at toll plazas to indicate the open or closed status of the toll plaza lanes.**

Guidance:

02 *Traffic control signals or devices that closely resemble traffic control signals that use red or green circular indications should not be used for new or reconstructed installations at toll plazas to indicate the success or failure of electronic toll payments or to alternately direct drivers making cash toll payments to stop and then proceed.*

Section 4K.02 Lane-Use Control Signals at or Near Toll Plazas

Standard:

01 **Lane-use control signals used at toll plazas shall comply with the provisions of Chapter 4M except as otherwise provided in this Section.**

02 **At toll plazas with multiple lanes where one or more lanes is sometimes closed to traffic, a lane-use control signal shall be installed above the center of each toll plaza lane to indicate the open or closed status of the controlled lane.**

Option:

03 The bottom of the signal housing of a lane-use control signal above a toll plaza lane having a canopy may be mounted lower than 15 feet above the pavement, but not lower than the vertical clearance of the canopy structure.

04 Lane-use control signals may also be used to indicate the open or closed status of an Open-Road ETC lane as a supplement to other devices used for the temporary closure of a lane (see Part 6).

Section 4K.03 Warning Beacons at Toll Plazas

Standard:

01 **Warning Beacons used at toll plazas shall comply with the provisions of Chapter 4L except as otherwise provided in this Section.**

Guidance:

02 *Warning Beacons, if used with a toll plaza canopy sign (see Section 2F.16) to assist drivers of such vehicles in locating the dedicated ETC Account-Only lane(s), should be installed in a manner such that the beacons are distinctly separate from the lane-use control signals (see Section 4M.01) for the toll plaza lane.*

Option:

03 Warning Beacons that are mounted on toll plaza islands, behind impact attenuators in front of toll plaza islands, and/or on toll booth pylons (ramparts) to identify them as objects in the roadway may be mounted at a height that is appropriate for viewing in a toll plaza context, even if that height is lower than the normal minimum of 8 feet above the pavement.

CHAPTER 4L. FLASHING BEACONS

Section 4L.01 General Design and Operation of Flashing Beacons

Support:

01 A Flashing Beacon is a highway traffic signal with one or more signal sections that operates in a flashing mode. It can provide traffic control when used as an intersection control beacon (see Section 4L.02) or it can provide warning when used in other applications (see Sections 4L.03, 4L.04, and 4L.05).

Standard:

02 **Flashing Beacon units and their mountings shall comply with the provisions of Chapter 4D, except as otherwise provided in this Chapter.**

03 **Beacons shall be flashed at a rate of not less than 50 or more than 60 times per minute. The illuminated period of each flash shall be a minimum of 1/2 and a maximum of 2/3 of the total cycle.**

04 **A beacon shall not be included within the border of a sign except for SCHOOL SPEED LIMIT sign beacons (see Sections 4L.04 and 7B.15).**

Guidance:

05 *If used to supplement a warning or regulatory sign, the edge of the beacon signal housing should normally be located no closer than 12 inches outside of the nearest edge of the sign.*

Option:

06 An automatic dimming device may be used to reduce the brilliance of flashing yellow signal indications during night operation.

Section 4L.02 Intersection Control Beacon

Standard:

01 **An Intersection Control Beacon shall consist of one or more signal faces directed toward each approach to an intersection. Each signal face shall consist of one or more signal sections of a standard traffic signal face, with flashing CIRCULAR YELLOW or CIRCULAR RED signal indications in each signal face. They shall be installed and used only at an intersection to control two or more directions of travel.**

02 **Application of Intersection Control Beacon signal indications shall be limited to the following:**

A. Yellow on one route (normally the major street) and red for the remaining approaches, and
B. Red for all approaches (if the warrant described in Section 2B.07 for a multi-way stop is satisfied).

03 **Flashing yellow signal indications shall not face conflicting vehicular approaches.**

04 **A STOP sign shall be used on approaches to which a flashing red signal indication is displayed on an Intersection Control Beacon (see Section 2B.04).**

05 **If two horizontally aligned red signal indications are used on an approach for an Intersection Control Beacon, they shall be flashed simultaneously to avoid being confused with grade crossing flashing-light signals. If two vertically aligned red signal indications are used on an approach for an Intersection Control Beacon, they shall be flashed alternately.**

Guidance:

06 *An Intersection Control Beacon should not be mounted on a pedestal in the roadway unless the pedestal is within the confines of a traffic or pedestrian island.*

Option:

07 Supplemental signal indications may be used on one or more approaches in order to provide adequate visibility to approaching road users.

08 Intersection Control Beacons may be used at intersections where traffic or physical conditions do not justify conventional traffic control signals but crash rates indicate the possibility of a special need.

09 An Intersection Control Beacon is generally located over the center of an intersection; however, it may be used at other suitable locations.

Section 4L.03 Warning Beacon

Support:

01 Typical applications of Warning Beacons include the following:

A. At obstructions in or immediately adjacent to the roadway;
B. As supplemental emphasis to warning signs;
C. As emphasis for midblock crosswalks;

D. As supplemental emphasis to regulatory signs, except STOP, DO NOT ENTER, WRONG WAY, and SPEED LIMIT signs; and
E. In conjunction with a regulatory or warning sign that includes the phrase WHEN FLASHING in its legend to indicate that the regulation is in effect or that the condition is present only at certain times.

Standard:

02 **A Warning Beacon shall consist of one or more signal sections of a standard traffic signal face with a flashing CIRCULAR YELLOW signal indication in each signal section.**

03 **A Warning Beacon shall be used only to supplement an appropriate warning or regnlatory sign or marker.**

04 **Warning Beacons, if used at intersections, shall not face conflicting vehicular approaches.**

05 **If a Warning Beacon is suspended over the roadway, the clearance above the pavement shall be a minimum of 15 feet and a maximum of 19 feet.**

Guidance:

06 *The condition or regulation justifying Warning Beacons should largely govern their location with respect to the roadway.*

07 *If an obstruction is in or adjacent to the roadway, illumination of the lower portion or the beginning of the obstruction or a sign on or in front of the obstruction, in addition to the beacon, should be considered.*

08 *Warning Beacons should be operated only during those periods or times when the condition or regulation exists.*

Option:

09 Warning Beacons that are actuated by pedestrians, bicyclists, or other road users may be used as appropriate to provide additional warning to vehicles approaching a crossing or other location.

10 If Warning Beacons have more than one signal section, they may be flashed either alternately or simultaneously.

11 A flashing yellow beacon interconnected with a traffic signal controller assembly may be used with a traffic signal warning sign (see Section 2C.36).

Section 4L.04 Speed Limit Sign Beacon

Standard:

01 **A Speed Limit Sign Beacon shall be used only to supplement a Speed Limit sign.**

02 **A Speed Limit Sign Beacon shall consist of one or more signal sections of a standard traffic control signal face, with a flashing CIRCULAR YELLOW signal indication in each signal section. The signal indications shall have a nominal diameter of not less than 8 inches. If two signal indications are used, they shall be vertically aligned, except that they shall be permitted to be horizontally aligned if the Speed Limit (R2-1) sign is longer horizontally than vertically. If two signal indications are used, they shall be alternately flashed.**

Option:

03 A Speed Limit Sign Beacon may be used with a fixed or variable Speed Limit sign. If applicable, a flashing Speed Limit Sign Beacon (with an appropriate accompanying sign) may be used to indicate that the displayed speed limit is in effect.

04 A Speed Limit Sign Beacon may be included within the border of a School Speed Limit (S5-1) sign (see Section 7B.15).

Section 4L.05 Stop Beacon

Standard:

01 **A Stop Beacon shall be used only to supplement a STOP sign, a DO NOT ENTER sign, or a WRONG WAY sign.**

02 **A Stop Beacon shall consist of one or more signal sections of a standard traffic signal face with a flashing CIRCULAR RED signal indication in each signal section. If two horizontally aligned signal indications are used for a Stop Beacon, they shall be flashed simultaneously to avoid being confused with grade crossing flashing-light signals. If two vertically aligned signal indications are used for a Stop Beacon, they shall be flashed alternately.**

03 **The bottom of the signal housing of a Stop Beacon shall be not less than 12 inches or more than 24 inches above the top of a STOP sign, a DO NOT ENTER sign, or a WRONG WAY sign.**

CHAPTER 4M. LANE-USE CONTROL SIGNALS

Section 4M.01 Application of Lane-Use Control Signals

Support:

01 Lane-use control signals are special overhead signals that permit or prohibit the use of specific lanes of a street or highway or that indicate the impending prohibition of their use. Lane-use control signals are distinguished by placement of special signal faces over a certain lane or lanes of the roadway and by their distinctive shapes and symbols. Supplementary signs are sometimes used to explain their meaning and intent.

02 Lane-use control signals are most commonly used for reversible-lane control, but are also used in certain non-reversible lane applications and for toll plaza lanes (see Section 4K.02).

Guidance:

03 *An engineering study should be conducted to determine whether a reversible-lane operation can be controlled satisfactorily by static signs (see Section 2B.26) or whether lane-use control signals are necessary. Lane-use control signals should be used to control reversible-lane operations if any of the following conditions are present:*

- A. *More than one lane is reversed in direction;*
- B. *Two-way or one-way left turns are allowed during peak-period reversible operations, but those turns are from a different lane than used during off-peak periods;*
- C. *Other unusual or complex operations are included in the reversible-lane pattern;*
- D. *Demonstrated crash experience occurring with reversible-lane operation controlled by static signs that can be corrected by using lane-use control signals at the times of transition between peak and off-peak patterns; and/or*
- E. *An engineering study indicates that the safety and efficiency of the traffic operations of a reversible-lane system would be improved by lane-use control signals.*

Standard:

04 **Pavement markings (see Section 3B.03) shall be used in conjunction with reversible-lane control signals.**

Option:

05 Lane-use control signals may also be used if there is no intent or need to reverse lanes, but there is a need to indicate the open or closed status of one or more lanes, such as:

- A. On a freeway, if it is desired to close certain lanes at certain hours to facilitate the merging of traffic from a ramp or other freeway;
- B. On a freeway, near its terminus, to indicate a lane that ends;
- C. On a freeway or long bridge, to indicate that a lane may be temporarily blocked by a crash, breakdown, construction or maintenance activities, or similar temporary conditions; and
- D. On a conventional road or driveway, at access or egress points to or from a facility, such as a parking garage, where one or more lanes of the access or egress are opened or closed at various times.

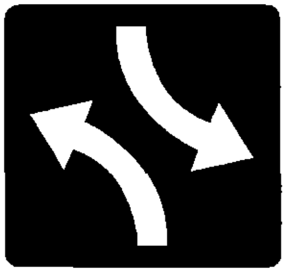
Section 4M.02 Meaning of Lane-Use Control Signal Indications

Standard:

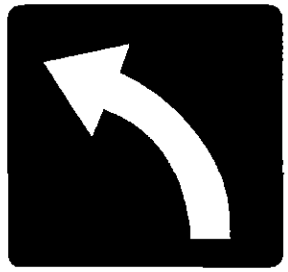
01 **The meanings of lane-use control signal indications shall be as follows:**

- **A. A steady DOWNWARD GREEN ARROW signal indication shall mean that a road user is permitted to drive in the lane over which the arrow signal indication is located.**
- **B. A steady YELLOW X signal indication shall mean that a road user is to prepare to vacate the lane over which the signal indication is located because a lane control change is being made to a steady RED X signal indication.**
- **C. A steady WHITE TWO-WAY LEFT-TURN ARROW signal indication (see Figure 4M-1) shall mean that a road user is permitted to use a lane over which the signal indication is located for a left turn, but not for through travel, with tbe understanding that common use of the lane by oncoming road users for left turns is also permitted.**
- **D. A steady WHITE ONE WAY LEFT-TURN ARROW signal indication (see Figure 4M-1) shall mean that a road user is permitted to use a lane over which the signal indication is located for a left turn (without opposing turns in the same lane), but not for through travel.**
- **E. A steady RED X signal indication shall mean that a road user is not permitted to use the lane over wbich the signal indication is located and that tbis signal indication sball modify accordingly the meaning of otber traffic controls present.**

Figure 4M-1. Left-Turn Lane-Use Control Signals



Two-way left-turn arrow



One-way left-turn arrow

White arrows on an opaque 30 x 30-inch background

Section 4M.03 Design of Lane-Use Control Signals

Standard:

01 **All lane-use control signal indications shall be in units with rectangular signal faces and shall have opaque backgrounds. Nominal minimum height and width of each DOWNWARD GREEN ARROW, YELLOW X, and RED X signal face shall be 18 inches for typical applications. The WHITE TWO-WAY LEFT-TURN ARROW and WHITE ONE WAY LEFT-TURN ARROW signal faces shall have a nominal minimum height and width of 30 inches.**

02 **Each lane to be reversed or closed shall have signal faces with a DOWNWARD GREEN ARROW and a RED X symbol.**

03 **Each reversible lane that also operates as a two-way or one-way left-turn lane during certain periods shall have signal faces that also include the applicable WHITE TWO-WAY LEFT-TURN ARROW or WHITE ONE WAY LEFT-TURN ARROW symbol.**

04 **Each non-reversible lane immediately adjacent to a reversible lane shall have signal indications that display a DOWNWARD GREEN ARROW to traffic traveling in the permitted direction and a RED X to traffic traveling in the opposite direction.**

05 **If in separate signal sections, the relative positions, from left to right, of the signal indications shall be RED X, YELLOW X, DOWNWARD GREEN ARROW, WHITE TWO-WAY LEFT-TURN ARROW, WHITE ONE WAY LEFT-TURN ARROW.**

06 **The color of lane-use control signal indications shall be clearly visible for 2,300 feet at all times under normal atmospheric conditions, unless otherwise physically obstructed.**

07 **Lane-use control signal faces shall be located approximately over the center of the lane controlled.**

08 **If the area to be controlled is more than 2,300 feet in length, or if the vertical or horizontal alignment is curved, intermediate lane-use control signal faces shall be located over each controlled lane at frequent intervals. This location shall be such that road users will at all times be able to see at least one signal indication and preferably two along the roadway, and will have a definite indication of the lanes specifically reserved for their use.**

09 **All lane-use control signal faces shall be located in a straight line across the roadway approximately at right angles to the roadway alignment.**

10 **On roadways having intersections controlled by traffic control signals, the lane-use control signal face shall be located sufficiently far in advance of or beyond such traffic control signals to prevent them from being misconstrued as traffic control signals.**

11 **Except as provided in Paragraph 12, the bottom of the signal housing of any lane-use control signal face shall be a minimum of 15 feet and a maximum of 19 feet above the pavement grade.**

Option:

12 The bottom of a lane-use control signal housing may be lower than 15 feet above the pavement if it is mounted on a canopy or other structure over the pavement, but not lower than the vertical clearance of the structure.

13 Except for lane-use control signals at toll plazas (see Section 4K.02), in areas with minimal visual clutter and with speeds of less than 40 mph, lane-use control signal faces with nominal height and width of 12 inches may be used for the DOWNWARD GREEN ARROW, YELLOW X, and RED X signal faces, and lane-use control signal faces with nominal height and width of 18 inches may be used for the WHITE TWO-WAY LEFT-TURN ARROW and WHITE ONE-WAY LEFT-TURN ARROW signal faces.

14 Other sizes of lane-use control signal faces larger than 18 inches with message recognition distances appropriate to signal spacing may be used for the DOWNWARD GREEN ARROW, YELLOW X, and RED X signal faces.

15 Non-reversible lanes not immediately adjacent to a reversible lane on any street so controlled may also be provided with signal indications that display a DOWNWARD GREEN ARROW to traffic traveling in the permitted direction and a RED X to traffic traveling in the opposite direction.

16 The signal indications provided for each lane may be in separate signal sections or may be superimposed in the same signal section.

Section 4M.04 Operation of Lane-Use Control Signals

Standard:

01 **All lane-use control signals shall be coordinated so that all the signal indications along the controlled section of roadway are operated uniformly and consistently. The lane-use control signal system shall be designed to reliably guard against showing any prohibited combination of signal indications to any traffic at any point in the controlled lanes.**

02 **For reversible-lane control signals, the following combination of signal indications shall not be simultaneously displayed over the same lane to both directions of travel:**

A. DOWNWARD GREEN ARROW in both directions,
B. YELLOW X in both directions,
C. WHITE ONE WAY LEFT-TURN ARROW in both directions,
D. DOWNWARD GREEN ARROW in one direction and YELLOW X in the other direction,
E. WHITE TWO-WAY LEFT-TURN ARROW or WHITE ONE WAY LEFT-TURN ARROW in one direction and DOWNWARD GREEN ARROW in the other direction,
F. WHITE TWO-WAY LEFT-TURN ARROW in one direction and WHITE ONE WAY LEFT-TURN ARROW in the other direction, and
G. WHITE ONE WAY LEFT-TURN ARROW in one direction and YELLOW X in the other direction.

03 **A moving condition in one direction shall be terminated either by the immediate display of a RED X signal indication or by a YELLOW X signal indication followed by a RED X signal indication. In either case, the duration of the RED X signal indication shall be sufficient to allow clearance of the lane before any moving condition is allowed in the opposing direction.**

04 **Whenever a DOWNWARD GREEN ARROW signal indication is changed to a WHITE TWO-WAY LEFT-TURN ARROW signal indication, the RED X signal indication shall continue to be displayed to the opposite direction of travel for an appropriate duration to allow traffic time to vacate the lane being converted to a two-way left-turn lane.**

05 **If an automatic control system is used, a manual control to override the automatic control shall be provided.**

Guidance:

06 *The type of control provided for reversible-lane operation should be such as to permit either automatic or manual operation of the lane-use control signals.*

Standard:

07 **If used, lane-use control signals shall be operated continuously, except that lane-use control signals that are used only for special events or other infrequent occurrences and lane-use control signals on non-reversible freeway lanes shall be permitted to be darkened when not in operation. The change from normal operation to non-operation shall occur only when the lane-use control signals display signal indications that are appropriate for the lane use that applies when the signals are not operated. The lane-use control signals shall display signal indications that are appropriate for the existing lane use when changed from non-operation to normal operations. Also, traffic control devices shall clearly indicate the proper lane use when the lane control signals are not in operation.**

Support:

08 Section 2B.26 contains additional information concerning considerations involving left-turn prohibitions in conjunction with reversible-lane operations.

CHAPTER 4N. IN-ROADWAY LIGHTS

Section 4N.01 Application of In-Roadway Lights

Support:

01 In-Roadway Lights are special types of highway traffic signals installed in the roadway surface to warn road users that they are approaching a condition on or adjacent to the roadway that might not be readily apparent and might require the road users to slow down and/or come to a stop. This includes situations warning of marked school crosswalks, marked midblock crosswalks, marked crosswalks on uncontrolled approaches, marked crosswalks in advance of roundabouts as described in Chapter 3C, and other roadway situations involving pedestrian crossings.

Standard:

02 **In-Roadway Lights shall not be used for any application that is not described in this Chapter.**

03 **If used, In-Roadway Lights shall not exceed a height of 3/4 inch above the roadway surface.**

04 **When used, In-Roadway Lights shall be flashed and shall not be steadily illuminated.**

Support:

05 Steadily illuminated lights installed in the roadway surface are considered to be internally illuminated raised pavement markers (see Section 3B.11).

Option:

06 In-Roadway Lights may be flashed in a manner that includes a continuous flash of varying intensity and time duration that is repeated to provide a flickering effect (see Section 4N.02).

Section 4N.02 In-Roadway Warning Lights at Crosswalks

Option:

01 In-roadway lights may be installed at certain marked crosswalks, based on an engineering study or engineering judgment, to provide additional warning to road users.

Standard:

02 **If used, In-Roadway Warning Lights at crosswalks shall be installed only at marked crosswalks with applicable warning signs. They shall not be used at crosswalks controlled by YIELD signs, STOP signs, or traffic control signals.**

03 **If In-Roadway Warning Lights are used at a crosswalk, the following requirements shall apply:**

A. Except as provided in Paragraphs 7 and 8, they shall be installed along both sides of the crosswalk and shall span its entire length.

B. They shall initiate operation based on pedestrian actuation and shall cease operation at a predetermined time after the pedestrian actuation or, with passive detection, after the pedestrian clears the crosswalk.

C. They shall display a flashing yellow light when actuated. The flash rate shall be at least 50, but no more than 60, flash periods per minute. If they are flashed in a manner that includes a continuous flash of varying intensity and time duration that is repeated to provide a flickering effect, the flickers or pulses shall not repeat at a rate that is between 5 and 30 per second to avoid frequencies that might cause seizures.

D. They shall be installed in the area between the outside edge of the crosswalk line and 10 feet from the outside edge of the crosswalk.

E. They shall face away from the crosswalk if unidirectional, or shall face away from and across the crosswalk if bidirectional.

04 **If used on one-lane, one-way roadways, a minimum of two In-Roadway Warning Lights shall be installed on the approach side of the crosswalk. If used on two-lane roadways, a minimum of three In-Roadway Warning Lights shall be installed along both sides of the crosswalk. If used on roadways with more than two lanes, a minimum of one In-Roadway Warning Light per lane shall be installed along both sides of the crosswalk.**

Guidance:

05 *If used, In-Roadway Warning Lights should be installed in the center of each travel lane, at the center line of the roadway, at each edge of the roadway or parking lanes, or at other suitable locations away from the normal tire track paths.*

06 *The location of the In-Roadway Warning Lights within the lanes should be based on engineering judgment.*

Option:

07 On one-way streets, In-Roadway Warning Lights may be omitted on the departure side of the crosswalk.

08 Based on engineering judgment, the In-Roadway Warning Lights on the departure side of the crosswalk on the left side of a median may be omitted.

09 Unidirectional In-Roadway Warning Lights installed at crosswalk locations may have an optional, additional yellow light indication in each unit that is visible to pedestrians in the crosswalk to indicate to pedestrians in the crosswalk that the In-Roadway Warning Lights are in fact flashing as they cross the street. These yellow lights may flash with and at the same flash rate as the light module in which each is installed.

Guidance:

10 *If used, the period of operation of the In-Roadway Warning Lights following each actuation should be sufficient to allow a pedestrian crossing in the crosswalk to leave the curb or shoulder and travel at a walking speed of 3.5 feet per second to at least the far side of the traveled way or to a median of sufficient width for pedestrians to wait. Where pedestrians who walk slower than 3.5 feet per second, or pedestrians who use wheelchairs, routinely use the crosswalk, a walking speed of less than 3.5 feet per second should be considered in determining the period of operation.*

Standard:

11 **If pedestrian pushbuttons are used to actuate the in-roadway lights, a Push Button To Turn On Warning Lights (with pushbutton symbol) (R10-25) sign (see Figure 2B-26) shall be mounted adjacent to or integral with each pedestrian pushbutton.**

12 **Where the period of operation is sufficient only for crossing from a curb or shoulder to a median of sufficient width for pedestrians to wait, median-mounted pedestrian actuators shall be provided.**

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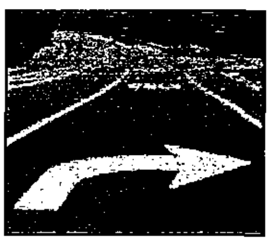
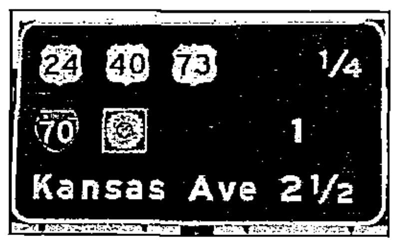
Manual on Uniform Traffic Control Devices

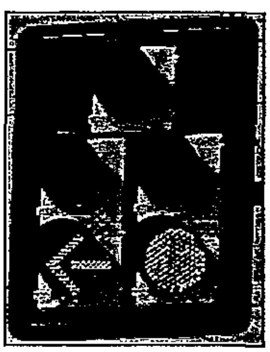
for Streets and Highways

2003 EDITION

Including Revision 1 dated November 2004







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Manual on Uniform Traffic Control Devices

for Streets and Highways

MUTCD

2003 EDITION

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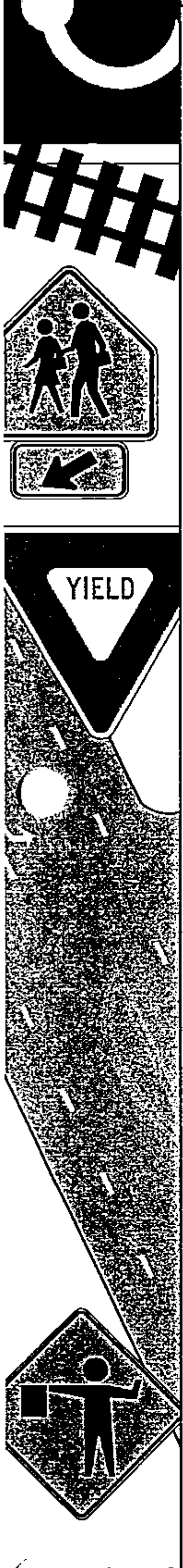

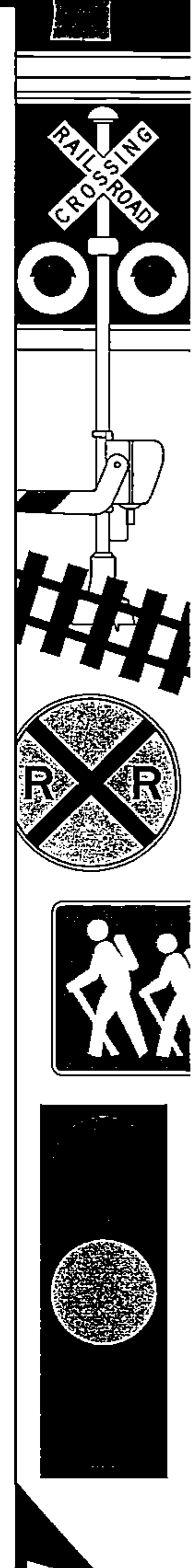

Manual on Uniform Traffic Control Devices

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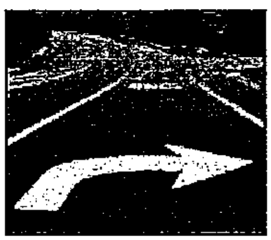

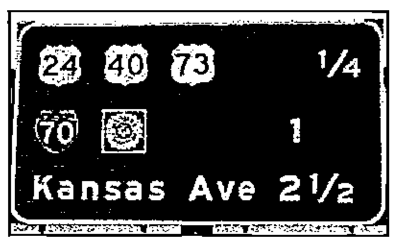

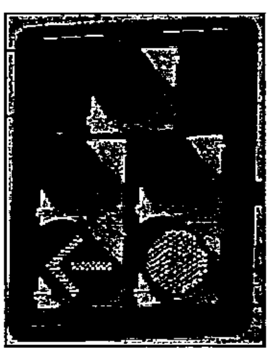

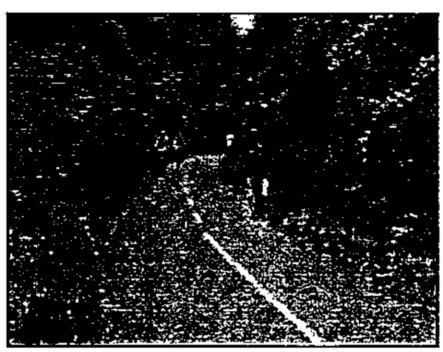

U.S. Department of Transportation
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The Manual on Uniform Traffic Control Devices (MUTCD) is approved by the Federal Highway Administrator as the National Standard in accordance with Title 23 U.S. Code, Sections 109(d), 114(a), 217, 315, and 402(a), 23 CFR 655, and 49 CFR 1.48(b)(8), 1.48(b)(33), and 1.48(c)(2).

Addresses for Publications Referenced in the MUTCD

American Association of State Highway and Transportation Officials (AASHTO)
444 North Capitol Street, NW, Suite 249
Washington, DC 20001
www.transportation.org

American Railway Engineering and Maintenance-of-Way Association (AREMA)
8201 Corporate Drive, Suite 1125
Landover, MD 20785-2230
www.arema.org

Federal Highway Administration Report Center
Facsimile number: 301.577.1421
report.center@fhwa.dot.gov

Illuminating Engineering Society (IES)
120 Wall Street, Floor 17
New York, NY 10005
www.iesna.org

Institute of Makers of Explosives
1120 19th Street, NW, Suite 310
Washington, DC 20036-3605
www.ime.org

Institute of Transportation Engineers (ITE)
1099 14th Street, NW, Suite 300 West
Washington, DC 20005-3438
www.ite.org

International Organization for Standards
c/o Mr. Gerard Kuso
Austrian Standards Institute
Heinestrabe 38
Postfach 130
A-1021
Wien, Austria
www.iso.ch

ISEA - The Safety Equipment Association
1901 North Moore Street, Suite 808
Arlington, VA 22209
www.safetyequipment.org

National Committee on Uniform Traffic Laws and Ordinances (NCUTLO)
107 South West Street, Suite 110
Alexandria, VA 22314
www.ncutlo.org

Occupational Safety and Health Administration (OSHA)
U.S. Department of Labor
200 Constitution Avenue, NW
Washington, DC 20210
www.osha.gov

Transportation Research Board (TRB)
The National Academies
2101 Constitution Avenue, NW
Washington, DC 20418
www.nas.edu/trb

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

Acknowledgments

The Federal Highway Administration gratefully acknowledges the valuable assistance that it received from the National Committee on Uniform Traffic Control Devices and its over 200 voluntary members in the development of this Manual.

MANUAL ON UNIFORM TRAFFIC CONTROL DEVICES
INTRODUCTION

Standard:

Traffic control devices shall be defined as all signs, signals, markings, and other devices used to regulate, warn, or guide traffic, placed on, over, or adjacent to a street, highway, pedestrian facility, or bikeway by authority of a public agency having jurisdiction.

The Manual on Uniform Traffic Control Devices (MUTCD) is incorporated by reference in 23 Code of Federal Regulations (CFR), Part 655, Subpart F and shall be recognized as the national standard for all traffic control devices installed on any street, highway, or bicycle trail open to public travel in accordance with 23 U.S.C. 109(d) and 402(a). The policies and procedures of the Federal Highway Administration (FHWA) to obtain basic uniformity of traffic control devices shall be as described in 23 CFR 655, Subpart F.

Any traffic control device design or application provision contained in this Manual shall be considered to be in the public domain. Traffic control devices contained in this Manual shall not be protected by a patent, trademark, or copyright, except for the Interstate Shield and any other items owned by FHWA.

Support:

The need for uniform standards was recognized long ago. The American Association of State Highway Officials (AASHO), now known as the American Association of State Highway and Transportation Officials (AASHTO), published a manual for rural highways in 1927, and the National Conference on Street and Highway Safety (NCSHS) published a manual for urban streets in 1930. In the early years, the necessity for unification of the standards applicable to the different classes of road and street systems was obvious. To meet this need, a joint committee of AASHO and NCSHS developed and published the original edition of this Manual on Uniform Traffic Control Devices (MUTCD) in 1935. That committee, now called the National Committee on Uniform Traffic Control Devices (NCUTCD), though changed from time to time in name, organization, and personnel, has been in continuous existence and has contributed to periodic revisions of this Manual. The FHWA has administered the MUTCD since the 1971 edition. The FHWA and its predecessor organizations have participated in the development and publishing of the previous editions. There were eight previous editions of the MUTCD, and several of those editions were revised one or more times. Table I-1 traces the evolution of the MUTCD, including the two manuals developed by AASHO and NCSHS.

Standard:

The U.S. Secretary of Transportation, under authority granted by the Highway Safety Act of 1966, decreed that traffic control devices on all streets and highways open to public travel in accordance with 23 U.S.C. 109(d) and 402(a) in each State shall be in substantial conformance with the Standards issued or endorsed by the FHWA.

Support:

23 CFR 655.603 adopts the MUTCD as the national standard for any street, highway, or bicycle trail open to public travel in accordance with 23 U.S.C. 109(d) and 402(a). The "Uniform Vehicle Code (UVC)" is one of the publications referenced in the MUTCD. The UVC contains a model set of motor vehicle codes and traffic laws for use throughout the United States. The States are encouraged to adopt Section 15-116 of the UVC, which states that, "No person shall install or maintain in any area of private property used by the public any sign, signal, marking, or other device intended to regulate, warn, or guide traffic unless it conforms with the State manual and specifications adopted under Section 15-104."

The Standard, Guidance, Option, and Support material described in this edition of the MUTCD provide the transportation professional with the information needed to make appropriate decisions regarding the use of traffic control devices on streets and highways. The material in this edition is organized to better differentiate between Standards that must be satisfied for the particular circumstances of a situation, Guidances that should be followed for the particular circumstances of a situation, and Options that may be applicable for the particular circumstances of a situation.

Throughout this Manual the headings Standard, Guidance, Option, and Support are used to classify the nature of the text that follows. Figures, tables, and illustrations supplement the text and might constitute a Standard, Guidance, Option, or Support. The user needs to refer to the appropriate text to classify the nature of the figure, table, or illustration.

Standard:

When used in this Manual, the text headings shall be defined as follows:

1. **Standard—a statement of required, mandatory, or specifically prohibitive practice regarding a traffic control device. All standards are labeled, and the text appears in bold type. The verb shall is typically used. Standards are sometimes modified by Options.**

Table I-1. Evolution of the MUTCD

Year	Name	Month / Year Revised
1927	Manual and Specifications for the Manufacture, Display, and Erection of U.S. Standard Road Markers and Signs (for rural roads)	4/29, 12/31
1930	Manual on Street Traffic Signs, Signals, and Markings (for urban streets)	No revisions
1935	Manual on Uniform Traffic Control Devices for Streets and Highways (MUTCD)	2/39
1942	Manual on Uniform Traffic Control Devices for Streets and Highways — War Emergency Edition	No revisions
1948	Manual on Uniform Traffic Control Devices for Streets and Highways	9/54
1961	Manual on Uniform Traffic Control Devices for Streets and Highways	No revisions
1971	Manual on Uniform Traffic Control Devices for Streets and Highways	11/71, 4/72, 3/73, 10/73, 6/74, 6/75, 9/76, 12/77
1978	Manual on Uniform Traffic Control Devices for Streets and Highways	12/79, 12/83, 9/84, 3/86
1988	Manual on Uniform Traffic Control Devices for Streets and Highways	1/90, 3/92, 9/93, 11/94, 12/96, 6/98, 1/00
2000	Manual on Uniform Traffic Control Devices for Streets and Highways — Millennium Edition	7/02
2003	Manual on Uniform Traffic Control Devices for Streets and Highways	

2. **Guidance—a statement of recommended, but not mandatory, practice in typical situations, with deviations allowed if engineering judgment or engineering study indicates the deviation to be appropriate. All Guidance statements are labeled, and the text appears in unbold type. The verb should is typically used. Guidance statements are sometimes modified by Options.**
3. **Option—a statement of practice that is a permissive condition and carries no requirement or recommendation. Options may contain allowable modifications to a Standard or Guidance. All Option statements are labeled, and the text appears in unbold type. The verb may is typically used.**
4. **Support—an informational statement that does not convey any degree of mandate, recommendation, authorization, prohibition, or enforceable condition. Support statements are labeled, and the text appears in unbold type. The verbs shall, should, and may are not used in Support statements.**

Support:

Throughout this Manual all dimensions and distances are provided in the International System of Units, a modernized version of the Metric system, and their English equivalent units are shown in parentheses.

Guidance:

Before laying out distances or determining sign sizes, the public agency should decide whether to use the International System of Units (Metric) or the English equivalent units. The chosen units should be specified on plan drawings. The chosen unit of measurement should be made known to those responsible for designing, installing, or maintaining traffic control devices.

Except when a specific numeral is required by the text of a Section of this Manual, numerals shown on the sign images in the figures that specify quantities such as times, distances, speed limits, and weights should be regarded as examples only. When installing any of these signs, the numerals should be appropriately altered to fit the specific signing situation.

Support:

The following information will be useful when reference is being made to a specific portion of text in this Manual.

There are ten Parts in this Manual and each Part is comprised of one or more Chapters. Each Chapter is comprised of one or more Sections. Parts are given a numerical identification, such as Part 2-Signs. Chapters are identified by the Part number and a letter, such as Chapter 2B-Regulatory Signs. Sections are identified by the Chapter number and letter followed by a decimal point and a number, such as Section 2B.03-Size of Regulatory Signs.

Each Section is comprised of one or more paragraphs. The paragraphs are indented but are not identified by a number or letter. Paragraphs are counted from the beginning of each Section without regard to the intervening text headings (Standard, Guidance, Option, or Support). Some paragraphs have lettered or numbered items. As an example of how to cite this Manual, the phrase "Not less than 12 m (40 ft) beyond the stop line" that appears on Page 4D-12 of this Manual would be referenced in writing as "Section 4D.15, P7, D1(a)," and would be verbally referenced as "Item D1(a) of Paragraph 7 of Section 4D.15."

Standard:

In accordance with 23 CFR 655.603(b)(1), States or other Federal agencies that have their own MUTCDs or Supplements shall revise these MUTCDs or Supplements to be in substantial conformance with changes to the National MUTCD within 2 years of issuance of the changes. Unless a particular device is no longer serviceable, non-compliant devices on existing highways and bikeways shall be brought into compliance with the current edition of the National MUTCD as part of the systematic upgrading of substandard traffic control devices (and installation of new required traffic control devices) required pursuant to the Highway Safety Program, 23 U.S.C. § 402(a). In cases involving Federal-aid projects for new highway or bikeway construction or reconstruction, the traffic control devices installed (temporary or permanent) shall be in conformance with the most recent edition of the National MUTCD before that highway is opened or re-opened to the public for unrestricted travel [23 CFR 655.603(d)(2)]. The FHWA has the authority to establish other target compliance dates for implementation of particular changes to the MUTCD [23 CFR 655.603(d)(4)]. These target compliance dates established by the FHWA shall be as follows:

Section 2A.19 Lateral Offset—crashworthiness of sign supports—January 17, 2013 for roads with posted speed limit of 80 km/h (50 mph) or higher.

Section 2B.03 Size of Regulatory Signs—increased sign sizes and other changes to Table 2B-1—10 years from the effective date of the Final Rule for the 2003 MUTCD.

Section 2B.04 STOP Sign (R1-1)—4-WAY plaque requirement—January 17, 2004.

Section 2B.06 STOP Sign Placement—signs mounted on back of STOP sign—10 years from the effective date of the Final Rule for the 2003 MUTCD.

Section 2B.09 YIELD Sign Applications—changes in YIELD sign application criteria from the 1988 MUTCD—January 17, 2011.

Section 2B.10 YIELD Sign Placement—signs mounted on back of YIELD sign—10 years from the effective date of the Final Rule for the 2003 MUTCD.

Section 2B.11 Yield Here to Pedestrians Signs (R1-5, R1-5a)—new section—10 years from the effective date of the Final Rule for the 2003 MUTCD.

Section 2B.13 Speed Limit Sign (R2-1)—color of changeable message legend of YOUR SPEED—10 years from the effective date of the Final Rule for the 2003 MUTCD.

Section 2B.25 Reversible Lane Control Signs (R3-9d, R3-9f through R3-9i)—removal of R3-9c and R3-9e signs—10 years from the effective date of the Final Rule for the 2003 MUTCD.

Section 2B.26 Preferential Only Lane Signs (R3-10 through R3-15)—10 years from the effective date of the Final Rule for the 2003 MUTCD.

Section 2B.27 Preferential Only Lanes for High-Occupancy Vehicles (HOVs)—new section in Millennium Edition—January 17, 2007.

Section 2B.28 Preferential Only Lane Sign Applications and Placement—10 years from the effective date of the Final Rule for the 2003 MUTCD.

Section 2B.37 ONE WAY Signs (R6-1, R6-2)—placement requirement at intersecting alleys—January 17, 2008.

Section 2B.46 Photo Enforced Signs (R10-18, R10-19)—new section—10 years from the effective date of the Final Rule for the 2003 MUTCD.

Section 2B.52 Hazardous Material Signs (R14-2, R14-3)—change in sign legend—10 years from the effective date of the Final Rule for the 2003 MUTCD.

Section 2C.04 Size of Warning Signs—increased sizes of W4-1, W5-2, W6-3, and W12-1 signs—January 17, 2008.

Section 2C.04 Size of Warning Signs—sizes of W1 Series Arrows signs, W7 Series truck runaway signs, W12-2p low clearance signs, and W10-1 advance grade crossing sign—10 years from the effective date of the Final Rule for the 2003 MUTCD.

Section 2C.11 Truck Rollover Warning Signs (W1-13, W1-13a)—new section—10 years from the effective date of the Final Rule for the 2003 MUTCD.

Section 2C.16 NARROW BRIDGE Sign (W5-2)—elimination of symbol sign—10 years from the effective date of the Final Rule for the 2003 MUTCD.

Section 2C.25 PAVEMENT ENDS Sign (W8-3)—removal of symbol sign—January 17, 2011.

Section 2C.26 Shoulder Signs (W8-4, W8-9, and W8-9a)—removal of symbol signs—January 17, 2011.

Section 2C.30 Speed Reduction Signs (W3-5, W3-5a)—removal of R2-5 Series Reduced Speed Ahead signs and use of W3-5 or W3-5a warning signs instead—15 years from the effective date of the Final Rule for the 2003 MUTCD.

Section 2C.31 Merge Signs (W4-1, W4-5)—Entering Roadway Merge sign (W4-1a)—10 years from the effective date of the Final Rule for the 2003 MUTCD.

Section 2C.32 Added Lane Signs (W4-3, W4-6)—Entering Roadway Added Lane sign (W4-3a)—10 years from the effective date of the Final Rule for the 2003 MUTCD.

Section 2C.33 Lane Ends Signs (W4-2, W9-1, W9-2)—new design of W4-2 sign—10 years from the effective date of the Final Rule for the 2003 MUTCD.

Section 2C.34 Two-Way Traffic Sign (W6-3)—transition from one-way street—5 years from the effective date of the Final Rule for the 2003 MUTCD.

Section 2C.37 Intersection Warning Signs (W2-1 through W2-6)—new design of Circular Intersection (W2-6) sign—10 years from the effective date of the Final Rule for the 2003 MUTCD.

Section 2C.40 Vehicular Traffic Signs (W8-6, W11-1, W11-5, W11-5a, W11-6, W11-8, W11-10, W11-11, W11-12, W11-14)—new symbol signs W11-1, W11-5, W11-5a, W11-6, W11-11, and W11-14—10 years from the effective date of the Final Rule for the 2003 MUTCD.

Section 2C.41 Nonvehicular Signs (W11-2, W11-3, W11-4, W11-7, W11-9)—elimination of crosswalk lines from crossing signs and use of diagonal downward pointing arrow supplemental plaque (W16-7) if at the crossing—January 17, 2011.

Section 2C.53 PHOTO ENFORCED Plaque (W16-10)—new section—10 years from the effective date of the Final Rule for the 2003 MUTCD.

Section 2D.38 Street Name Sign (D3-1)—symbol sizes, 150 mm (6 in) letter sizes for lettering on ground-mounted Street Name signs on roads that are not multi-lane streets with speed limits greater than 60 km/h (40 mph), other new provisions of Millennium Edition—January 9, 2012.

Section 2D.38 Street Name Sign (D3-1)—letter sizes on ground-mounted signs on multi-lane streets with speed limits greater than 60 km/h (40 mph) and letter sizes on overhead-mounted signs—15 years from the effective date of the Final Rule of the 2003 MUTCD.

Section 2D.39 Advance Street Name Signs (D3-2)—new section in 2000 MUTCD and revisions in 2003 MUTCD—15 years from the effective date of the Final Rule for the 2003 MUTCD.

Section 2D.45 General Service Signs (D9 Series)—Traveler Info Call 511 (D12-5) sign, Channel 9 Monitored (D12-3) sign—10 years from the effective date of the Final Rule for the 2003 MUTCD.

Section 2D.46 Reference Location Signs (D10-1 through D10-3) and Intermediate Reference Location Signs (D10-1a through D10-3a)—location and spacing of Reference Location signs and design of Intermediate Reference Location signs—10 years from the effective date of the Final Rule for the 2003 MUTCD.

Section 2E.28 Interchange Exit Numbering—size of exit number plaque—January 17, 2008.

Section 2E.28 Interchange Exit Numbering—LEFT on exit number plaques for left exits—5 years from the effective date of the Final Rule for the 2003 MUTCD.

Section 2E.30 Advance Guide Signs—advance placement distance—January 17, 2008.

Section 2E.54 Reference Location Signs and Enhanced Reference Location Signs (D10-4, D10-5)—design of Enhanced Reference Location signs and Intermediate Enhanced Reference Location signs—10 years from the effective date of the Final Rule for the 2003 MUTCD.

Section 2E.59 Preferential Only Lane Signs—new section in 2003 Edition—10 years from the effective date of the Final Rule for the 2003 MUTCD.

Section 2F.05 Size of Lettering—minimum height of letters and numerals on specific service signs—January 17, 2011.

Section 2I.03 EVACUATION ROUTE Sign (EM-1)—new design and size of EM-1 sign—15 years from the effective date of the Final Rule for the 2003 MUTCD.

Section 3B.01 Yellow Centerline Pavement Markings and Warrants—new section in Millennium Edition—January 3, 2003.

Section 3B.03 Other Yellow Longitudinal Pavement Markings—spacing requirements for pavement marking arrows in two-way left-turn lanes—5 years from the effective date of the Final Rule for the 2003 MUTCD.

Section 3B.07 Warrants for Use of Edge Lines—new section in Millennium Edition—January 3, 2003.

Section 3B.17 Crosswalk Markings—gap between transverse lines of a crosswalk—10 years from the effective date of the Final Rule for the 2003 MUTCD.

Section 3B.19 Pavement Word and Symbol Markings—typical spacing of lane-use arrows in two-way left-turn lanes shown in Figure 3B-7—5 years from the effective date of the Final Rule for the 2003 MUTCD.

Section 3C.01 Object Marker Design and Placement Height—width of stripes on Type 3 striped marker—10 years from the effective date of the Final Rule for the 2003 MUTCD.

Section 4D.01 General—location of signalized midblock crosswalks—10 years from the effective date of the Final Rule for the 2003 MUTCD.

Section 4D.05 Application of Steady Signal Indications—Item B.4 in STANDARD—5 years from the effective date of the Final Rule for the 2003 MUTCD.

Section 4D.12 Flashing Operation of Traffic Control Signals—duration of steady red clearance interval in change from red-red flashing mode to steady (stop-and-go) mode—10 years from the effective date of the Final Rule for the 2003 MUTCD.

Section 4E.06 Accessible Pedestrian Signals—new section in Millennium Edition—January 17, 2005.

Section 4E.07 Countdown Pedestrian Signals—new section—10 years from the effective date of the Final Rule for the 2003 MUTCD for countdown pedestrian signal hardware; 3 years from the effective date of the Final Rule for the 2003 MUTCD for operational requirements of countdown pedestrian signals.

Section 4E.09 Accessible Pedestrian Signal Detectors—new section in Millennium Edition—January 17, 2005.

Section 4E.10 Pedestrian Intervals and Signal Phases—pedestrian clearance time sufficient to travel to far side of the traveled way—5 years from the effective date of the Final Rule for the 2003 MUTCD.

Section 5C.05 NARROW BRIDGE Sign (W5-2)—elimination of symbol sign—10 years from the effective date of the Final Rule for the 2003 MUTCD.

Section 6D.01 Pedestrian Considerations—all new provisions for pedestrian accessibility—5 years from the effective date of the Final Rule for the 2003 MUTCD.

Section 6D.02 Accessibility Considerations—5 years from the effective date of the Final Rule for the MUTCD.

Section 6D.03 Worker Safety Considerations—high-visibility apparel requirements—3 years from the effective date of the Final Rule for the 2003 MUTCD.

Section 6E.02 High-Visibility Safety Apparel—high-visibility apparel requirements for flaggers—3 years from the effective date of the Final Rule for the 2003 MUTCD.

Section 6F.03 Sign Placement—crashworthiness of sign supports—January 17, 2005.

Section 6F.58 Channelizing Devices—crashworthiness—January 17, 2005.

Section 6F.59 Cones—width of retroreflective stripes—5 years from the effective date of the Final Rule for the 2003 MUTCD.

Section 6F.63 Type I, II, or III Barricades—crashworthiness—January 17, 2005.

Section 6F.66 Longitudinal Channelizing Barricades—crashworthiness—January 17, 2005.

Section 6F.82 Crash Cushions—crashworthiness—January 17, 2005.

Section 7B.08 School Advance Warning Assembly (S1-1 with Supplemental Plaque)—use of AHEAD plaque (W16-9p) or distance plaque (W16-2 or W16-2a)—January 17, 2011.

Section 7B.09 School Crosswalk Warning Assembly (S1-1 with Diagonal Arrow)—elimination of crosswalk lines from crossing signs and use of diagonal downward pointing arrow supplemental plaque (W16-7) —January 17, 2011.

Section 7B.12 Reduced Speed School Zone Ahead Sign (S4-5, S4-5a)—15 years from the effective date of the Final Rule for the 2003 MUTCD.

Section 7E.04 Uniform of Adult Crossing Guards and Student Patrols—requirement for high-visibility apparel for adult crossing gnards—5 years from the effective date of the Final Rule for the 2003 MUTCD.

Section 8B.03 Highway-Rail Grade Crossing (Crossbuck) Sign (R15-1) and Number of Tracks Sign (R15-2)—retroreflective strip on crossbuck support—January 17, 2011.

Section 8B.04 Highway-Rail Grade Crossing Advance Warning Signs (W10 Series)—removal of existing W10-6 series signs—January 17, 2006.

Section 8D.07 Traffic Control Signals at or Near Highway-Rail Grade Crossings—pre-signals—10 years from the effective date of the Final Rule for the 2003 MUTCD.

Section 9B.04 Bicycle Lane Signs (R3-17, R3-17a, R3-17b)—deletion of preferential lane symbol (diamond) for bicycle lane signs—January 17, 2006.

Section 9B.17 Bicycle Warning Sign (W11-1)—elimination of crosswalk lines from crossing signs and use of diagonal downward pointing arrow supplemental plaque (W16-7) if at the crossing—January 17, 2011.

Chapter 9C Markings—deletion of preferential lane symbol (diamond) for bicycle pavement markings—January 17, 2007.

Part 10 Traffic Controls for Highway-Light Rail Transit Grade Crossings—automatic gates, flashing-light signals, and blank-out signs—January 17, 2011.

Section 10C.15 Highway-Rail Grade Crossing Advance Warning Signs (W10 Series)—removal of existing W10-6 series signs—January 17, 2006.

Option:

In order for maintenance personnel to understand what to do when replacing a damaged non-compliant traffic control device, agencies may establish a policy regarding whether to replace the device in kind or to replace it with a compliant device.

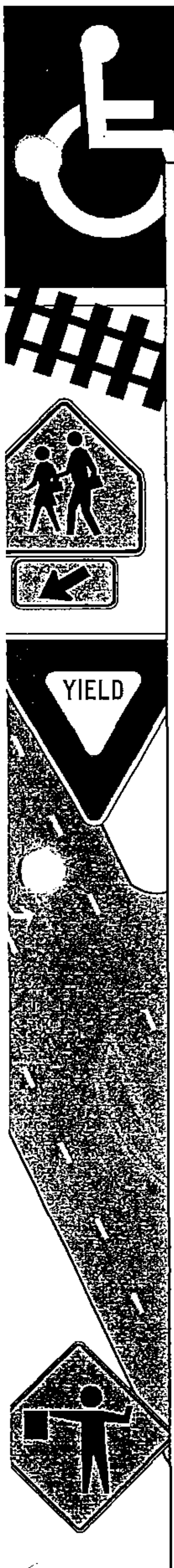
Support:

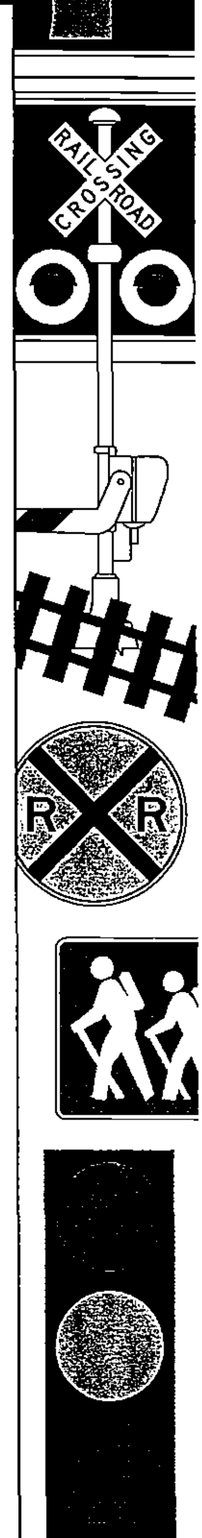
Often it is desirable to upgrade to a compliant device at the time of this maintenance of a damaged device. However, it might be appropriate to replace the damaged non-compliant device in kind at the time of this maintenance activity if engineering judgment indicates that:

A. One compliant device in the midst of a series of adjacent non-compliant devices could potentially be confusing to road users; and/or
B. The anticipated schedule for replacement of the whole series of non-compliant devices will result in achieving timely compliance with the MUTCD.

MANUAL ON UNIFORM TRAFFIC CONTROL DEVICES

TABLE OF CONTENTS





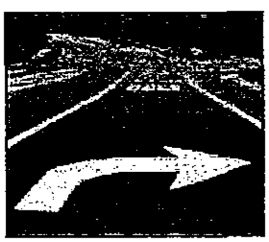
Manual on Uniform Traffic Control Devices

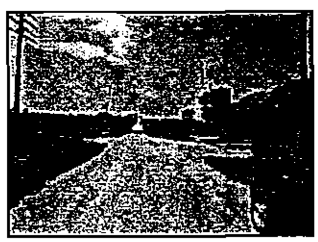
for Streets and Highways

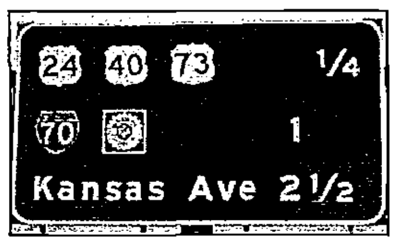
2003 EDITION

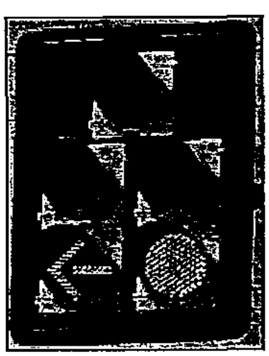
Part 1

General









U.S. Department of Transportation
Federal Highway Administration

PART 1. GENERAL

TABLE OF CONTENTS

CHAPTER 1A. GENERAL

Section 1A.01 Purpose of Traffic Control Devices

Support:

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 and highways throughout the Nation.

Traffic control devices notify road users of regulations and provide warning and guidance needed for the reasonably safe, uniform, and efficient operation of all elements of the traffic stream.

Standard:

Traffic control devices or their supports shall not bear any advertising message or any other message that is not related to traffic control.

Support:

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:

This Manual contains the basic principles that govern the design and use of traffic control devices for all streets and highways open to public travel regardless of type or class or the public agency 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:

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.*

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:

The definition of the word "speed" varies depending on its use. The definitions of specific speed terms are contained in Section 1A.13.

Guidance:

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 consistent with the "Uniform Vehicle Code."

The proper use of traffic control devices should provide the reasonable and prudent road user with the information necessary to reasonably safely and lawfully use the streets, highways, pedestrian facilities, and bikeways.

Support:

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:

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.

Standard:

All symbols shall be unmistakably similar to or mirror images of the adopted symbol signs, all of which are shown in the "Standard Highway Signs" book (see Section 1A.11). Symbols and colors shall not be modified unless otherwise stated herein. All symbols and colors for signs not shown in the "Standard Highway Signs" book shall follow the procedures for experimentation and change described in Section 1A.10.

Guidance:

Aspects of a device's design should be modified only if there is a demonstrated need.

Support:

An example of modifying a device's design would be to modify the Side Road (W2-2) sign to show a second offset intersecting road.

Option:

Highway agencies may develop word message signs to notify road users of special regulations or to warn road users of a situation that might not be readily apparent. Unlike symbol signs and colors, new word message signs may be used without the need for experimentation. With the exception of symbols and colors, minor modifications in the specific design elements of a device may be made provided the essential appearance characteristics are preserved. Although the standard design of symbol signs cannot be modified, it may be appropriate to change the orientation of the symbol to better reflect the direction of travel.

Section 1A.04 Placement and Operation of Traffic Control Devices

Guidance:

Placement of a traffic control device should be within the road user's view so that adequate visibility is provided. To aid in conveying the proper meaning, the traffic control device should be appropriately positioned with respect to the location, object, or situation to which it applies. The location and legibility of the traffic control device should be such that a road user has adequate time to make the proper response in both day and night conditions.

Traffic control devices should be placed and operated in a uniform and consistent manner.

Unnecessary traffic control devices should be removed. The fact that a device is in good physical condition should not be a basis for deferring needed removal or change.

Section 1A.05 Maintenance of Traffic Control Devices

Guidance:

Functional maintenance of traffic control devices should be used to determine if certain devices need to be changed to meet current traffic conditions.

Physical maintenance of traffic control devices should be performed to retain the legibility and visibility of the device, and to retain the proper functioning of the device.

Support:

Clean, legible, properly mounted devices in good working condition command the respect of road users.

Section 1A.06 Uniformity of Traffic Control Devices

Support:

Uniformity of devices simplifies the task of the road user because it aids in recognition and understanding, thereby reducing perception/reaction time. Uniformity assists road users, law enforcement officers, and traffic courts by giving everyone the same interpretation. Uniformity assists public highway officials through efficiency in manufacture, installation, maintenance, and administration. Uniformity means treating similar situations in a similar way. The use of uniform traffic control devices does not, in itself, constitute uniformity. A standard device used where it is not appropriate is as objectionable as a nonstandard device; in fact, this might be worse, because such misuse might result in disrespect at those locations where the device is needed and appropriate.

Section 1A.07 Responsibility for Traffic Control Devices

Standard:

The responsibility for the design, placement, operation, maintenance, and uniformity of traffic control devices shall rest with the public agency or the official having jurisdiction. 23 CFR 655.603 adopts the Manual on Uniform Traffic Control Devices as the national standard for all traffic control devices installed on any street, highway, or bicycle trail open to public travel. When a State or other Federal agency

manual or supplement is required, that manual or supplement shall be in substantial conformance with the national Manual on Uniform Traffic Control Devices.

23 CFR 655.603 also states that traffic control devices on all streets and highways open to public travel in each State shall be in substantial conformance with standards issued or endorsed by the Federal Highway Administrator.

Support:

The "Uniform Vehicle Code" (see Section 1A.11) has the following provision in Section 15-104 for the adoption of a uniform Manual:

> "(a)The [State Highway Agency] shall adopt a manual and specification for a uniform system of traffic control devices consistent with the provisions of this code for use upon highways within this State. Such uniform system shall correlate with and so far as possible conform to the system set forth in the most recent edition of the Manual on Uniform Traffic Control Devices for Streets and Highways, and other standards issued or endorsed by the Federal Highway Administrator."
>
> "(b) The Manual adopted pursuant to subsection (a) shall have the force and effect of law."

Additionally, States are encouraged to adopt Section 15-116 of the "Uniform Vehicle Code," which states that, "No person shall install or maintain in any area of private property used by the public any sign, signal, marking or other device intended to regulate, warn, or guide traffic unless it conforms with the State manual and specifications adopted under Section 15-104."

Section 1A.08 Authority for Placement of Traffic Control Devices

Standard:

Traffic control devices, advertisements, announcements, and other signs or messages within the highway right-of-way shall be placed only as authorized by a public authority or the official having jurisdiction, for the purpose of regulating, warning, or guiding traffic.

When the public agency or the official having jurisdiction over a street or highway has granted proper authority, others such as contractors and public utility companies shall be permitted to install temporary traffic control devices in temporary traffic control zones. Such traffic control devices shall conform with the Standards of this Manual.

Guidance:

Any unauthorized traffic control device or other sign or message placed on the highway right-of-way by a private organization or individual constitutes a public nuisance and should be removed. All unofficial or nonessential traffic control devices, signs, or messages should be removed.

Standard:

All regulatory traffic control devices shall be supported by laws, ordinances, or regulations.

Support:

Provisions of this Manual are based upon the concept that effective traffic control depends upon both appropriate application of the devices and reasonable enforcement of the regulations.

Section 1A.09 Engineering Study and Engineering Judgment

Standard:

This Manual describes the application of traffic control devices, but shall not be a legal requirement for their installation.

Guidance:

The decision to use a particular device at a particular location should be made on the basis of either an engineering study or the application of engineering judgment. Thus, while this Manual provides Standards, Guidance, and Options for design and application of traffic control devices, this Manual should not be considered a substitute for engineering judgment.

Engineering judgment should be exercised in the selection and application of traffic control devices, as well as in the location and design of the roads and streets that the devices complement. Jurisdictions with responsibility for traffic control that do not have engineers on their staffs should seek engineering assistance from others, such as the State transportation agency, their County, a nearby large City, or a traffic engineering consultant.

Section 1A.10 Interpretations, Experimentations, Changes, and Interim Approvals

Standard:

Design, application, and placement of traffic control devices other than those adopted in this Manual shall be prohibited unless the provisions of this Section are followed.

Support:

Continuing advances in technology will produce changes in the highway, vehicle, and road user proficiency; therefore, portions of the system of traffic control devices in this Manual will require updating. In addition, unique situations often arise for device applications that might require interpretation or clarification of this Manual. It is important to have a procedure for recognizing these developments and for introducing new ideas and modifications into the system.

Standard:

Requests for any interpretation, permission to experiment, interim approval, or change shall be sent to the Federal Highway Administration (FHWA), Office of Transportation Operations, 400 Seventh Street, SW, HOTO, Washington, DC 20590.

Support:

An interpretation includes a consideration of the application and operation of standard traffic control devices, official meanings of standard traffic control devices, or the variations from standard device designs.

Guidance:

Requests for an interpretation of this Manual should contain the following information:

A. A concise statement of the interpretation being sought;
B. A description of the condition that provoked the need for an interpretation;
C. Any illustration that would be helpful to understand the request; and
D. Any supporting research data that is pertinent to the item to be interpreted.

Support:

Requests to experiment include consideration of field deployment for the purpose of testing or evaluating a new traffic control device, its application or manner of use, or a provision not specifically described in this Manual.

A request for permission to experiment will be considered only when submitted by the public agency or private toll facility responsible for the operation of the road or street on which the experiment is to take place.

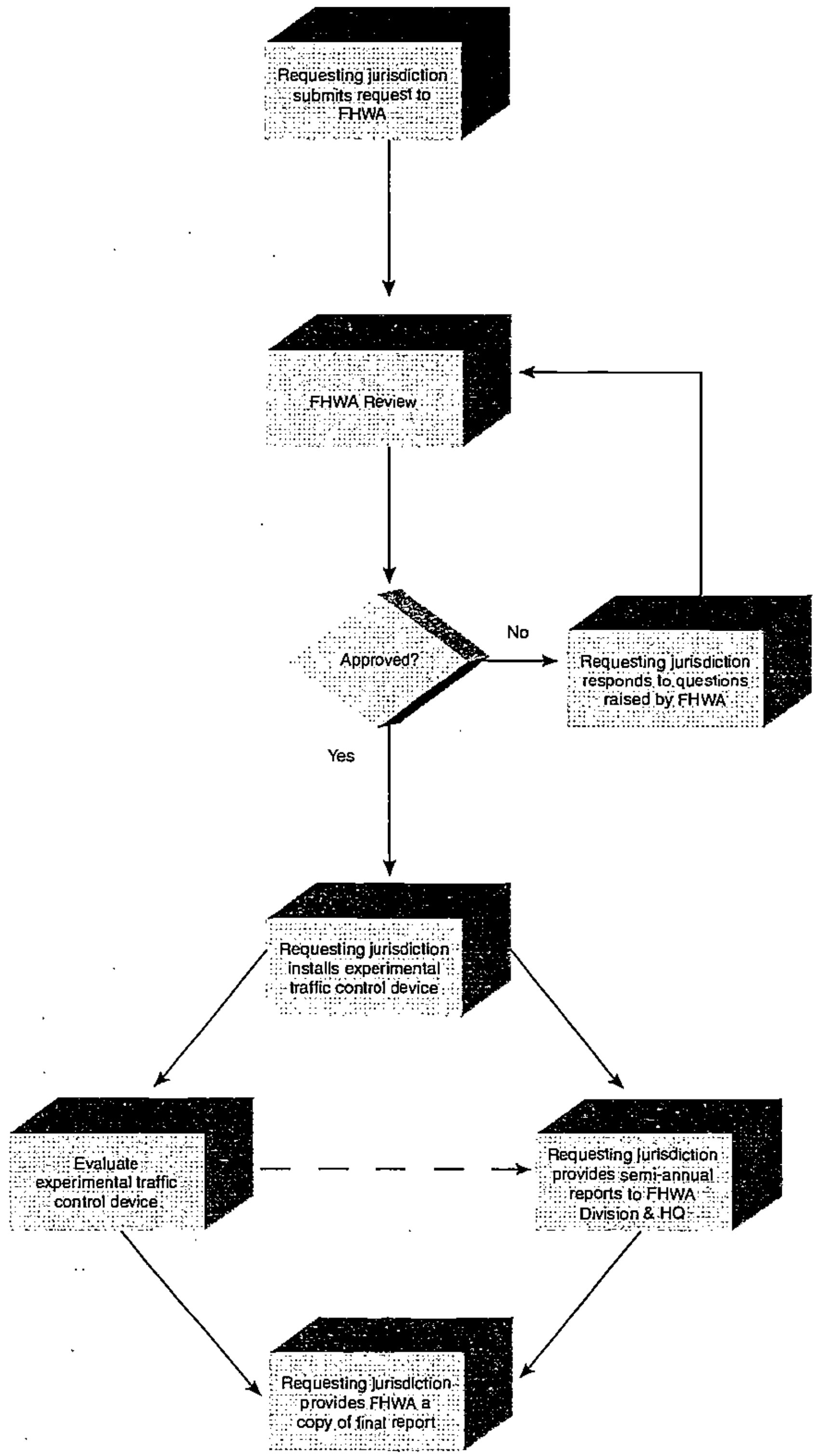
A diagram indicating the process for experimenting with traffic control devices is shown in Figure 1A-1.

Guidance:

The request for permission to experiment should contain the following:

A. A statement indicating the nature of the problem.
B. A description of the proposed change to the traffic control device or application of the traffic control device, how it was developed, the manner in which it deviates from the standard, and how it is expected to be an improvement over existing standards.
C. Any illustration that would be helpful to understand the traffic control device or use of the traffic control device.
D. Any supporting data explaining how the traffic control device was developed, if it has been tried, in what ways it was found to be adequate or inadequate, and how this choice of device or application was derived.
E. A legally binding statement certifying that the concept of the traffic control device is not protected by a patent or copyright. (An example of a traffic control device concept would be countdown pedestrian signals in general. Ordinarily an entire general concept would not be patented or copyrighted, but if it were it would not be acceptable for experimentation unless the patent or copyright owner signs a waiver of rights acceptable to the FHWA. An example of a patented or copyrighted specific device within the general concept of countdown pedestrian signals would be a manufacturer's design for its specific brand of countdown signal, including the design details of the housing or electronics that are unique to that manufacturer's product. As long as the general concept is not patented or copyrighted, it is acceptable for experimentation to incorporate the use of one or more patented devices of one or several manufacturers.)
F. The time period and location(s) of the experiment.
G. A detailed research or evaluation plan that must provide for close monitoring of the experimentation, especially in the early stages of its field implementation. The evaluation plan should include before and after studies as well as quantitative data describing the performance of the experimental device.

Figure 1A-1. Example of Process for Requesting and Conducting Experimentations for New Traffic Control Devices



H. An agreement to restore the site of the experiment to a condition that complies with the provisions of this Manual within 3 months following the end of the time period of the experiment. This agreement must also provide that the agency sponsoring the experimentation will terminate the experimentation at any time that it determines significant safety concerns are directly or indirectly attributable to the experimentation. The FHWA's Office of Transportation Operations has the right to terminate approval of the experimentation at any time if there is an indication of safety concerns. If, as a result of the experimentation, a request is made that this Manual be changed to include the device or application being experimented with, the device or application will be permitted to remain in place until an official rulemaking action has occurred.
I. An agreement to provide semiannual progress reports for the duration of the experimentation, and an agreement to provide a copy of the final results of the experimentation to the FHWA's Office of Transportation Operations within 3 months following completion of the experimentation. The FHWA's Office of Transportation Operations has the right to terminate approval of the experimentation if reports are not provided in accordance with this schedule.

Support:

A change includes consideration of a new device to replace a present standard device, an additional device to be added to the list of standard devices, or a revision to a traffic control device application or placement criteria.

Guidance:

Requests for a change to this Manual should contain the following information:

A. A statement indicating what change is proposed;
B. Any illustration that would be helpful to understand the request; and
C. Any supporting research data that is pertinent to the item to be reviewed.

Support:

Requests for interim approval include consideration of allowing interim use, pending official rulemaking, of a new traffic control device, a revision to the application or manner of use of an existing traffic control device, or a provision not specifically described in this Manual. If granted, interim approval will result in the traffic control device or application being placed into the next scheduled rulemaking process for revisions to this Manual. The device or application will be permitted to remain in place, under any conditions established in the interim approval, until an official rulemaking action has occurred.

Interim approval is considered based on the results of successful experimentation, results of analytical or laboratory studies, and/or review of non-U.S. experience with a traffic control device or application. Interim approval considerations include an assessment of relative risks, benefits, and costs. Interim approval includes conditions that jurisdictions agree to comply with in order to use the traffic control device or application until an official rulemaking action has occurred.

Guidance:

The request for permission to place a traffic control device under interim approval should contain the following:

A. A statement indicating the nature of the problem.
B. A description of the proposed change to the traffic control device or application of the traffic control device, how it was developed, the manner in which it deviates from the standard, and how it is expected to be an improvement over existing standards.
C. The location(s) where it will be used and any illustration that would be helpful to understand the traffic control device or use of the traffic control device.
D. A legally-binding statement certifying that the concept of the traffic control device is not protected by a patent or copyright. (An example of a traffic control device concept would be countdown pedestrian signals in general. Ordinarily an entire general concept would not be patented or copyrighted, but if it were it would not be acceptable for interim approval unless the patent or copyright owner signs a waiver of rights acceptable to the FHWA. An example of a patented or copyrighted specific device within the general concept of countdown pedestrian signals would be a manufacturer's design for its specific brand of countdown signal, including the design details of the housing or electronics that are unique to that manufacturer's product. Interim approval of a specific patented or copyrighted product is not acceptable.)
E. A detailed completed research or evaluation on this traffic control device.
F. An agreement to restore the site(s) of the interim approval to a condition that complies with the provisions in this Manual within 3 months following the issuance of a final rule on this traffic control device. This agreement must also provide that the agency sponsoring the interim approval will terminate use of the device or application installed under the interim approval at any time that it determines significant safety concerns are directly or indirectly attributable to the device or application. The FHWA's Office of Transportation Operations has the right to terminate the interim approval at any time if there is an indication of safety concerns.

Option:

A State may submit a request for interim approval for all jurisdictions in that State, as long as the request contains the information listed in the Guidance above.

Standard:

Once an interim approval is granted to any jurisdiction for a particular traffic control device or application, subsequent jurisdictions shall be granted interim approval for that device or application by submitting a letter to the FHWA Office of Transportation Operations indicating they will abide by Item F above and the specific conditions contained in the original interim approval.

A local jurisdiction using a traffic control device or application under an interim approval that was granted either directly to that jurisdiction or on a statewide basis based on the State's request shall inform the State of the locations of such use.

Support:

A diagram indicating the process for incorporating new traffic control devices into this Manual is shown in Figure 1A-2.

Procedures for revising this Manual are set out in the Federal Register of June 30, 1983 (48 FR 30145).

For additional information concerning interpretations, experimentation, changes, or interim approvals, write to the FHWA, 400 Seventh Street, SW, HOTO, Washington, DC 20590, or visit the MUTCD website at http://mutcd.fhwa.dot.gov.

Section 1A.11 Relation to Other Publications

Standard:

To the extent that they are incorporated by specific reference, the latest editions of the following publications, or those editions specifically noted, shall be a part of this Manual: "Standard Highway Signs" book (FHWA); and "Color Specifications for Retroreflective Sign and Pavement Marking Materials" (appendix to subpart F of Part 655 of Title 23 of the Code of Federal Regulations).

Support:

The "Standard Highway Signs" book includes standard alphabets and symbols for highway signs and pavement markings.

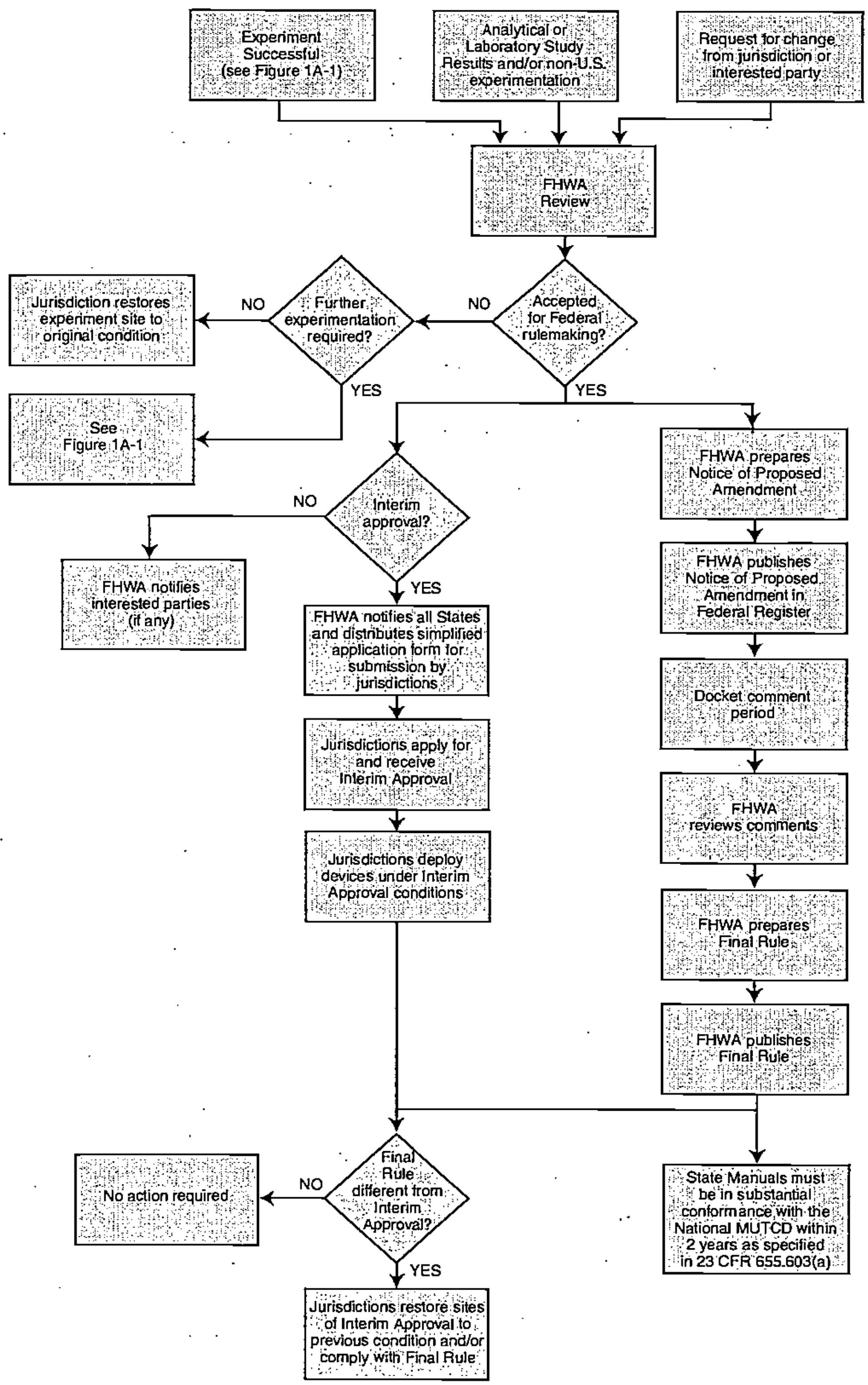
For information about the above publications, visit the Federal Highway Administration's MUTCD website at http://mutcd.fhwa.dot.gov, or write to the FHWA, 400 Seventh Street, SW, HOTO, Washington, DC 20590.

The publication entitled "Federal-Aid Highway Program Guidance on High Occupancy Vehicle (HOV) Lanes" is available at http://www.fhwa.dot.gov/operations/hovguide01.htm, or write to the FHWA, 400 Seventh Street, SW, HOTM, Washington, DC 20590.

Other publications that are useful sources of information with respect to use of this Manual are listed below. See Page i of this Manual for ordering information for the following publications:

1. "A Policy on Geometric Design of Highways and Streets," 2001 Edition (American Association of State Highway and Transportation Officials—AASHTO)
2. "Guide for the Development of Bicycle Facilities," 1999 Edition (AASHTO)
3. "Guide to Metric Conversion," 1993 Edition (AASHTO)
4. "Guidelines for the Selection of Supplemental Guide Signs for Traffic Generators Adjacent to Freeways," 2001 Edition (AASHTO)
5. "List of Control Cities for Use in Guide Signs on Interstate Highways," 2001 Edition (AASHTO)
6. "Roadside Design Guide," 2001 Edition (AASHTO)
7. "Standard Specifications for Movable Highway Bridges," 1988 Edition (AASHTO)
8. "Traffic Engineering Metric Conversion Folders— Addendum to the Guide to Metric Conversion," 1993 Edition (AASHTO)
9. "2000 AREMA Communications & Signals Manual," American Railway Engineering & Maintenance-of-Way Association (AREMA)
10. "Designing Sidewalks and Trails for Access—Part 2—Best Practices Design Guide," 2001 Edition (FHWA) [Publication No. FHWA-EP-01-027]
11. "Practice for Roadway Lighting," RP-8, 2001, Illuminating Engineering Society (IES)
12. "Safety Guide for the Prevention of Radio Frequency Radiation Hazards in the Use of Commercial Electric Detonators (Blasting Caps)," Safety Library Publication No. 20, Institute of Makers of Explosives
13. "American National Standard for High-Visibility Safety Apparel," (ANSI/ISEA 107-1999), 1999 Edition, ISEA - The Safety Equipment Association.
14. "Manual of Traffic Signal Design," 1998 Edition (Institute of Transportation Engineers—ITE)

Figure 1A-2. Example of Process for Incorporating New Traffic Control Devices into the MUTCD



15. "Manual of Transportation Engineering Studies," 1994 Edition (ITE)
16. "Pedestrian Traffic Control Signal Indications," 1985 Edition (ITE)
17. "Preemption of Traffic Signals at or Near Railroad Grade Crossings with Active Warning Devices," (ITE)
18. "Purchase Specification for Flashing and Steady Burn Warning Lights," 1981 Edition (ITE)
19. "School Trip Safety Program Guidelines," 1984 Edition (ITE)
20. "Traffic Detector Handbook," 1991 Edition (ITE)
21. "Traffic Engineering Handbook," 1999 Edition (ITE)
22. "Traffic Signal Lamps," 1980 Edition (ITE)
23. "Traffic Control Devices Handbook," 2001 Edition (ITE)
24. "Vehicle Traffic Control Signal Heads," Part 1—1985 Edition; Part 2—1998 Edition (ITE)
25. "Uniform Vehicle Code (UVC) and Model Traffic Ordinance," 2000 Edition (National Committee on Uniform Traffic Laws and Ordinances)
26. "Occupational Safety and Health Administration Regulations (Standards - 29 CFR), General Safety and Health Provisions - 1926.20," amended June 30, 1993, Occupational Safety and Health Administration (OSHA)
27. "Highway Capacity Manual," 2000 Edition (Transportation Research Board—TRB)
28. "Recommended Procedures for the Safety Performance Evaluation of Highway Features," (NCHRP Report 350), 1993 Edition (Transportation Research Board - TRB)
29. "Accessible Pedestrian Signals," A-37, 1998 Edition, U.S. Architectural and Transportation Barriers Compliance Board (The U.S. Access Board)
30. "Building a True Community—Final Report—Public Rights-of-Way Access Advisory Committee (PRWAAC)," 2001 Edition (The U.S. Access Board)
31. "The Americans with Disabilities Act Accessibility Guidelines for Buildings and Facilities (ADAAG)," July 1998 Edition (The U.S. Access Board)
32. "Highway-Rail Intersection Architecture," U.S. Department of Transportation, Federal Railroad Administration (USDOT/FRA)

Section 1A.12 Color Code

Support:

The following color code establishes general meanings for 10 colors of a total of 13 colors that have been identified as being appropriate for use in conveying traffic control information. Central values and tolerance limits for each color are available from the Federal Highway Administration, 400 Seventh Street, SW, HOTO, Washington, DC 20590, and at FHWA's MUTCD website at http://mutcd.fhwa.dot.gov.

The three colors for which general meanings have not yet been assigned are being reserved for future applications that will be determined only by FHWA after consultation with the States, the engineering community, and the general public. The meanings described in this Section are of a general nature. More specific assignments of colors are given in the individual Parts of this Manual relating to each class of devices.

Standard:

The general meaning of the 13 colors shall be as follows:

A. Black—regulation
B. Blue—road user services guidance, tourist information, and evacuation route
C. Brown—recreational and cultural interest area guidance
D. Coral—unassigned
E. Fluorescent Pink—incident management
F. Fluorescent Yellow-Green—pedestrian warning, bicycle warning, playground warning, school bus and school warning
G. Green—indicated movements permitted, direction guidance
H. Light Blue—unassigned
I. Orange—temporary traffic control
J. Purple—unassigned
K. Red—stop or prohibition
L. White—regulation
M. Yellow—warning

Section 1A.13 Definitions of Words and Phrases in This Manual

Standard:

Unless otherwise defined herein, or in the other Parts of this Manual, definitions contained in the most recent edition of the "Uniform Vehicle Code," "AASHTO Transportation Glossary (Highway Definitions)," and other publications specified in Section 1A.11 are also incorporated and adopted by reference.

The following words and phrases, when used in this Manual, shall have the following meanings:

1. **Active Grade Crossing Warning System—the flashing-light signals, with or without warning gates, together with the necessary control equipment used to inform road users of the approach or presence of trains at highway-rail or highway-light rail transit grade crossings.**
2. **Approach—all lanes of traffic moving towards an intersection or a midblock location from one direction, including any adjacent parking lane(s).**
3. **Arterial Highway (Street)—a general term denoting a highway primarily used by through traffic, usually on a continuous route or a highway designated as part of an arterial system.**
4. **Average Day—a day representing traffic volumes normally and repeatedly found at a location. Where volumes are primarily influenced by employment, the average day is typically a weekday. When volumes are primarily influenced by entertainment or recreation, the average day is typically a weekend day.**
5. **Beacon—a highway traffic signal with one or more signal sections that operates in a flashing mode.**
6. **Bicycle—a pedal-powered vehicle upon which the human operator sits.**
7. **Bicycle Lane—a portion of a roadway that has been designated by signs and pavement markings for preferential or exclusive use by bicyclists.**
8. **Centerline Markings—the yellow pavement marking line(s) that delineates the separation of traffic lanes that have opposite directions of travel on a roadway. These markings need not be at the geometrical center of the pavement.**
9. **Changeable Message Sign—a sign that is capable of displaying more than one message, changeable manually, by remote control, or by automatic control. These signs are referred to as Dynamic Message Signs in the National Intelligent Transportation Systems (ITS) Architecture.**
10. **Channelizing Line Marking—a wide or double solid white line used to form islands where traffic in the same direction of travel is permitted on both sides of the island.**
11. **Circular Intersection—an intersection that has an island, generally circular in design, located in the center of the intersection where traffic passes to the right of the island. Circular intersections include roundabouts, rotaries, and traffic circles.**
12. **Clear Zone—the total roadside border area, starting at the edge of the traveled way, that is available for an errant driver to stop or regain control of a vehicle. This area might consist of a shoulder, a recoverable slope, and/or a nonrecoverable, traversable slope with a clear run-out area at its toe.**
13. **Concurrent Flow HOV Lane—an HOV lane that is operated in the same direction as the adjacent mixed flow lanes, separated from the adjacent general purpose freeway lanes by a standard lane stripe, painted buffer, or barrier.**
14. **Contraflow Lane—a lane operating in a direction opposite to the normal flow of traffic designated for peak direction of travel during at least a portion of the day. Contraflow lanes are usually separated from the off-peak direction lanes by plastic pylons, or by moveable or permanent barrier.**
15. **Conventional Road—a street or highway other than a low-volume road (as defined in Section 5A.01), expressway, or freeway.**
16. **Collector Highway—a term denoting a highway that in rural areas connects small towns and local highways to arterial highways, and in urban areas provides land access and traffic circulation within residential, commercial, and business areas and connects local highways to the arterial highways.**
17. **Crashworthy—a characteristic of a roadside appurtenance that has been successfully crash tested in accordance with a national standard such as the National Cooperative Highway Research Program Report 350, "Recommended Procedures for the Safety Performance Evaluation of Highway Features."**

18. Crosswalk—(a) that part of a roadway at an intersection included within the connections of the lateral lines of the sidewalks on opposite sides of the highway measured from the curbs or in the absence of curbs, from the edges of the traversable roadway, and in the absence of a sidewalk on one side of the roadway, the part of a roadway included within the extension of the lateral lines of the sidewalk at right angles to the centerline; (b) any portion of a roadway at an intersection or elsewhere distinctly indicated as a pedestrian crossing by lines on the surface, which may be supplemented by contrasting pavement texture, style, or color.
19. Crosswalk Lines—white pavement marking lines that identify a crosswalk.
20. Delineator—a retroreflective device mounted on the roadway surface or at the side of the roadway in a series to indicate the alignment of the roadway, especially at night or in adverse weather.
21. Detectable—having a continuous edge within 150 mm (6 in) of the surface so that pedestrians who have visual disabilities can sense its presence and receive usable guidance information.
22. Dynamic Envelope—the clearance required for the train and its cargo overhang due to any combination of loading, lateral motion, or suspension failure.
23. Edge Line Markings—white or yellow pavement marking lines that delineate the right or left edge(s) of a traveled way.
24. End-of-Roadway Marker—a device used to warn and alert road users of the end of a roadway in other than temporary traffic control zones.
25. Engineering Judgment—the evaluation of available pertinent information, and the application of appropriate principles, Standards, Guidance, and practices as contained in this Manual and other sources, for the purpose of deciding upon the applicability, design, operation, or installation of a traffic control device. Engineering judgment shall be exercised by an engineer, or by an individual working under the supervision of an engineer, through the application of procedures and criteria established by the engineer. Documentation of engineering judgment is not required.
26. Engineering Study—the comprehensive analysis and evaluation of available pertinent information, and the application of appropriate principles, Standards, Guidance, and practices as contained in this Manual and other sources, for the purpose of deciding upon the applicability, design, operation, or installation of a traffic control device. An engineering study shall be performed by an engineer, or by an individual working under the supervision of an engineer, through the application of procedures and criteria established by the engineer. An engineering study shall be documented.
27. Expressway—a divided highway with partial control of access.
28. Flashing—an operation in which a signal indication is turned on and off repetitively.
29. Freeway—a divided highway with full control of access.
30. Guide Sign—a sign that shows route designations, destinations, directions, distances, services, points of interest, or other geographical, recreational, or cultural information.
31. High Occupancy Vehicle (HOV)—a motor vehicle carrying at least two or more persons, including carpools, vanpools, and buses.
32. Highway—a general term for denoting a public way for purposes of travel by vehicular travel, including the entire area within the right-of-way.
33. Highway-Rail Grade Crossing—the general area where a highway and a railroad's right-of-way cross at the same level, within which are included the railroad tracks, highway, and traffic control devices for highway traffic traversing that area.
34. Highway Traffic Signal—a power-operated traffic control device by which traffic is warned or directed to take some specific action. These devices do not include signals at toll plazas, power-operated signs, illuminated pavement markers, warning lights (see Section 6F.78), or steady burning electric lamps.
35. HOV Lane—any preferential lane designated for exclusive use by high-occupancy vehicles for all or part of a day—including a designated lane on a freeway, other highway, street, or independent roadway on a separate right-of-way.
36. Inherently Low Emission Vehicle (ILEV)—any kind of vehicle that is certified by the U.S. Environmental Protection Agency and that because of inherent properties of the fuel system design, will not have significant evaporative emissions, even if its evaporative emission control system has failed.
37. Interchange—a system of interconnecting roadways providing for traffic movement between two or more highways that do not intersect at grade.
38. Intermediate Interchange—an interchange with an urban or rural route that is not a major or minor interchange as defined herein.

39. Intersection—(a) the area embraced within tbe prolongation or connection of the lateral curb lines, or if none, the lateral boundary lines of the roadways of two highways tbat join one another at, or approximately at, rigbt angles, or the area within which vehicles traveling on different highways tbat join at any other angle might come into conflict; (b) the junction of an alley or driveway with a roadway or highway shall not constitute an intersection.
40. Island—a defined area between traffic lanes for control of vehicular movements or for pedestrian refuge. It includes all end protection and approach treatments. Within an intersection area, a median or an outer separation is considered to be an island.
41. Lane Line Markings—white pavement marking lines tbat delineate the separation of traffic lanes that have the same direction of travel on a roadway.
42. Lane-Use Control Signal—a signal face displaying indications to permit or prohibit the use of specific lanes of a roadway or to indicate the impending prohibition of sucb use.
43. Legend—see Sign Legend.
44. Logo—a distinctive emblem, symbol, or trademark that identifies a product or service.
45. Longitudinal Markings—pavement markings that are generally placed parallel and adjacent to the flow of traffic such as lane lines, centerlines, edge lines, channelizing lines, and others.
46. Major Interchange—an interchange with anotber freeway or expressway, or an interchange with a high-volume multi-lane highway, principal urban arterial, or major rural route where the interchanging traffic is heavy or includes many road users unfamiliar with the area.
47. Major Street—the street normally carrying the higher volume of vehicular traffic.
48. Median—the area between two roadways of a divided bighway measured from edge of traveled way to edge of traveled way. The median excludes turn lanes. The median width might be different between intersections, interchanges, and at opposite approaches of the same intersection.
49. Minor Interchange—an interchange where traffic is local and very light, such as interchanges with land service access roads. Where the sum of tbe exit volumes is estimated to be lower than 100 vehicles per day in the design year, the interchange is classified as local.
50. Minor Street—the street normally carrying the lower volume of vehicular traffic.
51. Object Marker—a device used to mark obstructions within or adjacent to the roadway.
52. Occupancy Requirement—any restriction that regulates the use of a facility for any period of the day based on a specified number of persons in a vehicle.
53. Occupant—a person driving or riding in a car, truck, bus, or other vehicle.
54. Paved—a bituminous surface treatment, mixed bituminous concrete, or Portland cement concrete roadway surface that has both a structural (weight bearing) and a sealing purpose for the roadway.
55. Pedestrian—a person afoot, in a wheelcbair, on skates, or on a skateboard.
56. Pedestrian Facilities—a general term denoting improvements and provisions made to accommodate or encourage walking.
57. Platoon—a group of vehicles or pedestrians traveling together as a group, either voluntarily or involuntarily, because of traffic signal controls, geometrics, or other factors.
58. Principal Legend—place names, street names, and route numbers placed on guide signs.
59. Public Road—any road or street under the jurisdiction of and maintained by a public agency and open to public travel.
60. Raised Pavement Marker—a device with a height of at least 10 mm (0.4 in) mounted on or in a road surface that is intended to be used as a positioning guide or to supplement or substitute for pavement markings or to mark the position of a fire hydrant.
61. Regulatory Sign—a sign that gives notice to road users of traffic laws or regulations.
62. Retroreflectivity—a property of a surface that allows a large portion of the light coming from a point source to be returned directly back to a point near its origin.
63. Right-of-Way [Assignment]—the permitting of vehicles and/or pedestrians to proceed in a lawful manner in preference to other vehicles or pedestrians by the display of sign or signal indications.
64. Road—see Roadway.
65. Roadway—that portion of a highway improved, designed, or ordinarily used for vehicular travel and parking lanes, but exclusive of the sidewalk, berm, or shoulder even though sucb sidewalk, berm, or shoulder is used by persons riding bicycles or other human-powered vehicles. In the event a highway includes two or more separate roadways, the term roadway as used herein shall refer to any such roadway separately, but not to all such roadways collectively.
66. Roadway Network—a geographical arrangement of intersecting roadways.
67. Road User—a vehicle operator, bicyclist, or pedestrian within the highway, including persons with disabilities.

68. Roundabout Intersection—a circular intersection with yield control of all entering traffic, channelized approaches, and appropriate geometric curvature, such that travel speeds on the circulatory roadway are typically less than 50 km/h (30 mph).
69. Rumble Strip—a series of intermittent, narrow, transverse areas of rough-textured, slightly raised, or depressed road surface that is installed to alert road users to unusual traffic conditions.
70. Rural Highway—a type of roadway normally characterized by lower volumes, higher speeds, fewer turning conflicts, and less conflict with pedestrians.
71. Shared Roadway—a roadway that is officially designated and marked as a bicycle route, but which is open to motor vehicle travel and upon which no bicycle lane is designated.
72. Shared-Use Path—a bikeway outside the traveled way and physically separated from motorized vehicular traffic by an open space or barrier and either within the highway right-of-way or within an independent alignment. Shared-use paths are also used by pedestrians (including skaters, users of manual and motorized wheelchairs, and joggers) and other authorized motorized and non-motorized users.
73. Sidewalk—that portion of a street between the curb line, or the lateral line of a roadway, and the adjacent property line or on easements of private property that is paved or improved and intended for use by pedestrians.
74. Sign—any traffic control device that is intended to communicate specific information to road users through a word or symbol legend. Signs do not include traffic control signals, pavement markings, delineators, or channelization devices.
75. Sign Assembly—a group of signs, located on the same support(s), that supplement one another in conveying information to road users.
76. Sign Illumination—either internal or external lighting that shows similar color by day or night. Street or highway lighting shall not be considered as meeting this definition.
77. Sign Legend—all word messages, logos, and symbol designs that are intended to convey specific meanings.
78. Sign Panel—a separate panel or piece of material containing a word or symbol legend that is affixed to the face of a sign.
79. Speed—speed is defined based on the following classifications:
    (a) Advisory Speed—a recommended speed for all vehicles operating on a section of highway and based on the highway design, operating characteristics, and conditions.
    (b) Average Speed—the summation of the instantaneous or spot-measured speeds at a specific location of vehicles divided by the number of vehicles observed.
    (c) Design Speed—a selected speed used to determine the various geometric design features of a roadway.
    (d) 85th-Percentile Speed—The speed at or below which 85 percent of the motor vehicles travel.
    (e) Operating Speed—a speed at which a typical vehicle or the overall traffic operates. Operating speed might be defined with speed values such as the average, pace, or 85th-percentile speeds.
    (f) Pace Speed—the highest speed within a specific range of speeds that represents more vehicles than in any other like range of speed. The range of speeds typically used is 10 km/h or 10 mph.
    (g) Posted Speed—the speed limit determined by law and shown on Speed Limit signs.
    (h) Statutory Speed—a speed limit established by legislative action that typically is applicable for highways with specified design, functional, jurisdictional and/or location characteristic and is not necessarily shown on Speed Limit signs.
80. Speed Limit—the maximum (or minimum) speed applicable to a section of highway as established by law.
81. Speed Measurement Marking—a white transverse pavement marking placed on the roadway to assist the enforcement of speed regulations.
82. Speed Zone—a section of highway with a speed limit that is established by law but which might be different from a legislatively specified statutory speed limit.
83. Stop Line—a solid white pavement marking line extending across approach lanes to indicate the point at which a stop is intended or required to be made.
84. Street—see Highway.
85. Temporary Traffic Control Zone—an area of a highway where road user conditions are changed because of a work zone or incident by the use of temporary traffic control devices, flaggers, uniformed law enforcement officers, or other authorized personnel.
86. Traffic—pedestrians, bicyclists, ridden or herded animals, vehicles, streetcars, and other conveyances either singularly or together while using any highway for purposes of travel.

87. **Traffic Control Device—a sign, signal, marking, or other device used to regulate, warn, or guide traffic, placed on, over, or adjacent to a street, highway, pedestrian facility, or shared-use path by authority of a public agency having jurisdiction.**
88. **Traffic Control Signal (Traffic Signal)—any highway traffic signal by which traffic is alternately directed to stop and permitted to proceed.**
89. **Train—one or more locomotives coupled, with or without cars, that operates on rails or tracks and to which all other traffic must yield the right-of-way by law at highway-rail grade crossings.**
90. **Transverse Markings—pavement markings that are generally placed perpendicular and across the flow of traffic such as shoulder markings, word and symbol markings, stop lines, crosswalk lines, speed measurement markings, parking space markings, and others.**
91. **Traveled Way—the portion of the roadway for the movement of vehicles, exclusive of the shoulders, berms, sidewalks, and parking lanes.**
92. **Urban Street—a type of street normally characterized by relatively low speeds, wide ranges of traffic volumes, narrower lanes, frequent intersections and driveways, significant pedestrian traffic, and more businesses and houses.**
93. **Vehicle—every device in, upon, or by which any person or property can be transported or drawn upon a highway, except trains and light rail transit operating in exclusive or semiexclusive alignments. Light rail transit operating in a mixed-use alignment, to which other traffic is not required to yield the right-of-way by law, is a vehicle.**
94. **Warning Sign—a sign that gives notice to road users of a situation that might not be readily apparent.**
95. **Warrant—a warrant describes threshold conditions to the engineer in evaluating the potential safety and operational benefits of traffic control devices and is based upon average or normal conditions. Warrants are not a substitute for engineering judgment. The fact that a warrant for a particular traffic control device is met is not conclusive justification for the installation of the device.**
95. **Wrong-Way Arrow—a slender, elongated, white pavement marking arrow placed upstream from the ramp terminus to indicate the correct direction of traffic flow. Wrong-way arrows are intended primarily to warn wrong-way road users that they are going in the wrong direction.**

Section 1A.14 Abbreviations Used on Traffic Control Devices

Standard:

When the word messages shown in Table 1A-1 need to be abbreviated in connection with traffic control devices, the abbreviations shown in Table 1A-1 shall be used.

Guidance:

The abbreviations for the words listed in Table 1A-2 should not be used in connection with traffic control devices unless the prompt word shown in Table 1A-2 either precedes or follows the abbreviation.

Standard:

The abbreviations shown in Table 1A-3 shall not be used in connection with traffic control devices because of their potential to be misinterpreted by road users.

Guidance:

Where multiple abbreviations are permitted in Tables 1A-1 or 1A-2, the same abbreviation should be used throughout a single jurisdiction.

Table 1A-1. Acceptable Abbreviations

Word Message	Standard Abbreviation
Afternoon / Evening	PM
Alternate	ALT
Avenue	AVE, AV
Bicycle	BIKE
Boulevard	BLVD
Cannot	CANT
CB Radio	CB
Center	CNTR
Circle	CIR
Civil Defense	CD
Compressed Natural Gas	CNG
Court	CT
Crossing (other than highway-rail)	XING
Diesel Fuel	D
Do Not	DONT
Drive	DR
East	E
Eastbound	E-BND
Electric Vehicle	EV
Emergency	EMER
Entrance, Enter	ENT
Expressway	EXPWY
Feet	FT
FM Radio	FM
Freeway	FRWY, FWY
Friday	FRI
Hazardous Material	HAZMAT
High Occupancy Vehicle	HOV
Highway	HWY
Highway-Rail Grade Crossing Pavement Marking	RXR
Hospital	H
Hour(s)	HR
Information	INFO
Inherently Low Emission Vehicle	ILEV
It Is	ITS
Junction / Intersection	JCT
Kilogram	kg
Kilometer(s)	km
Kilometers Per Hour	km/h
Lane	LN
Left	LFT
Liquid Propane Gas	LP-GAS
Maintenance	MAINT
Meter(s)	m
Metric Ton	t
Mile(s)	MI
Miles Per Hour	MPH
Minute(s)	MIN
Monday	MON
Morning / Late Night	AM
Normal	NORM
North	N
Northbound	N-BND
Parking	PKING
Parkway	PKWY
Pedestrian	PED
Place	PL
Pounds	LBS
Right	RHT
Road	RD
Saturday	SAT
Service	SERV
Shoulder	SHLDR
Slippery	SLIP
South	S
Southbound	S-BND
Speed	SPD
Street	ST
Sunday	SUN
Telephone	PHONE
Temporary	TEMP
Terrace	TER
Thursday	THURS
Tires With Lugs	LUGS
Tons of Weight	T
Traffic	TRAF
Trail	TR
Travelers	TRAVLRS
Tuesday	TUES
Two-Way Intersection	2-WAY
Two-Wheeled Vehicles	CYCLES
US Numbered Route	US
Vehicle(s)	VEH
Warning	WARN
Wednesday	WED
West	W
Westbound	W-BND
Will Not	WONT

Table 1A-2. Abbreviations That Are Acceptable Only with a Prompt Word

Word	Abbreviation	Prompt Word
Access	ACCS	Road
Ahead	AHD	Fog*
Blocked	BLKD	Lane*
Bridge	BRDG	[Name]*
Chemical	CHEM	Spill
Condition	COND	Traffic*
Congested	CONG	Traffic*
Construction	CONST	Ahead
Downtown	DWNTN	Traffic
Exit	EX, EXT	Next*
Express	EXP	Lane
Frontage	FRNTG	Road
Hazardous	HAZ	Driving
Interstate	I	[Number]
Local	LOC	Traffic
Lower	LWR	Level
Major	MAJ	Accident
Minor	MNR	Accident
Oversized	OVRSZ	Load
Prepare	PREP	To Stop
Pavement	PVMT	Wet*
Quality	QLTY	Air*
Roadwork	RDWK	Ahead [Distance]
Route	RT, RTE	Best*
Township	TWNSHP	Limits
Turnpike	TRNPK	[Name]*
Upper	UPR	Level

* These prompt words should precede the abbreviation

Table 1A-3. Unacceptable Abbreviations

Abbreviation	Intended Word	Common Misinterpretations
ACC	Accident	Access (Road)
CLRS	Clears	Colors
DLY	Delay	Daily
FDR	Feeder	Federal
L	Left	Lane (Merge)
LT	Light (Traffic)	Left
PARK	Parking	Park
POLL	Pollution (Index)	Poll
RED	Reduce	Red
STAD	Stadium	Standard
WRNG	Warning	Wrong

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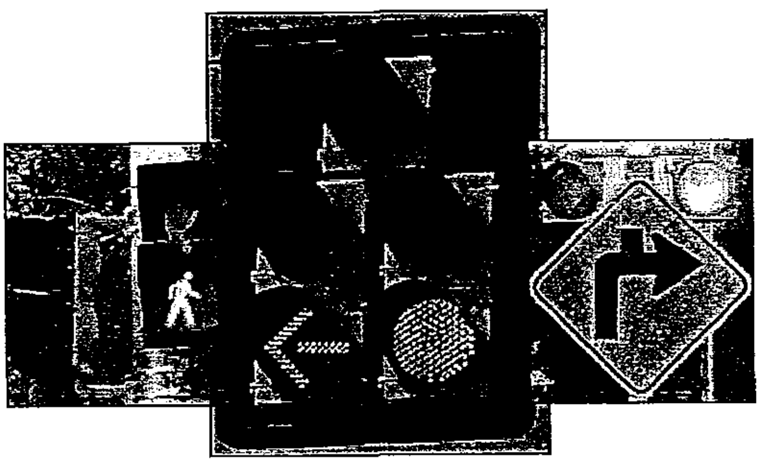


U.S. Department of Transportation
Federal Highway Administration

PART 4. HIGHWAY TRAFFIC SIGNALS

TABLE OF CONTENTS

FIGURES

TABLES

CHAPTER 4A. GENERAL

Section 4A.01 Types

Support:

The following types and uses of highway traffic signals are discussed in Part 4: traffic control signals; pedestrian signals; emergency-vehicle traffic control signals; traffic control signals for one-lane, two-way facilities; traffic control signals for freeway entrance ramps; traffic control signals for movable bridges; lane-use control signals; flashing beacons; and in-roadway lights.

Section 4A.02 Definitions Relating to Highway Traffic Signals

Standard:

The following technical terms, when used in Part 4, shall be defined as follows:

1. **Accessible Pedestrian Signal—a device that communicates information about pedestrian timing in nonvisual format such as audible tones, verbal messages, and/or vibrating surfaces.**
2. **Active Grade Crossing Warning System—the flashing-light signals, with or without warning gates, together with the necessary control equipment used to inform road users of the approach or presence of trains at highway-rail grade crossings or highway-light rail transit grade crossings.**
3. **Actuated Operation—a type of traffic control signal operation in which some or all signal phases are operated on the basis of actuation.**
4. **Actuation—initiation of a change in or extension of a traffic signal phase through the operation of any type of detector.**
5. **Approach—all lanes of traffic moving towards an intersection or a midblock location from one direction, including any adjacent parking lane(s).**
6. **Average Day—a day representing traffic volumes normally and repeatedly found at a location, typically a weekday when volumes are influenced by employment or a weekend day when volumes are influenced by entertainment or recreation.**
7. **Backplate—see Signal Backplate.**
8. **Beacon—a highway traffic signal with one or more signal sections that operates in a flashing mode.**
9. **Conflict Monitor—a device used to detect and respond to improper or conflicting signal indications and improper operating voltages in a traffic controller assembly.**
10. **Controller Assembly—a complete electrical device mounted in a cabinet for controlling the operation of a highway traffic signal.**
11. **Controller Unit—that part of a controller assembly that is devoted to the selection and timing of the display of signal indications.**
12. **Crosswalk—(a) that part of a roadway at an intersection included within the connections of the lateral lines of the sidewalks on opposite sides of the highway measured from the curbs or in the absence of curbs, from the edges of the traversable roadway, and in the absence of a sidewalk on one side of the roadway, the part of a roadway included within the extension of the lateral lines of the sidewalk at right angles to the centerline; (b) any portion of a roadway at an intersection or elsewhere distinctly indicated as a pedestrian crossing by lines on the surface, which may be supplemented by a contrasting pavement texture, style, or color.**
13. **Cycle Length—the time required for one complete sequence of signal indications.**
14. **Dark Mode—the lack of all signal indications at a signalized location. (The dark mode is most commonly associated with power failures, ramp meters, beacons, and some movable bridge signals.)**
15. **Detector—a device used for determining the presence or passage of vehicles or pedestrians.**
16. **Dual-Arrow Signal Section—a type of signal section designed to include both a yellow arrow and a green arrow.**
17. **Emergency Vehicle Traffic Control Signal—a special traffic control signal that assigns the right-of-way to an authorized emergency vehicle.**
18. **Flasher—a device used to turn highway traffic signal indications on and off at a repetitive rate of approximately once per second.**
19. **Flashing—an operation in which a highway traffic signal indication is turned on and off repetitively.**
20. **Flashing Mode—a mode of operation in which at least one traffic signal indication in each vehicular signal face of a highway traffic signal is turned on and off repetitively.**
21. **Full-Actuated Operation—a type of traffic control signal operation in which all signal phases function on the basis of actuation.**

22. Highway Traffic Signal—a power-operated traffic control device by which traffic is warned or directed to take some specific action. These devices do not include signals at toll plazas, power-operated signs, illuminated pavement markers, warning lights (see Section 6F.78), or steady-burning electric lamps.
23. In-Roadway Lights—a special type of highway traffic signal installed in the roadway surface to warn road users that they are approaching a condition on or adjacent to the roadway that might not be readily apparent and might require the road users to slow down and/or come to a stop.
24. Intersection—(a) the area embraced within the prolongation or connection of the lateral curb lines, or if none, the lateral boundary lines of the roadways of two highways that join one another at, or approximately at, right angles, or the area within which vehicles traveling on different highways that join at any other angle might come into conflict; (b) the junction of an alley or driveway with a roadway or highway shall not constitute an intersection.
25. Intersection Control Beacon—a beacon used only at an intersection to control two or more directions of travel.
26. Interval—the part of a signal cycle during which signal indications do not change.
27. Interval Sequence—the order of appearance of signal indications during successive intervals of a signal cycle.
28. Lane-Use Control Signal—a signal face displaying signal indications to permit or prohibit the use of specific lanes of a roadway or to indicate the impending prohibition of such use.
29. Lens—see Signal Lens.
30. Louver—see Signal Louver.
31. Major Street—the street normally carrying the higher volume of vehicular traffic.
32. Malfunction Management Unit—same as Conflict Monitor.
33. Minor Street—the street normally carrying the lower volume of vehicular traffic.
34. Movable Bridge Resistance Gate—a type of traffic gate, which is located downstream of the movable bridge warning gate, that provides a physical deterrent to vehicle and/or pedestrian traffic when placed in the appropriate position.
35. Movable Bridge Signal—a highway traffic signal installed at a movable bridge to notify traffic to stop during periods when the roadway is closed to allow the bridge to open.
36. Movable Bridge Warning Gate—a type of traffic gate designed to warn, but not primarily to block, vehicle and/or pedestrian traffic when placed in the appropriate position.
37. Pedestrian Change Interval—an interval during which the flashing UPRAISED HAND (symbolizing DONT WALK) signal indication is displayed. When a verbal message is provided at an accessible pedestrian signal, the verbal message is "wait."
38. Pedestrian Clearance Time—the time provided for a pedestrian crossing in a crosswalk, after leaving the curb or shoulder, to travel to the far side of the traveled way or to a median.
39. Pedestrian Signal Head—a signal head, which contains the symbols WALKING PERSON (symbolizing WALK) and UPRAISED HAND (symbolizing DONT WALK), that is installed to direct pedestrian traffic at a traffic control signal.
40. Permissive Mode—a mode of traffic control signal operation in which, when a CIRCULAR GREEN signal indication is displayed, left or right turns are permitted to be made after yielding to pedestrians and/or oncoming traffic.
41. Platoon—a group of vehicles or pedestrians traveling together as a group, either voluntarily or involuntarily, because of traffic signal controls, geometrics, or other factors.
42. Preemption Control—the transfer of normal operation of a traffic control signal to a special control mode of operation.
43. Pretimed Operation—a type of traffic control signal operation in which none of the signal phases function on the basis of actuation.
44. Priority Control—a means by which the assignment of right-of-way is obtained or modified.
45. Protected Mode—a mode of traffic control signal operation in which left or right turns are permitted to be made when a left or right GREEN ARROW signal indication is displayed.
46. Pushbutton—a button to activate pedestrian timing.
47. Pushbutton Locator Tone—a repeating sound that informs approaching pedestrians that they are required to push a button to actuate pedestrian timing and that enables pedestrians who have visual disabilities to locate the pushbutton.
48. Ramp Control Signal—a highway traffic signal installed to control the flow of traffic onto a freeway at an entrance ramp or at a freeway-to-freeway ramp connection.
49. Ramp Meter—see Ramp Control Signal.
50. Red Clearance Interval—an optional interval that follows a yellow change interval and precedes the next conflicting green interval.

51. Right-of-Way (Assignment)—the permitting of vehicles and/or pedestrians to proceed in a lawful manner in preference to other vehicles or pedestrians by the display of signal indications.
52. Roadway Network—a geographical arrangement of intersecting roadways.
53. Semiactuated Operation—a type of traffic control signal operation in which at least one, but not all, signal phases function on the basis of actuation.
54. Separate Left-Turn Signal Face—a signal face for controlling a left-turn movement that sometimes displays a different color of circular signal indication than the adjacent through signal faces display.
55. Shared Left-Turn Signal Face—a signal face, for controlling both a left turn movement and the adjacent through movement, that always displays the same color of circular signal indication that the adjacent through signal face or faces display.
56. Signal Backplate—a thin strip of material that extends outward from and parallel to a signal face on all sides of a signal housing to provide a background for improved visibility of the signal indications.
57. Signal Coordination—the establishment of timed relationships between adjacent traffic control signals.
58. Signal Face—that part of a traffic control signal provided for controlling one or more traffic movements on a single approach.
59. Signal Head—an assembly of one or more signal sections.
60. Signal Housing—that part of a signal section that protects the light source and other required components.
61. Signal Indication—the illumination of a signal lens or equivalent device.
62. Signal Lens—that part of the signal section that redirects the light coming directly from the light source and its reflector, if any.
63. Signal Louver—a device that can be mounted inside a signal visor to restrict visibility of a signal indication from the side or to limit the visibility of the signal indication to a certain lane or lanes, or to a certain distance from the stop line.
64. Signal Phase—the right-of-way, yellow change, and red clearance intervals in a cycle that are assigned to an independent traffic movement or combination of movements.
65. Signal Section—the assembly of a signal housing, signal lens, and light source with necessary components to be used for providing one signal indication.
66. Signal System—two or more traffic control signals operating in signal coordination.
67. Signal Timing—the amount of time allocated for the display of a signal indication.
68. Signal Visor—that part of a signal section that directs the signal indication specifically to approaching traffic and reduces the effect of direct external light entering the signal lens.
69. Signal Warrant—a threshold condition that, if found to be satisfied as part of an engineering study, shall result in analysis of other traffic conditions or factors to determine whether a traffic control signal or other improvement is justified.
70. Speed Limit Sign Beacon—a beacon used to supplement a SPEED LIMIT sign.
71. Steady (Steady Mode)—the continuous illumination of a signal indication for the duration of an interval, signal phase, or consecutive signal phases.
72. Stop Beacon—a beacon used to supplement a STOP sign, a DO NOT ENTER sign, or a WRONG WAY sign.
73. Traffic Control Signal (Traffic Signal)—any highway traffic signal by which traffic is alternately directed to stop and permitted to proceed.
74. Vibrotactile Pedestrian Device—a device that communicates, by touch, information about pedestrian timing using a vibrating surface.
75. Visibility-Limited Signal Face or Signal Section—a type of signal face or signal section designed (or shielded, hooded, or louvered) to restrict the visibility of a signal indication from the side, to a certain lane or lanes, or to a certain distance from the stop line.
76. Walk Interval—an interval during which the WALKING PERSON (symbolizing WALK) signal indication is displayed. When a verbal message is provided at an accessible pedestrian signal, the verbal message is "walk sign."
77. Warning Beacon—a beacon used ouly to supplement an appropriate warning or regulatory sign or marker.
78. Yellow Change Interval—the first interval following the green interval during which the yellow signal indication is displayed.

CHAPTER 4B. TRAFFIC CONTROL SIGNALS—GENERAL

Section 4B.01 General

Standard:

A traffic control signal (traffic signal) shall be defined as any highway traffic signal by which traffic is alternately directed to stop and permitted to proceed.

Traffic shall be defined as pedestrians, bicyclists, ridden or herded animals, vehicles, streetcars, and other conveyances either singularly or together while using any highway for purposes of travel.

Support:

Words such as pedestrians and bicyclists are used redundantly in selected sections of Part 4 to encourage sensitivity to these elements of "traffic."

Standards for traffic control signals are important because traffic control signals need to attract the attention of a variety of road users, including those who are older, those with impaired vision, as well as those who are fatigued or distracted, or who are not expecting to encounter a signal at a particular location.

Section 4B.02 Basis of Installation or Removal of Traffic Control Signals

Guidance:

The selection and use of traffic control signals should be based on an engineering study of roadway, traffic, and other conditions.

Support:

A careful analysis of traffic operations, pedestrian and bicyclist needs, and other factors at a large number of signalized and unsignalized locations, coupled with engineering judgment, has provided a series of signal warrants, described in Chapter 4C, that define the minimum conditions under which installing traffic control signals might be justified.

Guidance:

Engineering judgment should be applied in the review of operating traffic control signals to determine whether the type of installation and the timing program meet the current requirements of all forms of traffic.

If changes in traffic patterns eliminate the need for a traffic control signal, consideration should be given to removing it and replacing it with appropriate alternative traffic control devices, if any are needed.

Option:

If the engineering study indicates that the traffic control signal is no longer justified, removal may be accomplished using the following steps:

A. Determine the appropriate traffic control to be used after removal of the signal.
B. Remove any sight-distance restrictions as necessary.
C. Inform the public of the removal study, for example by installing an informational sign (or signs) with the legend TRAFFIC SIGNAL UNDER STUDY FOR REMOVAL at the signalized location in a position where it is visible to all road users.
D. Flash or cover the signal heads for a minimum of 90 days, and install the appropriate stop control or other traffic control devices.
E. Remove the signal if the engineering data collected during the removal study period confirms that the signal is no longer needed. Instead of total removal of the traffic control signal, the poles and cables may remain in place after removal of the signal heads for continued analysis.

Section 4B.03 Advantages and Disadvantages of Traffic Control Signals

Support:

When properly used, traffic control signals are valuable devices for the control of vehicular and pedestrian traffic. They assign the right-of-way to the various traffic movements and thereby profoundly influence traffic flow.

Traffic control signals that are properly designed, located, operated, and maintained will have one or more of the following advantages:

A. They provide for the orderly movement of traffic.
B. They increase the traffic-handling capacity of the intersection if:
   1. Proper physical layouts and control measures are used, and
   2. The signal operational parameters are reviewed and updated (if needed) on a regular basis (as engineering judgment determines that significant traffic flow and/or land use changes have occurred)

to maximize the ability of the traffic control signal to satisfy current traffic demands.
C. They reduce the frequency and severity of certain types of crashes, especially right-angle collisions.
D. They are coordinated to provide for continuous or nearly continuous movement of traffic at a definite speed along a given route under favorable conditions.
E. They are used to interrupt heavy traffic at intervals to permit other traffic, vehicular or pedestrian, to cross.

Traffic control signals are often considered a panacea for all traffic problems at intersections. This belief has led to traffic control signals being installed at many locations where they are not needed, adversely affecting the safety and efficiency of vehicular, bicycle, and pedestrian traffic.

Traffic control signals, even when justified by traffic and roadway conditions, can be ill-designed, ineffectively placed, improperly operated, or poorly maintained. Improper or unjustified traffic control signals can result in one or more of the following disadvantages:

A. Excessive delay;
B. Excessive disobedience of the signal indications;
C. Increased use of less adequate routes as road users attempt to avoid the traffic control signals; and
D. Significant increases in the frequency of collisions (especially rear-end collisions).

Section 4B.04 Alternatives to Traffic Control Signals

Guidance:

Since vehicular delay and the frequency of some types of crashes are sometimes greater under traffic signal control than under STOP sign control, consideration should be given to providing alternatives to traffic control signals even if one or more of the signal warrants has been satisfied.

Option:

These alternatives may include, but are not limited to, the following:

A. Installing signs along the major street to warn road users approaching the intersection;
B. Relocating the stop line(s) and making other changes to improve the sight distance at the intersection;
C. Installing measures designed to reduce speeds on the approaches;
D. Installing a flashing beacon at the intersection to supplement STOP sign control;
E. Installing flashing beacons on warning signs in advance of a STOP sign controlled intersection on major- and/or minor-street approaches;
F. Adding one or more lanes on a minor-street approach to reduce the number of vehicles per lane on the approach;
G. Revising the geometrics at the intersection to channelize vehicular movements and reduce the time required for a vehicle to complete a movement, which could also assist pedestrians;
H. Installing roadway lighting if a disproportionate number of crashes occur at night;
I. Restricting one or more turning movements, perhaps on a time-of-day basis, if alternate routes are available;
J. If the warrant is satisfied, installing multiway STOP sign control;
K. Installing a roundabout intersection; and
L. Employing other alternatives, depending on conditions at the intersection.

Section 4B.05 Adequate Roadway Capacity

Support:

The delays inherent in the alternating assignment of right-of-way at intersections controlled by traffic control signals can frequently be reduced by widening the major roadway, the minor roadway, or both roadways. Widening the minor roadway often benefits the operations on the major roadway, because it reduces the green time that must be assigned to minor-roadway traffic. In urban areas, the effect of widening can be achieved by eliminating parking on intersection approaches. It is desirable to have at least two lanes for moving traffic on each approach to a signalized location. Additional width on the departure side of the intersection, as well as on the approach side, will sometimes be needed to clear traffic through the intersection effectively.

Guidance:

Adequate roadway capacity should be provided at a signalized location. Before an intersection is widened, the additional green time pedestrians need to cross the widened roadways should be considered to determine if it will exceed the green time saved through improved vehicular flow.

CHAPTER 4C. TRAFFIC CONTROL SIGNAL NEEDS STUDIES

Section 4C.01 Studies and Factors for Justifying Traffic Control Signals

Standard:

An engineering study of traffic conditions, pedestrian characteristics, and physical characteristics of the location shall be performed to determine whether installation of a traffic control signal is justified at a particular location.

The investigation of the need for a traffic control signal shall include an analysis of the applicable factors contained in the following traffic signal warrants and other factors related to existing operation and safety at the study location:

Warrant 1, Eight-Hour Vehicular Volume.
Warrant 2, Four-Hour Vehicular Volume.
Warrant 3, Peak Hour.
Warrant 4, Pedestrian Volume.
Warrant 5, School Crossing.
Warrant 6, Coordinated Signal System.
Warrant 7, Crash Experience.
Warrant 8, Roadway Network.

The satisfaction of a traffic signal warrant or warrants shall not in itself require the installation of a traffic control signal.

Support:

Sections 8D.07 and 10D.05 contain information regarding the use of traffic control signals instead of gates and/or flashing light signals at highway-railroad grade crossings and highway-light rail transit grade crossings, respectively.

Guidance:

A traffic control signal should not be installed unless one or more of the factors described in this Chapter are met.

A traffic control signal should not be installed unless an engineering study indicates that installing a traffic control signal will improve the overall safety and/or operation of the intersection.

A traffic control signal should not be installed if it will seriously disrupt progressive traffic flow.

The study should consider the effects of the right-turn vehicles from the minor-street approaches. Engineering judgment should be used to determine what, if any, portion of the right-turn traffic is subtracted from the minor-street traffic count when evaluating the count against the above signal warrants.

Engineering judgment should also be used in applying various traffic signal warrants to cases where approaches consist of one lane plus one left-turn or right-turn lane. The site-specific traffic characteristics dictate whether an approach should be considered as one lane or two lanes. For example, for an approach with one lane for through and right-turning traffic plus a left-turn lane, engineering judgment could indicate that it should be considered a one-lane approach if the traffic using the left-turn lane is minor. In such a case, the total traffic volume approaching the intersection should be applied against the signal warrants as a one-lane approach. The approach should be considered two lanes if approximately half of the traffic on the approach turns left and the left-turn lane is of sufficient length to accommodate all left-turn vehicles.

Similar engineering judgment and rationale should be applied to a street approach with one lane plus a right-turn lane. In this case, the degree of conflict of minor-street right-turn traffic with traffic on the major street should be considered. Thus, right-turn traffic should not be included in the minor-street volume if the movement enters the major street with minimal conflict. The approach should be evaluated as a one-lane approach with only the traffic volume in the through/left-turn lane considered.

At a location that is under development or construction and where it is not possible to obtain a traffic count that would represent future traffic conditions, hourly volumes should be estimated as part of an engineering study for comparison with traffic signal warrants. Except for locations where the engineering study uses the satisfaction of Warrant 8 to justify a signal, a traffic control signal installed under projected conditions should have an engineering study done within 1 year of putting the signal into stop-and-go operation to determine if the signal is justified. If not justified, the signal should be taken out of stop-and-go operation or removed.

For signal warrant analysis, a location with a wide median, even if the median width is greater than 9 m (30 ft), should be considered as one intersection.

Option:

At an intersection with a high volume of left-turn traffic from the major street, the signal warrant analysis may be performed in a manner that considers the higher of the major-street left-turn volumes as the "minor-street" volume and the corresponding single direction of opposing traffic on the major street as the "major-street" volume.

For signal warrant analysis, bicyclists may be counted as either vehicles or pedestrians.

Support:

When performing a signal warrant analysis, bicyclists riding in the street with other vehicular traffic are usually counted as vehicles and bicyclists who are clearly using pedestrian facilities are usually counted as pedestrians.

Option:

Engineering study data may include the following:

A. The number of vehicles entering the intersection in each hour from each approach during 12 hours of an average day. It is desirable that the hours selected contain the greatest percentage of the 24-hour traffic volume.
B. Vehicular volumes for each traffic movement from each approach, classified by vehicle type (heavy trucks, passenger cars and light trucks, public-transit vehicles, and, in some locations, bicycles), during each 15-minute period of the 2 hours in the morning and 2 hours in the afternoon during which total traffic entering the intersection is greatest.
C. Pedestrian volume counts on each crosswalk during the same periods as the vehicular counts in Item B above and during hours of highest pedestrian volume. Where young, elderly, and/or persons with physical or visual disabilities need special consideration, the pedestrians and their crossing times may be classified by general observation.
D. Information about nearby facilities and activity centers that serve the young, elderly, and/or persons with disabilities, including requests from persons with disabilities for accessible crossing improvements at the location under study. These persons might not be adequately reflected in the pedestrian volume count if the absence of a signal restrains their mobility.
E. The posted or statutory speed limit or the 85th-percentile speed on the uncontrolled approaches to the location.
F. A condition diagram showing details of the physical layout, including such features as intersection geometrics, channelization, grades, sight-distance restrictions, transit stops and routes, parking conditions, pavement markings, roadway lighting, driveways, nearby railroad crossings, distance to nearest traffic control signals, utility poles and fixtures, and adjacent land use.
G. A collision diagram showing crash experience by type, location, direction of movement, severity, weather, time of day, date, and day of week for at least 1 year.

The following data, which are desirable for a more precise understanding of the operation of the intersection, may be obtained during the periods specified in Item B of the preceding paragraph:

A. Vehicle-hours of stopped time delay determined separately for each approach.
B. The number and distribution of acceptable gaps in vehicular traffic on the major street for entrance from the minor street.
C. The posted or statutory speed limit or the 85th-percentile speed on controlled approaches at a point near to the intersection but unaffected by the control.
D. Pedestrian delay time for at least two 30-minute peak pedestrian delay periods of an average weekday or like periods of a Saturday or Sunday.
E. Queue length on stop-controlled approaches.

Section 4C.02 Warrant 1, Eight-Hour Vehicular Volume

Support:

The Minimum Vehicular Volume, Condition A, is intended for application at locations where a large volume of intersecting traffic is the principal reason to consider installing a traffic control signal.

The Interruption of Continuous Traffic, Condition B, is intended for application at locations where Condition A is not satisfied and where the traffic volume on a major street is so heavy that traffic on a minor intersecting street suffers excessive delay or conflict in entering or crossing the major street.

It is intended that Warrant 1 be treated as a single warrant. If Condition A is satisfied, then the criteria for Warrant 1 is satisfied and Condition B and the combination of Conditions A and B are not needed. Similarly, if Condition B is satisfied, then the criteria for Warrant 1 is satisfied and the combination of Conditions A and B is not needed.

Table 4C-1. Warrant 1, Eight-Hour Vehicular Volume

Condition A—Minimum Vehicular Volume									
Number of lanes for moving traffic on each approach		Vehicles per hour on major street (total of both approaches)				Vehicles per hour on higher-volume minor-street approach (one direction only)			
Major Street	Minor Street	100%[a]	80%[b]	70%[c]	56%[d]	100%[a]	80%[b]	70%[c]	56%[d]
1.................	1.................	500	400	350	280	150	120	105	84
2 or more...	1.................	600	480	420	336	150	120	105	84
2 or more...	2 or more...	600	480	420	336	200	160	140	112
1.................	2 or more....	500	400	350	280	200	160	140	112

Condition B—Interruption of Continuous Traffic									
Number of lanes for moving traffic on each approach		Vehicles per hour on major street (total of both approaches)				Vehicles per hour on higher-volume minor-street approach (one direction only)			
Major Street	Minor Street	100%[a]	80%[b]	70%[c]	56%[d]	100%[a]	80%[b]	70%[c]	56%[d]
1.................	1.................	750	600	525	420	75	60	53	42
2 or more...	1.................	900	720	630	504	75	60	53	42
2 or more...	2 or more...	900	720	630	504	100	80	70	56
1.................	2 or more....	750	600	525	420	100	80	70	56

[a] Basic minimum hourly volume.
[b] Used for combination of Conditions A and B after adequate trial of other remedial measures.
[c] May be used when the major-street speed exceeds 70 km/h or exceeds 40 mph or in an isolated community with a population of less than 10,000.
[d] May be used for combination of Conditions A and B after adequate trial of other remedial measures when the major-street speed exceeds 70 km/h or exceeds 40 mph or in an isolated community with a population of less than 10,000.

Standard:

The need for a traffic control signal shall be considered if an engineering study finds that one of the following conditions exist for each of any 8 hours of an average day:

A. The vehicles per hour given in both of the 100 percent columns of Condition A in Table 4C-1 exist on the major-street and the higher-volume minor-street approaches, respectively, to the intersection; or

B. The vehicles per hour given in both of the 100 percent columns of Condition B in Table 4C-1 exist on the major-street and the higher-volume minor-street approaches, respectively, to the intersection.

In applying each condition the major-street and minor-street volumes shall be for the same 8 hours. On the minor street, the higher volume shall not be required to be on the same approach during each of these 8 hours.

Option:

If the posted or statutory speed limit or the 85th-percentile speed on the major street exceeds 70 km/h or exceeds 40 mph, or if the intersection lies within the built-up area of an isolated community having a population of less than 10,000, the traffic volumes in the 70 percent columns in Table 4C-1 may be used in place of the 100 percent columns.

Guidance:

The combination of Conditions A and B is intended for application at locations where Condition A is not satisfied and Condition B is not satisfied and should be applied only after an adequate trial of other alternatives that could cause less delay and inconvenience to traffic has failed to solve the traffic problems.

Standard:

The need for a traffic control signal shall be considered if an engineering study finds that both of the following conditions exist for each of any 8 hours of an average day:

- **A. The vehicles per hour given in both of the 80 percent columns of Condition A in Table 4C-1 exist on the major-street and the higher-volume minor-street approaches, respectively, to the intersection; and**
- **B. The vehicles per hour given in both of the 80 percent columns of Condition B in Table 4C-1 exist on the major-street and the higher-volume minor-street approaches, respectively, to the intersection.**

These major-street and minor-street volumes shall be for the same 8 hours for each condition; however, the 8 hours satisfied in Condition A shall not be required to be the same 8 hours satisfied in Condition B. On the minor street, the higher volume shall not be required to be on the same approach during each of the 8 hours.

Option:

If the posted or statutory speed limit or the 85th-percentile speed on the major street exceeds 70 km/h or exceeds 40 mph, or if the intersection lies within the built-up area of an isolated community having a population of less than 10,000, the traffic volumes in the 56 percent columns in Table 4C-1 may be used in place of the 80 percent columns.

Section 4C.03 Warrant 2, Four-Hour Vehicular Volume

Support:

The Four-Hour Vehicular Volume signal warrant conditions are intended to be applied where the volume of intersecting traffic is the principal reason to consider installing a traffic control signal.

Standard:

The need for a traffic control signal shall be considered if an engineering study finds that, for each of any 4 hours of an average day, the plotted points representing the vehicles per hour on the major street (total of both approaches) and the corresponding vehicles per hour on the higher-volume minor-street approach (one direction only) all fall above the applicable curve in Figure 4C-1 for the existing combination of approach lanes. On the minor street, the higher volume shall not be required to be on the same approach during each of these 4 hours.

Option:

If the posted or statutory speed limit or the 85th-percentile speed on the major street exceeds 70 km/h or exceeds 40 mph or if the intersection lies within the built-up area of an isolated community having a population of less than 10,000, Figure 4C-2 may be used in place of Figure 4C-1.

Section 4C.04 Warrant 3, Peak Hour

Support:

The Peak Hour signal warrant is intended for use at a location where traffic conditions are such that for a minimum of 1 hour of an average day, the minor-street traffic suffers undue delay when entering or crossing the major street.

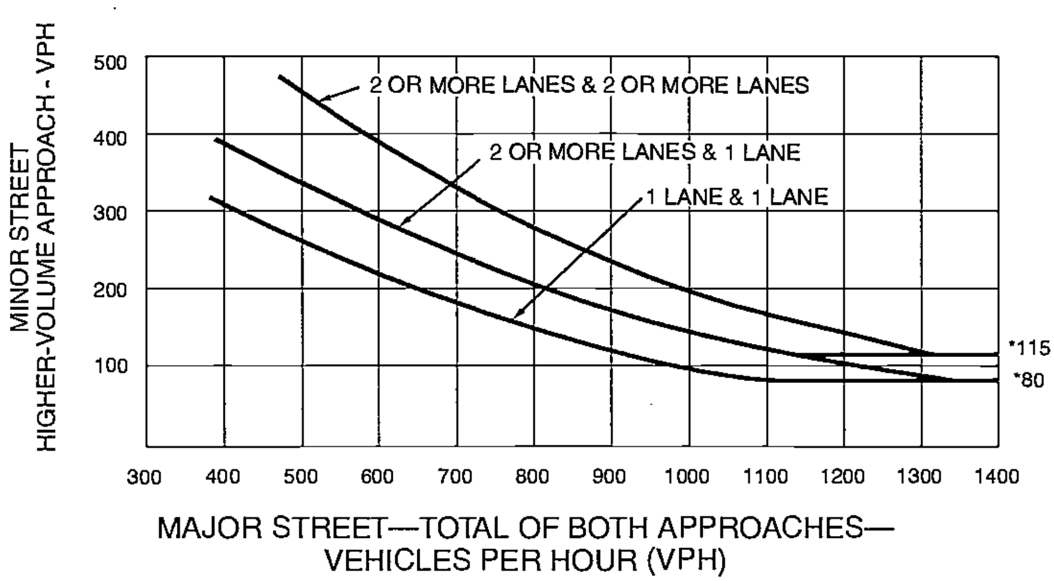
Standard:

This signal warrant shall be applied only in unusual cases, such as office complexes, manufacturing plants, industrial complexes, or high-occupancy vehicle facilities that attract or discharge large numbers of vehicles over a short time.

The need for a traffic control signal shall be considered if an engineering study finds that the criteria in either of the following two categories are met:

- **A. If all three of the following conditions exist for the same 1 hour (any four consecutive 15-minute periods) of an average day:**
  1. **The total stopped time delay experienced by the traffic on one minor-street approach (one direction only) controlled by a STOP sign equals or exceeds: 4 vehicle-hours for a one-lane approach; or 5 vehicle-hours for a two-lane approach, and**

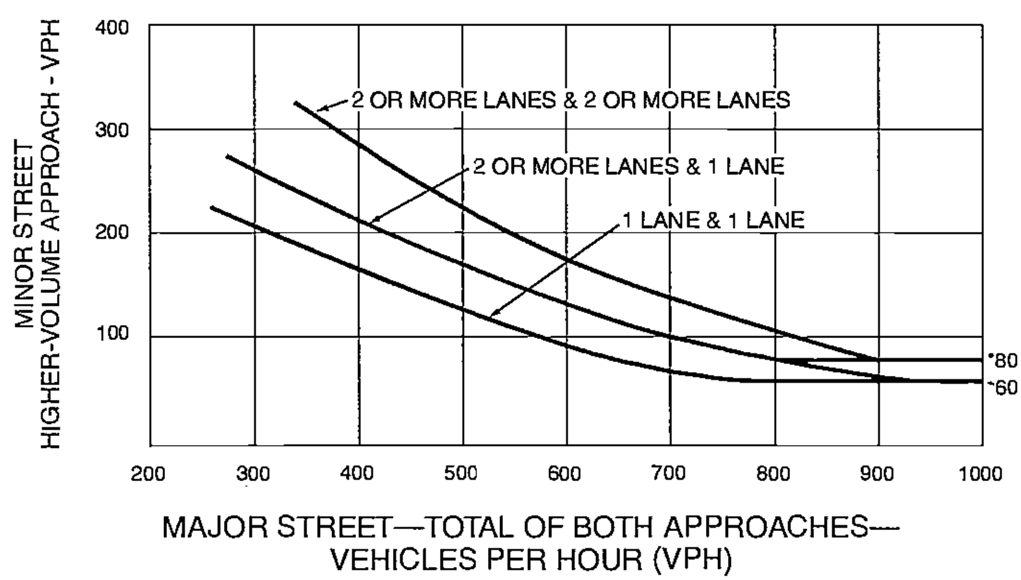
Figure 4C-1. Warrant 2, Four-Hour Vehicular Volume



*Note: 115 vph applies as the lower threshold volume for a minor-street approach with two or more lanes and 80 vph applies as the lower threshold volume for a minor-street approach with one lane.

Figure 4C-2. Warrant 2, Four-Hour Vehicular Volume (70% Factor)

(COMMUNITY LESS THAN 10,000 POPULATION OR ABOVE 70 km/h OR ABOVE 40 mph ON MAJOR STREET)



*Note: 80 vph applies as the lower threshold volume for a minor-street approach with two or more lanes and 60 vph applies as the lower threshold volume for a minor-street approach with one lane.

2. The volume on the same minor-street approach (one direction only) equals or exceeds 100 vehicles per hour for one moving lane of traffic or 150 vehicles per hour for two moving lanes, and

3. The total entering volume serviced during the hour equals or exceeds 650 vehicles per hour for intersections with three approaches or 800 vehicles per hour for intersections with four or more approaches.

B. The plotted point representing the vehicles per hour on the major street (total of both approaches) and the corresponding vehicles per hour on the higher-volume minor-street approach (one direction only) for 1 hour (any four consecutive 15-minute periods) of an average day falls above the applicable curve in Figure 4C-3 for the existing combination of approach lanes.

Option:

If the posted or statutory speed limit or the 85th-percentile speed on the major street exceeds 70 km/h or exceeds 40 mph, or if the intersection lies within the built-up area of an isolated community having a population of less than 10,000, Figure 4C-4 may be used in place of Figure 4C-3 to satisfy the criteria in the second category of the Standard.

Section 4C.05 Warrant 4, Pedestrian Volume

Support:

The Pedestrian Volume signal warrant is intended for application where the traffic volume on a major street is so heavy that pedestrians experience excessive delay in crossing the major street.

Standard:

The need for a traffic control signal at an intersection or midblock crossing shall be considered if an engineering study finds that both of the following criteria are met:

A. The pedestrian volume crossing the major street at an intersection or midblock location during an average day is 100 or more for each of any 4 hours or 190 or more during any 1 hour; and

B. There are fewer than 60 gaps per hour in the traffic stream of adequate length to allow pedestrians to cross during the same period when the pedestrian volume criterion is satisfied. Where there is a divided street having a median of sufficient width for pedestrians to wait, the requirement applies separately to each direction of vehicular traffic.

The Pedestrian Volume signal warrant shall not be applied at locations where the distance to the nearest traffic control signal along the major street is less than 90 m (300 ft), unless the proposed traffic control signal will not restrict the progressive movement of traffic.

If this warrant is met and a traffic control signal is justified by an engineering study, the traffic control signal shall be equipped with pedestrian signal heads conforming to requirements set forth in Chapter 4E.

Guidance:

If this warrant is met and a traffic control signal is justified by an engineering study, then:

A. If at an intersection, the traffic control signal should be traffic-actuated and should include pedestrian detectors.

B. If at a nonintersection crossing, the traffic control signal should be pedestrian-actuated, parking and other sight obstructions should be prohibited for at least 30 m (100 ft) in advance of and at least 6.1 m (20 ft) beyond the crosswalk, and the installation should include suitable standard signs and pavement markings.

C. Furthermore, if installed within a signal system, the traffic control signal should be coordinated.

Option:

The criterion for the pedestrian volume crossing the major roadway may be reduced as much as 50 percent if the average crossing speed of pedestrians is less than 1.2 m/sec (4 ft/sec).

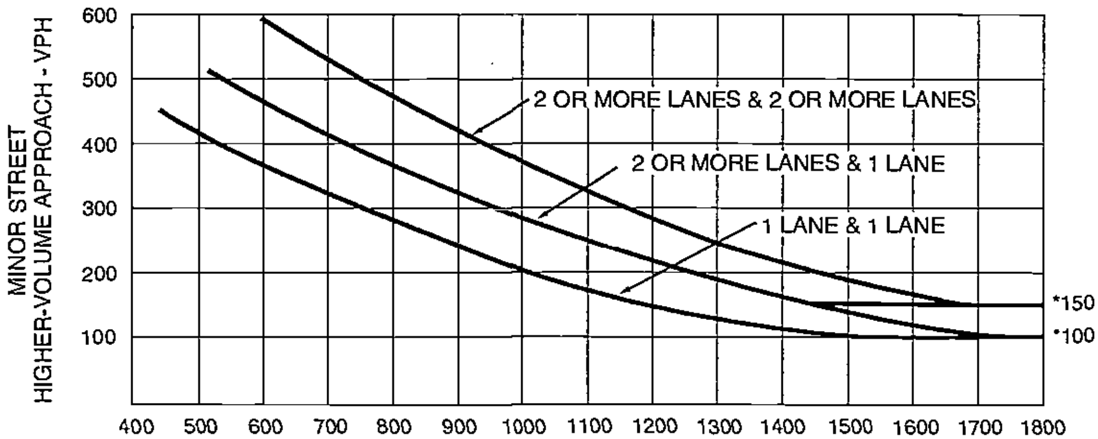
A traffic control signal may not be needed at the study location if adjacent coordinated traffic control signals consistently provide gaps of adequate length for pedestrians to cross the street, even if the rate of gap occurrence is less than one per minute.

Section 4C.06 Warrant 5, School Crossing

Support:

The School Crossing signal warrant is intended for application where the fact that school children cross the major street is the principal reason to consider installing a traffic control signal.

Figure 4C-3. Warrant 3, Peak Hour

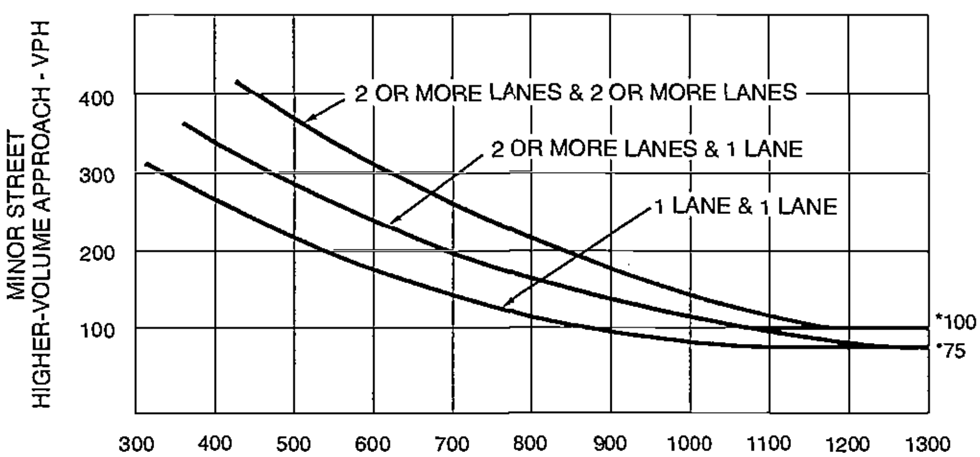


MAJOR STREET—TOTAL OF BOTH APPROACHES—
VEHICLES PER HOUR (VPH)

*Note: 150 vph applies as the lower threshold volume for a minor-street approach with two or more lanes and 100 vph applies as the lower threshold volume for a minor-street approach with one lane.

Figure 4C-4. Warrant 3, Peak Hour (70% Factor)

(COMMUNITY LESS THAN 10,000 POPULATION OR ABOVE 70 km/h OR ABOVE 40 mph ON MAJOR STREET)



MAJOR STREET—TOTAL OF BOTH APPROACHES—
VEHICLES PER HOUR (VPH)

*Note: 100 vph applies as the lower threshold volume for a minor-street approach with two or more lanes and 75 vph applies as the lower threshold volume for a minor-street approach with one lane.

Standard:

The need for a traffic control signal shall be considered when an engineering study of the frequency and adequacy of gaps in the vehicular traffic stream as related to the number and size of groups of school children at an established school crossing across the major street shows that the number of adequate gaps in the traffic stream during the period when the children are using the crossing is less than the number of minutes in the same period (see Section 7A.03) and there are a minimum of 20 students during the highest crossing hour.

Before a decision is made to install a traffic control signal, consideration shall be given to the implementation of other remedial measures, such as warning signs and flashers, school speed zones, school crossing gnards, or a grade-separated crossing.

The School Crossing signal warrant shall not be applied at locations where the distance to the nearest traffic control signal along the major street is less than 90 m (300 ft), unless the proposed traffic control signal will not restrict the progressive movement of traffic.

Guidance:

If this warrant is met and a traffic control signal is justified by an engineering study, then:

A. If at an intersection, the traffic control signal should be traffic-actuated and should include pedestrian detectors.
B. If at a nonintersection crossing, the traffic control signal should be pedestrian-actuated, parking and other sight obstructions should be prohibited for at least 30 m (100 ft) in advance of and at least 6.1 m (20 ft) beyond the crosswalk, and the installation should include suitable standard signs and pavement markings.
C. Furthermore, if installed within a signal system, the traffic control signal should be coordinated.

Section 4C.07 Warrant 6, Coordinated Signal System

Support:

Progressive movement in a coordinated signal system sometimes necessitates installing traffic control signals at intersections where they would not otherwise be needed in order to maintain proper platooning of vehicles.

Standard:

The need for a traffic control signal shall be considered if an engineering study finds that one of the following criteria is met:

A. On a one-way street or a street that has traffic predominantly in one direction, the adjacent traffic control signals are so far apart that they do not provide the necessary degree of vehicular platooning.
B. On a two-way street, adjacent traffic control signals do not provide the necessary degree of platooning and the proposed and adjacent traffic control signals will collectively provide a progressive operation.

Guidance:

The Coordinated Signal System signal warrant should not be applied where the resultant spacing of traffic control signals would be less than 300 m (1,000 ft).

Section 4C.08 Warrant 7, Crash Experience

Support:

The Crash Experience signal warrant conditions are intended for application where the severity and frequency of crashes are the principal reasons to consider installing a traffic control signal.

Standard:

The need for a traffic control signal shall be considered if an engineering study finds that all of the following criteria are met:

A. Adequate trial of alternatives with satisfactory observance and enforcement has failed to reduce the crash frequency; and
B. Five or more reported crashes, of types susceptible to correction by a traffic control signal, have occurred within a 12-month period, each crash involving personal injury or property damage apparently exceeding the applicable requirements for a reportable crash; and
C. For each of any 8 hours of an average day, the vehicles per hour (vph) given in both of the 80 percent columns of Condition A in Table 4C-1 (see Section 4C.02), or the vph in both of the 80 percent columns of Condition B in Table 4C-1 exists on the major-street and the higher-volume minor-street approach, respectively, to the intersection, or the volume of pedestrian traffic is not

less than 80 percent of the requirements specified in the Pedestrian Volume warrant. These major-street and minor-street volumes shall be for the same 8 hours. On the minor street, the higher volume shall not be required to be on the same approach during each of the 8 hours.

Option:

If the posted or statutory speed limit or the 85th-percentile speed on the major street exceeds 70 km/h or exceeds 40 mph, or if the intersection lies within the built-up area of an isolated community having a population of less than 10,000, the traffic volumes in the 56 percent columns in Table 4C-1 may be used in place of the 80 percent columns.

Section 4C.09 Warrant 8, Roadway Network

Support:

Installing a traffic control signal at some intersections might be justified to encourage concentration and organization of traffic flow on a roadway network.

Standard:

The need for a traffic control signal shall be considered if an engineering study finds that the common intersection of two or more major routes meets one or both of the following criteria:

A. The intersection has a total existing, or immediately projected, entering volume of at least 1,000 vehicles per hour during the peak hour of a typical weekday and has 5-year projected traffic volumes, based on an engineering study, that meet one or more of Warrants 1, 2, and 3 during an average weekday; or

B. The intersection has a total existing or immediately projected entering volume of at least 1,000 vehicles per hour for each of any 5 hours of a nonnormal business day (Saturday or Sunday).

A major route as used in this signal warrant shall have one or more of the following characteristics:

A. It is part of the street or highway system that serves as the principal roadway network for through traffic flow; or

B. It includes rural or suburban highways outside, entering, or traversing a City; or

C. It appears as a major route on an official plan, such as a major street plan in an urban area traffic and transportation study.

CHAPTER 4D. TRAFFIC CONTROL SIGNAL FEATURES

Section 4D.01 General

Support:

The features of traffic control signals of interest to road users are the location, design, and meaning of the signal indications. Uniformity in the design features that affect the traffic to be controlled, as set forth in this Manual, is especially important for reasonably safe and efficient traffic operations.

Pavement markings (see Part 3) that clearly communicate the operational plan of an intersection to road users play an important role in the effective operation of traffic control signals. By designating the number of lanes, the use of each lane, the length of additional lanes on the approach to an intersection, and the proper stopping points, the engineer can design the signal phasing and timing to best match the goals of the operational plan.

Standard:

When a traffic control signal is not in operation, such as before it is placed in service, during seasonal shutdowns, or when it is not desirable to operate the traffic control signal, the signal faces shall be covered, turned, or taken down to clearly indicate that the traffic control signal is not in operation.

A traffic control signal shall control traffic only at the intersection or midblock location where the signal faces are placed.

STOP signs shall not be used in conjunction with any traffic control signal operation, except in either of the following cases:

A. If the signal indication for an approach is a flashing red at all times; or
B. If a minor street or driveway is located within or adjacent to the area controlled by the traffic control signal, but does not require separate traffic signal control because an extremely low potential for conflict exists.

Midblock crosswalks shall not be signalized if they are located within 90 m (300 ft) from the nearest traffic control signal, unless the proposed traffic control signal will not restrict the progressive movement of traffic.

Guidance:

Midblock crosswalks should not be signalized if they are located within 30 m (100 ft) from side streets or driveways that are controlled by STOP signs or YIELD signs.

Pavement markings should be used at traffic control signal locations as provided in Part 3. If the road surface will not retain pavement markings, signs should be installed to provide the needed road user information.

Engineering judgment should be used to determine the proper phasing and timing for a traffic control signal. Since traffic flows and patterns change, phasing and timing should be reevaluated regularly and updated if needed.

Section 4D.02 Responsibility for Operation and Maintenance

Guidance:

Prior to installing any traffic control signal, the responsibility for the maintenance of the signal and all of the appurtenances, hardware, software, and the timing plan(s) should be clearly established. The responsible agency should provide for the maintenance of the traffic control signal and all of its appurtenances in a competent manner.

To this end the agency should:

A. Keep every controller assembly in effective operation in accordance with its predetermined timing schedule; check the operation of the controller assembly frequently enough to verify that it is operating in accordance with the predetermined timing schedule; and establish a policy to maintain a record of all timing changes and that only authorized persons are permitted to make timing changes;
B. Clean the optical system of the signal sections and replace the light sources as frequently as experience proves necessary;
C. Clean and service equipment and other appurtenances as frequently as experience proves necessary;
D. Provide for alternate operation of the traffic control signal during a period of failure, using flashing mode or manual control, or manual traffic direction by proper authorities as might be required by traffic volumes or congestion, or by erecting other traffic control devices;
E. Have properly skilled maintenance personnel available without undue delay for all emergency and lamp failure calls;

F. Provide spare equipment to minimize the interruption of traffic control signal operation as a result of equipment failure;
G. Provide for the availability of properly skilled maintenance personnel for the repair of all components; and
H. Maintain the appearance of the signal displays and equipment.

Section 4D.03 Provisions for Pedestrians

Support:

Chapter 4E contains additional information regarding pedestrian signals.

Standard:

The design and operation of traffic control signals shall take into consideration the needs of pedestrian as well as vehicular traffic.

If engineering judgment indicates the need for provisions for a given pedestrian movement, signal faces conveniently visible to pedestrians shall be provided by pedestrian signal heads or a signal face for an adjacent vehicnlar movement.

Guidance:

Safety considerations should include the installation, where appropriate, of accessible pedestrian signals (see Sections 4E.06 and 4E.09) that provide information in nonvisual format (such as audible tones, verbal messages, and/or vibrating surfaces).

Where pedestrian movements regularly occur, pedestrians should be provided with sufficient time to cross the roadway by adjusting the traffic control signal operation and timing to provide sufficient crossing time every cycle or by providing pedestrian detectors.

Option:

If it is desirable to prohibit certain pedestrian movements at a traffic control signal, a PEDESTRIANS PROHIBITED (R9-3) or No Pedestrian Crossing (R9-3a) sign may be used (see Section 2B.44).

Section 4D.04 Meaning of Vehicular Signal Indications

Support:

The "Uniform Vehicle Code" (see Section 1A.11) is the primary source for the standards for the meaning of vehicular signal indications to both vehicle operators and pedestrians as set forth below, and the standards for the meaning of separate pedestrian signal indications as set forth in Section 4E.02.

Standard:

The following meanings shall be given to highway traffic signal indications for vehicles and pedestrians:

A. Steady green signal indications shall have the following meanings:
   1. Traffic, except pedestrians, facing a CIRCULAR GREEN signal indication is permitted to proceed straight through or turn right or left except as such movement is modified by lane-use signs, turn prohibition signs, lane markings, or roadway design. But vehicular traffic, including vehicles turning right or left, shall yield the right-of-way to other vehicles, and to pedestrians lawfnlly within the intersection or an adjacent crosswalk, at the time such signal indication is exhibited.
   2. Traffic, except pedestrians, facing a GREEN ARROW signal indication, shown 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 shown at the same time. Such vehicular traffic shall yield the right-of-way to pedestrians lawfully within an adjacent crosswalk and to other traffic lawfully using the intersection.
   3. Unless otherwise directed by a pedestrian signal head, pedestrians facing any green signal indication, except when the sole green signal indication is a turn arrow, are permitted to proceed across the roadway within any marked or unmarked crosswalk. The pedestrian shall yield the right-of-way to vehicles lawfully within the intersection at the time that the green signal indication is first shown.

B. Steady yellow signal indications shall have the following meanings:
   1. Traffic, except pedestrians, facing a steady CIRCULAR YELLOW or YELLOW ARROW signal indication is thereby warned that the related green movement is being terminated or that a red signal indication will be exhibited immediately thereafter when vehicular traffic shall not enter the intersection.

2. Pedestrians facing a steady CIRCULAR YELLOW or YELLOW ARROW signal indication, unless otherwise directed by a pedestrian signal head, are thereby advised that there is insufficient time to cross the roadway before a red signal indication is shown, and no pedestrian shall then 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 alone 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 shown, or as provided below.

   Except when a sign is in place prohibiting a turn on red or a RED ARROW signal indication is displayed, vehicular traffic facing a 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. Such vehicular traffic shall yield the right-of-way to pedestrians lawfully within an adjacent crosswalk and to other traffic lawfully using the intersection.
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 permitting the movement indicated by such RED ARROW is shown.

   When an R10-17a sign (see Section 2B.45) is in place permitting a turn on a RED ARROW signal indication, vehicular traffic facing a RED ARROW 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. Such vehicular traffic shall yield the right-of-way to pedestrians lawfully within an adjacent crosswalk and to other traffic lawfully using the intersection.
3. Unless otherwise directed by a pedestrian signal head, pedestrians facing a steady CIRCULAR RED or RED ARROW signal indication alone shall not enter the roadway.

D. Flashing signal indications shall have the following meanings:
1. Flashing yellow—When a yellow lens is illuminated with rapid intermittent flashes, vehicular traffic is permitted to proceed through the intersection or past such signal indication only with caution.
2. Flashing red—When a red lens is illuminated with rapid intermittent flashes, vehicular traffic 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, at the point nearest the intersecting roadway where the driver has a view of approaching traffic on the intersecting roadway before entering the intersection. The right to proceed shall be subject to the rules applicable after making a stop at a STOP sign.
3. Flashing RED ARROW and flashing YELLOW ARROW signal indications have the same meaning as the corresponding flashing circular signal indication, except that they apply only to vehicular traffic intending to make the movement indicated by the arrow.

Section 4D.05 Application of Steady Signal Indications

Standard:

When a traffic control signal is being operated in a steady (stop-and-go) mode, at least one lens in each signal face shall be illuminated at any given time.

A signal face(s) that controls a particular vehicular movement during any interval of a cycle shall control that same movement during all intervals of the cycle.

Steady signal indications shall be applied as follows:

A. A steady CIRCULAR RED signal indication:
1. Shall be displayed when it is intended to prohibit traffic, except pedestrians directed by a pedestrian signal head, from entering the intersection or other controlled area. Turning after stopping is permitted as stated in Item C.1 of Section 4D.04.
2. Shall be displayed with the appropriate GREEN ARROW signal indications when it is intended to permit traffic to make a specified turn or turns, and to prohibit traffic from proceeding straight ahead through the intersection or other controlled area, except in protected only mode turn signal faces, or in protected/permissive mode left-turn operation with separate left-turn signal faces (see Section 4D.06).

B. A steady CIRCULAR YELLOW signal indication:
1. **Shall be displayed following a CIRCULAR GREEN or straight-through GREEN ARROW signal indication in the same signal face.**
2. **Shall not be displayed in conjunction with the change from the CIRCULAR RED signal indication to the CIRCULAR GREEN signal indication.**
3. **Shall be followed by a CIRCULAR RED signal indication except that, when entering preemption operation, the return to the previous CIRCULAR GREEN signal indication shall be permitted following a CIRCULAR YELLOW signal indication (see Section 4D.13).**
4. **Shall not be displayed to an approach from which drivers are turning left permissively unless one of the following conditions exists:**
   (a) **A steady CIRCULAR YELLOW signal indication is also being shown simultaneously to the opposing approach;**
   (b) **A separate left-turn signal face is provided and operated as described in Section 4D.06;**
   (c) **An engineering study has determined that, because of unique intersection conditions, the conditions described in items (a) and (b) above cannot reasonably be implemented without causing significant operational or safety problems and that the volume of impacted left-turning traffic is relatively low, and those left-turning drivers are advised that the opposing traffic is not simultaneously being shown a CIRCULAR YELLOW signal indication if this operation occurs continuously by the installation near the left-most signal head of a W25-1 sign (see Section 2C.39) with the legend ONCOMING TRAFFIC HAS EXTENDED GREEN; or**
   (d) **Drivers are advised of the operation if it occurs ouly occasionally, such as during a preemption sequence or because of the skipping of actuated phases, by the installation near the left-most signal head of a W25-2 sign (see Section 2C.39) with the legend ONCOMING TRAFFIC MAY HAVE EXTENDED GREEN.**

C. A steady CIRCULAR GREEN signal indication shall be displayed only when it is intended to permit traffic to proceed in any direction that is lawful and practical.

D. A steady RED ARROW signal indication shall be displayed when it is intended to prohibit traffic, except pedestrians directed by a pedestrian signal head, from entering the intersection or other controlled area to make the indicated turn. Except as described in Item C.2 of Section 4D.04, turning on a steady RED ARROW signal indication shall not be permitted.

E. A steady YELLOW ARROW signal indication:
1. **Shall be displayed in the same direction as a GREEN ARROW signal indication following a GREEN ARROW signal indication in the same signal face, unless:**
   (a) **The GREEN ARROW signal indication and a CIRCULAR GREEN (or straight-through GREEN ARROW) signal indication terminate simultaneously in the same signal face, or**
   (b) **The green arrow is a straight-through GREEN ARROW.**
2. **Shall not be displayed in conjunction with the change from a RED ARROW signal indication to a GREEN ARROW signal indication.**
3. **Shall not be displayed when any conflicting vehicular movement has a green or yellow signal indication or any conflicting pedestrian movement has a WALKING PERSON (symbolizing WALK) or flashing UPRAISED HAND (symbolizing DONT WALK) signal indication (see Section 4D.09).**
4. **Shall be terminated by a RED ARROW signal indication for the same direction or a CIRCULAR RED signal indication except:**
   (a) **When entering preemption operation, the return to the previous GREEN ARROW signal indication shall be permitted following a YELLOW ARROW signal indication.**
   (b) **When the movement controlled by the arrow is to continue on a permissive mode basis during an immediately following CIRCULAR GREEN signal indication.**

F. A steady GREEN ARROW signal indication:
1. **Shall be displayed only to allow vehicular movements, in the direction indicated, that are not in conflict with other vehicles moving on a green or yellow signal indication or with pedestrians crossing in conformance with a WALKING PERSON (symbolizing WALK) or flashing UPRAISED HAND (symbolizing DONT WALK) signal indication (see Section 4D.09).**
2. **Shall be displayed on a signal face that controls a left-turn movement when said movement is not in conflict with other vehicles moving on a green or yellow signal indication or with pedestrians crossing in conformance with a WALKING PERSON (symbolizing WALK) or flashing UPRAISED HAND (symbolizing DONT WALK) signal indication (see Section 4D.09).**
3. **Shall not be required on the stem of T-intersections or for turns from one-way streets.**

Option:

Steady RED ARROW, YELLOW ARROW, and GREEN ARROW signal indications, if not otherwise prohibited, may be used instead of the corresponding circular signal indications at the following locations:

A. On an approach intersecting a one-way street;
B. Where certain movements are prohibited; and
C. Where certain movements are physically impossible.

If U-turns are permitted from the approach and if drivers making a right turn from the conflicting approach to the left are simultaneously being shown a right-turn GREEN ARROW signal indication, drivers making a U-turn may be advised of the operation by the installation near the left-turn signal face of a U-TURN YIELD TO RIGHT TURN (R10-16) sign (see Section 2B.45).

Section 4D.06 Application of Steady Signal Indications for Left Turns

Support:

Left-turning traffic is controlled by one of four modes as follows:

A. Permissive Only Mode—turns made on the CIRCULAR GREEN signal indication after yielding to oncoming traffic and pedestrians;
B. Protected Only Mode—turns made only when the left-turn GREEN ARROW signal indication is displayed;
C. Protected/Permissive Mode—both modes occur on an approach during the same cycle; or
D. Variable Left-Turn Mode—the operating mode changes among the protected only mode and/or the protected/permissive mode and/or the permissive only mode during different periods of the day.

Option:

In areas having a high percentage of elderly drivers, special consideration may be given to the use of protected only mode left-turn phasing, when appropriate.

Standard:

The required left-turn signal faces and operation for an approach shall be determined by the selected mode of left-turn operation, as follows:

A. Permissive Only Mode—The signal indications for permissive only mode left turns shall be provided by the signal faces controlling the through movement, or by a permissive-only left-turn signal face that is either a shared signal face or a separate signal face. A permissive-only shared signal face, regardless of where the permissive-only left-turn signal face is positioned and regardless of how many adjacent through signal faces are provided, shall always simultaneously display the same color of circular indication that the adjacent through signal face or faces display. A separate permissive-only left-turn signal face sometimes displays a different color of circular signal indication than the adjacent through signal faces display.

If a separate left-turn signal face is provided for permissive only left turns, it shall meet the following requirements:

1. During the permissive left-turn movement, the left-turn signal face shall display a CIRCULAR GREEN signal indication.
2. If the CIRCULAR GREEN and CIRCULAR YELLOW signal indications in the left-turn signal face are visibility-limited from the adjacent through movement, the left-turn signal face shall not be required to simultaneously display the same color of circular signal indication as the signal faces for the adjacent through movement.
3. If the CIRCULAR GREEN and CIRCULAR YELLOW signal indications in the left-turn signal face are visibility-limited from the adjacent through movement, the display of a CIRCULAR GREEN signal indication for a permissive left-turn movement while the signal faces for the adjacent through movement display CIRCULAR RED signal indications and the opposing left-turn signal faces display left-turn GREEN ARROW signal indications for a protected left-turn movement shall be permitted.
4. If the left-turn signal face does not simultaneously display the same color of circular signal indication as the signal faces for the adjacent through movement, a LEFT TURN YIELD ON GREEN (symbolic green ball) (R10-12) sign or a LEFT TURN SIGNAL—YIELD ON GREEN (symbolic green ball) (R10-21) sign (see Figure 2B-19) shall be used.

B. Protected Only Mode—The left-turn signal face shall be capable of displaying one of the following sets of signal indications:

1. Left-turn RED ARROW, YELLOW ARROW, and GREEN ARROW signal indications only. At least one left-turn signal face shall be provided in addition to the two approach signal faces

required in Section 4D.15 for the major movement. Only one of the three colors shall be illuminated at any given time. A signal instruction sign shall not be required with this set of signal indications. If used, it shall be a LEFT ON GREEN ARROW ONLY sign (R10-5).

2. CIRCULAR RED, left-turn YELLOW ARROW, and left-turn GREEN ARROW signal indications. At least one left-turn signal face shall be provided in addition to the two approach signal faces required in Section 4D.15 for the major movement. Only one of the three colors shall be illuminated at any given time. Unless the CIRCULAR RED signal indication is shielded, hooded, louvered, positioned, or designed such that it is not readily visible to drivers in the through lane(s), a LEFT TURN SIGNAL sign (R10-10) shall be used.
3. CIRCULAR RED, CIRCULAR YELLOW, CIRCULAR GREEN, and left-turn GREEN ARROW signal indications. This four-section signal face shall be used only when the CIRCULAR GREEN and left-turn GREEN ARROW signal indications begin and terminate together. During each interval, the circular signal indication shall be the same color as the signal indication on the signal face(s) for the adjacent through traffic.

C. Protected/Permissive Mode—The signal indications for protected/permissive mode left turns shall be provided in either a shared signal face or a separate signal face. Any protected/permissive left-turn signal face that always simultaneously displays the same color of circular signal indication that the adjacent through signal faces display shall be considered to be a shared signal face, regardless of where the left-turn signal face is positioned and regardless of how many adjacent through signal faces are provided. Any protected/permissive left-turn signal face that sometimes displays a different color of circular signal indication than the adjacent through signal faces display shall be considered to be a separate signal face. The requirements for each type of signal face are as follows:

1. If a shared signal face is provided, it shall be considered an approach signal face, and shall meet the following requirements:
   (a) During the protected left-turn movement, the signal face shall simultaneously display a left-turn GREEN ARROW signal indication and a circular signal indication that is the same color as the signal indication for the adjacent through lane on the same approach as the protected left turn.
   During the protected left-turn movement, the signal faces for through traffic on the opposing approach shall simultaneously display CIRCULAR RED signal indications.
   (b) During the permissive left-turn movement, all signal faces on the approach shall display CIRCULAR GREEN signal indications.
   (c) All signal faces on the approach shall simultaneously display the same color of circular signal indications to both through and left-turn road users.
   (d) A supplementary sign shall not be required. If used, it shall be a LEFT TURN YIELD ON GREEN (symbolic green ball) (R10-12) sign (see Figure 2B-19).
2. If a separate signal face is provided, it shall be considered a left-turn signal face, and shall meet the following requirements:
   (a) During the protected left-turn movement, the left-turn signal face shall display a left-turn GREEN ARROW signal indication.
   During the protected left-turn movement, the signal faces for through traffic on the opposing approach shall simultaneously display CIRCULAR RED signal indications.
   (b) During the permissive left-turn movement, the left-turn signal face shall display a CIRCULAR GREEN signal indication.
   (c) If the CIRCULAR GREEN and CIRCULAR YELLOW signal indications in the left-turn signal face are visibility-limited from the adjacent through movement, the left-turn signal face shall not be required to simultaneously display the same color of circular signal indication as the signal faces for the adjacent through movement.
   (d) If the CIRCULAR GREEN and CIRCULAR YELLOW signal indications in the left-turn signal face are visibility-limited from the adjacent through movement, the display of a CIRCULAR GREEN signal indication for a permissive left-turn movement while the signal faces for the adjacent through movement display CIRCULAR RED signal indications and the opposing left-turn signal face displays a left-turn GREEN ARROW for a protected left-turn movement shall be permitted.
   (e) If the left-turn signal face does not simultaneously display the same color of circular signal indication as the signal faces for the adjacent through movement, a LEFT TURN SIGNAL—YIELD ON GREEN (symbolic green ball) (R10-21) sign (see Figure 2B-19) shall be used.

D. Variable Left-Turn Mode—If the protected only mode occurs during one or more periods of the day, and the permissive only mode or the combined protected/permissive mode occurs during other periods of the day, the requirements of Items A, B, and C in this Standard that are appropriate to that mode of operation shall be met, subject to the following:

1. The CIRCULAR GREEN and CIRCULAR YELLOW signal indications shall not be displayed when operating in the protected only mode.

2. The left-turn GREEN ARROW and left-turn YELLOW ARROW signal indications shall not be displayed when operating in the permissive only mode.

Option:

Additional appropriate signal indications or changeable message signs may be used to meet the requirements for the variable left-turn mode.

Section 4D.07 Application of Steady Signal Indications for Right Turns

Support:

Right-turning traffic is controlled by one of four modes as follows:

A. Permissive Only Mode—turns made on the CIRCULAR GREEN signal indication after yielding to pedestrians.

B. Protected Only Mode—turns made only when the right-turn GREEN ARROW signal indication is displayed.

C. Protected/Permissive Mode—both modes occur on an approach during the same cycle.

D. Variable Right-Turn Mode—the operating mode changes among the protected only mode and/or the protected/permissive mode and/or the permissive only mode during different periods of the day.

Standard:

The required right-turn signal faces and operation for an approach shall be determined by the selected mode of right-turn operation, as follows:

A. Permissive Only Mode—A separate signal indication or signal face for right turns shall not be required. The signal indication for permissive only mode right turns shall be the same color as the signal indication for adjacent through traffic, except that if the right turn is held to provide an exclusive pedestrian movement, a separate right-turn RED ARROW signal indication shall be provided.

B. Protected Only Mode—The right-turn signal face shall be capable of displaying one of the following sets of signal indications:

1. Right-turn RED ARROW, YELLOW ARROW, and GREEN ARROW signal indications only. At least one right-turn signal face shall be provided in addition to the two approach signal faces required in Section 4D.15 for the major movement. Only one of the three colors shall be illuminated at any given time. A signal instruction sign shall not be required with this set of signal indications. If used, it shall be a RIGHT ON GREEN ARROW ONLY sign (R10-5a).

2. CIRCULAR RED, right-turn YELLOW ARROW, and right-turn GREEN ARROW signal indications. At least one right-turn signal face shall be provided in addition to the two approach signal faces required in Section 4D.15 for the major movement. Only one of three colors shall be illuminated at any given time. Unless the CIRCULAR RED signal indication is shielded, hooded, louvered, positioned, or designed such that it is not readily visible to drivers in the through lane(s), a RIGHT TURN SIGNAL sign (R10-10R) shall be used.

3. CIRCULAR RED, CIRCULAR YELLOW, CIRCULAR GREEN, and right-turn GREEN ARROW signal indications. This four-section signal face shall be used only when the CIRCULAR GREEN and right-turn GREEN ARROW signal indications begin and terminate together. During each interval, the circular signal indication shall be the same color as the signal indication on the signal faces for the adjacent through traffic.

C. Protected/Permissive Mode—A separate signal face is not required for the right turn, but, if provided, it shall be considered an approach signal face, and shall meet the following requirements:

1. During the protected right-turn movement, the signal face shall simultaneously display:

(a) A right-turn GREEN ARROW signal indication, and

(b) A circular signal indication that is the same color as the signal indication for the adjacent through lane on the same approach as the protected right turn.

2. During the permissive right-turn movement, all signal faces on the approach shall display a CIRCULAR GREEN signal indication.

3. **All signal faces on the approach shall simultaneously display the same color of circular signal indications to both through and right-turn road users.**

D. Variable Right-Turn Mode—If the protected ouly mode occurs during one or more periods of the day, and the permissive ouly mode or the combined protected/permissive mode occurs during other periods of the day, the requirements of Items A, B, and C in this Standard that are appropriate to that mode of operation shall be met subject to the following:

1. **The CIRCULAR GREEN and CIRCULAR YELLOW signal indications shall not be displayed when operating in the protected ouly mode.**
2. **The right-turn GREEN ARROW and right-turn YELLOW ARROW signal indications shall not be displayed when operating in the permissive ouly mode.**

Option:

Additional appropriate signal indications or changeable message signs may be used to meet the requirements for the variable right-turn mode.

Section 4D.08 Prohibited Steady Signal Indications

Standard:

The following combinations of signal indications shall not be simultaneously displayed on any one signal face:

A. CIRCULAR GREEN with CIRCULAR YELLOW.
B. CIRCULAR RED with CIRCULAR YELLOW.
C. CIRCULAR GREEN with CIRCULAR RED.
D. Straight-through GREEN ARROW with CIRCULAR RED.

The above combinations shall not be simultaneously displayed in different signal faces on any one approach unless one of the following conditions exists:

A. One of the signal faces is a turn signal controlling a protected ouly mode turn, and a LEFT (RIGHT) TURN SIGNAL sign (R10-10) (see Sections 4D.06 and 4D.07) is mounted adjacent to each such signal face, or
B. The signal faces are shielded, hooded, louvered, positioned, or designed so that the combination is not confusing to approaching road users.

A straight-through RED ARROW signal indication or a straight-through YELLOW ARROW signal indication shall not be displayed on any signal face, either alone or in combination with any other signal indication.

Section 4D.09 Unexpected Conflicts During Green or Yellow Intervals

Standard:

A steady GREEN ARROW or YELLOW ARROW signal indication shall not be displayed to vehicular movements that are in conflict with the following:

A. Other vehicles moving on a green or yellow signal indication, except for the situation regarding U-turns described in Section 4D.05. Vehicles departing in the same direction shall not be considered in conflict if, for each turn lane with moving traffic, there is a separate departing lane, and pavement markings or raised channelization clearly indicate which departure lane to use.
B. Pedestrians crossing in conformance with a WALKING PERSON (symbolizing WALK) or flashing UPRAISED HAND (symbolizing DONT WALK) signal indication.

Guidance:

No movement that creates an unexpected crossing of pathways of moving vehicles or pedestrians should be allowed during any green or yellow interval, except when all three of the following conditions are met:

A. The movement involves only slight conflict, and
B. Serious traffic delays are substantially reduced by permitting the conflicting movement, and
C. Drivers and pedestrians subjected to the unexpected conflict are effectively warned thereof by a sign.

Section 4D.10 Yellow Change and Red Clearance Intervals

Standard:

A yellow signal indication shall be displayed following every CIRCULAR GREEN or GREEN ARROW signal indication.

The exclusive function of the yellow change interval shall be to warn traffic of an impending change in the right-of-way assignment.

The duration of a yellow change interval shall be predetermined.

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.

Option:

The yellow change interval may be followed by a red clearance interval to provide additional time before conflicting traffic movements, including pedestrians, are released.

Standard:

The duration of a red clearance interval shall be predetermined.

Guidance:

A red clearance interval should have a duration not exceeding 6 seconds.

Section 4D.11 Application of Flashing Signal Indications

Standard:

The light source of a flashing signal indication shall be flashed continuously at a rate of not less than 50 nor more than 60 times per minute. The illuminated period of each flash shall be not less than half and not more than two-thirds of the total flash cycle.

Flashing signal indications shall comply with the requirements of other Sections of this Manual regarding shielding or positioning of conflicting signal indications, except that flashing yellow signal indications for through traffic shall not be required to be shielded or positioned to prevent visual conflict for road users in separately controlled turn lanes.

The following applications shall apply whenever a traffic control signal is operated in the flashing mode:

- **A. Each approach or protected ouly mode turn movement that is controlled during steady mode (stop-and-go) operation shall display a signal indication during flashing operation.**
- **B. All signal faces that are flashed on an approach shall flash the same color, either yellow or red, except that separate signal faces for protected only mode turn movements and separate signal faces for protected/permissive left-turn movements shall be permitted to flash a CIRCULAR RED or RED ARROW signal indication when the through signal indications are flashed yellow. Shared signal faces for protected/permissive left-turn movements shall not be permitted to flash a CIRCULAR RED signal indication when the through signal indications are flashed yellow.**
- **C. The appropriate RED ARROW or YELLOW ARROW signal indication shall be flashed when a signal face consists entirely of arrow lenses.**
- **D. If a signal face includes both circular and arrow signal lenses of the color that is to be flashed, only the circular signal indication shall be flashed.**

Guidance:

When a traffic control signal is operated in the flashing mode, a flashing yellow signal indication should be used for the major street and a flashing red signal indication should be used for the other approaches unless flashing red signal indications are used on all approaches.

Section 4D.12 Flashing Operation of Traffic Control Signals

Standard:

Each traffic control signal shall be provided with an independent flasher mechanism that operates in compliance with Section 4D.11. The flashing operation shall not be terminated by removal or turn off of the controller unit or of the conflict monitor (malfunction management unit) or both.

When a traffic control signal is operated in the flashing mode:

- **A. Flashing yellow signal indications shall not be displayed for approaches with conflicting traffic movements, except for permissive left-turn movements.**
- **B. At least one signal indication in each signal face on an approach shall be flashed except in the following circumstance:**

  A single-section signal face consisting of a continuously-illuminated GREEN ARROW signal lens that is used alone to indicate a continuous movement in the steady (stop-and-go) mode shall remain continuously illuminated when the traffic control signal is operated in the flashing mode.

A manual switch, a conflict monitor (malfunction management unit) circuit, and, if appropriate, automatic means shall be provided to initiate the flashing mode.

The transition from steady (stop-and-go) mode to flashing mode, if initiated by a conflict monitor (malfunction management unit) or by a manual switch, shall be permitted to be made at any time.

Programmed changes from steady (stop-and-go) mode to flashing mode shall be made under either of the following circumstances:

A. At the end of the common major-street red interval (such as just prior to the start of the green in both directions on the major street), or

B. Directly from a steady CIRCULAR GREEN or GREEN ARROW signal indication to a flashing CIRCULAR YELLOW or YELLOW ARROW signal indication, respectively.

During programmed changes, no steady green signal indication or flashing yellow signal indication shall be terminated and immediately followed by a steady red or flashing red signal indication without first displaying the steady yellow signal indication.

Changes from flashing mode to steady (stop-and-go) mode shall be made under one of the following procedures:

A. Yellow-red flashing mode: Changes from flashing mode to steady (stop-and-go) mode shall be made at the beginning of the major-street green interval (when a green signal indication is shown to through traffic in both directions on the major street), or if there is no common major-street green interval, at the beginning of the green interval for the major traffic movement on the major street.

B. Red-red flashing mode: Changes from flashing mode to steady (stop-and-go) mode shall be made by changing the flashing red indications to steady red indications followed by appropriate green indications to begin the steady mode cycle. These green indications shall be the beginning of the major-street green interval (when a green signal indication is shown to through traffic in both directions on the major street) or if there is no common major-street green interval, at the beginning of the green interval for the major traffic movement on the major street.

Guidance:

When changing from the yellow-red flashing mode to steady (stop-and-go) mode, if there is no common major-street green interval, the provision of a steady red clearance interval for the other approaches before changing from a flashing yellow or a flashing red signal indication to a green signal indication on the major approach should be considered.

The steady red clearance interval provided during the change from red-red flashing mode to steady (stop-and-go) mode should have a duration of 6 seconds.

Support:

Section 4E.09 contains information regarding the operation of accessible pedestrian signal detector pushbutton locator tones during flashing operation.

Section 4D.13 Preemption and Priority Control of Traffic Control Signals

Option:

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:

Preemption control (see definition in Section 4A.02) is typically given to trains, boats, emergency vehicles, and light rail transit.

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 provide additional clearance time for vehicles to clear the tracks prior to the arrival of a train; and

C. A special sequence of signal phases to display a red indication to prohibit turning movements towards the tracks during the approach or passage of a train or transit vehicle.

Priority control (see definition in Section 4A.02) is typically given to certain nonemergency vehicles such as buses and light-rail vehicles.

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.

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. Typically, the order of priority is: train, boat, heavy vehicle (fire vehicle, emergency medical service), light vehicle (law enforcement), light rail transit, rubber-tired transit.

Standard:

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 steady green signal indication shall be permitted following a steady yellow signal indication in the same signal face, omitting the red clearance interval, if any.

During preemption control and during the transition out of preemption control:

A. The shortening or omission of any yellow change interval, and of any red clearance interval that follows, shall not be permitted.

B. A signal indication sequence from a steady yellow signal indication to a steady green signal indication shall not be permitted.

During priority control and during the transition into or out of priority control:

A. The shortening or omission of any yellow change interval, and of any red clearance interval that follows, shall not be permitted.

B. The shortening of any pedestrian walk interval below that time described in Section 4E.10 shall not be permitted.

C. The omission of a pedestrian walk interval and its associated change interval shall not be permitted unless the associated vehicular phase is also omitted or the pedestrian phase is exclusive.

D. The shortening or omission of any pedestrian change interval shall not be permitted.

E. A signal indication sequence from a steady yellow signal indication to a steady green signal indication shall not be permitted.

Guidance:

When a traffic control signal that is returning to a steady mode from a dark mode (typically upon restoration from a power failure) receives a preemption or priority request, care should be exercised to minimize the possibility of vehicles or pedestrians being misdirected into a conflict with the vehicle making the request.

If a traffic control signal is installed near or within a highway-railroad grade crossing or if a highway-railroad grade crossing with active traffic control devices is within or near a signalized highway intersection, Chapter 8D should be consulted.

Traffic control signals operating under preemption control or under priority control should be operated in a manner designed to keep traffic moving.

Traffic control signals that are designed to respond under preemption or priority control to more than one type or class of vehicle should be designed to respond in the relative order of importance or difficulty in stopping the type or class of vehicle.

Option:

During the change from a dark mode to a steady mode under a preemption or priority request, the display of signal indications that could misdirect road users may be prevented by the following:

A. Having the traffic control signal remain in the dark mode;

B. Having the traffic control signal remain in the flashing mode;

C. Altering the flashing mode;

D. Executing the normal start-up routine before responding; and

E. Responding directly to initial or dwell period.

A distinctive indication may be provided at the intersection to show that an emergency vehicle has been given control of the traffic control signal (see Section 11-106 of the "Uniform Vehicle Code").

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 nonintersection 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.

Section 4D.14 Coordination of Traffic Control Signals

Guidance:

Traffic control signals within 800 m (0.5 mi) of one another along a major route or in a network of intersecting major routes should be coordinated, preferably with interconnected controller units. However, signal coordination need not be maintained across boundaries between signal systems that operate on different cycle lengths.

Support:

For coordination with railroad-highway grade crossing signals, see Sections 4D.13 and 8D.07.

Section 4D.15 Size, Number, and Location of Signal Faces by Approach

Support:

Sections 4D.05, and 4D.16 through 4D.18 contain additional information regarding the design of signal faces.

Standard:

There shall be two nominal diameter sizes for vehicular signal lenses: 200 mm (8 in) and 300 mm (12 in).

Three-hundred millimeter (12 in) signal lenses shall be used:

A. For signal indications for approaches (see definition in Section 4A.02) where road users view both traffic control and lane-use control signal heads simultaneously;
B. If the nearest signal face is between 35 m (120 ft) and 45 m (150 ft) beyond the stop line, unless a supplemental near-side signal face is provided;
C. For signal faces located more than 45 m (150 ft) from the stop line;
D. For approaches to all signalized locations for which the minimum sight distance in Table 4D-1 cannot be met; and
E. For arrow signal indications.

A 200 mm (8 in) signal lens for a CIRCULAR RED signal indication shall not be used in combination with a 300 mm (12 in) signal lens for a CIRCULAR GREEN signal indication or a 300 mm (12 in) signal lens for a CIRCULAR YELLOW signal indication.

Option:

Different sizes of signal lenses may be used in the same signal face or signal head, except for the prohibitions listed in the Standards in this Section.

Guidance:

Three-hundred millimeter (12 in) signal lenses should be used for all signal indications for the following:

A. Approaches with 85th-percentile approach speeds exceeding 60 km/h (40 mph);
B. Approaches where a traffic control signal might be unexpected;
C. All approaches without curbs and gutters where only post-mounted signal heads are used; and
D. Locations where there is a significant percentage of elderly drivers.

Standard:

The signal faces for each approach to an intersection or a midblock location shall be provided as follows:

A. A minimum of two signal faces shall be provided for the major movement on the approach, even if the major movement is a turning movement.
B. See Section 4D.06 for left-turn signal faces.
C. See Section 4D.07 for right-turn signal faces.
D. Except where the width of an intersecting roadway or other conditions make it physically impractical:
   1. A signal face installed to satisfy the requirements for left-turn signal faces (see Section 4D.06) and right-turn signal faces (see Section 4D.07), and at least one and preferably both of the two signal faces required for the major movement on the approach shall be located:
      (a) Not less than 12 m (40 ft) beyond the stop line.
      (b) Not more than 55 m (180 ft) beyond the stop line unless a supplemental near side signal face is provided.
      (c) As near as practical to the line of the driver's normal view, if mounted over the roadway.

Table 4D-1. Minimum Sight Distance

85th-Percentile Speed (km/h)	Minimum Sight Distance (meters)
30	50
40	65
50	85
60	110
70	140
80	165
90	195
100	220

85th-Percentile Speed (mph)	Minimum Sight Distance (feet)
20	175
25	215
30	270
35	325
40	390
45	460
50	540
55	625
60	715

---

2. Where the nearest signal face is located between 45 and 55 m (150 and 180 ft) beyond the stop line, engineering judgment of the conditions, including the worst-case visibility conditions, shall be used to determine if the provision of a supplemental near side signal face would be beneficial.
3. A signal face installed to satisfy the requirements for left-turn signal faces (see Section 4D.06) and right-turn signal faces (see Section 4D.07), and at least one and preferably both of the two signal faces required for the major movement on the approach shall be located no higher than at a maximum height to the top of the signal housing mounted over a roadway of 7.8 m (25.6 ft) above the pavement (see Section 4D.17). For viewing distances between 12 m (40 ft) and 16 m (53 ft) from the stop line, the maximum mounting height to the top of the signal housing shall be as shown on Fignre 4D-1. (See Section 4D.17 for additional information regarding mounting heights.)
4. At least one and preferably both of the signal faces required by Item A in this Standard shall be located between two lines intersecting with the center of the approach at a point 3 m (10 ft) behind the stop line, one making an angle of approximately 20 degrees to the right of the center of the approach extended, and the other making an angle of approximately 20 degrees to the left of the center of the approach extended (see Figure 4D-2)
5. If both of the signal faces required by Item A in this Standard are post-mounted, they shall both be on the far side of the intersection, one on the right and one on the left of the approach lane(s).

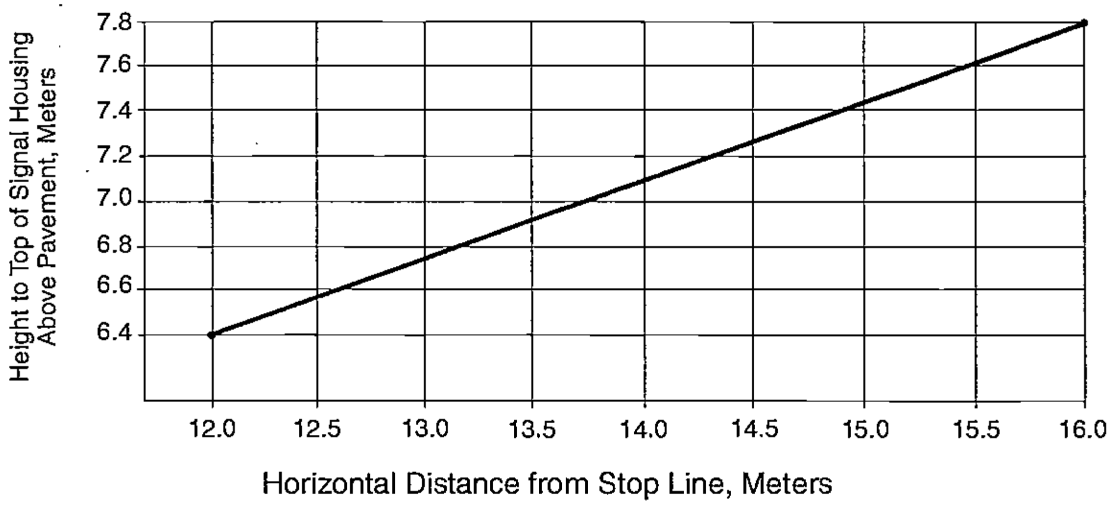
E. If the minimum sight distance in Table 4D-1 cannot be met, a sign shall be installed to warn approaching traffic of the traffic control signal.

F. Required signal faces for through traffic on any one approach shall be located not less than 2.4 m (8 ft) apart measured horizontally perpendicular to the approach between the centers of the signal faces.

G. If more than one turn signal face is provided for a protected-mode turn and if one or both of the signal faces are located over the roadway, the signal faces shall be located not less than 2.4 m (8 ft) apart measured horizontally perpendicular to the approach between the centers of the signal faces.

H. If supplemental signal faces are used, the following limitations shall apply:
1. Left-turn arrows shall not be used in near-right signal faces.
2. Right-turn arrows shall not be used in far-left signal faces. A far-side median-mounted signal face shall be considered a far-left signal for this application.

Figure 4D-1. Maximum Mounting Height of Signal Faces Located Between 12 Meters (40 Feet) and 16 Meters (53 Feet) from Stop Line



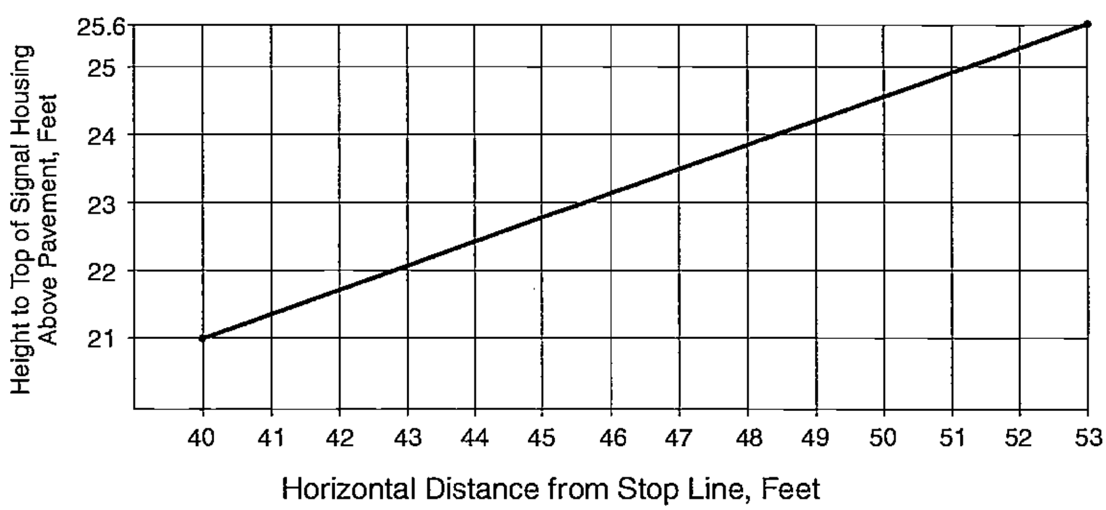
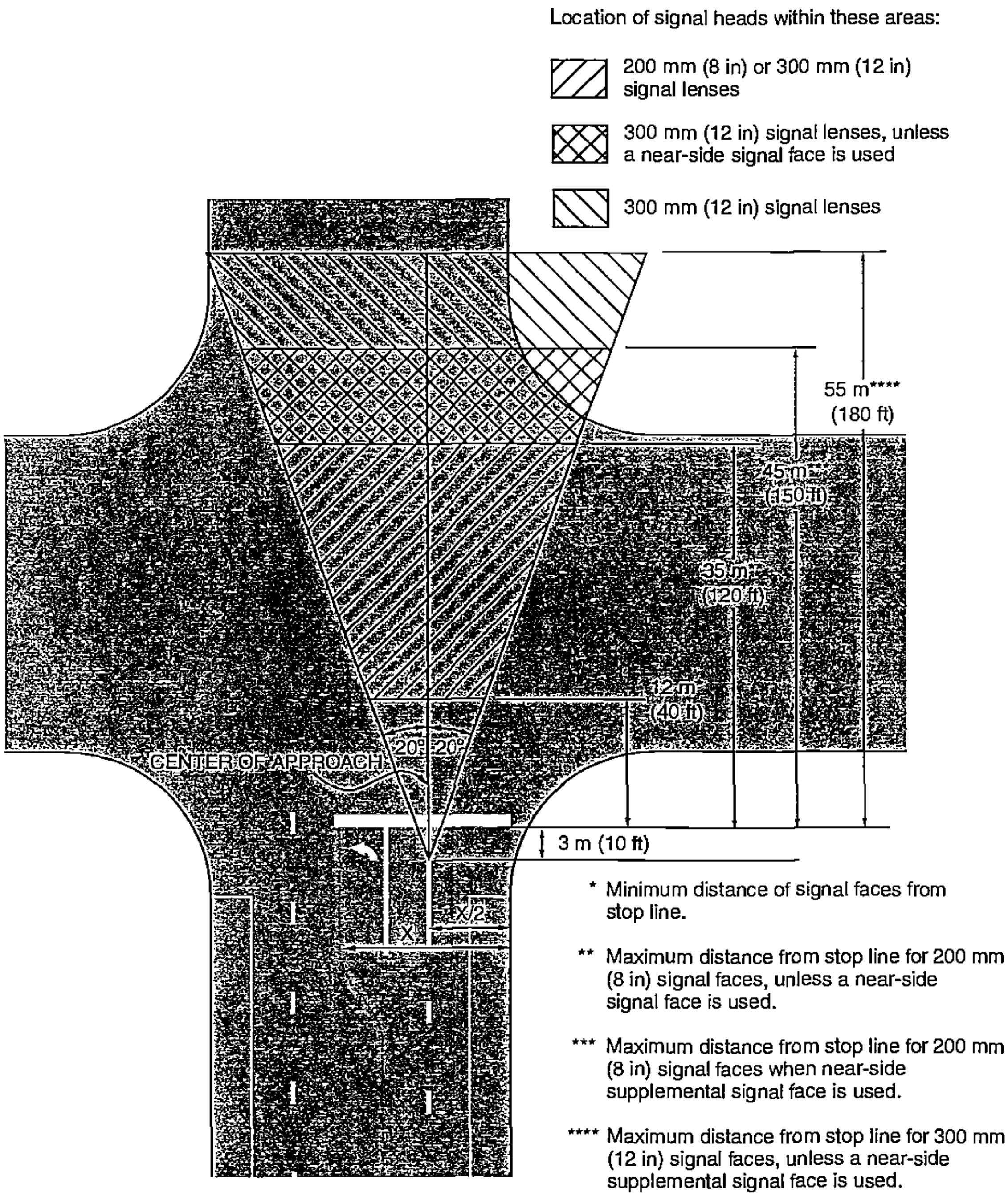


Figure 4D-2. Horizontal Location of Signal Faces



Guidance:

The two signal faces required for each approach should be continuously visible to traffic approaching the traffic control signal, from a point at least the minimum sight distance indicated in Table 4D-1 in advance of and measured to the stop line. This range of continuous visibility should be provided unless precluded by a physical obstruction or unless another signalized location is within this range.

If two or more left-turn lanes are provided for a separately controlled protected only mode left-turn movement, or if a left-turn movement represents the major movement from an approach, two left-turn signal faces should be provided.

If two or more right-turn lanes are provided for a separately controlled right-turn movement, or if a right-turn movement represents the major movement from an approach, two right-turn signal faces should be provided.

Near-side signal faces should be located as near as practical to the stop line.

If a signal face controls a specific lane or lanes of an approach, its position should make it readily visible to road users making that movement.

Supplemental signal faces should be used if engineering judgment has shown that they are needed to achieve intersection visibility both in advance and immediately before the signalized location. If supplemental signal faces are used, they should be located to provide optimum visibility for the movement to be controlled.

At signalized midblock crosswalks, at least one of the signal faces should be over the traveled way for each approach.

Option:

If a sign is installed to warn approaching road users of the traffic control signal, the sign may be supplemented by a Warning Beacon (see Section 4K.03).

A Warning Beacon used in this manner may be interconnected with the traffic signal controller assembly in such a manner as to flash yellow during the period when road users passing this beacon at the legal speed for the roadway might encounter a red signal indication (or a queue resulting from the display of the red signal indication) upon arrival at the signalized location.

Section 4D.16 Number and Arrangement of Signal Sections in Vehicular Traffic Control Signal Faces

Standard:

Each signal face at a signalized location shall have three, four, or five signal sections.

A single-section signal face shall be permitted at a traffic control signal if it consists of a continuously illuminated GREEN ARROW signal lens that is being used to indicate a continuous movement.

Arrows shall be pointed:

A. Vertically upward to indicate a straight-through movement;
B. Horizontally in the direction of the turn to indicate a turn at approximately or greater than a right angle; and
C. Upward with a slope at an angle approximately equal to that of the turn if the angle of the turn is substantially less than a right angle.

The signal lenses in a signal face shall be arranged in a vertical or horizontal straight line, except that in a vertical array, signal lenses of the same color may be arranged horizontally adjacent to each other at right angles to the basic straight line arrangement. Such clusters shall be limited to two identical signal lenses or to two or three different signal lenses of the same color.

In each signal face, all red signal lenses in vertically arranged signal faces shall be located above, and in horizontally arranged signal faces shall be located to the left, of all yellow and green signal lenses.

If a CIRCULAR YELLOW signal lens is used, it shall be located between the red signal lens or lenses and all other signal lenses.

In vertically arranged signal faces, each YELLOW ARROW signal lens shall be located immediately above the GREEN ARROW signal lens to which it applies. If a dual-arrow signal section (capable of alternating between the display of a GREEN ARROW and a YELLOW ARROW signal indication) is used, the lenses shall be in the same position relative to other lenses as are the GREEN ARROW signal lenses in a vertically arranged signal face.

In horizontally arranged signal faces, the YELLOW ARROW signal lens shall be located immediately to the left of the GREEN ARROW signal lens. If a dual-arrow signal section (capable of alternating between the display of a GREEN ARROW and a YELLOW ARROW signal indication) is used, the dual left-turn arrow signal lens shall be located immediately to the right of the CIRCULAR YELLOW signal

lens, the straight-through GREEN ARROW signal lens shall be located immediately to the right of the CIRCULAR GREEN signal lens, and the dual right-turn arrow signal lens shall be located to the right of all other signal lenses.

The relative positions of signal lenses within the signal face shall be as follows:

A. In a vertically arranged signal face from top to bottom:
CIRCULAR RED
Left-turn RED ARROW
Right-turn RED ARROW
CIRCULAR YELLOW
CIRCULAR GREEN
Straight-through GREEN ARROW
Left-turn YELLOW ARROW
Left-turn GREEN ARROW
Right-turn YELLOW ARROW
Right-turn GREEN ARROW

B. In a horizontally arranged signal face from left to right:
CIRCULAR RED
Left-turn RED ARROW
Right-turn RED ARROW
CIRCULAR YELLOW
Left-turn YELLOW ARROW
Left-turn GREEN ARROW
CIRCULAR GREEN
Straight-through GREEN ARROW
Right-turn YELLOW ARROW
Right-turn GREEN ARROW

C. If adjacent signal indications in a signal face are not identical, their arrangement shall follow Items A or B above, as applicable.

Option:

In a vertically arranged signal face, identical signal indications may be repeated in adjacent horizontal locations within the same signal face.

Horizontally arranged and vertically arranged signal faces may be used on the same approach provided they are separated to meet the lateral separation spacing required in Section 4D.15.

Support:

Figure 4D-3 illustrates some of the possible arrangements of signal lenses in signal faces.

Section 4D.17 Visibility, Shielding, and Positioning of Signal Faces

Standard:

The primary consideration in signal face placement, aiming, and adjustment shall be to optimize the visibility of signal indications to approaching traffic. Road users approaching a signalized intersection or other signalized area, such as a midblock crosswalk, shall be given a clear and unmistakable indication of their right-of-way assignment.

The geometry of each intersection to be signalized, including vertical grades, horizontal curves, and obstructions as well as the lateral and vertical angles of sight toward a signal face, as determined by typical driver-eye position, shall be considered in determining the vertical, longitudinal, and lateral position of the signal face.

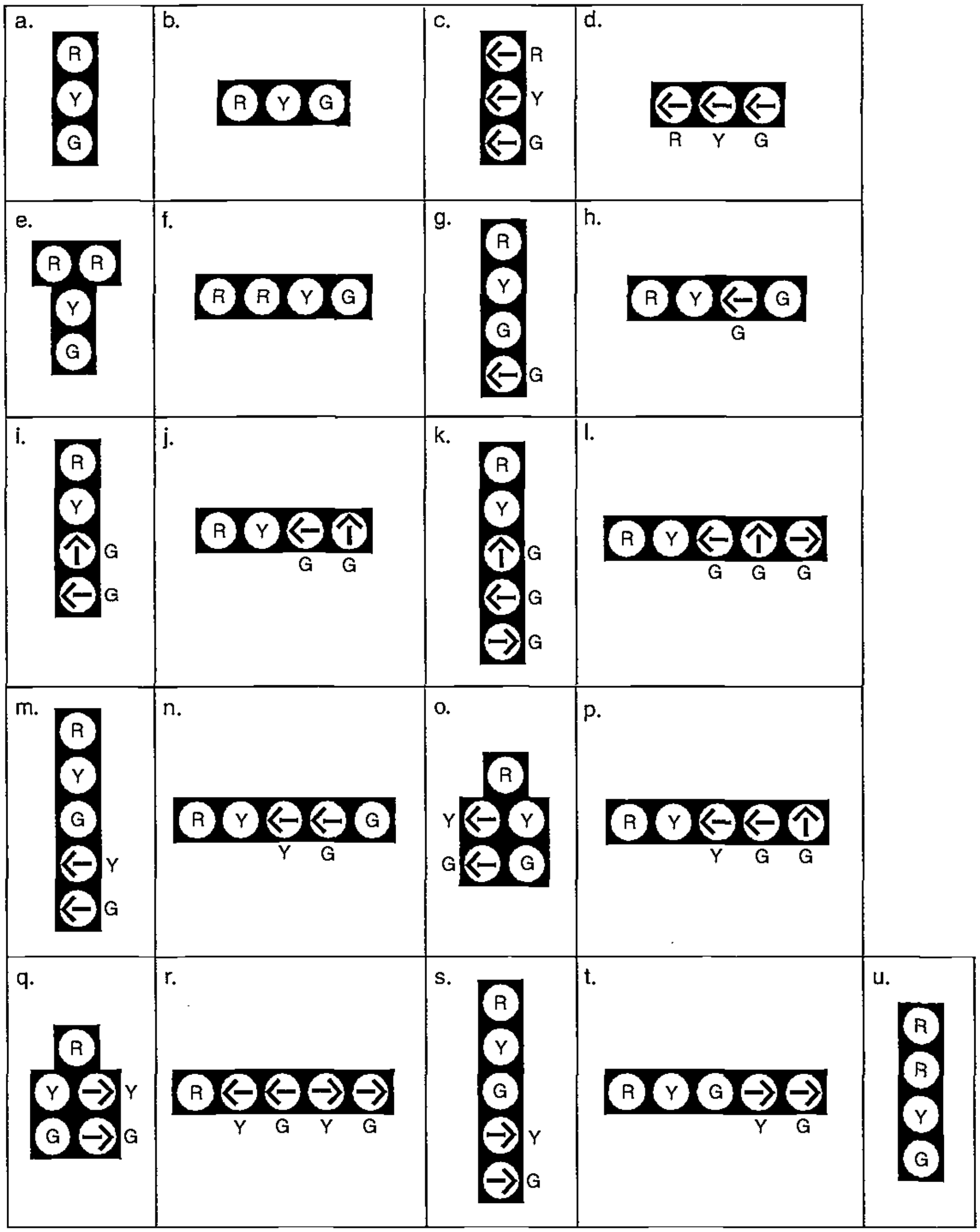
In cases where irregular street design necessitates placing signal faces for different street approaches with a comparatively small angle between their respective signal lenses, each signal lens shall, to the extent practical, be shielded or directed by signal visors, signal louvers, or other means so that an approaching road user can see only the signal lens(es) controlling the movements on the road user's approach.

The bottom of the signal housing and any related attachments to a vehicular signal face located over a roadway shall be at least 4.6 m (15 ft) above the pavement. The top of the signal housing of a vehicular signal face located over a roadway shall not be more than 7.8 m (25.6 ft) above the pavement.

Signal visors exceeding 300 mm (12 in) in length shall not be used on free-swinging signal heads.

The bottom of the signal housing (including brackets) of a vehicular signal face that is vertically arranged and not located over a roadway:

Figure 4D-3. Typical Arrangements of Signal Lenses in Signal Faces



A. Shall be at least 2.4 m (8 ft) but not more than 5.8 m (19 ft) above the sidewalk or, if there is no sidewalk, above the pavement grade at the center of the roadway.
B. Shall be at least 1.4 m (4.5 ft) but not more than 5.8 m (19 ft) above the median island grade of a center median island if located on the near side of the intersection.

The bottom of the signal housing (including brackets) of a vehicular signal face that is horizontally arranged and not located over a roadway:

A. Shall be at least 2.4 m (8 ft) but not more than 6.7 m (22 ft) above the sidewalk or, if there is no sidewalk, above the pavement grade at the center of the roadway.
B. Shall be at least 1.4 m (4.5 ft) but not more than 6.7 m (22 ft) above the median island grade of a center median island if located on the near side of the intersection.

Signal heads mounted at less than 4.6 meters (15 feet) from the bottom of the housing and any related attachments at the side of a roadway with curbs shall have a horizontal clearance of not less than 0.6 m (2 ft) from the face of a vertical curb. If there is no curb, signal heads shall have a horizontal clearance of not less than 0.6 m (2 ft) from the edge of a shoulder.

Guidance:

There should be legal authority to prohibit the display of any unauthorized sign, signal, marking, or device that interferes with the effectiveness of any official traffic control device (see Section 11-205 of the "Uniform Vehicle Code").

Signal visors should be used on signal faces to aid in directing the signal indication specifically to approaching traffic, as well as to reduce "sun phantom," which can result when external light enters the lens.

The use of signal visors, or the use of signal faces or devices that direct the light without a reduction in intensity, should be considered as an alternative to signal louvers because of the reduction in light output caused by signal louvers.

The use of a signal backplate for target value enhancement should be considered on signal faces viewed against a bright sky or bright or confusing backgrounds.

Support:

The use of backplates enhances the contrast between the traffic signal indications and their surroundings for both day and night conditions, which is also helpful to elderly drivers.

Option:

Special signal faces, such as visibility-limited signal faces, may be used such that the road user does not see signal indications intended for other approaches before seeing the signal indications for their own approach, if simultaneous viewing of both signal indications could cause the road user to be misdirected.

If the sight distance to the signal heads facing the approach is limited by horizontal or vertical alignment, supplemental signal faces aimed at a point on the approach at which the signal indications first become visible may be used.

Section 4D.18 Design, Illumination, and Color of Signal Sections

Standard:

Each signal indication, except those used for pedestrian signal heads and lane-use control signals, shall be circular or arrow.

Letters or numbers shall not be displayed as part of a vehicular signal indication.

Each signal indication shall be independently illuminated.

Each circular signal indication shall emit a single color: red, yellow, or green.

Each arrow signal indication shall emit a single color: red, yellow, or green except that the alternate display (dual-arrow signal section) of a GREEN ARROW and a YELLOW ARROW signal indication, both pointing in the same direction, shall be permitted, provided that they are not displayed simultaneously.

The arrow, which shall show only one direction, shall be the only illuminated part of an arrow signal indication.

Except for the requirements of this section, the requirements of the "Standards for Vehicle Traffic Control Signal Heads" (see Section 1A.11) shall be met.

References to signal lenses in this section shall not be used to limit signal optical units to incandescent lamps within optical assemblies that include lenses.

Support:

Research has resulted in signal optical units that are not lenses, such as, but not limited to, light-emitting diode (LED) traffic signal modules. Some units are practical for all signal indications, and some are practical for specific types such as visibility-limited signal indications.

Guidance:

The intensity and distribution of light from each illuminated signal lens should conform to the current "Standards for Vehicle Traffic Control Signal Heads" and "Traffic Signal Lamps" (see Section 1A.11).

If a signal indication is operated in the flashing mode for nighttime operation and the signal indication is so bright as to cause excessive glare, some form of automatic dimming should be used to reduce the brilliance of the signal indication.

Standard:

The inside of signal visors (hoods), the entire surface of louvers and fins, and the front surface of backplates shall have a dull black finish to minimize light reflection and to increase contrast between the signal indication and its background.

Section 4D.19 Lateral Placement of Signal Supports and Cabinets

Guidance:

The following items should be considered when placing signal supports and cabinets:

A. Reference should be made to the American Association of State Highway and Transportation Officials (AASHTO) "Roadside Design Guide" (see Section 1A.11) and to the "Americans with Disabilities Act Accessibility Guidelines for Buildings and Facilities (ADAAG)" (see Section 1A.11).
B. Signal supports should be placed as far as practical from the edge of the traveled way without adversely affecting the visibility of the signal indications.
   Where supports cannot be located based on the recommended AASHTO clearances, consideration should be given to the use of appropriate safety devices.
   No part of a concrete base for a signal support should extend more than 100 mm (4 in) above the ground level at any point. This limitation does not apply to the concrete base for a rigid support.
C. In order to minimize hindrance to the passage of persons with physical disabilities, a signal support or controller cabinet should not obstruct the sidewalk, or access from the sidewalk to the crosswalk.
D. Controller cabinets should be located as far as practical from the edge of the roadway.
E. On medians, the above minimum clearances for signal supports should be obtained if practical.

Section 4D.20 Temporary Traffic Control Signals

Standard:

A temporary traffic control signal shall be defined as a traffic control signal that is installed for a limited time period. A portable traffic control signal shall be defined as a temporary traffic control signal that is designed so that it can be easily transported and reused at different locations.

Support:

A temporary traffic control signal is generally installed using methods that minimize the costs of installation, relocation, and/or removal. Typical temporary traffic control signals are for specific purposes, such as for one-lane, two-way facilities in temporary traffic control zones (see Chapter 4G), for a haul-road intersection, or for access to a site that will have a permanent access point developed at another location in the near future.

Standard:

Advance signing shall be used when employing a temporary traffic control signal.

A temporary traffic control signal shall:

A. Meet the physical display and operational requirements of a conventional traffic control signal.
B. Be removed when no longer needed.
C. Be placed in the flashing mode when not being used if it will be operated in the steady mode within 5 working days; otherwise, it shall be removed.
D. Be placed in the flashing mode during periods when it is not desirable to operate the signal, or the signal heads shall be covered, turned, or taken down to indicate that the signal is not in operation.

Guidance:

A temporary traffic control signal should be used only if engineering judgment indicates that installing the signal will improve the overall safety and/or operation of the location. The use of temporary traffic control signals by a work crew on a regular basis in their work area should be subject to the approval of the jurisdiction having authority over the roadway.

A temporary traffic control signal should not operate longer than 30 days unless associated with a longer-term temporary traffic control zone project.

For use of temporary traffic control signals in temporary traffic control zones, reference should be made to Section 6F.80.

Section 4D.21 Traffic Signal Signs, Auxiliary

Support:

Traffic signal signs are sometimes used at highway traffic signal locations to instruct or guide pedestrians, bicyclists, or motorists.

Standard:

The minimum vertical and horizontal clearance of the total assembly of traffic signal signs (see Section 2B.45) shall conform to the provisions of Section 4D.17.

If used, illuminated traffic signal signs shall be designed and mounted in such a manner as to avoid glare and reflections that seriously detract from the signal indications. Traffic control signal faces shall be given dominant position and brightness to maximize their priority in the overall display.

Guidance:

Traffic signal signs should be located adjacent to the signal face to which they apply.

CHAPTER 4E. PEDESTRIAN CONTROL FEATURES

Section 4E.01 Pedestrian Signal Heads

Support:

Pedestrian signal heads provide special types of traffic signal indications exclusively intended for controlling pedestrian traffic. These signal indications consist of the illuminated symbols of a WALKING PERSON (symbolizing WALK) and an UPRAISED HAND (symbolizing DONT WALK).

Guidance:

Engineering judgment should determine the need for separate pedestrian signal heads (see Section 4D.03) and accessible pedestrian signals (see Section 4E.06).

Section 4E.02 Meaning of Pedestrian Signal Head Indications

Standard:

Pedestrian signal head indications shall have the following meanings:

A. A steady WALKING PERSON (symbolizing WALK) signal indication means that a pedestrian facing the signal indication is permitted to start to cross the roadway in the direction of the signal indication, possibly in conflict with turning vehicles. The pedestrian shall yield the right-of-way to vehicles lawfully within the intersection at the time that the WALKING PERSON (symbolizing WALK) signal indication is first shown.

B. A flashing UPRAISED HAND (symbolizing DONT WALK) signal indication means that a pedestrian shall not start to cross the roadway in the direction of the signal indication, but that any pedestrian who has already started to cross on a steady WALKING PERSON (symbolizing WALK) signal indication shall proceed out of the traveled way.

C. A steady UPRAISED HAND (symbolizing DONT WALK) signal indication means that a pedestrian shall not enter the roadway in the direction of the signal indication.

D. A flashing WALKING PERSON (symbolizing WALK) signal indication has no meaning and shall not be used.

Section 4E.03 Application of Pedestrian Signal Heads

Standard:

Pedestrian signal heads shall be used in conjunction with vehicular traffic control signals under any of the following conditions:

A. If a traffic control signal is justified by an engineering study and meets either Warrant 4, Pedestrian Volume or Warrant 5, School Crossing (see Chapter 4C);

B. If an exclusive signal phase is provided or made available for pedestrian movements in one or more directions, with all conflicting vehicular movements being stopped; or

C. At an established school crossing at any signalized location.

D. Where engineering judgment determines that multiphase signal indications (as with split-phase timing) would tend to confuse or cause conflicts with pedestrians using a crosswalk guided only by vehicular signal indications.

Guidance:

Pedestrian signal heads should be used under any of the following conditions:

A. If it is necessary to assist pedestrians in making a reasonably safe crossing or if engineering judgment determines that pedestrian signal heads are justified to minimize vehicle-pedestrian conflicts;

B. If pedestrians are permitted to cross a portion of a street, such as to or from a median of sufficient width for pedestrians to wait, during a particular interval but are not permitted to cross the remainder of the street during any part of the same interval; and/or

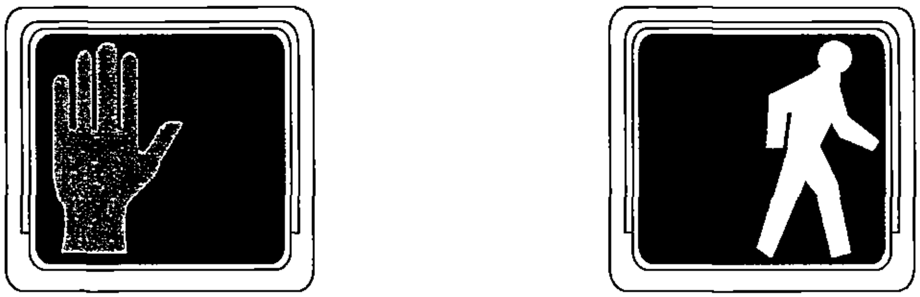
C. If no vehicular signal indications are visible to pedestrians, or if the vehicular signal indications that are visible to pedestrians starting or continuing a crossing provide insufficient guidance for them to decide when it is reasonably safe to cross, such as on one-way streets, at T-intersections, or at multiphase signal operations.

Section 4E.04 Size, Design, and Illumination of Pedestrian Signal Head Indications

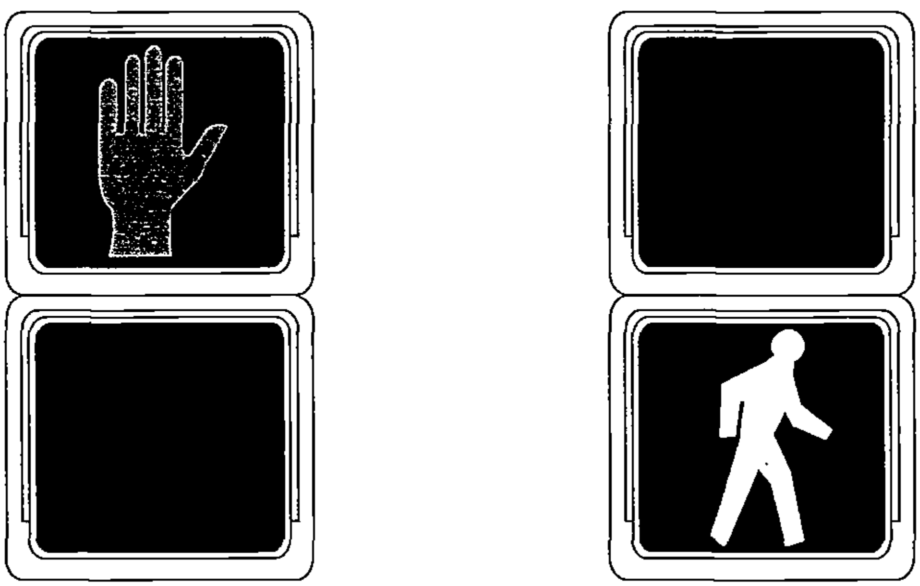
Standard:

All new pedestrian signal head indications shall be displayed within a rectangnlar background and sball consist of symbolized messages (see Figure 4E-1), except that existing pedestrian signal head indications with lettered or outline style symbol messages may be retained for the remainder of their useful

Figure 4E-1. Typical Pedestrian Signal Indications



One Section



Two Section

service life. The symbol designs that are set forth in the "Standard Highway Signs" book shall be used. Each pedestrian signal head indication shall be independently illuminated and emit a single color.

The UPRAISED HAND (symbolizing DONT WALK) signal section shall be mounted directly above or integral with the WALKING PERSON (symbolizing WALK) signal section.

The WALKING PERSON (symbolizing WALK) signal indication shall be white, conforming to the publication entitled "Pedestrian Traffic Control Signal Indications" (see Section 1A.11), with all except the symbol obscured by an opaque material.

The UPRAISED HAND (symbolizing DONT WALK) signal indication shall be Portland orange, conforming to the publication entitled "Pedestrian Traffic Control Signal Indications" (see Section 1A.11), with all except the symbol obscured by an opaque material.

When not illuminated, the WALKING PERSON (symbolizing WALK) and UPRAISED HAND (symbolizing DONT WALK) symbols shall not be readily visible to pedestrians at the far end of the crosswalk that the pedestrian signal head indications control.

For pedestrian signal head indications, the symbols shall be at least 150 mm (6 in) high.

The light source of a flashing UPRAISED HAND (symbolizing DONT WALK) signal indication shall be flashed continuously at a rate of not less than 50 nor more than 60 times per minute. The illuminated period of each flash shall be not less than half and not more than two-thirds of the total flash cycle.

Guidance:

Pedestrian signal head indications should be conspicuous and recognizable to pedestrians at all distances from the beginning of the controlled crosswalk to a point 3 m (10 ft) from the end of the controlled crosswalk during both day and night.

For crosswalks where the pedestrian enters the crosswalk more than 30 m (100 ft) from the pedestrian signal head indications, the symbols should be at least 225 mm (9 in) high.

Option:

An animated eyes symbol may be added to a pedestrian signal head in order to prompt pedestrians to look for vehicles in the intersection during the time that the WALK signal indication is displayed.

Standard:

If used, the animated eyes symbol shall consist of an outline of a pair of white steadily-illuminated eyes with white eyeballs that scan from side to side at a rate of approximately once per second. The animated eyes symbol shall be at least 300 mm (12 in) wide with each eye having a width of at least 125 mm (5 in) and a height of at least 62 mm (2.5 in). The animated eyes symbol shall be illuminated at the start of the walk interval and shall terminate at the end of the walk interval.

Section 4E.05 Location and Height of Pedestrian Signal Heads

Standard:

Pedestrian signal heads shall be mounted with the bottom of the signal housing including brackets not less than 2.1 m (7 ft) nor more than 3 m (10 ft) above sidewalk level, and shall be positioned and adjusted to provide maximum visibility at the beginning of the controlled crosswalk.

If pedestrian signal heads are mounted on the same support as vehicular signal heads, there shall be a physical separation between them.

Section 4E.06 Accessible Pedestrian Signals

Support:

The primary technique that pedestrians who have visual disabilities use to cross streets at signalized locations is to initiate their crossing when they hear the traffic in front of them stop and the traffic alongside them begin to move, corresponding to the onset of the green interval. This technique is effective at many signalized locations. The existing environment is often sufficient to provide the information that pedestrians who have visual disabilities need to operate reasonably safely at a signalized location. Therefore, many signalized locations will not require any accessible pedestrian signals.

Guidance:

If a particular signalized location presents difficulties for pedestrians who have visual disabilities to cross reasonably safely and effectively, an engineering study should be conducted that considers the safety and effectiveness for pedestrians in general, as well as the information needs of pedestrians with visual disabilities.

Support:

The factors that might make crossing at a signalized location difficult for pedestrians who have visual disabilities include: increasingly quiet cars, right turn on red (which masks the beginning of the through phase), continuous right-turn movements, complex signal operations, traffic circles, and wide streets. Further, low traffic volumes might make it difficult for pedestrians who have visual disabilities to discern signal phase changes.

Local organizations, providing support services to pedestrians who have visual and/or hearing disabilities, can often act as important advisors to the traffic engineer when consideration is being given to the installation of devices to assist such pedestrians. Additionally, orientation and mobility specialists or similar staff also might be able to provide a wide range of advice. The U.S. Access Board's Document A-37, "Accessible Pedestrian Signals," provides various techniques for making pedestrian signal information available to persons with visual disabilities (see Page i for the address for the U.S. Access Board).

Accessible pedestrian signals provide information in nonvisual format (such as audible tones, verbal messages, and/or vibrating surfaces).

Information regarding detectors for accessible pedestrian signals is found in Section 4E.09.

Standard:

When used, accessible pedestrian signals shall be used in combination with pedestrian signal timing. The information provided by an accessible pedestrian signal shall clearly indicate which pedestrian crossing is served by each device.

Under stop-and-go operation, accessible pedestrian signals shall not be limited in operation by the time of day or day of week.

Guidance:

The installation of accessible pedestrian signals at signalized locations should be based on an engineering study, which should consider the following factors:

- A. *Potential demand for accessible pedestrian signals;*
- B. *A request for accessible pedestrian signals;*
- C. *Traffic volumes during times when pedestrians might be present, including periods of low traffic volumes or high turn-on-red volumes;*
- D. *The complexity of traffic signal phasing; and*
- E. *The complexity of intersection geometry.*

Support:

Technology that provides different sounds for each nonconcurrent signal phase has frequently been found to provide ambiguous information.

Standard:

When choosing audible tones, possible extraneous sources of sounds (such as wind, rain, vehicle back-up warnings, or birds) shall be considered in order to eliminate potential confusion to pedestrians who have visual disabilities.

Guidance:

Audible pedestrian tones should be carefully selected to avoid misleading pedestrians who have visual disabilities when the following conditions exist:

- A. *Where there is an island that allows unsignalized right turns across a crosswalk between the island and the sidewalk.*
- B. *Where multileg approaches or complex signal phasing require more than two pedestrian phases, such that it might be unclear which crosswalk is served by each audible tone.*
- C. *At intersections where a diagonal pedestrian crossing is allowed, or where one street receives a WALKING PERSON (symbolizing WALK) signal indication simultaneously with another street.*

Standard:

When accessible pedestrian signals have an audible tone(s), they shall have a tone for the walk interval. The audible tone(s) shall be audible from the beginning of the associated crosswalk. If the tone for the walk interval is similar to the pushbutton locator tone, the walk interval tone shall have a faster repetition rate than the associated pushbutton locator tone.

Support:

A pushbutton locator tone is a repeating sound that informs approaching pedestrians that they are required to push a button to actuate pedestrian timing, and that enables visually impaired pedestrians to locate the pushbutton (see Section 4E.09).

Guidance:

The accessible walk signal tone should be no louder than the locator tone, except when there is optional activation to provide a louder signal tone for a single pedestrian phase.

Automatic volume adjustment in response to ambient traffic sound level should be provided up to a maximum volume of 89 dBA. Where automatic volume adjustment is used, tones should be no more than 5 dBA louder than ambient sound. The A-weighted sound pressure level should conform to the requirements of "ISO 1996-1:1982" and "ISO 1996-2:1987" (see Page i for the address for the International Organization for Standards).

Standard:

When verbal messages are used to communicate the pedestrian interval, they shall provide a clear message that the walk interval is in effect, as well as to which crossing it applies.

The verbal message that is provided at regular intervals throughout the timing of the walk interval shall be the term "walk sigu," which may be followed by tbe name of the street to be crossed.

A verbal message is not required at times when the walk interval is not timing, but, if provided:

A. It shall be the term "wait."

B. It need not be repeated for the entire time that tbe walk interval is not timing.

Option:

Accessible pedestrian signals that provide verbal messages may provide similar messages in languages other than English, if needed, except for the terms "walk sign" and "wait."

Support:

A vibrotactile pedestrian device communicates information about pedestrian timing through a vibrating surface by touch.

Standard:

Vibrotactile pedestrian devices, where used, shall indicate that the walk interval is in effect, and for which direction it applies, through the use of a vibrating directional arrow or some other means.

Guidance:

When provided, vibrotactile pedestrian devices should be located next to, and on the same pole as, the pedestrian pushbutton, if any, and adjacent to the intended crosswalk.

Section 4E.07 Countdown Pedestrian Signals

Option:

A pedestrian interval countdown display may be added to a pedestrian signal head in order to inform pedestrians of the number of seconds remaining in the pedestrian change interval.

Standard:

If used, countdown pedestrian signals shall consist of Portland orange numbers tbat are at least 150 mm (6 in) in height on a black opaque background. The countdown pedestrian signal shall be located immediately adjacent to the associated UPRAISED HAND (symbolizing DONT WALK) pedestrian signal head indication.

If used, the display of the number of remaining seconds shall begin ouly at the beginning of the pedestrian change interval. After the countdown displays zero, the display shall remain dark until the beginning of the next countdown.

If used, the countdown pedestrian signal shall display the number of seconds remaining until the termination of the pedestrian change interval. Countdown displays shall not be used during the walk interval nor during the yellow change interval of a concurrent vehicular phase.

Guidance:

If used with a pedestrian signal head that does not have a concurrent vehicular phase, the pedestrian change interval (flashing UPRAISED HAND) should be set to be approximately 4 seconds less than the required pedestrian crossing time (see Section 4E.10) and an additional clearance interval (during which steady UPRAISED HAND is displayed) should be provided prior to the start of the conflicting vehicular phase. In this case, the countdown display of the number of remaining seconds should be displayed only during the display of the flashing UPRAISED HAND, should display zero at the time when the flashing UPRAISED HAND changes to steady UPRAISED HAND, and should be dark during the additional clearance interval prior to the conflicting vehicular phase.

For crosswalks where the pedestrian enters the crosswalk more than 30 m (100 ft) from the countdown pedestrian signal display, the numbers should be at least 225 mm (9 in) in height.

Because some technology includes the countdown pedestrian signal logic in a separate timing device that is independent of the timing in the traffic signal controller, care should be exercised by the engineer when timing changes are made to pedestrian change intervals.

If the pedestrian change interval is interrupted or shortened as a part of a transition into a preemption sequence (see Section 4E.10), the countdown pedestrian signal display should be discontinued and go dark immediately upon activation of the preemption transition.

Section 4E.08 Pedestrian Detectors

Guidance:

When pedestrian actuation is used, pedestrian pushbutton detectors should be capable of easy activation and conveniently located near each end of the crosswalks.

Standard:

Signs (see Section 2B.44) shall be mounted adjacent to or integral with pedestrian pushbutton detectors, explaining their purpose and use.

Option:

At certain locations, a sign in a more visible location may be used to call attention to the pedestrian detector.

Guidance:

If two crosswalks, oriented in different directions, end at or near the same location, the positioning of pedestrian detectors and/or the legends on the pedestrian detector signs should clearly indicate which crosswalk signal is actuated by each pedestrian detector.

Standard:

If the pedestrian clearance time is sufficient only to cross from the curb or shoulder to a median of sufficient width for pedestrians to wait and the signals are pedestrian actuated, an additional pedestrian detector shall be provided in the median.

Guidance:

The use of additional pedestrian detectors on islands or medians where a pedestrian might become stranded should be considered.

A mounting height of approximately 1.1 m (3.5 ft) above the sidewalk should be used for pedestrian pushbutton detectors.

If used, special purpose pushbuttons (to be operated only by authorized persons) should include a housing capable of being locked to prevent access by the general public and do not need an instructional sign.

Standard:

If used, a pilot light or other means of indication installed with a pedestrian pushbutton shall not be illuminated until actuation. Once it is actuated, it shall remain illuminated until the pedestrian's green or WALKING PERSON (symbolizing WALK) signal indication is displayed.

Option:

At signalized locations with a demonstrated need and subject to equipment capabilities, pedestrians with special needs may be provided with additional crossing time by means of an extended pushbutton press.

Section 4E.09 Accessible Pedestrian Signal Detectors

Standard:

An accessible pedestrian signal detector shall be defined as a device designated to assist the pedestrian who has visual or physical disabilities in activating the pedestrian phase.

At accessible pedestrian signal locations with pedestrian actuation, each pushbutton shall activate both the walk interval and the accessible pedestrian signals.

Option:

Accessible pedestrian signal detectors may be pushbuttons or passive detection devices.

Pushbutton locator tones may be used with accessible pedestrian signals.

Guidance:

At accessible pedestrian signal locations, pushbuttons should clearly indicate which crosswalk signal is actuated by each pushbutton. Pushbuttons and tactile arrows should have high visual contrast as described in the

"Americans with Disabilities Act Accessibility Guidelines for Buildings and Facilities (ADAAG)" (see Section 1A.11). Tactile arrows should point in the same direction as the associated crosswalk. At corners of signalized locations with accessible pedestrian signals where two pedestrian pushbuttons are provided, the pushbuttons should be separated by a distance of at least 3 m (10 ft). This enables pedestrians who have visual disabilities to distinguish and locate the appropriate pushbutton.

Pushbuttons for accessible pedestrian signals should be located (see Figure 4E-2) as follows:

A. Adjacent to a level all-weather surface to provide access from a wheelchair, and where there is an all-weather surface, wheelchair accessible route to the ramp;
B. Within 1.5 m (5 ft) of the crosswalk extended;
C. Within 3 m (10 ft) of the edge of the curb, shoulder, or pavement; and
D. Parallel to the crosswalk to be used.

If the pedestrian clearance time is sufficient only to cross from the curb or shoulder to a median of sufficient width for pedestrians to wait and accessible pedestrian detectors are used, an additional accessible pedestrian detector should be provided in the median.

Standard:

When used, pushbutton locator tones shall be easily locatable, shall have a duration of 0.15 seconds or less, and shall repeat at 1-second intervals.

Guidance:

Pushbuttons should be audibly locatable. Pushbutton locator tones should be intensity responsive to ambient sound, and be audible 1.8 to 3.7 m (6 to 12 ft) from the pushbutton, or to the building line, whichever is less. Pushbutton locator tones should be no more than 5 dBA louder than ambient sound.

Pushbutton locator tones should be deactivated during flashing operation of the traffic control signal.

Option:

At locations with pretimed traffic control signals or nonactuated approaches, pedestrian pushbuttons may be used to activate the accessible pedestrian signals.

The audible tone(s) may be made louder (up to a maximum of 89 dBA) by holding down the pushbutton for a minimum of 3 seconds. The louder audible tone(s) may also alternate back and forth across the crosswalk, thus providing optimal directional information.

The name of the street to be crossed may also be provided in accessible format, such as Braille or raised print.

Section 4E.10 Pedestrian Intervals and Signal Phases

Standard:

When pedestrian signal heads are used, a WALKING PERSON (symbolizing WALK) signal indication shall be displayed only when pedestrians are permitted to leave the curb or shoulder.

A pedestrian clearance time shall begin immediately following the WALKING PERSON (symbolizing WALK) signal indication. The first portion of the pedestrian clearance time shall consist of a pedestrian change interval during which a flashing UPRAISED HAND (symbolizing DONT WALK) signal indication shall be displayed. The remaining portions shall consist of the yellow change interval and any red clearance interval (prior to a conflicting green being displayed), during which a flashing or steady UPRAISED HAND (symbolizing DONT WALK) signal indication shall be displayed.

If countdown pedestrian signals are used, a steady UPRAISED HAND (symbolizing DONT WALK) signal indication shall be displayed during the yellow change interval and any red clearance interval (prior to a conflicting green being displayed) (see Section 4E.07).

At intersections equipped with pedestrian signal heads, the pedestrian signal indications shall be displayed except when the vehicular traffic control signal is being operated in the flashing mode. At those times, the pedestrian signal lenses shall not be illuminated.

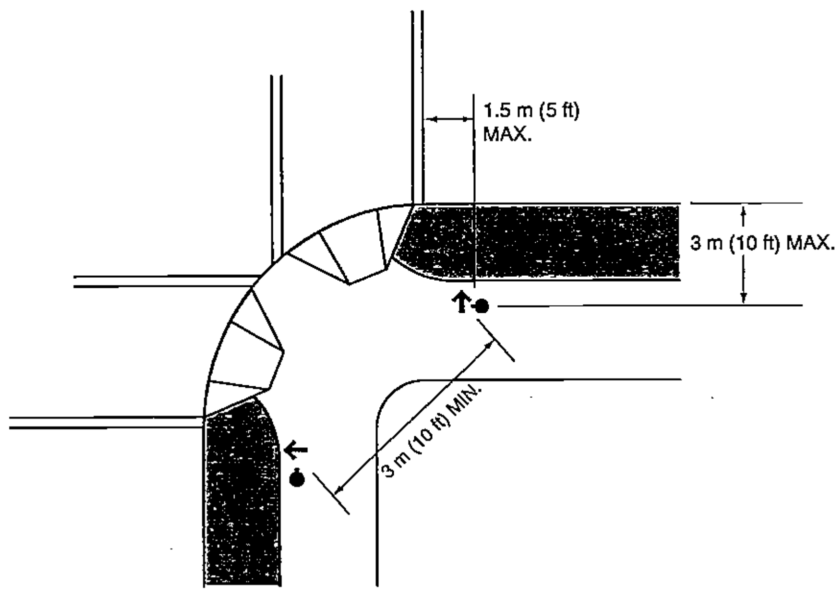
Guidance:

Except as noted in the Option, the walk interval should be at least 7 seconds in length so that pedestrians will have adequate opportunity to leave the curb or shoulder before the pedestrian clearance time begins.

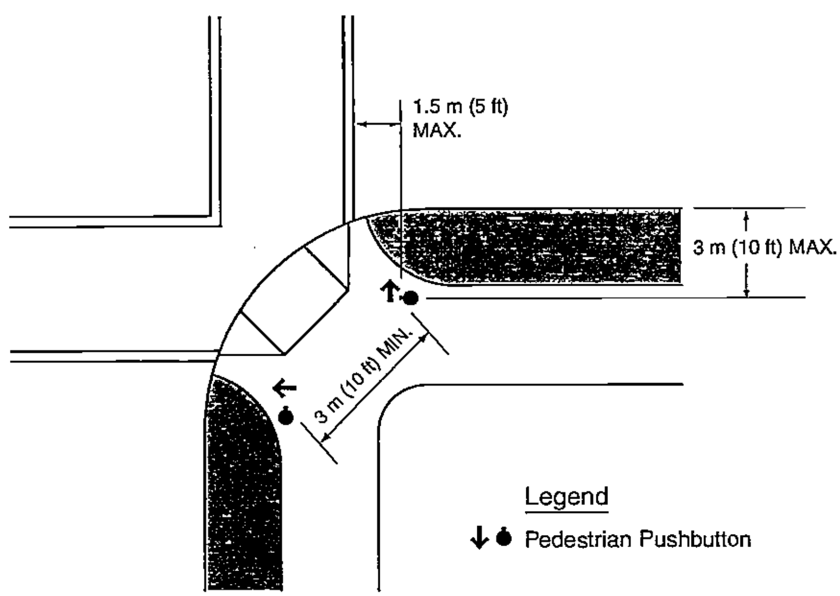
Option:

If pedestrian volumes and characteristics do not require a 7-second walk interval, walk intervals as short as 4 seconds may be used.

Figure 4E-2. Recommended Pushbutton Locations for Accessible Pedestrian Signals



Two Curb-Cut Ramps



One Curb-Cut Ramp

Support:

The walk interval itself need not equal or exceed the pedestrian clearance time calculated for the roadway width, because many pedestrians will complete their crossing during the pedestrian clearance time.

Guidance:

The pedestrian clearance time should be sufficient to allow a pedestrian crossing in the crosswalk who left the curb or shoulder during the WALKING PERSON (symbolizing WALK) signal indication to travel at a walking speed of 1.2 m (4 ft) per second, to at least the far side of the traveled way or to a median of sufficient width for pedestrians to wait. Where pedestrians who walk slower than 1.2 m (4 ft) per second, or pedestrians who use wheelchairs, routinely use the crosswalk, a walking speed of less than 1.2 m (4 ft) per second should be considered in determining the pedestrian clearance time.

Option:

Passive pedestrian detection equipment, which can detect pedestrians who need more time to complete their crossing and can extend the length of the pedestrian clearance time for that particular cycle, may be used in order to avoid using a lower walking speed to determine the pedestrian clearance time.

Guidance:

Where the pedestrian clearance time is sufficient only for crossing from the curb or shoulder to a median of sufficient width for pedestrians to wait, additional measures should be considered, such as median-mounted pedestrian signals or additional signing.

Option:

The pedestrian clearance time may be entirely contained within the vehicular green interval, or may be entirely contained within the vehicular green and yellow change intervals.

On a street with a median of sufficient width for pedestrians to wait, a pedestrian clearance time that allows the pedestrian to cross only from the curb or shoulder to the median may be provided.

During the transition into preemption, the walk interval and the pedestrian change interval may be shortened or omitted as described in Section 4D.13.

CHAPTER 4F. TRAFFIC CONTROL SIGNALS FOR EMERGENCY VEHICLE ACCESS

Section 4F.01 Applications of Emergency-Vehicle Traffic Control Signals

Support:

An emergency-vehicle traffic control signal is a special traffic control signal that assigns the right-of-way to an authorized emergency vehicle.

Option:

An emergency-vehicle traffic control signal may be installed at a location that does not meet other traffic signal warrants such as at an intersection or other location to permit direct access from a building housing the emergency vehicle.

Guidance:

If a traffic control signal is not justified under the signal warrants of Chapter 4C and if gaps in traffic are not adequate to permit reasonably safe entrance of emergency vehicles, or the stopping sight distance for vehicles approaching on the major street is insufficient to permit reasonably safe entrance of emergency vehicles, installing an emergency-vehicle traffic control signal should be considered. If one of the signal warrants of Chapter 4C is met and a traffic control signal is justified by an engineering study, and if a decision is made to install a traffic control signal, it should be installed based upon the provisions of Chapter 4D.

The sight distance determination should be based on the location of the visibility obstruction for the critical approach lane for each street or drive and the posted or statutory speed limit or 85th-percentile speed on the major street, whichever is higher.

Section 4F.02 Design of Emergency-Vehicle Traffic Control Signals

Standard:

Except as specified in this Section, an emergency-vehicle traffic control signal shall meet the requirements of this Manual.

An Emergency Vehicle (W11-8) sign (see Section 2C.40) with an EMERGENCY SIGNAL AHEAD (W11-12p) supplemental plaque shall be placed in advance of all emergency-vehicle traffic control signals. If a warning beacon is installed to supplement the W11-8 sign, the design and location of the beacon shall conform to the Standards specified in Sections 4K.01 and 4K.03.

Guidance:

At least one of the two required signal faces for each approach on the major street should be located over the roadway.

The following size signal lenses should be used for emergency-vehicle traffic control signals: 300 mm (12 in) diameter for red and steady yellow signal indications, and 200 mm (8 in) diameter for flashing yellow or steady green signal indications.

Standard:

An EMERGENCY SIGNAL (R10-13) sign shall be mounted adjacent to a signal face on each major street approach (see Section 2B.45). If an overhead signal face is provided, the EMERGENCY SIGNAL sign shall be mounted adjacent to the overhead signal face.

Option:

An approach that only serves emergency vehicles may be provided with only one signal face consisting of one or more signal sections.

Besides using a 200 mm (8 in) diameter signal indication, other appropriate means to reduce the flashing yellow light output may be used.

Section 4F.03 Operation of Emergency-Vehicle Traffic Control Signals

Standard:

Right-of-way for emergency vehicles at signalized locations operating in the steady (stop-and-go) mode shall be obtained as specified in Section 4D.13.

As a minimum, the signal indications, sequence, and manner of operation of an emergency-vehicle traffic control signal installed at a midblock location shall be as follows:

A. The signal indication, between emergency-vehicle actuations, shall be either steady green or flashing yellow. If the flashing yellow signal indication is used instead of the steady green signal indication, it shall be displayed in the normal position of the steady green signal indication, while the red and steady yellow signal indications shall be displayed in their normal positions.
B. When an emergency vehicle actuation occurs, a steady yellow change interval followed by a steady red interval shall be displayed to traffic on the major street.
C. A yellow change interval is not required following the green interval for the emergency-vehicle driveway.

Emergency-vehicle traffic control signals located at intersections shall either be operated in the flashing mode between emergency-vehicle actuations (see Section 4D.12) or be fully or semi-traffic-actuated, to accommodate normal vehicular and pedestrian traffic on the streets.

Warning beacons, if used with an emergency-vehicle traffic control signal, shall be flashed only:

A. For an appropriate time in advance of and during the steady yellow change interval for the major street; and
B. During the steady red interval for the major street.

Guidance:

The duration of the red interval for traffic on the major street should be determined by on-site test-run time studies, but should not exceed 1.5 times the time required for the emergency vehicle to clear the path of conflicting vehicles.

Option:

An emergency-vehicle traffic control signal sequence may be initiated manually from a local control point such as a fire station or law enforcement headquarters or from an emergency vehicle equipped for remote operation of the signal.

CHAPTER 4G. TRAFFIC CONTROL SIGNALS FOR ONE-LANE, TWO-WAY FACILITIES

Section 4G.01 Application of Traffic Control Signals for One-Lane, Two-Way Facilities

Support:

A traffic control signal at a narrow bridge, tunnel, or roadway section is a special signal that assigns the right-of-way for vehicles passing over a bridge or through a tunnel or roadway section that is not of sufficient width for two opposing vehicles to pass reasonably safely.

Temporary traffic control signals (see Sections 4D.20 and 6F.80) are the most frequent application of one-lane, two-way facilities.

Guidance:

Sight distance across or through the one-lane, two-way facility should be considered as well as the approach speed and sight distance approaching the facility when determining whether traffic control signals should be installed.

Option:

At a narrow bridge, tunnel, or roadway section where a traffic control signal is not justified under the conditions of Chapter 4C, a traffic control signal may be used if gaps in opposing traffic do not permit the reasonably safe flow of traffic through the one-lane section of roadway.

Section 4G.02 Design of Traffic Control Signals for One-Lane, Two-Way Facilities

Standard:

The provisions of Chapter 4D shall apply to traffic control signals for one-lane, two-way facilities, except that:

- **A. Durations of red clearance intervals shall be adequate to clear the one-lane section of conflicting vehicles.**
- **B. Adequate means, such as interconnection, shall be provided to prevent conflicting signal indications, such as green and green, at opposite ends of the section.**

Section 4G.03 Operation of Traffic Control Signals for One-Lane, Two-Way Facilities

Standard:

Traffic control signals at one-lane, two-way facilities shall operate in a manner consistent with traffic requirements.

When in the flashing mode, the signal indications shall flash red.

Guidance:

Adequate time should be provided to allow traffic to clear the narrow facility before opposing traffic is allowed to move. Engineering judgment should be used to determine the proper timing for the signal.

CHAPTER 4H. TRAFFIC CONTROL SIGNALS FOR FREEWAY ENTRANCE RAMPS

Section 4H.01 Application of Freeway Entrance Ramp Control Signals

Support:

Ramp control signals are traffic control signals that control the flow of traffic entering the freeway facility.

Freeway entrance ramp control signals are sometimes used if controlling traffic entering the freeway could reduce the total expected delay to traffic in the freeway corridor, including freeway ramps and local streets, and if at least one of the following conditions is present:

A. Congestion recurs on the freeway because traffic demand is in excess of the capacity, or congestion recurs or a high frequency of crashes exist at the freeway entrance because of inadequate ramp merging area. A good indicator of recurring freeway congestion is freeway operating speeds less than 80 km/h (50 mph) occurring regularly for at least a half-hour period. Freeway operating speeds less than 50 km/h (30 mph) for a half-hour period or more would indicate severe congestion.
B. Controlling traffic entering a freeway assists in meeting local transportation system management objectives identified for freeway traffic flow, such as the following:
    1. Maintenance of a specific freeway level of service.
    2. Priority treatments with higher levels of service for mass transit and carpools.
    3. Redistribution of freeway access demand to other on-ramps.
C. Predictable, sporadic congestion occurs on isolated sections of freeway because of short-period peak traffic loads from special events or from severe peak loads of recreational traffic.

Guidance:

The installation of ramp control signals should be preceded by an engineering study of the physical and traffic conditions on the highway facilities likely to be affected. The study should include the ramps and ramp connections and the surface streets that would be affected by the ramp control, as well as the freeway section concerned. Types of traffic data that should be obtained include, but are not limited to, traffic volumes, traffic crashes, freeway operating speeds, and travel time and delay on the freeway, approaches, ramps, and alternate surface routes.

Capacities and demand/capacity relationships should be determined for each freeway section. The locations and causes of capacity restrictions and those sections where demand exceeds capacity should be identified. From these and other data, estimates should be made of desirable metering rates, probable reductions in the delay of freeway traffic, likely increases in delay to ramp traffic, and the potential impact on surface streets. The study should include an evaluation of the ramp's storage capacities for vehicles delayed at the signal, the impact of queued traffic on the local street intersection, and the availability of suitable alternate surface routes having adequate capacity to accommodate any additional traffic volume.

Before installing ramp control signals, consideration should be given to their potential acceptance by the public and the requirements for enforcing ramp control, as well as alternate means of increasing the capacity, reducing the demand, or improving the characteristics of the freeway.

Section 4H.02 Design of Freeway Entrance Ramp Control Signals

Standard:

Ramp control signals shall meet all of the standard design specifications for traffic control signals, except as noted herein:

A. The signal face for freeway entrance ramp control signals shall be either a two-lens signal face containing red and green signal lenses or a three-lens signal face containing red, yellow, and green signal lenses.
B. A minimum of two signal faces per ramp shall face entering traffic.
C. Ramp control signal faces need not be illuminated when not in use.

Ramp control signals shall be located and designed to minimize their viewing by mainline freeway traffic.

Option:

The required signal faces, if located at the side of the ramp roadway, may be mounted such that the height above the pavement grade at the center of the ramp roadway to the bottom of the signal housing of the lowest signal face is between 1.4 m (4.5 ft) and 1.8 m (6 ft).

CHAPTER 4I. TRAFFIC CONTROL FOR MOVABLE BRIDGES

Section 4I.01 Application of Traffic Control for Movable Bridges

Support:

Traffic control signals for movable bridges are a special type of highway traffic signal installed at movable bridges to notify road users to stop because of a road closure rather than alternately giving the right-of-way to conflicting traffic movements. The signals are operated in coordination with the opening and closing of the movable bridge, and with the operation of movable bridge warning and resistance gates, or other devices and features used to warn, control, and stop traffic.

Movable bridge warning gates installed at movable bridges decrease the likelihood of vehicles and pedestrians passing the stop line and entering an area where potential hazards exist because of bridge operations.

A movable bridge resistance gate is sometimes used at movable bridges and located downstream of the movable bridge warning gate. A movable bridge resistance gate provides a physical deterrent to road users when placed in the appropriate position. The movable bridge resistance gates are considered a design feature and not a traffic control device; requirements for them are contained in AASHTO's "Standard Specifications for Movable Highway Bridges" (see Page i for AASHTO's address).

Standard:

Traffic control at movable bridges shall include both signals and gates, except in the following cases:

A. Neither is required if other traffic control devices or measures considered appropriate are used under either of the following conditions:
   1. On low-volume roads (roads of less than 400 vehicles average daily traffic); or
   2. At manually operated bridges if electric power is not available.

B. Only signals are required in urban areas if intersecting streets or driveways make gates ineffective.

C. Only movable bridge warning gates are required if a traffic control signal that is controlled as part of the bridge operations exists within 150 m (500 ft) of the movable bridge resistance gates and no intervening traffic entrances exist.

Section 4I.02 Design and Location of Movable Bridge Signals and Gates

Standard:

The signal heads and mountings of movable bridge signals shall follow the provisions of Chapter 4D except as noted in this Section.

Since movable bridge operations cover a variable range of time periods between openings, the signal faces shall be one of the following types:

A. Three-section signal faces with red, yellow, and green signal lenses; or

B. Two one-section signal faces with red signal lenses in a vertical array separated by a STOP HERE ON RED (R10-6) sign (see Section 2B.45).

Regardless of which signal type is selected, two signal faces shall be provided for each approach to the movable span.

Guidance:

If movable bridge operation is frequent, the use of three-section signal faces should be considered.

Standard:

If physical conditions prevent a road user from having a continuous view of at least two signal indications for the distance specified in Table 4D-1, an auxiliary device (either a supplemental signal face or the mandatory DRAWBRIDGE AHEAD warning sign to which has been added a warning beacon that is interconnected with the movable bridge controller unit) shall be provided in advance of movable bridge signals and gates.

A DRAWBRIDGE AHEAD warning sign shall be used in advance of movable bridge signals and gates to give warning to road users, except in urban conditions where such signing would not be practical.

Movable bridge warning gates, if used, shall extend at least across the full width of the approach lanes if movable bridge resistance gates are used. On divided highways in which the roadways are separated by a barrier median, movable bridge warning gates, if used, shall extend across all roadway lanes approaching the span openings. Except where physical conditions make it impractical, movable bridge warning gates shall be located 30 m (100 ft) or more from the movable bridge resistance gates or, if movable bridge resistance gates are not used, 30 m (100 ft) or more from the movable span.

Movable bridge warning gates shall be at least standard railroad size, striped with 400 mm (16 in) alternate diagonal, fully reflectorized red and white stripes. Flashing red lights in accordance with the Standards for those on railroad gates (see Section 8D.04) shall be included on the gate arm and they shall only be operated if the gate is closed or in the process of being opened or closed. In the horizontal position, the top of the gate shall be approximately 1.2 m (4 ft) above the pavement.

If two sets of gates (both a warning and a resistance gate) are used for a single direction, highway traffic signals need not accompany the resistance gate nearest the span opening, but there shall be flashing red lights on the movable bridge warning gate.

Guidance:

Signal faces with 300 mm (12 in) diameter signal lenses should be used for movable bridge signals.

Insofar as practical, the height and lateral placement of signal faces should conform to the requirements for other traffic control signals in accordance with Section 4D.15. They should be located not more than 15 m (50 ft) in advance of the movable bridge warning gate.

Movable bridge warning gates should be of lightweight construction. In its normal upright position, the gate arm should provide adequate lateral clearance. If the movable bridge is close to a highway-rail grade crossing and traffic might possibly be stopped on the crossing as a result of the bridge opening, a traffic control device should notify the road users to not stop on the railroad tracks.

If movable bridge resistance gates are not used on undivided highways, movable bridge warning gates, if used, should extend across the full width of the roadway.

On bridges or causeways that cross a long reach of water and that might be hit by large marine vessels, within the limits of practicality, traffic should not be halted on a section of the bridge or causeway that is subject to impact.

In cases where it is not practical to halt traffic on a span that is not subject to impact, traffic should be halted at least one span from the opening. If traffic is halted by signals and gates more than 100 m (330 ft) from the movable bridge warning gates (or from the span opening if movable bridge warning gates are not used), a second set of gates should be installed approximately 30 m (100 ft) from the gate or span opening.

Option:

Movable bridge signals may be supplemented with audible warning devices to provide additional warning to drivers and pedestrians.

If prevailing approach speeds are 40 km/h (25 mph) or less, signal heads with 200 mm (8 in) diameter lenses may be used.

The movable bridge resistance gates may be delineated, if practical, in a manner similar to the movable bridge warning gate.

The DRAWBRIDGE AHEAD sign may be supplemented by a Warning Beacon (see Section 4K.03).

A single full-width gate or two half-width gates may be used.

Support:

Highway traffic signals need not accompany the gates nearest the span opening.

The locations of movable bridge signals and gates are determined by the location of the movable bridge resistance gate (if used) rather than by the location of the movable spans. The movable bridge resistance gates for high-speed highways are preferably located 15 m (50 ft) or more from the span opening except for bascule and lift bridges, where they are often attached to, or are a part of, the structure.

Section 4I.03 Operation of Movable Bridge Signals and Gates

Standard:

Traffic control devices at movable bridges shall be coordinated with the movable spans, so that the signals, gates, and movable spans are controlled by the bridge tender through an interlocked control.

If the three-section type of signal face is used, the green signal indication shall be illuminated at all times between bridge openings, except that if the bridge is not expected to open during continuous periods in excess of 5 hours, a flashing yellow signal indication may be used. The signal shall display a steady red signal indication when traffic is required to stop. The duration of the yellow change interval between the display of the steady green and steady red signal indications, or flashing yellow and steady red signal indications, shall be predetermined.

If the vertical array of red signal lenses is the type of signal face selected, the red signal lenses shall flash alternately only when traffic is required to stop.

Guidance:

The duration of the yellow change interval should have a range from 3 to 6 seconds.

Signals on adjacent streets and highways should be interconnected with the drawbridge control if indicated by engineering judgment.

CHAPTER 4J. LANE-USE CONTROL SIGNALS

Section 4J.01 Application of Lane-Use Control Signals

Support:

Lane-use control signals are special overhead signals that permit or prohibit the use of specific lanes of a street or highway or that indicate the impending prohibition of their use. Lane-use control signals are distinguished by placement of special signal faces over a certain lane or lanes of the roadway and by their distinctive shapes and symbols. Supplementary signs are sometimes used to explain their meaning and intent.

Lane-use control signals are most commonly used for reversible-lane control, but are also used in nonreversible freeway lane applications.

Guidance:

An engineering study should be conducted to determine whether a reversible-lane operation can be controlled satisfactorily by static signs (see Section 2B.25) or whether lane-use control signals are necessary. Lane-use control signals should be used to control reversible-lane operations if any of the following conditions are present:

A. More than one lane is reversed in direction;
B. Two-way or one-way left turns are allowed during peak-period reversible operations, but those turns are from a different lane than used during off-peak periods;
C. Other unusual or complex operations are included in the reversible-lane pattern;
D. Demonstrated crash experience occurring with reversible-lane operation controlled by static signs that can be corrected by using lane-use control signals at the times of transition between peak and off-peak patterns; and/or
E. An engineering study indicates that safer and more efficient operation of a reversible-lane system would be provided by lane-use control signals.

Option:

Lane-use control signals also may be used for reversible-lane operations at toll booths. They may also be used if there is no intent or need to reverse lanes, including:

A. On a freeway, if it is desired to keep traffic out of certain lanes at certain hours to facilitate the merging of traffic from a ramp or other freeway;
B. On a freeway, near its terminus, to indicate a lane that ends; and
C. On a freeway or long bridge, to indicate that a lane may be temporarily blocked by a crash, breakdown, construction or maintenance activities, and so forth.

Section 4J.02 Meaning of Lane-Use Control Signal Indications

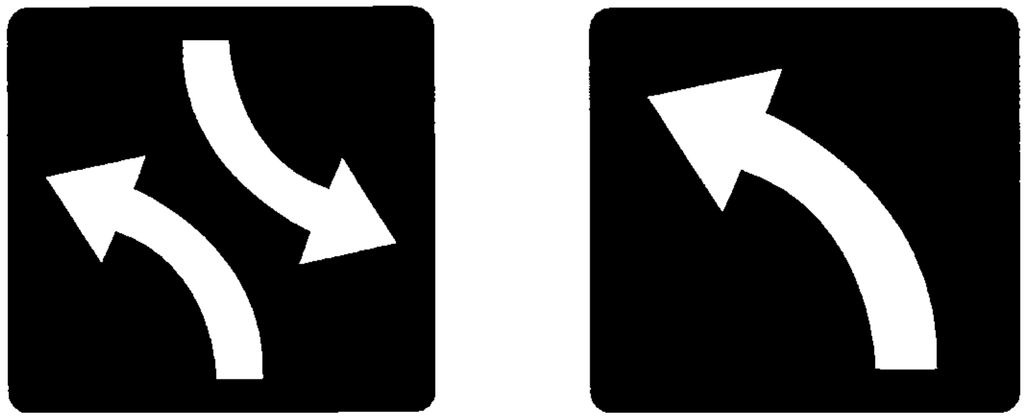
Standard:

The meanings of lane-use control signal indications are as follows:

A. A steady DOWNWARD GREEN ARROW signal indication shall mean that a road user is permitted to drive in the lane over which the arrow signal indication is located.
B. A steady YELLOW X signal indication shall mean that a road user is to prepare to vacate, in a reasonably safe manner, the lane over which the signal indication is located because a lane control change is being made to a steady RED X signal indication.
C. A steady WHITE TWO-WAY LEFT-TURN ARROW signal indication (see Figure 4J-1) shall mean that a road user is permitted to use a lane over which the signal indication is located for a left turn, but not for through travel, with the understanding that common use of the lane by oncoming road users for left turns is also permitted.
D. A steady WHITE ONE WAY LEFT-TURN ARROW signal indication (see Figure 4J-1) shall mean that a road user is permitted to use a lane over which the signal indication is located for a left turn (without opposing turns in the same lane), but not for through travel.
E. A steady RED X signal indication shall mean that a road user is not permitted to use the lane over which the signal indication is located and that this signal indication shall modify accordingly the meaning of all other traffic controls present. The road user shall obey all other traffic controls and follow normal safe driving practices.

Pavement markings (see Section 3B.03) shall be used in conjunction with reversible-lane control signals.

Figure 4J-1. Left-Turn Lane-Use Control Signals



Two-way left-turn arrow One-way left-turn arrow

White arrows on opaque background
750 x 750 mm
(30 x 30 in)

Section 4J.03 Design of Lane-Use Control Signals

Standard:

All lane-use control signal indications shall be in units with rectangular signal faces and shall have opaque backgrounds. Nominal minimum height and width of each DOWNWARD GREEN ARROW, YELLOW X, and RED X signal face shall be 450 mm (18 in) for typical applications. The WHITE TWO-WAY LEFT-TURN ARROW and WHITE ONE WAY LEFT-TURN ARROW signal faces shall have a nominal minimum height and width of 750 mm (30 in).

Each lane to be reversed or closed shall have signal faces with a DOWNWARD GREEN ARROW and a RED X symbol.

Each reversible lane that also operates as a two-way or one-way left-turn lane during certain periods shall have signal faces that also include the applicable WHITE TWO-WAY LEFT-TURN ARROW or WHITE ONE WAY LEFT-TURN ARROW symbol.

Each nonreversible lane immediately adjacent to a reversible lane shall have signal indications that display a DOWNWARD GREEN ARROW to traffic traveling in the permitted direction and a RED X to traffic traveling in the opposite direction.

If in separate signal sections, the relative positions, from left to right, of the signal indications shall be RED X, YELLOW X, DOWNWARD GREEN ARROW, WHITE TWO-WAY LEFT-TURN ARROW, WHITE ONE WAY LEFT-TURN ARROW.

The color of lane-use control signal indications shall be clearly visible for 700 m (2,300 ft) at all times under normal atmospheric conditions, unless otherwise physically obstructed.

Lane-use control signal faces shall be located approximately over the center of the lane controlled.

If the area to be controlled is more than 700 m (2,300 ft) in length, or if the vertical or horizontal alignment is curved, intermediate lane-use control signal faces shall be located over each controlled lane at frequent intervals. This location shall be such that road users will at all times be able to see at least one signal indication and preferably two along the roadway, and will have a definite indication of the lanes specifically reserved for their use.

All lane-use control signal faces shall be located in a straight line across the roadway approximately at right angles to the roadway alignment.

The bottom of the signal housing of any lane-use control signal face shall be at least 4.6 m (15 ft) but not more than 5.8 m (19 ft) above the pavement grade.

On roadways having intersections controlled by traffic control signals, the lane-use control signal face shall be located sufficiently far in advance of or beyond such traffic control signals to prevent them from being misconstrued as traffic control signals.

Option:

In areas with minimal visual clutter and with speeds of less than 70 km/h or less than 40 mph, lane-use control signal faces with nominal height and width of 300 mm (12 in) may be used for the DOWNWARD GREEN ARROW, YELLOW X, and RED X signal faces, and lane-use control signal faces with nominal height and width of 450 mm (18 in) may be used for the WHITE TWO-WAY LEFT-TURN ARROW and WHITE ONE-WAY LEFT-TURN ARROW signal faces.

Other sizes of lane-use control signal faces larger than 450 mm (18 in) with message recognition distances appropriate to signal spacing may be used for the DOWNWARD GREEN ARROW, YELLOW X, and RED X signal faces.

Nonreversible lanes not immediately adjacent to a reversible lane on any street so controlled may also be provided with signal indications that display a DOWNWARD GREEN ARROW to traffic traveling in the permitted direction and a RED X to traffic traveling in the opposite direction.

The signal indications provided for each lane may be in separate signal sections or may be superimposed in the same signal section.

Section 4J.04 Operation of Lane-Use Control Signals

Standard:

All lane-use control signals shall be coordinated so that all the signal indications along the controlled section of roadway are operated uniformly and consistently. The lane-use control signal system shall be designed to reliably guard against showing any prohibited combination of signal indications to any traffic at any point in the controlled lanes.

For reversible-lane control signals, the following combination of signal indications shall not be shown simultaneously over the same lane to both directions of travel:

A. DOWNWARD GREEN ARROW in both directions;
B. YELLOW X in both directions;
C. WHITE ONE WAY LEFT-TURN ARROW in both directions;
D. DOWNWARD GREEN ARROW in one direction and YELLOW X in the other direction;
E. WHITE TWO-WAY LEFT-TURN ARROW or WHITE ONE WAY LEFT-TURN ARROW in one direction and DOWNWARD GREEN ARROW in the other direction;
F. WHITE TWO-WAY LEFT-TURN ARROW in one direction and WHITE ONE WAY LEFT-TURN ARROW in the other direction; and
G. WHITE ONE WAY LEFT-TURN ARROW in one direction and YELLOW X in the other direction.

A moving condition in one direction shall be terminated either by the immediate display of a RED X signal indication or by a YELLOW X signal indication followed by a RED X signal indication. In either case, the duration of the RED X signal indication shall be sufficient to allow clearance of the lane before any moving condition is allowed in the opposing direction.

Whenever a DOWNWARD GREEN ARROW signal indication is changed to a WHITE TWO-WAY LEFT-TURN ARROW signal indication, the RED X signal indication shall continue to be displayed to the opposite direction of travel for an appropriate duration to allow traffic time to vacate the lane being converted to a two-way left-turn lane.

If an automatic control system is used, a manual control to override the automatic control shall be provided.

Guidance:

The type of control provided for reversible-lane operation should be such as to permit either automatic or manual operation of the lane-use control signals.

Standard:

If used, lane-use control signals shall be operated continuously, except that lane-use control signals that are used only for special events or other infrequent occurrences and lane-use control signals on nonreversible freeway lanes may be darkened when not in operation. The change from normal operation to nonoperation shall occur only when the lane-use control signals display signal indications that are appropriate for the lane use that applies when the signals are not operated. The lane-use control signals shall display signal indications that are appropriate for the existing lane use when changed from nonoperation to normal operations. Also, traffic control devices shall clearly indicate the proper lane use when the lane control signals are not in operation.

Support:

Section 2B.25 contains additional information concerning considerations involving left-turn prohibitions in conjunction with reversible-lane operations.

CHAPTER 4K. FLASHING BEACONS

Section 4K.01 General Design and Operation of Flashing Beacons

Support:

A Flashing Beacon is a highway traffic signal with one or more signal sections that operates in a flashing mode. It can provide traffic control when used as an intersection control beacon or warning in alternative uses.

Standard:

Flashing Beacon units and their mountings shall follow the provisions of Chapter 4D, except as specified herein.

Beacons shall be flashed at a rate of not less than 50 nor more than 60 times per minute. The illuminated period of each flash shall not be less than one-half and not more than two-thirds of the total cycle.

Guidance:

If used to supplement a warning or regnlatory sign, the edge of the beacon signal housing should normally be located no closer than 300 mm (12 in) outside of the nearest edge of the sign.

Option:

An automatic dimming device may be used to reduce the brilliance of flashing yellow signal indications during night operation.

Section 4K.02 Intersection Control Beacon

Standard:

An Intersection Control Beacon shall consist of one or more signal faces directed toward each approach to an intersection. Each signal face shall consist of one or more signal sections of a standard traffic signal face, with flashing CIRCULAR YELLOW or CIRCULAR RED signal indications in each signal face. They shall be installed and used only at an intersection to control two or more directions of travel.

Application of Intersection Control Beacon signal indications shall be limited to the following:

A. Yellow on one route (normally the major street) and red for the remaining approaches; and
B. Red for all approaches (if the warrant for a multiway stop is satisfied).

Flashing yellow signal indications shall not face conflicting vehicnlar approaches.

A STOP sign shall be used on approaches to which a flashing red signal indication is shown on an Intersection Control Beacon (see Section 2B.04).

Guidance:

An Intersection Control Beacon should not be mounted on a pedestal in the roadway unless the pedestal is within the confines of a traffic or pedestrian island.

Option:

Supplemental signal indications may be used on one or more approaches in order to provide adequate visibility to approaching road users.

Intersection Control Beacons may be used at intersections where traffic or physical conditions do not justify conventional traffic control signals but crash rates indicate the possibility of a special need.

An Intersection Control Beacon is generally located over the center of an intersection; however, it may be used at other suitable locations.

Section 4K.03 Warning Beacon

Support:

Typical applications of Warning Beacons include the following:

A. At obstructions in or immediately adjacent to the roadway;
B. As supplemental emphasis to warning signs;
C. As emphasis for midblock crosswalks;
D. On approaches to intersections where additional warning is required, or where special conditions exist; and
E. As supplemental emphasis to regulatory signs, except STOP, YIELD, DO NOT ENTER, and SPEED LIMIT signs.

Standard:

A Warning Beacon shall consist of one or more signal sections of a standard traffic signal face with a flashing CIRCULAR YELLOW signal indication in each signal section.

A Warning Beacon shall be used only to supplement an appropriate warning or regulatory sign or marker. The beacon shall not be included within the border of the sign except for SCHOOL SPEED LIMIT sign beacons.

Warning Beacons, if used at intersections, shall not face conflicting vehicular approaches.

If a Warning Beacon is suspended over the roadway, the clearance above the pavement shall be at least 4.6 m (15 ft) but not more than 5.8 m (19 ft).

Guidance:

The condition or regulation justifying Warning Beacons should largely govern their location with respect to the roadway.

If an obstruction is in or adjacent to the roadway, illumination of the lower portion or the beginning of the obstruction or a sign on or in front of the obstruction, in addition to the beacon, should be considered.

Warning Beacons should be operated only during those hours when the condition or regulation exists.

Option:

If Warning Beacons have more than one signal section, they may be flashed either alternately or simultaneously.

A flashing yellow beacon interconnected with a traffic signal controller assembly may be used with a traffic signal warning sign (see Section 2C.29).

Section 4K.04 Speed Limit Sign Beacon

Standard:

A Speed Limit Sign Beacon shall be used only to supplement a Speed Limit sign.

A Speed Limit Sign Beacon shall consist of one or more signal sections of a standard traffic control signal face, with a flashing CIRCULAR YELLOW signal indication in each signal section. The signal lenses shall have a nominal diameter of not less than 200 mm (8 in). If two lenses are used, they shall be vertically aligned, except that they may be horizontally aligned if the Speed Limit (R2-1) sign is longer horizontally than vertically. If two lenses are used, they shall be alternately flashed.

Option:

A Speed Limit Sign Beacon may be used with a fixed or variable Speed Limit sign. If applicable, a flashing Speed Limit Sign Beacon (with an appropriate accompanying sign) may be used to indicate that the speed limit shown is in effect.

Support:

Section 7B.11 contains additional Options for the use of Speed Limit Sign Beacons with SCHOOL SPEED LIMIT signs.

Section 4K.05 Stop Beacon

Standard:

A Stop Beacon shall consist of one or more signal sections of a standard traffic signal face with a flashing CIRCULAR RED signal indication in each signal section. If two horizontally aligned signal lenses are used, they shall be flashed simultaneously to avoid being confused with a highway-rail grade crossing flashing- light signals. If two vertically aligned signal lenses are used, they shall be flashed alternately.

The bottom of the signal housing of a Stop Beacon shall be not less than 300 mm (12 in) nor more than 600 mm (24 in) above the top of a STOP sign (see Section 2B.04).

CHAPTER 4L. IN-ROADWAY LIGHTS

Section 4L.01 Application of In-Roadway Lights

Support:

In-Roadway Lights are special types of highway traffic signals installed in the roadway surface to warn road users that they are approaching a condition on or adjacent to the roadway that might not be readily apparent and might require the road users to slow down and/or come to a stop. This includes, but is not necessarily limited to, situations warning of marked school crosswalks, marked midblock crosswalks, marked crosswalks on uncontrolled approaches, marked crosswalks in advance of roundabout intersections as described in Sections 3B.24 and 3B.25, and other roadway situations involving pedestrian crossings.

Standard:

If used, In-Roadway Lights shall not exceed a height of 19 mm (0.75 in) above the roadway surface.

Option:

The flash rate for In-Roadway Lights may be different from the flash rate of standard beacons.

Section 4L.02 In-Roadway Warning Lights at Crosswalks

Standard:

If used, In-Roadway Warning Lights at crosswalks shall be installed only at marked crosswalks with applicable warning signs. They shall not be used at crosswalks controlled by YIELD signs, STOP signs, or traffic control signals.

If used, In-Roadway Warning Lights at crosswalks shall be installed along both sides of the crosswalk and shall span its entire length.

If used, In-Roadway Warning Lights at crosswalks shall initiate operation based on pedestrian actuation and shall cease operation at a predetermined time after the pedestrian actuation or, with passive detection, after the pedestrian clears the crosswalk.

If used, In-Roadway Warning Lights at crosswalks shall display a flashing yellow signal indication when actuated. The flash rate for In-Roadway Warning Lights at crosswalks shall be at least 50, but not more than 60, flash periods per minute. The flash rate shall not be between 5 and 30 flashes per second to avoid frequencies that might cause seizures.

If used on one-lane, one-way roadways, a minimum of two In-Roadway Warning Lights shall be installed on the approach side of the crosswalk. If used on two-lane roadways, a minimum of three In-Roadway Warning Lights shall be installed along both sides of the crosswalk. If used on roadways with more than two lanes, a minimum of one In-Roadway Warning Light per lane shall be installed along both sides of the crosswalk.

If used, In-Roadway Warning Lights shall be installed in the area between the outside edge of the crosswalk line and 3 m (10 ft) from the outside edge of the crosswalk. In-Roadway Warning Lights shall face away from the crosswalk if unidirectional, or shall face away from and across the crosswalk if bidirectional.

Guidance:

If used, the period of operation of the In-Roadway Warning Lights following each actuation should be sufficient to allow a pedestrian crossing in the crosswalk to leave the curb or shoulder and travel at a normal walking speed of 1.2 m (4 ft) per second to at least the far side of the traveled way or to a median of sufficient width for pedestrians to wait. Where pedestrians who walk slower than normal, or pedestrians who use wheelchairs, routinely use the crosswalk, a walking speed of less than 1.2 m (4 ft) per second should be considered in determining the period of operation. Where the period of operation is sufficient only for crossing from a curb or shoulder to a median of sufficient width for pedestrians to wait, additional measures should be considered, such as median-mounted pedestrian actuators.

If used, In-Roadway Warning Lights should be installed in the center of each travel lane, at the centerline of the roadway, at each edge of the roadway or parking lanes, or at other suitable locations away from the normal tire track paths.

The location of the In-Roadway Warning Lights within the lanes should be based on engineering judgment.

Option:

In-Roadway Warning Lights at crosswalks may use pedestrian detectors to determine the duration of the operation instead of ceasing operation after a predetermined time.

On one-way streets, In-Roadway Warning Lights may be omitted on the departure side of the crosswalk.

Based on engineering judgment, the In-Roadway Warning Lights on the departure side of the crosswalk on the left side of a median may be omitted.

Unidirectional In-Roadway Warning Lights installed at crosswalk locations may have an optional, additional yellow light indication in each unit that is visible to pedestrians in the crosswalk to indicate to pedestrians in the crosswalk that the In-Roadway Warning Lights are in fact flashing as they cross the street. These lights may flash with and at the same flash rate as the light module in which each is installed.

General Statutes of North Carolina

*** Statutes current through the 2011 Regular Session ***
*** Annotations current through June 15, 2012 ***

CHAPTER 160A. CITIES AND TOWNS
ARTICLE 1. DEFINITIONS AND STATUTORY CONSTRUCTION

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N.C. Gen. Stat. § 160A-1 (2012)

§ 160A-1. Application and meaning of terms

Unless otherwise specifically provided, or unless otherwise clearly required by the context, the words and phrases defined in this section shall have the meaning indicated when used in this Chapter.

(1) "Charter" means the entire body of local acts currently in force applicable to a particular city, including articles of incorporation issued to a city by an administrative agency of the State, and any amendments thereto adopted pursuant to 1917 Public Laws, Chapter 136, Subchapter 16, Part VIII, sections 1 and 2, or Article 5, Part 4, of this Chapter.

(2) "City" means a municipal corporation organized under the laws of this State for the better government of the people within its jurisdiction and having the powers, duties, privileges, and immunities conferred by law on cities, towns, and villages. The term "city" does not include counties or municipal corporations organized for a special purpose. "City" is interchangeable with the terms "town" and "village," is used throughout this Chapter in preference to those terms, and shall mean any city as defined in this subdivision without regard to the terminology employed in charters, local acts, other portions of the General Statutes, or local customary usage. The terms "city" or "incorporated municipality" do not include a municipal corporation that, without regard to its date of incorporation, would be disqualified from receiving gasoline tax allocations by *G.S. 136-41.2(a)*, except that the end of status as a city under this sentence shall not affect the levy or collection of any tax or assessment, or any criminal or civil liability, and shall not serve to escheat any property until five years after the end of such status as a city, or until September 1, 1991, whichever comes later.

(3) "Council" means the governing board of a city. "Council" is interchangeable with the terms "board of aldermen" and "board of commissioners," is used throughout this Chapter in preference to those terms, and shall mean any city council as defined in this subdivision without regard to the terminology employed in charters, local acts, other portions of the General Statutes, or local customary usage.

(4) "General law" means an act of the General Assembly applying to all units of local government, to all cities, or to all cities within a class defined by population or other criteria, including a law that meets the foregoing standards but contains a clause or section exempting from its effect one or more cities or all cities in one or more counties.

(5) "Local act" means an act of the General Assembly applying to one or more specific cities by name, or to all cities within one or more specifically named counties. "Local act" is interchangeable with the terms "special act," "public-local act," and "private act," is used throughout this Chapter in preference to those terms, and shall mean a local act

DEFENDANT'S
EXHIBIT
10/30/12
NO. 6 MMV

as defined in this subdivision without regard to the terminology employed in charters, local acts, or other portions of the General Statutes.

(6) "Mayor" means the chief executive officer of a city by whatever title known.

(7) "Publish," "publication," and other forms of the verb "to publish" mean insertion in a newspaper qualified under *G.S. 1-597* to publish legal advertisements in the county or counties in which the city is located.

(8) "Rural Fire Department" means, for the purpose of Articles 4A or 14 of this Chapter, a bona fide department which, as determined by the Commissioner of Insurance, is classified as not less than class "9" in accordance with rating methods, schedules, classifications, underwriting rules, bylaws or regulations effective or applied with respect to the establishment of rates or premiums used or charged pursuant to Article 36 or Article 40 of Chapter 58 of the General Statutes, and which operates fire apparatus and equipment of the value of five thousand dollars ($ 5,000) or more; but it does not include a municipal fire department.

HISTORY: 1971, c. 698, s. 1; 1973, c. 426, s. 3; 1983, c. 636, s. 17.1; 1985 (Reg. Sess., 1986), c. 934, s. 1.

NOTES: LOCAL MODIFICATION. --Union: 1983, c. 150; (As to Chapter 160A) Cabarrus: 1985, c. 194, s. 3.

EXHIBIT A

The Law in 2009

N.C.G.S. § 160A-300.2, as enacted by S.L. 2001-286, and amended by S.L. 2003-380, and S.L. 2004-141.

§ 160A-300.2. Use of traffic control photographic systems in Wake County.

(a) A traffic control photographic system is an electronic system consisting of a photographic, video, or electronic camera and a vehicle sensor installed to work in conjunction with an official traffic control device to automatically produce photographs, video, or digital images of each vehicle violating a standard traffic control statute or ordinance.

(b) Any traffic control photographic system or any device which is a part of that system, as described in subsection (a) of this section, installed on a street or highway which is a part of the State highway system shall meet requirements established by the North Carolina Department of Transportation. Any traffic control system installed on a municipal street shall meet standards established by the municipality and shall be consistent with any standards set by the Department of Transportation.

(c) Any traffic control photographic system installed on a street or highway shall be identified by appropriate advance warning signs conspicuously posted not more than 300 feet from the location of the traffic control photographic system. All advance warning signs shall be consistent with a statewide standard adopted by the Department of Transportation in conjunction with local governments authorized to install traffic control photographic systems.

(d) Municipalities may adopt ordinances for the civil enforcement of G.S. 20-158 by means of a traffic control photographic system, as described in subsection (a) of this section. If a municipality adopts an ordinance pursuant to this section then, notwithstanding G.S. 20-176, a violation of G.S. 20-158 detected only by a traffic control photographic system shall not be an infraction. If a violation of G.S. 20-158 is detected by both a law enforcement officer and a traffic control photographic system, the officer may charge the offender with an infraction. If the officer charges the offender with an infraction, a civil penalty issued by the municipality for the same offense is void and unenforceable. An ordinance authorized by this subsection shall provide that:

(1) The owner of a vehicle shall be responsible for a violation unless the owner can furnish evidence that the vehicle was, at the time of the violation, in the care, custody, or control of another person. The owner of the vehicle shall not be responsible for the violation if the owner of the vehicle, within 30 days after receiving notification of the violation, furnishes the office of the mayor of the municipality that issued the citation any of the following:

a. An affidavit stating the name and address of the person or company who had the care, custody, and control of the vehicle.

b. An affidavit stating that the vehicle involved was, at the time, stolen. The affidavit must be supported with evidence that supports the affidavit, including insurance or police report information.

c. An affidavit stating that the person who received the citation is not the owner or driver of the vehicle, or that the person who received the citation was not driving a vehicle at the time and location designated in the citation.

(2) Subdivision (1) of this subsection shall not apply, and the registered owner of the vehicle shall not be responsible for the violation, if notice of the violation is given to the registered owner of the vehicle more than 90 days after the date of the violation.

(3) A violation detected by a traffic control photographic system shall be deemed a noncriminal violation for which a civil penalty of fifty dollars ($50.00) shall be assessed and for which no points authorized by G.S. 20-16(c) shall be assigned to the owner or driver of the vehicle nor insurance points as authorized by G.S. 58-36-65.

(4) The owner of the vehicle shall be issued a citation that shall be attached to photographic evidence of the violation that identifies the vehicle involved. The citation shall clearly state the manner in which the violation may be challenged. The owner of the vehicle shall comply with the directions on the citation. The citation shall be processed by officials or agents of the municipality and shall be forwarded by personal service or first-class mail to the address given on the motor vehicle registration. If the owner fails to pay the civil penalty or to respond to the citation within the time period specified on the citation, the owner shall have waived the right to contest responsibility for the violation and shall be subject to a civil penalty not to exceed one hundred dollars ($100.00). The municipality may establish procedures for the collection of these penalties and may enforce the penalties by civil action in the nature of debt.

(5) The municipality shall establish a nonjudicial administrative hearing process to review objections to citations or penalties issued or assessed under this section. The municipality may establish an appeals panel composed of municipal employees to review objections. If the municipality does not establish an appeals panel composed of municipal employees, the mayor of the municipality shall review and make a final decision on all objections.

(e) The duration of the yellow light change interval at intersections where traffic control photographic systems are in use shall be no less than the yellow light change interval duration on the traffic signal plan of record signed and sealed by a licensed North Carolina Professional Engineer in accordance with Chapter 89C of the General Statutes, and shall be in full conformance with the requirements of the Manual on Uniform Traffic Control Devices.

(f) A municipality enacting an ordinance implementing a traffic control photographic system may enter into a contract with a contractor for the lease, lease-purchase, or purchase of the system. The municipality may enter into only one contract for the lease, lease-purchase, or purchase of the system and the duration of the contract may be for no more than 60 months. After the period specified in the contract has expired, the system shall either be the property of the municipality or the system shall be removed and returned to the contractor.

(g) The clear proceeds from the citations issued pursuant to the ordinance authorized by this section shall be paid to the county school fund. The clear proceeds from the citations shall mean the funds remaining after paying for the lease, lease-purchase, or purchase of the traffic control photographic system; paying a contractor for operating the system; and paying any administrative costs incurred by the municipality related to the use of the system.

(h) This section applies only to the municipalities in Wake County. For purposes of this section, a municipality is in Wake County if fifty-one percent (51%) or more of the land area of the municipality lies within Wake County.

The Law in 2010 (effective December 1, 2010)

N.C.G.S. § 160A-300.2, as enacted by S.L. 2001-286, and amended by S.L. 2003-380, S.L. 2004-141, and S.L. 2010-132.

§ 160A-300.2. Use of traffic control photographic systems in Wake County.

(a) A traffic control photographic system is an electronic system consisting of a photographic, video, or electronic camera and a vehicle sensor installed to work in conjunction with an official traffic control device to automatically produce photographs, video, or digital images of each vehicle violating a standard traffic control statute or ordinance.

(b) Any traffic control photographic system or any device which is a part of that system, as described in subsection (a) of this section, installed on a street or highway which is a part of the State highway system shall meet requirements established by the North Carolina Department of Transportation. Any traffic control system installed on a municipal street shall meet standards established by the municipality and shall be consistent with any standards set by the Department of Transportation.

(c) Any traffic control photographic system installed on a street or highway shall be identified by appropriate advance warning signs conspicuously posted not more than 300 feet from the location of the traffic control photographic system. All advance warning signs shall be consistent with a statewide standard adopted by the Department of Transportation in conjunction with local governments authorized to install traffic control photographic systems.

(d) Municipalities may adopt ordinances for the civil enforcement of G.S. 20-158 by means of a traffic control photographic system, as described in subsection (a) of this section. If a municipality adopts an ordinance pursuant to this section then, notwithstanding G.S. 20-176, a violation of G.S. 20-158 detected only by a traffic control photographic system shall not be an infraction. If a violation of G.S. 20-158 is detected by both a law enforcement officer and a traffic control photographic system, the officer may charge the offender with an infraction. If the officer charges the offender with an infraction, a civil penalty issued by the municipality for the same offense is void and unenforceable. An ordinance authorized by this subsection shall provide that:

(1) The owner of a vehicle shall be responsible for a violation unless the owner can furnish evidence that the vehicle was, at the time of the violation, in the care, custody, or control of another person. The owner of the vehicle shall not be responsible for the violation if the owner of the vehicle, within 30 days after receiving notification of the violation, furnishes the office of the mayor of the municipality that issued the citation any of the following:

a. An affidavit stating the name and address of the person or company who had the care, custody, and control of the vehicle.

b. An affidavit stating that the vehicle involved was, at the time, stolen. The affidavit must be supported with evidence that supports the affidavit, including insurance or police report information.

c. An affidavit stating that the person who received the citation is not the owner or driver of the vehicle, or that the person who received the citation was not driving a vehicle at the time and location designated in the citation.

(2) Subdivision (1) of this subsection shall not apply, and the registered owner of the vehicle shall not be responsible for the violation, if notice of the violation is given to the registered owner of the vehicle more than 90 days after the date of the violation.

(3) A violation detected by a traffic control photographic system shall be deemed a noncriminal violation for which a civil penalty of fifty dollars ($50.00) shall be assessed and for which no points authorized by G.S. 20-16(c) shall be assigned to the owner or driver of the vehicle nor insurance points as authorized by G.S. 58-36-65.

(4) The owner of the vehicle shall be issued a citation that shall be attached to photographic evidence of the violation that identifies the vehicle involved. The citation shall clearly state the manner in which the violation may be challenged. The owner of the vehicle shall comply with the directions on the citation. The citation shall be processed by officials or agents of the municipality and shall be forwarded by personal service or first-class mail to the address given on the motor vehicle registration. If the owner fails to pay the civil penalty or to respond to the citation within the time period specified on the citation, the owner shall have waived the right to contest responsibility for the violation and shall be subject to a civil penalty not to exceed one hundred dollars ($100.00). The municipality may establish procedures for the collection of these penalties and may enforce the penalties by civil action in the nature of debt.

(5) The municipality shall establish a nonjudicial administrative hearing process to review objections to citations or penalties issued or assessed under this section. The municipality may establish an appeals panel composed of municipal employees to review objections. If the municipality does not establish an appeals panel composed of municipal employees, the mayor of the municipality shall review and make a final decision on all objections.

(e) The duration of the yellow light change interval at intersections where traffic control photographic systems are in use shall be no less than the yellow light change interval duration on the traffic signal plan of record signed and sealed by a professional engineer, licensed in accordance with the provisions of Chapter 89C of the General Statutes, and shall comply with the provisions of the Manual on Uniform Traffic Control Devices.

(f) A municipality enacting an ordinance implementing a traffic control photographic system may enter into a contract with a contractor for the lease, lease-purchase, or purchase of the system. The municipality may enter into only one contract for the lease, lease-purchase, or purchase of the system and the duration of the contract may be for no more than 60 months. After the period specified in the contract has expired, the system shall either be the property of the municipality or the system shall be removed and returned to the contractor.

(g) The clear proceeds from the citations issued pursuant to the ordinance authorized by this section shall be paid to the county school fund. The clear proceeds from the citations shall mean the funds remaining after paying for the lease, lease-purchase, or purchase of the traffic control photographic system; paying a contractor for operating the system; and paying any administrative costs incurred by the municipality related to the use of the system.

(h) This section applies only to the municipalities in Wake County. For purposes of this section, a municipality is in Wake County if fifty-one percent (51%) or more of the land area of the municipality lies within Wake County.

Cary Police Department
Safelight Cary
315 N. Academy St. Suite 204
Cary, NC 27513

IN ORDER TO PAY THE FINE, make sure this address appears in the window of the enclosed envelope.

Safelight Cary
Payment Center
P.O.Box 76674
Cleveland, OH 44101

LORI MILLETTE
126 RIVERWALK CI
CARY NC 27511

Notice of Traffic Violation

Tear Here *Tear Here* *Tear Here*

IF YOU WERE NOT THE DRIVER, make sure this address appears in the window of the enclosed envelope.

Redflex Enforcement Office
315 N. Academy St. Ste. 204
Cary, NC 27513

Fold Here *Fold Here* *Fold Here*

PAGE 1

DEFENDANT'S EXHIBIT
NO. 8 10/30/12 MMV

OPTION A: MAKE A PAYMENT SAFELIGHT CARY

Violator Name: LORI MILLETTE Citation #: CA10110173

Thank you in advance for responding to this notice by 7/12/2010 so that we can avoid additional fines and civil action against you.

☐ Check or Money Order Please make check or Money Order payable to "SAFELIGHT CARY"
(ensure address on reverse side appears in the window of the envelope)

☐ Credit Card ☐ Visa Card# ____________ Expiration Date: Month ______ Year ______

Security Code (from the back of the Card): ____________

☐ MasterCard

Credit card payments can also be made online at www.photonotice.com (Enter City code: CNC)

Payments CAN NOT be made in person. Please mail payments to the address on the reverse side.

Name as it appears on card : ____________

Mailing Address: ____________ City ____________ State ______ Zip ______

Signature ____________ Date ____________

FINE AMOUNT: $ 50 PAID: $ 51.95

Tear Here Tear Here Tear Here

SAFELIGHT CARY

OPTION B: AFFIDAVIT OF NON-LIABILITY - IDENTIFY NEW OWNER OR DRIVER (see instructions on Page 4)

Violator Name: LORI MILLETTE Citation #: CA10110173

☐ New Owner
Name (Last, First, Middle): ____________ Driver's License #: ____________
Address (Number & Street): ____________ Driver's License State: ____________
City, State, Zip Code: ____________ Date of Birth: ____________

☐ Driver / Lessee
Name (Last, First, Middle): ____________ Driver's License #: ____________
Address (Number & Street): ____________ Driver's License State: ____________
City, State, Zip Code: ____________ Date of Birth: ____________

☐ Stolen
Police Dept. Reported To: ____________ Date: ____________
Police Report #: ____________ Signature: ____________

Subscribed and Sworn to before me, a Notary of the State of ________, on this ______ day of ____________ 20______

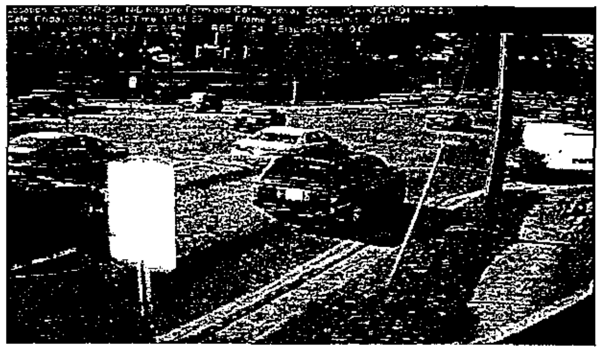
____
Notary Public

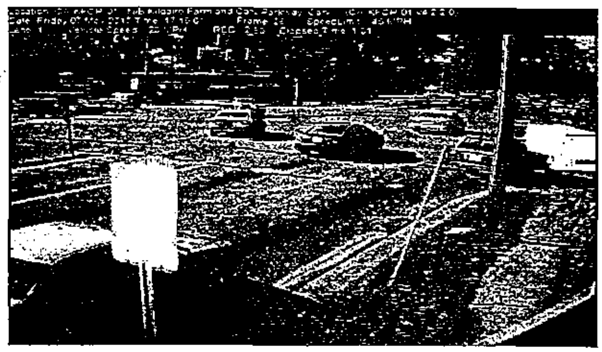
You may also fax this form to 919-380-9498

SAFELIGHT CARY
TOWN OF CARY, NC
NOTICE OF VIOLATION

NOTICE NUMBER: CA10110173

Unfortunately, and as you can see from the photos to the right, the vehicle registered in your name and described below appears to have run a red light. Such action violates Cary Town Code 34-303.





DATE OF VIOLATION	TIME OF VIOLATION	
07-May-2010	5:18 PM	
REGISTERED OWNER OR LESSEE		
LORI MILLETTE		
ADDRESS		
126 RIVERWALK CI		
CITY	STATE	ZIP CODE
CARY	NC	27511
VEH. LIC. NO	STATE	VEH. YEAR
LXH3774	NC	2006
VEH. MAKE	BODY STYLE	
HONDA	4 door Automobile	

PLEASE NOTE THAT RECORDED IMAGES DO CONSTITUTE EVIDENCE OF A VIOLATION OF CARY TOWN CODE 34-303 (FAILURE TO STOP AT A RED LIGHT)

LOCATION OF VIOLATION

Intersection of Kildaire Farm Rd / Cary Parkway NB

THIS VIOLATION WAS NOT COMMITTED IN MY PRESENCE. BASED UPON MY REVIEW AND INSPECTION OF THE RECORDED IMAGES, I STATE THAT A VIOLATION OF CARY TOWN CODE 34-303 DID OCCUR. I DECLARE, UNDER PENALTY OF PERJURY UNDER THE LAWS OF THE STATE OF NORTH CAROLINA, THAT THE FOREGOING IS TRUE AND CORRECT.

DATE ISSUED	SIGNATURE	CARY POLICE REPRESENTATIVE
21-May-2010	Brad Hudson	Brad Hudson

Please respond to this notice in one of the following ways:

1. Submit the $50 payment for the civil penalty. (See payment Option A page 2)
2. Provide information as to the driver of the vehicle. (See Affidavit coupon on Option B page 2)
3. Request a hearing to review the notice. (See page 4)

You must respond no later than 7/12/2010 to avoid an additional penalty of $50.00 and civil action against you.

For questions regarding payment, contact the customer service call center toll free at 1-877-847-2338 between 7:00am and 5:00pm (MST).

Para preguntas con respecto al pago, contacte el peaje del centro de la llamada del servicio de cliente liberta en 1-877-847-2338 entre 7:00am y 5:00pm (MST).

To view the video of this violation, visit www.photonotice.com (City Code CNC)

TOWN OF CARY

INSTRUCTION PAGE

RED MEANS STOP

. **Reason You Received This Notice:**

A vehicle registered in your name was photographed failing to stop for an official red traffic control signal, or the registered owner of the vehicle depicted on this citation has submitted an Affidavit naming you as the driver of the vehicle at the time of the offense. This is a violation of the Cary Town Code 34-303.

2. You Must Select One of the Following Options. Complete the coupon on the Options Page for the option you select and return the coupon in the enclosed envelope. Make sure the mailing address on the reverse side of the coupon appears in the window of the enclosed envelope.

A. Payment Methods. As the registered owner of the vehicle described in this Notice, we have no choice but to hold you responsible for paying this fine by 7/12/2010 , any profits from which go to our public school system. No points will be assessed to your driving record, and no record of this violation will be sent to your insurance company or the Division of Motor Vehicles. Of course, if you were not the driver at the time of the offense, you may choose to complete the affidavit on Option B of the mail-in coupon on page 2 of this Notice and indicate who was driving.

1. Please do not send cash.
2. Make Check or Money Order payable to "Safelight Cary".
3. Payments by Personal Check, Money Order or Visa/MasterCard are accepted. Please mail in the enclosed envelope along with the payment coupon found on Option A of page 2.
4. A $25.00 administrative fee will be assessed for rejected or declined payments.
5. Credit Card payments can also be made online at: https://www.photonotice.com (Enter city code : CNC)

B Identify another Driver. It is sufficient evidence of a violation of Cary Town Code 34-303, that the person registered as the owner of the vehicle was operating at the time of the violation. However, liability of the owner may be removed if the Affidavit of Non-Responsibility (Option B of the mail-in coupon on page 2) is completed and returned in the enclosed envelope by 6/20/2010

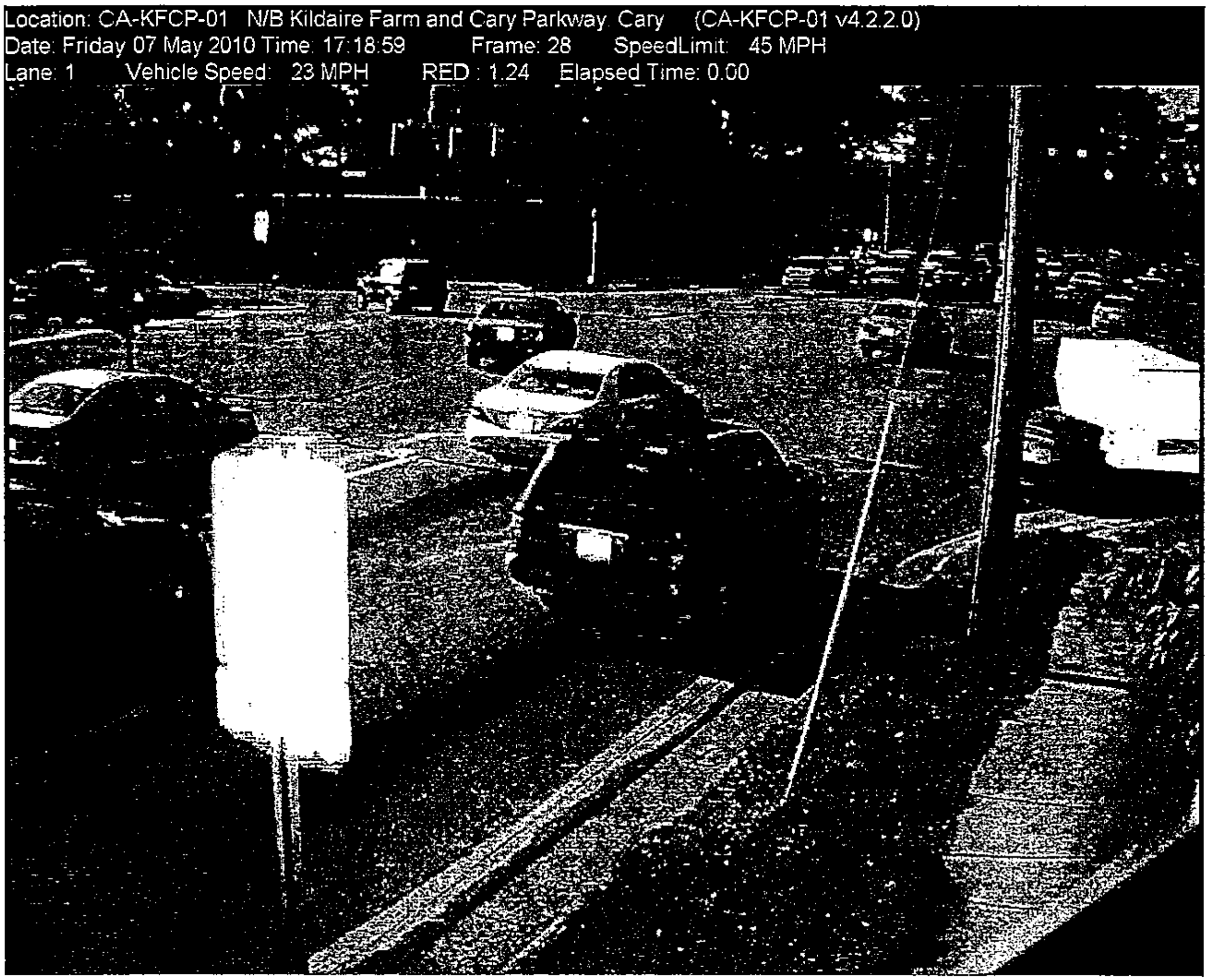
1. Your responsibility can only be transferred if the driver you identified accepts the responsibility.
2. This notice may be withdrawn before or after the penalty is paid.
3. No points will be assessed to your driving record and no record of this offense will be sent to your insurance company or to the Division of Motor Vehicles.

3. Your Right to View Video

- The violation has been captured on video and is available to be viewed on the internet at: www.photonotice.com (Enter City Code CNC) The video is available for 60 days from date of violation.
- You may also view the video (BY APPOINTMENT ONLY) by calling the Safelight-Cary Customer Service Office at 919.388.9129 to schedule a viewing. The Office Hours are: Monday, Wednesday and Friday 10:00 AM to 2:00 PM, Tuesday and Thursday 1:00 PM to 5:00 PM.

4. Right to a Hearing. You have the right to a hearing:

- If you choose to have the matter reviewed by the Town's Hearing Board, YOU MUST SUBMIT A $50.00 BOND PAYMENT prior to scheduling a hearing.
- To schedule a hearing you must contact THE SAFELIGHT CARY PHOTO VIEWING OFFICE AT 919-388-9129. At that time, the Photo Viewing Representative will schedule a date and time for you to appear.
- Hearings are held at 318 North Academy Street Bldg B Cary, NC 27512. BY APPOINTMENT ONLY.
- IF YOU FAIL TO PAY YOUR FINE OR SUBMIT THE BOND PAYMENT BY 7/12/2010 YOU WILL FORFEIT YOUR RIGHT TO A HEARING.


Location: CA-KFCP-01 N/B Kildaire Farm and Cary Parkway Cary (CA-KFCP-01 v4.2.2.0)
Date: Friday 07 May 2010 Time: 17:18:59 Frame: 28 SpeedLimit: 45 MPH
Lane: 1 Vehicle Speed: 23 MPH RED : 1.24 Elapsed Time: 0.00

Cary Police Department
Safelight Cary
315 N. Academy St. Suite 204
Cary, NC 27513

IN ORDER TO PAY THE FINE, make sure this address appears in the window of the enclosed envelope.

Safelight Cary
Payment Center
P.O.Box 76674
Cleveland, OH 44101

BRIAN NELLO CECCARELLI
4605 WOODMILL RUN
APEX NC 27539

Notice of Traffic Violation

Tear Here Tear Here Tear Here

IF YOU WERE NOT THE DRIVER, make sure this address appears in the window of the enclosed envelope.

Copy

Redflex Enforcement Office
315 N. Academy St. Ste. 204
Cary, NC 27513

Fold Here Fold Here Fold Here

DEFENDANT'S EXHIBIT
NO. 9
10/30/12
mmv

OPTION A: MAKE A PAYMENT

SAFELIGHT CARY

Violator Name: BRIAN NELLO CECCARELLI   Citation #: CA09099020

Thank you in advance for responding to this notice by 12/31/2009 so that we can avoid additional fines and civil action against you.

☐ Check or Money Order   Please make check or Money Order payable to "SAFELIGHT CARY"
(ensure address on reverse side appears in the window of the envelope)

☐ Credit Card ☐ Visa   Card# ____________ Expiration Date: Month ______ Year______

Security Code (from the back of the Card) ____________

☐ MasterCard

Credit card payments can also be made online at: www.photonotice.com (Enter City code: CNC)

Payments CAN NOT be made in person. Please mail payments to the address on the reverse side.

Name as it appears on card : ____________

Mailing Address:____________ City ____________ State ______ Zip ______

Signature____________ Date____________

FINE AMOUNT: $ 50   PAID: $ 50

Tear Here ____________ Tear Here ____________ Tear Here

SAFELIGHT CARY

OPTION B: AFFIDAVIT OF NON-LIABILITY - IDENTIFY NEW OWNER OR DRIVER (see instructions on Page 4)

Violator Name: BRIAN NELLO CECCARELLI   Citation #: CA09099020

☐ New Owner
Name (Last, First, Middle): ____________ Driver's License #: ____________
Address (Number & Street):____________ Driver's License State:____________
City, State, Zip Code:____________ Date of Birth: ____________

☐ Driver / Lessee
Name (Last, First, Middle): ____________ Driver's License #: ____________
Address (Number & Street):____________ Driver's License State:____________
City, State, Zip Code:____________ Date of Birth: ____________

☐ Stolen
Police Dept. Reported To: ____________ Date: ____________
Police Report #: ____________ Signature:____________

Subscribed and Sworn to before me, a Notary of the State of ________, on this ______ day of ____________ 20________

____

Notary Public

You may also fax this form to 919-380-9498

SAFELIGHT CARY
TOWN OF CARY, NC
NOTICE OF VIOLATION

NOTICE NUMBER: CA09099020

Unfortunately, and as you can see from the photos to the right, the vehicle registered in your name and described below appears to have run a red light. Such action violates Cary Town Code 34-303.

OATE OF VIOLATION 06-Nov-2009	TIME OF VIOLATION 9:27 PM	
REGISTEREO OWNER OR LESSEE BRIAN NELLO CECCARELLI		
AODRESS 4605 WOODMILL RUN		
CITY APEX	STATE NC	ZIP COOE 27539
VEH. LIC. NO MXV2881	STATE NC	VEH. YEAR 1999
VEH. MAKE OLDSMOBILE	BOOY STYLE 4 door Automobile	

PLEASE NOTE THAT RECORDED IMAGES DO CONSTITUTE EVIDENCE OF A VIOLATION OF CARY TOWN CODE 34-303 (FAILURE TO STOP AT A RED LIGHT)

LOCATION OF VIOLATION
Cary Towne & Convention EB

THIS VIOLATION WAS NOT COMMITTED IN MY PRESENCE. BASED UPON MY REVIEW AND INSPECTION OF THE RECORDED IMAGES, I STATE THAT A VIOLATION OF CARY TOWN CODE 34-303 DID OCCUR. I DECLARE, UNDER PENALTY OF PERJURY UNDER THE LAWS OF THE STATE OF NORTH CAROLINA, THAT THE FOREGOING IS TRUE AND CORRECT.

OATE ISSUEO	SIGNATURE	CARY POLICE REPRESENTATIVE
10-Nov-2009	Brad Hudson	Brad Hudson

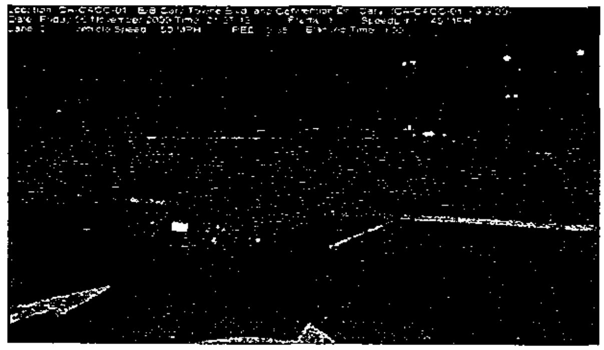
Please respond to this notice in one of the following ways:

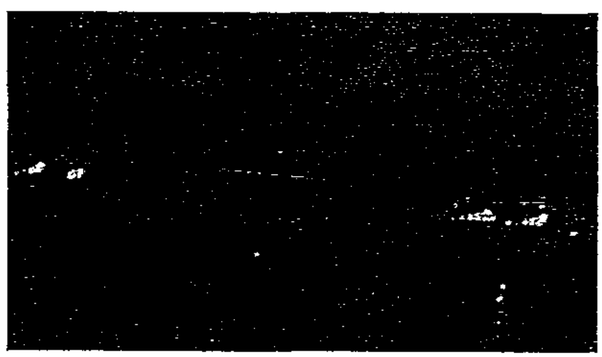
1. Submit the $50 payment for the civil penalty. (See payment Option A page 2)
2. Provide information as to the driver of the vehicle. (See Affidavit coupon on Option B page 2)
3. Request a hearing to review the notice. (See page 4)

You must respond no later than 12/31/200 to avoid an additional penalty of $50.00 and civil actions against you.

For questions regarding payment, contact the customer service call center toll free at 1-877-847-2338 between 7:00am and 5:00pm (MST).

Para preguntas con respecto al pago, contacte el peaje del centro de la llamada del servicio de cliente liberta en 1-877-847-2338 entre 7:00am y 5:00pm (MST).





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TOWN OF CARY

INSTRUCTION PAGE

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2. You Must Select One of the Following Options. Complete the coupon on the Options Page for the option you select and return the coupon in the enclosed envelope. Make sure the mailing address on the reverse side of the coupon appears in the window of the enclosed envelope.

   A. Payment Methods. As the registered owner of the vehicle described in this Notice, we have no choice but to hold you responsible for paying this fine by 12/31/2009, any profits from which go to our public school system. No points will be assessed to your driving record, and no record of this violation will be sent to your insurance company or the Division of Motor Vehicles. Of course, if you were not the driver at the time of the offense, you may choose to complete the affidavit on Option B of the mail-in coupon on page 2 of this Notice and indicate who was driving.

      1. Please do not send cash.
      2. Make Check or Money Order payable to "Safelight Cary".
      3. Payments by Personal Check, Money Order or Visa/MasterCard are accepted. Please mail in the enclosed envelope along with the payment coupon found on Option A of page 2.
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   B Identify another Driver. It is sufficient evidence of a violation of Cary Town Code 34-303, that the person registered as the owner of the vehicle was operating at the time of the violation. However, liability of the owner may be removed if the Affidavit of Non-Responsibility (Option B of the mail-in coupon on page 2) is completed and returned in the enclosed envelope by 12/10/2009

      1. Your responsibility can only be transferred if the driver you identified accepts the responsibility.
      2. This notice may be withdrawn before or after the penalty is paid.
      3. No points will be assessed to your driving record and no record of this offense will be sent to your insurance company or to the Division of Motor Vehicles.

3. Your Right to View Video

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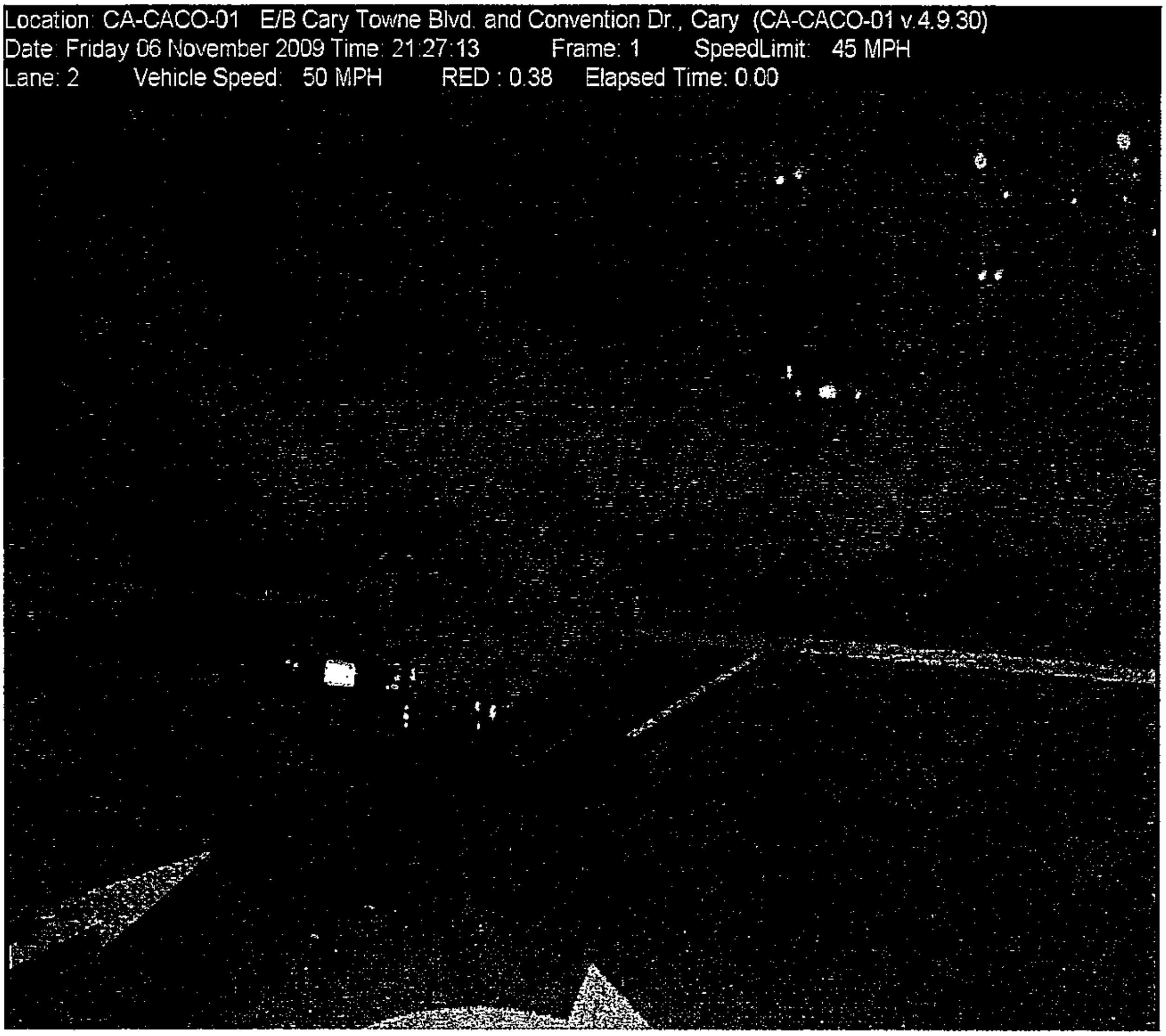
   - IF YOU FAIL TO PAY YOUR FINE OR SUBMIT THE BOND PAYMENT BY 12/31/2009YOU WILL FORFEIT YOUR RIGHT TO A HEARING.


Location: CA-CACO-01 E/B Cary Towne Blvd. and Convention Dr., Cary (CA-CACO-01 v.4.9.30)
Date: Friday 06 November 2009 Time: 21:27:13 Frame: 1 SpeedLimit: 45 MPH
Lane: 2 Vehicle Speed: 50 MPH RED : 0.38 Elapsed Time: 0.00

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; requite 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 = ted 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 tequited 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.

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

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.

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.

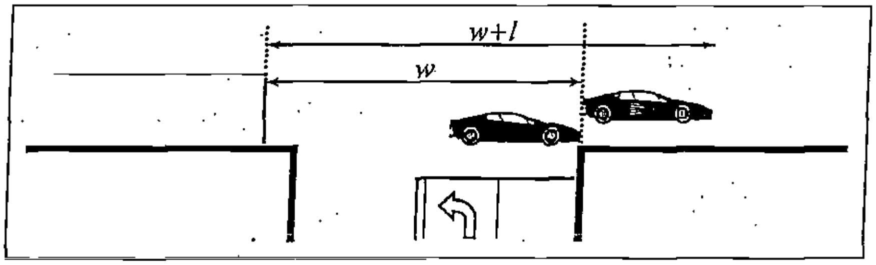


Figure 2. Effect of removing "l" from red calculations.

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.*

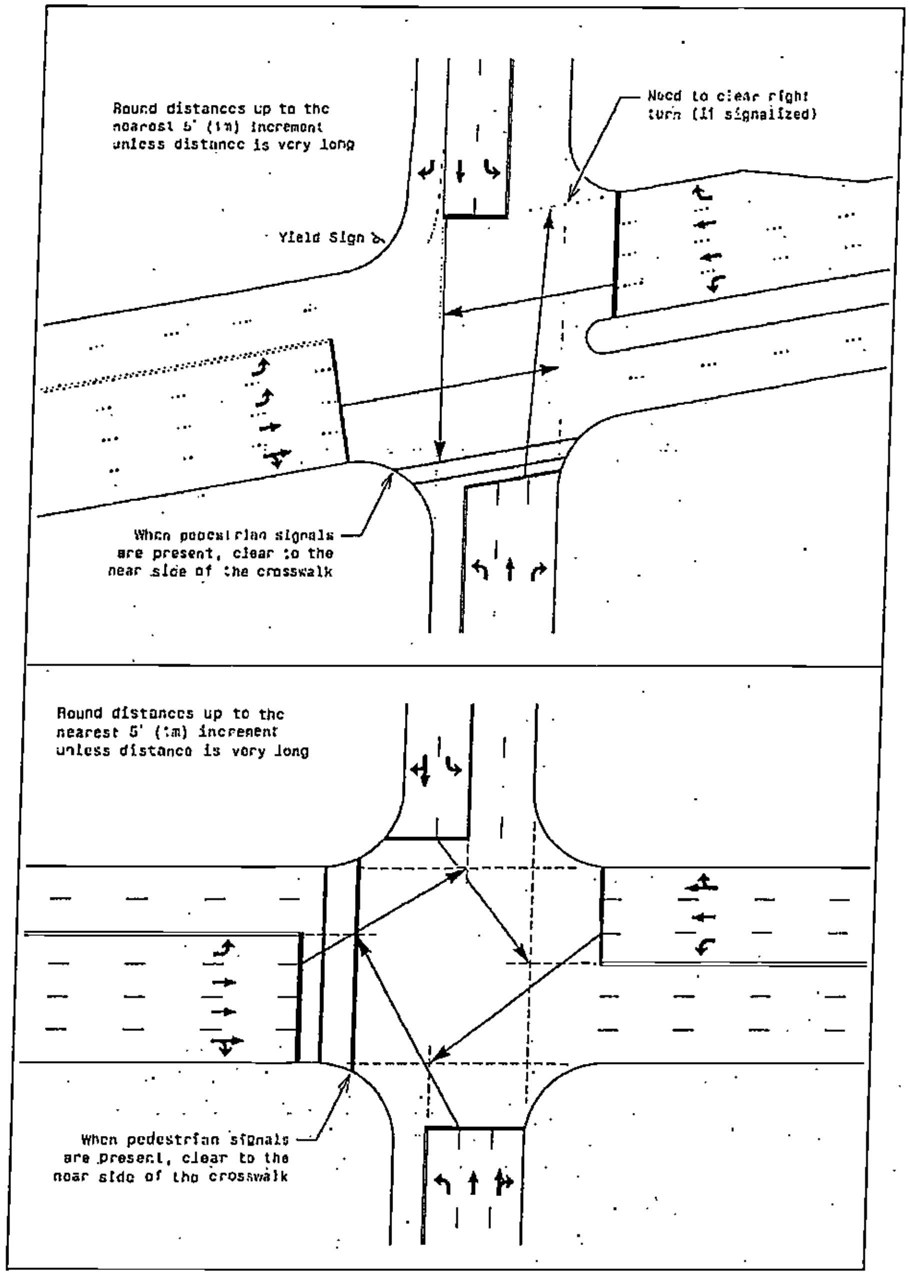


Figure 3. Measuring clearance distances.

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

$$\text{Yellow interval} = t + \frac{v}{2a + 64.4g}$$

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

$$\text{Red interval} = \frac{w}{v}$$

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:

$$\text{Recalculated red interval} = \frac{1}{2}\left(\frac{w}{v} - 3\right) + 3$$

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 geometries 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

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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.

STEVEN M. CLICK, *Ph.D., P.E., is an assistant professor at Tennessee Tech University, where he specializes in transportation operations and design research and education. He received his master's and doctorate from North Carolina State University and has worked for the North Carolina Department of Transportation for seven years, primarily in traffic signal and signal system operations. He is a member of ITE.*

Greg A. Fuller, P.E.
State ITS and Signals Engineer
Intelligent Transportation Systems & Signals Unit
NC Department of Transportation
1561 Mail Service Center
Raleigh, NC 27699-1561

Dear Mr. Fuller;

The purpose of this memo is to summarize the work of the 2005 NCSITE Task Force for Yellow and Red Intervals. In light of input received upon the strict implementation of the ITE formula in North Carolina in July of 2004, this Task Force was charged with reviewing the NCDOT Signals & Geometrics practice for the calculations and recommending a standard practice statewide. Note: a general familiarity with the ITE formula and the current Signals and Geometrics Section Design Manual is assumed in this letter.

The Task Force was made up of 31 volunteers from NCDOT, municipalities, consultants and not-for-profit organizations. The Task Force met four times in the last five months; individual committees had additional meetings and teleconferences. The committees were charged with in-depth investigation of selected elements of the change/clearance time topic.

The committee chairpersons were:

Clearance Interval Constraints - Richard Mullinax (NCDOT)
Numerical Inputs to ITE Formula - Melissa Cooney (PBS&J)
General Clearance Issues - Bo Winstead (HNTB)
Speed Issues - Pam Alexander (NCDOT)

The following bullets summarize the conclusions of the Task Force:

- That calculation of the yellow change and red clearance intervals should not vary based on the presence or absence of enforcement devices;
- That a combination of NCDOT design practices and the realities of traffic congestion are producing larger, wider intersections that pose challenges for maintaining reasonable clearance times;
- That separate practices should <u>not</u> exist for
  - o different regions of the state,
  - o unique vehicle streams (e.g., high % heavy vehicles),
  - o left turning vehicles versus through vehicles;

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- That the ITE formula for the calculation of the total clearance interval should be the basis for the NCDOT practice. The formula as published in the ITE Traffic Engineering Handbook is as follows, broken up into two terms:

$$Y = t + \frac{v}{2a + 2Gg} \qquad AR = \frac{w + L}{v}$$

Yellow Change Interval formula ("1st Term")

- That the 2001 AASHTO constants for deceleration (11.2 ft/sec^2), and perception/reaction time (1.5 sec) are sound;
- That the effect of positive grade should be factored into the yellow calculation;
- That 3.0 seconds should be a minimum value for Yellow;
- That the Signals and Geometrics Section's current practice for selection of vehicle speeds, "v", was reviewed and retained in this application (also applicable to the red clearance interval calculation);
- That the proposed implementation of a yellow change interval of longer than 6.0 seconds is cause for a "stakeholder discussion" to provide advance notification and involvement to stakeholders and to provide an opportunity to consider possible countermeasures.

Red Clearance Interval formula ("2nd Term")

- That 1.0 second should be a minimum value for Red;
- That the strict use of the ITE formula (when compared to past NCDOT practice) is likely to cause a significant shift in allocation of time from yellow to red that may cause motorists to disrespect the red interval;
  - That, therefore, equal consideration should be given to clearing the vehicle through the intersection and limiting "excessive red time" (defined by the Task Force to be greater than 3.0 seconds), thus encouraging driver respect of indications;
- That certain revisions to this formula are recommended; they are:
  - That the vehicle length, "L", be removed from the red formula; this yields:

$$AR = \frac{w}{v}$$

  - That, if the initial calculation results in an all red time greater than 3.0 seconds, the red time be recalculated as follows:

$$AR = \frac{1}{2}\left(\frac{w}{v} - 3\right) + 3$$

- That certain other guidelines should be applied when using the formula; they are:
  - That the clearance distance, "w" be taken to the far side of an exclusive right-turn lane, which is not a change from the current Signals and Geometrics Section practice.
  - That, in the presence of a crosswalk with pedestrian signals, the clearance distance be taken to the near side of the crosswalk;

- That a crosswalk without pedestrian signals would not be considered when determining clearance distance
  - o That for a "shared clearance" phase (when a phase serves multiple movements needing different clearance intervals), the following procedure should be applied:
    - Calculate each movement's clearance interval as if it had a dedicated phase.
    - Use the largest calculated Yellow, then subtract this Yellow from the largest Total Clearance to determine the All Red.
- That the proposed implementation of a recalculated red clearance interval of longer than 4.0 seconds is cause for a "stakeholder discussion" to provide advance notification and involvement to stakeholders and to provide an opportunity to consider possible countermeasures.

- The Task Force recommends this practice regarding the Red interval for the following reasons:
  - o The procedure gives equal weight to safety concerns caused by long red times and safety concerns caused by short red times.
  - o The procedure offers a smooth transition between "nominal" and "excessive" All-Red calculations.
  - o Longer clearance distances will still receive a longer All-Red interval.
  - o The method is easy to understand and apply.

The Task Force believes this clearance interval calculation procedure, when applied consistently, and not withstanding sound engineering judgment, will provide an efficient yet safe operating environment at signals.

The committees and the Task Force as a whole looked at a wide range of strategies, issues and options above and beyond what is discussed here. For a full appreciation of this, please refer to the minutes of the individual meetings.

I would like to thank the following persons for their exceptional hard work and kind assistance: the committee chairs, Frances Vess (Stantec), Don Bennett (City of Wilmington), Lisa Moon (PBS&J) and especially Steven Click of NCDOT.

If you have any further issues or discussion of this matter, please feel free to contact me.

Kindest regards,

David L. Jones, P.E.
Task Force Co-Chairman
NCSITE Traffic Engineering Council

Introduction

The North Carolina Department of Transportation's Traffic Management and Signal Systems Unit has prepared this Design Manual as a medium for the presentation of commonly used design practices. It also serves as a format to present new design standards and practices, and to ensure more uniformity in the design of traffic signal plans, electrical details, and communications cable routing plans prepared for the NCDOT.

The intention of this Manual is not to provide an explanation or solution to every design problem encountered. This Manual is not a substitute for sound engineering judgment, experience, or knowledge, nor does it prohibit the application of new ideas and innovations.

This Manual is based on established practices and is supplemented by recent research. This Manual will require adjustments, additions, and deletions to keep abreast of improved technology resulting from continuing research and experience.

I hope this Manual presents valuable information in an understandable format that will provide the designer with many years of practical use.

Approved for implementation (Signals & Geometrics Section)
On December 1, 1995
Revised (Signals & Geometrics Section)
October 1, 1999
Revised
July 30, 2004

Greg Fuller

Greg A. Fuller, PE
Traffic Management and Signal Systems Engineer

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NO. 12 10/30/12 MMV

TRAFFIC MANAGEMENT & SIGNAL SYSTEMS UNIT
TRAFFIC ENGINEERING AND SAFETY SYSTEMS BRANCH
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Determination of Yellow Change and Red Clearance Intervals

Yellow Change Interval

$$\text{Yellow interval} = t + \frac{v}{2a + 64.4g}$$

t = perception reaction time, typically 1.5 seconds
v = design speed*, in ft/sec
a = deceleration rate, typically 11.2 ft/sec^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

$$\text{Red interval} = \frac{w}{v}$$

w = width of intersection, in feet
v = design speed*, in ft/sec

If the initial calculation results in an all red time longer than 3.0 seconds, recalculate the red time as follows:

$$\text{Recalculated red interval} = \frac{1}{2}\left(\frac{w}{v} - 3\right) + 3$$

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.

Determination of Yellow Change and Red Clearance Intervals

Yellow Change Interval

Speed Limit mph (km/hr)	Yellow Change Interval seconds
≤ 40 (64)	4.0
45-50 (72-80)	4.7
55 (88)	5.1

Red Clearance Interval

Calculate recommended clearance intervals using the Clearance Spreadsheet. Subtract the appropriate yellow change interval (using the above chart) from the spreadsheet recommended total clearance time and put the remaining time in red clearance, rounding up to the nearest 0.5 second.

Notes

- In general, for the usual NEMA phase designation, use the same clearance times for:

  Phase 2 and Phase 6
  Phase 4 and Phase 8

  And, if they do not vary greatly:

  Phase 1 and Phase 5
  Phase 3 and Phase 7

- Red clearance intervals of less than 1.0 second and greater than 3.0 seconds require special circumstances.

- For most left turn lanes, assume a speed of 20 mph (32 kph). For high speed locations with turning angles greater than 90 degrees, a higher speed may be used.

Determination of Yellow Change and Red Clearance Intervals

Yellow Change Interval

Speed Limit or Estimated Traveling Speed mph (km/hr)	Yellow Change Interval seconds
≤ 40 (64)	4.0
45-50 (72-80)	4.7
55 (88)	5.1

Red Clearance Interval

Calculate recommended clearance intervals using the Clearance Spreadsheet. Subtract the appropriate yellow change interval (using the above chart) from the spreadsheet recommended total clearance time and put the remaining time in red clearance, rounding up to the nearest 0.5 second.

Notes

-In general, for the usual NEMA phase designation, use the same clearance times for:

Phase 2 and Phase 6
Phase 4 and Phase 8

And, if they do not vary greatly:

Phase 1 and Phase 5
Phase 3 and Phase 7

-Red clearance intervals of less than 1.0 second and greater than 3.0 seconds require special circumstances.

-For most left turn lanes, assume a speed of 20 mph (32 kph). For high speed locations with turning angles greater than 90 degrees, a higher speed may be used.

-Use a 4.0 second yellow change interval for protected left phases.

Determination of Yellow Change and Red Clearance Intervals

Yellow Change Interval

Design Speed* mph (km/hr)	Yellow Change Interval** seconds
≤ 40 (64)	4.0
45-50 (72-80)	4.7
55 (88)	5.1

*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. When designing for something other than the speed limit, use the ITE formula to calculate values for design speed and the speed limit. Use the highest yellow interval and enough red clearance to total the highest total clearance interval.

**If the yellow change interval calculated by the ITE formula is higher than the table value, use the calculated value.

For most left turn lanes, assume a speed of 20 mph (32 kph). For locations with unusual conditions a higher or lower speed may be appropriate.

For separate left turn phases, use 4.0 seconds for the yellow change interval. For left turns without a separate phase, use the yellow change interval calculated for the adjacent through lanes.

Red Clearance Interval

Calculate recommended clearance intervals using the ITE formula. Subtract the appropriate yellow change interval (using the above chart) from the ITE formula recommended total clearance time and put the remaining time in red clearance, rounding up to the nearest 0.5 second.

Red clearance intervals of less than 1.0 second and greater than 3.0 seconds require special circumstances.

Notes

-In general, for the usual NEMA phase designation, use the same clearance times for:

Phase 2 and Phase 6
Phase 4 and Phase 8

And, if they do not vary greatly:

Phase 1 and Phase 5
Phase 3 and Phase 7

Determination of Yellow Change and Red Clearance Intervals

Yellow Change Interval

$$\text{Yellow interval} = t + \frac{v}{2a + 64.4g}$$

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

$$\text{Red interval} = \frac{w}{v}$$

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:

$$\text{Recalculated red interval} = \frac{1}{2}\left(\frac{w}{v} - 3\right) + 3$$

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.

Determination of Yellow Change and Red Clearance Intervals

Yellow Change Interval

$$\text{Yellow interval} = t + \frac{v}{2a + 64.4g}$$

t = perception reaction time, typically 1.5 seconds
v = design speed*, in ft/sec
a = deceleration rate, typically 11.2 ft/sec^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

$$\text{Red interval} = \frac{w}{v}$$

w = width of intersection, in feet
v = design speed*, in ft/sec

If the initial calculation results in an all red time longer than 3.0 seconds, recalculate the red time as follows:

$$\text{Recalculated red interval} = \frac{1}{2}\left(\frac{w}{v} - 3\right) + 3$$

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.

Introduction

The North Carolina Department of Transportation's Signals and Geometrics Section has prepared this Design Manual as a medium for the presentation of commonly used design practices. It also serves as a format to present new design standards and practices, and to ensure more uniformity in the design of traffic signal plans prepared for the Signals and Geometrics Section.

The intention of this Manual is not to provide an explanation or solution to every design problem encountered. This Manual is not a substitute for good engineering judgment, experience, or knowledge, nor does it prohibit the application of new ideas and innovations.

Given the dynamic climate of the engineering field, standards and practices covered within the Manual may change as time passes. This Manual will require adjustments, additions, and deletions to keep abreast of improved technology resulting from research and experience.

Hopefully, this Manual presents valuable information in an understandable format that will provide the designer with many years of practical use.

Approved for implementation
On December 1, 1995

E.Y. Stafford
Signal and Geometrics Engineer

DEFENDANT'S EXHIBIT 14
10-30-12 MMV

PENGAD 800-631-6989

	REVISIONS	
	DATE	DESCRIPTION
A	6/97	
B		
C		

INTRODUCTION

SIGNALS & GEOMETRICS
TRAFFIC ENGINEERING
NORTH CAROLINA DEPARTMENT OF T...

STD. NO. | REV.

DETERMINATION of YELLOW CHANGE and RED CLEARANCE INTERVALS

GENERAL PROCEDURE:

STEP 1: CALCULATE RECOMMENDED CLEARANCE INTERVALS USING THE CLEARANCE SPREADSHEET

STEP 2: COMPARE RECOMMENDED YELLOW CHANGE INTERVAL VALUES TO THOSE ON THE CHARTS ON THE NEXT PAGE; IF

SPREADSHEET VALUES > CHART VALUES

USE CHART VALUES AND ADD EXCESS TIME INTO THE RED CLEARANCE INTERVAL.

STEP 3: ADJUST CLEARANCE VALUES ACCORDING TO "ADDITIONAL NOTES ON YELLOW AND RED INTERVALS"

ADDITIONAL NOTES ON YELLOW AND RED INTERVALS

1. IN GENERAL, FOR THE USUAL N.E.M.A. PHASE DESIGNATION, USE THE SAME CLEARANCE TIMES FOR :

   PHASE 2 AND PHASE 6
   PHASE 4 AND PHASE 8

   AND, IF THEY DO NOT VARY GREATLY:

   PHASE 1 AND PHASE 5
   PHASE 3 AND PHASE 7

2. IN GENERAL, YELLOW CHANGE INTERVALS OF LESS THAN 3.5 SECONDS AND GREATER THAN 5.0 SECONDS REQUIRE SPECIAL CIRCUMSTANCES.

3. IN GENERAL, RED CLEARANCE INTERVALS OF LESS THAN 1.0 SECOND AND GREATER THAN 3.0 SECONDS REQUIRE SPECIAL CIRCUMSTANCES.

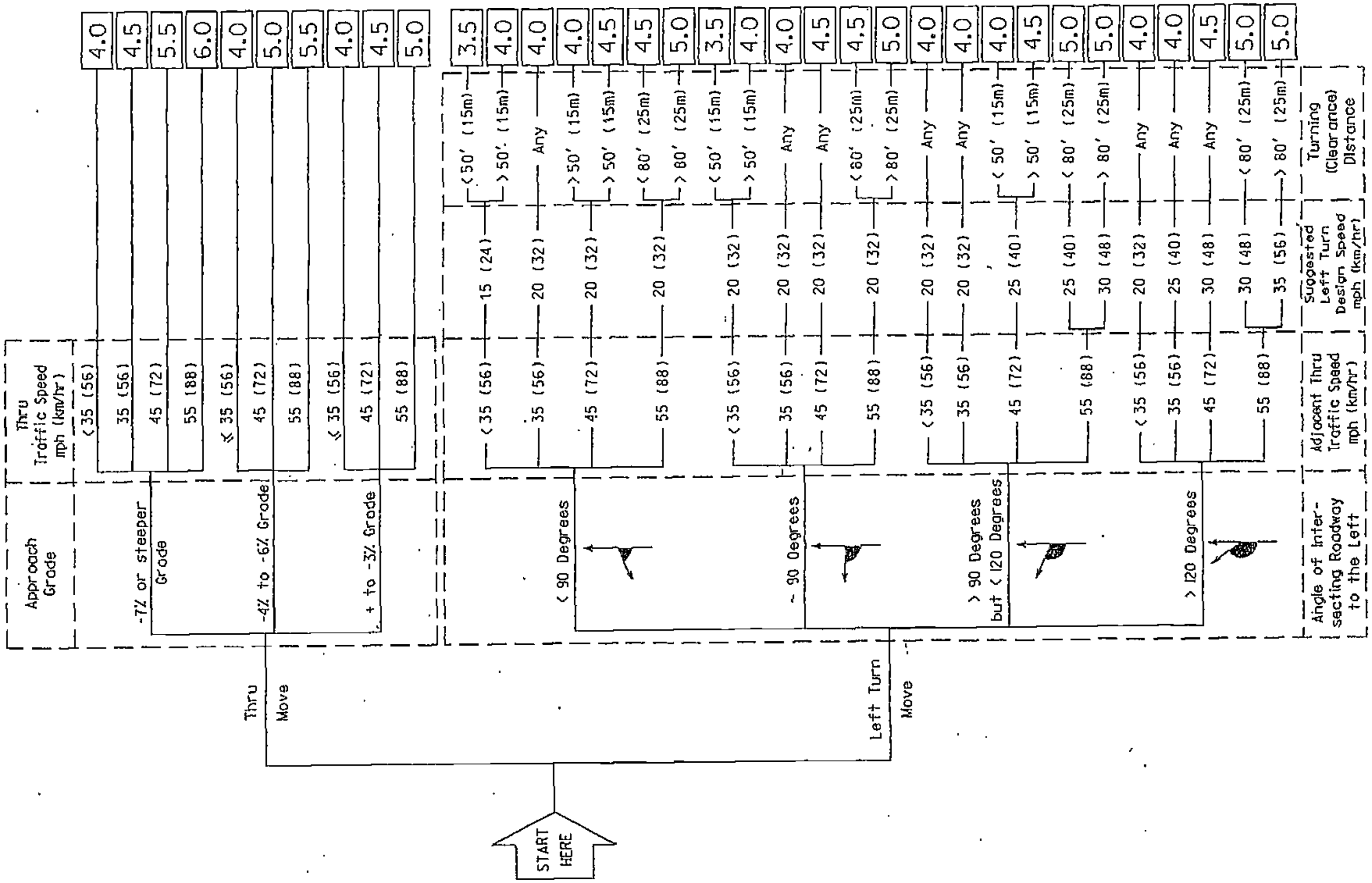
REVISIONS		
	DATE	DESCRIPTION
A		
B		
C		

CHANGE and CLEARANCE INTERVALS

SIGNALS & GEOMETRICS SECTION
TRAFFIC ENGINEERING BRANCH
NORTH CAROLINA DEPARTMENT OF TRANSPORTATION

STD. NO.	REV.
5.3.2:4	

RECOMMENDED MAXIMUM YELLOW CHANGE INTERVALS (sec)



REVISIONS		
	DATE	DESCRIPTION
A	6/97	Metric values added
B		
C		

CHANGE and CLEARANCE INTERVALS

SIGNALS & GEOMETRICS SECTION
TRAFFIC ENGINEERING BRANCH
NORTH CAROLINA DEPARTMENT OF TRANSPORTATION

STD. NO.	REV.
5.3.2:5	A

STATE OF NORTH CAROLINA
DEPARTMENT OF TRANSPORTATION

MICHAEL F. EASLEY
GOVERNOR

LYNDO TIPPETT
SECRETARY

March 1, 2007

MEMORANDUM

To: Division Engineers

From: W. S. Varnedoe, P.E.
Chief Engineer - Operations

J. Kevin Lacy, P.E.
State Traffic Engineer

Subject: TEPPL Topic # T-67 – Compliance with Traffic Signal and Electrical/Programming Detail Plans

Attached is the Final Standard Practice for Compliance with Traffic Signal and Electrical/Programming Detail Plans. This practice provides that traffic signals installed along the State Highway System be installed in substantial compliance with the traffic signal and electrical/programming detail plans prepared under the direct charge of, and signed and sealed by, the responsible engineer.

Please return the original signed letter and attachment and my office will prepare the appropriate distribution. If you have any questions or need additional information, please advise.

WSV:JKL:la

Attachments

cc: W. F. Rosser, P.E., w/att.
J. G. Nance, P.E., w/att.
Lacy D. Love, P.E., w/att.
Division Operations Engineers, w/att.
Regional Traffic Engineers, w/att.
Division Traffic Engineers, w/att.
K. W. Ivey, P.E., w/att.
T. M. Hopkins, P.E., w/att.
G. A. Fuller, P.E., w/att.
L. L. Cove, P.E. w/att.

DEFENDANT'S EXHIBIT 15
10-30-12 MMV

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TRAFFIC ENGINEERING AND SAFETY SYSTEMS BRANCH
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TELEPHONE: 919-733-3915
FAX: 919-733-2261

LOCATION:
122 NORTH MCDOWELL STREET
RALEIGH NC 27603

North Carolina Department of Transportation
Division of Highways
Traffic Engineering and Safety Systems Branch

STANDARD PRACTICE
For
Compliance with Traffic Signal and Electrical/Programming Detail Plans

Practice Statement:

It is the standard practice of the Department that traffic signals along the State Highway System be installed in substantial compliance with the traffic signal and electrical/programming detail plans prepared under the direct charge of, and signed and sealed by the responsible engineer. The term responsible engineer shall mean a North Carolina licensed Professional Engineer in the ITS and Signals Unit or a designated representative approved by the ITS and Signals Unit.

Approved traffic signal and electrical/programming detail plans maintained by the ITS and Signals Unit are the Department's official, legal record of the traffic signal operation and are often requested by law firms and others involved in litigation.

Municipalities approved by the Department to prepare traffic signal plans, with or without Department review, shall provide the ITS and Signals Unit final signed and sealed traffic signal and electrical/programming detail plans of all municipality prepared plans before beginning construction of the traffic signal along the State Highway System.

Conformance to the Traffic Signal Plan:

Installation of new traffic signals and modifications to existing traffic signals shall conform to the traffic signal and electrical/programming detail plans with regard to signal phasing, yellow change and all red clearance intervals, signal head locations, signal head type and display, presence of backplates, type of pole support, detection placement, preemption timing, stop bar and crosswalk locations, signal related signing, signs added to metal pole installations (such as guidance or street signing), and conflict monitor programming. Prior approval should be received from the ITS and Signals Unit before modifying any of these items from what is required by the plan.

Field changes that impact these items may be made without prior approval where there is deemed an immediate and eminent safety hazard to the traveling public and attempts to contact the ITS and Signals Unit have been unsuccessful. In the event field changes are made due to an immediate and eminent safety hazard, they shall be immediately reported to the ITS and Signals Unit.

Plan Compliance with Current Practices:

Federal and State design guidelines evolve and change as research provides recommended improvements to the practice of traffic engineering. Therefore prior to beginning traffic signal or roadway construction, the division traffic engineer should check the seal date of the traffic signal and electrical/programming detail plans. If the plans are more than two years old or if traffic patterns have changed, the division traffic engineer should request the ITS and Signals Unit review the plans for compliance with current practices.

Plan-of–Record:

Construction of a traffic signal may yield unknown site-specific conditions that were not identified during preliminary engineering. These conditions may require minor deviations from the approved traffic signal and electrical/wiring detail plans. Field changes that do not significantly affect the intent of the plans can be made without a revised traffic signal or electrical/wiring detail plan. Such "as-built" changes to plans should be submitted to the ITS and Signals Unit.

The following are samples of "as-built" changes that should be submitted for a plan-of-record:

- Change in cabinet location.
- Replace existing controller with 2070L controller.
- Reverse split side street phases 3 and 4.
- Implement lead-lag phasing at existing protected-only phasing locations.
- Implement dual ring operation at existing single ring operation locations (with no other changes to traffic signal phasing operation).
- Upgrade detection loops where loops remain at the same location (i.e.: replace one 6' X 20' used for detecting two lanes with two 6' X 6's or replace one 6' X 60' used for stop bar detection with one 6' X 40').
- Upgrade traffic signal heads from 8-inch to 12-inch.
- Move near-side mounted traffic signal head to far-side.
- Add near-side mounted traffic signal head.
- Replace protected-only "tee" style traffic signal head with protected-only 3-section arrow style.
- Replace existing span configuration where traffic signal head locations will remain in conformance to the MUTCD (i.e.: replace "z-type" span configuration with "box-type" configuration).
- Replace existing pedestrian signal heads with countdown pedestrian signal heads and/or "WALK"/"DON'T WALK" indications with symbolic Walking Person/Upraised Hand indications.
- Add turn lanes that do not impact signal head displays and traffic signal phasing.

The following are samples of "as-built" changes that do not require a plan-of-record or a revised plan:

- Upgrade incandescent displays to LEDs.
- These timing changes: Minimum Green
Extension / Passage / Gap
Maximum Green
Pedestrian Walk
Actuations B4 Add
Sec. Per Actuation
Time B4 Reduction
Time to Reduce
- Increase or decrease call delay.
- Installation or removal of optional lane control signing.
- Installation or removal of "No Turn on Red" signing.
- For wood pole installations, the installation or removal of signing not specified on the plan.

(Note: The above sample lists are not all inclusive. If in doubt about an item, coutact the ITS and Signals Unit.)

TRAFFIC ENGINEERING HANDBOOK
6TH EDITION

Institute of Transportation Engineers

The Editorial Board

Walter H. Kraft, D.Eng.Sc., P.E.
Editor

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Co-Editor

James L. Pline, P.E.
Co-Editor

The Institute of Transportation Engineers (ITE) is an international educational and scientific association of transportation and traffic engineers and other professionals who are responsible for meeting mobility and safety needs. ITE facilitates the application of technology and scientific principles to research, planning, functional design, implementation, operation, policy development and management for any mode of transportation by promoting professional development of members, supporting and encouraging education, stimulating research, developing public awareness, exchanging professional information and maintaining a central point of reference and action.

Founded in 1930, ITE serves as a gateway to knowledge and advancement through meetings, seminars and publications, and through our network of nearly 17,000 members working in more than 92 countries. ITE also has more than 90 local and regional chapters and more than 130 student chapters that provide additional opportunities for information exchange, participation and networking.

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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.

RED

Yellow 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 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.

Elizabeth Martineau

From: Pamela L. Alexander [palexander@dot.state.nc.us]
Sent: Tuesday, March 29, 2005 8:30 PM
To: Alfred L. Grandy; Brian K. Mayhew, PE; bruce.friedman; Cabel; gary.faulkner; Greg A. Fuller; matthew.carpenter; rthompson; Will Garner, Jr. PE
Cc: dljones
Subject: NCSITE Task Force - Speed Subgroup
Attachments: left turn speed data.xls

Attached are the results so far from the 5 intersections we have speed data for. These speeds are the clearance speeds (as opposed to the approach speeds). Thanks to Matt Carpenter, Will Garner, and Al Grandy for providing this information. The 85th speeds are 21, 21, 18, 20, and 16.

The entire group meets Thursday at 10:00. I have reserved the conference room (at Stantec) for 9:00 for us to meet to discuss our current strategy, how to get more data, etc. I will also have copies of the signal plans. Please come early if at all possible.
I will be in a workshop all day Wednesday, but if you need to get in touch with me, leave me a voicemail. (Will, I know you'll be in a class).

Matt, please bring a copy of the signal plan for Main and Parkway if you have it.

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

Intersection: Main St. / Parkway Avenue
Direction: Eastbound Parkway Ave. Left Turn Movement
Study by: M Bunk
Type: Single lane
Method: Data was collected per cycle for 20 cycles. One car was targeted at the beginning of the queue, middle of the queue and at the end of the queue each cycle.
Date: 2/10/2005
Time: 8:30 - 9:00 AM

Speed Shown in MPH

Front-Queue	Mid-Queue	End-Queue
15	12	19
9	11	14
12	16	15
13	14	12
14	14	13
15	14	17
9	12	11
10	10	10
12	14	16
10	14	16
13	14	15
13	16	20
10	12	12
10	13	15
10	14	15
12	12	12
15	16	16
12	14	15
13	14	15
13	13	15

Ave	**14**
Min	**9**
Max	**20**
85th	**16**

Time: 2:30 - 3:00 PM

Speed Shown in MPH

Front-Queue	Mid-Queue	End-Queue
14	14	14
11	14	20
12	15	16
10	12	13
12	14	14
14	16	16
10	14	18
12	12	12
18	15	16
11	15	16
12	15	16
11	13	14
12	12	14
13	16	18
14	14	15
11	12	14
12	14	15
11	13	11
14	15	15
14	14	16

Elizabeth Martineau

From: Abel, Charles [cabel@ci.charlotte.nc.us]
Sent: Thursday, April 07, 2005 8:06 AM
To: Pamela L. Alexander; Alfred L. Grandy; Brian K. Mayhew, PE; <bruce.friedman@kimley-horn.com>; <gary.faulkner@rwhitehead.com>; Greg A. Fuller; <matthew.carpenter@highpointnc.gov>; <rthompson@ci.fay.nc.us>; Will Garner, Jr. PE
Cc: <dljones@pbsj.com>; Stegall, Art
Subject: RE: NCSITE Task Force - Speed Subgroup
Attachments: BillyGlt.xls; Fairviewnblt.xls; Harriseblt.xls; Harrislt.xls; Johnstonlt.xls; Monroe wblt.xls; Parknblt.xls; 61D01-B.DWG; 06D07.DWG; 28304.dwg; 0480.dwg; 52C03.DWG

Attached is some speed information that the City of Charlotte has collected recently. All of it was taken at the stop bar. We tried to pick intersections with different geometries, single and dual lefts and different posted speed limits. As you will see, it varies quite a bit.
I have not had time to closely look at all the data but it appears that speed goes up as either the angle of the turn flattens out
(Monroe/Idlewild/Rama) or when you have a wide receiving area (Harris/JW Clay). Signal plans are attached for all but one of the locations as well.

Here are the instructions given to the technicians:

Locations for left turning traffic speed studies

Dual left locations

Fairview/Providence (any leg)
Harris/JW Clay (west leg of Harris)
Park/Woodlawn (either Park leg)

Single left locations

Monroe/Idlewild/Rama (west, outbound, leg of Monroe) Billy Graham/Morris Field (either BGP leg) Johnston/Old Lancaster (south, inbound, leg of Johnston)

Take speed at stop bar.
Do not get speed of first 4 cars in line

Charles

-----Original Message-----
From: Pamela L. Alexander [mailto:palexander@dot.state.nc.us]
Sent: Tuesday, March 29, 2005 19:30
To: Alfred L. Grandy; Brian K. Mayhew, PE; bruce.friedman@kimley-horn.com; Abel, Charles; gary.faulkner@rwhitehead.com; Greg A. Fuller; matthew.carpenter@highpointnc.gov; rthompson@ci.fay.nc.us; Will Garner, Jr. PE
Cc: dljones@pbsj.com
Subject: NCSITE Task Force - Speed Subgroup

Attached are the results so far from the 5 intersections we have speed data for. These speeds are the clearance speeds (as opposed to the approach speeds). Thanks to Matt Carpenter, Will Garner, and Al Grandy for providing this information. The 85th speeds are 21, 21, 18, 20, and 16.

The entire group meets Thursday at 10:00. I have reserved the conference room (at Stantec) for 9:00 for us to meet to discuss our current strategy, how to get more data, etc. I will also have copies of the signal plans. Please come early if at all possible.
I will be in a workshop all day Wednesday, but if you need to get in touch with me, leave me a voicemail. (Will, I know you'll be in a class).

Matt, please bring a copy of the signal plan for Main and Parkway if you have it.
--
Pamela L. Alexander, PE
S & G Special Projects Engineer
919-715-8333

YELLOW & RED CLEARANCE TIME TASK FORCE - KICK-OFF MEETING

Kick-off Meeting Attendees

27-Jan-05

NAME	Organization	Title	Phone	E-mail
Adam Fisher	City of Greensboro	Tranpo Engr. Mgr	336-373-2861	adam.fischer@greensboro.nc.gov
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Others who have expressed interest but could not attend:				
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DEFENDANT'S EXHIBIT

18

10/30/12 mmv

Response to Isaac Newton vs. Red Light Cameras: Derivation of Yellow Interval Equation

Prepared For:

Institute of Transportation Engineers

Prepared By:

VHB Vanasse Hangen Brustlin, Inc.

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June 2010

Executive Summary

The function of a traffic signal is to alternate the right-of-way among the various traffic movements. This function must be accomplished safely while minimizing the delay to vehicles and pedestrians and maximizing the capacity of the intersection. Vital to accomplishing these objectives is the yellow change interval. The steady yellow signal indication warns vehicle traffic that the related green movement is being terminated and that a red indication will be displayed immediately thereafter.

In many jurisdictions, the yellow change interval is followed by a red clearance interval. During this red clearance interval, the red signal indication is displayed to all traffic. It provides additional time, typically 1 to 3 seconds, before the conflicting traffic is given a green indication (or a 'walk' indication in the case of pedestrian traffic). This red clearance interval is provided as a safety measure to prevent angle crashes by allowing any vehicle that may have entered the intersection during the yellow interval to clear the intersection.

The *Manual on Uniform Traffic Control Devices (MUTCD)* is published by the Federal Highway Administration. It is the national standard for traffic control devices on any road open to public travel. The *MUTCD* is used to provide consistent application of traffic control devices. Section 4D.26 of the 2009 edition of the *MUTCD* addresses the yellow change interval. Under Standard' (a shall requirement) it states "The duration of the yellow change interval shall be determined using engineering practices." It provides Guidance (a should recommendation) that,in part states: "A yellow change interval should have a minimum duration of 3 seconds and a maximum duration of 6 seconds." Under Support (informational only statements) the following is stated: "engineering practices for determining the duration of the yellow change and red clearance intervals can be found in ITE's [Institute of Transportation Engineers] *Traffic Control Devices Handbook* and in ITE's *Manual of Traffic Signal Design.*" Both of these ITE publications suggest applying a form of a kinematic equation for determining change intervals.

In February 2010, Brian Ceccarelli disseminated a report "Issac Newton vs. Red Light Cameras" disputing the calculation of the yellow change interval at traffic signals using the kinematic equation. This memorandum summarizes a response Mr. Ceccarelli's report.

Mr. Ceccarelli's general thesis is that the yellow interval duration calculated using the kinematic equation supported by ITE is not long enough for vehicles to stop at the onset of yellow. His thesis is based on a misunderstanding of the yellow change interval—that this interval is equal to the time needed for a vehicle to stop before the intersection before the yellow signal indication terminates. Mr. Ceccarelli also questions the grade variable applied in the kinematic equation and the duration of yellow change intervals in the state of North Carolina and other locations that use the kinematic equation.

To respond to Mr. Ceccarelli's report, the following is offered in support of applying the kinematic equation for determining yellow change intervals:

- The kinematic equation suggested for determining yellow change intervals first appeared in the third edition of the ITE *Traffic Engineering Handbook*, published in 1965. The equation is based on work by Gazis, Herman, and Maradudin. The derivation of the equation considers both the vehicle that stops before the intersection and the vehicle that continues through the intersection, while minimizing the dilemma zone.
- The duration of the yellow change intervals is not the time to traverse the braking stopping distance. The vehicle does not need to be stopped by the end of the yellow change interval. For the stopping vehicle, the important element is that the stopping distance is sufficient.
- The kinematic equation for determining yellow change intervals determines the minimum yellow change interval that considers the needs of both of the stopping vehicle and the vehicles that goes through the intersection.
- The modification for grade is based on the standard formula for stopping distance on a grade.
- In the state of North Carolina, yellow change intervals must be timed according to the traffic signal plan designed by the professional engineer. The designing engineer is not required to use the kinematic equation suggested by ITE and may determine the variables applied in the equation or the full change interval based on engineering judgment.

Millions of vehicles travel on our nation's roadways every day at signalized intersections with yellow intervals based on the kinematic equation. They are able to do this without any unusual maneuvers. The kinematic equation used to determine yellow change intervals is based on a sound application of equations of motion. The traffic engineering profession continues to confirm the assumed parameters used in the equation based on the best available research to ensure that intersections are timed to safely and effectively accommodate the nation's traffic.

Background

The function of a traffic signal is to alternate the right-of-way among the various traffic movements. This function must be accomplished safely while minimizing the delay to vehicles and pedestrians and maximizing the capacity of the intersection. Vital to accomplishing these objectives is the yellow change interval. The steady yellow signal indication warns vehicle traffic that the related green movement is being terminated and that a red indication will be displayed immediately thereafter. This yellow change interval normally has a duration of 3 to 6 seconds.

In many jurisdictions, the yellow change interval is followed by a red clearance interval. During this red clearance interval, the red signal indication is displayed to all traffic. It provides additional time, typically 1 to 3 seconds, before the conflicting traffic is given a green indication (or a 'walk' indication in the case of pedestrian traffic). This red clearance interval is provided as a safety measure to prevent angle crashes by allowing any vehicle that may have entered the intersection during the yellow interval to clear the intersection. The yellow interval and red clearance interval are often referred to collectively as the change period.

The *Manual on Uniform Traffic Control Devices (MUTCD)* is published by the Federal Highway Administration. It is accepted as the national standard for traffic control devices on any road open to public travel. The *MUTCD* is used to provide consistent application of traffic control devices. Section 4D.26 of the 2009 edition of the *MUTCD* addresses the yellow change interval through standards (a shall requirement), guidance (a recommendation but not required), and supporting information. As as a standard it states: "The duration of the yellow change interval shall be determined using engineering practices." It provides guidance that, "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." It also supports that "engineering practices for determining the duration of the yellow change and red clearance intervals can be found in ITE's [Institute of Transportation Engineers] *Traffic Control Devices Handbook* and in ITE's *Manual of Traffic Signal Design* (see Section 1A.11)." Both of these ITE publications suggest applying a form of a kinematic equation for determining change intervals.

Several ITE publications include information on a kinematic equation that can be used to calculate change intervals. Agencies often refer to this equation as the "ITE Equation." The equation is based on the work of Gazis, Herman, and Maradudin. The calculated change interval allows time for the motorist upon seeing the yellow signal indication to decide whether to stop or enter the intersection. It allows time for motorists further away from the signal to decelerate comfortably and motorists closer to the signal to continue through to the far side of the intersection. Generally, the first two terms of this equation are used to calculate the yellow change interval, while the third term is used for calculation of the red clearance interval.

The most current edition of the *ITE Traffic Engineering Handbook, 6th Edition* provides Equation 1 and Equation 2 for calculating the yellow change and red clearance intervals, or change period:

$$Y = t + \frac{V}{2a + 2Gg} \qquad \text{[Equation 1]}$$

$$R = \frac{W + L}{V} \qquad \text{[Equation 2]}$$

Where:

Y = yellow change interval, in seconds;
t = perception-reaction time, nominally 1 second;
a = deceleration rate, (ft/s^2, typical 10 ft/s^2)
V = design speed, (ft/s);
G = acceleration due to gravity, 32.2 ft/s^2;
g = percent grade, positive for upgrade, negative for downgrade;
R = red clearance interval, in seconds;
W = width of intersection, curb to curb, in feet; and
L = length of vehicle, typically 20 feet.

The history of the development of this equation is documented in *A History of the Yellow and All-Red Intervals for Traffic Signals*. This report, prepared for ITE, chronicles the history of the published guidelines and practices for determining the length of time for the display of the yellow change interval and the red clearance interval. As previously mentioned, this kinematic equation is based on the work of Gazis et al. and has been used in some form by the traffic engineering community for nearly 50 years.

Objective

In February 2010, Brian Ceccarelli disseminated a report "Issac Newton vs. Red Light Cameras" disputing the calculation of the yellow interval at traffic signals. Mr. Caccarelli believes that the kinematic equation used for determining yellow change intervals is in error and states that yellow change intervals in the state of North Carolina and other jurisdictions that apply the kinematic equation do not provide adequate change intervals. This memorandum summarizes a response to Mr. Ceccarelli's report. This memorandum first directly responds to Mr. Ceccarelli's general thesis. Second, it summarizes the derivation of the kinematic equation for determining yellow change intervals based on the work of Gazis et al. Third, it responds to specific statements made by Mr. Ceccarelli in his document.

Response to Ceccarelli's General Thesis

Mr. Ceccarelli's general thesis is that the yellow interval duration calculated using the ITE kinematic equation is not long enough for vehicles to stop at the onset of yellow. His thesis is that the yellow interval should be equal to the time needed for a braking vehicle to traverse the stopping distance. Mr. Ceccarelli has misunderstood the need of the stopping vehicle and the duration of the yellow interval. The duration of the yellow interval is not the time to traverse the stopping distance of a braking vehicle. For the stopping vehicle, the important element is not the amount of time that is needed to stop, but that there is sufficient distance in which to stop in advance of the stop bar at a comfortable deceleration. The calculated time of the yellow interval is used to determine that the vehicle has an adequate distance in which to stop. As the vehicle is stopping, the light may turn red. The signal indication at the time the vehicle comes to a complete stop has no bearing on the vehicle. This is explained in more detail in the next section of this memorandum.

Derivation of Kinematic Equation

The kinematic equation for determining change intervals is derived in the following manner, based on the work of Gazis et al.

At the onset of the yellow signal indication, a driver may decide to: a) decelerate and stop before the intersection, or b) continue through the intersection. Assuming that the stopping vehicles decelerate uniformly, the kinematic equations of motion apply to vehicles approaching the intersection. For this derivation, we assume two vehicles approaching an intersection (Figure 1):

- **Vehicle A** decelerates and stops before the intersection. Vehicle A is farther from the intersection and at a distance from the intersection where the vehicle is able to decelerate and stop but cannot continue through the intersection.
- **Vehicle B** continues through the intersection. Vehicle B is closer to the intersection and at a distance from the intersection where the vehicle is unable to decelerate and stop but able to continue through the intersection.

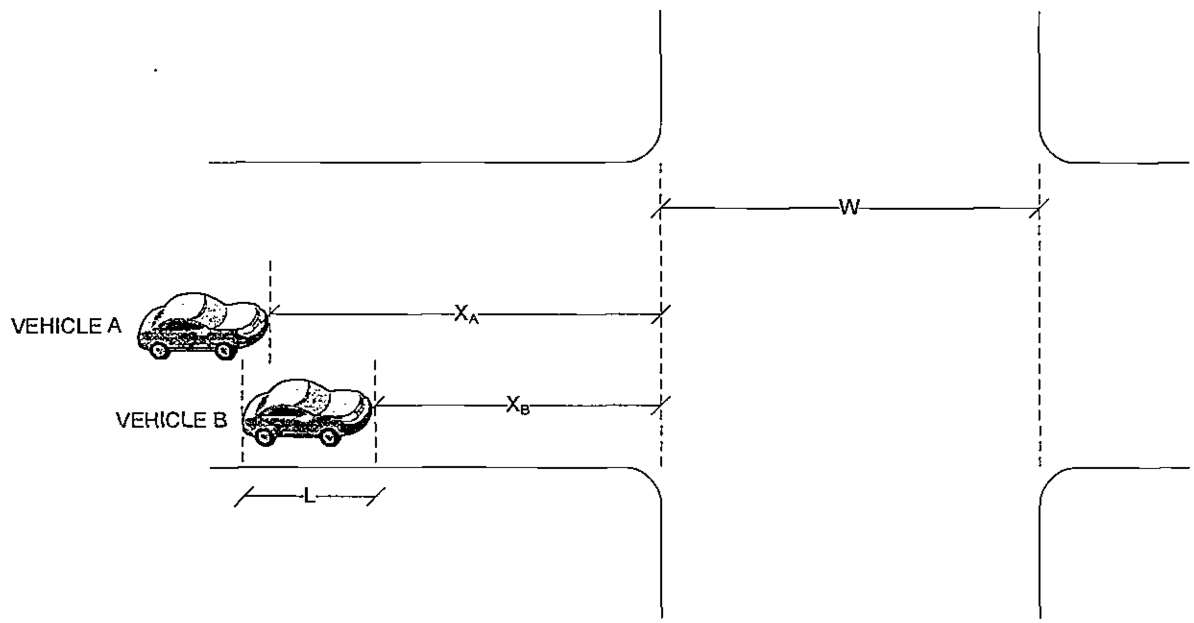


Figure 1

Vehicle A travels an initial speed, v_i, and decelerates at a constant rate of a to final speed, v_f. Applying a kinematic equation (Equation 3), the stopping distance, s, shown in Equation 4.

$$v_f^2 \quad = \quad v_i^2 + 2as \qquad \text{[Equation 3]}$$

Setting $v_f = 0\ mph$ and solving for s

$$0 \quad = \quad v_i^2 + 2as$$

$$s \quad = \quad \frac{V_i^2}{2a} \qquad \text{[Equation 4]}$$

Taking into account that the driver of Vehicle A has a perception-reaction time, δ, the minimum distance a vehicle must be from the intersection if they are to stop before the intersection is shown in Equation 5, where the first term is the stopping distance and the second term is the distance traveled while the driver perceives and reacts to the yellow signal indication.

$$X_A \quad \geq \quad \frac{V_i^2}{2a} + V_i\delta \qquad \text{[Equation 5]}$$

Since X_A is a minimum distance, all vehicles that are at a distance greater than X_A should be able to stop before the intersection, and all vehicles less than X_A should continue through the intersection, assuming they have the same deceleration rate and approach speed. Vehicles that continue through the intersection are represented by Vehicle B in Figure 1 and are at a distance, X_B, from the intersection. The "stop" and "go through" areas are shown in Figure 2. The minimum time, t_{min}, needed to travel at uniform velocity, V_i, the distance, X_B, to and through

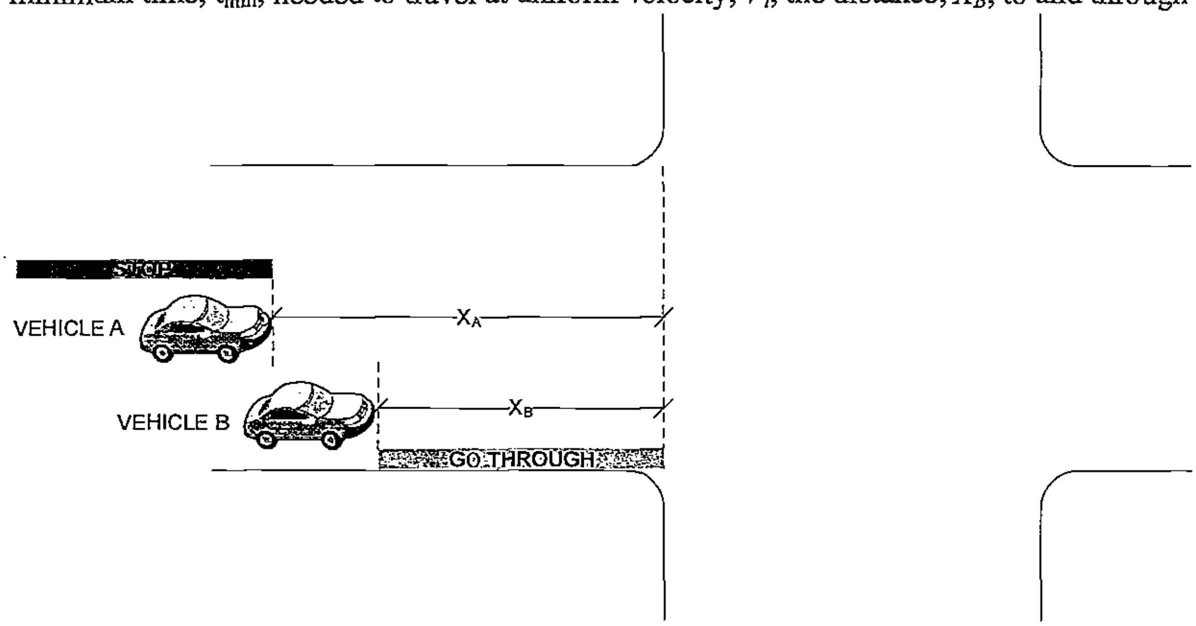


Figure 2

the intersection of width, W, for a vehicle with length, L, can be calculated as follows based on a kinematic equation (Equation 6):

$$t = \frac{d}{v} \qquad \text{[Equation 6]}$$

Where:

t = time
d = distance
v = speed

$$t_{min} = \frac{X_B + W + L}{V_i} \qquad \text{[Equation 7]}$$

The driver also has a perception-reaction time, but during that time, they are still traveling at speed, V_i, towards their goal of the far side of the intersection. Therefore, Equation 7 has only one term.

For all points closer than the distance X_A from the intersection, vehicles will continue through the intersection. The resulting minimum yellow interval needed so that no vehicles find themselves in the situation where they are too close to the intersection to stop safely (distances less than X_A from the intersection), but without enough time to get through the intersection safely is $\tau_{\min}$. In order to find that time, $\tau_{\min}$, we set X_B equal to X_A. If X_B is greater than X_A, a dilemma zone is created. Setting $X_A = X_B$, the resulting $\tau_{\min}$ is shown in Equation 8.

$$X_A = X_B$$

$$\frac{V_i^2}{2a} + V_i\delta = \tau_{\min}V_i - (W + L)$$

$$\tau_{\min} = \frac{V_i}{2a} + \delta + \frac{W + L}{V_i} \qquad \text{[Equation 8]}$$

Gazis et al. describes this time as the minimum yellow interval needed. Yellow change intervals less than this value will either necessitate that vehicles decelerate to a stop unsafely and uncomfortably or that vehicles are still in the intersection after the yellow interval ends.

The Gazis derivation did not consider the roadway grade along the approach to the intersection. If the grade is positive (uphill), the stopping distance will be shorter and if it is negative then a longer stopping distance will be needed. The ITE *Manual of Traffic Signal Design* introduces an additional parameter to accommodate the effects of approach grade. Based on the standard formula for stopping distance on a grade, a modified coefficient of friction is added to the first term in Equation 8. The yellow change interval becomes:

$$\tau_{\min} = \frac{V_i}{2a + 64.4g} + \delta + \frac{W + L}{V_i} \qquad \text{[Equation 9]}$$

Where:

g = percent of grade divided by 100 (positive for upgrade, negative for downgrade)

The *Manual of Traffic Signal Design* notes that for very steep downgrades, the equation results in excessively long yellow change intervals, which may be remedied by reducing the speed limit, and thus the approach speed, using warning signs, or other similar measures.

Response to Specific Statements

Mr. Ceccarelli's statements and corresponding responses are as follows:

Statement: *"I searched the internet for a derivation [of the equation], but I found none... Not even the engineering books bother to show a derivation. Every book and website take the equation for granted and assume it is correct."*

Response: The widely-accepted kinematic equation suggested for determining yellow change intervals first appeared in the third edition of the Institute of Transportation Engineers (ITE) *Traffic Engineering Handbook*, published in 1965. Prior to 1965, the ITE suggested determining the change interval based on the stopping distance and intersection width.

The equation and procedure presented by ITE in the third edition of the *Traffic Engineering Handbook* is based on formative work by Gazis et al. Their paper is one of the first published studies on change intervals and presents a theoretical analysis and observational study of driver behavior in reaction to the yellow signal indication. The derivation presented in the paper is the foundation for the kinematic equation method suggested by ITE for the past 45 years. A simplified summary of this derivation has also been presented in this memorandum. For a thorough history of the determination of change intervals in the United States, refer to ITE's report, "A History of the Yellow and All-Red Intervals for Traffic Signals."

Statement: *"While the distance equation is right, the way the NCDOT and ITE computed how much time it takes for the driver to travel the distance is wrong."*

Response: Mr. Ceccarelli mistakenly assumes that the yellow change interval should be equal to the time needed for a braking vehicle to traverse the stopping distance. For the stopping vehicle, the important element is not the time needed to stop, but the stopping distance. For the vehicle that continues through the intersection, the important element is that there is sufficient time to clear the intersection (or in the case of permissive laws, for the vehicle to enter the intersection and then clear the intersection during red). The kinematic equation for determining yellow change intervals determines the minimum time that considers both vehicles. The calculated change interval allows a driver to either stop or go through the intersection without accelerating. This minimum time is calculated by setting the critical distance for stopping equal to the maximum distance for clearing the intersection. In the theoretical case, this equation eliminates the dilemma zone (i.e., do you go or do you stop).

The yellow change interval, by definition, warns traffic of an impending change in the right-of-way. It allows drivers to decide to either stop or go through the intersection. The duration of the yellow change intervals is not the time to traverse the braking stopping distance. For Vehicle A in Figure 1, the important element is not the amount of time that is needed to stop, but that there is sufficient distance in which to stop. The vehicle does not need to be stopped by the end of the yellow change interval as long as they are able to comfortably stop before entering the intersection.

Statement: *"The creators of the official equation erroneously divided both sides of the braking distance equation by the speed limit (v_0)."*

Response: As shown in the derivation in Gazis et al. and in this memorandum, the kinematic equation considers the minimum distance from the intersection for the vehicle that stops (Vehicle A) and the maximum distance for the vehicle that goes through the intersection (Vehicle B). The equation does not determine the time required to traverse the braking stopping distance. Additionally, the speed variable typically represents the approach speed rather than the posted speed limit. The *Traffic Control Devices Handbook* refers to this speed as the 85^{th} percentile approach speed, while the *Manual of Traffic Signal Design* suggests applying the approach speed.

Statement: *"Apparently ITE's focus was on cars going through the intersection, not cars stopping at the intersection."*

Response: The derivation by Gazis et al. and in this memorandum show that the kinematic equation considers the vehicle that stops (Vehicle A) and the vehicle that goes through the intersection (Vehicle B).

Statement: *"The small angle approximation is satisfactory for grades between -10 and 10. But for grades outside those bounds, the small angle approximation gives less time than it needs to for inclines, and more than it needs to for declines."*

Response: The modification for grade is based on the standard formula for stopping distance on a grade. Grades are generally not larger than 3% on an approach and rarely is an approach grade 10%. This modification accommodates the effect of upgrades and downgrades on the rate of deceleration. The *Manual of Traffic Signal Design* notes that for very steep downgrades, the equation results in excessively long yellow change intervals, which may be remedied by reducing the speed limit, and thus the approach speed, using warning signs, or other similar measures.

Statement: *"...I had discovered that my intersection's yellow light interval did not meet the minimum required by the NCDOT's equation."*

Response: In the state of North Carolina, yellow change intervals must be timed according to the traffic signal plan designed by the professional engineer. The designing engineer is not required to use the kinematic equation suggested by ITE and may determine the variables applied in the equation or the full change interval based on engineering judgment. Session Law 2004-141, Section G.S. 160A-300.2(e) states:

> "The duration of the yellow light change interval at intersections where traffic control photographic systems are in use shall be no less than the yellow light change interval duration on the traffic signal plan of record signed and sealed by a licensed North Carolina Professional Engineer in accordance with Chapter 89C of the General Statutes, and shall be in full conformance with the requirements of the Manual on Uniform Traffic Control Devices."

The yellow change interval must also conform to the requirements in the Manual on Uniform Traffic Control Devices (MUTCD). Section 4D.26 of the 2009 edition of the MUTCD states the following standard, which is "a statement of required, mandatory, or specifically prohibitive practice regarding a traffic control device":

> "The duration of the yellow change interval shall be determined using engineering practices."

The MUTCD also provides the following guidance, which is "a statement of recommended, but not mandatory, practice in typical situations, with deviations allowed if engineering judgment of engineering study indicates the deviation is appropriate":

> "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."

The following is provided as additional support, "an informational statement that does not convey any degree of mandate, recommendation, authorization, prohibition, or enforceable condition":

> "Engineering practices for determining the 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)."

Summary

In summary, millions of vehicles travel on our nation's roadways every day at signalized intersections with yellow intervals based on the kinematic equation. They are able to do this without any unusual maneuvers. The kinematic equation used to determine yellow change intervals is based on a sound application of equations of motion. The kinematic equation is a flexible and defensible method for calculating change intervals with the aim of allowing vehicles to safely and comfortably stop before the intersection or go through the intersection. However, the profession continues to confirm the assumed parameters used in the equation based on the best available research to ensure that intersections are timed to safely and effectively accommodate the nation's traffic. ITE is currently working on a proposed recommended practice for determining change intervals, and a separate, on-going change interval study through the National Highway Cooperative Research Program (NCHRP) will present new field studies on change intervals.

Glossary of Terms

15th Percentile Speed – The speed at which 15 percent of the vehicles in a sample are traveling at or below.

85th Percentile Speed – The speed at which 85 percent of the vehicles in a sample are traveling at or below.

95th Percentile Speed – The speed at which 95 percent of the vehicles in a sample are traveling at or below.

All-Red Interval or All-Red Clearance Interval – An optional interval following the yellow interval and preceding the next conflicting green interval during which all traffic at an intersection view a red signal indication and are not permitted in the intersection.

Amber Light – A term describing the yellow signal indication.

Amber Light Phase – The duration of the yellow signal indication.

Approach Grade – The slope of the roadway at the entrance, or approach, to an intersection.

Approach Speed – The velocity of a vehicle approaching an intersection.

Change Interval – Refers to the period of time between conflicting green signal indications, may consist of a yellow interval only or a yellow and all-red interval.

Change Period – Refers to the period of time between conflicting green signal indications, may consist of a yellow interval only or a yellow and all-red interval.

Conflicting Traffic Movements – Traffic movements that if allowed into the intersection at the same time would intersect paths.

Cycle – One complete sequence of all traffic signal indications.

Dilemma Zone – An area in advance of the signal where, if a yellow interval duration is not long enough, vehicles in this area at the onset of yellow can neither stop safely and comfortably before the intersection nor continue through the intersection without accelerating before the onset of the red signal indication.

Green Interval – A period of time indicating that vehicles have the right-of-way.

Green Signal Indication – The illumination of the green traffic signal lens during which traffic movements facing the lens are permitted.

Interval – the part of a signal cycle during which signal indications do not change.

Kinematic Equation – An equation based on the aspects of motion apart from considerations of mass and force.

Non-Dilemma Change and Clearance Interval – Duration of the yellow and possibly all-red interval(s) that does not create a dilemma zone for approaching motorists. That is, all vehicles, depending on their distance from the intersection at the onset of the yellow interval can either stop safety and comfortably before the intersection or continue through the intersection without accelerating before conflicting traffic is released.

Perception-Reaction Time – The time needed for a motorist to see the signal indication (perception) and then begin executing the appropriate response (reaction).

Permissive Yellow Law – Describes local laws that allow vehicles to enter the intersection throughout the entire yellow interval, and be in the intersection during the red indication as long as they entered the intersection during the yellow interval.

Phase – The entire sequence of green, yellow and red intervals in a cycle assigned to an independent traffic movement or combination of movements.

Phase-Change Interval – Refers to the period of time between conflicting green signal indications. May consist of a yellow interval only or a yellow and an all-red interval.

Red Clearance Interval -- An optional interval following the yellow interval and preceding the next conflicting green interval during which all traffic at an intersection view a red signal indication and are not permitted in the intersection; allows time for vehicles who entered the intersection during the yellow interval to exit, or clear, the intersection.

Red Signal Indication – The illumination of the red traffic signal lens during which traffic movements facing the lens are not permitted to enter the intersection.

Restrictive Yellow Law – Describes local laws that do not allow vehicles to be in the intersection during the red indication, even if the entered the intersection during the yellow interval.

Right-of-Way – The precedence of passage of a traffic movement into an intersection over other traffic movements at an intersection.

Signal Timing – The distribution of a length of time (cycle) between traffic movements including the allocation of green, yellow and red indications for each movement.

Signal Indication – The illumination of a traffic signal lens.

Signal Lens—that part of the signal section that redirects the light coming directly from the light source and its reflector, if any.

Speed Limit – The maximum (or minimum) travel speed on a street established by law, ordinance, or regulation.

Stop Line or Stop Bar – A pavement marking that denotes where traffic should stop in advance of an intersection.

Stopping Distance – The distance a vehicle travels while decelerating to a complete stop.

Traffic Movements – Describes both vehicles and pedestrians at an intersection grouped together by the direction they are traveling through the intersection.

Traffic Signal – A power-operated traffic control device by which traffic is warned or directed to take a specific action. Traffic is warned or directed by a series of green, yellow and red lens that illuminate.

Velocity – The speed and direction that a vehicle is traveling.

Warning Clearance Interval – A superseded term that refers to the yellow interval.

Warning Interval – A term that refers to the yellow interval.

Yellow Interval or Yellow Change Interval – The first interval following the green interval **during which the steady yellow signal indication is displayed.**

Yellow Clearance Interval – An outdated term to describe the yellow interval.

Yellow Signal Indication – The illumination of the yellow signal lens.

Yellow Warning Indication – A term that the yellow signal indication results.

References

Manual on Uniform Traffic Control Devices, 2009 Edition. Federal Highway Administration, Washington, D.C., 2009.

Gazis, D., R. Herman, and A. Maradudin. "The Problem of the Amber Signal Light in Traffic Flow." Operations Research, Vol. 8, No. 1, Jan-Feb 1960, pp. 112-132.

Kraft, W.H. *Traffic Engineering Handbook*, 6th Edition, Institute of Traffic Engineers, Washington, D.C., 2009.

Eccles, K.A., and H.W. McGee. "A History of the Yellow and All-Red Intervals for Traffic Signals." Institute of Transportation Engineers, Washington, D.C., 2001.

Kell, J.H., and I.J. Fullerton. *Manual of Traffic Signal Design. Institute of Transportation Engineers*, Washington, D.C., 1982.

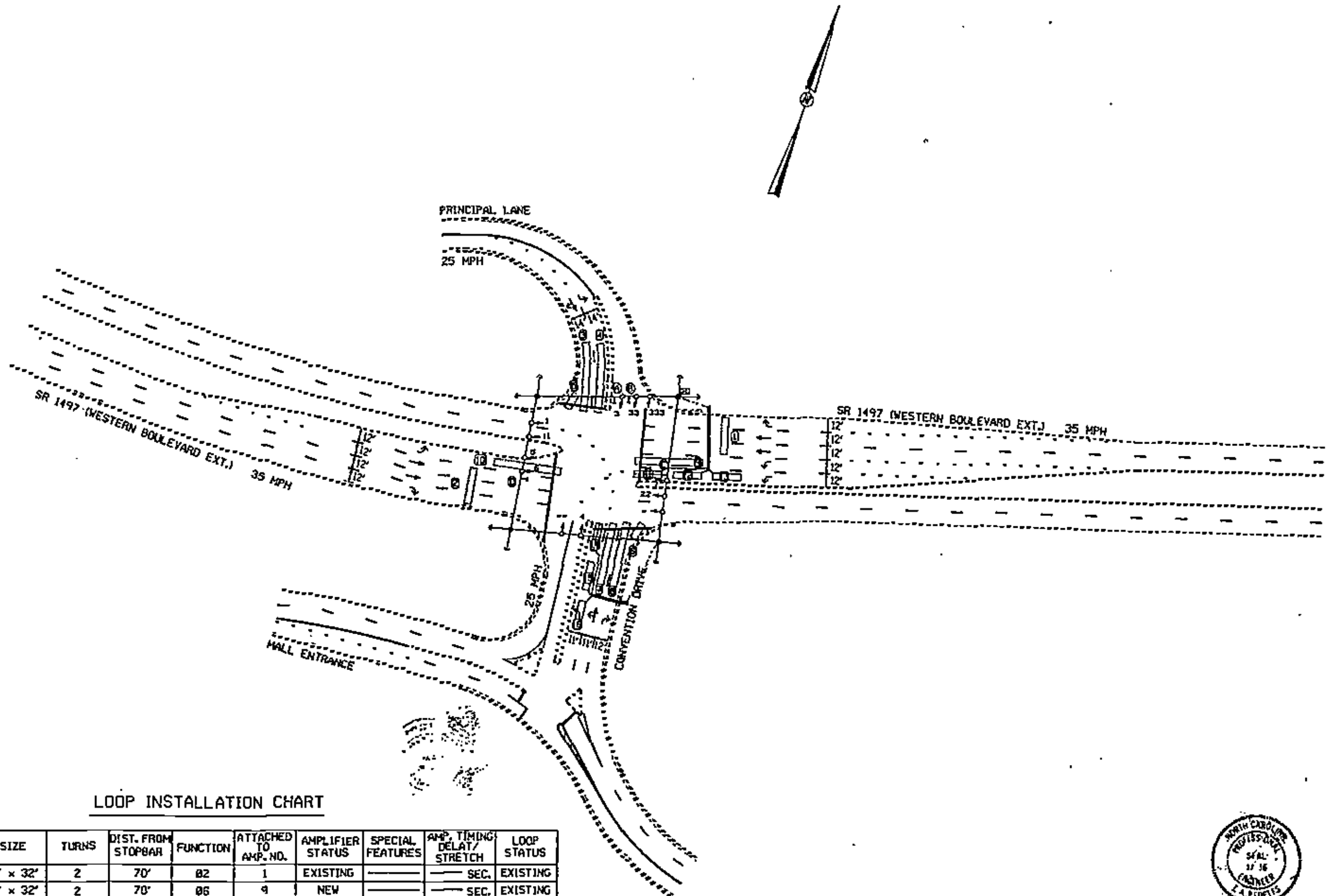
Baerwald, J.E. *Traffic Engineering Handbook*, 3rd Edition, Institute of Transportation Engineers, Washington, D.C., 1965.

MONTH/YEAR	STYLE	COURT
September 2001	Harland Vs. Parex, et al.	**GENERAL COURT OF JUSTICE** Circuit Court, Shelby County, Alabama No.: CV-99-325
June 2004	Timothy J. Montgomery and Kristi J. Montgomery Vs. Parex	**GENERAL COURT OF JUSTICE** Circuit Court, Colbert County, Alabama No.: CV-2001-53
April 2006	Park Vs. Young Homes	**GENERAL COURT OF JUSTICE** Superior Court, Wake County, NC No.: 05 CVS 1505
April 2006	State of NC Vs. Danny Bailey	**GENERAL COURT OF JUSTICE** Superior Court, Burke County, NC No.: 03-CRS-8968
September 2007	June Pittman Vs. Crawley Timber Suppliers, LLC	**GENERAL COURT OF JUSTICE** Superior Court, Edgecombe County, NC No.: 06-CVS-261
September 2007	State Vs. Eric Plummer	**GENERAL COURT OF JUSTICE** Superior Court, Wake County, NC No.: 07-CRS-24418
December 2008	Barbara Stacy, Administratrix Of the Estate of Joshua Quentin Mitchell Stacy Vs. Alamance-Burlington Board Of Education	**N.C. INDUSTRIAL COMMISSION** I.C. No. TA-19616

DEFENDANT'S
EXHIBIT
NO. 20
10-30-12 mmv

June 2009	Thomas Drake Matteson Vs. Ronald Hunter Grove and John Doe	**GENERAL COURT OF JUSTICE** Superior Court, Wake County, NC No.: 07-CVS-1541
Mar 2010	Zenith Insurance Company Dean Dupont vs NC DOT	**N.C.INDUSTRIAL COMMISSION** I.C. File No. TA-19688 A.G. File No. 06-0372
Aug 2010	Brown, Bartlett & Jones vs Wayne County Board of Education	**N.C. INDUSTRIAL COMMISSION** I.C. File No. TA-21022 A.G. File No. 05-1896
May 2011	Harry James O'Connor vs Sue E. Mako and Mako and Associates, PA	**GENERAL COURT OF JUSTICE** Superior Court New Hanover County, N.C. No.: 09-CVS-1076
November 2011	State of North Carolina v. Jerry Black	**GENERAL COURT OF JUSTICE** Superior Court Division Davidson County
April 2012	State of North Carolina v. Vincent Colucci	**WAKE COUNTY DISTRICT COURT**

STATE	PROJECT NO.	SHEET NO.	TOTAL SHEETS
N.C.	4.6332069	1	4
F. A. PROJ. NO.	N/A		
PROJECT ID. NO.	N/A		



NOTES

1. SIGNAL UPGRADE.
2. REUSE EXISTING EQUIPMENT AS SHOWN.
3. WHEN IN FLASH MODE, ALL SIGNAL FACES FOR SAME APPROACH SHALL FLASH CONCURRENTLY.
4. CONTROLLER SHOULD BE PROGRAMMED TO START UP IN PHASE 2+6 GREEN.
5. SIGNAL TO FLASH FROM 11:00 PM UNTIL 6:00 AM UNLESS OTHERWISE DIRECTED BY AREA TRAFFIC ENGINEER.
6. PAVEMENT MARKING PLANS TO BE PREPARED BY OTHERS.
7. STOPBAR LOCATIONS ON ALL APPROACHES ARE EXISTING.
8. NO COUNTS AVAILABLE.

LEGEND

PROPOSED | EXISTING

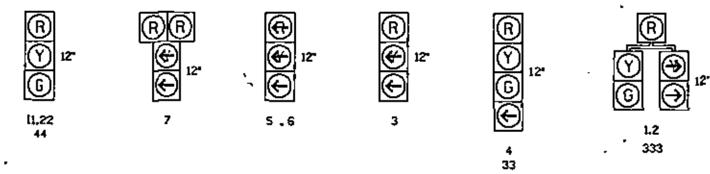
- TRAFFIC SIGNAL FACE
- N/A MODIFIED TRAFFIC SIGNAL FACE
- PEDESTRIAN SIGNAL FACE WITH PUSH BUTTON & SIGN
- SIGNAL POLE WITH GUY
- SIGNAL POLE WITH SIDEWALK GUY
- INDUCTIVE LOOP DETECTOR
- CONTROLLER & CABINET
- LOOP DETECTOR PULL BOX
- 2" UNDERGROUND PVC
- INTERCONNECT CABLE (HARDWIRE)
- RIGHT OF WAY WITH MARKER
- DIRECTIONAL ARROW
- PAVEMENT MARKING ARROW

Ⓐ LEFT ARROW "ONLY" SIGN (30"X36") R3-5L
Ⓑ COMBINATION VERTICAL AND LEFT ARROW SIGN (30"X36") R3-6L
Ⓒ "LEFT TURN SIGNAL" SIGN (30"X36") R10-10L
Ⓓ U "TURN MUST YIELD" SYMBOL SIGN (24"X30") R3-27

LOOP INSTALLATION CHART

LOOP NO.	SIZE	TURNS	DIST. FROM STOPBAR	FUNCTION	ATTACHED TO AMP. NO.	AMPLIFIER STATUS	SPECIAL FEATURES	AMP. TIMING DELAY/ STRETCH	LOOP STATUS
1	6' x 32'	2	70'	Ø2	1	EXISTING	——	—— SEC.	EXISTING
2	6' x 32'	2	70'	Ø6	9	NEW	——	—— SEC.	EXISTING
3 , 4	6' x 60'	1	5' BEYOND	Ø4	2	EXISTING	——	—— SEC.	EXISTING
5	6' x 15'	2	5' BEYOND	Ø4	3	EXISTING	CALL DELAY	15 SEC.	EXISTING
6	6' x 15'	2	5' BEYOND	Ø3	4	NEW	CALL DELAY	15 SEC.	EXISTING
7	6' x 60'	1	5' BEYOND	Ø3	5	EXISTING	——	—— SEC.	EXISTING
8	6' x 60'	1	5' BEYOND	Ø3	6	NEW	CALL DELAY	15 SEC.	EXISTING
9	6' x 60'	1	5' BEYOND	Ø1	7	EXISTING	——	—— SEC.	EXISTING
10	6' x 60'	1	5' BEYOND	Ø5	8	EXISTING	——	—— SEC.	EXISTING
11	6' x 25'	2-4-2	5' BEYOND	Ø1	10	NEW/DIGITAL	QUADRUPOLE	—— SEC.	NEW
12	6' x 25'	2	30'	Ø1	10	NEW/DIGITAL	——	—— SEC.	NEW
13	6' x 25'	2	65'	Ø1	10	NEW/DIGITAL	——	—— SEC.	NEW
14	6' x 25'	2-4-2	5' BEYOND	Ø3	11	NEW/DIGITAL	QUADRUPOLE	—— SEC.	NEW
15	6' x 25'	2	30'	Ø3	11	NEW/DIGITAL	——	—— SEC.	NEW
16	6' x 25'	2	65'	Ø3	11	NEW/DIGITAL	——	—— SEC.	NEW

SIGNAL FACE I.D.



TA Peoples 5-31-91

SIGNAL UPGRADE

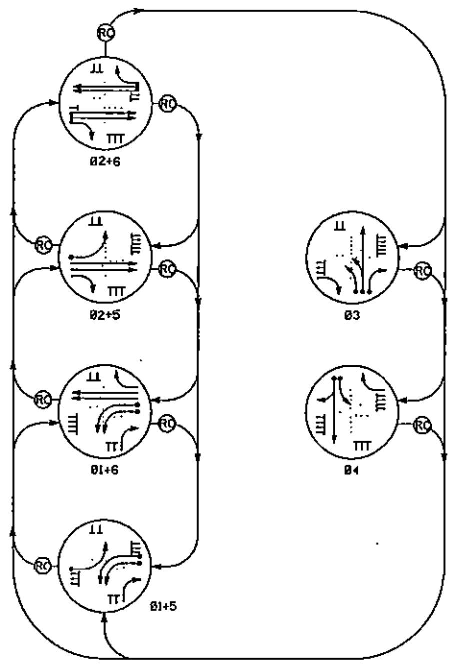
CORR. FILE NO. 05-90-71

SR 1497 (WESTERN BOULEVARD EXT.) AND CONVENTION DRIVE - PRINCIPAL LANE		
DIV. 05	WAKE COUNTY	CART
SCALE 1"=50'	N. C. DEPARTMENT OF TRANSPORTATION	REVISIONS
DATE 05-20-91	DIVISION OF HIGHWAYS	
DWG. BY TCP	TRAFFIC ENGINEERING BRANCH	CADD NO.
DESIGN BY TCP		S/S INV. NO. 05-0873
APPROVED [signature]		

PENGAD 800-631-6989
DEFENDANT'S EXHIBIT
24
10-30-12 MMV

N.C.	4.6332069	2	4
T.A. PROJ. NO.	N/A		
PROJECT I.D. NO.	N/A		

PHASING DIAGRAM



60
FULLY ACTUATED
(ISOLATED)

COLOR SEQUENCE CHART

SIGNAL FACE	Ø2+6 R/W	Ø2+6 CLEAR Ø3 1	Ø3 2	Ø4 1	Ø4 2	Ø1+5 1	Ø1+5 2	Ø1+6 1	Ø1+6 2	Ø2+5 1	Ø2+5 2
11	G	Y	R	Y	R	Y	R	G	G	Y	R
22	G	Y	R	Y	R	Y	R	Y	R	G	G
3	R	—	—	—	—	—	—	—	—	—	R
33	R	—	—	—	—	—	—	—	—	—	R
333	R	—	—	—	—	—	—	—	—	—	R
4	R	—	—	—	—	—	—	—	—	—	R
44	R	—	—	—	—	—	—	—	—	—	R
5 ,6	←R	—	—	—	—	—	—	—	—	—	←R
7	R	—	—	—	—	—	—	—	—	—	R
1	G/→	Y/→	R	Y/→	R/→	Y/→	R	G/→	G/→	Y/→	R
2	G/→	Y/→	R/→	Y/→	R	Y/→	R	Y/→	R	G/→	G/→

SIGNAL FACE	Ø3 R/W	Ø3 CLEAR Ø2+6 1	Ø2+6 2	Ø4 1	Ø4 2	Ø1+5 1	Ø1+5 2	Ø1+6 1	Ø1+6 2	Ø2+5 1	Ø2+5 2
11	R	—	—	—	—	—	—	—	—	—	R
22	R	—	—	—	—	—	—	—	—	—	R
3	←	←Y	R	←Y	R	←Y	R	←Y	R	←Y	R
33	G←	Y	R	Y	R	Y	R	Y	R	Y	R
333	G/→	Y/→	R	Y/→	R	Y/→	R/→	Y/→	R/→	Y/→	R
4	R	—	—	—	—	—	—	—	—	—	R
44	R	—	—	—	—	—	—	—	—	—	R
5 ,6	←R	—	—	—	—	—	—	—	—	—	←R
7	R	—	—	—	—	—	—	—	—	—	R
1	R	—	—	—	—	—	—	—	—	—	R
2	R/→	R/→	R/→	R/→	R	R/→	R	R/→	R	R/→	R/→

SIGNAL FACE	Ø4 R/W	Ø4 CLEAR Ø2+6 1	Ø2+6 2	Ø1+5 1	Ø1+5 2	Ø1+6 1	Ø1+6 2	Ø2+5 1	Ø2+5 2
11	R	—	—	—	—	—	—	—	R
22	R	—	—	—	—	—	—	—	R
3	R	—	—	—	—	—	—	—	R
33	R	—	—	—	—	—	—	—	R
333	R	—	—	—	—	—	—	—	R
4	G←	Y	R	Y	R	Y	R	Y	R
44	G	Y	R	Y	R	Y	R	Y	R
5 ,6	←R	—	—	—	—	—	—	—	←R
7	R	—	—	—	—	—	—	—	R
1	R/→	R/→	R/→	R/→	R	R/→	R/→	R/→	R
2	R	—	—	—	—	—	—	—	R

SIGNAL FACE	Ø1+5 R/W	Ø1+5 CLEAR Ø2+6 1	Ø2+6 2	Ø1+6 1	Ø1+6 2	Ø2+5 1	Ø2+5 2
11	R	—	—	—	—	—	R
22	R	—	—	—	—	—	R
3	R	—	—	—	—	—	R
33	R	—	—	—	—	—	R
333	R/→	R/→	R	R/→	R/→	R/→	R
4	R	—	—	—	—	—	R
44	R	—	—	—	—	—	R
5 ,6	←	←Y	←R	←	←	←Y	←R
7	←	←Y	R	←Y	R	←	←
1	R	—	—	—	—	—	R
2	R	—	—	—	—	—	R

SIGNAL FACE	Ø1+6 R/W	Ø1+6 CLR Ø2+6 1	Ø2+6 2	Ø1+5 1	Ø1+5 2	Ø2+5 1	Ø2+5 2
11	G	G	G	Y	R	Y	R
22	R	—	—	—	—	—	R
3	R	—	—	—	—	—	R
33	R	—	—	—	—	—	R
333	R/→	R/→	R	R/→	R/→	R/→	R
4	R	—	—	—	—	—	R
44	R	—	—	—	—	—	R
5 ,6	←	←Y	←R	←	←	←Y	←R
7	R	—	—	—	—	—	R
1	G/→	G/→	G/→	Y/→	R	Y/→	R
2	R	—	—	—	—	—	R

SIGNAL FACE	Ø2+5 R/W	Ø2+5 CLR Ø2+6 1	Ø2+6 2	Ø1+5 1	Ø1+5 2	Ø1+6 1	Ø1+6 2	FLASH	SIGNAL FACE
11	R	—	—	—	—	—	R	Y	11
22	G	G	G	Y	R	Y	R	Y	22
3	R	—	—	—	—	—	R	R	3
33	R	—	—	—	—	—	R	R	33
333	R	—	—	—	—	—	R	R	333
4	R	—	—	—	—	—	R	R	4
44	R	—	—	—	—	—	R	R	44
5 ,6	←R						←R	←R	5 .6*
7	←	←Y	R	←	←	←Y	R	R	7*
1	R	—	—	—	—	—	R	Y	1
2	G/→	G/→	G/→	Y/→	R	Y/→	R	Y	2

* REFER TO NOTE 3

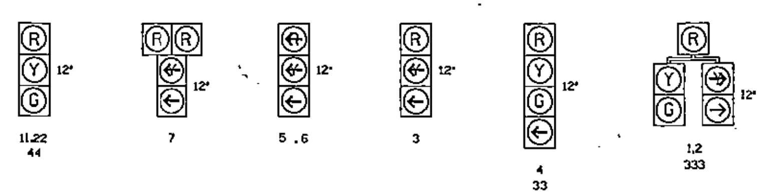
TIMING CHART

PHASE	Ø2	Ø6	Ø3	Ø4	Ø5	Ø1
MINIMUM GREEN	10 SEC.	10 SEC.	7 SEC.	7 SEC.	7 SEC.	7 SEC.
PASSAGE/GAP	3 SEC.	3 SEC.	1 SEC.	1 SEC.	1 SEC.	1 SEC.
YELLOW CLEARANCE	4.0 SEC.	4.0 SEC.	5.0 SEC.	4.5 SEC.	4.0 SEC.	4.5 SEC.
RED CLEARANCE	1.7 SEC.	1.3 SEC.	1.6 SEC.	1.6 SEC.	1.7 SEC.	1.6 SEC.
MAX. 1	40 SEC.	40 SEC.	30 SEC.	20 SEC.	20 SEC.	20 SEC.
MAX. 2	— SEC.	— SEC.	— SEC.	— SEC.	— SEC.	— SEC.
RECALL POSITION	MIN. RECALL	MIN. RECALL	NONE	NONE	NONE	NONE
VEHICLE CALL MEMORY	LOCK	LOCK	NONLOCK	NONLOCK	NONLOCK	NONLOCK

NORTH CAROLINA PROFESSIONAL SEAL ENGINEER T.A. PEOPLES

T.A. Peoples 5-31-91

SIGNAL FACE I.D.



SIGNAL UPGRADE

CORR. FILE NO. 05-90-71

SR 1497 (WESTERN BOULEVARD EXT.)
AND
CONVENTION DRIVE - PRINCIPAL LANE

DIV. 05 | WAKE COUNTY | CARY

SCALE	N/A	N. C. DEPARTMENT OF TRANSPORTATION	REVISIONS
DATE	05-20-91		
DWG. BY	TGP	DIVISION OF HIGHWAYS	
DESIGN BY	TGP	TRAFFIC ENGINEERING BRANCH	CADD NO.

CLEARANCE TIME SHEET

Signal Inventory No.: 05-0873

Division: 5

County: Wake

Location: SR 1497 (Westren Blvd.) & Convention Drive at Cary Village Mall Entrance

Computed by: T. Parker Date: May 20, 1991

Checked by: CTA Date: 5/30/91

Approved by: EMS Date: 5/31/91

PHASE:	φ2 →	φ5 ↱	φ6 ←	φ1 ↶	φ5 ↑	φ3 ↰	φ4 ↓	φ4 ↳
SPEED:	35	20	35	20	25	20	25	20
% GRADE:	0	0	0	0	0	0	0	0
DISTANCE:	85 ✓	85	65 ✓	~~81~~ 55 ✓	100 ✓	80 ✓	100 ✓	80 ✓
TOTAL CLEARANCE	5.7 ✓	~~5.4~~ 7	5.3 ✓	~~5.4~~ 7.1	6.1 ✓	5.9 6.6	6.1 ✓	5.9 ✓
MINIMUM YELLOW	3.6 (4.0)	3.0	3.6 ✓ (4.0)	3.0 4.5	3.0 4.5	3.0 5.0	3.0 4.5	3.0
MINIMUM RED	2.1 (1.5)	[illegible] 1.4	1.7 ✓ 1.3	[illegible] 1.6 1.4	[illegible] 1.6	[illegible] 1.6 1.4	[illegible] 1.6	[illegible]
ENGINEERS REC. YEL:	4.0	[illegible]	[illegible]	4.5	4.5	5.0	4.5	4.5
ENGINEERS REC. RED:	1.7	1.7	[illegible]	1.6	1.6	1.6	1.6	1.4

1.5 1.6 1.1 1.5 1.4

DEFENDANT'S EXHIBIT 22

10-30-12 mmv

DEFENDANT'S EXHIBIT 23

10-3692 MMV

PENGAD 800-631-6989

Clearance Time Calculat

Rev 2005-08-10

City:	Cary	Division:	5
County:	Wake	Sig. Inv. #	05-0213 Final
NB Street:	SR 1300 (Kildare Farm Road)	Project/TIP #:	
SB Street:	SR 1300 (Kildare Farm Road)	Computed by:	LAE
EB Street:	SR 1415 (W. Maynard Rd.)	Checked by:	FDV
WB Street:	SR 1415 (W. Maynard Rd.)	Approved by:	

Movement	Street Name	SR 1300 (Kildare Farm Road)		SR 1300 (Kildare Farm Road)		SR 1415 (W. Maynard Rd.)		SR 1415 (W. Maynard Rd.)	
	Orientation	Northbound		Southbound		Eastbound		Westbound	
	Turn movement	Left	Thru	Left	Thru	Left	Thru	Left	Thru
NEMA Phase #	Protected	5	2	1	6	3	8	7	4
	Permissive	2		6		8		4	
Speed	mph	20	35	20	35	20	35	20	35
	ft/sec	29.33	51.33	29.33	51.33	29.33	51.33	29.33	51.33
Grade	%	2%		-2%		-1%		0%	
	Elevation at Stopbar, ft								
	Elevation at Setback, ft								
	Dist to Setback, ft								
	-OR- Enter Grade, %	2.0%		-2.0%		-1.0%		0.0%	
Clear Distance	feet	115	110	100	115	75	110	105	110
	meters								
Ped Cross Dist	feet		85		85		80		80
	meters								
Parameters	Percept-React Time, sec	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
	Decel Rate, ft/sec^2	11.2	11.2	11.2	11.2	11.2	11.2	11.2	11.2
	Walk Speed, fps	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
Movement Calcs	Yellow, sec	2.8	3.7	2.9	4.0	2.9	3.9	2.9	3.8
	All Red, sec	4.0	2.2	3.5	2.3	2.6	2.2	3.6	2.2
	Mitigated Red, sec	3.5	-	3.3	-	-	-	3.3	-
	Unadjusted FDW, sec		21.3		21.3		20.0		20.0
Movement Results	Yellow, sec	3.0	3.7	3.0	4.0	3.0	3.9	3.0	3.8
	All Red, sec	3.5	2.2	3.3	2.3	2.6	2.2	3.3	2.2
	Total Clear, sec	6.5	5.9	6.3	6.3	5.6	6.1	6.3	6.0
Shared Mvmt Calc	Yellow, sec	3.7		4.0		3.9		3.8	
	All Red, sec	2.8		2.3		2.2		2.5	
	Total Clear, sec	6.5		6.3		6.1		6.3	
	Unadjusted FDW, sec	21.3		21.3		20.0		20.0	
Recommended:	Phase #	5	2	1	6	3	8	7	4
Yellow	sec	3.0	3.7	3.0	4.0	3.0	3.9	3.0	3.8
All Red	sec	3.5	2.8	3.3	2.3	2.6	2.2	3.3	2.5
FDW	sec		18		18		17		17

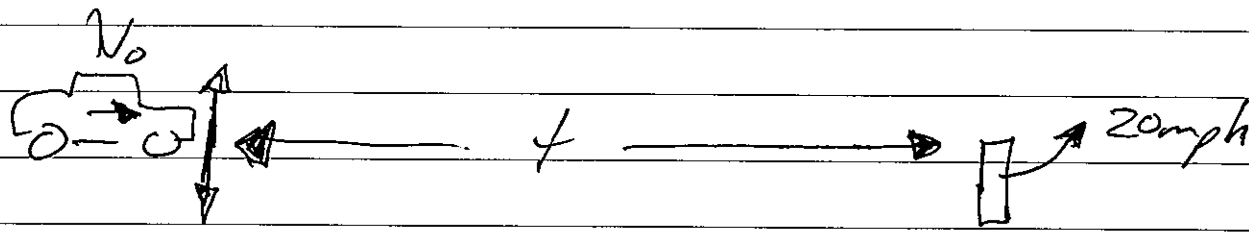
Straight through

$$Y_T = P+R + \frac{V_o}{2a}$$

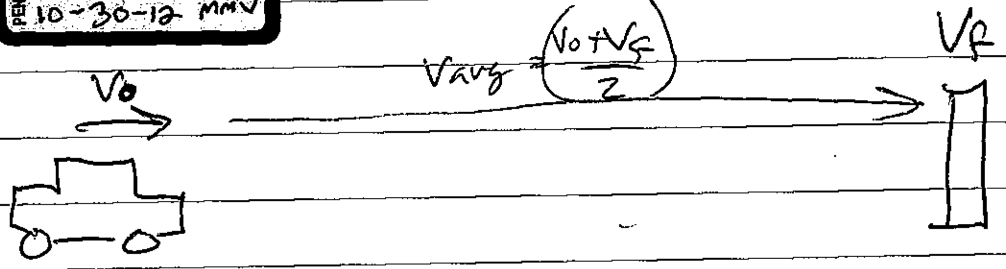
$$= 2.5$$

Turn

$$T_T = PtR + \frac{V_o^2}{2a\,(V_{avg})}$$



$V_f = 20mph$



$V_o = 45mph$
$V_f = 20mph$

$$T_t = (P+R) + \frac{V_o^2}{2a(V_{avg})}$$

$$T_t = (2.5) + \frac{(66)^2}{2(11)\left(\frac{66+29}{2}\right)} = \frac{66^2}{22(47.5)} = \frac{4356}{1045}$$

$$= 4.17$$

$$= P+R + 4.17$$
$$= 2.5 + 4.17$$
$$= 6.67$$