traffic TECHNOLOGY INTERNATIONAL

October/November 2013

WWW.TRAFFICTECHNOLOGYTODAY.

Articles on Meir Tunnel's LED upgrade, Berlin, Dartford Crossing's free-flow ambitions, traffic forecasting and much, much more!

Best-case scenarios
Innovative practices in road weather management

Countryside alliance
The technology champions bringing ITS to our rural areas

Blinded by the truth?

Does the multibillion-dollar red light camera sector owe its existence – and profits – to traffic engineers' misapplication of the yellow change interval formula?

PLUS

Coming soon...
With driverless cars nearing the production line, how will they alter your ATMS landscape?

Rooms with a view
How smart thinking in the control room is redefining collaboration – and reducing operational costs

Dr Alan Stevens, TRL
"Step by step we're getting to where there'll be completely autonomous vehicles in certain situations"

SIEMENS

©2013 Siemens Industry, Inc.

usa.siemens.com/ruggedcom

Fresh look. Trusted name. Proven technology.

RUGGEDCOM is now a Siemens product line. All RUGGEDCOM products will soon look different but the technology inside will remain unchanged, ensuring the best performance for the demanding communication needs of our customers.

Fresh Look: The cases for the RUGGEDCOM product family have been redesigned, consistent with the Siemens product portfolio.

Trusted Name: The name "RUGGEDCOM" won't go away and will continue to represent rugged communications equipment designed for mission critical applications in harsh environments.

Proven Technology: At heart, the RUGGEDCOM products will remain unchanged – the functionality, technical specifications, and 5 year warranty that has forged our reputation as the leading provider of rugged network infrastructure solutions will not be affected by the branding change.

As your partner, we understand your requirements for fast, reliable, and standardized communication. We are one of the world's most tightly meshed service and support providers always with an eye on your needs. Innovation and our passion for communication will help you to be competitive now and in the future!

Answers for industry.

Cover story

56 Defying the laws of physics?

Why traffic engineers could be introducing error into intersections

Brian Ceccarelli and Dr Joseph Shovlin may ruffle a few feathers with their theory on why we have red light runners

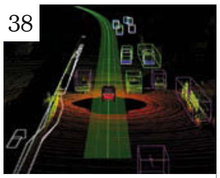
Features

14

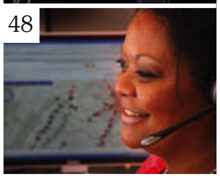
22

32

38



48



71

Interviews

Regulars

Technology Profiles

81

Linked in
Join our group via the banner at
www.traffictechnologytoday.com

Foreword

"There are no such things as stupid questions, Master Bradley, just stupid people!" That's what my mathematics teacher, Professor Rottenbury, used to revel in telling me – regularly – as he watched me struggling with long division, algebra and in the end even turning up for classes. But after a few retakes, some private tuition and what I like to refer to as state-of-the-art cheating, I got my pass – just. Physics was a complete non-starter, though.

But it's what Brian Ceccarelli, author of our cover article (and the man behind the *www.redlightrobber.com* website), excels at. And following citations for running red lights back in 2009 – in one case by 0.34 seconds on a yellow duration that he says was 0.5 seconds short of the DOT's own spec – he's been on a mission to apply his expertise in the field to prove that the reason most people run red lights is because traffic engineers have simplified, misinterpreted and misapplied the 1959 amber light duration formula (p56). "The formula was developed by three physicists, not traffic engineers," Ceccarelli tells me.

Perhaps it's down to my failings in the math department, but I've lost count of the times I've heard "the minority often shouts the loudest" in the context of why so many people are seemingly against what numerous respected bodies and researchers categorically state is a life-saver.

Ceccarelli's campaign is certainly loud. Yet he insists he is not against red light cameras *per se*; he's against the way the signal formula has been applied and as a result induces red light running and is the very reason the red light camera sector exists. In February of this year, he ramped up his efforts by bringing a lawsuit against Cary, the North Carolina city in which he was ticketed. Ceccarelli lost. "The judge used a city ordinance to trump the laws of physics – a decision that made it irrelevant whether those engineering practices were correct," he explains.

One industry professional who agrees with the Cary crusader is Professor Alexei Maradudin – the inventor of the amber light formula. "Physics is an open book," Ceccarelli says. "I can look at his equation and know with 100% certainty what it means. Physics and math is a *Lingua Franca*, but unfortunately – and surprisingly – the collective body of traffic engineers doesn't seem to know."

I'm sure some of you will dispute Ceccarelli's findings – even be incensed by them – but something I've learned from traffic engineers is that this isn't an industry that subscribes to the 'if it ain't broke, don't fix it' school of thought.

As you'll read in our feature on road weather management (p22), there are always gains to be had – and sometimes we have to break from convention to get them. Our feature on page 14, meanwhile, highlights how technology is improving mobility and safety in our rural areas, where intersections especially are a cause for concern. And not a red light camera in sight!

While on the subject of improvements, you can now download *Traffic Technology International* as a free app for use on Apple and Android tablets. Whichever platform you're on, enjoy the read!

Nick Bradley, Editor-in-chief

Who's **Who**

Editor-in-chief
Nick Bradley
nick.bradley@ukipme.com
Deputy editor
Louise Smyth
louise.smyth@ukipme.com
Assistant editor
Lauren Ansell
Contributing editor
Izzy Kington

Production editor
Alex Bradley
Chief sub-editor
Andrew Pickering
Deputy chief sub-editor
Nick Shepherd
Proofreaders
Frank Millard, Lynn Wright

Art director
James Sutcliffe
Art editor
Ben White
Design team
Louise Adams, Andy Bass, Anna Davie, Andrew Locke, Craig Marshall, Nicola Turner, Julie Welby

Head of production and logistics
Ian Donovan
Deputy production manager
Lewis Hopkins
Production team
Carole Doran, Cassie Inns, Robyn Skalsky
Circulation
Adam Frost

Publication director
Mike Robinson
mike.robinson@ukipme.com
Sales manager
Godfrey Hooper
godfrey.hooper@ukipme.com
Sales manager
Jaspreet Rayat
jaspreet.rayat@ukipme.com
Australasia business manager
Chris Richardson
chris.richardson@ukipme.com
+61 4207 64110

CEO
Tony Robinson
Managing director
Graham Johnson
Editorial director
Anthony James

Traffic Technology International
UKIP Media & Events Ltd, Abinger House, Church Street, Dorking, Surrey RH4 1DF, UK
Tel: +44 1306 743744 ▪ Fax: +44 1306 742525
Email: traffic@ukipme.com ▪ www.ukipme.com

The views expressed in the articles and technical papers are those of the authors and are not necessarily endorsed by the publisher. While every care has been taken during production, the publisher does not accept any liability for errors that may have occurred.

Traffic Technology International USPS 012-893 is published bi-monthly – in February, March, April, June, August, and October by UKIP Media & Events Ltd, Abinger House, Church Street, Dorking, Surrey, RH4 1DF, UK. Annual subscription price is US$131. Airfreight and mailing in the USA by agent named Air Business Ltd, c/o Worldnet Shipping USA Inc, 155-11 146th Street, Jamaica, New York 11434. Periodicals postage paid at Jamaica, New York 11431.

US Postmaster: send address changes to *Traffic Technology International* c/o Air Business Ltd, c/o Worldnet Shipping USA Inc, 155-11 146th Street, Jamaica, New York 11434. Subscription records are maintained at UKIP Media & Events Ltd, Abinger House, Church Street, Dorking, Surrey, RH4 1DF, UK. Air Business is acting as our mailing agent.

published by UKiP

Member of the Audit Bureau of Circulations

Average net circulation per issue for the period January 1-December 31, 2012 was 17,336
Annual subscription US$131/£73
USPS Periodicals Registered Number **012-893**

ISSN 1356-9252
Traffic Technology International

This publication is protected by copyright © 2013

Printed by William Gibbons, Willenhall, West Midlands, WV13 3XT, UK

Defying the laws of physics?

Brian Ceccarelli and **Joseph Shovlin** think we're blind to the 'fact' that red light cameras are profiting from enforcing ordinances that prohibit the laws of physics. Although their arguments may fly in the face of the status quo, is there any substance to what they have to say?

Main illustration courtesy of Ben White

There continues to be a great deal of debate surrounding the effectiveness of red light cameras – on TV news bulletins, in the mainstream press, within the corridors of academia and even within these pages. Do they prevent or do they incite crashes? It's not hard to find data supporting both cases. So in light of these inconsistent results, asking whether or not red light cameras prevent crashes isn't necessarily the right question.

Red light cameras are intended to moderate driver behavior and cause drivers to run fewer red lights. But can drivers be trained in this way? There are some people who believe that their immediate goal is to catch red light violators, in doing so leading to billions of dollars of revenue. So the purpose here is to ask (and answer) why the industry is so profitable, why crash data is inconsistent and why drivers run red lights – the latter answering the former.

Down to the formulae

Underpinning the support of the red light camera lobbyists and government legislators – and beneath the pro-camera front organizations and anti-camera activists – there is a single physical formula that models the behavior of vehicles as they interact with traffic lights. But it's a formula that we're convinced has been simplified and misapplied by traffic engineers and as a result it induces motorists to run red lights inadvertently and consequently break the local ordinances.

Red light cameras catch these inadvertent violations and send out citations. Is driving ability thus irrelevant? Is the ability to stop before the light turns red irrelevant? Good or bad driver, everyone must obey the laws of physics (see the *It's physics!* sidebar).

Mathematically speaking

The first of the three formulae that determine the length of a yellow light, Formula 1 ('the Formula') applies to all traffic movements. Formula 2 narrows Formula 1's scope by applying only to traffic decelerating at a constant rate into an intersection – for example, turning traffic. Formula 3 narrows the scope even further and applies only to traffic that doesn't slow down when the light turns from green to yellow. Formula 3 only applies to unimpeded traffic moving straight.

But with traffic engineers universally applying Formula 3, are they actually forcing drivers in many situations to run red lights?

Formula 1 expresses the meaning of the yellow light duration for the general case for all traffic movements. The yellow light duration equals the time that it takes for a vehicle to traverse the critical distance. If a vehicle is farther from the intersection than the critical distance when the light turns from green to yellow, the vehicle has the distance to stop – and then yellow means stop. If the vehicle is closer to the intersection than the critical distance, then yellow means go. In order for the vehicle to legally enter the intersection, the light must remain yellow for long enough to reach the intersection. The Formula is a basic rate x time = distance formula.

It's physics!

There are three related physics formulae[1] that determine the length of a yellow light duration. First there's the general formula (Formula 1):

$$Y \geq \frac{t_p v_0 + \frac{v_0^2}{2[a+Gg]}}{v_{avg}}$$

The second (Formula 2) rearranges the terms and uses a constant deceleration:

$$Y \geq \frac{2\left[t_p + \frac{v_0}{2(a+Gg)}\right]}{(1+v_i/v_0)}$$

And the third (Formula 3), the simplified form for straight-through traffic, is the ITE yellow change interval formula:

$$Y \geq t_p + \frac{v_0}{2[a+Gg]}$$

Where

$$v_0 \geq \begin{cases} v_l, & v_l = speed\ limit \\ v_{85}, & v_{85} > v_l \end{cases}$$

Y = the yellow change interval;

t_p = perception/reaction time (P&R time);

v_0= the velocity of the vehicle at the safe and comfortable stopping distance (critical distance;

v_i = the velocity of the vehicle at the intersection stop bar;

v_{avg} = average velocity of the vehicle as it traverses the critical distance

v_{85} = the 85th percentile speed of free flowing traffic. When $v_{85} > v_l$, use v_{85}

a = the safe and comfortable decelerate rate of the vehicle

G = the earth's gravitational constant

g = the grade of the road

Traffic signals: 1868-2013

1868: The two-way red-green traffic signal is invented in London

1920: William Potts, a Detroit police officer, invents the amber light. First signal head with amber light erected at Woodward and Michigan Avenue

1930: Institute of Traffic Engineers founded in 1930 in the USA

1959: Physicists Denos Gazis, Robert Herman and Alexei Maradudin (GHM) develop amber light duration formula. They restrict use of the formula to vehicles that approach the intersection from the critical distance at a constant speed v_0, which is the maximum allowable speed. The formula includes the all-red clearance interval

1965: Institute of Traffic Engineers adopts GHM's formula, which ITE writes into the *Traffic Engineering Handbook* 3rd edition. ITE omits GHM's restrictions and omits the 'naught' in v_0, leaving v subject to future misunderstanding. From then on, this formula is known as the ITE yellow change interval formula

1975: Institute of Traffic Engineers changes its name to Institute of Transportation Engineers

1982: The *Transportation and Traffic Engineering Handbook* from the ITE describes that the formula requires some drivers to beat the light

1983: ITE introduces gravity's effects into the formula. Many jurisdictions adopt new formula. Surprisingly California with hilly San Francisco does not

1997: Herman, co-inventor of the original amber light formula, dies

2002: Dr Chiu Liu, physicist and civil engineer for Caltrans, and Dr Lei Yu publish paper in ASCE Journal of Transportation Engineering. Liu

The numerator expresses the distance:

$$\textit{critical distance} = t_p v_0 + \frac{v_0^2}{2[a + Gg]}$$

The critical distance is the distance needed to stop – i.e. the distance the driver travels while reacting to change from a green to yellow light and then braking to a stop. If you divide this distance by the average velocity the driver traverses this distance, the result will be the time that it takes to reach the intersection. That's the minimum time required for the light to be yellow.

In its unsimplified form, the Formula allows all drivers in all situations to enter an intersection legally. It covers situations when drivers slow down at different rates, when drivers slow down at a constant rate as in preparing to execute turns, or when drivers go straight without being hindered by other traffic. Traffic engineers never use this Formula in its unsimplified form.

Formula 2 represents a specialized case[2] of the Formula and applies to drivers decelerating at a constant rate into the intersection. Movements that fit this formula are vehicles approaching the intersection with intent to turn left, right or perform a U-turn, who are not in a queue waiting to turn. The average velocity is the average of the driver's velocities at the beginning of the critical distance and at the intersection stop bar.

> We are not trying to justify all red light violators. We are looking at the vast majority of cases where red light camera violations are caused by the underlying physics
>
> **Brian Ceccarelli , science and engineering software consultant, North Carolina, USA**

(Above left) **The yellow light duration is a critical component within the issue of red light running**

Formula 3 represents an even more specialized case. This is the Institute of Transportation Engineers' (ITE) yellow change interval formula. By setting v_i to v_0, this formula assumes drivers travel at their initial speed unimpededly though the critical distance. Once inside the critical distance, drivers must proceed at the speed limit or accelerate[3] in order to enter the intersection before the light changes to red.

Because the yellow time is half the time that it takes to stop, the yellow light forces the driver to make a judgment between stop and go. At the critical distance upstream from the intersection, this decision is most vital because at this distance it is the most difficult for the driver to choose correctly. Without knowledge of the exact location of the critical distance, some drivers guess wrong and run red lights unintentionally – some slam on the brakes while others try to beat the light. Although this formula works only for the singular case, traffic engineers have actually been applying it to all types of traffic movement.

Going back in time...

Formula 3, the classic yellow change interval formula, first appeared in 1959 in a white paper written by physicists Denos Gazis, Robert Herman and Alexei Maradudin (GHM).[4] In 1965, the ITE appears to have miscopied Formula 9 from GHM's paper into ITE's *Traffic Engineering Handbook*.[5] From there it became known as the ITE yellow change interval formula (see *There's been a misunderstanding* sidebar).

There are many rationalizations that traffic engineers devise to justify blanket

concludes that turn yellows must be longer than the ITE formula. Liu defines the formula that allows all traffic to proceed legally into the intersection

2003: Dr Lei Yu, co-author to Dr Liu paper, writes TxDOT report *0-4273-2*. Yu takes poll of traffic engineers, which shows that goal of legal motion of traffic does not make top 10 considerations for a yellow light duration. Traffic flow takes precedence. Accordingly, Yu plugs in numbers into new formula which meet traffic flow goals but simultaneously create illegal movement (Yu contradicts his previous paper)

2004: Gazis, primary inventor of the original amber light formula, dies.

2012: McGee, Moriarty, Eccles, M Liu, Gates and Retting write Transportation Research Board *NCHRP-731*. Authors make an acceptable guess where to measure v but still do not realize that v's measurement location is exact. The formula continues to be misapplied to turning movements. Cases where drivers decelerate en route into the intersection continue to be ignored

2013: Dr Alexei Maradudin, sole surviving inventor of ITE formula, writes letter to Caltrans enumerating the improper uses of his formula

2013: ITE has spread to more than 90 countries

PREMIUM IMAGE QUALITY

MULTI-STREAMING AND MULTI-ENCODING

MJPEG, MPEG-4, H.264 OPTIONS

IN TRAFFIC
TRUST
MATTERS.

WHO'S RELYING ON YOUR CAMERA CHOICE?
Real people—you and your customers—are. That's why, at Basler, trust is as crucial to our business as our innovative technology.

You can trust in the reliability of Basler cameras—and Basler people. You can be confident of both high performance and fair pricing with every purchase. And you can rely on our industry insight to help you build your business. Visit baslerweb.com to learn how our passion translates into your profitability.

baslerweb.com

BASLER
the power of sight

Rule your traffic kingdom.

With IRD's ITS Solutions

HTMS/Traffic Safety Systems

Commercial Vehicle Enforcement/Operations

Traffic Data Collection Systems

Highway Toll Collection Systems

Border and Security Systems

Weigh-In-Motion (WIM) Scales & Sensors

Fleet Telematics

Service and Maintenance

ird® PAT™ Traffic

INTERNATIONAL ROAD DYNAMICS INC.
www.irdinc.com | info@irdinc.com

There's been a misunderstanding

Of all the authors of *The Problem of the Amber Signal Light in Traffic Flow* white paper, only Alexei Maradudin, a physics professor at the University of California at Irvine, remains alive to this day. Just a few months ago, Jay Beeber, the executive director of the grassroots organization Safer Streets LA asked Maradudin to set the record straight. And in a letter dated July 23, 2013 to California's Traffic Devices Committee, Maradudin enumerated the don'ts of his formula "...in the hope that our work not be misunderstood and therefore misused". In his letter, he wrote[6], "Applying the formula to circumstances where a driver must decelerate within the critical distance into the intersection results in a minimum amber time which is shorter than what is necessary to eliminate the dilemma zone."

Maradudin also emphasized some of these specific circumstances that did not apply. They include 1) Turning traffic where the speed limit is greater than the intersection entry velocity; 2) Traffic approaching two close-by intersections: traffic may have to slow down for the second light (or traffic waiting for the second light) before arriving at the first light; 3) Traffic going straight that slows down for vehicles entering and exiting the highway to and from business entrances and sidestreets near the intersection; 4) Traffic slowing down before entering the intersection as a result of traffic density, traffic turning in the lane and traffic changing lanes; 5) Traffic where the speed limit decreases on the far side of the intersection; and 6) Traffic slowing down due to pedestrians, railroad tracks and potholes and other hazards.

use of the simplified formula and it's not within the scope of this article to elaborate on them. But engineering judgment starts with the proper application – not the misapplication – of the physical sciences. The definition of engineering is the application of physics, chemistry and earth science. The mandate of every state's statutes for professional engineers is that they comply with the laws of physics. Although signal head visibility, intersection geometry and human factors are important to computing proper perception/reaction times and comfortable deceleration rates, these considerations cannot come at the sacrifice of the laws of physics.

To traffic engineers who rationalize shorter yellow times using traffic flow goals or 'drivers disrespecting the yellow' arguments, we dismiss those arguments, just as Gazis, Herman and Maradudin did. We must provide the driver a solvable decision problem.

Understanding the physics

As long as all-red clearance times were sufficient for drivers to enter the intersection late but exit it before conflicting traffic gets the right-of-way, the problem was masked. But it became readily apparent when red light cameras – running 24-7 and catching every violation – exposed its magnitude.

We have no problem with the cameras in themselves. As a matter of fact, without them these underlying engineering errors wouldn't have been discovered. And we are not trying to justify all red light violators. Everyone has seen drivers who, with plenty of stopping distance, speed up and enter intersections many seconds after a light turns red. These are the violators the cameras should be catching. Instead we are looking at the vast majority of cases where camera violations are caused by the underlying physics.

(Left) **Anti-camera protestors take to the streets in Port Richey, Florida**

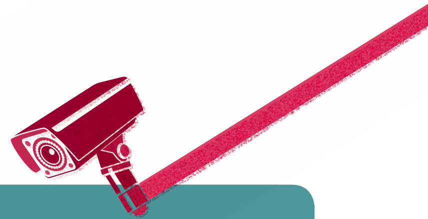
> Engineering judgment starts with the proper application – not the misapplication – of the physical sciences

Dr Joseph Shovlin, research scientist at Cree Labs, Research Triangle Park, North Carolina, USA

Using the simplified formula with common speed limits leads to 3- to 5-second yellow change intervals; the unsimplified Formula requires 2 to 3 seconds more than those. Without understanding the physics, some jurisdictions try to appease the outcry by reluctantly adding a small grace time to the yellow. In Florida, for example, FDOT is currently transferring 0.4 seconds from the all-red clearance interval to the yellow change interval at some of its red light camera intersections.

Anti-camera organizations such as the National Motorists Association lobby governments to add one second to the yellow. Many organizations such as the FHWA and NTSB want engineers to use the 85^{th} percentile velocity rather than the posted speed limit in the calculation. Attempts such as these add at most one second to the yellow. But this just skims the surface.

The New Orleans Regional Traffic Safety Coalition led by Steven Strength – a P.E. for



the Louisiana DOTD – set up a test course to measure the yellow duration needs for right-turning drivers. They measured about 6.2 seconds for several 40mph vehicles.[7] But by conforming to Formula 3, Louisiana grants such vehicles only 4 seconds. Some jurisdictions ignore the formulae altogether (see *Against the grain* sidebar).

The case of Cary

Actual red light running data is hard to come by. Is this because the companies and municipalities involved don't want the magnitude of the problem to come out? If driver behavior was modulating red light violations, you'd expect similar intersections would have similar violation rates. But this wasn't the case in Cary, North Carolina, where the difference was the yellow change interval – in fact huge differences existed from intersection to intersection.[8]

At specific intersections we were able to track changes in yellow change interval based on changes in the violation rates. For example, a 600% increase of violations for a solitary left turn lane was due to the NCDOT decreasing the yellow change interval from four to three seconds. We saw a 50% increase of violations for straight-through movements on a different intersection due to the NCDOT decreasing the yellow interval from 4.5 to 4.4 seconds. Even a 0.10-second change has radical consequences.

Because engineers have been systematically introducing error, one finds the most red light runners where there are the most turning lanes, nearby business entrances, or other intersections near a traffic signal. Indeed it is in these locations where the ITE formula fails the most. Is it therefore a coincidence that it is at these locations where most cameras take vigil?

Against the grain?

New York City and Winnipeg are two cities seemingly ignoring the ITE formulae entirely, setting the yellow to arbitrary durations below even that of the ITE formula. One has to accept that the ITE formula is still physics; yellows cannot get shorter than it. The ITE formula also represents the shortest yellow times and those are for the quickest traffic movements. You cannot invent new laws of nature and expect drivers to conform. Any duration below ITE's formula guarantees a high-volume steady stream of unintentional red light runners.

> If one wants to increase safety yet cause more drivers to run red lights, one increases the all-red interval while decreasing the yellow change interval

Camera-equipped intersections tend to be at locations where the ITE formula doesn't stand up

Physics is an open book, so it's doubtful that nobody is aware of the exact same statistics that we have, a pattern that is especially evident in Cary, Raleigh and Knightdale, North Carolina.

Crash course?

Intersections ripe for revenue can also be ripe for crashes but that is not a given. Crashes are a function of the combined yellow and all-red intervals. Red light running is a function of the yellow interval alone. Lengthening the all-red clearance interval reduces crashes without affecting the number of red light runners. If one wants to increase safety yet cause more drivers to run red lights, one increases the all-red interval while decreasing the yellow change interval.

This practice is par for the course for some transportation agencies. And because we're striving for honesty, some of those DOTs do not decrease the yellows with the intention to cause more red light running. They decrease the yellows to increase traffic flow, but the result is the same – a sustained increase of red light runners. The goals of traffic flow and safety compete, a fascinating topic with a long history and in itself perhaps the subject of a future article. ○

• *Brian Ceccarelli is a science and engineering software consultant in Cary, North Carolina, who has a B.S. in physics. Joseph Shovlin, meanwhile, is a research scientist at Cree Labs in Research Triangle Park, North Carolina and also has a Ph.D. in physics.*

References

[1] *Brian Ceccarelli, Joseph Shovlin, Derivation of the Yellow Light Interval Formula, http://redlightrobber.com (2013).*
[2] *Chiu Liu, et al., Determination of Left-Turn Yellow Change and Red Clearance Interval, Journal of Transportation Engineering, Vol 128, Issue 5; equation 13, 454 (2002).*
[3] *Institute of Transportation Engineers, Transportation and Traffic Engineering Handbook, Second Edition, Institute of Transportation Engineers, 759 (1982).*
[4] *Gazis, Herman, and Maradudin, GM Research Labs The Problem of the Amber Signal Light in Traffic Flow, Institute for Operations Research and the Management Sciences, Vol 8, No. 1, 114 (1960).*
[5] *Institute of Traffic Engineers, Traffic Engineering Handbook, 3rd Edition, Institute of Traffic Engineers, Washington DC, 101 (1965).*
[6] *Alexei Maradudin, Letter to California Traffic Devices Committee, http://redlightrobber.com (2013)*
[7] *New Orleans Regional Traffic Safety Coalition. Yellow Light Timing Study, YouTube, http://youtu.be/P3j2p5SNKIE (2013).*
[8] *Brian Ceccarelli, Cary, North Carolina Citation Counts for Red Light Camera Approaches, http://redlightrobber.com (2013)ctrma.org*