AN EVALUATION OF RED LIGHT CAMERA (PHOTO-RED) ENFORCEMENT PROGRAMS IN VIRGINIA

A Report in Response to a Request by Virginia's Secretary of Transportation

Virginia Transportation Research Council
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DISCLAIMER

The contents of this report reflect the views of the authors, who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the Virginia Department of Transportation, the Commonwealth Transportation Board, or the Federal Highway Administration. This report does not constitute a standard, specification, or regulation.

PREFACE

On June 2, 2004, Virginia's Secretary of Transportation Whittington W. Clement directed the Virginia Transportation Research Council to "prepare a report detailing the advantages and disadvantages of red light camera (photo red) programs . . . summarizing the experiences of those localities that use red light programs." This report responds to that request.

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The study was directed by Mr. Wayne Ferguson of the Virginia Transportation Research Council. Dr. Nick Garber was the principal investigator, and Dr. John Miller was the co-principal investigator. Mr. Saeed Eslambolchi, Mr. Rahul Khandelwal, Ms. Kimberly Mattingly, Ms. Kristin Sprinkle, and Mr. Patrick Wachendorf were also co-authors of this report.

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EXECUTIVE SUMMARY

Introduction

Red light running, which is defined as the act of a motorist entering an intersection after the traffic signal has turned red, caused almost 5,000 crashes in Virginia in 2003, resulting in at least 18 deaths and more than 3,800 injuries (VDOT, 2004a).

In response to a June 2, 2004, directive from Secretary of Transportation Whittington W. Clement, an evaluation of the photo-red enforcement programs that operate in Virginia was undertaken (see Appendix A). *Photo-red enforcement* is a technique in which a camera photographs a vehicle that enters an intersection after the traffic light has turned red; a human reviewer validates the potential violation; and if appropriate, the reviewer sends a civil citation for red light running to the vehicle's registered owner.

Because Section 46.2-833.01 of the *Code of Virginia,* which authorized such programs on a limited basis, will expire July 1, 2005, the Virginia General Assembly is expected to debate this issue during its 2005 Session.

Methods

This study evaluated Virginia's photo-red enforcement programs using three tests of feasibility: technical feasibility (whether the program meets legal standards, performs with sufficient accuracy to be accepted, and enjoys the support of the public), fiscal feasibility (whether program revenues and costs are in balance), and operational feasibility (whether the program improves safety).

To support this evaluation, operational and technical information was collected for the seven Virginia jurisdictions that operate a photo-red program: Alexandria, Arlington, Fairfax City, Fairfax County, Falls Church, Vienna, and Virginia Beach. In addition, crash data and citation data were sought and obtained for as many of these jurisdictions as was possible within the 6-month time frame of the study. Thus, detailed citation data were collected from Alexandria, Arlington, Fairfax County, and Vienna, and detailed crash data from Fairfax City, Fairfax County, Falls Church, and Vienna. A review of the literature and the case law revealed lessons learned by others in this area. Finally, a survey of public opinion was conducted in five locations to support the analysis: Albemarle, Fairfax, Arlington, Roanoke, and Martinsville.

Findings

Technical Feasibility

Generally, Virginia's photo-red programs pass the test of technical feasibility. The systems work properly, and case law strongly indicates that the programs pass legal muster in the three key areas: privacy, equal protection, and due process. The programs also appear to pass public scrutiny. Public opinion surveys suggest that roughly two-thirds of respondents (more than 500 people total, distributed unevenly among the survey locations) support red light cameras.

There is a practical issue with regard to issuing citations for red light running: the *Code of Virginia* requires that an in-person summons, rather than certified mail, be used to compel an individual to appear in court. Because of the high cost of delivering summonses outside Virginia, this requirement could make the programs administratively difficult for some localities if it became commonly known that only an in-person summons can require a vehicle owner either to pay the penalty or to appear in court. However, the program can still legally continue in its present form without a change in the *Code*.

A number of jurisdictions outside Virginia have implemented photo-red programs, and in a few of these cases, specific concerns with their operation have been noted. These concerns include establishing an adequate yellow interval for traffic signals, not using the program to raise revenue, and avoiding software or hardware errors in the operation of the system. Although those problems do not appear to be evident in the Virginia programs at present, their existence elsewhere suggests the need for jurisdictions to follow key practices when implementing such programs to ensure the continued avoidance of problems.

Fiscal Feasibility

Fiscal feasibility pertains to the financial costs of the program from the viewpoint of the agency operating the program. Thus fiscal feasibility does not include social impacts, such as a change in crashes or injuries, that would be encompassed in a full test of economic feasibility. The fiscal feasibility of the program *as it is currently administered* is questionable. Certain factors currently in place limit the revenue potential for some, if not most, of Virginia's programs. One factor concerns whether the fee charged by the equipment vendor is flat or is based on the number of valid citations. Equipment malfunctions and data capture errors can result in invalid citations. In such a case, if the jurisdiction pays a flat vendor fee, it will incur a fixed cost while receiving a smaller than expected revenue stream when vehicle owners successfully contest invalid citations. The citation payment percentage ranges from 69.6% (Alexandria) to 85.7% (Vienna). Another factor affecting the fiscal feasibility is that the six jurisdictions evaluated have separate contracts with separate vendors in implementing the program. As a result, no *volume* cost savings or discounts are realized.

With regard to only the annual financial impact of the programs, three comparison categories show the result: revenue/cost ratio, annual net revenue, and net revenue per citation. The revenue/cost ratios range from 0.62 (in Vienna) to 1.03 (in the City of Fairfax). The annual net revenues range from a loss of $97,811 (in Fairfax County) to a gain of $12,499 (in Arlington). The net revenues per citation range from a loss of $29.45 per citation (in Vienna) to a gain of $1.33 per citation (in the city of Fairfax). This disparity is likely attributable to the fact that the jurisdictions do not use the same calculation components in determining cost. For example, some jurisdictions do not consider *all* of the internal cost components of the program and thus either overestimate their net revenue or underestimate their net loss. In addition, although some jurisdictions incur lower startup costs by renting the camera and other related equipment, others incur higher upfront costs by purchasing this equipment.

These data show that, in general, localities are not generating net revenue. More data are needed, however, to conduct a full economic feasibility analysis to determine the full societal benefits and costs, such as the impacts on various crash types and injuries.

Operational Feasibility

Operational feasibility is defined in this report as the impact of the photo-red program on crashes and citations. The number of citations for red light running issued per month varied substantially by intersection and ranged from 7 (Route 50 and Fair Ridge Drive in Fairfax County) to 1,205 (Patrick and Gibbon Street in Alexandria). Across the 23 intersections where reliable citation data could be obtained, the citations decreased by an average of 21% per intersection. However, the most dramatic reductions occurred at the intersections associated with the larger numbers of citations. When total "before and after" numbers are compared, the data suggest that the programs reduced net citations by 34%. This reduction reflects the number of citations issued in the most recent 3 months divided by the number of citations issued in the 4th, 5th, and 6th months of operation, thus capturing the longer-term impact of the cameras. (The latter months of operation were chosen to capture an early time period when the cameras were stable.) Therefore, cameras are definitely reducing the number of violations.

The data from four jurisdictions—Fairfax City, Fairfax County, Falls Church, and Vienna—suggested that photo-red enforcement reduced the number of crashes *directly attributable to red light running*, i.e., crashes where one or more drivers were charged with failure to yield to a stop-go light. Further analysis indicated that the cameras are contributing to a definite increase in rear-end crashes, a possible decrease in angle crashes, a net decrease in injury crashes attributable to red light running, and an increase in total injury crashes. Therefore, cameras are leading to a net improvement in safety if, as might be expected, the severity of the eliminated red light running crashes was greater than that of the induced rear-end crashes. Such a hypothesis is plausible based on general assumptions about the severity of rear-end crashes and angle crashes, but a more detailed analysis of injury crashes is needed before this hypothesis can be proved or disproved.

Just as motorist safety is a part of the test of operational feasibility, so is the safety of law enforcement officers. For some intersections, law enforcement officers stated they could not safely follow motorists who were running a red light through the intersection. This safety aspect was not explicitly studied.

Limitations to the Analysis

There were three chief limitations to this analysis, which could be resolved by collecting more data while the program is continued:

1. *With regard to technical feasibility,* formal industry-wide equipment testing standards have not yet been established by the International Association of Chiefs of Police. As noted in the text and Appendix G, these standards will merit examination when they are developed. Despite this limitation, evidence of a review process to ensure that the program is working properly was collected through interviews with one jurisdiction, as noted in Appendix G. Similar approaches may be adopted by other localities, but the decision regarding the exact process for verification rests with each locality.

2. *With regard to fiscal feasibility,* a consistent method of estimating costs across all seven jurisdictions is needed. Although qualitative comparisons between traditional enforcement and photo-red enforcement were made, a detailed quantitative assessment was not performed because of limitations in available cost data, especially for traditional enforcement approaches.

3. *With regard to operational feasibility,* a more precise index of crash severity needs to be developed to compare the noted decrease in injury crashes attributable to red light running and the increase in total injury crashes. Further, as noted in this report, a modified crash rate (based on major road volumes) rather than a full intersection crash rate (based on mainline and minor road volumes) was used.

Conclusions

The reader must keep in mind that these conclusions are based on observations that could be drawn from Virginia's seven photo-red enforcement programs. Although the legal and technical implications should apply to all seven programs, basic cost information was extracted for only six (all but Virginia Beach, which is too new to have operational data), citation information for only four (Alexandria, Arlington, Fairfax County, and Vienna), summary crash information for only four (Fairfax County, Fairfax City, Falls Church, and Vienna), and extremely detailed crash information for only one (Fairfax County).

The conclusions are as follows:

- Virginia's photo-red enforcement programs are technically feasible in terms of meeting Virginia's legal requirements, performing with sufficient accuracy, and enjoying the support of Virginia's public.

- The fiscal feasibility of Virginia's programs depends on efforts to bring operational costs in line with revenue. A full determination of economic feasibility would depend on the outcome of a complete crash analysis.

- In terms of operational feasibility, there are indications that Virginia's programs potentially improve safety. The number of crashes attributable to red light running has decreased, although the number of rear-end crashes has increased. These two findings are consistent with those in the majority of the literature surveyed. The number of citations mailed has also decreased. Thus, the cameras do appear to be affecting driver behavior. The unresolved question, however, hinges on the injury crashes: the cameras are associated with an increase in total injury crashes and a decrease in red light running injury crashes. As discussed in this report, the injuries associated with red light running crashes may be more severe; this evaluation, however, did not encompass crash severity (except to classify crashes as injury or non-injury). Thus, it can be said only that Virginia's programs potentially improve safety but that additional data are desirable.

Recommendations

1. *Continue photo-red programs in Virginia*. These programs have the potential to improve safety in Virginia. However, as discussed in this report, additional information is required to determine their net safety impact, such as the comparison of the severity of the injuries in total injury crashes and red light running injury crashes. Therefore, continuing the program for at least one year would allow necessary information to be obtained and more definitive conclusions to be drawn.

2. *If programs are continued or expanded, strongly encourage localities to plan their own evaluation strategy before initiating a program and continue to monitor the existing programs statewide*. One way to facilitate this evaluation is to develop a "best practices" guide describing the types of detailed data that must be collected even before the program begins. Such a guide might help localities conduct their own evaluations, given that incorporated cities and towns, with smaller staff, manage their own roadways. The guide could be based on the approaches illustrated in Appendix D. In particular, the interaction effects discussed in Appendix D suggest that traffic engineering factors—yellow interval, approach volume, speed, and truck percentages—need to be considered along with crash history when sites are being selected. From a statewide perspective, the tradeoff between increased rear-end crashes (along with increased total injury crashes) and decreased red light running crashes (along with decreased injury red light running crashes) needs to be probed further by examining crash severity, as previously described.

3. *Consider revising the in-person service requirement of the Code of Virginia.* Although Virginia's photo-red enforcement programs may legally continue without changes to the *Code,* revisions pertaining to the delivery of the summonses could make the program easier to administer. Virginia's current red light camera statute (§ 46.2-833.01) requires that persons be summoned in accordance with Section 19.2-76.3 of the *Code,* which in turn requires an in-person summons should a person not appear in court or pay the penalty after having received a citation. Thus, the statute could be revised so that personal service would not be required before a default judgment could be entered against no-shows. The relevant language is provided in Appendix H.

4. *Introduce steps to reduce program net costs, but consider the role of public perception and the message sent to vendors when taking such steps.* Generally, the number of violations will decrease (which will reduce revenue) while many cost components will remain fixed, such as maintenance expenses. At least three options can be considered. First, the Commonwealth

should consider using the group buying power of all jurisdictions to acquire equipment and vendor contracts. Second, jurisdictions could increase the penalty for violations from $50 to $100, which would be more in line with the fine most jurisdictions levy under traditional police enforcement. (That figure does not include court costs). A third option, which the investigators do not recommend, is that localities can consider a fee-per-citation payment method. The reason for not favoring this option is that jurisdictions should consider the manner in which the contractor is paid from a public appearances perspective. Each of the seven jurisdictions has some differences in how the contractor is paid: some jurisdictions pay a flat fee and others pay an amount based on the number of citations. There is no evidence in this study that Virginia jurisdictions ever used a fee-per-citation as a way to increase revenue; however, the existence of a fee-per-citation could give the appearance of such a practice. Thus, the first two options, rather than the use of a fee-per-citation system, is recommended.

5. *To support an effective statewide evaluation, consider steps for sharing crash data between VDOT and localities.* Collaborative steps between VDOT and jurisdictions that manage their own roadway systems may be taken to facilitate the sharing of crash data. VDOT already has complete crash data for such jurisdictions with one exception—the specific street or intersection must be queried manually. That is, one cannot identify all crashes at a particular intersection in a given city unless one reviews all crash reports for that city and manually sorts these reports by location. If VDOT and the localities can agree on a method for obtaining this crash location information (whether by localities entering the data or VDOT entering the data), this large resource of VDOT crash data for independent jurisdictions could be used in safety evaluations. (Note that these changes do not require modifications to the crash report form).

INTRODUCTION

Red light running, defined herein as the act of a motorist entering the intersection after a traffic signal has turned red, caused almost 5,000 crashes in Virginia in 2003, resulting in at least 18 deaths and more than 3,800 injuries. Unfortunately, the problem is not limited to a single year: for the period 1998 through 2003, red light running in Virginia resulted in more than 30,000 crashes, 115 fatalities, and 24,000 injuries (Virginia Department of Transportation [VDOT], 2004a).

The sources of these Virginia data are queries performed by the investigators of VDOT's Microsoft Access Crash Database, where red light running crashes are defined as those where the officer charged one or more drivers with "disregarded stop-go light." Because not all crashes that involve red light running necessarily resulted in one of the drivers being charged with this offense, the true number of crashes related to red light running related in Virginia may be higher than 30,000.

The problem of red light running is not limited to Virginia: across the United States, red light running crashes kill more than 800 people and injure more than 200,000 people annually (Retting et. al., 1999a; Retting and Kyrychenko, 2002). Over a 6-year period in the United States, 6,000 deaths and 1.5 million injuries resulted from red light running, with more than half of the deaths being persons not in the vehicle with the motorist who ran the red light (Insurance Institute for Highway Safety, 2000).

The Photo-Red Enforcement Alternative

One technology that has been proposed to address red light running is a camera that photographs the license plates of vehicles entering the intersection after the signal has turned red and after a grace period has elapsed. The accompanying system automatically indicates relevant data such as the time of the violation, the license plate, the speed of the vehicle, and the time elapsed since the signal turned red. Following a review and validation process, a citation showing photos of the violation is sent to the registered owner of the vehicle. These systems have been described in the literature as photo-red enforcement, photo-red cameras, automated enforcement, photo-monitoring, photo-red light running programs, and red light cameras. In this paper, the term *photo-red enforcement* is used.

Photo-red enforcement programs have received praise and criticism in the academic literature and the popular press. Proponents have argued that these programs reduce violations (Maccubbin et al., 2001; Retting et al., 1999b; Winn, 1995), whereas opponents have argued that the program is designed to raise revenue (Office of the Majority Leader, 2001; House Committee on Transportation and Infrastructure, 2001). Studies have documented a crash reduction benefit (Retting and Kyrychenko, 2002; Ruby and Hobeika, 2003), but studies have also challenged the efficacy of these programs, noting that they either increase crashes or do not reduce crashes (Andreassen, 1995; Burkey and Obeng, 2004). Proponents have cited the benefit that these cameras eliminate the potentially dangerous situation of a law enforcement officer traversing an intersection when a violation occurs, but opponents have argued privacy concerns. In fact, a study conducted for the Transportation Research Board concluded that while these programs have potential, more information is needed to evaluate them (McGee and Eccles, 2003).

Although controversy surrounding photo-red programs has gained attention in the popular press, the debate is not surprising given that any traffic control technology—including traditional traffic signals—offers benefits and risks. The replacement of a stop sign with a traffic signal at a high-speed four-way intersection, for example, may reduce angle collisions because turning drivers must no longer decide for themselves whether it is safe to enter the intersection. Yet this change may also increase rear-end crashes if the leading driver on the major route stops suddenly as a result of the signal and the lagging driver is following too closely. Accordingly, any traffic signal, before it is placed in operation, must be evaluated in terms of its risks and benefits (VDOT, 2004b). The same logic applies to other traffic control devices, including red light cameras.

Background for This Study

In Virginia, seven jurisdictions have active photo-red enforcement programs: the cities of Alexandria, Fairfax, Falls Church, and Virginia Beach; the counties of Arlington and Fairfax; and the Town of Vienna. In May 2004, the Virginia Transportation Research Council (VTRC) submitted a work plan to the Federal Highway Administration (FHWA) proposing a detailed 2-year investigation of the safety impacts of photo-red enforcement in Virginia. The proposed work was expected to take 2 years. The reason for the lengthy study was to isolate the safety effects of the photo-red program from the myriad of other factors that could contribute to crashes and violation rates: changing traffic volumes, the presence of heavy trucks in the traffic stream, the duration of the yellow and red time at the traffic signals, enforcement policies, and reconstruction of the intersections. FHWA approved the proposal.

One month later, Virginia's Secretary of Transportation Whittington W. Clement directed VTRC to undertake a technical study reporting the efficacy of photo-red enforcement and that the study should be completed within 6 months (see the letter in Appendix A). He indicated that the study should summarize key data regarding each locality's program (e.g., costs, revenue, duration of the program, and technology used), how the red light running programs affect crashes and violations at these intersections relative to intersections where no cameras are used, how photo-red enforcement compares to traditional methods of enforcement, and levels of public support for such programs (see Appendix A). Secretary Clement also requested that the study discuss recommended changes, if any, to the *Code of Virginia* pertaining to photo-red enforcement. The reason for his directive was that the legislation authorizing red light cameras will expire on July 1, 2005. In its 2005 Session, the Virginia General Assembly is expected to debate the advantages and disadvantages of amending the legislation to continue Virginia's photo-red enforcement program.

PURPOSE AND SCOPE

The purpose of the study documented in this report was to evaluate the effectiveness of Virginia's photo-red enforcement programs as directed by Secretary Clement. The study evaluated Virginia's photo-red enforcement programs using three tests of feasibility: technical feasibility (whether the system meets legal standards, performs with sufficient accuracy to be accepted, and enjoys the support of the public), fiscal feasibility (whether system costs are in line with revenue), and operational feasibility (whether the system improves safety).

The scope of this analysis was limited to data available from the seven jurisdictions, published literature, and surveys that could be conducted during the 6-month study time frame.

The use of significant additional staff for the research team as well as extensive cooperation from the jurisdictions helped to increase what could be accomplished within the study time frame. However, because there were real-world constraints to obtaining, verifying, and analyzing the data in such a short time, the evaluation focused most heavily on those jurisdictions where data were readily available. The limitations of this analysis are detailed in the report.

METHODS

Overview

Four iterative steps comprised the methodology used to evaluate photo-red enforcement in Virginia: conduct a literature review, document what is known with respect to Virginia's programs, collect data, and analyze the effects of the programs. The resultant analysis focused on the technical, fiscal, and operational feasibility of Virginia's photo-red enforcement programs.

Literature Review

The literature review covered four broad categories:

1. the *Code of Virginia,* Virginia-specific case law, Supreme Court precedents, and legal journal articles arguing for and articles arguing against the constitutionality of red light camera systems

2. published studies documenting the impact of photo-red enforcement on violations and crashes

3. articles documenting "best practices" for applying photo-red programs

4. results of public opinion polls that indicate citizen attitudes toward such programs.

The articles came from diverse sources in terms of geography (e.g., the Australian Road Research Board, the United Kingdom's Central Research Unit, Canada's City of Edmonton, and the U.S. Transportation Research Board), type of organization (consulting firms, insurance organizations, and the federal government), and type of journal (e.g., *Journal of Public Health,* *Institute of Transportation Engineers (ITE) Journal*, *Urban Transportation Monitor,* and the *Triangle Business Journal*).

Documentation of Virginia Programs

Representatives from seven jurisdictions that maintain a photo-red program in Virginia (City of Alexandria, Arlington County, Fairfax City, Fairfax County, City of Falls Church, the Town of Vienna, and the City of Virginia Beach) were contacted by phone, fax, and email regarding the status of their programs. Each jurisdiction received two customized surveys; an example of each is shown in Appendix B. The first survey sought basic program information pertaining to cost, placement of the cameras, intersections under study, and procedures for operating the cameras. The second survey, distributed a few weeks later, investigated the feasibility of obtaining more detailed crash and citation data from the jurisdictions. Additional phone calls and electronic mailings were necessary to clarify financial details associated with operating the program, and phone calls to system vendors clarified how the technology functions. A short questionnaire was also sent to the Virginia Association of Chiefs of Police to determine how jurisdictions address red light running with traditional methods of enforcement.

Data Collection

Detailed data on citations, crashes, traffic engineering factors, costs, and public opinion regarding photo-red enforcement were collected, and the data were carefully screened before the analysis could begin. Table 1 lists the data collected from each jurisdiction.

Table 1. Summary of Data from Six Photo-Red Jurisdictions[a]

Type of Data	Alexandria	Arlington	Fairfax City	Fairfax County	Falls Church	Vienna	Other[b]
Citation	X	X		X		X	
Crash			X	X	X	X	
Traffic engineering factors				X			
Costs	X	X	X	X	X	X	
Public opinion		X		X			X

[a]Virginia Beach data were not available because their program just began in 2004.
[b]Public opinion data were also collected in Albemarle County, Roanoke, and Martinsville.

Citation Data

Citation data were sought from the six jurisdictions that had an operational program as of July 2003 and from each of the two vendors that serve the jurisdictions: Affiliated Computer Services, Inc. (ACS), which covers Alexandria, Arlington, Fairfax City, and Fairfax County, and Nestor, Inc., which covers Falls Church and Vienna. Virginia Beach is served by RedFlex Traffic Systems, Inc., but their program did not begin until September 2004.

Citation data reflect the number of citations mailed out (i.e., the number of actual violations), not the number of events where a vehicle was photographed.

Crash Data

Crash data were sought for January 1, 1998, through December 31, 2003, which, for at least a few signals in each jurisdiction, reflected a period before and after the cameras were installed. Camera installation dates varied by jurisdiction and within jurisdictions. Crash data were ultimately used from four jurisdictions: Fairfax County, the City of Falls Church, the City of Fairfax, and the Town of Vienna. Substantial effort was required to obtain the raw data, verify their accuracy, and synthesize them into a format suitable for analysis.

The investigators started with *Fairfax County* for two reasons: first, a good relationship had been established before the study with Fairfax County's traffic safety manager who offered to obtain some of the crash data. Second, it is generally possible to determine the location of Fairfax County crashes in VDOT's crash databases. Data for the 13 camera sites came from two sources: (1) a spreadsheet provided by Fairfax County and VDOT's Oracle databases, which became available in August 2004, and (2) manual examination of crash report forms, i.e., the FR300 forms (FR300s), provided by VDOT's Mobility Management Division at 54 comparison sites (intersections without cameras in Fairfax County and adjacent Prince William County). These sites were selected based on recommendations from VDOT staff who had funded a previous study of Fairfax County's photo-red program (BMI, 2003).

The location of crashes in incorporated cities, towns, and the counties of Arlington and Henrico are not given in VDOT's Access database. Thus, for the remaining jurisdictions with active photo-red programs (Alexandria, Arlington, Fairfax City, Falls Church, and Vienna), the FR300 forms had to be examined manually to obtain crash locations.

For *Falls Church*, FR300s were obtained from Falls Church directly for three intersections with cameras and three without. However, there were concerns regarding whether they comprised the complete data set. Thus, *all* Falls Church FR300s were extracted from the VDOT database for 2002, manually catalogued by intersection, and then compared to the FR300s provided by Falls Church. Based on the 2002 sample, a decision could be made regarding the completeness of the Falls Church data set. This procedure, detailed in Appendix C, was repeated for other jurisdictions where it was deemed advantageous to take data provided by the jurisdiction but necessary to verify them. For the *Town of Vienna* and the *City of Fairfax*, all FR300 crash report forms were extracted for the years 1998 through 2003, and they were manually matched to specific intersections. For *Arlington* and *Alexandria*, the number of crashes for the entire jurisdiction was too high to complete the manual matching within the study time frame. As shown in Appendix D, data from the FR300s were categorized by crash type; an excerpt of the FR300 template is also shown in Appendix D.

Traffic Engineering Data

Traffic engineering data, such as average daily traffic (ADT) on the major road for the intersection, percentage of heavy trucks (trucks with six or more tires), duration of the yellow time at the traffic signal, and duration of the all red time at the signal were obtained from three sources. For Fairfax and Prince William counties, where the roads are maintained by VDOT, data were obtained directly from VDOT district and central office staff. (Prince William data were sought as a potential comparison set for Fairfax County.) Historical data (again for Fairfax County) were obtained from previous reports, such as an analysis conducted by BMI for VDOT (BMI, 2003) and traffic counts available from the VDOT Mobility Management internal website. For the other jurisdictions, these data were obtained directly from the jurisdictions. Posted speed limit data were also collected: although approach speed data would have been preferable, approach speeds were not available for most intersections; hence, posted speed limit data were used.

Cost Data

Three types of cost data were collected. Cost data related to traditional enforcement methods were obtained by sending a survey to all police departments in the Commonwealth to ascertain how many red light running violators could be captured per hour at a particular intersection using traditional enforcement methods. Revenue data were obtained by requesting from the jurisdictions that operate a photo-red program the number of mailed citations as well as estimates, in some cases, of how many citations were paid. Other cost data were obtained through telephone conversations and emails with representatives from local jurisdictions who could describe how equipment purchase costs, equipment rental costs, maintenance costs, and processing costs were handled for the programs.

Public Opinion Data

Public opinion data were obtained through five surveys conducted in Albemarle, Arlington, Fairfax, Martinsville, and Roanoke. These diverse locations were chosen to capture areas where red light cameras were in use and where such cameras were not in use. They also provided a mix of urban and rural locations. Respondents were asked 10 questions pertaining to the seriousness of red light running, whether they favored or opposed red light cameras, and reasons for their position. The Albemarle survey was a pilot effort distributed to Albemarle County government employees electronically. The other subsequent surveys sought to capture a wide mix of respondents and were done in person. The survey at the Fairfax County Government Center captured the opinions of some residents of the county (who were doing business at the center); however, it took a team of seven investigators 2 hours to obtain just 200 responses. Because this was a relatively small number of responses, the remaining surveys were conducted at malls to obtain a larger sample of respondents. Table 2 summarizes how each survey was conducted, and Appendix E shows an example survey. The surveys were conducted at times that representatives of the host facilities suggested would yield a large number of responses.

Table 2. Surveys of Public Opinion

Location	Date	How Survey Was Conducted	Responses
Albemarle County Government Office Building	August 4-20	Electronic survey mailed to Albemarle County Government employees	44
Fairfax County Government Center	Thursday, August 19, 11 am-1 pm	Seven investigators distributed surveys and clipboards to persons entering and exiting building; audience included public and private employees	200
Arlington County Ballston Mall	Thursday, October 14, 11 am-2 pm	Table set up at mall; surveys and clipboards distributed to persons walking by display	116
Roanoke City Tanglewood Mall	Friday, October 15, 11 am-3 pm		113
Martinsville Liberty Fair Mall	Monday, October 18, 11:30 am-2:30 pm		73
VDOT's Martinsville Residency	Monday, October 18	VDOT resident engineer asked VDOT employees to complete survey	63

Analysis of Virginia's Photo-Red Enforcement Programs

The analysis of Virginia's photo-red enforcement programs focused on their technical, fiscal, and operational feasibility.

Technical Feasibility Analysis

The technical feasibility analysis determined if the system met Virginia's legal requirements, performed with sufficient accuracy to be accepted, and enjoyed the support of the public in Virginia.

Legal Requirements

The research team first determined what was allowed under the current law in the Commonwealth. Three legal issues were assessed, the first being the privacy challenges such programs could face in state or federal courts. Privacy in this sense could be contested as a constitutional matter, notably as falling within the definition of constitutionally protected privacy or unreasonable search and seizure, or as a violation of the privacy protections afforded by Virginia's statutory and common law. Accordingly, Supreme Court precedents relating to the Due Process Clause of the Fourteenth Amendment and the Fourth Amendment of the U.S. Constitution were reviewed, as well as applicable provisions of the Code of Virginia and Virginia case law.

The second legal issue concerned the Equal Protection Clause of the Fourteenth Amendment of the U.S. Constitution, which provides that no state shall deny any person equal protection under that state's laws. The Supreme Court's Equal Protection Clause doctrine was reviewed and applied to Virginia's photo-red programs.

The third legal issue was procedural due process, focusing most heavily on whether an automated camera enforcement program is an unconstitutional deprivation of private property.

Due process has been interpreted by the courts as having two fundamental components: (1) an opportunity to be heard and (2) providing that reasonable notice is served to the defendant. Thus, the review of Virginia case law in this area focused on how courts would likely evaluate Virginia's photo-red programs with respect to these areas. In particular, issues related to burden of proof were examined.

Determination of Accuracy

The manufacturers of the cameras were contacted and interviews were conducted to gain an understanding of the operation and technology behind the red light cameras. Local representatives from jurisdictions in the Commonwealth were interviewed to gain a better understanding of the operation from the government's viewpoint. Articles were also analyzed as a basis for previous failures of red light cameras around the nation. Through interviews of vendors, a technical understanding of the cameras was developed and the positives and negative elements of the technology were determined. A survey of law enforcement officers, shown in Appendix F, provided an overview of how jurisdictions address red light running with traditional methods of enforcement.

Determination of Public Opinion

Results of the public opinion surveys previously described were tabulated and analyzed to determine the proportion of respondents from each jurisdiction who would favor or oppose a photo-red program. "Free response" comments were also tabulated. In addition, motorist attitudes toward red light running from each of these locations where the surveys were conducted were analyzed.

Fiscal Feasibility

Fiscal feasibility was determined strictly from the net financial impact perspective of the program *as currently administered* in each jurisdiction (i.e., revenue versus cost and the resulting net revenue/loss factor). No other consequential benefits (e.g., reduced or increased crashes) were considered in the fiscal analysis. Because of inconclusive and limited data available for the traditional police enforcement methodology, no financial comparison was performed. However, a qualitative comparison of the two methods was carried out. Details of the analysis are provided in Appendix F.

Because the program is implemented differently in each jurisdiction, collected jurisdictional data were converted into a consistent format for cross-comparison purposes. This included the grouping of financial information into four categories: initial investment, ongoing cost, revenue, and net revenue.

Operational Feasibility

The determination of operational feasibility focused on whether the program improved safety in Virginia. Two variables were analyzed in this regard: citation impacts and safety impacts.

Citation Impacts

Citation impacts were assessed by comparing how the number of citations changed over time. The early period was defined as the fourth, fifth, and sixth months after camera installation so that a stable earlier period could be captured. The number of citations in this period was compared with the number of citations occurring during the most recent 3 months of operation. In addition, the time into the red signal at which 85% of the violations (i.e., citations) had occurred was examined. This time was considered the 85th percentile value for time into the red for the particular signal.

Safety Impacts

Safety impacts were assessed by comparing changes in crashes while controlling for confounding factors. Crash data were available at sites with and without cameras and were available before and after the photo-red programs were evaluated. Thus changes in crash frequency (absolute number of crashes) and modified crash rates (number of crashes as a function of vehicle volume on the major road) were determined. In addition, changes within specific categories of crashes were studied: rear-end crashes, angle crashes, crashes where one or more drivers were charged with disregarding stop-go light, total injury crashes, injury crashes attributable to red light running, and total crashes.

Four increasingly sophisticated levels of crash analysis were performed, with level 1—the simplest—being performed for all four jurisdictions, and level 4—the most sophisticated—being performed only for Fairfax County. Generally, the level 1 analysis is computationally the easiest to do and the easiest to interpret, but it has the greatest risk of not addressing other factors that influence crashes. The level 4 analysis is the opposite: it is time-consuming and difficult to interpret but can be useful insurance against attributing crashes to the wrong explanatory factor. Table 3 summarizes the strengths and weaknesses of the analysis levels, based on the data available for each jurisdiction. Details of the analysis are presented in Appendix D.

There was one other discriminating factor with regard to how jurisdictions were analyzed. For all crashes, it was relatively easy to categorize the crashes as rear-end, angle, or driver being charged with red light running because this information is coded directly on the FR-300 by the police officer. These categories, however, may omit useful information that is gleaned only by carefully reviewing the crash narrative and diagram drawn by the officer. These enable the determination of *rear-end crashes attributable to the red light,* which is a subset of total rear-end crashes. In addition, as noted by the Fairfax County police, in some crashes, the driver was not charged with red light running but the narrative clearly indicates that red light running occurred—a category designated herein as crashes that are *likely attributable to red light running.* One survey responder noted that "in most crashes in Fairfax County where a violator ran the red light they were charged with 'fail to pay full time and attention.'" The precise techniques used to determine these classifications are detailed in Appendix D.

Table 3. Crash Analyses Performed for Each Jurisdiction

Level	Type of Analysis	Strengths	Weaknesses	Jurisdictions
1	Compare crashes/year at each intersection before and after installation of camera[a]	Easiest type of analysis to interpret	Assumes all confounding factors remained constant during before/after periods	Fairfax City Fairfax Co. Falls Church Vienna
2	Same as 1 except crash rates are compared; rates are crashes/million entering vehicles on major road[a]	Controls for changes in traffic volume; is traditional method of evaluating intersection safety	Assumes crashes are directly proportional to volume (e.g., 10% increase in volume yields 10% increase in crashes); assumes all other factors remained constant	Fairfax City Fairfax Co. Falls Church Vienna
3	Compare crashes/year at intersections with and without camera for before/after periods, but stratify for volumes, difference between actual and desired yellow time, and heavy truck percentages[b]	Classic experimental design approach; systematically determines how variety of factors influence number of crashes	Assumes crashes follow normal distribution when in fact they often are negative binomially distributed; although a balanced design can usually compensate, rarely are crash data balanced for each factor; interaction effects may be difficult to interpret	Fairfax Co.
4	Use Empirical Bayes approach: crashes that "would have occurred" are estimated from models based on data and then compared to crashes that did occur[c]	Considered most rigorous type of analysis by many; technique encouraged by FHWA and TRB.	Extremely sensitive to how mathematical models are estimated; previous work by authors suggests technique should be viewed with caution unless multiple models from different jurisdictions are developed	Fairfax Co.

[a]Statistical tests include the t-test and the paired sample t-test.
[b]Statistical test is the analysis of variance (ANOVA).
[c]The Empirical Bayes approach was based on the following crash estimation model

$$Crashes = \alpha_y (Volume)^b (Speed)^c (Yellow)^d (Trucks)^e (Lanes)^f$$

where

α_y = parameter that reflects specific year (1998 through 2003)
Volume = average daily traffic on major road
Speed = speed limit on major road in mph
Yellow = difference between yellow time recommended by ITE and actual yellow time
Trucks = percentage of trucks in major road traffic stream
Lanes = number of through lanes on major road approach.

In general,

- For all four jurisdictions, *total crashes* and *total injury crashes* were tabulated.
- For Fairfax County and Falls Church, where the diagrams and narratives were reviewed, *rear-end crashes attributable to the red light*, *crashes likely attributable to red light running*, and *injury crashes attributable to red light running* were determined.

- For Fairfax City and Vienna, where the diagrams were not reviewed, *total rear-end crashes*, *total angle crashes*, and *crashes definitely attributable to red light running* were reviewed.

RESULTS AND DISCUSSION

Literature Review

More than two-dozen studies or evaluations have been published on the topic of red light cameras in the United States and abroad. The studies may be classified into three broad categories: the impact of the cameras on violations at the traffic signal, the impact of cameras on various types of crash rates, and recommended best practices for agencies that are considering the use of these cameras. The literature review was conducted using the Transportation Research Information Search (TRIS) database, and the results are summarized in Table I1 of Appendix I.

Violation Studies

Red light camera programs within and outside the United States have reported reductions in red light violations after the installation of cameras. As shown in Appendix I, a larger number of studies have examined changes in violation rates. Maccubbin et al. (2001) reported that reduction figures range from 20% to 87% for jurisdictions in United States, with half of the jurisdictions reporting between 40% and 62%. Figures were similar for programs in Australia, Singapore, Canada, and the United Kingdom (Winn, 1995; Mullen, 2001, Lum and Wong, 2003; Zaal, 1994; Chin, 1989). The Insurance Institute for Highway Safety reported a 40% reduction in red light violations in Oxnard, California (Retting et al., 1999b). Reductions in red light violations at the nearby signalized intersections without cameras were found to be identical with those at the photo-enforced intersections. This suggests that photo-enforcement not only reduces violations at the particular signal but also improves driver compliance at other signals in the same jurisdiction, also known as a “spillover” effect.

Two studies have evaluated the impact of cameras on red light violations in Virginia (Retting et al., 1999c, Ruby and Hobeika, 2003). Violation rates decreased by 36% over the initial 3 months and by 69% after 6 months (Ruby and Hobeika, 2003). The Insurance Institute for Highway Safety study showed reductions at the five camera sites were 7% after 3 months and 44% after 1 year. The study also noted that public support for camera use increased from 75% before enforcement to 84% 1 year after enforcement (Retting et al., 1999c).

Ideally red light violations at a particular intersection should be compared before and after the traffic signals are installed. However, prior to camera installation, there is often no complete set of violation data, because it is with the camera that automated data can be obtained (Retting et al., 1999c). However, some researchers collected “before” data with cameras or video recorders prior to camera installation (Lum and Wong, 2003). Generally, large reduction in violations after the installation of cameras have been reported.

The type of violations affected by the cameras also require examination. Winn (1995) studied the impact of cameras on the number of violations at different time periods during the red signal phase. The study revealed that the decline in violations was greatest during the periods of 0.5 and 1.0 second into the red, i.e., 42% of total violations. In comparison, the number of violations occurring more than 5 seconds into the red was less than 1% of the total recorded violations. This type of analysis illustrates how red light cameras may change particular aspects of motorists' behavior. However, because studies such as Winn's have been conducted abroad (Scotland), more detailed data based on the U.S. experience are needed.

Crash Studies

Several studies have evaluated the impact of red light cameras on crashes, both in the United States and abroad, as shown in Appendix I. The majority of the studies reported a decrease in angle crashes with a slight increase in rear-end crashes (Hillier et al., 1993; Mann et al., 1994; Fox, 1996; Retting and Kyrychenko, 2002). To the extent angle crashes are more severe than rear-end crashes, a net safety gain is realized if the reduction in angle crashes is greater as compared to the increase in rear-end crashes. Although there is some evidence of a spillover effect, some studies indicate no such effect (Hillier et al., 1993).

Table I2 of Appendix I provides the results of crash evaluations after installation of cameras as reported by various jurisdictions based on a survey conducted for the National Cooperative Highway Research Program (McGee and Eccles, 2003). The information includes location, type of evaluation, and findings for each jurisdiction that responded to the survey. Almost all the jurisdictions reported a reduction in crashes, although some noted an increase in rear-end crashes at camera intersections.

The red light camera programs are relatively older in Europe and Australia as compared to United States, which is the reason many of their evaluations are better able to examine the longer-term impacts of red light cameras. The results of these studies are mixed: a few studies (Hillier et al., 1993; Fox, 1996) show a reduction in crashes, and others (Andreassen, 1995) show an increase. A study with a 5-year before period and a 5-year after period performed in Australia that compared crashes at 41 enforcement sites found no long-term reduction in crashes and an increase in the rear-end crashes after the installation of the cameras (Andreassen, 1995). One study in Australia showed a 40% reduction in angle crashes with no increase in rear-end crashes (Office of Auditor General, 1993). Another Australian study showed a 50% reduction in angle and right-turn opposing crashes and 20% to 60% increase in rear-end crashes (Hillier et al., 1993). A Scottish study indicated significant benefits after installation of cameras based on a 3-year before and a 3-year after period (Fox, 1996). However, the author stated that the impacts of cameras could not be isolated, as engineering improvement in intersections during the study period might have also influenced the reduction (Fox, 1996). Another Australian study found that crashes at the sites with red light cameras and other modifications decreased significantly more than in the control group (Mann et al., 1994). Because of these other modifications, such as an increase in yellow time from 3 to 4 seconds throughout the metropolitan area during the study period, the crash reductions cannot be said to be solely attributable to photo-red enforcement. Another methodological issue with the study was that cameras were installed at high-risk sites, and thus the sites were not comparable to the control sites.

A few U.S. studies focus on crash impacts. Three are from Oxnard, California (Retting and Kyrychenko, 2002) and Fairfax County, Virginia (Ruby and Hobeika, 2003; BMI, 2003). Citywide crash data for Oxnard were compared with the citywide crash data for three comparison cities. Crashes at signalized intersections throughout Oxnard were reduced by 7%. Injury crashes, total right angle crashes, and right angle crashes involving injuries throughout the city were reduced by 29%, 32%, and 68% respectively (Retting and Kyrychenko, 2002). Although cameras were installed at only 11 of 125 signalized intersections in Oxnard, crash reductions at signalized intersections were found on a citywide basis. The authors suggested that the cameras can change driver behavior and can provide general deterrence against red light violations, as the crash reductions are not limited to intersections with cameras (Retting and Kyrychenko, 2002).

A Fairfax County assessment showed a 40% reduction in accidents after 3 months of camera operation (Ruby and Hobeika, 2003). A limitation of the study, however, was that it covered only a 3-month period. Further, the study did not account for the changes in the yellow time while the impact of the cameras was examined. Another recent study that compared crash frequencies and crash rates at camera intersections and 40 reference intersections in Fairfax and Prince William counties did not detect any effect from the cameras and recommended reanalysis of the data as the study was based on a very limited (less than 18 months for most of the camera intersections) after period and a small sample size (BMI, 2003).

A fourth study suggested that red light cameras have a negative impact. Burkey and Obeng (2004) found that based on a before-after comparison in Greensboro, North Carolina, of 303 intersections over a 57-month period that red light cameras did not reduce crashes or severity; in fact, they increased crash rates by 40%. Further the authors found no other positive impacts—with one exception: a decrease in crashes that involved "a left turning car and a car traveling on a different roadway"—a type of crash the current investigators would consider an "angle" crash (Burkey and Obeng, 2004). Because the findings of this one report were in contrast with those in the previous literature, they are reviewed closely in the latter portion of Appendix I. The review questions the findings but does not categorically disprove them.

Best Practices

From a public policy perspective, the purpose of the red light camera is to increase safety at signalized intersections by reducing red light violations and the resultant crashes attributable to red light running. Guidance has been issued on the proper use of red light cameras.

The National Highway Traffic Safety Administration (NHTSA) and the Federal Highway Administration (FHWA) have published guidance for implementation and operation of the red light camera systems. The report (NHTSA and FHWA, 2003) provides a systematic approach to identify intersections with a red light running problem and the feasible countermeasures to address it. It suggests that appropriate cost-effective engineering, educational, and traditional enforcement solutions should be considered before deciding to use red light running cameras to enhance intersection safety. It lists the key steps to implement the red light camera program. These steps include establishing an oversight committee, establishing program objectives, and identifying legal requirements. The report provides guidance for camera system installation, operation and maintenance, citation data processing, and a public information campaign. However these procedures are based on guidelines, not real data.

The Institute of Transportation Engineers (ITE) has issued a report that identifies various engineering features at an intersection that should be considered to curb the problem of red light running (ITE, 2003). The report provides a background on the characteristics of the problem; identifies how various engineering measures can be implemented to address it; suggests a procedure for selecting the appropriate engineering measures; and provides guidance on when enforcement measures, including red-light cameras, may be appropriate.

VDOT's former Traffic Engineering Division, now referred to as the Mobility Management Division, has developed a seven-step process for selecting sites where photo-red enforcement is a suitable countermeasure (VDOT, 2002). The process includes determining the appropriate yellow time, considering other countermeasures that may be implemented before or in lieu of photo-red enforcement, studying crash and violation data, reviewing physical characteristics of the intersection, and instituting a public awareness campaign.

Limitations to Findings in the Literature

The literature clearly suggests that red light cameras have contributed to reductions in violations. Firm proof remains elusive. Although several studies have suggested a reduction in crashes, at least one study suggests an increase. Further, there are limitations with the analyses, including the following:

- Most of the programs studied (BMI, 2003; Ruby and Hobeika, 2003; Retting et al., 1999c) were new with only 1 to 2 years of after camera data. Thus, long-term camera impacts were difficult to determine.

- In many cases, a direct comparison of before and after crash frequencies shows a net reduction in crashes, but the reductions were often not statistically significant.

- In many studies, no reference sites were identified for comparison with the camera sites, introducing a potential bias in the evaluation. Generally, cameras are installed at the intersections with higher crash rates. Yet, there is random variation in the number of crashes from year to year at any particular intersection; it is possible that after a particularly "bad" year, the crashes will drop the following year for no reason except this random variation. This is called the regression to the mean phenomenon. Thus, if before and after crash frequencies are compared at an intersection, there is the possibility that a future drop in crashes will be erroneously attributed to the installation of a camera rather than being correctly attributed to random variation. To account for this potential bias introduced by the phenomenon, reference sites should be included in the analysis.

Similarities and Differences in Virginia's Programs

Virginia's seven jurisdictions that operate photo-red programs have several similarities in terms of how they manage their programs. An understanding of these similarities is helpful before evaluating the technical, fiscal, and operational feasibility of Virginia's programs.

All seven of Virginia's programs indicated common objectives: to reduce violations, to reduce crashes, to increase pedestrian safety, and to change driver behavior. In terms of choosing where to place the cameras, most representatives of the jurisdictions surveyed indicated a combination of factors: crash and violation data, input from citizens and law enforcement, and a review of the site. Arlington County noted just three of those factors: crashes, input from citizens, and input from law enforcement. For most jurisdictions, the grace period (lag time) varied between 0.1 and 0.4 seconds, and the reasons for the variation appear to be the year the program was started, the technology in place, and information available to the jurisdiction. For example, Fairfax City indicated that the reason they have the largest lag time (0.4 second) is because they had the first program and wanted to be conservative in terms of issuing citations; the most recent jurisdiction to initiate a program (Virginia Beach) uses a time of 0.3 second based on a recommendation it obtained from a North Carolina study. The Town of Vienna does not have a set grace period per se. Table 4 summarizes key characteristics of each program.

Table 4. Overview of Virginia Photo-Red Programs

Jurisdiction	Program Start Date	Number of Cameras	Lag Time (sec)	Yellow Time (sec)[a]	Vendor	Camera Technology	Contractor Payment Method
Alexandria	11/97	3 rotated among 4 locations	0.3	3.0 to 5.0	ACS	35 mm wet film	Flat fee
Arlington	2/99	5 stationary	0.1	3.5 to 4.5	ACS	35 mm wet film	Flat fee
Fairfax City	7/97	7 stationary	0.4	3.5 to 4.5	ACS	35 mm wet film	Flat fee for equipment + a fee per citation
Fairfax County	10/00	13 that have been used in 15 locations	0.2	4.0 to 5.5	ACS	35 mm wet film	Flat fee for equipment + a fee per citation
Falls Church	10/00	8 stationary	0.1	3.0 to 4.0	Nestor Traffic System	Digital video	Flat fee
Virginia Beach	7/04	10 stationary	0.3	3.75 to 4.25	Redflex Traffic Systems	Digital video and digital still photos	Flat fee
Vienna	6/99	3 stationary	Officer's discretion	4.0	Nestor Traffic System	Digital video	Flat fee for equipment + fee per citation that decreases as number of citations increases

[a]Yellow times provided in the table are based on current data; in some cases these have increased from the past.

The greatest variation in Table 4, other than the technology employed, is the method of payment. Some jurisdictions pay only a flat fee; for example, the City of Alexandria pays $27,000 per month per intersection and then pays $27,750 per month for processing citations (regardless of the number). Fairfax City, on the other hand, pays $23.50 for each citation (in addition to standard equipment costs, such as a monthly maintenance fee of $515 per camera). The Town of Vienna also pays a per-citation fee, with the fee dropping as the number of citations increases.

Additional operational and equipment details for Virginia's programs are given in Appendix G. In sum, the system—composed of the camera technology and the human reviewers—does appear to function properly. There are, however, cases in jurisdictions outside Virginia where the photo-red program has the potential to be operated improperly; the examples provided in Appendix G include locations where the yellow duration was timed incorrectly and where citations were issued for a flashing signal.

Technical Feasibility

Legal Issues

The legal viability of red light camera use in Virginia has been analyzed in terms of its compatibility with three broad constitutional issues: *privacy*, *equal protection*, and *procedural due process*. The program in its current form satisfactorily meets possible legal challenges in all three areas. However, the legal implications of certain due process requirements give rise to a potential *practical* obstacle.

Privacy

The U.S. Supreme Court has long recognized a "right of personal privacy, or a guarantee of certain areas or zones of privacy" as an aspect of the liberty protected under the Due Process Clause of the Fourteenth Amendment (*Roe v. Wade*, 1973). Moreover, the Fourth Amendment provides that "[t]he right of the people to be secure in their persons, houses, papers, and effects, against unreasonable searches and seizures, shall not be violated." Privacy has also traditionally been protected through four common-law torts: unreasonable intrusion on an individual's seclusion; public disclosure of true, embarrassing facts; untruthful publicity; and misappropriation of an individual's name or likeness for commercial purposes. In Virginia, however, the application of these torts has been limited by statute so that only a misappropriation of an individual's name or likeness for commercial purposes is recognized as an actionable claim for invasion of privacy.

Equal Protection

The Equal Protection Clause of the Fourteenth Amendment provides that no state shall "deny to any person within its jurisdiction equal protection of the laws" (U.S. Const., amend. XIV, § 1).

Procedural Due Process

The due process clauses of the U.S. and Virginia constitutions provide that no person shall be deprived of life, liberty, or property without due process of law (U.S. Const., amend. XIV, § 1; Va. Const., art. I, § 11). Procedural due process has been interpreted to require both reasonable notice of the offense and a meaningful opportunity for an individual to be heard.

Challenges

The Virginia red light camera enabling statute has been challenged on all three of these broad fronts. Critics claim, for example, that photo-enforcement amounts to an unconstitutional governmental intrusion, thus usurping citizens' right to privacy; that it affords disparate penalties for camera citations versus live stops, thus contravening the equal protection requirement; or that it deems the violator "guilty until proven innocent," thus running afoul of procedural due process requirements.

Appendix H surveys the statutory and case law pertinent to each of these three legal concepts. Challenges posed by the first two—privacy and equal protection—are fairly easily dealt with, revealing that ultimately no intractable legal obstacles to Virginia's photo-red program stem from them. Most of the concerns related to procedural due process are *also* shown to be insufficient to undermine the legal viability of photo-red programs (including the "guilty until proven innocent" objection), with one exception noted here.

The one surviving legal worry actually turns out to be a *practical* problem, generated by the interaction of the notice provisions in the enabling statute and the Commonwealth's other service requirements. Because the mere mailing of a ticket without personal service by a law enforcement officer does not constitute sufficient notice under the statute's own terms, successful enforcement may require *personal in-hand service* if the accused fails to either pay the penalty or come to court. Although the statute *permits* the jurisdiction to make the initial attempt to summon the accused to court via mail, if the person fails to respond, he or she is not considered to have been satisfactorily served with notice. However, personal service on all violators is obviously a very expensive proposition, involving many personnel hours, and would defeat one of the primary motivating factors for employing automated detection systems in the first place—a reduction in the number of officers required to enforce red light laws. Thus, unless a jurisdiction is willing to devote resources to implementing extensive in-hand service, citations mailed for red light camera violations become essentially unenforceable. The average citizen is probably not aware of this loophole, but if word were widely disseminated, such knowledge could completely undermine the effectiveness of red light camera programs, as citations issued to violators would lose their practical impact. Again, this is a practical, but not legal, challenge.

Accuracy of System

Although equipment standards have not yet been established across the industry, the International Association of Chiefs of Police (IACP) has created a committee to investigate the photo-monitoring systems. One of the goals of the committee is to rate the accuracy of various cameras, including guidelines for how cameras should be certified. At present, verification of systems in Virginia generally takes place at two points. First, inspections of the physical system usually occur when the 35 mm wet film is removed from the camera. Second, the photographs are inspected and affirmed by the contractor and by a unit of the police department to ensure their accuracy before a citation is issued to a vehicle owner. Registered owner information is then obtained from the Virginia Department of Motor Vehicles based on the data submitted by the owner in accordance with the Commonwealth's vehicle laws. The exact procedure is chosen by the locality. Appendix G details these steps in the verification process.

Public Opinion

Survey respondents at five locations in Albemarle County, Fairfax, Arlington, Roanoke, and Martinsville were asked a variety of questions pertaining to their opinions regarding photo-red enforcement (see Figure 1). VDOT staff completed a survey at a sixth location (the VDOT Martinsville Residency). Overall, approximately two-thirds of respondents indicated they would support a program (see question 3 in Appendix E), as indicated in Table 5. A few persons indicated their support was conditioned on the program being for used for red light running and not for speeding. When asked whether they thought a photo-red enforcement program could help improve safety (see question 8 in Appendix E), more than three-fourths of respondents indicated yes.

Figure 1. Display for Public Opinion Survey Conducted in Arlington, Roanoke, and Martinsville Malls

Table 5. Public Opinion Results (% of Respondents)

Location	Favor Photo-Red Program	Oppose Program	Think Program Can Improve Safety	Think Program Cannot Improve Safety
Albemarle	79	21	84	16
Fairfax	64	36	77	23
Arlington	59	41	72	28
Roanoke	66	34	81	19
Martinsville	72	28	90	10
VDOT Martinsville Residency	68	32	79	21
Overall	66	34	80	20

Fiscal Feasibility

Net Cost to a Jurisdiction

Costs and revenues were analyzed strictly in monetary terms with respect to the operation of the program in various jurisdictions without considering the financial impact of crashes or any other consequential effects. Because the duration of the program varies in each jurisdiction, annual costs and annual revenues were converted into net present worth for a particular year of operation. Interest rates of 3%, 4% and 5% were analyzed, but since no significant difference was found in the three interest rate scenarios, the 3% rate was considered for the final study. The resultant difference in revenue and cost (i.e., net revenue) for each year was then summed and the equivalent uniform annual worth was determined. This amount is hereafter referred to as the *annual net revenue* and intuitively reflects the average net revenue for a single year. Although the programs have varying contracts as shown in Table 4, it was possible to find common calculation elements. These elements are defined in Appendix F.

Table 6 shows the revenue-cost ratio, the annual net revenue, and the net revenue-per-citation for each jurisdiction, *based on the data provided*. The difference in the amounts among jurisdictions is likely attributable to the fact that jurisdictions do not use the same calculation components in determining cost. For example, some do not consider *all* of the internal cost components of the program, resulting in the overestimation of the revenue-cost ratio. Another factor responsible for the variation in amounts is that some jurisdictions incur lower startup costs by renting the camera and related equipment whereas other jurisdictions incur higher startup costs by purchasing the equipment.

Table 6. Summary of Financial Impacts for Photo-Red Programs[a]

Jurisdiction	Revenue-Cost Ratio	Annual Net Revenue	Net Revenue Per Citation
Alexandria	0.88	–$40,382	–$6.32
Arlington	1.02	$12,499	$0.88
Fairfax City	1.03	$11,004	$1.33
Fairfax County	0.90	–$97,811	–$5.31
Falls Church	1.00	$545	$0.06
Vienna	0.62	–$52,677	–$29.45

[a]See Appendix F for the full calculations.

Costs of Traditional Methods of Enforcement

A survey was sent to all police departments in Virginia to ascertain how red light violations are treated in the Commonwealth. Thirty-six jurisdictions responded to the survey. A question of interest was "If a police officer is working at an intersection for one hour, how many red light violators will he or she cite (best estimate)?" Twenty-six jurisdictions answered this question, giving answers ranging from 1 to 12, with on average a single police officer at an intersection being able to write 3.6 citations per hour. Because of inconclusive and limited data available for the traditional police enforcement methodology (as opposed to camera enforcement methodology), no financial comparison was performed. However, a qualitative comparison highlighting the differences is provided in Table 7.

Table 7 shows how the cost for camera and traditional approaches varies. Fundamentally, the camera enforcement and traditional enforcement have two different niches. For situations where there are many violations at a specific approach or intersection, the camera may offer an advantage, given its low marginal cost and its ability to capture all violations. For situations where there are not as many violations in any given intersection but rather the violations are scattered among different approaches, the traditional enforcement may be preferable. Both of these statements assume no spillover effects.

Table 7. Summary of Cost Characteristics Affecting Camera and Traditional Approaches

Characteristic	Camera Enforcement	Traditional Enforcement
Initial costs	*High*: installation of a camera at an intersection requires creation of a complete system for processing and verifying citations	*Low*
Marginal costs	*Low*: once system is in place, there is relatively little additional cost to operate it every hour of year	*High*: each additional hour of police enforcement generally increases cost by proportionate amount
Ability to randomly target select intersections on the fly	*Low*: cameras must be installed at specific intersection (but they can be relocated to some degree)	*High*: patrols can be dispatched to different locations with relative ease
Ability to randomly target select approaches on the fly	*Low*: the specific approach to be monitored must be chosen in advance	*High*: officers can monitor a wide variety of approaches
Ability to continually track violations	*High*: if a large number of violations occur simultaneously, camera can capture them all	*Low*: officers generally need to be focused on one or possibly a couple of violations at a time
Revenue per citation	*Low*: $50	*High*: $100
Ability to detect vehicles that run the red light in high-traffic situations	*High* in that regardless of traffic conditions, license plate will generally be noted	*Low*: in some high-traffic situations, officers have noted it is not safe to travel through intersection
Consistency of pricing among jurisdictions	*Varies:* depends on (1) contractor, and (2) even for same contractor the jurisdictions may have negotiated a different pricing schedule	*Varies:* depends on (1) number of law enforcement officers, and (2) even within same jurisdiction, salaries of officers will vary
Spillover effects	*Possible* in sense that motorists may perceive cameras at one site as indicative that all sites are monitored	*Possible* in sense that motorists may perceive officers at one site as indicative that all sites are patrolled

Operational Feasibility

Citation Impacts

Changes in Citation Rate

Reliable citation data were successfully obtained from four jurisdictions: Alexandria, Arlington, Fairfax County, and Vienna. To evaluate the impact of camera enforcement on citations, a 3-month stabilization period was considered and the number of citations in the 4th, 5th, and 6th months after camera installation were compared with the number of citations during the most recent 3 months of operation.

At some intersections in Fairfax County, the yellow interval was changed after installation of the cameras. In those cases, a period with a constant yellow interval was considered. For example, the intersection of Leesburg Pike and Towlston Road had a camera installed in October 2000 and then had its yellow interval changed in March 2003. The total number of citations sent in January 2001, February 2001, and March 2001 were compared with the total number of citations sent in December 2002, January 2003, and February 2003. For the other jurisdictions of Alexandria, Arlington, and Vienna, yellow timing information was not used in the creation of Table 8.

Table 8 summarizes these results for each intersection and each jurisdiction. Thus, for the Leesburg Pike and Towlston Road intersection, the number of citations from January through March 2001 (1,036) is compared to the number of citations from December 2002 through February 2003 (292), which yields a 72% reduction for this period when the yellow interval did not change.

Overall, most intersections showed a net reduction: this was the case for 9 of the 11 Fairfax County intersections, 1 of the 2 Vienna intersections, 2 of the 3 Alexandria intersections, and 4 of the 5 Arlington intersections. By jurisdiction, the average reductions in intersection citations were 46% (Alexandria), 12% (Arlington), and 23% (Fairfax County), with a 6% increase in Vienna.

The comparisons for Fairfax County are based on periods with a constant yellow time. When the periods are expanded to include changes in the yellow time, it is logical that changes in the yellow time would further affect the number of violations. Figures 2, 3, and 4 graph the number of citations at three Fairfax County intersections after the installation of cameras. In Figures 2 and 3, the yellow time was increased in March 2003, whereas in Figure 4 the yellow time remained constant.

Table 8. Impact of Cameras on Number of Citations in Different Jurisdictions in Virginia

Intersection	Month (Early Period) 4th	5th	6th	Month (Later Period) 3rd most recent	2nd most recent	1st most recent	% Reduction in Crashes
Alexandria							
Patrick & Gibbon Street	1047	1205	878	306	351	388	67
Seminary & Nottingham	589	616	533	101	141	166	77
Duke St. & Walker St.	408	238	566	472	589	212	–5 (increase)
Average Reduction for Alexandria							46
Arlington							
Rt. 50 @Fillmore St. (EB, started Feb 1999)	103	56	654	29	19	28	91
Rt. 50 @ Manchester St. (WB, started July, 2001)	292	284	319	868	950	619	–172 (increase)
Wilson @ Lynn St. (EB, started Feb, 1999)	1249	1322	1650	783	906	646	45
Lynn St. @ Lee Hwy. (NB, started Jan, 2000)	340	355	333	147	138	84	64
Jeff Davis Hwy @ S 27th St. (SB, started July 2001)	880	818	811	498	500	688	33
Average Reduction for Arlington							12
Fairfax County							
Fairfax County Pkwy. & Newington Rd.	370	253	353	282	217	173	31
Fairfax County Pkwy. & Popes Head Rd.	495	442	486	397	329	287	29
Leesburg Pike & Towlston Rd.	370	293	373	101	100	91	72
Little River Tnpk. & Heritage Drive	115	119	152	101	107	74	27
Route 28 & Old Mill	547	274	182	180	165	119	54
Route 50 & Fair Ridge Dr.[a]	16	23	7	30	21	8	–28 (increase)
Route 50 & Jaguar Trail	365	465	397	346	341	238	25
Route 50 & Rugby Rd.	197	231	85	113	194	196	2
Route 7 & Dranesville Rd.	285	372	350	314	219	219	25
Route 7 & Route 66	448	510	395	264	296	312	36
Route 7 & Westpark Drive	286	170	156	244	215	234	–13 (increase)
Telegraph Rd & Huntington Ave.	193	174	163	160	177	158	7
Route 7 & Carlin Spring Rd.	200	145	212	149	138	89	32
Average Reduction for Fairfax County							23
Vienna							
Maple Ave. E/Follin Lane (EB, started June 1999)	466	518	343	283	336	320	29
Maple Ave. E/Nutley St. (EB, started Sep 2003)	33	53	64	76	69	68	–42 (increase)
Average reduction for Vienna							–6 (increase)
Average reduction for all four jurisdictions (each *intersection* carries equal weight)							**21**
Average reduction for all four jurisdictions (each *citation* carries equal weight)							**34**

[a]Because the number of citations for Route 50 & Fair Ridge Drive is quite small relative to the other intersections in Fairfax County, this increase may be an anomaly.

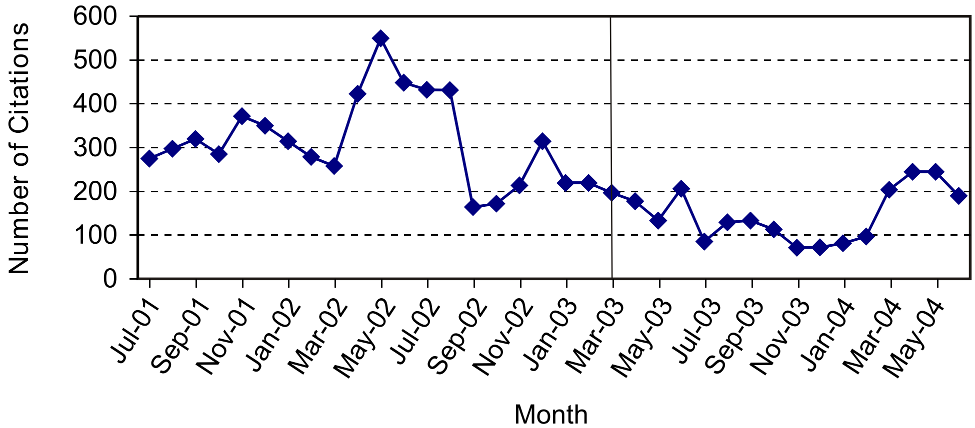

Figure 2. Changes in Number of Citations at Route 7 and Dranesville Road (Yellow interval changed in March 2003)

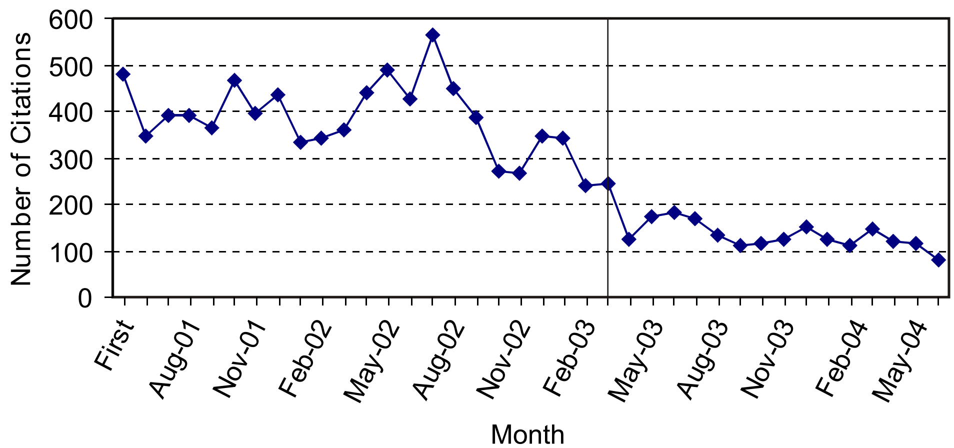

Figure 3. Changes in Number of Citations at Route 50 and Jaguar Trail (Yellow interval changed in March 2003)

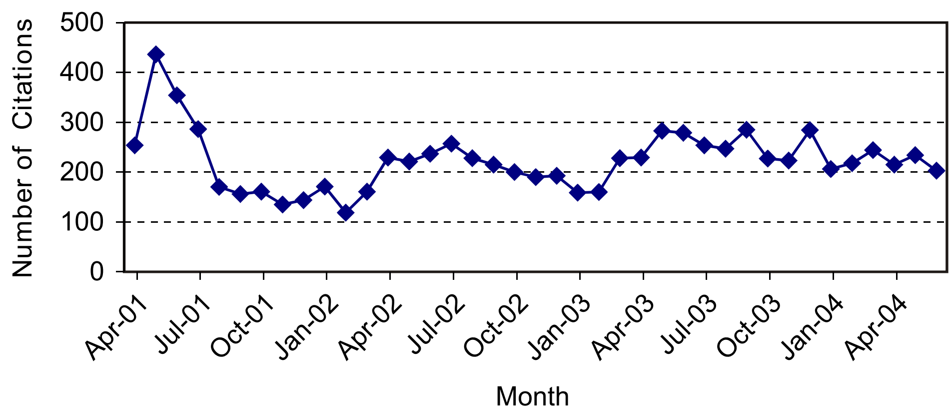

Figure 4. Changes in Number of Citations at Route 7 and Westpark Drive

Changes in Citation Pattern

The *time into the red* is another relevant feature of the citations: after the signal turns red, at what point do most of the citations occur? Table 9 shows how the *85th percentile time into the* *red* changed at the various traffic signals. For example, the first row of Table 9 shows that for the Patrick and Gibbon Street intersection in Alexandria, 85% of all citations occurred within 1.30 seconds of the signal changing to red in the 3 early months of the signal's operation. In the 3 most recent months, however, that 85th percentile time had increased slightly; in the most recent month, 85% of citations occurred with 1.50 seconds of the signal changing to red. For that particular signal, therefore, the difference between the earlier and later periods is positive, reflecting that in the later period, the violations were occurring later into the red than in the earlier period.

Table 9. Impact of Cameras on 85th Percentile Time in Red in Different Jurisdictions in Virginia

Intersection	Month (Early Period)			Month (Later Period)			Difference
	4th	5th	6th	3rd most recent	2nd most recent	1st most recent	
Alexandria							
Patrick & Gibbon Street	1.30	1.30	1.30	1.30	1.40	1.50	0.10
Seminary & Nottingham	1.30	1.30	1.30	1.20	1.30	1.10	-0.10
Duke St. & Walker St.	1.30	1.40	1.40	1.60	1.60	1.64	0.25
Arlington							
Rt. 50 @Fillmore St.	1.20	1.20	1.50	1.80	0.93	1.30	0.04
Rt. 50 @ Manchester St.	1.10	1.00	0.93	1.60	1.60	1.60	0.59
Wilson @ Lynn St.	1.80	1.70	2.06	1.10	1.20	1.10	-0.72[a]
Lynn St. @ Lee Hwy.	1.30	1.20	1.30	1.42	1.90	1.46	0.33
Jeff Davis Hwy @ S 27th St.	1.00	1.00	1.00	0.90	1.00	1.00	-0.03
Fairfax County							
Fairfax County Pkwy. & Newington Rd.	1.40	1.50	1.50	1.20	1.10	0.93	-0.39
Fairfax County Pkwy. & Popes Head Rd.	1.00	1.10	1.00	1.10	1.00	1.00	0.00
Leesburg Pike & Towlston Rd.	1.10	1.00	1.10	1.00	1.10	1.23	0.04
Little River Tnpk. & Heritage Drive	0.80	0.80	1.10	0.93	0.90	0.89	0.00
Route 28 & Old Mill	1.00	0.82	1.00	1.00	1.00	0.90	0.03
Route 50 & Fair Ridge Dr.	1.81	1.09	1.73	2.44	1.89	0.91	0.21
Route 50 & Jaguar Trail	1.00	1.00	1.00	1.20	1.00	1.06	0.09
Route 50 & Rugby Rd.	1.10	1.10	1.10	1.00	1.00	1.00	-0.10
Route 7 & Dranesville Rd.	1.20	1.00	1.10	1.00	1.00	1.00	-0.10
Route 7 & Route 66	1.20	1.10	1.10	1.20	1.40	1.00	0.07
Route 7 & Westpark Drive	1.00	1.10	1.10	1.10	1.02	0.98	-0.03
Telegraph Rd & Huntington Ave.	1.30	1.30	1.20	1.30	2.86	2.51	0.96[c]
Route 7 & Carlin Spring Rd.	0.93	0.90	0.80	0.90	0.90	1.06	0.08
Vienna							
Maple Ave. E/Follin Lane	1.97	2.04	2.24	1.43	1.41	1.57	-0.61
Maple Ave. E/Nutley St.	0.98	1.06	2.71	1.82	1.25	1.88	0.06[b]

[a]Because this signal showed the greatest reduction in the 85th percentile time into the red, its citation history is shown in Figure 5.
[b]Because this signal showed little change in the 85th percentile time into the red, its citation history is shown in Figure 6.
[c]Because this signal showed the greatest increase in the 85th percentile time into the red, its citation history is shown in Figure 7.

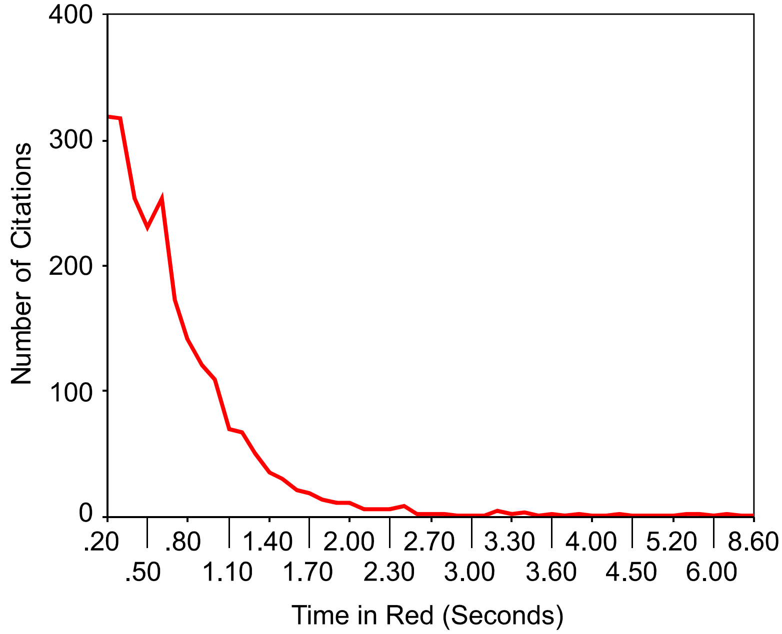

Figure 5. Citation History at Wilson/Lynn St., Arlington
(This is the signal with the greatest reduction in 85th percentile time into the red.)

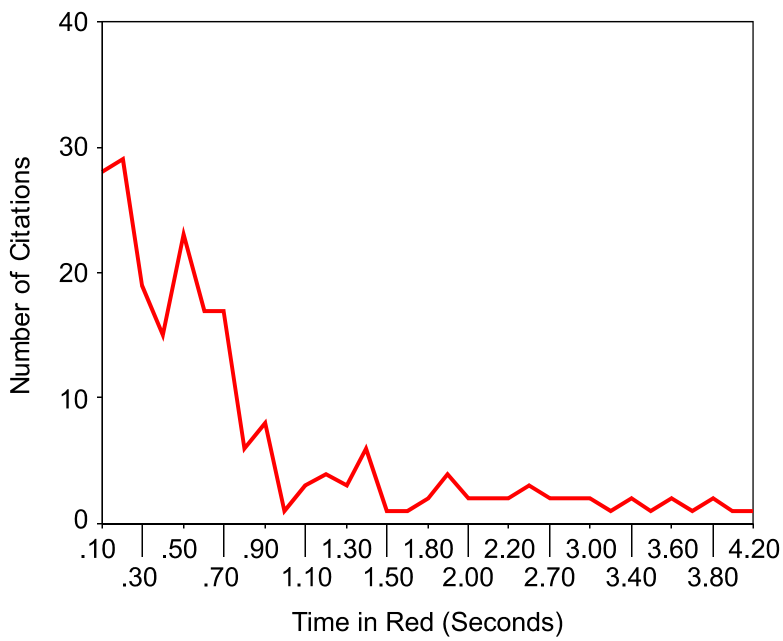

Figure 6. Citation History at Maple Ave. E/Nutley St., Town of Vienna
(This is the signal with little change in 85th percentile time into the red.)

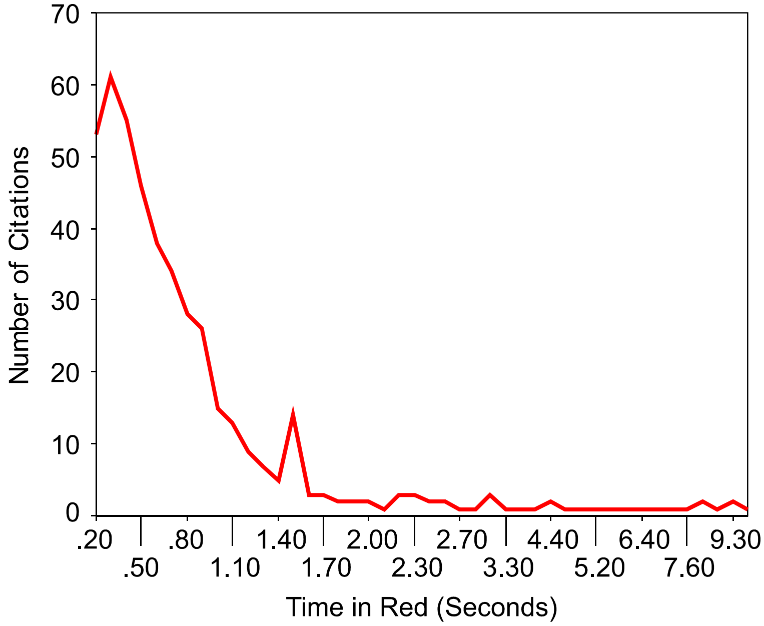

Figure 7. Citation History at Telegraph Rd./Huntington Ave., Fairfax County
(This is the signal with the greatest increase in 85th percentile time into the red.)

There is no apparent pattern between the percentage reduction in citations (from Table 8) and the change in 85th percentile time into the red (from Table 9 or Figures 5, 6, and 7). These types of figures may be appropriate for future study, however, to examine crashes more closely at specific signals with driver violation patterns.

Safety Impacts

Safety impacts based on reportable crashes are presented for the four jurisdictions for which crash data were available: Fairfax County, Fairfax City, Falls Church, and the Town of Vienna. For Fairfax City, Falls Church, and Vienna, results for the level 1 and level 2 analysis are presented, which is the number of crashes per intersection year and the modified crash rates per intersection year. The limitation of this analysis is that as shown in Table 3, the results do not control for confounding factors such as changes in signal timing. Rather, these results are an imperfect and rough indication of the impact red light cameras may be having if a variety of assumptions listed in Table 3 are made. For Fairfax County only, level 3 and 4 analyses are presented. Details of the results are provided in Appendix D, and Tables D5, D9, D13, and D17 in that Appendix focus on the statistical inferences that may be drawn.

Summary of Before and After Comparison (Level 1 and Level 2 Analyses)

The analysis procedures used in levels 1 and 2 do not consider the confounding factors—yellow time, lag time, and percentage heavy trucks—considered in levels 3 and 4. They are, however, easiest to interpret. Based on comparing the crash frequency or the modified crash rates at intersections before cameras were installed with those after cameras were installed, five key findings are:

1. *The presence of the cameras is generally correlated with a decrease in the number of crashes directly attributable to red light running, where one driver is charged with the offense of "failure to yield to stop-go light.*" In Fairfax City and Falls Church, this decrease is statistically insignificant, whereas in Fairfax County and Vienna, this decrease is statistically significant.

2. *The presence of the cameras also seems somewhat correlated with an increase in the number of rear-end crashes*. In Fairfax County, these increases were significant, whereas in Fairfax City and Vienna, the increases were statistically insignificant. In Falls Church, cameras were associated with an insignificant decrease in rear-end crashes.

3. *The presence of the cameras gives mixed results for total angle crashes*. For Fairfax City, there was an insignificant increase, and for Vienna, there was a significant decrease.

4. *The presence of the cameras gives mixed results for total crashes*. For Fairfax City and Fairfax County, there were insignificant increases, and for Vienna and Falls Church, there were insignificant decreases.

5. *The presence of the cameras may be weakly correlated with an increase in total injury crashes.* The cameras were associated with an insignificant increase in total injury crashes in all four jurisdictions.

Interestingly, the level 1 results (based only on a before-after comparison) and the level 2 results (which incorporate traffic volumes) are largely consistent. Thus for a basic analysis, although having volume data is helpful, some insights can be garnered even without such data.

One plausible interpretation of the data is that the red light cameras are affecting collision types as would be expected: they are reducing the number of crashes attributable to red light running, they are increasing rear-end crashes, and they are reducing angle crashes (the increase in angle crashes in Fairfax City and the decrease in rear-end crashes in Falls Church were statistically insignificant.) However, none of the four jurisdictions showed an overall reduction in total injury crashes, even when increased volumes were taken into account as shown in the rightmost columns of Tables D5, D9, D13, and D17.

In short, the cameras are clearly reducing crashes directly attributable to red light running, but the decrease in total injury crashes is not evident from a simple before-after comparison. The question remains as to whether this is attributable to the cameras not reducing injury crashes or that this type of analysis has not yet isolated injuries due to red light running and injuries associated with other crash events. For that reason, a more detailed analysis was performed.

Summary of Analysis of Variance (Level 3 Analysis)

By themselves, the analysis of variance (ANOVA) results raised almost as many questions as they answered. In one sense, the results were not surprising. Generally, ANOVA suggests that cameras are correlated with an increase in total crashes, rear-end crashes, and total injury crashes, and they are correlated with a decrease in injury crashes attributable to red light running and total crashes attributable to red light running. Statistically, however, all of these effects are insignificant (i.e., $p > 0.05$) except for the increase in rear-end crashes.

However, as shown in Tables D19 through D23 in Appendix D, the interaction effects raise questions about how to interpret some of these effects. For example, a strict interpretation of one of the results in Table D23 is that cameras are correlated with a decrease in red light running crashes in some cases with a higher speed limit (yet correlated with an increase in such crashes in some cases with a lower speed limit.) As discussed in Table D23, there are several legitimate reasons for questioning the latter result, including the fact that speed limit data (rather than approach speed data) were used, since approach speeds were unavailable. However, the interaction effects represent an avenue for further exploration with these programs and should be considered in performing site selection. As exemplified in Tables D22 and D23, these interaction effects can provide some guidance for determining the situations in which cameras should be used.

Summary of Empirical Bayes Method (Level 4 Analysis)

The latter half of Appendix D shows the results of an Empirical Bayes analysis for Fairfax County crash data only. These results suggest the following:

- The cameras are correlated with an increase in total crashes of 8% to 17%.
- The cameras are correlated with an increase in rear-end crashes related to the presence of a red light; the increase ranges between 50% and 71%.
- The cameras are correlated with a decrease in crashes attributable to red light running, and the decrease is between 24% and 33%.
- The cameras are correlated with a decrease in injury crashes attributable to red light running, with the decrease being between 20% and 33%.
- The cameras are correlated with an increase in total injury crashes, with the increase being between 7% and 24%.

Summary of Crash Data Interpretation

Taken in tandem, these results strongly suggest that the cameras reduce crashes attributable to red light running and lead to an increase in rear-end crashes. These results also suggest that the cameras likely reduce angle crashes. Because rear-end crashes comprise the bulk of total crashes, the increase in total crashes might have been attributable to the increase in rear-end crashes.

Finally, the bullets pertaining to injury crashes under each of the previous sections merit attention. The Empirical Bayes results suggest that red light cameras do, in fact, reduce injury crashes attributable to red light running. However, total injury crashes are not reduced. A contributing factor may be that because red light running crashes are only a portion of the total crashes at an intersection, reductions in injury red light running crashes may be masked by other types of injury crashes. That does not answer two fundamental questions about the increase in total injury crashes, however. First, what are the reasons for the increase in other types of injury crashes? The level 4 analysis controls for volume, signal timing, truck percentages, and yellow timing; thus, some factor other than these is responsible for the increase. Second, how does the severity of the crashes compare?

In response to the first question, there are two possible answers. One possibility is that there may be confounding factors unrelated to the cameras that are leading to an increase in the injury crashes. A second possibility is that the cameras are contributing to rear-end crashes or other types of crashes that are resulting in increased injuries. The latter possibility leads to the question concerning severity. It may be the case that despite the increase in total injury crashes, the overall crash severity is reduced. This latter finding could result from the fact that when the narrative and diagram were examined for Fairfax County crashes, almost all crashes attributable to red light running were angle crashes, which are thought to be severe relative to rear-end crashes. However, because severity was not explicitly studied (i.e., crashes were only categorized as “injury” or “non-injury”), such a hypothesis cannot be verified or refuted by this study. The generalization that angle crashes are more severe than rear-end crashes, however, may apply (see discussion in Appendix D, Table D26), and the statement that this study suggests that most red light running crashes were angle crashes is true.

Figure 8 illustrates how the crash types (total, total injury, angle, rear-end, and crashes where the driver was charged with disregarding a red light) evolved in relation to the composite average annual daily traffic (which is the average major road volume in thousands of vehicles) for one particular jurisdiction: Vienna. Figure 8 suggests substantial variation in the data.

Safety Impacts for Enforcement Techniques

Finally, anecdotal information was provided (by representatives from some jurisdictions who have a photo-red program) regarding another safety impact directly related to how intersections are patrolled: the cameras relieve the law enforcement officer of the necessity to enter the intersection. For example, the City of Alexandria noted:

> [P]hoto enforcement can be conducted safely without the need to pursue and stop violators in traffic lanes. In fact, some locations are virtually unenforceable from a safety standpoint due to design and volume of traffic. In these locations, enforcement is likely to be more dangerous than the red light violation.

Similarly, Arlington County noted that “safe enforcement for police” was a reason for having the photo-red program.

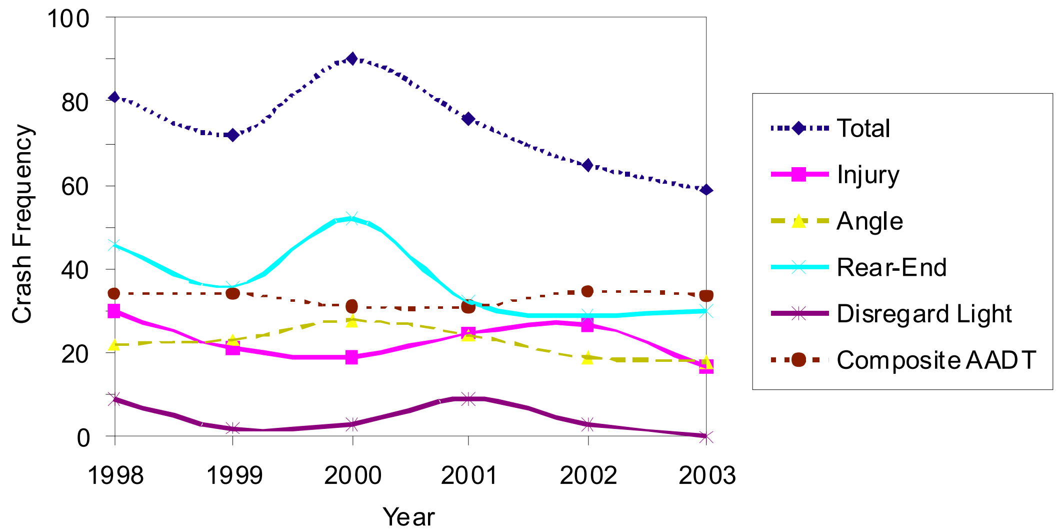

Figure 8. Changes in Vienna Crash Frequency for the Six Intersections Over the 6-Year Study Period

CONCLUSIONS

Conclusions regarding the technical, fiscal, and operational feasibility of Virginia's photo-red enforcement programs may be drawn based on the results of this study. A summary of the advantages and disadvantages of Virginia's photo-red enforcement programs is provided in Table 10.

The reader must keep in mind that these conclusions are based on observations that could be drawn from Virginia's seven photo-red enforcement programs. Although the legal and technical implications should apply to all seven programs, basic cost information was extracted for only six (all but Virginia Beach, which is too new to have operational data), citation information for only four (Alexandria, Arlington, Fairfax County, and Vienna), summary crash information for only four (Fairfax County, Fairfax City, Falls Church, and Vienna), and detailed crash information for only one (Fairfax County).

The conclusions are as follows:

- *Virginia's photo-red enforcement programs are technically feasible in terms of meeting Virginia's legal requirements, performing with sufficient accuracy, and enjoying the support of Virginia's public.*

- *The fiscal feasibility of Virginia's programs will depend on efforts to bring operational costs in line with revenue.* A full determination of economic feasibility would depend on the outcome of a complete crash analysis.

- *With regard to operational feasibility, there are indications that Virginia's programs potentially improve safety.* The number of crashes attributable to red light running has decreased, although the number of rear-end crashes has increased. These two findings are consistent with those in the majority of the literature surveyed. The number of citations mailed has also decreased. Thus, the cameras do appear to be affecting driver behavior. The unresolved question, however, hinges on the injury crashes: the cameras are associated with an increase in total injury crashes and a decrease in red light running injury crashes. As discussed in this report, the injuries associated with red light running crashes may be more severe; this evaluation, however, did not encompass crash severity (except to classify crashes as injury or non-injury). Thus, it can be said only that Virginia's programs potentially improve safety but that additional data are needed to fully determine the merits of the cameras.

Table 10. Advantages and Disadvantages of Virginia's Photo-Red Enforcement Programs

Test of Feasibility	Advantages	Disadvantages
Technical	• Legally feasible • Programs appear to operate without bias	• May be challenging to administer because of in-person service requirement in Code • Concerns exist about programs outside Virginia
Fiscal	In some cases where program does not appear to generate revenue, it may be stated from a public relations perspective that revenue generation is not the reason for the program.	In some cases where program does not appear to generate revenue, the monies spent for photo-red enforcement might be better spent on other safety programs.
Operational[a]	• Reduces crashes attributable to red light running • Reduces injury crashes attributable to red light running • Reduces violation rates	• Increases rear-end crashes • Increases total injury crashes

[a]All crashes were coded as "injury" or "non-injury." When the narrative and diagram were examined for Fairfax County crashes, almost all crashes attributable to red light running were angle crashes. Angle crashes are thought to be more severe than rear-end crashes. However, severity was not explicitly evaluated in this study.

RECOMMENDATIONS

Because they appear to meet the three tests of technical, fiscal, and operational feasibility and because they show some indication of improving safety, photo-red programs in Virginia should continue. However, to improve their effectiveness, five recommendations are noted:

1. *Continue photo-red programs in Virginia*. These programs have the potential to improve safety in Virginia. However, as discussed in this report, additional information is required to determine their feasibility, such as the comparison of the severity of the injuries in total injury crashes and red light running injury crashes. Therefore, continuing the program for at least one year would allow necessary information to be obtained and more definitive conclusions to be drawn.

2. *If programs are continued or expanded, strongly encourage localities to plan their own evaluation strategy before initiating a program and continue to monitor the*

existing programs statewide. One way to facilitate this evaluation is to develop a "best practices" guide describing the types of detailed data that must be collected even before the program begins. Such a guide might help localities conduct their own evaluations, given that incorporated cities and towns, with smaller staff, manage their own roadways. The guide could be based on the approaches illustrated in Appendix D. In particular, the interaction effects discussed in Appendix D suggest that traffic engineering factors—yellow interval, approach volume, speed, and truck percentages—need to be considered along with crash history when sites are being selected. From a statewide perspective, the tradeoff between increased rear-end crashes (along with increased total injury crashes) and decreased red light running crashes (along with decreased injury red light running crashes) needs to be probed further by examining crash severity, as previously described.

3. *Consider revising the in-person service requirement of the Code of Virginia.* Although Virginia's photo-red enforcement programs may legally continue without changes to the *Code,* revisions pertaining to the delivery of the summonses could make the program easier to administer. Virginia's current red light camera statute (§ 46.2-833.01) requires that persons be summoned in accordance with Section 19.2-76.3 of the *Code,* which in turn requires an in-person summons should a person not appear in court or pay the penalty after having received a citation. Thus, the statute could be revised so that personal service would not be required before a default judgment could be entered against no-shows. The relevant language is provided in Appendix H.

4. *Introduce steps to reduce program net costs, but consider the role of public perception and the message sent to vendors when taking such steps.* Generally, the number of violations will decrease (which will reduce revenue) while many cost components will remain fixed, such as maintenance expenses. At least three options can be considered. First, the Commonwealth should consider using the group buying power of all jurisdictions to acquire equipment and vendor contracts. Second, jurisdictions could increase the penalty for violations from $50 to $100, which would be more in line with the fine most jurisdictions levy under traditional police enforcement. (That figure does not include court costs). A third option, which the investigators do not recommend, is that localities consider a fee-per-citation payment method. The reason for not favoring this option is that jurisdictions should consider the manner in which the contractor is paid from a public relations perspective. Each of the seven jurisdictions has differences in how the contractor is paid: some pay a flat fee and others pay an amount based on the number of citations. There is no evidence in this study that Virginia jurisdictions ever used a fee-per-citation as a way to increase revenue; however, the existence of a fee-per-citation could give the appearance of such a practice. Thus, the first two options are recommended.

5. *To support an effective statewide evaluation, consider steps for sharing crash data between VDOT and localities.* Collaborative steps between VDOT and jurisdictions that manage their own roadway systems may be taken to facilitate the sharing of crash data. VDOT already has complete crash data for such jurisdictions with one

exception—the specific street or intersection must be queried manually. That is, all crashes at a particular intersection in a given city cannot be identified unless all crash reports for the city are reviewed and manually sorted by location. If VDOT and the localities can agree on a method for obtaining this crash location information (whether by localities entering the data or VDOT entering the data), this large resource for VDOT crash data for independent jurisdictions could be used in safety evaluations. These changes would not require modifications to the crash report form.

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APPENDIX A
LETTER FROM SECRETARY CLEMENT REQUESTING THIS STUDY

COMMONWEALTH of VIRGINIA

Office of the Governor

Whittington W. Clement
Secretary of Transportation

P.O. Box 1475
Richmond, Virginia 23218

(804) 786-8032
Fax: (804) 786-6683
TTY: (804) 786-7765

June 2, 2004

Dr. Gary R. Allen, Director
Virginia Transportation Research Council
530 Edgemont Road
Charlottesville, Virginia 22903

Dear Dr. Allen:

The purpose of this letter is to request that you undertake a study and prepare a report detailing the advantages and disadvantages of red light camera (photo red) programs, and summarizing the experiences of those localities that use red light cameras. As you know, the statute authorizing red light cameras (§ 46.2-833.01 of the Code of Virginia) expires July 1, 2005, and must be amended by the 2005 General Assembly if these programs are to continue beyond that date.

Localities with red light cameras believe they are very effective in promoting traffic safety and are anxious to have this amendment enacted during the next General Assembly Session. Conversely, opponents of the legislation are not anxious to have this amendment enacted. Therefore, an unbiased and technical study is in order.

Please include the following in your study and report:

- A summary of each Virginia locality's program, including the date it was initiated, the number of intersections and cameras in use, the type of technology, annual program costs (capital and operating), annual revenues, and the effect the cameras have had on red light violations at intersections where they are used (i.e. some type of before and after comparison).
- A comparison, if available, of red light violations at intersections where a camera is in use and intersections where no camera is used.
- Available data on the accident rate (including rear end collisions) at intersections that have cameras versus those that do not.
- A comparison of the costs and benefits of addressing red light violations using traditional police enforcement (i.e., having police officers watch for and apprehend violators) versus red light camera enforcement.

- Survey and other data showing levels of public support for red light camera programs.

- Summaries of studies and analyses of red light camera programs in use outside the Commonwealth.

- Recommendations on any technical changes that should be made to the current red light camera law (e.g., timing of yellow lights, grace period between the time a light turns red and a violation is recorded, signage) if it is extended.

- Any other matters that the Research Council believes will help the General Assembly and the Governor evaluate the effectiveness of red light cameras.

Since the localities that operate red light camera programs are directly affected by any amendments to the existing law and have developed a great deal of expertise in this area, I ask that you work with them as full partners in preparing your report. Those localities should be able to provide you with most of the data necessary for this study. I have been assured that they are anxious to work with you. Mike Edwards of the Virginia Municipal League (telephone 804-649-8471) and Bernard Caton of the City of Alexandria (telephone 703-838-3828) have agreed to coordinate the participation of the red light camera jurisdictions and appropriate law enforcement agencies in this study.

Please complete your report by December 1, 2004, so that it will be ready in time for full consideration by the 2005 General Assembly. I intend to distribute copies to legislative leaders.

Sincerely,

Whittington W. Clement

WWC/kl

CC: The Honorable Martin E. Williams
The Honorable Leo C. Wardrup, Jr.
The Honorable Beverly J. Sherwood
The Honorable John Marshall
Mr. Philip A. Shucet, Commissioner

APPENDIX B
TWO-PART SURVEY SENT TO VIRGINIA JURISDICTIONS

Survey of Photo-Red Enforcement Programs in Virginia

Conducted by: Virginia Transportation Research Council
Please return to: (434) 293-1990 (fax) or Wayne.Ferguson@Virginiadot.org

Name of the Contact: Commander Daniel Gollhardt   Locality: City of Alexandria
Email: Daniel.Gollhardt@ci.alexandria.va.us
Fax: (703) 838-6309 also B CATON
W HANES
P STORY

1. Please provide the date when Alexandria's enforcement program was initiated. 11/97

2. Pleases indicate the specific objectives of your program (check all that apply).

- [X] To reduce violations
- [X] To reduce accidents
- [X] To increase pedestrian safety
- [X] To change driver behavior
- [ ] Other, please specify

3. Please indicate below who is responsible for the different functions shown (check all that apply).

	Project Planning and Management	Equipment Ownership	Design and Installation	Operation and Maintenance	Citation Data Processing	Decision To Issue Citation	Violator Inquiries	Archive Violation Data	Public Information Program
Alexandria Police Department	[X]	[ ]	[X]	[X]	[X]	[X]	[X]	[X]	[X]
Alexandria Traffic Engineering Section	[X]	[ ]	[X]	[X]	[ ]	[ ]	[ ]	[ ]	[ ]
VDOT Northern Virginia District	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Contractor	[ ]	[X]	[X]	[X]	[X]		[X]	[X]	[ ]
Other, specify	City MANAGER Staff [X] & COUNCIL	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]

4. Please indicate the criteria used to select intersections for camera locations (check all that apply).

- [X] Accident data
- [X] Violation data
- [X] Input from police personnel
- [X] Input from citizens
- [X] Site review by (Specify agency)
- [X] Other, please specify TRAFFIC VOLUME

5. What is the number of cameras currently used in your locality? 3

6. Are these cameras:

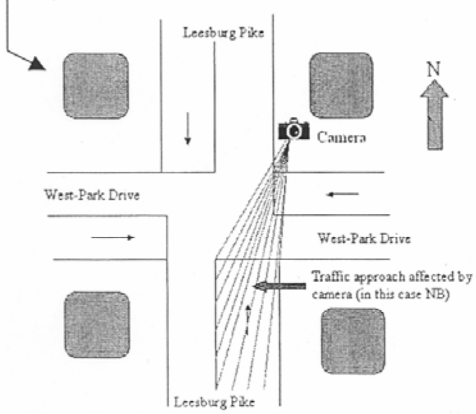
- [ ] Stationary
- [X] Rotated among different intersections

7. If cameras are rotated, what is the number of camera housings in your locality?

8. In the table below, please name the intersections where cameras are located.

Intersection Locations

Intersections Where Cameras Are in Use		
Location: Street 1/ Street2	Traffic approach affected by camera NB/SB/EB/WB	Date camera was installed
Example. Leesburg Pike/ Westpark Drive	*NB*	*15th Oct, 2000*
PATRICK & GIBBON STS.	SB	11/97
SEMINARY RD & NOTTINGHAM DR.	NWB	11/97
DUKE & WALKER STS.	EB	11/97
DUKE STREET & TAYLOR RUN PARKWAY	WB	3/04



9. How long after the light turns red does the camera begin taking pictures (lag time)?

☐ 0.1 sec ☐ 0.2 sec ☒ 0.3 sec ☐ 0.4 sec ☐ Other, please specify

10. Please give the name of the manufacturer of the cameras.

11. Please indicate the camera technology.

☒ 35 mm wet film ☐ Digital still photos ☐ Digital video ☐ Other, please specify

12. Does the agency use a contractor to operate the red light camera system?

☒ Yes (If yes, please skip question 13 and go to question 14)
☐ No (If no, please go to question 13 and skip question 14)

13. **Agency-operated systems:** Please provide us with the following cost data for your program.

Initial Purchase Cost	$
Installation Cost	$
Annual Maintenance Cost	$
Annual Revenues from Violations Issued	$
Any other financial data you deem relevant	

14. **Contractor-operated systems**: Please answer questions (a) and (b).

a. Please complete the following table. (Check all that apply)

Payment Option	Equipment Purchase Price		Equipment Installation Price		Equipment Maintenance Price		Citation Data Processing Price	
Fixed Price Payment	☐	$	☒ *	$27,000/ INTERSECTION	☐	$	☐	$
Fixed Monthly Payments	☐	$	☐	$	☒	$	☒	$27,750
Time Worked and Materials Used	☐	$	☐	$	☐	$	☐	$

Is there any threshold (maximum/minimum) limit on the payments made to the contractor? If yes, briefly explain

* THE $27K cost is only for intersections installed after 11/97.

b. How does the contractor get paid? (Check all that apply)

☐ Per violation ☐ Per citation ☒ Flat fee ☐ Other, please specify

Photo Red Light Questionnaire
15. Impact Data

a. Red light violations at sites where cameras are used versus comparable site where cameras are not used.

Response: No. We do not have violation data by location for non-camera sites.

b. Crash data at sites where cameras are used versus comparable site where cameras are not used.

Response: We can access crash data since 2001 for camera sites. See attached table. We are unable to identify comparable non-camera sites.

c. Traffic volume data for camera sites and comparable non-camera sites.

Response: We are still checking on traffic volume data for camera sites.

d. Signal timing data for camera sites and comparable non-camera sites.

Response: Our signal timing is based on intersection design and speed limits, not the presence of Photo Red light (i.e., red light camera intersections are no different than other intersections).

e. Speed data for camera sites and comparable non-camera sites.

Response: We capture speed at the time of violation in the intersection at Photo Red sites only. Comparison not possible. Photo sites are operated in 25 and 35 MPH zones.

f. Comparison of costs and benefits when comparing tradition enforcement to photo-red enforcement. Does one technique have a higher rate of successful appeals.

Response: We have not done formal cost analysis. It is obvious that photo enforcement is more effective than traditional (officer operated) in most respects. Photo enforcement is 24/7, traditional is not. No agency has the personnel to stake a red light for several hours a day let alone 24/7. Another important aspect is the fact that photo enforcement can be conducted safely without the need to pursue and stop violators in traffic lanes. In fact, some locations are virtually unenforceable from a safety standpoint due to design and volume of traffic. In these locations, enforcement is likely to be more dangerous than the red light violation.

Photo enforcement has fewer successful appeals. Photos and system data on the violation provide clear and convincing evidence in court as opposed to the "judgement" issues raised in court relative to officer issued citations. In addition, the $50 civil penalty assessed for a photo violation is not appealable to Circuit Court.

g. Any surveys or polls indicating public opinion of photo-red enforcement?

Response: No official surveys conducted. However, informally, requests for new photo red sites far outweigh complaints about photo enforcement.

Commander Daniel Gollhardt
Alexandria Police Department
FAX: (703) 838-6309
Email: Daniel.Gollhardt@ci.alexandria.va.us

Dear Commander Gollhardt,

Earlier in July we sent you a questionnaire regarding Alexandria's photo-red enforcement programs, which we are required to study as part of a report requested by Virginia Transportation Secretary Whitt Clement. The purpose of this letter is to obtain the additional crash and violation data we discussed on the last page of the questionnaire. To minimize your effort, we will accept your data in their native format. We ask that you ensure, however, that we can extract the following information if either you have these data or another person in Alexandria has these data:

(1) For each of the three Alexandria intersections where there is a red light camera:

a.	*List of red light violations* by date and hour
b.	*List of crashes*. For each crash, please include date, time, severity, type (angle, rear-end), approach (NB, SB, EB, or WB), and violation that indicates whether or not crash was related to red light running
c.	*Individual approach volumes*
	Percentage of truck volumes
d.	*Cycle length*
	Yellow time
	Phasing
e.	*Posted speed limit*
	Mean approach speed
	85th percentile approach speed
f.	*Dates of any changes* for the above such as changes in yellow times.

(2) The same data as above for at least three comparable intersections where there is not a red light camera

(3) Any other person who might be able to provide information on the following:

- Comparison of costs and benefits when comparing traditional enforcement to photo-red enforcement. (For example, does one technique have a higher rate of successful appeals?)
- Any surveys or polls indicating public opinion of photo-red enforcement.

(4) We need detailed violation data for the cameras such as the exact fraction of a second a violation occurred after the signal turned red. Who should we contact for that information?

For example, the contact might be (a) your agency, (b) the traffic engineering department, or (c) the contractor (ACS).

Thank you for your assistance,

Wayne S. Ferguson, Associate Director; Virginia Transportation Research Council; 530 Edgemont Road; Charlottesville, Virginia 22903; (434) 293-1900 (voice); (434) 293-1990 (fax).

APPENDIX C
PROCEDURE FOR CHECKING THE COMPLETENESS OF FALLS CHURCH CRASH DATA

For crashes that occur within incorporated cities, VDOT's internal Microsoft Access database and VDOT's internal FR300 database generally do not store the complete roadway location of the crash. Thus, when a crash occurs in an incorporated city, it is not possible to extract from VDOT databases only those crashes that occurred at a particular intersection. Further, if one has an interest in a particular type of crash in these cities—such as those located at signalized intersections—it is still *not* appropriate to extract only the crashes categorized as being "at a traffic signal" because coding discrepancies may result in these crashes being missed. For example, the team found that at a Fairfax County Parkway intersection, two out of eight crashes for a given year were missed because for those two crashes, the officer had not indicated a traffic control device, even though there was such a device. Thus, for crashes in these cities, the team would have had to examine all FR300s for the cities and then manually categorize them by location—with one potential exception.

Representatives from the City of Falls Church had kindly provided copies of the FR300 crash report forms for six Falls Church intersections for the years 1998 through 2003. These paper copies had the potential to eliminate the time-consuming manual extraction process described. The team desired to verify, however, that all of the relevant FR300s had been included in the Falls Church data set. Thus, the team chose a single year of Falls Church data—2002—and manually extracted all 288 crashes that occurred in Falls Church during that period from the VDOT crash report database. The 288 crashes were examined, and it was found that up to 52 crashes occurred at the six intersections of interest, as shown in Table C1. Then, the number of crashes based on the data provided by Falls Church was tabulated, as shown in the far right column of Table C1. A comparison of these two columns suggests the accuracy that would result from using the Falls Church data.

Table C1. Number of Crashes at Falls Church Intersections for 2002

Site	FR300s Extracted From VDOT Crash Database	FR300s Provided by the City of Falls Church
West Broad Street (Route 7) and North West Street (Route 705)	14[a]	13[b]
West Broad Street (Route 7) and Little Falls Street	5	5
East Broad Street (Route 7) and Roosevelt Street (South Street)	16[b]	15[b]
West Broad Street (Route 7) and Annandale Road (Route 649)	3	1[a]
West Broad Street (Route 7) and Birch Street	11[a]	11[a]
West Broad Street (Route 7) and Cherry Street	2[a]	3[a]
Total	51	48

[a]Includes one crash located more than 150 feet from the intersection.
[b]Includes two crashes located more than 150 feet from the intersection.

Neither data set in Table C1 is perfect. For example, 5 of the 288 crash report forms could not be located in the VDOT database. Further, initially the team erroneously attributed 1 of the 288 crashes (that had occurred at the intersection of Roosevelt *Boulevard* and Broad Street) as occurring at the intersection of Roosevelt *Street* and Broad Street. Although that error was corrected, there may be similar undetected reasons the left column of Table C1—the 51 crashes—is imperfect. The 48 crashes, therefore, from Falls Church should be sufficiently close such that the data can be used reliably for comparison purposes.

REFERENCE

Virginia Department of Motor Vehicles. *1998 Virginia Traffic Cras*h Facts. Richmond, 1999.

APPENDIX D
CRITERIA USED TO CLASSIFY CRASH DATA

Although brief summaries are presented in the body of the report, Appendix D describes how crashes were classified and details the results of statistical testing.

Classification of Crashes

It is possible to classify crashes using the entire crash report form (the FR300) including the diagram and narrative. This method generally is viewed as quite precise, but it is also labor intensive. It is also possible to classify crashes based on those data elements from the FR300 that lend themselves to being placed in a tabular database. This method is generally not as precise as looking at the diagram and narrative; thus, the categories are broader. The advantage of this latter method, however, is that classification takes much less time; thus, data from a greater number of jurisdictions may be analyzed. The critical factor is to ensure that the same category of crashes is studied when making comparisons. The categories, listed here, are not mutually exclusive:

1. Crashes not attributable to a red light or red light running
2. Rear-end crashes attributable to a red light
3. Crashes likely attributable to red light running
4. Injury crashes attributable to red light running
5. Total rear-end crashes
6. Total angle crashes
7. Crashes definitely attributable to red light running
8. Total injury-related crashes.

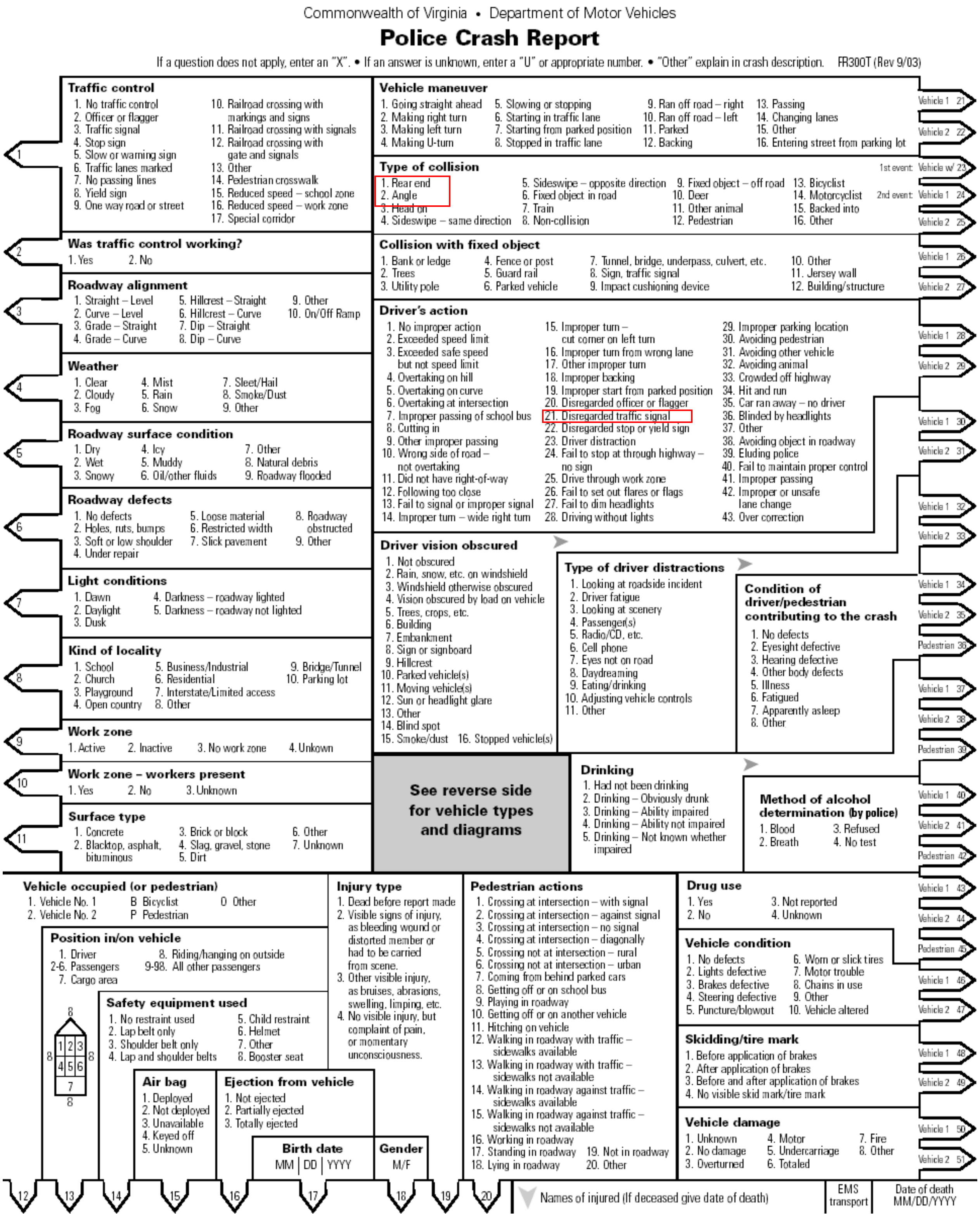
Categories 1, 2, 3, and 4 require that the diagram and narrative of the FR300 be used, whereas categories 5, 6, 7, and 8 do not require examination of the diagram or narrative. Table D1 illustrates how these crashes were classified. Thus, it is possible for a single crash to "fit" into one of several categories. For example, suppose a left-turning driver who has the right of way is hit by an opposing through driver who is charged with running a red light and suffers a broken arm. Based on Table D1, this could be classified as a crash in categories 3, 4, 6, 7, and 8.

When comparing the impacts at two intersections, it may be the case that more insight may be gained if the numbers of *rear-end crashes attributable to a red light* are compared rather than simply the number of *total rear-end crashes*. However, the critical decision is to be consistent and to avoid, at all costs, comparing *total rear-end crashes* from one location to *rear-end crashes attributable to the red light* at another location.

Figure D1 shows the part of the FR300 template that is relevant to understanding the codes described in Table D1.

Table D1. Criteria for Classifying Crashes

Category	Criteria Based on Examining the FR300 Crash Report Form
(1) Crash not related to red light or red light running	• The crash did not occur at the intersection (i.e. signal) in question • Both drivers claim to have had the green light and no independent witnesses are available • Both drivers had a green light, and one simply failed to yield right of way • No charges are filed due to conflicting statements • A rear-end crash occurred, and the description states that the front car was stopped due to traffic • A rear-end crash occurred, and the description states that the rear car could not stop due to mechanical failure • A rear-end crash occurred, and the rear driver had a medical emergency • The crash involves one vehicle, a vehicle and an animal or fixed object, or a vehicle and a pedestrian or bicyclist, unless box 17 or 18 is coded as a 21 (which indicates the driver disregarded stop-go light, as shown in Figure D1) • In a rear-end crash, both vehicles were stopped at a red light, and the rear car accidentally let off the brake or the rear car accelerated too quickly after the light turned green • There is no crash, and a car has mechanical failure or catches fire Note: Any crashes that meet this criteria may not be included in categories (2), (3), or (4).
(2) Rear-end crash attributable to red light	• A rear-end crash occurred, and the description states that the front car was stopped due to a red light • The front car was stopped at the red light and the rear car did not stop • The rear car claimed to be braking for a yellow or red light, and could not stop in time (even if driver could not stop due to wet pavement Note: Rear-end crashes are often coded in box 17 or 18 as #12 (Following too closely), #23 (Driver Inattention), or #37 (with "Failure to maintain control" note) in Fairfax County. In Prince William County, rear-end crashes are almost always coded as #37 with a "Reckless driving" note.
(3) Crash likely attributable to red light running	• Either box 17 or 18 (or both) has the code 21 (the driver "disregarded stop-go light"). • Either box 17 or 18 has the code 34 (Hit and Run), and the description states one of the drivers ran the red light. • For some reason, neither box 17 nor 18 is coded 21, but the description clearly states that one of the drivers ran the red light. • Note that in Fairfax County, almost all of these crashes were angle crashes.
(4) Injury crash attributable to red light running	A crash that is likely attributable to red light running (category 3 directly above) results in an injury.
Category	**Criteria Based on Extracting the Tabular Data Elements from VDOT's Crash Data Base**
(5) Rear-end Crash	Collision type is coded as 01 (rear-end crash)
(6) Angle crash	Collision type is coded as 02 (angle crash)
(7) Crash definitely attributable to red light running	Driver Action has code 21 (disregarded stop-go light)
(8) Injury-related crash	Injury Count is equal to 1 or more


Commonwealth of Virginia • Department of Motor Vehicles

Police Crash Report

If a question does not apply, enter an "X". • If an answer is unknown, enter a "U" or appropriate number. • "Other" explain in crash description. FR300T (Rev 9/03)

Traffic control (1)
1. No traffic control
2. Officer or flagger
3. Traffic signal
4. Stop sign
5. Slow or warning sign
6. Traffic lanes marked
7. No passing lines
8. Yield sign
9. One way road or street
10. Railroad crossing with markings and signs
11. Railroad crossing with signals
12. Railroad crossing with gate and signals
13. Other
14. Pedestrian crosswalk
15. Reduced speed – school zone
16. Reduced speed – work zone
17. Special corridor

Was traffic control working? (2)
1. Yes 2. No

Roadway alignment (3)
1. Straight – Level
2. Curve – Level
3. Grade – Straight
4. Grade – Curve
5. Hillcrest – Straight
6. Hillcrest – Curve
7. Dip – Straight
8. Dip – Curve
9. Other
10. On/Off Ramp

Weather (4)
1. Clear
2. Cloudy
3. Fog
4. Mist
5. Rain
6. Snow
7. Sleet/Hail
8. Smoke/Dust
9. Other

Roadway surface condition (5)
1. Dry
2. Wet
3. Snowy
4. Icy
5. Muddy
6. Oil/other fluids
7. Other
8. Natural debris
9. Roadway flooded

Roadway defects (6)
1. No defects
2. Holes, ruts, bumps
3. Soft or low shoulder
4. Under repair
5. Loose material
6. Restricted width
7. Slick pavement
8. Roadway obstructed
9. Other

Light conditions (7)
1. Dawn
2. Daylight
3. Dusk
4. Darkness – roadway lighted
5. Darkness – roadway not lighted

Kind of locality (8)
1. School
2. Church
3. Playground
4. Open country
5. Business/Industrial
6. Residential
7. Interstate/Limited access
8. Other
9. Bridge/Tunnel
10. Parking lot

Work zone (9)
1. Active 2. Inactive 3. No work zone 4. Unkown

Work zone – workers present (10)
1. Yes 2. No 3. Unknown

Surface type (11)
1. Concrete
2. Blacktop, asphalt, bituminous
3. Brick or block
4. Slag, gravel, stone
5. Dirt
6. Other
7. Unknown

Vehicle maneuver (Vehicle 1 21; Vehicle 2 22)
1. Going straight ahead
2. Making right turn
3. Making left turn
4. Making U-turn
5. Slowing or stopping
6. Starting in traffic lane
7. Starting from parked position
8. Stopped in traffic lane
9. Ran off road – right
10. Ran off road – left
11. Parked
12. Backing
13. Passing
14. Changing lanes
15. Other
16. Entering street from parking lot

Type of collision (1st event: Vehicle w/ 23; 2nd event: Vehicle 1 24; Vehicle 2 25)
1. Rear end
2. Angle
3. Head on
4. Sideswipe – same direction
5. Sideswipe – opposite direction
6. Fixed object in road
7. Train
8. Non-collision
9. Fixed object – off road
10. Deer
11. Other animal
12. Pedestrian
13. Bicyclist
14. Motorcyclist
15. Backed into
16. Other

Collision with fixed object (Vehicle 1 26; Vehicle 2 27)
1. Bank or ledge
2. Trees
3. Utility pole
4. Fence or post
5. Guard rail
6. Parked vehicle
7. Tunnel, bridge, underpass, culvert, etc.
8. Sign, traffic signal
9. Impact cushioning device
10. Other
11. Jersey wall
12. Building/structure

Driver's action (Vehicle 1 28; Vehicle 2 29; Vehicle 1 30; Vehicle 2 31; Vehicle 1 32; Vehicle 2 33)
1. No improper action
2. Exceeded speed limit
3. Exceeded safe speed but not speed limit
4. Overtaking on hill
5. Overtaking on curve
6. Overtaking at intersection
7. Improper passing of school bus
8. Cutting in
9. Other improper passing
10. Wrong side of road – not overtaking
11. Did not have right-of-way
12. Following too close
13. Fail to signal or improper signal
14. Improper turn – wide right turn
15. Improper turn – cut corner on left turn
16. Improper turn from wrong lane
17. Other improper turn
18. Improper backing
19. Improper start from parked position
20. Disregarded officer or flagger
21. Disregarded traffic signal
22. Disregarded stop or yield sign
23. Driver distraction
24. Fail to stop at through highway – no sign
25. Drive through work zone
26. Fail to set out flares or flags
27. Fail to dim headlights
28. Driving without lights
29. Improper parking location
30. Avoiding pedestrian
31. Avoiding other vehicle
32. Avoiding animal
33. Crowded off highway
34. Hit and run
35. Car ran away – no driver
36. Blinded by headlights
37. Other
38. Avoiding object in roadway
39. Eluding police
40. Fail to maintain proper control
41. Improper passing
42. Improper or unsafe lane change
43. Over correction

Driver vision obscured
1. Not obscured
2. Rain, snow, etc. on windshield
3. Windshield otherwise obscured
4. Vision obscured by load on vehicle
5. Trees, crops, etc.
6. Building
7. Embankment
8. Sign or signboard
9. Hillcrest
10. Parked vehicle(s)
11. Moving vehicle(s)
12. Sun or headlight glare
13. Other
14. Blind spot
15. Smoke/dust
16. Stopped vehicle(s)

Type of driver distractions
1. Looking at roadside incident
2. Driver fatigue
3. Looking at scenery
4. Passenger(s)
5. Radio/CD, etc.
6. Cell phone
7. Eyes not on road
8. Daydreaming
9. Eating/drinking
10. Adjusting vehicle controls
11. Other

Condition of driver/pedestrian contributing to the crash (Vehicle 1 34; Vehicle 2 35; Pedestrian 36; Vehicle 1 37; Vehicle 2 38; Pedestrian 39)
1. No defects
2. Eyesight defective
3. Hearing defective
4. Other body defects
5. Illness
6. Fatigued
7. Apparently asleep
8. Other

See reverse side for vehicle types and diagrams

Drinking
1. Had not been drinking
2. Drinking – Obviously drunk
3. Drinking – Ability impaired
4. Drinking – Ability not impaired
5. Drinking – Not known whether impaired

Method of alcohol determination (by police) (Vehicle 1 40; Vehicle 2 41; Pedestrian 42)
1. Blood
2. Breath
3. Refused
4. No test

Vehicle occupied (or pedestrian) (12)
1. Vehicle No. 1
2. Vehicle No. 2
B Bicyclist
P Pedestrian
0 Other

Position in/on vehicle (13)
1. Driver
2-6. Passengers
7. Cargo area
8. Riding/hanging on outside
9-98. All other passengers

Safety equipment used (14)
1. No restraint used
2. Lap belt only
3. Shoulder belt only
4. Lap and shoulder belts
5. Child restraint
6. Helmet
7. Other
8. Booster seat

Air bag (15)
1. Deployed
2. Not deployed
3. Unavailable
4. Keyed off
5. Unknown

Ejection from vehicle (16)
1. Not ejected
2. Partially ejected
3. Totally ejected

Birth date (17)
MM | DD | YYYY

Gender (18)
M/F

Injury type (19)
1. Dead before report made
2. Visible signs of injury, as bleeding wound or distorted member or had to be carried from scene.
3. Other visible injury, as bruises, abrasions, swelling, limping, etc.
4. No visible injury, but complaint of pain, or momentary unconsciousness.

Pedestrian actions (20)
1. Crossing at intersection – with signal
2. Crossing at intersection – against signal
3. Crossing at intersection – no signal
4. Crossing at intersection – diagonally
5. Crossing not at intersection – rural
6. Crossing not at intersection – urban
7. Coming from behind parked cars
8. Getting off or on school bus
9. Playing in roadway
10. Getting off or on another vehicle
11. Hitching on vehicle
12. Walking in roadway with traffic – sidewalks available
13. Walking in roadway with traffic – sidewalks not available
14. Walking in roadway against traffic – sidewalks available
15. Walking in roadway against traffic – sidewalks not available
16. Working in roadway
17. Standing in roadway
18. Lying in roadway
19. Not in roadway
20. Other

Drug use (Vehicle 1 43; Vehicle 2 44; Pedestrian 45)
1. Yes
2. No
3. Not reported
4. Unknown

Vehicle condition (Vehicle 1 46; Vehicle 2 47)
1. No defects
2. Lights defective
3. Brakes defective
4. Steering defective
5. Puncture/blowout
6. Worn or slick tires
7. Motor trouble
8. Chains in use
9. Other
10. Vehicle altered

Skidding/tire mark (Vehicle 1 48; Vehicle 2 49)
1. Before application of brakes
2. After application of brakes
3. Before and after application of brakes
4. No visible skid mark/tire mark

Vehicle damage (Vehicle 1 50; Vehicle 2 51)
1. Unknown
2. No damage
3. Overturned
4. Motor
5. Undercarriage
6. Totaled
7. Fire
8. Other

Names of injured (If deceased give date of death) | EMS transport | Date of death MM/DD/YYYY

Figure D1. Excerpt of FR300 Crash Report Form Template
(Virginia Department of Motor Vehicles, 2003; Annotation added by VTRC)

Basic Crash Analysis Results (Levels 1 and 2)

What Happened at Intersections Where Cameras Were Installed?

Tables D2 through D17 summarize the basic crash results for Fairfax City, Fairfax County, Falls Church, and Vienna. To facilitate validation of these results for each jurisdiction, the results for each jurisdiction are presented separately. Each jurisdiction has four associated tables:

1. The first table simply compares the *total number* of crashes at each intersection during the study period. For example, as shown in Table D2, there were 19 crashes in 1998 in Fairfax City at the intersection of U.S. 50 and Jermantown Road.

2. The second table divides the number of crashes by the number of years for each period with and without cameras, which *gives the number of crashes per intersection year*. For example, of the 19 crashes in 1998 at U.S. 50 and Jermantown Road, 7 crashes occurred between January and May 1998 when there was no camera in place. Thus, 7 crashes divided by 0.42 year yields a crash rate of 16.8 crashes per intersection year as shown in Table D3.

3. The third table shows the *modified crash rate*, which is the number of crashes per year divided by the average yearly volume on the major road, with the results in units of millions of vehicle miles traveled (VMT). For example, for the same intersection in 1998, the AADT was 63,000 vehicles per day. Thus, 16.8 crashes divided by 63,000 VMT yields 0.000266 crash per one VMT or 266 crashes per million VMT as shown in Table D4.

4. The fourth table shows the *results of significance testing* based on before-after comparisons of the intersections where cameras were added. For example, for Fairfax City, the number of crashes per intersection year was higher at the three sites of U.S. 50/Jermantown Road, Lee Highway/Plantation Parkway, and Main Street/Pickett Road after the cameras were installed than before the cameras were installed. Thus, as shown in Table D5, this change in crash rate was an increase. (However, as shown in Table D5, the change was not statistically significant.)

The results from Fairfax City, Falls Church, and Vienna are comparable in that the crash types described therein are defined consistently as shown in the lower half of Table D1. For those three jurisdictions, rear-end crashes, angle crashes, and total injury crashes are directly taken from the FR-300 report form as coded by the officer. For Fairfax County, however, the crash narrative was also used to classify the crash types as shown in the upper half of Table D1.

For Fairfax City in particular, the before period was extremely short, because their program started in 1998. The investigators did not wish to pull crash data for 1997 (because there were concerns about the accuracy of VDOT volumes for data before 1998). However, later analysis suggests that the nature of Fairfax City's data was not different than that of the other jurisdictions studied; thus, they were included in the analysis.

Table D2. Summary of Fairfax City Total Crashes: 1998 – 2003

Camera Installation Date	Years without Camera	Years with Camera	Location	1998	1999	2000	2001	2002	2003
May 1998	0.4	5.6	US 50 & Jermantown Rd.	19[a]	16	31	37	38	36
May 1998	0.4	5.6	Lee Hwy & Plantation Pkwy	6[a]	9	15	13	8	16
May 1998	0.4	5.6	Main St & Pickett Rd.	7[a]	25	16	22	15	15

[a]Red light camera was installed during this year at the intersection.

Table D3. Crashes per Intersection Year in Fairfax City: 1998 – 2003

Location	Total		Rear-End		Angle		Total Injury		Disregard Red Light	
	Without Camera	With Camera	Without Camera	With Camera	Without Camera	With Camera	Without Camera	With Camera	Without Camera	With Camera
US 50 & Jermantown Rd.	16.8	30.4	7.2	14.9	7.2	11.8	9.6	10.9	2.4	0.4
Lee Hwy & Plantation Pkwy	7.2	11.5	4.8	6.3	2.4	1.8	7.2	3.0	0.8	0.5
Main St & Pickett Rd.	4.8	17.6	0.0	12.2	4.8	2.0	2.4	7.3	0.0	0.5

Table D4. Modified Crash Rates for Fairfax City: 1998 – 2003[a]

Location	Total		Rear-End		Angle		Total Injury		Disregard Red Light	
	Without Camera	With Camera	Without Camera	With Camera	Without Camera	With Camera	Without Camera	With Camera	Without Camera	With Camera
US 50 & Jermantown Rd.	267	664	114	324	114	258	152	238	38	8
Lee Hwy & Plantation Pkwy	232	289	155	158	77	45	232	77	26	14
Main St & Pickett Rd.	103	425	0	295	103	48	52	178	0	13

[a]*Modified crash rate* is the number of crashes per intersection year per million ADT on the major road

Table D5. Results of Significance Testing for Fairfax City

Crash Type	Change in Number of Crashes per Intersection Year	Change in Modified Crash Rates[c]
Total Crashes	Insignificant increase ($p = 0.08$)	Insignificant increase ($p = 0.13$)
Rear-End Crashes	Insignificant increase ($p = 0.15$)	Insignificant increase ($p = 0.19$)
Angle Crashes	Insignificant increase ($p = 0.87$)	Insignificant increase ($p = 0.80$)
Injury Crashes	Insignificant increase ($p = 0.81$)	Insignificant increase ($p = 0.85$)
Red Light Running Crashes	Insignificant decrease ($p = 0.52$)	Insignificant decrease ($p = 0.52$)

Table D6. Summary of Fairfax County Total Crashes: 1998 – 2003

Camera Installation Date	Years Without Camera	Years With Camera	Location	1998	1999	2000	2001	2002	2003
May 2001	3.3	2.7	Arlington & Jaguar Trail	23	12	25	21[a]	26	20
October 2001	3.8	2.3	Fairfax Co. Pkwy & Newington	6	1	0	0[a]	1	0
July 2001	3.5	2.5	Fairfax Co. Pkwy & Popes Head	7	4	11	5[a]	8	15
February 2001	3.1	1.7	Lee Jackson Hwy & Fair Ridge	40	19	22	15[a]	16[b]	31
February 2001	3.1	2.9	Lee Jackson & Rugby/Middle River	9	18	16	16[a]	18	24
June 2001	3.4	2.6	Leesburg Pike & Dranesville	18	10	22	24[a]	14	20
May 2001	3.3	2.7	Leesburg Pike & Route 66	14	14	13	12[a]	12	20
October 2000	2.8	2.4	Leesburg Pike & Towlston	2	5	9	11[a]	5	15[b]
March 2001	3.2	2.8	Leesburg Pike & Westpark/Gosnell	39	21	26	33[a]	38	44
September 2002	4.7	1.3	Route 236 & Heritage/Hummer	27	26	27	40	26[a]	34
June 2001	3.4	1.8	Route 28 & Green Trails/Old Mill	6	9	8	13[a]	14	18[b]
March 2003	5.2	0.8	Route 7 & Carlin Springs	24	22	14	21	11	13[a]
March 2003	5.2	0.8	Telegraph & Huntington	43	39	37	41	56	49[a]

[a]Red light camera was installed during this year at the intersection.
[b]Red light camera use was discontinued during this year at the intersection.

Table D7. Crashes Per Intersection Year in Fairfax County: 1998 – 2003

Location	Total		Rear-end		Injury Due to Red Light Running		Total Injury		Disregard Red Light	
	Without Camera	With Camera	Without Camera	With Camera	Without Camera	With Camera	Without Camera	With Camera	Without Camera	With Camera
Arlington & Jaguar Trail	18.48	24.44	5.15	11.11	2.12	0.37	7.58	7.41	3.94	0.74
Fairfax Co Pkwy & Newington	1.87	0.44	0.53	0.00	0.00	0.00	0.27	0.00	0.53	0.00
Fairfax Co Pkwy & Popes Head	6.57	10.80	1.43	6.00	0.57	0.00	3.43	5.60	0.57	0.00
Lee Jackson Hwy & Fair Ridge	26.62	14.12	10.39	7.06	2.92	1.18	10.06	5.29	4.55	1.18
Lee Jackson Hwy & Rugby/Middle River	13.96	19.86	5.19	8.22	1.95	1.37	5.84	5.82	2.60	2.05
Leesburg Pike & Dranesville	16.67	19.77	5.56	5.04	1.46	1.55	5.56	8.91	2.63	2.33
Leesburg Pike & Route 66	13.33	15.19	3.94	5.19	0.91	1.85	4.24	6.30	2.42	3.33
Leesburg Pike & Towlston	5.09	7.82	0.00	3.70	0.73	0.00	2.18	2.88	0.73	0.00
Leesburg Pike & Westpark/Gosnell	29.34	37.81	8.52	13.43	1.26	0.35	10.09	11.31	3.15	1.77
Route 236 & Heritage/Hummer	28.09	36.92	5.96	8.00	0.64	0.00	8.30	10.00	3.83	0.00
Route 28 & Green Trails/Old Mill	7.89	14.86	1.75	8.57	0.29	0.00	2.92	8.00	1.17	0.00
Route 7 & Carlin Springs	18.38	12.05	2.71	3.61	0.77	0.00	7.35	6.02	1.74	0.00
Telegraph & Huntington	43.13	49.40	8.32	14.46	3.48	3.61	17.02	24.10	7.74	6.02

Table D8. Modified Crash Rates for Fairfax County: 1998 – 2003[a]

Location	Total		Rear-end		Injury due to Red Light Running		Total Injury		Disregard Red Light	
	Without Camera	With Camera	Without Camera	With Camera	Without Camera	With Camera	Without Camera	With Camera	Without Camera	With Camera
Arlington & Jaguar Trail	330	427	38	6	92	194	135	129	70	13
Fairfax Co Pkwy & Newington	80	11	0	0	23	0	11	0	23	0
Fairfax Co Pkwy & Popes Head[a]		188		0		104		97		0
Lee Jackson Hwy & Fair Ridge	367	182	40	15	143	91	139	68	63	15
Lee Jackson Hwy & Rugby/Middle River	246	295	34	20	91	122	103	86	46	30
Leesburg Pike & Dranesville	332	351	29	28	111	89	111	158	52	41
Leesburg Pike & Route 66	501	392	34	48	148	134	160	163	91	86
Leesburg Pike & Towlston	100	153	14	0	0	73	43	56	14	0
Leesburg Pike & Westpark/Gosnell	533	574	23	5	155	204	183	172	57	27
Route 236 & Heritage/Hummer	617	805	14	0	131	174	182	218	84	0
Route 28 & Green Trails/Old Mill	148	296	5	0	33	171	55	159	22	0
Route 7 & Carlin Springs	423	264	18	0	62	79	169	132	40	0
Telegraph & Huntington	1376	1496	111	109	265	438	543	730	247	182

[a]AADT was unavailable for years without camera.

Table D9. Results of Significance Testing for Fairfax County[ab]

Crash Type	Change in Number of Crashes per Intersection Year	Change in Modified Crash Rates[c]
Total Crashes	Insignificant increase (p = 0.15)	Insignificant increase (p = 0.65)
Rear-End Crashes Attributable to Signal	Significant increase (p = 0.01)	Significant increase (p = 0.05)
Total injury crashes	Insignificant increase (p = 0.14)	Insignificant increase (p = 0.34)
Injury Crashes Attributable to Red Light Running	Significant decrease (p = 0.02)	Significant decrease (p = 0.01)
Red Light Running Crashes	Significant decrease (p = 0.00)	Significant decrease (p = 0.00)

Table D10. Summary of Falls Church Total Crashes: 1998-2003

Location	Camera Installation Date	Years Without Camera	Years With Camera	1998	1999	2000	2001	2002	2003
West Broad Street/Annandale Road	1-Oct-01	3.75	2.25	6	3	3	6	0	3
West Broad Street/Birch Street	8-May-02	4.35	1.65	10	8	7	7	12	8

Table D11. Crashes per Intersection Year in Falls Church: 1998-2003

Location	Total		Rear-End		Total Injury		Disregard Red Light	
	Without Camera	With Camera	Without Camera	With Camera	Without Camera	With Camera	Without Camera	With Camera
West Broad St/Annandale Rd	4.4	2.0	1.5	0.7	0.7	0.1	1.0	0.1
West Broad St/Birch St	8.3	9.6	0.5	0.6	0.1	1.0	0.1	0.4

Table D12. Modified Crash Rates for Falls Church: 1998-2003

Location	Total		Rear-End		Total Injury		Disregard Red Light	
	Without Camera	With Camera	Without Camera	With Camera	Without Camera	With Camera	Without Camera	With Camera
West Broad St/Annandale Rd	137	75	46	25	23	4	31	4
West Broad St/Birch St	305	302	17	19	3	32	3	12

Table D13. Results of Significance Testing for Falls Church

Location	Change in Number of Crashes per Intersection Year	Change in Modified Crash Rates
Total Crashes	Insignificant decrease of $p = 0.81$	Insignificant decrease of $p = 0.47$
Rear-End Crashes	Insignificant decrease of $p = 0.62$	Insignificant decrease of $p = 0.57$
Total Injury Crashes	Insignificant increase of $p = 0.88$	Insignificant increase of $p = 0.87$
Red Light Running Crashes	Insignificant decrease of $p = 0.72$	Insignificant decrease of $p = 0.71$

Table D14. Summary of Total Vienna Crashes: 1998 – 2003

Camera Installation Date	Years without Camera	Years with Camera	Location	1998	1999	2000	2001	2002	2003
June 1999	1.4	4.6	Maple and Follin Ln	19	20[a]	24	10	9	9
May 2004	6	0	Maple and Glyndon St	7	10	16	17	9	8
Sept. 2003	5.7	0.3	Maple and Nutley St	21	13	13	15	10	11[a]

[a]Red light camera was installed during this year at the intersection.

Table D15. Crashes Per Intersection Year in Vienna: 1998 – 2003

Location	Total		Rear-End		Angle		Total Injury		Disregard Red Light	
	Without Camera	With Camera	Without Camera	With Camera	Without Camera	With Camera	Without Camera	With Camera	Without Camera	With Camera
Maple and Follin Ln	16.2	14.8	13.4	13.1	1.4	0.9	6.4	4.4	0.7	0.2
Maple and Glyndon St	11.2		4.7		4.8		3.7		1.8	
Maple and Nutley St	13.9	12.0	7.8	9.0	3.5	3.0	6	9	0.5	0.0

Table D16. Modified Crash Rates for Vienna: 1998 – 2003[a]

Location	Total		Rear-End		Angle		Total Injury		Disregard Red Light	
	Without Camera	With Camera	Without Camera	With Camera	Without Camera	With Camera	Without Camera	With Camera	Without Camera	With Camera
Maple and Follin Ln	473	451	391	398	41	27	185	133	21	7
Maple and Glyndon St	336		140		145		110		55	
Maple and Nutley St	449	395	250	297	114	99	193	297	17	0
Maple and Center St	321		115		120		60		15	
Maple and East St.	281		135		85		100		30	
Maple and Lawyers Rd.	411		105		186		95		5	

Table D17. Results of Significance Testing for Vienna

Crash Type	Change in Number of Crashes per Intersection Year	Change in Modified Crash Rates[c]
Total Crashes	Insignificant decrease ($p = 0.10$)	Insignificant decrease ($p = 0.25$)
Rear-End Crashes	Insignificant increase ($p = 0.66$)	Insignificant increase ($p = 0.40$)
Angle Crashes	Significant decrease ($p = 0.01$)	Significant decrease ($p = 0.01$)
Total Injury Crashes	Insignificant increase ($p = 0.87$)	Insignificant increase ($p = 0.80$)
Red Light Running Crashes	Significant decrease ($p = 0.03$)	Insignificant decrease ($p = 0.06$)

What Happened at Intersections Where Cameras Were Never Installed?

It is also possible to replicate the analysis shown in Table D17 at intersections where cameras were never installed. Since Fairfax City began its program in May 1998, the before data are considered to be crashes for the period January 1998 through May 1998 and the after data are considered to be crashes for the period June 1998 through December 2003. For Fairfax County and adjacent Prince William County, the before data are 1998, 1999, and 2000, with 2001, 2002, and the after data are 2003. Table D18 summarizes the comparison of crashes in these three jurisdictions at intersections where cameras were *never* installed.

Table D18. Results of Significance Testing at Locations Where Cameras Were Never Installed

Jurisdiction	Crash Type	Change in Number of Crashes per Intersection Year	Change in Modified Crash Rates[c]
Fairfax City	Total Crashes	Insignificant increase ($p = 0.14$)	Insignificant increase ($p = 0.21$)
	Rear-End Crashes	Insignificant increase ($p = 0.18$)	Insignificant increase ($p = 0.18$)
	Angle Crashes	Insignificant increase ($p = 0.23$)	Insignificant increase ($p = 0.21$)
	Total Injury Crashes	Insignificant increase ($p = 0.27$)	Insignificant increase ($p = 0.26$)
	Red Light Running Crashes	Insignificant increase ($p = 0.27$)	Insignificant increase ($p = 0.27$)
Fairfax County	Total Crashes	Insignificant decrease ($p = 0.51$)	Insignificant decrease ($p = 0.21$)
	Rear-End Crashes	Insignificant increase ($p = 0.87$)	Insignificant decrease ($p = 0.6$)
	Total Injury Crashes	Insignificant decrease ($p = 0.34$)	Insignificant decrease ($p = 0.12$)
	Red Light Running Crashes	Insignificant decrease ($p = 0.11$)	Insignificant decrease ($p = 0.11$)
Prince William County	Total injury Crashes	Significant increase ($p = 0.02$)	Insignificant increase ($p = 0.65$)
	Rear-End Crashes	Insignificant increase ($p = 0.55$)	Insignificant decrease ($p = 0.28$)
	Angle Crashes	Insignificant increase ($p = 0.53$)	Insignificant decrease ($p = 0.64$)
	Red Light Running Crashes	Significant increase ($p = 0.00$)	Significant increase ($p = 0.03$)

Taken by themselves, the results in Table D18 are inconclusive. For example, consider only the crashes attributable to red light running in Fairfax County and adjacent Prince William County. In Fairfax County, at intersections where cameras were never installed, there was an decrease in crashes for the period 2001 through 2003 relative to the period 1998 through 2000, the decrease was not significant. Even if the decrease had been statistically significant, the reader could attribute the drop in crashes to one of two factors: (1) the installation of Fairfax County cameras at other intersections is "spilling over" to non-camera sites (good news for camera proponents), or (2) the installation of Fairfax County cameras has had no effect, because the number of red light running crashes is dropping not just at camera sites but also at non-camera sites. The Prince William County section of Table D18 does seem to support the proponents' view because in adjacent Prince William County where cameras were never installed, crashes attributable to red light running for the same period increased rather than decreased—significantly. However, this must be seen in light of Fairfax City's increase in the same category of red light running crashes—even if the increase was not significant.

A better way to analyze these data is to study the impact of cameras and non-camera locations in the same statistical experiment, which was done with the level 3 and 4 approaches.

Analysis of Variance Results (Level 3)

Details of the level 3 analysis—the analysis of variance (ANOVA)—are presented in Tables D19, D20, D21, and D22. The purpose of the level 3 analysis was to determine, in a systematic manner, whether consideration of main effects (e.g., a *single variable*, such as a high AADT) and second order interaction effects (e.g, the combination of *two variables*, such as a high AADT in conjunction with a high speed limit) added insights into the impact of red light cameras. In some aspects, ANOVA is comparable to the level 4 analysis (Empirical Bayes), as both approaches consider all key variables simultaneously. The main reason for performing both analyses was to satisfy two groups of readers: persons more familiar with the classical experimental design approaches might prefer the level 3 analysis, and persons more familiar with recent safety statistical research methods might prefer the level 4 analysis. A second reason is the underlying distribution of crashes: ANOVA generally presumes a normal distribution, whereas Empirical Bayes assumes a negative binomial distribution, which historically has been the case for crash data.

Tables D19 and D20 were first used to identify which main effects and second order effects are significant. Table D19 shows such effects (where $p < 0.10$). The left column of Table D19 shows the crash type, the next column shows the main or second order effect, the next column shows the significance level, and the rightmost column shows the R^2 value. The findings are that the most important factor for predicting the number of crashes is the site; note that relatively high R^2 values are obtained. (The "site" reflects the particular intersection.)

Table D20 shows the results of the analysis of variance (ANOVA) where the site was removed. Again, for variables where p was less than 0.10, the leftmost column shows the crash type, the next column shows the main or second order effect, the next column shows the significance level, and the rightmost column shows the R^2 value for that particular crash type.

A practical interpretation of Tables D19 and D20 is that despite the inclusion of yellow time, AADT, number of through lanes, and truck percentages, there are other factors at the intersection that influence the number of crashes. The drop in R^2 values that results in omitting site as a variable in Table D20 suggests that it is very difficult to compare one intersection to another based on these other factors. This lends credence to using a test such as the paired sample t-test (used in the levels 1 and 2 analyses) that controlled for the effect of the intersection.

Table D19. Results of Analysis of Variance With Intersection Site as One of the Independent Variables

Crash Type	Main or Second Order Effect	*p*	R^2
All Crashes	SITE	0.00	0.856
	YELLOW	0.00	
	CAMERA * SPEED	0.04	
	CAMERA * YELLOW	0.05	
	AADT * SPEED	0.09	
	AADT * YELLOW	0.05	
	YELLOW * TRUCK	0.08	
All Injury Crashes	SITE	0.00	0.711
	YELLOW	0.10	
All Red Light Running Crashes	SITE	0.00	0.533
	YELLOW	0.10	
	CAMERA * SPEED	0.07	
	CAMERA * YELLOW	0.03	
Rear-end Crashes	CAMERA	0.00	0.752
	SITE	0.00	
	CAMERA * AADT	0.03	
	CAMERA * THRULANE	0.06	
	AADT * THRULANE	0.01	
	AADT * YELLOW	0.02	
Injury Crashes Due to Red Light Running Only	SITE	0.00	0.463
	CAMERA * YELLOW	0.08	

Table D20. Results of Analysis of Variance Including Intersection Site as an Independent Variable

Crash Type	Main or Second Order Effect	*p*	R^2
All Crashes	CAMERA	0.09	0.358
	THRULANE	0.02	
	YELLOW	0.06	
	AADT * SPEED	0.02	
	AADT * THRULANE	0.02	
All Injury Crashes	CAMERA	0.06	0.269
	THRULANE	0.09	
	CAMERA * AADT	0.07	
	CAMERA * TRUCK	0.07	
Rear-end Crashes	CAMERA	0.00	0.452
	THRULANE	0.02	
	YELLOW	0.04	
	AADT * THRULANE	0.00	

For other crash categories, all main and second order effects resulted in $p > 0.10$.

By themselves, Tables D19 and D20 show *which* variables are most likely affecting crashes but not *how* they affect crashes. This is the reason for Tables D21 and D22. Table D21 is the most straightforward table to interpret and simply shows the main effects for all variables. Generally, the effects shown in Table D21 are similar to the level 1 and 2 analyses: cameras are correlated with an increase in total crashes, rear-end crashes, and total injury crashes, and they are correlated with a decrease in injury crashes attributable to red light running and total crashes attributable to red light running. Statistically, however, all of these effects are insignificant (i.e., $p > 0.05$) except for the increase in rear-end crashes.

Table D21. Linear Regression With All Independent Variables Except Sites

Crash Type	Variable	Standardized Coefficients	Effect	*p*	R^2
All Crashes	CAMERA	0.05	Increase	0.32	0.33
	AADT	0.46	Increase	0.00	
	SPEEDLMT	-0.20	Decrease	0.00	
	THRULANE	-0.08	Decrease	0.16	
	YELLOW	0.23	Increase	0.00	
	TRUCK	0.12	Increase	0.04	
All Red Light Running Crashes	CAMERA	-0.04	Decrease	0.50	0.05
	AADT	0.12	Increase	0.10	
	SPEEDLMT	-0.01	Decrease	0.92	
	THRULANE	-0.07	Decrease	0.30	
	YELLOW	0.18	Increase	0.01	
	TRUCK	0.01	Increase	0.83	
Rear-end Crashes	CAMERA	0.29	Increase	0.00	0.39
	AADT	0.39	Increase	0.00	
	SPEEDLMT	-0.09	Decrease	0.12	
	THRULANE	0.07	Increase	0.24	
	YELLOW	0.22	Increase	0.00	
	TRUCK	0.07	Increase	0.24	
Injury Crashes Due to Red Light Running Only	CAMERA	-0.04	Decrease	0.53	0.06
	AADT	0.11	Increase	0.11	
	SPEEDLMT	0.07	Increase	0.31	
	THRULANE	0.04	Increase	0.62	
	YELLOW	0.18	Increase	0.01	
	TRUCK	-0.05	Decrease	0.50	
All Injury Crashes	CAMERA	0.05	Increase	0.38	0.23
	AADT	0.42	Increase	0.00	
	SPEEDLMT	-0.15	Decrease	0.02	
	THRULANE	-0.06	Decrease	0.33	
	YELLOW	0.15	Increase	0.01	
	TRUCK	0.13	Increase	0.04	

Table D22. Non Linear Regression Estimates for Total Red Light Running Crashes

Variable	Parameter (From Non Linear Regression)	Increase/Decrease
Intercept	-25.99	Decrease
CAMERA	11.12	Increase
AADT	0.00	Increase
SPEED	0.42	Increase
THRULANE	11.16	Increase
YELLOW	-5.47	Decrease
TRUCK	3.76	Increase
CAMERA * AADT	0.00	Increase
CAMERA * SPEED	-0.16	Decrease
CAMERA * THRULANE	0.27	Increase
CAMERA * YELLOW	-3.03	Decrease
CAMERA * TRUCK	0.24	Increase
AADT * SPEED	0.00	Increase
AADT * THRULANE	0.00	Increase
AADT * YELLOW	0.00	Increase
AADT * TRUCK	0.00	Increase
SPEED * THRULANE	-0.21	Decrease
SPEED * YELLOW	0.42	Increase
SPEED * TRUCK	-0.03	Decrease
THRULANE * YELLOW	-4.37	Decrease
THRULANE * TRUCK	-0.57	Decrease
YELLOW * TRUCK	-0.57	Decrease

Table D22 exemplifies how more study is needed to understand the interaction effects. As an illustration, Table D22 shows the regression model using main effects and second order interaction effects for total red light running crashes. Note that although a main effect shows that cameras increase crashes, the interaction effects suggest that cameras decrease crashes under the following circumstances:

- a higher speed limit
- a higher AADT
- fewer through lanes
- yellow times that exceed the ITE yellow times by a longer margin (Institute of Transportation Engineers, 1999)
- lower truck percentages.

These impacts can be ascertained with the regression model. Table D23 compares two opposite scenarios: those where, according to the model, cameras would help reduce crashes attributable to red light running, and those where, according to the model, cameras would increase crashes attributable to red light running.

Table D23. Impacts of Cameras on Red Light Running Crashes According to Regression Model of Table D22

Factors Favoring Cameras	Factors Opposing Cameras
• High AADT (60000)	• Low AADT (20000)
• High Speed Limit (55 mph)	• High Speed Limit (35 mph)
• Fewer Through Lanes (2)	• More Through Lanes (3)
• Actual yellow time exceeds ITE yellow time by larger margin (1.1 sec)	• Actual yellow time exceeds ITE yellow time by smaller margin (0.5 sec)
• Low truck percentage (1%)	• Larger truck percentage (5%)

When the values shown in the left column of Table D23 are used, the regression model from Table D22 suggests that cameras *decrease* crashes attributable to red light running. That is, the model computes 9.57 crashes (if cameras are not used) compared with 5.21 crashes (if cameras are used), for a reduction of 4.36 crashes. Yet, if the values on the right side of Table D23 are used, the model suggests that cameras *increase* crashes attributable to red light running. In that scenario, the model suggests that without cameras there would be 2.71 crashes whereas with cameras there would be 7.27 crashes, for a net increase of 4.56 crashes.

The impacts are based on a strict interpretation of the results in Table D22 and represent a direction for future exploration. However, because of the low R^2 values and the fact that approach speeds were not available (thus necessitating the use of speed limits), the level 3 analysis should be considered but only in tandem with the other analyses.

Advanced Crash Analysis Results—Empirical Bayes Method (Level 4)

Tables D24 and D25 summarize the crash estimation model and resultant impacts for Fairfax County crashes based on the Empirical Bayes approach, using the crash estimation model presented in Eq. 1. Confidence intervals for the percentage reduction in crashes according to the Empirical Bayes approach are shown in the second row of Table D25; for example, a range of 1.15 to 1.16 means that the cameras are correlated with an increase in crashes on the order of 15% to 16%. This increase adjusts for variation in the five variables shown in Eq. 1—volume, speed limit, difference between recommended and actual ITE yellow time, truck percentages, and the number of lanes.

There was also uncertainty about the data: for example, at a few roadway sections, the investigators could not be certain of the annual volume. In those instances, the results of the Empirical Bayes approach were tested with different data values for these volumes, and each of these tests is shown as a different scenario. Further, there was concern as to whether the number of left-turn lanes should be included as an independent variable, which is the reason for Table D25 instead of Table D24. As an example, consider the number of total crashes: the first four scenarios in Table D24 suggest θ values of 1.11 to 1.16, and the first four scenarios in Table D25 suggest θ values of 1.08 to 1.17. These yield a total range for θ of 1.08 to 1.16; thus, total crashes increased by a value between 8% and 17%.

Table D24. Summary of Empirical Bayes Results for Fairfax County Crashes With Thorough Lanes as One of the Dependent Variables

Crash Type (Category as defined in Table D1).[a]	Scenario	Volume (b)	Speed Limit (c)	Yellow (d)	Trucks (e)	Through Lanes (f)	α_{1998}	α_{1999}	α_{2000}	α_{2001}	α_{2002}	α_{2003}	Confidence Interval For The Reduction In Crashes (Θ)	
Total crashes (Sum of all crashes at the intersection)	1	0.101	0.000	0.392	0.170	0.061	4.243	4.183	4.299	4.372	3.943	4.519	1.16	1.15
	2	0.117	0.000	0.392	0.169	0.061	3.590	3.542	3.634	3.694	3.331	3.817	1.16	1.15
	3	0.059	0.000	0.398	0.140	0.000	7.005	7.042	7.418	7.630	6.931	7.819	1.12	1.11
	4	0.100	0.000	0.397	0.136	0.000	4.562	4.591	4.808	4.936	4.488	5.059	1.12	1.11
Total injury crashes (Category 8)	1	0.447	0.000	0.402	0.138	0.059	0.040	0.041	0.043	0.038	0.040	0.040	1.24	1.20
	2	0.449	0.000	0.407	0.141	0.059	0.039	0.040	0.042	0.038	0.039	0.039	1.24	1.20
	3	0.439	0.000	0.556	0.110	0.000	0.048	0.052	0.055	0.049	0.052	0.050	1.17	1.13
	4	0.453	0.000	0.482	0.053	0.000	0.043	0.046	0.048	0.043	0.046	0.042	1.19	1.16
Injury Crashes Attributable to red light running (Category 4)	1	0.397	0.000	0.472	0.000	1.381	0.004	0.003	0.004	0.003	0.003	0.004	0.79	0.68
	2	0.440	0.376	0.498	0.000	1.351	0.001	0.001	0.001	0.000	0.000	0.001	0.78	0.68
	3	0.438	0.142	0.504	0.142	0.091	0.004	0.004	0.004	0.003	0.003	0.005	0.79	0.68
	4	0.429	0.231	0.520	0.129	0.072	0.003	0.003	0.004	0.002	0.003	0.004	0.78	0.67
Rear-end crash related to red light (Category 2)	1	0.544	0.100	0.433	0.175	0.159	0.005	0.005	0.005	0.006	0.005	0.005	1.66	1.59
	2	0.540	0.000	0.433	0.179	0.167	0.008	0.008	0.008	0.009	0.007	0.008	1.71	1.64
	3	0.401	0.000	0.386	0.109	0.441	0.031	0.030	0.031	0.036	0.029	0.031	1.65	1.57
	4	0.389	0.100	0.419	0.099	0.684	0.020	0.019	0.020	0.023	0.019	0.020	1.61	1.54
Crash attributable to red light running (Category 3)	1	0.150	0.422	0.686	0.022	0.000	0.101	0.086	0.096	0.091	0.057	0.085	0.76	0.70
	2	0.184	0.392	0.682	0.020	0.000	0.079	0.067	0.075	0.071	0.044	0.066	0.76	0.70
	3	0.099	0.438	0.727	0.039	0.000	0.150	0.136	0.158	0.142	0.088	0.142	0.74	0.68
	4	0.144	0.393	0.721	0.034	0.000	0.111	0.101	0.116	0.105	0.065	0.105	0.72	0.67

[a]Please see Table D1 for precise definitions of crashes.

Table D25. Summary of Empirical Bayes Results for Fairfax County Crashes With Left Turn Lanes as One of the Dependent Variables

Crash Type (Category as defined in Table D1).[a]	Scenario	Volume (b)	Speed Limit (c)	Yellow (d)	Trucks (e)	Left Turn Lanes (f)	α_{1998}	α_{1999}	α_{2000}	α_{2001}	α_{2002}	α_{2003}	Confidence Interval For Reduction In Crashes (Θ)	
Total crashes (Sum of all crashes at the intersection)	1	0.095	0.000	0.394	0.166	0.423	3.119	3.078	3.166	3.220	2.902	3.319	1.16	1.15
	2	0.113	0.000	0.394	0.165	0.433	2.557	2.525	2.592	2.634	2.374	2.714	1.17	1.15
	3	0.051	0.000	0.399	0.136	0.506	4.672	4.698	4.955	5.098	4.629	5.208	1.09	1.08
	4	0.069	0.000	0.399	0.134	0.504	3.888	3.912	4.116	4.232	3.844	4.322	1.09	1.08
Total injury crashes (Category 8)	1	0.439	0.002	0.538	0.143	0.001	0.047	0.048	0.050	0.045	0.047	0.047	1.21	1.17
	2	0.430	0.005	0.573	0.160	0.000	0.051	0.053	0.055	0.050	0.051	0.052	1.19	1.15
	3	0.429	0.000	0.611	0.179	0.001	0.049	0.054	0.057	0.051	0.055	0.054	1.11	1.08
	4	0.426	0.001	0.622	0.195	0.000	0.049	0.054	0.058	0.051	0.055	0.055	1.11	1.07
Injury Crashes Attributable to red light running (Category 4)	1	0.377	0.000	0.441	0.121	0.000	0.016	0.014	0.016	0.012	0.012	0.017	0.80	0.69
	2	0.429	0.033	0.470	0.073	0.000	0.009	0.008	0.008	0.006	0.006	0.009	0.80	0.69
	3	0.409	0.001	0.513	0.076	0.000	0.011	0.011	0.012	0.008	0.009	0.013	0.78	0.67
	4	0.432	0.001	0.515	0.065	0.000	0.009	0.009	0.010	0.006	0.007	0.010	0.78	0.67
Rear-end crash related to red light (Category 2)	1	0.382	0.000	0.475	0.175	1.418	0.012	0.012	0.012	0.013	0.010	0.012	1.64	1.57
	2	0.386	0.000	0.479	0.175	1.432	0.011	0.011	0.011	0.012	0.010	0.011	1.70	1.62
	3	0.390	0.000	0.462	0.089	1.581	0.010	0.010	0.010	0.012	0.010	0.010	1.57	1.50
	4	0.396	0.000	0.465	0.089	1.584	0.010	0.009	0.010	0.011	0.009	0.010	1.57	1.50
Crash attributable to red light running (Category 3)	1	0.142	0.302	0.672	0.000	0.478	0.111	0.093	0.105	0.099	0.062	0.091	0.74	0.69
	2	0.173	0.274	0.669	0.000	0.467	0.089	0.075	0.084	0.080	0.049	0.074	0.74	0.69
	3	0.098	0.366	0.711	0.004	0.413	0.140	0.125	0.146	0.131	0.081	0.129	0.72	0.67
	4	0.140	0.329	0.706	0.000	0.402	0.103	0.093	0.107	0.097	0.060	0.095	0.72	0.67

[a]Please see Table D1 for precise definitions of crashes.

Thus, to the extent that all confounding factors are represented in Eq. 1, these initial Fairfax County data suggest the following:

- The cameras are correlated with an increase in total crashes of 8% to 17%.

- The cameras are correlated with an increase in rear-end crashes related to the presence of a red light; the increase ranges between 50% and 71%.

- The cameras are correlated with a decrease in crashes attributable to red light running, and the decrease is between 24% and 33%.

- The cameras are correlated with a decrease in injury crashes attributable to red light running, with the decrease being between 20% and 33%.

- The cameras are correlated with an increase in total injury crashes, with the increase being between 7% and 24%.

$$Crashes = \alpha_y (Volume)^b (Speed)^c (Yellow)^d (Trucks)^e (Lanes)^f \qquad \text{(Eq. 1)}$$

α_y = parameter that reflects the specific year (1998 through 2003)
Volume = average daily traffic on the major road
Speed = speed limit on the major road in miles/hour
Yellow = the difference between the yellow time recommended by ITE and the actual yellow time
Trucks = the percentage of trucks in the major road traffic stream
Lanes = the number of through lanes or left turn lanes on the major road approach.

Severity of Rear-End and Angle Crashes

Part of the earlier discussion focused on the type of crashes that were affected by the cameras. Generally, the investigators believe that angle crashes are more severe than rear-end crashes. For example, a tabulation of intersection crashes in Fairfax County from 1998 through 2003 showed that 40% of the rear-end crashes resulted in an injury whereas 45% of the angle crashes resulted in an injury. Further, as shown in Table D26, the proportion of angle crashes in the "other visible injury" category appears to be higher than the proportion of rear-end crashes in the "other visible injury" category. In addition, the number of deaths before the police officer completed the crash report that was associated with angle crashes was greater than the number associated with rear-end crashes. The information in Table D26 does not capture injury severity at the desired level of detail, but this limited information suggests that angle crashes may be generally more severe than rear-end crashes.

Table D26. Injury Type for Fairfax County Intersection Crashes, 1998–2003

Crash Type	Number of Deaths Before Report Made	Other Visible Injury (e.g., Bruises, Abrasions, Swelling, Lumps)	No Visible Injury But Complaint of Pain or Momentary Unconsciousness
Rear-End	4 (0.03%)	4,868 (40%)	7,244 (60%)
Angle	29 (0.25%)	5,194 (45%)	6,377 (55%)

REFERENCE

Institute of Transportation Engineers. *Traffic Engineering Handbook*, Fifth Edition, Washington, D.C., 1999.

Virginia Department of Motor Vehicles. Police Crash Report FR300T. Richmond, 2003. Accessed at http://www.vcu.edu/cppweb/tstc/fr3000903/FR300T.pdf.

APPENDIX E
SURVEY DISTRIBUTED TO THE GENERAL PUBLIC

Fairfax County Public Opinion Poll of Photo-Red Enforcement

The Virginia Transportation Research Council is surveying citizens in Fairfax County regarding photo-red enforcement, which is the practice of using cameras at intersections to record license plates of red light runners (citations are then mailed to violators). Please complete the survey by checking the boxes. Responses will be kept confidential and used for research purposes only. If you have questions about the study, you may contact Nick Garber at the University of Virginia (434-924-6366) or John Miller at the Virginia Transportation Research Council (434-293-1999). The survey takes about five minutes to complete.

1. How serious is the problem of red light running in Fairfax County?

   ☐ Very Serious ☐ Somewhat serious ☐ Not a problem at all

2. Why do drivers run red lights? *(Check all that apply)*

   ☐ Yellow interval is too short ☐ Conscious decision not to stop
   ☐ Driving too fast to stop ☐ Other, Please Specify ______________________

3. Do you support or oppose the photo-red enforcement program in Fairfax County?

   ☐ Support ☐ Oppose

   a. If you *support*, please indicate why you support the photo-red enforcement program (*Check all that apply*).
   ☐ Reduce Crashes ☐ Reduce Violations ☐ Reduce Speeds ☐ Other, Please Specify ____________

   b. If you *oppose*, please indicate why you oppose the photo-red enforcement program (*Check all that apply*).
   ☐ Privacy Concerns ☐ Not Reliable ☐ Unfair Practice ☐ Other, Please Specify ____________

4. How should the photo-red enforcement program be operated in Fairfax County? (*Check all that apply*)

   ☐ There should be fine for a red light violation. If yes, how much $____________________
   ☐ Points should be assigned for red light violation.
   ☐ Only a warning should be issued.
   ☐ Other, Please Specify______________________________

5. Are you less likely to run a red light at an intersection where it is known there is photo-red enforcement?

   ☐ Yes ☐ No

6. Please answer the following questions based on your observations in Fairfax County:

   a. How many times per week have you observed drivers running red lights?
   ☐ Never ☐ 1 to 5 ☐ 6 to 10 ☐ 11 to 15 ☐ more than 15

   b. How many of these resulted in accidents? ☐

   c. Do you think red light photo-red enforcement can help improve safety at intersections?
   ☐ Yes ☐ No

7. Have you received a ticket for running a red light during the past year?

   ☐ Yes ☐ No

8. Were you aware of the photo-red enforcement programs in Fairfax County before you took this survey?

   ☐ Yes ☐ No

9. Please indicate your age. ☐

10. Do you have any other comments regarding photo-red enforcement programs?

    ____

    ____

Thank you for your time and assistance!

APPENDIX F
DETAILED FINANCIAL DATA

Introduction

The fiscal analysis was conducted to illustrate the costs and the revenues associated with Virginia's photo-red enforcement programs.

Six jurisdictions in Northern Virginia are included in the analysis: Alexandria, Arlington, Fairfax (city), Fairfax (county), Falls Church, and Vienna. The financial information for each jurisdiction has been analyzed consistently across the board using the same calculation components. The final results are used for cross-comparison purposes highlighting the differences among jurisdictions. Because the program characteristics, and therefore the financial components, were unique for each jurisdiction, certain calculations were necessary to convert data to a consistent format for cross-comparison purposes. Detailed information about these conversion calculations is provided in the Methodology section of this Appendix.

Definitions

The following terminology is used throughout the fiscal analysis.

Citation Data Processing: The cost of all elements that lead to issuing and mailing a citation to the appropriate vehicle owner. Specific components include the cost of camera film, film processing, database-related inquiries to identify the vehicle owner through DMV records, printing/issuance of citations, and mailing of citations to vehicle owners.

Citation Payment Percentage: The number of paid citations as a percentage of mailed citations. For example, an 84.9% citation payment percentage means that 84.9% of all mailed citations were actually paid by violators.

Equipment Design and Installation: All efforts made in the design and installation of the red light camera enforcement system (e.g., equipment/hardware, network systems software, camera housing, camera pole, wiring).

Equipment Operation and Maintenance: Activities associated with the day-to-day operation and maintenance of the system. This includes any necessary repair or replacement of system component parts.

Project Planning and Management: All activities associated in the pre-implementation planning stage and ongoing project management activities during the implementation of the program.

Public Information Program: All activities associated with the task of increasing public awareness of the program in a jurisdiction. This can include distribution of leaflets, direct mailing, posting of street signs, displaying posters and bulletin boards, and TV or radio announcements.

Revenue: This is based on dollars generated from red light traffic citations through one of the camera-monitored intersections. It is calculated by multiplying the number of citations paid by the citation amount of $50.

Study Period: For all jurisdictions, this consists of the years for which revenue and cost amounts have been calculated in the study. The study period is not necessarily the period during which the program has been in effect. For example, one jurisdiction may have started implementing its program in late 1997 but for revenue and cost calculations, the study period of 1998 through 2003 was considered. This was done consistently in all jurisdictions in order to examine revenue and cost amounts for "whole" years (12-month years) and not "partial" years. The end of the study period for all jurisdictions is December 2003, with the exception of the City of Falls Church whose period is from September 2001 through August 2004. This was done especially to reflect the extraordinary large increase of citations reported in Falls Church in 2004. This exceptional trend was not observed in any other jurisdiction.

System: All equipment hardware and software that support the operation of the program.

Violator Inquiries/ Data Management: After a citation has been issued and mailed to the vehicle owner, there may be violation-related inquiry calls coming in from the vehicle owner. These inquiries may initiate data management activities (e.g., record look-up, record verification, database inquiries) in order to respond to the inquiry. All these activities are grouped under "Violator Inquiries/Data Management."

Calculation Components

The financial components taken into consideration for this fiscal analysis consist of the following:

1. *Initial Cost.* This includes all one-time upfront costs including that of equipment purchase (e.g., camera, housing, interface, poles, wiring), installation (labor and materials), and any systems related expenses (e.g., traffic monitoring equipment, computer hardware and software).

2. *Ongoing Cost.* This is the cost of maintaining the red light camera enforcement program and includes charges for equipment maintenance, any applicable equipment rental/lease expenses, costs associated with project planning and management, citation data processing expenses (camera film, film processing, DMV database query, citation mailing, payment tracking, etc.) and all other operational costs associated with the day-to-day implementation of the program (staff salaries, systems

costs, contractor fees, administrative expenses, cost of supplies and materials, postage fees, etc.).

3. *Revenue:* The revenue for the jurisdiction consists of dollars generated from red light traffic citations through one of the camera-monitored intersections and is based on the number of citations that were paid by violators. For all jurisdictions, the penalty for a red light citation caught on camera is $50, although it is possible for this penalty to be reduced in cases where the penalty is appealed in court.

4. *Net Revenue.* This amount is the difference between the revenue and the cost. The amount may be positive in some jurisdictions (i.e., net revenue) or negative in others (i.e., net loss).

5. *Annual Net Revenue:* This is the sum of all net revenue amounts for each year of the study period converted to an equivalent uniform annual worth amount. This amount intuitively reflects the average net revenue for a single year of operation.

6. *Net Present Worth*: Because the period in which the program has been in effect in various jurisdictions is different (e.g., 3 years for one jurisdiction versus 5 for another) and also for consistency purposes, all cost, revenue, and net revenue amounts in the cash flow analysis were converted into Net Present Worth (NPW) and then compared among jurisdictions on an average annual basis (i.e, annual net revenue). A Net Present Worth Factor was used for this calculation.

7. *Revenue-Cost Ratio:* This ratio is calculated by dividing the total revenue amount by the total cost amount (both in net present worth terms) for the entire study period.

Methodology

The fiscal analysis was carried out through the following tasks:

1. *Data Collection:* This was accomplished through field survey questionnaires. Surveys were mailed/faxed/emailed to contact individuals within each jurisdiction with a deadline for receipt of responses. Survey follow-up was made via email and/or telephone calls. For data consistency and accuracy, all efforts were made to follow up with the same individual who initially completed the survey.

   The survey questionnaire asked for specific information (including cost and revenue data) associated with the implementation of the program. The financial information received was used to calculate the costs and revenues of the program in each jurisdiction. Because the program is implemented differently in each jurisdiction, collected data were converted into a consistent format for cross-comparison purposes. This included the grouping of financial information into specific categories (e.g., Initial Cost, Ongoing Cost, Revenue, Net Revenue).

2. *Calculation and Analysis:* This involved the development of a spreadsheet for each jurisdiction. Financial information received from the field was analyzed and entered into each spreadsheet for calculation along with assumption notes. The spreadsheet contained calculation fields to determine the initial cost, all annual ongoing operational expenses, and the revenue generated from the implementation of the program. This information was then used to illustrate the financial impact of the program on each jurisdiction. Several cash-flow analyses showed all annual cost and revenue amounts and the net financial impact of the program (net revenue/loss) for each year of the study period. All annual cost, revenue, and net revenue amounts were converted into NPW for each year. The total net revenue amount for the study period (in NPW form) was converted into annual net revenue, using a capital recovery factor, and then shown in comparison with other jurisdictions. A revenue/cost ratio was also used for cross-comparison purposes among all the jurisdictions. The NPW and the capital recovery factors used in the calculation for each jurisdiction were based on a 3% interest/inflation rate (i = 3%).

Program Enforcement Information by Jurisdiction

Arlington

This jurisdiction has the following program characteristics:

Study Period: 2000-2003
Number of Cameras: 5
Number of Intersections Monitored: 5
Contractor vs. Agency Operated Program: Contractor
Contractor Responsibilities: Project planning and management, equipment installation, equipment operation and maintenance, citation processing/inquiries/data management.
Agency Responsibilities: Project planning and management, decision to issue citations.
Equipment Acquisition Type: Rental

The City of Arlington signed a contract with the equipment manufacturer in December 1998 and installed the first camera by February 1999. There are currently five stationary cameras used in five intersections in the city. Two cameras were installed in 1999, followed by one in 2000, and two additional units in 2001. The city rents the cameras from the manufacturer/vendor and pays the vendor a bundled flat fee of approximately $47,080 on a monthly basis for equipment rental and maintenance expenses, citation data processing, citation inquiries/data management, and the technical operation of the program. The city mailed 70,050 citations from January 2000 through December 2003. Of these, 53,086 citations (75.8%) were paid by violators.

Arlington Cash Flow Analysis (i = 3%)

	Revenue	Cost	Net Revenue	NPW Revenue	NPW Cost	NPW Net Revenue	Annual Net Revenue
2000	$494,282	$560,383	-$66,101	$479,898	$544,076	-$64,177	
2001	$634,377	$703,142	-$68,765	$597,964	$662,782	-$64,818	
2002	$687,253	$670,903	$16,350	$628,905	$613,943	$14,962	
2003	$858,926	$678,288	$180,638	$763,156	$602,659	$160,497	
Total	$2,674,838	$2,612,716	$62,122	$2,469,923	$2,423,460	$46,463	$12,499

Revenue/Cost Ratio	1.02
Total Citations Paid	53,086
Cost/Citation	$45.65
Revenue/Citation	$46.53
Net Revenue/Citation	$.88

City of Fairfax

This jurisdiction has the following program characteristics:

Study Period: 1998-2003
Number of Cameras: 7
Number of Intersections Monitored: 7
Contractor vs. Agency Operated Program: Contractor
Contractor Responsibilities: Equipment installation, equipment operation and maintenance, citation processing/inquiries/data management.
Agency Responsibilities: Project planning and management, decision to issue citations.
Equipment Acquisition Type: Rental

The City of Fairfax program has been in effect since July 1997. There are seven stationary cameras used in seven intersections in the city. Two cameras were installed in 1997, followed by five more in 1997. The city rents the cameras from the manufacturer/vendor and pays vendor on a monthly basis for equipment rental and maintenance expenses. The rental rate ranges from $1,145 to $2,005 per camera per month, depending on various factors such as vendor discount due to addition of new camera units and equipment failure discount (equipment malfunction, loop cut) among other things. The cost of equipment maintenance is $515 per camera per month. Citation data processing, violator inquiries, and archive violation data management are handled by vendor. The city pays the vendor $23.50 per citation for data processing. The payment of this charge depends on the validity of the violation cited by the vendor. There are circumstances when a discrepancy exists in validating a violation (e.g., equipment misalignment, wrong violation date, wrong violation parameter, over/under exposed film). Under these circumstances, the city may reject a violation as being invalid, in which case the $23.50 payment to the vendor will not apply. The city issued 52,641 citations from January 1998 through December 2003. Of these, 44,687 citations (84.9%) were paid by violators.

Fairfax Cash Flow Analysis (i = 3%)

	Revenue	Cost	Net Revenue	NPW Revenue	NPW Cost	NPW Net Revenue	Annual Net Revenue
1998	$328,269	$427,906	-$99,637	$318,716	$415,454	-$96,738	
1999	$474,945	$325,396	$149,549	$447,683	$306,718	$140,965	
2000	$355,916	$321,050	$34,866	$325,699	$293,793	$31,906	
2001	$355,000	$349,546	$5,454	$315,418	$310,572	$4,846	
2002	$347,732	$357,851	-$10,119	$299,954	$308,682	-$8,729	
2003	$374,126	$389,219	-$15,093	$313,331	$325,971	-$12,640	
Total	$2,235,988	$2,170,968	$65,020	$2,020,800	$1,961,190	$59,610	$11,004

Revenue/Cost Ratio	1.03
Total Citations Paid	44,687
Cost/Citation	$43.89
Revenue/Citation	$45.22
Net Revenue/Citation	$1.33

Vienna

This jurisdiction has the following program characteristics:

Study Period: 2000-2003
Number of Cameras: 3
Number of Intersections Monitored: 3
Contractor vs. Agency Operated Program: Joint Partnership
Contractor Responsibilities: Project planning and management, equipment installation, equipment operation and maintenance, violator inquiries/data management.
Agency Responsibilities: Project planning and management, violator inquiries/data management, decision to issue citations, citation processing.
Equipment Acquisition Type: Lease

The City of Vienna started its program in June 1999 by installing the first camera unit, followed by the installation of the second unit in September 2003 and the third in May 2004. There are currently three stationary cameras covering six approaches within three intersections in the city. The program is supported by the city and the contractor. The technical areas such as equipment design/installation, operations, and maintenance are handled by the contractor whereas other responsibilities such as citation data processing and the public information program are handled by the city.

The city has agreed on a contractor fee-per-citation pay scale, but there is a minimum fee of $2,262 per month per approach ($2,262 x 6 approaches x 12 = $162,864 per year) that applies if the contractor charge from the fee-per-citation pay scale falls below this minimum amount. As it turned out in the analysis, the minimum fee amount applied in each month for the cost calculation. The fee-per-citation pay scale is as follows:

Monthly Citation Volume	Fee-per-Citation
0 to 750	$25.00
751 to 1000	$23.75
1001 to 1500	$22.56
1501 to 2500	$21.43
2501+	$20.36

The city mailed 7,755 citations from January 2000 through December 2003. Of these, 6,649 citations (85.7%) were paid by violators.

Vienna Cash Flow Analysis (i = 3%)

	Revenue	Cost	Net Revenue	NPW Revenue	NPW Cost	NPW Net Revenue	Annual Net Revenue
2000	$103,395	$139,613	-$36,218	$100,386	$135,550	-$35,164	
2001	$157,019	$149,330	$7,689	$148,006	$140,758	$7,248	
2002	$28,250	$139,209	-$110,959	$25,852	$127,390	-$101,539	
2003	$43,800	$118,499	-$74,699	$38,916	$105,286	-$66,370	
Total	$332,464	$546,651	-$214,187	$313,160	$508,985	-$195,825	-$52,677

Revenue/Cost Ratio	0.62
Total Citations Paid	6,649
Cost/Citation	$76.55
Revenue/Citation	$47.10
Net Revenue/Citation	-$29.45

Alexandria

This jurisdiction has the following program characteristics:

Study Period: 1998-2003
Number of Cameras: 3
Number of Intersections Monitored: 4
Contractor vs. Agency Operated Program: Joint Partnership
Contractor Responsibilities: Equipment installation, equipment operation and maintenance, citation processing, violator inquiries/data management.
Agency Responsibilities: Project planning and management, equipment installation, equipment operation and maintenance, decision to issue citations, citation processing, violator inquiries/data management, public information program.
Equipment Acquisition Type: Rental

The City of Alexandria started their program in November 1997 by installing three camera units in three intersections. A fourth intersection was added in March 2004, but this did not require the addition of a new camera unit since the cameras are used on a rotating basis among the four intersections. The program is supported by the city and the contractor.

The city mailed 49,774 citations from January 1998 through December 2003. Of these, 34,629 citations (69.6%) were paid by violators.

Alexandria Cash Flow Analysis (i = 3%)

	Revenue	**Cost**	**Net Revenue**	**NPW Revenue**	**NPW Cost**	**NPW Net Revenue**	**Annual Net Revenue**
1998	$653,150	$323,560	$329,590	$634,143.34	$314,144.40	$319,999	
1999	$286,150	$323,560	-$37,410	$269,724.99	$304,987.66	-$35,263	
2000	$133,400	$323,560	-$190,160	$122,074.34	$296,089.76	-$174,015	
2001	$137,550	$334,060	-$196,510	$122,213.18	$296,812.31	-$174,599	
2002	$318,950	$352,560	-$33,610	$275,126.27	$304,118.26	-$28,992	
2003	$202,250	$352,560	-$150,310	$169,384.38	$295,269.00	-$125,885	
Total	$1,731,450	$2,009,860	-$278,410	$1,592,666.49	$1,811,421.38	-$218,755	-$40,382

Revenue/Cost Ratio	0.88
Total Citations Paid	34,629
Cost/Citation	$52.31
Revenue/Citation	$45.99
Net Revenue/Citation	-$6.32

Fairfax County

This jurisdiction has the following program characteristics:

Study Period: 2001-2003
Number of Cameras: 10
Number of Intersections Monitored: 13
Contractor vs. Agency Operated Program: Agency
Contractor Responsibilities: Equipment installation, equipment operation and maintenance, violation data management.
Agency Responsibilities: Project planning and management, equipment installation, decision to issue citations, citation processing, violator inquiries/data management, public information program.
Equipment Acquisition Type: Purchase

Fairfax County started their program by installing the first camera in October 2000 followed by installing cameras in 8 intersections in 2001, 2 intersections in 2002, and 2 intersections in 2003. The county rotates 10 cameras among 13 intersections. The program is mainly operated by the county, with some support from the contractor.

The county mailed 73,657 citations from January 2001 through December 2003. Of these, 52,087 citations (70.1%) were paid by violators.

Fairfax County Cash Flow Analysis (i = 3%)

	Revenue	Cost	Net Revenue	NPW Revenue	NPW Cost	NPW Net Revenue	Annual Net Revenue
2001	$235,969	$727,364	-$491,395	$229,102	$706,198	-$477,095	
2002	$1,248,297	$888,676	$359,621	$1,176,645	$837,666	$338,979	
2003	$1,120,086	$1,271,518	-$151,432	$1,024,991	$1,163,566	-$138,575	
Total	$2,604,352	$2,887,558	-$283,206	$2,430,738	$2,707,430	-$276,692	-$97,811

Revenue/Cost Ratio	.90
Total Citations Paid	52,087
Cost/Citation	$51.98
Revenue/Citation	$46.67
Net Revenue/Citation	-$5.31

Falls Church

This jurisdiction has the following program characteristics:

Study Period: September 2001-August 2004
Number of Cameras: 6 (for two approaches/intersection, @ 3 intersections)
Number of Intersections Monitored: 3
Contractor vs. Agency Operated Program: Joint Partnership
Contractor Responsibilities: Project planning and management, equipment installation, equipment operation and maintenance, citation processing, violator inquiries/data management.
Agency Responsibilities: Project planning and management, equipment installation, equipment operation and maintenance, decision to issue citations, citation processing, violator inquiries/data management, public information program.
Equipment Acquisition Type: Purchase

The City of Falls Church began their program by installing the first two camera units in October 2001 followed by two additional cameras in 2002, and two more in 2004. Each of the three intersections uses two stationary cameras (one for each direction).

The city mailed 30,448 citations from September 2001 through August 2004. Of these, 25,623 citations (84.1%) were paid by violators.

Falls Church Cash Flow Analysis (i = 3%)

	Revenue	Cost	Net Revenue	NPW Revenue	NPW Cost	NPW Net Revenue	Annual Net Revenue
2002	$212,750	$406,113	-$193,363	$206,558.98	$394,295.11	-$187,736	
2003	$511,950	$423,445	$88,505	$482,564.07	$399,139.26	$83,425	
2004	$556,450	$440,777	$115,673	$509,207.40	$403,355.03	$105,852	
Total	$1,281,150	$1,270,335	$10,815	$1,198,330.44	$1,196,789.40	$1,541	$545

Revenue/Cost Ratio	1.00
Total Citations Paid	25,623
Cost/Citation	$46.71
Revenue/Citation	$46.77
Net Revenue/Citation	$.06

Comparison Chart for Jurisdictions

Jurisdiction	Benefit/Cost Ratio	Annual Net Revenue	Annual Net Revenue per Citation Annual Net Revenue/Average Annual Citations
Arlington	1.02	$12,499	$0.88
Fairfax	1.03	$11,004	$1.33
Vienna	0.62	-$52,677	-$29.45
Alexandria	0.88	-$40,382	-$6.32
Fairfax County	0.90	-$97,811	-$5.31
Falls Church	1.00	$545	$.06

APPENDIX G
TECHNICAL FEASIBILITY: IN-DEPTH DESCRIPTION OF THE PHOTO-RED SYSTEM

Three basic questions need to be examined from the perspective of the technical feasibility of the photo-red cameras. First, do the systems themselves, composed of equipment and human reviewers, operate correctly under normal conditions and are they free from bias? Second, how does the system handle the issuance of citations to potential violators? Third, what mechanical or performance standards are applicable for this technology?

Does the System Function Properly?

There are many elements to a red light camera system and in order to have a proper understanding of the system in its entirety, a basic understanding of the technology and the process is necessary. Despite some questionable results and occurrences, the technology appears to function properly.

Definitions

Red Light Violation

Each red light camera jurisdiction states that once the light changes to red, if the vehicle enters the intersection after that moment and continues to cross the intersection, the driver is guilty of a red light violation (Va. Code Ann. § 46.2–833). In addition, for red light cameras, the localities built in a delay, but these delays vary on the amount of time that must pass between the traffic light turning red and the point the vehicle enters the intersection before the camera starts to photograph it. The time for the delay range usually varies between 0.1 second (Ellis, questionnaire, 2004) after the light turns red to 0.4 second (Veneziano, questionnaire, 2004). The statute does not speak to the minimum amount of time required before a red light violation is cited or if the delay is necessary. Throughout this analysis, the definition of a *red light violation on a red light camera* will depend on the definition adopted by each jurisdiction. It is possible for a driver to be cited for a red light infraction in one jurisdiction and not in another while committing the same driving act (e.g., entering the intersection at 0.2 second after the light turned red would be a violation in Falls Church but not in Virginia Beach). Therefore, the term *red light violation* as used in this report is a violation in a particular jurisdiction and does not make reference to a specific cause or event (e.g., a specific delay on the camera) but to a violation in the context used.

Intersection

A red light violation occurs only if a vehicle illegally enters an intersection (Va. Code Ann. § 46.2–833.01). The Commonwealth defines an intersection as:

> (i) [T]he area embraced within the prolongation or connection of the lateral curb lines or, if none, then 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

> joining at any other angle may come in conflict; (ii) where a highway includes two roadways 30 feet or more apart, then every crossing of each roadway of such divided highway by an intersecting highway shall be regarded as a separate intersection, in the event such intersecting highway also includes two roadways 30 feet or more apart, then every crossing of two roadways of such highways shall be regarded as a separate intersection; or (iii) for purposes only of authorizing installation of traffic-control devices, every crossing of a highway or street at grade by a pedestrian crosswalk (Va. Code Ann. § 46.2–100).

The curb lines, not the white line that may be painted across the lane, define the intersection. The vehicle must enter the intersection for a red light camera violation (Va. Code Ann. § 46.2–833.01). If the vehicle is halfway across the stop line at the time the light changes to red, there is no violation if it has not passed the curb line. The *stop line* is the imaginary line that defines the borders of the intersection, and the term will be used accordingly in this report. For this report, the *border of the intersection* and the *stop line* are synonymous.

Code Requirements

Grace Period

Although there is no Virginia Code requirement for a delay (i.e., grace period) after the light turns red for the locality to start recording violations of individuals entering the intersection, all localities in Virginia have voluntarily enabled one. Each locality in the Commonwealth has a delay above 0.0 second (the smallest being 0.1 second) or various reasons. Sometimes it is a technology requirement since 0.1 second is the approximate time the light signal takes to send a message to the camera that the light has turned red. Other reasons include fairness and the desire to catch the more blatant offenders as opposed to the questionable incidents. The delays provide additional evidence that the localities are not trying to use the cameras as revenue-raising devices.

It is important to note that the delay occurs before the camera photographs the vehicle *entering* the intersection. If the vehicle is already in the intersection, the camera will not photograph it for a red light violation. Since the Virginia Code requires a red light camera to take two photographs, and "at least one recorded image shall be of the vehicle before it has illegally entered the intersection" (Va. Code Ann. § 46.2–833.01), it would be impossible to capture the vehicle entering the intersection if the still camera does not record prior to the light turning red (if the vehicle is already in the intersection).

If the photo system is a video camera, the system does not operate in the same manner. Nestor Traffic Systems (Nestor), an implementer of video camera technology to capture red light violations, uses a technology that can predict the violation prior to the vehicle reaching the stop line (Nestor Traffic Systems, 2004, Overview section). According to the pre-negotiated time (down to the millisecond [Borkat, interview, 2004]) of recording dictated in the contract between Nestor and the public entity, the video from the video unit is captured. Due to the length of the video image and the precision of the technology, the vehicle entering the intersection and the entire light change can be reviewed. Since the video can be separated to show precise moments in time, there is little doubt as to how much time passed between the light change and the red light running incident. But, because the captured clip may not be a violation if the driver increased his or her speed to enter the intersection before the light turned to red, the clip may not represent a violation. Technically, this means that the technology could capture information too early; however, if this situation occurs, the information is discarded. Although the example is a Nestor video system, the process is similar for other red light camera video systems.

The violation occurs only if the vehicle enters the intersection at the moment the camera starts to record or later. If a photograph is taken at 0.1 second after the light turned red and the delay for the particular locality is 0.3 second, under Virginia law, the driver is guilty of a red light running violation. However, since the cameras are set to record only after a delay, this situation would not result in a citation being issued. In addition, two reviews are conducted by the vendor and the police to remove any questionable results the may occur prior to the delay having passed. This is more of a concern for video cameras than for still cameras, since video cameras have the possibility of capturing a red light violation prior to the delay time.

Locality Requirements

The Virginia Code states that only certain localities are permitted to use photo-monitoring systems to enforce traffic signals.

> The governing body of any city having a population of more than 390,000, any city having a population of at least 200,000 but less than 225,000, any county having the urban county executive form of government, any county adjacent to such county, and any city or town adjacent to or surrounded by such county except any county having the county executive form of government and the cities surrounded by such county may provide by ordinance for the establishment of a demonstration program imposing monetary liability on the operator of a motor vehicle for failure to comply with traffic light signals in such locality in accordance with the provisions of this section. Each such locality may install and operate traffic light signal photo-monitoring systems at no more than twenty-five intersections within each locality at any one time (Va. Code Ann. § 46.2–833.01).

The statute permits six counties, two towns ,and two cities to operate a "photo monitoring system to enforce traffic signals"(Va. Code Ann. § 46.2–833.01). Currently, five counties (Fairfax County, Alexandria, Arlington, Falls Church, and Virginia Beach), one town (Vienna), and one city (City of Fairfax) have implemented photo-monitoring systems to enforce red light signals. One town (Herndon), one city (Richmond), and one county (Loudoun) are permitted by the statute to implement a photo-monitoring system, but at the time this report was written, they chose not to do so. Depending on the interpretation of the statute, additional towns and jurisdictions may be permitted to install red light cameras.

Penalty Requirements

Unlike many states, Virginia localities are permitted to punish the violator only with a monetary penalty and are not allowed to attach any points to their license. The statute permitting photo-monitoring systems states "[n]o monetary penalty imposed under this section shall exceed fifty dollars nor shall it include court costs" (Va. Code Ann. § 46.2–833.01). A jurisdiction may not penalize the owner more than $50, which is extremely low when compared to the penalties assessed in other states. Many other jurisdictions outside Virginia have penalties of at least $75 (Maccubbin et al., 2001).

If a driver were to receive a red light running violation from a law enforcement officer and not by virtue of a red light camera, the penalties are quite harsh. In addition to a large fine (often $100 + court costs of $56 but this amount may be different in some jurisdictions), the driver may have points attributed to his or her license. Many jurisdictions in the Commonwealth assess only three points, though many assess the maximum four points.

Photograph Requirements

The Virginia Code states:

> For each such vehicle, at least one recorded image shall be of the vehicle before it has illegally entered the intersection, and at least one recorded image shall be of the same vehicle after it has illegally entered that intersection (Va. Code Ann. § 46.2–833.01).

There must be two photographs of the vehicle: one prior to entering the intersection and one after it has entered the intersection. Since the cameras are not activated until the light turns red and the delay has passed, if a vehicle is in the intersection when the light changes to red, it is not possible under current operations to cite the driver. It is possible for a locality to change their process to take pictures of vehicles prior to entering the intersection, but there are questions related to whether that would be a legal practice since the language of the statute uses the words "illegally entered" (Va. Code Ann. § 46.2–833.01).

Regarding yellow light times, the Virginia Code states:

> Steady amber indicates that a change is about to be made in the direction of the moving of traffic. When the amber signal is shown, traffic, which has not already entered the intersection, including the crosswalks, shall stop if it is not reasonably safe to continue, but traffic, which has already entered the intersection, shall continue to move until the intersection has been cleared. The amber signal is a warning that the steady red signal is imminent (Va. Code Ann. § 46.2–833).

Throughout this report, the term *yellow light* is interchangeable with *amber light.* Concerning a red light, the Virginia Code states:

> Steady red indicates that moving traffic shall stop and remain stopped as long as the red signal is shown, except in the direction indicated by a lighted green arrow (Va. Code Ann. § 46.2–833).

Although a yellow light enforcement situation has not occurred in Virginia, and likely will not occur due to the localities desire for fairness, this mechanism may be available to the localities. The questionable situation would occur if the locality chose to initiate the photograph sequence while the light was yellow for the first photograph and red or yellow for the second photograph. Under the Virginia Code, the photographs are "prima facie evidence that the vehicle described . . . was operated in violation of" (Va. Code Ann. § 46.2–833.01) the photo-monitoring systems section. Given that the photo-monitoring system is in place to "enforce traffic light signals" (Va. Code Ann. § 46.2 – 833.01), the question would be whether the first photograph with the yellow light showed the intersection as not "reasonably safe" (Va. Code Ann. § 46.2–833) to continue. Since the pictures are prima facie evidence, the burden of production shifts to the owner of the vehicle to show that he or she was proceeding into a "reasonably safe" (Va. Code Ann. § 46.2–833) intersection. It would likely be extremely difficult for the owner of the vehicle to prove that it was "reasonably safe" (Va. Code Ann. § 46.2–833) since he or she would probably have no more than his or her word to combat the pictures. It is unlikely that a motorist records photographs of intersections that the motorist enters.

Owner's Defenses

If the driver of the vehicle cited for a photo-monitoring system violation is not the owner of the vehicle, the driver will not receive the citation. Under the Virginia Code, the registered owner of the vehicle is the recipient of the citation (Va. Code Ann. § 46.2–833.01).

> The presumption shall be rebutted if the owner, lessee, or renter of the vehicle (i) files an affidavit by regular mail with the clerk of the general district court that he or she was not the driver of the vehicle at the time of the alleged violation or (ii) testifies in open court under oath that he or she was not the operator of the vehicle at the time of the alleged violation (Va. Code Ann. § 46.2–833.01).

When a vehicle owner receives a red light violation citation in the mail, the affidavit is available on the reverse side. The owner merely needs to sign it and send it to the appropriate locality to have the citation extinguished. The second option of testifying in court under oath is a more time-consuming option than the first that achieves the same result: a statement under oath that the owner was not the driver of the vehicle and the citation is removed. Virginia is the only state that allows a signed affidavit to expunge the owner's penalty (other states offer the affidavit but require the owner to inform the jurisdiction who the driver was).

The Virginia Code also allows for the admission of a certified copy of a police report that the vehicle was stolen prior to the alleged violation to admonish the owner of the citation (Va. Code Ann. § 46.2–833.01).

The System: Technical Component

There are multiple systems currently in use in the Commonwealth, the most common being a still 35 mm wet film camera. Due to innovations in the red light camera industry, new technologies have progressed and have been implemented in the form of digital still cameras and digital video. Other innovations include the ability for immediate download of digital media through phone lines or additional modes of communication (e.g., broadband). The modes of detection have also progressed from inductive loops to video modes of detection, though inductive loops remain a reliable and often-used technology. The placement of cameras has changed as well. The standard location was curb based, but some technologies (primarily digital video) use overhead camera placement.

In Virginia, each locality acts independently. Each is responsible for funding their program, creating their review standards, setting their delay ("grace period), creating their contract, choosing a vendor, and establishing and carrying out all other aspects of their program. The state receives no funds from the violations, and most localities will lose money on their photo-monitoring program.

The Federal Highway Administration identifies six components as common to all systems (Federal Highway Administration, 2003):

1. camera units
2. intersection lighting
3. camera housing and supporting structure
4. vehicle detection
5. communications
6. warning signs.

Each component is further analyzed here.

Camera Unit

There are primarily three types of systems used in the Commonwealth: 35 mm wet film, digital still pictures, and digital video. The most common type is 35 mm wet film; however, digital video is currently the apparent preference of jurisdictions employing red light cameras for the first time. Virginia Beach is the most recent jurisdiction to implement a red light camera system, choosing a combination of a digital still camera and a digital video camera.

Each camera unit has pros and cons, as listed in Table G1. The concepts in the table comprise a combination of published reports and interviews with company representatives and represent only a few of the pros and cons of the various systems. It is not intended to be an exhaustive accounting.

Table G1. Photo-Red Camera Technologies

Camera Unit Type	Pros	Cons
35 mm Wet Film	• Relatively inexpensive installation • Higher pixel count (usually 18-20 million) • Less chance for manipulation	• Labor intensive for collection • Storage
Digital Still Pictures	• Collection can be immediate • Digital format • Storage	• Lower pixel count (usually 2 million) • Needs communication link (telephone wires, etc.) • Can be manipulated
Digital Video	• Collection can be immediate • Captures entire sequence • Storage	• Needs communication link (telephone wires, etc.) • Impression of surveillance

Intersection Lighting

Each contractor outlined the lighting requirements for their camera system. Additional lighting is likely required beyond what is already in place (e.g., street lights). This may take the form of additional lighting fixtures, or the camera may be equipped with synchronized flashes that work in conjunction with the camera unit. Additional light fixtures called auxiliary lights may be placed near the camera to offer additional light for the picture. The auxiliary lights are located on independent poles and are connected to the main unit to ensure that an additional flash is synchronously produced with the camera unit's flash.

Lighting is the common reason for devices marketed as being able to "beat" red light cameras. The devices usually attempt to bounce the flash back toward the camera, resulting in over-exposed film. There is a debate over the effectiveness of the devices, but it may be a moot issue if the lighting requirement can be reduced. If the lighting required for the photograph unit were reduced, then the flash of light that would reflect off the license plate would not be a strong enough flash to result in an over-exposed area of the picture.

Camera Housing and Supporting Structures

Each manufacturer has individual requirements for a housing structure.

Curb-mounted structures typically require a housing unit for the camera and a pole to position the housing unit at a proper height. Digital cameras require an additional, separate enclosure inside the housing unit for data storage and communication equipment (Federal Highway Administration, 2003). There are various types of poles that can be used. The pole may have a hinge in the middle to lower the housing unit or the pole may be solid while a motorized "elevator" moves the housing unit up and down (Federal Highway Administration, 2003).

Overhead mounted cameras are usually attached to a curbside pole that overhangs the street, providing a wider viewing angle. The structure that holds the camera likely will not allow a civilian see in which direction the camera is pointed due to the dark, consistent structure surrounding the camera. Some have alleged that the unit may evoke a feeling of governmental surveillance. However, there are multiple cameras in use throughout Virginia for viewing traffic, some of which are available for anyone to view through a website (www.trafficland.com).

Vehicle Detection

There are various systems used to detect the presence and speed of a vehicle.

Inductive loops are the most widely used and accepted traffic detection technology in the United States (Federal Highway Administration, 1996). However, no technology is perfect and there may be minor problems, such as susceptibility to being damaged during road construction (Federal Highway Administration, 1996). Regardless, inductive loops have proven to be reliable and are used throughout the United States. When operated properly, inductive loops are "very accurate" (Federal Highway Administration, 1997).

A photo-monitoring system may use other forms of detection such as video-based devices. Video based systems may use a detection system involving video cameras that predict violators, though some video-based systems still implement inductive loops. All of the still cameras in Virginia use an inductive loop to initiate the camera system.

Individual companies should have documentation on the accuracy of their systems for detection purposes.

An important element of stationary devices for detection is the placement of such devices. The Virginia Code states:

> For each such vehicle, at least one recorded image shall be of the vehicle before it has illegally entered the intersection, and at least one recorded image shall be of the same vehicle after it has illegally entered that intersection [Va. Code Ann. § 46.2–833.01(E)].

The cameras must be placed properly to comply with the statute. Video-based detection devices anticipate the vehicle and therefore do not have the associated issue of where the vehicle is located in the picture since the video clip is commonly 4 to 5 seconds long and encompasses the driver prior to entering the intersection and the continuation of the vehicle through it.

Communications

Digital media typically require a method of communication to download the digital pictures and/or digital video to the central processor. Each company has individual requirements, though the desired mode of transmission is usually over a line with a greater capacity (bandwidth) than an ordinary telephone modem (e.g., broadband). Although the digital medium is not always downloaded immediately, the pictures are available for viewing quicker than with a 35 mm wet film. The quicker communication may allow the contractor to resolve problems with the camera earlier due to the constant digital access to the camera.

No communication equipment is needed for 35 mm wet film. However, labor is required to accomplish the same task that the communications equipment enables.

Warning Signs

The Virginia Code does not mandate warning signs; however, some localities voluntarily provide them for drivers. The signs may be placed prior to the driver reaching the intersection and at the intersection, or there may be general signs warning the public that they have just entered a red light camera jurisdiction. There are no stipulations for the use of warning signs for photo-monitoring systems in the Virginia Code.

The System: Human Component

Selected processes from localities in the Commonwealth to capture red light violations and issue citations are described here. An important note must be made on industry terminology. Prior to the picture set being considered a violation by the police department, the picture set is termed an *event*. When the contractor reviews the pictures, they are still *events* and not yet *violations*.

Due to each contract being negotiated individually between the locality and the vendor, there are numerous possibilities for defined roles for each. Although the descriptions show how a locality in the Commonwealth interacts with a vendor, the vendor may not act in the same manner with another locality in the Commonwealth. Each contract outlines the different roles of each party.

Fairfax County

Fairfax County's red light program was cited by the American Automobile Association (AAA) as an "effective tool in curtailing violations, and thus preventing crashes and the resulting injuries and fatalities" (Fairfax County, Office of Public Affairs). Fairfax County started their program on October 1, 2000, maintaining 13 cameras while building additional housing units through which to rotate them. Fairfax County has issued more than 72,000 citations for red light running and has seen a drop of 70% of red light running events at monitored intersections (Fairfax County Police Department, Cameras at Street Intersections).

The system consists of 35 mm wet film cameras and is checked daily by an ACS (Affiliated Computer Services) employee who services the camera while removing the pictures from the unit. The camera records the date, time, speed of the vehicle, and the time elapsed since the beginning of the red light signal for each event (Fairfax County Police Department, Cameras at Street Intersections). There is a 0.2-second delay after the light turns red until the camera begins to photograph vehicles entering the intersection. The camera is connected to the traffic signal, and no picture is taken unless there is a possible violation. The vendor reviews the pictures and removes non-violations and events that contain insufficient information to be used in court. The remaining pictures are given to the Fairfax County Police Department where they undergo another round of review, and additional events are removed. ACS no longer retains access to the events after they are released to the Fairfax County Police Department. There is also a third review of the printed notice by someone who did not conduct the online review prior to placing the citation in the envelope for mailing. Once the pictures are declared violations by the police department, Fairfax County obtains the names and addresses of each vehicles registrant from the Department of Motor Vehicles (DMV). This contact information is then added to the violation information on the ACS computer, although ACS is prevented from accessing it (Taylor, e-mail interview, 2004). The system is owned by ACS, which dictates the information be placed on the same computer for the programs to work properly instead of being stored on a separate computer. Fairfax County issues the violation notice to the vehicle registrant with instructions to mail the fine to the Department of Tax Administration. ACS has no part in collecting the fines. If the police department has received no response after two attempts at mailing a citation and the registrant is a Virginia resident, a summons will be issued and served by the sheriff (Taylor, personal interview, 2004).

Fairfax County has a relatively low rate for citations resulting from red light running events (the Fairfax County citation rate is approximately 54% for events captured on the cameras) (Fairfax County Police Department, 2004). This is a result of Fairfax County's desire to be as fair as possible and not to issue a citation unless it will in all likelihood be upheld in court (Taylor, telephone interview, 2004).

Virginia Beach

Virginia Beach is the newest county in the Commonwealth to install a red light photo monitoring system. The county employs the Redflex red light camera system to capture the violation in a digital video and in digital still photographs. Each unit has a separate digital still camera and a digital video camera (Carpinteri, interview, 2004). The video camera is used for persuasive evidence and not for the issuance of citations. When a possible violation occurs, the digital still camera takes two photographs. The first is just prior to the vehicle entering the intersection, and the second is the vehicle in the intersection (Virginia Beach Government, Photo Safe Virginia Beach). The system is initiated by a signal received from inductive loops placed in the road and is active only once the light turns red and the delay has passed. The camera records the date, time of day, speed of vehicle, and the time elapsed since the beginning of the red light signal for each red light running event. Virginia Beach sets its cameras to a 0.3-second delay after the light turns red prior to recording a possible violator entering the intersection. The camera is connected to the traffic signal, and no video or still digital picture is taken unless there is a possible violation. The events are downloaded from the camera several times a day by Redflex and stored. Redflex and the Virginia Beach Police Department are the only ones that can view the video (Summerell, interview, 2004). Redflex reviews the pictures, removes improper events, and places the remaining events in a format for the police department to review. Redflex stores all of the data, including the names and addresses for the violators, which are retrieved by the police department from the DMV. Redflex sends out the citations for the violations and collects the fees.

Due to the newness of the Virginia Beach program, its effectiveness cannot yet be tested. However, the Virginia Beach Police Department has shown great flexibility and deference to fairness by acting on suggestions to increase the delay time from 0.1 second to 0.3 second prior to recording a violation.

Falls Church

Falls Church uses a digital video camera system provided by Nestor Traffic Systems (Nestor) to capture red light violations. The cameras overhang the street in enclosures and capture a video clip starting prior to the vehicle illegally entering into the intersection through its continuation into the intersection. The CrossingGuard system (Nestor's proprietary system) uses a high-speed video camera to predict possible violations and a "pan-tilt-zoom video camera" to record the event (Nestor Traffic Systems, CrossingGuard Video-based Red Light Enforcement). As a result of the high-speed camera used to predict possible violations, no inductive loops are necessary. No video is recorded unless there is a possible violation, and there is a 0.1-second grace period after the light turns red for the owner not to receive a citation. The system records the date, time of day, the speed of the vehicle, and the time elapsed since the beginning of the red light signal for each red light running event (Borkat, interview 2004). Once the system anticipates a red light running violation, it can delay the green light to avoid side impact crashes (Nestor Traffic Systems, CrossingGuard Video-based Red Light Enforcement). Nestor downloads the images from the unit and performs an initial review of the events prior to forwarding the remaining pictures to the Falls Church Police Department. Once the police department performs a second review, they obtain the owner's information from the DMV. The information is forwarded to the vendor so that the citation can be printed and mailed.

All violation data are recorded on a secure Nestor or police department server at a central processing facility. Authorized Nestor employees and authorized city employees are the only persons that have access to the data.

Nestor mails the first violation notice and if no response if received, then Nestor mails a second notice. If the second notice does not elicit a response, the Falls Church Police Department sends a third notice. If there is no response to the third notice, a fourth notice is sent by the Falls Church Police Department. If no response is received to a fourth notice, a Sheriff Summons is obtained for Virginia residents only (Ellis, interview, 2004). The penalties received by Falls Church are sent by the owner of the vehicle to a lock box that was established in the city's name (Ellis, interview, 2004).

Capturing Red Light Violations

Jurisdictions take numerous steps to ensure that no improper citations are mailed. When the contractor removes the pictures or video from the red light camera, they conduct their review to remove databox errors, exposed film, improper framing of pictures, and similar causes for no violation being able to be cited. The remaining events are sent to a trained law enforcement officer (or other properly trained individual) for review. The law enforcement officer may remove non-violations for reasons ranging from emergency vehicles to unclear tags to no actual violation. After the law enforcement officer reviews each event set and removes the non-violations, the remaining events are declared violations and are mailed to registered owners. After having gone through two complete checks for the violation, the registered owner can contest the citation in court, pay the citation, or sign an affidavit stating that he or she was not the driver. The affidavit is mailed back to the jurisdictional office where the violation is removed from their record. The availability of an affidavit is required under the Virginia Code (Va. Code Ann. § 46.2–833.01).

Due to the two complete checks prior to the mailing of the citation and the availability of the affidavit to the registered owner, there are few violations dismissed by the court. In Fairfax County, there were 66,566 violations mailed from October 1, 2000, through July 31, 2003, resulting in only 1,312 violations being categorized as "Dismissed/Suspended/Other" (Fairfax County Police Department, Traffic Signal Violation, 2004). These results suggest the courts (the bodies that dismiss most of the tickets) are dismissing a relatively small percentage of issued citations. It should also be noted that from August 1, 2003, through April 30, 2004, only one citation has been dismissed by the courts, furthering the likelihood of a trend toward fewer dismissals (Fairfax County Police Department, Traffic Signal Violation, 2004). Fairfax County has had less than two dozen cases dismissed in court with the defendant present (Taylor, e-mail interview, November 2004). It is important to note that dismissals may be for numerous reasons, including procedural reasons, and do not necessarily indicate an improper citation being mailed.

One reason for the larger number of dismissals in the past was the reluctance of the judiciary to uphold citations. It was commented by numerous jurisdictions and vendors that judges were skeptical at first, but over time, their concerns were addressed and changes to the system were made. In support of this view, the judges in Fairfax County did not believe they needed additional training at the beginning of enforcement because they were already familiar with the program (Taylor, e-mail interview, November 2004).

Non-violations

Unfortunately, numerous drivers violate red light laws every day, and some situations will occur where the photo-monitoring system does not produce a citation. The following categories were developed as a guide for understanding and they should not be taken as official categories of red light non-violations: (1) the camera cannot capture the possible violation, (2) human error, (3) no violation exists, and (4) technical malfunctions.

Possibilities for the first category include the vehicle has no license plate, the camera captures the violation, but the recorded address for the registered owner of the vehicle is no longer valid. In Alexandria County, from November 12, 1997, through January 31, 2004, 2.66% of the citations mailed were undeliverable (Alexandria Police Department Parking Office, 2004).

The second category of human error accounts for numerous rejections of violations. However, historical trends suggest that this category is getting smaller. The setup of a camera is a difficult process and will often require minor initial adjustments to capture the red light violator. Once the system is functioning properly, fewer adjustments are needed. Human error will occur, but with thorough oversight, extended durations of continuous errors should be diminished. Examples of human error are improper removal of film, causing overexposed film, and the angle of the camera being misdirected. Another example is when the police department and the vendor disagree over the numbers on the license plate. In such a situation, the event would be removed.

The third category, no actual violation, encompasses various situations ranging from funeral processions to traffic being controlled at intersections by a law enforcement officer. If a driver turns right on red, which is allowed in the Commonwealth if there is no sign stating the contrary (Va. Code Ann. § 46.2–835), the camera may take a picture (though the vehicle would have to meet the minimum speed requirements, suggesting that the picture would not be taken). If the camera does take a picture, the review process will remove it from the other possible violations. Other examples of non-violations are emergency vehicles crossing the intersection on a red light, which is specifically allowed in the Virginia Code (Va. Code Ann. § 46.2–920). Many jurisdictions check to make sure the emergency lights are on and that the driver of the emergency vehicle is not abusing the deference shown to him or her. The review phases will remove all non-violation events from the list of violations, and no citations should be mailed. Depending on the jurisdiction's preference for the level of clarity regarding a red light violation and their standard of review, the number of possible violations may be skewed from jurisdiction to jurisdiction.

The fourth category is a mix of technical malfunctions. Technical malfunctions are rare, but they do occur. The data stamp the camera places on the photograph can cause one type of error. Fairfax County's stamp is representative of those of other jurisdictions and places the date, time of day, speed of the vehicle, and the time elapsed since the beginning of the red light signal (Fairfax County, Office of Public Affairs). Fairfax County has occasionally encountered the stamp being absent or improperly made, but it has taken steps to fix the problem, resulting in only a few violations being discarded due to “V-dash” errors (Fairfax County Police Department, Traffic Signal Violation, 2004). A blurry picture will also cause an event to be removed. The lens may be out of focus or temporary weather conditions may have altered the positioning of the camera. These issues may result in a large batch of discarded events, but the malfunctions are quickly corrected. Such issues are commonly cited as the reason for an unusually high number of removals of events in one category for a month in a jurisdiction.

Collection of the Penalty

As stated previously, there are reasons that may make it impossible for the jurisdiction to send a citation to the registered owner of the vehicle. However, there is another major issue of the cited individual paying the penalty once he or she receives the citation. There has been little research in this area, and the main source of data for this section are the Virginia jurisdictional questionnaires completed by each red light camera jurisdiction.

From October 1, 2000, through July 31, 2003, Fairfax County mailed 66,556 citations, of which only 16,558 were paid in the same month they were issued (Fairfax County Police Department, Traffic Signal Violation, 2004). There were some affidavits filed and others that were dismissed, but approximately 90% to 95% of Fairfax County’s citations are paid (Taylor, telephone interview, 2004). Recent months have shown a wide range of citations being repaid in the same month (from less than 10% to more than 50%) (Fairfax County Police Department, Traffic Signal Violation, 2004).

From November 12, 1997, through January 31, 2004, Alexandria mailed 52,883 deliverable citations (Alexandria Police Department Parking Office, Composite Data, 2004). A total of 1,408 citations were mailed but were undeliverable (Alexandria Police Department Parking Office, Composite Data, 2004). A total of 33,804 citations were paid within 5 months, and 975 of the citations were returned with an affidavit (Alexandria Police Department Parking Office, Composite Data, 2004). The collection rate of penalties for Alexandria is at least 64% as stated on the documentation provided by the City. ACS tracks penalties all the way back to the beginning of the contract; however, the monthly report given to Alexandria goes back only 5 months (per contract) but Alexandria at anytime can obtain payment information for other previous months (Koutris, interview, 2004).

Malfunctions

This section describes various incidents that show the unfortunate problems that could be associated with red light cameras. Although none of the reported incidents mentioned occurred in the Commonwealth, it is important to understand the errors that occurred elsewhere so they will not be repeated. .

A camera in Los Angeles operated by ACS improperly took pictures a half second too early while the light was still yellow and not yet red, resulting in 3,018 improper citations (Staff, KABC-TV, 2003). ACS claimed this was the first time the malfunction has occurred and that it was a human error and not a malfunction of the system (Staff, KABC-TV, 2003). A county worker improperly set up the system, but ACS had given routine checks on the camera and said that everything was working properly when in fact it was not (Guccione, 2003). Prior to the realization that the camera was working improperly, there were 2,014 convictions, though it was not stated whether these convictions were individuals simply paying the fine or individuals unsuccessfully challenging the citation. It was not until a citizen complained to a retiree operating a website (www.highwayrobbery.net) that action was taken. The retiree videotaped the intersection and realized the camera was working improperly. He complained to the County Department of Public Works, who investigated the claim, finding that the complaint was accurate and the system had been malfunctioning for 42 months (Guccione, 2003). The intersection demonstrates that errors do occur, in this case due to human error, and the errors have been costly. The refund of collected fines totaled more than $500,000 and motorists were also able to recover costs for lost wages, increased insurance premiums, and traffic school (Staff, KABC-TV, 2003).

Questionable citations also occur and did in Washington, D.C. The reasons behind the oversight are debatable; however, the situation drivers were put in is not. At one point, 1 camera of 37 in Washington, D.C., accounted for 20% of the red light violations (Santana, 2000). After 20,000 violations, the police have deemed the camera so "unfair" that they have stopped issuing fines; however, they are not refunding any fines that were already distributed (Santana, 2000). The camera was at a constant blinking yellow light that would change to a solid yellow prior to turning red. Drivers were uncertain whether to stop or not, and the sudden change to red resulted in numerous violations. Combined with the budget proposed by Mayor Anthony Williams including $16 million in fines for the year 2000 and $14.5 million per year for future years (Santana, 2000), it is easily understandable why so many citizens question the true reason behind some red light cameras.

Another rather large revenue stream was created in Bethesda when one camera was timed to catch violators after a 3-second yellow light while the preceding intersections had 4-second yellow lights (Cella, 2003). The problem was not that the light was set for a 3-second interval, it was that the preceding light was a full 1 second longer and this confused drivers. The camera led to more than $1 million dollars in revenue from 14,000 violations before it was reset (Cella, 2003). It was not until 4 days after CBS taped an interview with Doug Duncan, a Montgomery County Executive, that all the lights on the stretch of road were reset to 3.5 seconds (CBS Worldwide Inc., 2003). Montgomery County at the time of the CBS report had no plans to return any of the $1 million collected (CBS Worldwide Inc., 2003). The practice of issuing citations to motorists by adjusting yellow light times to be inconsistent with the surrounding traffic lights should be avoided.

Due to the relative newness of the red light camera program, glitches in the technology are bound to occur. In Wilmington, Delaware, 45,000 notifications were distributed with the wrong law enforcement officer's signature due to a computer error (Taylor, 2004). Although the error is relatively small and likely does not make the citations invalid, it does represent the potential software malfunctions that do occur. It was unclear whether the software malfunction was due to a software or human error.

A number of malfunctions have occurred with red light cameras, mostly due to human error. Unless careful attention is paid to the entire system, false positives may result in faulty citations. However, it is unrealistic to expect the system to work perfectly. Careful monitoring will minimize such malfunctions, as will the judiciary through dismissing improper citations.

Government Vehicles

There is a question for jurisdictions nationwide of how government vehicles running red lights should be handled. Because it is often quite difficult to figure out exactly who was driving, these citations will often be discarded and never issued. In Washington, D.C., government vehicles had been photographed more than 800 times from the program's inception until early in 2001 (Santana, 2001). The agency that operates the vehicle will receive a citation and will attempt to track down the driver; however, they are often unsuccessful and the citations usually go unpaid. Although it would be wrong to make the agency and therefore the taxpayer pay for an employee running a red light, it is also unfair to let drivers of government vehicles violate the law. In Virginia, the agency that owns the vehicle often determines who the driver was and either pays the citation, later to be reimbursed by the driver, or makes the driver responsible for paying it. Drivers of government vehicles running red lights without paying the penalty is not as large a problem in Virginia as in Washington, D.C. In Alexandria County, from November 12, 1997, through January 31, 2004, 104 government vehicles were issued citations and 49 were paid in the first 5 months after the citation was issued (Alexandria Police Department Parking Office, Composite Data, 2004). To put that number in perspective, about 64% of regular citations mailed are paid in the first 5 months for Alexandria County (Alexandria Police Department Parking Office, Composite Data, 2004).

Standards

There are no recognized, independent standards or certifications for the red light camera industry. The industry is subject to no oversight at this time, aside from self-regulation and individual state regulations (Federal Highway Administration, 2003). The U.S. Department of Transportation and the International Association of Chiefs of Police (IACP) are developing specifications for uniformity in the industry (Federal Highway Administration, 2003).

Equipment Specifications

The IACP has created a committee to investigate the photo monitoring systems. The goals of the committee are (1) to rate the accuracy of the cameras and (2) to state how the systems should be operated (Larson, interview, 2004). The project is approximately 50% complete, and photo monitoring will be a major topic at the IACP conference in Los Angeles in November 2004 (Larson, interview, 2004). Once the guidelines are created, each manufacturer may submit its cameras for certification. The manufacturers will pay a fee, and the certification process will be conducted in a manner similar to that of certifying other products, such as radar/lidar testing and CPL (Consumer Products Listing) that is currently available (Larson, interview, 2004). Courts often use the CPL as prima facie evidence of the reliability of the equipment when it is tested in court (Larson, interview, 2004). It is hoped the standards will be released by the end of 2005 (Larson, interview, 2004). This would be the first set of independent certifications available for red light cameras.

More than an initial test should be created. The IACP standards will likely include a process for re-certification and will be useful. However, the system should also be checked every few days or, preferably, daily to ensure the basic sound operation of the camera. The inspections should include areas such as placement of the camera to make sure the camera angle has not been altered and proper lighting. Many issues, such as improper lighting, should become obvious when the vendor reviews the pictures. The locality is usually unable to perform the inspections, as the vendor is likely the only one authorized to inspect the hardware of the photo-monitoring system. It is important to note that many of these inspections currently take place when 35 mm wet film is removed from the camera. It may not be necessary for a service technician to be at the camera site for an inspection as the digital form of communication may allow the vendor to view the camera angle and all other aspects through a real-time monitor that receives a signal from the unit.

Human Specifications

A service technician should be certified by the vendor to inspect and conduct service inspections on the camera system. The vendor is the only one in the proper position to provide this certification since the technician will be working on a proprietary piece of equipment. Depending on the language in the contract, the vendor is likely responsible for the hardware and would not take any actions that would harm their equipment. As a result, it is likely that all vendors would permit only authorized service technicians to conduct inspections of their equipment.

Due to the autonomy of each locality concerning their red light camera program, there are no state mandated minimum qualifications for the inspectors of the events once they are received from the vendor. Each locality creates their own minimum standards for the reviewers. It is common practice to use retired or current law enforcement officers to conduct the reviews of photographs instead of law enforcement officers. It is preferred to employ individuals with a background in traffic enforcement to conduct the reviews, as they are more familiar with the laws and practices of the police department. The individual reviewers for the police departments remove numerous violations and are entrusted with an enormous amount of responsibility. It is preferred that the most qualified individuals available are employed.

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APPENDIX H
LEGAL CHALLENGES: PRIVACY, EQUAL PROTECTION, AND PROCEDURAL DUE PROCESS

As noted in the text, there are three broad issues on which the viability of a photo-red program may be challenged: privacy, equal protection, and due process. Ultimately the case law and relevant statutes suggest that for two areas, the program is viable, but challenges may arise in the third area—due process—because of the manner in which the *Code of Virginia* requires persons to be notified of offenses. This challenge is one of practicality as much as legality: the Code ultimately requires a personal notification, which may prove prohibitively expensive for some jurisdictions.

Privacy

Perhaps the most prevalent claim raised against red light cameras is that their photographs violate the automobile driver's right to privacy. This privacy claim implicates two legal inquiries: (1) whether red light cameras violate a constitutional right to personal privacy, as guaranteed by provisions of the federal and state constitutions, and (2) whether red light cameras constitute an invasion of an individual's common law or statutory right to privacy (National Cooperative Highway Research Program, 1986).

Constitutional Issues

An automobile driver in Virginia may claim his or her privacy constitutionally protected from the operation of a red light camera under the U.S. Constitution and the Virginia Constitution. Virginia's courts, however, consistently hold "that the protections afforded under the Virginia Constitution are co-extensive with those in the United States Constitution" (*Bennefield v. Commonwealth*, 1996). Therefore, the same analysis applies to a privacy claim whether it is grounded in provisions of the U.S. Constitution, the Virginia Constitution, or both.

Privacy as an Aspect of Protected Liberty

There is no explicit mention of privacy in the U.S. Constitution. However, the Supreme Court has long recognized a "right of personal privacy, or a guarantee of certain areas or zones of privacy" as an aspect of the liberty protected by the Due Process Clause of the Fourteenth Amendment (*Roe v. Wade*, 1973). Under the Court's substantive due process analysis, the right of personal privacy "is not unqualified and must be considered against important state interests in regulation." Moreover, the Supreme Court has narrowly construed its privacy protection to include "only personal rights that can be deemed 'fundamental' or 'implicit in the concept of ordered liberty.'" Thus, the Court's cases have protected personal privacy in activities relating to marriage, procreation, contraception, family relationships, and child rearing and education.

Driving is simply not included within the Court's definition of constitutionally protected privacy; it is neither fundamental nor implicit in the concept of ordered liberty. To the contrary, the Court has declared that "the physical characteristics of an automobile and its use result in a lessened expectation of privacy therein" and that "automobiles are justifiably the subject of pervasive regulation by the State" (*New York v. Class*, 1986). Thus, the automobile driver's claimed right to privacy falls outside the scope of privacy protection afforded by the Due Process Clause of the Fourteenth Amendment.

Privacy in the Context of Search and Seizure

As an alternative, the automobile driver may claim his or her privacy protected by the Fourth Amendment, which provides that "[t]he right of the people to be secure in their persons, houses, papers, and effects, against unreasonable searches and seizures, shall not be violated" (U.S. Const., amend IV). The Supreme Court has emphasized that "the Fourth Amendment cannot be translated into a general constitutional 'right to privacy.'" (*Katz v. United States*, 1967). Rather, it protects individual privacy only against certain types of governmental intrusion. Specifically, the Fourth Amendment serves "to safeguard the privacy and security of individuals against arbitrary invasions by government officials" (*Camara v. Municipal Court of San Francisco*, 1967).

To bring a claim under the Fourth Amendment, the automobile driver must first show that the operation of a red light camera constitutes a "search" within the meaning of the Amendment. The Fourth Amendment itself does not define the contours of an unconstitutional search, and in fact, such definition has changed over time. Historically, courts linked Fourth Amendment doctrine to common law trespass and required a physical invasion of tangible property—a constitutionally protected area, such as one's home—as a prerequisite for their finding that an unconstitutional search had occurred (*Katz v. United States*, 1967). The Supreme Court's 1967 decision in *Katz*, however, articulated a conception of the Fourth Amendment that "protects people, not places." Since *Katz*, the Fourth Amendment's reach "cannot turn upon the presence or absence of a physical intrusion into any given enclosure."

In *Katz*, the Supreme Court held that the government's installation of an electronic listening and recording device on the outside of a public telephone booth violated the Fourth Amendment. The Court recognized that "what [Katz] sought to exclude when he entered the booth was not the intruding eye—it was the uninvited ear." By entering the phone booth, shutting its door, and paying the requisite toll, Katz "justifiably relied" on the privacy protection afforded him by the Fourth Amendment. Because the government's electronic listening and recording of Katz's conversation violated his expectation of privacy therein, the Court held these activities constitutive of a search. It made no difference, as far as the constitutional inquiry was concerned, that the government's electronic device was placed on the outside of the telephone booth and thus, did not physically invade its walls.

Justice Harlan's concurring opinion in *Katz* established a test that has since become the touchstone of the Supreme Court's Fourth Amendment jurisprudence. For an individual to find constitutional privacy protection under the Fourth Amendment, "there is a twofold requirement, first that a person have exhibited an actual (subjective) expectation of privacy and, second, that the expectation be one that society is prepared to recognize as 'reasonable.'" Consistent with its opinion in *Katz*, the Court has expressly recognized that "[a] citizen does not surrender all the protections of the Fourth Amendment by entering an automobile" (*New York v. Class*, 1986). The *Katz* test applies in the automobile context, just as it does in any other. Thus, an automobile driver may claim that a red light camera violates his or her Fourth Amendment rights if, and only if, there is a "constitutionally protected reasonable expectation of privacy."

Few red light camera cases have actually been litigated, and constitutional challenges have yet to reach the federal circuit level on appeal (Lehman, 2002; FHWA and NHTSA, 2003). Thus, there is no binding precedent regarding the automobile driver's "reasonable subjective expectation of privacy" in the red light camera context. The Ninth Circuit has upheld the use of photo radar—a related form of automated enforcement—against a driver's claim that it constituted a seizure within the meaning of the Fourth Amendment (*McNeill v. Town of Paradise Valley*, 2003). However, because the claim was one of unconstitutional *seizure*, and not of unconstitutional *search*, the court did not consider the *Katz* test. Instead, it upheld the government's use of photo radar because it did not involve an "intentional acquisition of physical control" as required under the Supreme Court's definition of seizure. Finally, although a California Superior Court suggested its willingness to uphold that state's red light camera statute on constitutional grounds, it ultimately invalidated the program at issue based on operational deficiencies (*California v. John Allen*, 2001).

Despite the absence of binding precedent, the Supreme Court's Fourth Amendment cases offer some guidance on the question of whether the operation of a red light camera offends a driver's reasonable subjective expectation of privacy. For example, the Court has previously held that aerial observation does not constitute a search within the meaning of the Fourth Amendment (*California v. Ciraolo*, 1986; *Dow Chemical Co. v. United States*, 1986). Moreover, the Court has "recognized that the characteristics of an automobile and its use result in a *lessened* expectation of privacy therein" (*New York v. Class*, 1986). Finally, although the Court has recently placed some additional limit on the government's ability to use technology to enhance its searches, that limit is not implicated by the operation of a red light camera (*Kyllo v. United States*, 2001). Each of these precedents is discussed in greater detail here. Taken together, they suggest that the automobile driver has no reasonable subjective expectation of privacy and, thus, that a red light camera cannot constitute a search within the meaning of the Fourth Amendment.

Fourth Amendment Cases

Aerial Observation

The Supreme Court has previously held that aerial observation does not constitute a search within the meaning of the Fourth Amendment. In *California v. Ciraolo* (1986), the issue before the Court was whether police violated the Fourth Amendment with their warrantless observation, from an altitude of 1,000 feet, of marijuana plants within the respondent's fenced-in backyard. The Court recognized the significance of the 6-foot outer fence and 10-foot inner fence that completely enclosed the yard: "Clearly—and understandably—respondent has met the test of manifesting his own subjective intent and desire to maintain privacy as to his unlawful agricultural pursuits." However, the Court concluded that, because the observation "took place within a public navigable airspace," the respondent's expectation of privacy was unreasonable, and thus, aerial observation by the police did not constitute a search. "The Fourth Amendment simply does not require the police traveling in the public airways…to obtain a warrant in order to observe what is visible to the naked eye." The Court extended this reasoning in *Dow Chemical* *v. United States* (1986), decided the same day, and held "that the use of an aerial mapping camera to photograph an industrial manufacturing complex from navigable airspace similarly does not require a warrant under the Fourth Amendment."

Based on the Court's reasoning in *Ciraolo* and *Dow Chemical*, it would appear that automobile drivers do not have a reasonable subjective expectation of privacy from visual observation as they travel on public highways. In fact, it is unclear whether a driver may claim even a subjective expectation of privacy in this instance. Unlike the respondent in *Ciraolo*, who constructed two fences around his backyard in an attempt to keep his agricultural pursuits private, there are few measures a driver could conceivably take to maintain a level of privacy on a public highway. Rather, once the decision is made to travel a public highway, a driver knowingly exposes his or her vehicle to the public.

Moreover, since vehicles and their license plates are always visible to the public, it can be argued that a red light camera observes nothing more than that which is readily observable by any member of the traveling public. The Supreme Court determined in *Ciraolo* and *Dow Chemical* that the Fourth Amendment does not require the police to obtain a warrant for the readily observable; therefore, it cannot require a warrant for the operation of a red light camera. Thus, even if a driver exhibits a subjective expectation of privacy, that expectation becomes unreasonable under the second prong of the *Katz* test.

Automobiles

In *New York v. Class* (1986), the Supreme Court considered whether a police officer violated a driver's Fourth Amendment rights when he reached into an automobile's interior to move papers obscuring the vehicle identification number (VIN) on the dashboard. The Court held the officer's actions constitutionally permissible because the driver had no reasonable expectation of privacy. The VIN, like the automobile itself, is subject to pervasive regulation under both federal and state law. Because federal law required the VIN "to be located in a place ordinarily in plain view from the exterior of the automobile," the Court found any expectation of privacy in the VIN unreasonable. Moreover, because the VIN served an important role in the government's regulation of automobiles, any driver must expect that the government may, on occasion, be required to identify his or her vehicle. The Court found this "especially true in the case of a driver who has committed a traffic violation."

In *Shirley v. Commonwealth* (1977), the Virginia Supreme Court used similar reasoning to uphold a provision of the state's code that gave police the right to inspect vehicles in public garages and repair shops.

> A car is not a home. An automobile runs and stops on the public roads, where viewers may crawl under it or press their faces against its windows. Its exterior and much of its interior are within the "plain view" of the casual or purposeful onlooker, and thus are not protected by the Fourth Amendment from searching eyes.

Since it is routine for police officers to stop vehicles for the purpose of inspecting driver's licenses and registration papers, and since such police behavior is an accepted part of the regulatory system, the court held that there is no reasonable expectation of privacy with respect to the identification of a vehicle. Thus, the police may take any action necessary to read a vehicle identification number (VIN)—they can open a vehicle door, look under its hood, or crawl underneath a vehicle to inspect its rear axle—without implicating the Fourth Amendment. Although such action may technically constitute a trespass, it cannot constitute an invasion of privacy because no reasonable expectation of privacy exists in a vehicle's identification.

Under Virginia law, red light cameras photograph the license plates of vehicles that run through red light intersections. Like the VIN in *Class*, the license plate plays an important role in the pervasive governmental regulation of the automobile. In Virginia, motor vehicle owners are required by law to register their vehicles and to certify their title or ownership with the Commonwealth's Department of Motor Vehicles (DMV) (Va. Code Ann. § 46.2-600). Each vehicle's registration card and certificate of title contain the registration number assigned to it by the DMV, the owner's name and address, and a description of the vehicle itself (Va. Code Ann. § 46.2-604). In conjunction with these registration and certificate of title requirements, Virginia law mandates that all vehicles operated on its highways have license plates displayed on both their front and rear (Va. Code Ann. §§ 46.2-613, 46.2-715). Given these statutory requirements, an automobile driver in Virginia must anticipate that the Commonwealth may be occasionally required to identify his or her vehicle. Thus, a driver cannot have a reasonable expectation of privacy in the vehicle's identification.

It is particularly unreasonable for an automobile driver in the process of committing a red light violation to maintain such expectation of privacy. As the Virginia Supreme Court emphasized in *Shirley*, it is a routine and well-accepted practice for police officers to stop vehicles for the purpose of inspecting a driver's license and registration papers. It is also routine for the police to pull over and ticket drivers who commit traffic violations, and presentation of a driver's license and registration papers for identification purposes is always required as part of that process. Therefore, it can be argued that a driver who commits a traffic violation knowingly increases the risk of his or her being required to show identification.

Advanced Technology

In *Kyllo v. United States* (2001), the Supreme Court considered it "foolish to contend that the degree of privacy secured to citizens by the Fourth Amendment has been entirely unaffected by the advance of technology." The issue before the Court in *Kyllo* was whether the use of a thermal imaging device by police officers on a public street to detect the level of heat radiated within a private home amounted to an unconstitutional search. The Court refined the *Katz* test, at least in the context of the interior of a home, to recognize a minimum level of guaranteed privacy. Thus, the Court held that "obtaining by sense-enhancing technology any information regarding the interior of the home that could not otherwise have been obtained without physical 'intrusion into a constitutionally protected area' constitutes a search—at least where . . . the technology in question is not in general public use."

The Court's opinion in *Kyllo* provides some limit "upon the power of technology to shrink the realm of guaranteed privacy." However, that limit is not implicated by the operation of a red light camera. Photo-red technology seems to meet the Court's general public use requirement; 35-mm, digital, and video cameras are integrated into many aspects of everyday life. Certainly the general public—perhaps even an overwhelming majority of the population—owns and operates cameras on a regular basis. In addition, surveillance cameras are commonly deployed in banks, grocery stores, and other public settings, so that citizens are photographed numerous times each day. Moreover, the *Kyllo* decision is restricted to the particular context at issue—the interior of a home. The Court explicitly recognized the difficulty of refining the *Katz* test in the public context of an automobile.

Probable Cause

Even if a red light camera could be considered a search within the meaning of the Fourth Amendment, it would likely be upheld as reasonable, and thus, constitutional. "[A]s a general rule a search of private property without proper consent is unreasonable unless it has been authorized by a valid search warrant" (*Shirley v. Commonwealth*, 1977). However, the Supreme Court has created an exception to this rule for "the warrantless search of motor vehicles under exigent circumstances when probable cause for a search exists." Assuming a red light camera is working properly, it photographs only vehicles in the process of committing red light violations. Thus, red light camera photographs will most likely satisfy the Fourth Amendment's requirement of probable cause.

Moreover, under constitutional inquiry, "the permissibility of a particular law enforcement practice is judged by balancing its intrusion on the individual's Fourth Amendment interests against its promotion of legitimate governmental interests" (*Delaware v. Prouse*, 1979). The Supreme Court has consistently recognized the government's interest in promoting highway safety, particularly when it involves more than general crime control. In *Michigan Department of State Police v. Sitz* (1990), for example, the Court upheld a state's use of sobriety checkpoints: "No one can seriously dispute the magnitude of the drunken driving problem or the States' interest in eradicating it." Here, the magnitude of the problem of red light running is similarly supported by empirical evidence, and Virginia's interest in eradicating it seems beyond question. When the state's compelling interest is compared to the minimal intrusion actually caused by a red light camera, the balancing test weighs heavily in favor of the camera's constitutionality.

Common Law and Statutory Privacy Protection

There are four common law torts of invasion of privacy: (1) unreasonable intrusion upon an individual's seclusion or solitude, or into an individual's private affairs; (2) public disclosure of true, embarrassing facts about an individual; (3) publicity that places an individual in a false light; and (4) misappropriation of an individual's name or likeness for commercial purposes (Prosser, 1971). Although all four torts are recognized in other states, Virginia has limited their application by statute (*WJLA-TV v. Levin*, 2002). The Privacy Protection Act of 1976 codified only the last of these torts—it prohibited the misappropriation of an individual's name or likeness for commercial purposes (Va. Code Ann. §§ 2.1-377—2.1-386). The Virginia Supreme Court has held that, in enacting the statute, "the General Assembly . . . implicitly *excluded* the remaining three as actionable torts in Virginia" (*WJLA-TV v. Levin*, 2002).

In 2001, the General Assembly replaced the Privacy Protection Act of 1976 with the Government Data Collection and Dissemination Practices Act, codified at Va. Code Ann. §§ 2.2-

3800—2.2-3809. The Act sets forth the following principles of information practice for record-keeping agencies of the Commonwealth and political subdivisions to ensure safeguards for personal privacy [Va. Code Ann. § 2.2-3800(C)]:

1. There shall be no personal information system whose existence is secret.
2. Information shall not be collected unless the need for it has been clearly established in advance.
3. Information shall be appropriate and relevant to the purpose for which it has been collected.
4. Information shall not be obtained by fraudulent or unfair means.
5. Information shall not be used unless it is accurate and current.
6. There shall be a prescribed procedure for an individual to learn the purpose for which information has been recorded and particulars about its use and dissemination.
7. There shall be a clearly prescribed and uncomplicated procedure for an individual to correct, erase or amend inaccurate, obsolete or irrelevant information.
8. Any agency holding personal information shall assure its reliability and take precautions to prevent its misuse.
9. There shall be a clearly prescribed procedure to prevent personal information collected for one purpose for being used for another purpose.
10. The Commonwealth or any agency or political subdivision thereof shall not collect personal information except as explicitly or implicitly authorized by law.

The Virginia Supreme Court has defined "agencies of the Commonwealth" to include all units of municipal government (*Hinderliter v. Humphries*, 1982). Thus, the city and county police departments responsible for the operation of red light camera systems are "agencies" within the meaning of the statute and subject to its provisions. The statute contemplates the term "personal information" as meaning "all information that describes, locates or indexes anything about an individual . . ., or that affords a basis for inferring personal characteristics, such as…photographs, or things done by or to such individual; and the record of his presence, registration, or membership in an organization or activity, or admission to an institution" [Va. Code Ann. § 2.2-3801(2)]. "Information system" means "the total components of a record-keeping process, whether automated or manual, containing personal information" (*Hinderliter v. Humprhies*, 1982). Under these statutory definitions, a red light camera is an information system involving two types of personal information—the photographs of vehicle license plates taken at the time of alleged violations and the registered owner information obtained from the Department of Motor Vehicles.

The Virginia Supreme Court has emphasized that the statute does not render personal information confidential, nor does it generally prohibit the dissemination of such information (*Hinderliter v. Humphries*, 1982). Rather, "it requires certain procedural steps to be taken in the collection, maintenance, use, and dissemination of such data." Consistent with this statutory construction, Virginia's Attorney General has opined that while the Act prohibits a state agency's collection of secret personal information, it permits a town to install surveillance and audio monitoring equipment on the premises of its public recreation center, so long as adequate notice of the surveillance is posted (Op. Va. Att'y Gen. 00-044, 2002).

Red light camera systems satisfy the requirements of the act. Certainly, the need for red light camera systems is well established by statistical evidence of red light running and its consequential accidents, and of the state's limited police resources with which to combat the problem. Red light cameras are thus utilized to increase law enforcement's ability to ticket red light violators, with the ultimate goal of reducing red light running behavior. The two types of personal information collected by red light camera systems are necessary for their successful operation. The photographs provide prima facie evidence of a red light camera violation; the registered driver information provides for the rebuttable presumption of liability necessary for enforcement.

Virginia's red light camera enabling statute prescribes procedural steps for the collection of personal information by red light camera systems. Signs that identify red light camera intersections ensure that such systems do not exist in secret and that their photographs are obtained through neither fraudulent nor unfair means. Moreover, red light camera photographs are inspected and affirmed by a technician, in order to ensure their accuracy, before a citation is issued to a vehicle's owner. Registered owner information is then obtained from the Department of Motor Vehicles based on the data submitted by the owner in accordance with the Commonwealth's vehicle laws. Since vehicle owners are legally required to provide accurate and current information to the DMV, it is fair to assume such information is correct in the red light camera context.

The enabling statute further provides procedures for the use, maintenance, and dissemination of personal information. Any photographs evidencing a red light violation are available for inspection in any proceeding to adjudicate liability. In addition, citations based on red light camera photographs include notice of an owner's ability to rebut the presumption of liability by filing an affidavit that he or she was not operating the vehicle at the time of the alleged violation. This provides a clear and uncomplicated procedure for the correction of inaccurate information as contemplated by the privacy protection statute. Finally, the red light camera statute expressly provides that a private entity, working in conjunction with a locality, may not obtain registered owner information from the DMV. This provision aims to prevent personal information collected for the purpose of enforcing red light violations from being used for other purposes.

Equal Protection

An automobile driver may attempt to challenge the constitutionality of a red light camera statute under the Equal Protection Clause of the Fourteenth Amendment, which provides that no state shall "deny to any person within its jurisdiction equal protection of the laws" (U.S. Const., amend. XIV, § 1). A driver may claim, for example, that the enabling statute violates the Equal Protection Clause by affording a civil penalty for red light violations evidenced by an automated enforcement system instead of the criminal penalty typically imposed through traditional enforcement mechanisms. Regardless of the manner in which an equal protection challenge is phrased, however, a red light camera statute will likely be upheld as constitutional because it is a rational means of furthering the state's legitimate interest in highway safety.

Under the Supreme Court's Equal Protection doctrine, "legislation is [generally] presumed valid and will be sustained if the classification drawn by the statute is rationally related to a legitimate state interest" (*City of Cleburne v. Cleburne Living Ctr.*, 1985). There are just two exceptions to this rule. When a statute classifies based on race, alienage, or national origin, or when it impinges on fundamental personal rights protected by the Constitution, the Court employs "strict scrutiny" and sustains legislation only if it is narrowly tailored to serve a compelling government interest. When a statute classifies based on gender, the Court employs "heightened scrutiny" and sustains legislation only if it is substantially related to a legitimate government interest.

Red light camera laws do not classify based on race, alienage, national origin, or gender. Moreover, driving is not considered by the Court to be a fundamental right. Thus, any equal protection challenge to a red light camera law will be subject to the Court's rational basis review; that is, the law will be presumed valid and will be sustained as long as its classification of drivers is rationally related to a legitimate state interest.

The Supreme Court has long recognized a state's legitimate—even vital—interest in promoting highway safety (*New York v. Class*, 1986). Thus, the constitutionally of red light camera laws turns on whether they are rationally related to the furtherance of this interest. Rational basis review allows state governments wide latitude in implementing policy decisions, based on the assumption that the democratic process will eventually rectify any unwise decisions (*City of Cleburne v. Cleburne Living Ctr.*, 1985). However, a state "may not rely on a classification whose relationship to an asserted goal is so attenuated as to render the distinction arbitrary or irrational."

Virginia's red light camera statute purposes to reduce incidences of red light running and the number of crashes that occur as a result. Clearly, such a statute is rationally related to the state's interest in promoting highway safety. Under the Supreme Court's doctrine, the state is not required to present a court with empirical evidence to support its legislative judgment (*Minnesota v. Clover Leaf Creamery Co.*, 1981). Thus, because a red light camera law may reasonably be considered as a means of furthering the state's interest in highway safety, it passes constitutional muster under rational basis review, regardless of the law's actual effect.

On its face, Virginia's red light camera statute makes a classification between violators in that it imposes different penalties through automated and traditional enforcement means. However, this classification does not implicate further equal protection analysis. The difference in penalties is reasonably justified by the presumption of liability necessary under the automated enforcement scheme. Although traditional enforcement allows a police officer to identify the driver of the vehicle and issue a ticket for the violation to that individual, a red light camera system must presume that the registered owner of the vehicle is its driver at the time of the alleged violation. Because the imposition of a criminal penalty based on such a presumption could potentially implicate due process concerns, the Virginia legislature has elected to impose a civil penalty for violations captured by red light cameras. This constitutes a policy decision within the legislature's discretion. Since it is neither arbitrary nor irrational, it would withstand rational basis review by any court.

Procedural Due Process

The due process clauses of the U.S. and Virginia Constitutions provide that no person shall be deprived of life, liberty, or property without due process of law (U.S. Const., amend. XIV, § 1; Va. Const., art. I, § 11). Assessing the constitutionality of any law on procedural due process grounds thus requires a three-step analysis: (1) Is there a deprivation?; (2) If so, is it of a protected life, liberty, or property interest?; and (3) If so, does the mechanism for such deprivation meet the standards of "due process"?

Virtually every government law enforcement action involves a deprivation of some sort. The harder question is whether or not it may be considered a deprivation of a life, liberty, or property interest in the constitutional sense.

It is fairly clear that citing someone for a red light violation does not deprive them of their life, so we can leave that ground aside and turn to potential deprivations of liberty. Liberty in the procedural due process context has been defined as freedom of choice, freedom from physical restraint, and freedom to engage in constitutionally protected activities. The Supreme Court has held that a deprivation affecting this liberty must be more than *de minimus* to implicate Fourteenth Amendment protection (*Watson v. City of Kansas City*, 1999). Even if they are is not *de minimus*, deprivations of liberty and property are not actionable violations of the Fourteenth Amendment's guarantee of due process "unless they are atypical and significant in relation to inevitable deprivations that people suffer as result of contractual disputes and other ordinary frictions of life" (*Baerwald v. City of Milwaukee*, 1997). The Court has been fairly liberal in interpreting this constraint, ruling, for example, that a three-day detention of an innocent person pursuant to a valid warrant was not an unconstitutional deprivation of liberty (*Baker v. McCollan*, 1979).

If red light camera programs do not affect life or liberty in a constitutional sense, the only remaining basis for a constitutional challenge on due process grounds is a claim that such programs involve an unconstitutional deprivation of property. The Supreme Court has held that a driver's license is a constitutionally recognizable property interest (*Bell v. Burson*, 1971). But under Virginia's red light camera law, no points are assessed against one's license. Because there's no possibility of losing one's license for a citation, no property interest in one's driver's license is implicated. However, the money paid in penalties for such infractions is indeed property, and in this sense constitutes a deprivation of property by the government. Therefore, we are not spared addressing the final question of whether this deprivation of property meets procedural due process requirements.

Standards of Procedural Due Process

The Virginia case of *Parker v. Commonwealth* (2004) reiterates two fundamental components of procedural due process: "procedural due process guarantees a litigant the right to reasonable notice and a meaningful opportunity to be heard . . . before any binding order can be made affecting the person's rights to liberty or property." These two components of procedural due process—reasonable notice and meaningful opportunity to be heard—are explored here in the context of red light cameras.

Service of Process in Virginia. Before looking at the constitutional issues, we must consider how the notice provisions in Virginia's red light camera statute, Va. Code Ann. § 46.2-833.01, work in conjunction with the Commonwealth's other service requirements. (Please see Figure H-1 for a visual representation of the legislation cited.)

Subsection G of §46.2-833.01 prescribes that:

> A summons for a violation of this section may be executed pursuant to §19.2-76.2. Notwithstanding the provisions of §19.2-76, a summons for a violation of this section may be executed by mailing by first-class mail a copy thereof to the address of the owner, lessee, or renter of the vehicle.

Service of Process in Virginia Under §46.2-833.01 (RLC Statute)

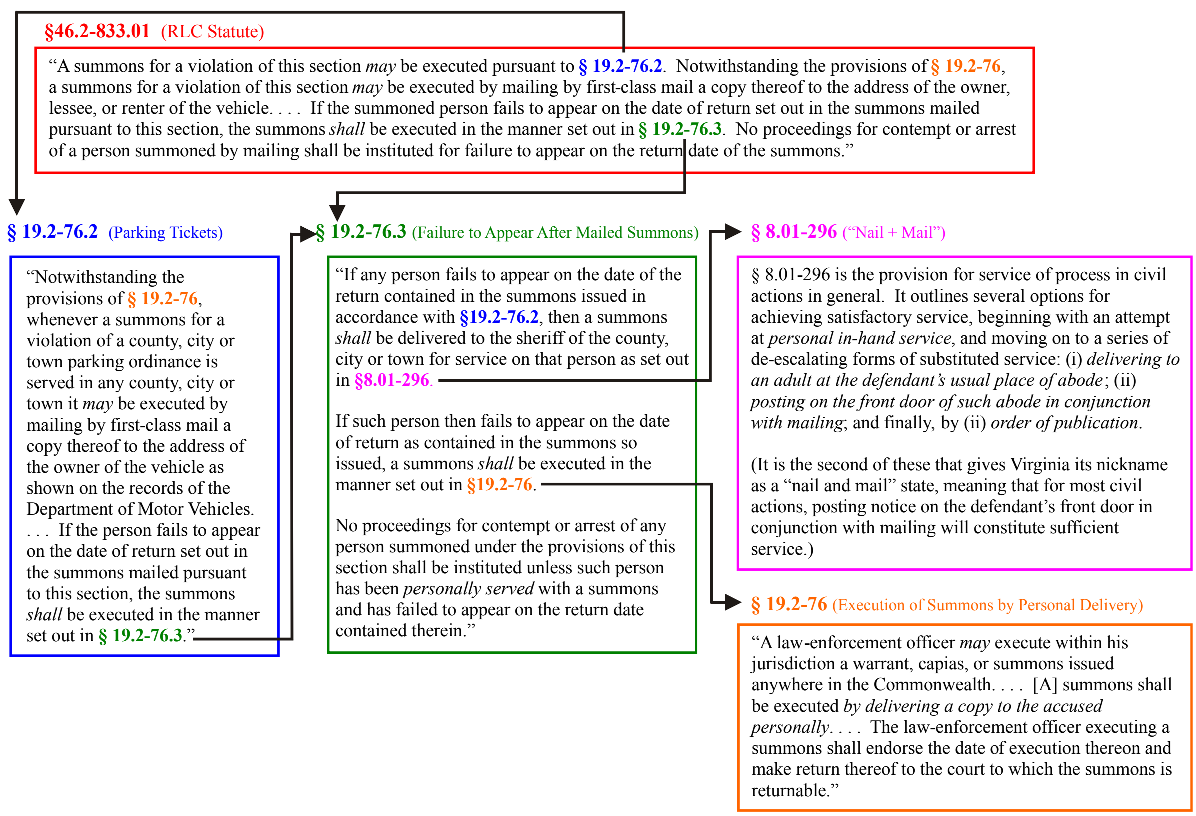

Figure H1. Code Sections Ultimately Requiring In-Person Delivery of Camera-Based Citations

The first law referenced here, Va. Code Ann. § 19.2-76.2, is the statute covering notice for parking tickets, which simply reiterates that a summons for a violation may be executed by mailing, *notwithstanding* the provisions of § 19.2-76, which grants power to a law-enforcement officer to execute within his or her jurisdiction a summons issued anywhere in the Commonwealth and requires that such a summons be executed by delivering a copy to the accused personally.

So far, this would seem to render service by mail sufficient for summons for both parking and red light camera violations. However, there is a complication in that the red light camera statute, § 46.2-833.01, goes on to state:

> If the summoned person fails to appear on the date of return set out in the summons mailed pursuant to this section, the summons shall be executed in the manner set out in § 19.2-76.3. No proceedings for contempt or arrest of a person summoned by mailing shall be instituted for failure to appear on the return date of the summons.

Virginia statute § 19.2-76.3 in turn provides that:

> A. If any person fails to appear on the date of the return contained in the summons issued in accordance with § 19.2-76.2 [i.e., by mail], then a summons shall be delivered to the sheriff of the county, city or town for service on that person as set out in § 8.01-296.
>
> B. If such person then fails to appear on the date of return as contained in the summons so issued, a summons shall be executed in the manner set out in § 19.2-76.

The new statute referenced in section A., § 8.01-296, is the provision for service of process in civil actions, which has been borrowed by the Virginia General Assembly for the present purpose. It outlines several options for achieving satisfactory service, beginning with an attempt at personal in-hand service, and moving on to a series of de-escalating forms of substituted service: delivering to an adult at the defendant's usual place of abode; posting on the front door of such abode in conjunction with mailing; and finally, by order of publication in appropriate cases under the provisions of the applicable code sections. It is the second of these that gives Virginia its nickname as a "nail and mail" state, meaning that for most civil actions, posting notice on the defendant's front door in conjunction with mailing will constitute sufficient notice. However, this is not so for red light camera citations under the code, for the second statute referenced above is § 19.2-76 which, as we have already seen, requires *personal in-hand service* if the "nail and mail" approach does not succeed in bringing the defendant into court.

Thus, under Virginia's red light camera statute as it is now worded, the mere mailing of a citation without personal service by a law enforcement officer does *not* constitute sufficient notice under the statute's own terms. While the statute *permits* the jurisdiction to make the initial attempt to summon the accused to court via mail, if that person fails to respond, he or she is not considered to have been satisfactorily served with notice. Default judgments entered under such circumstances (when the defendant fails to appear in court on the appointed return date) would thus not be binding, and the defendant could not be charged with contempt for failing to comply with such a judgment. Hence, despite its ostensive distancing from the requirements of Va. Code Ann. § 19.2-76, Virginia's red light camera statute comes full circle and, in the end, requires personal service before a default judgment may be entered against no-shows.

Personal service on all violators is obviously an expensive proposition, involving many staff hours of time, and would defeat one of the primary motivating factors for employing automated detection systems in the first place: a reduction in the number of live officers required to enforce red light laws. (Even the "nail and mail" approach would involve more time, money, and effort than some people would view as warranted relative to the nature of the offense.) Thus, unless a jurisdiction is willing to devote resources to implementing extensive in-hand service, citations mailed for red light camera violations become essentially unenforceable. The average citizen is probably not aware of this loophole, but if word got out on a widespread basis, such knowledge could completely undermine the effectiveness of entire red light camera programs, as citations issued to violators would lose their practical impact.

Delay Between Violation and Notice.

Constitutional Issues

Opponents of red light camera programs often point to the delay between the infraction (running the red light) and the date of notification (receiving the citation in the mail) as a potential violation of due process. However there is no constitutional guarantee that a person will be charged contemporaneously with an alleged offense. While there may be a constitutional right—guaranteed by the Sixth Amendment (U.S. Const., amend. VI)—to a speedy trial once indicted, absent violations of a statute of limitations, there is no corresponding right to a speedy *indictment* following the offense (*United States v. Delario*, 1990). In fact, in many situations (for example, a vehicle crash), traffic citations are issued days or weeks after the event. In order to raise Sixth Amendment concerns, the defendant must demonstrate that "the government intentionally delayed indictment to gain tactical advantage." Since in the red light camera situation, the time delay between committing the offense and receiving the citation in the mail is actually designed to *help* the defendant (by providing for human oversight of the automated ticketing process) rather than a self-serving tactical move on the part of the government, this delay is not in itself sufficient to render this form of notice inadequate on due process grounds. Moreover, the Sixth Amendment only applies to criminal prosecutions. Since red light camera violations carry only *civil* penalties in Virginia, Sixth Amendment protections are inapplicable in this context regardless of the outcome of the preceding argument.

Public Policy Concerns

The preceding observations notwithstanding, the fact that defendants may not receive citations until several days, sometimes weeks, after the alleged violation paves the way for complaints that this procedure undercuts the viability of certain timely equitable defenses that would be available in a live citation situation. For example there may have existed mitigating circumstances that justified being in a controlled intersection during a red light, or confounding factors that led to a photo being taken in error. The time delay between the infraction and notice makes it extremely difficult to reconstruct the circumstances surrounding a supposed violation. The more time that elapsed, the harder it is for the driver to accurately remember the details of the specific date in question, especially if he or she travels that same route regularly. (For example, a person who traverses a given intersection twice daily will find it nearly impossible to recall the specific circumstances of a two-week-old trip.)

Moreover—perhaps due in part to the pervasiveness of the preceding phenomenon—trial judges may be more likely to find a defendant's "after the fact" explanation of the mitigating circumstances much *less credible* than it would be if uttered spontaneously seconds after the event took place. Under red light camera programs, however, such contemporaneous pronouncements, if they are uttered at all, would fall on the deaf ears of a piece of machinery.

Hence, when, as in this case, the delay between infraction and notification can span several weeks, not only is a defendant *more* likely to have forgotten any exigencies justifying the violation, he or she is also *less* likely to believed by the adjudicator if he or she does happen to remember them. Although not unconstitutional, this outcome is still arguably unfair. As such, however, it is best addressed as a public policy issue, rather than a legal one.

Fair Opportunity to Be Heard

The second component of procedural due process—opportunity to be heard—originates in the fact that "the due process clause entitles a person to an impartial and disinterested tribunal in both civil and criminal cases" (*Marshall v. Jerrico, Inc.*, 1980). Relying on this aspect of procedural due process, opponents of red light camera legislation have argued that such laws are unconstitutional both because they deprive defendants of an opportunity to confront their accusers and present a defense and because the potential for in errors in creating the photographs which serve as evidence for a conviction may undermine the fairness of the procedure.

The first complaint is groundless because the defendant *does* have an adequate avenue for confronting his or her accuser and presenting a defense: He or she may appear in court on the return date indicated on the citation, just as someone who receives a citation from a live police officer may do. The fact that the recipient of a citation generated by a red light camera system cannot "confront" his or her accuser contemporaneously with the violation does little to undermine the constitutionality of this process, for as we have already noted, there is nothing in the Constitution that requires an *instantaneous* indictment or hearing.

The second complaint—that the potential for error renders the procedure inherently unfair—sounds initially plausible but ultimately proves untenable as well. Contrary to popular perception, a fair tribunal does not necessarily equate to an error-proof tribunal. Rather, the Supreme Court has advocated a balancing test to determine the procedural adequacy of a deprivation of life, liberty, or property. In this test, three factors are taken into account and weighed against each other: (1) the private interest affected by the government action; (2) the risk that the private interest will be erroneously deprived by the procedure and the probable value of alternatives or additional safeguards; and (3) the government's interest (*Gilmar v. Homar*, 1997). As a result of this balancing approach, constitutional due process need not require that "the procedures used to guard against an erroneous deprivation . . . be so comprehensive as to preclude any possibility of error" (*Mackey v. Montrym*, 1979). On the contrary, "the marginal gains from affording an additional procedural safeguard often may be outweighed by the societal cost of providing such a safeguard" (*Walters v. National Assoc. of Radiation Survivors*, 1985). Given that the Supreme Court has recognized the government's interest in highway safety as "compelling," it is likely that the application of such a balancing test would weigh in favor of red light camera legislation (*Mackey v. Montrym*, 1979).

Presumption That Owner Was Driver

The evidentiary role of the photograph used to indict violators comes into play when assessing another potential due process pitfall for photo-red legislation. Some opponents claim that because the registered owner of the vehicle is assumed to be the driver at the time of the violation, the owner is presumed guilty until he or she can prove himself innocent, thus inappropriately shifting the burden of proof to the accused. However, this characterization misconstrues both the nature of procedural due process and the function of rebuttable presumptions.

Probable Cause

In the first place, the presumption of innocence until proven guilty attaches at *trial*, not at the time the defendant is charged. Police and prosecutors are not bound by a presumption of innocence when issuing a summons—if that were true, no one could ever be charged with an offense! Rather, they need only have *probable cause* that the person charged committed the infraction. Although "no accurate definition can be given of probable cause, . . . belief in the charge, on facts, based on sufficient circumstances to reasonably induce such belief in a person of ordinary prudence will suffice" (*Virginia Electric and Power Co. v. Wynne***,** 1928). Since the fact that the vehicle was registered to the accused could plausibly "induce in a person of ordinary prudence" the belief that that the owner was also the driver, the current version of Va. Code Ann. § 46.2-833.01 satisfies the probable cause requirement as it has been defined by Virginia courts.

Moreover, in red light camera situations, there is no detainment involved and the deprivation of property comes only after the case is heard (or the driver pleads guilty and pays the penalty). Hence, logically speaking, complaints based on lack of due process cannot even get a foothold at this stage—notwithstanding the ubiquitous outcry from opponents along these lines. In light of this observation, critics of red light camera legislation may attempt to reframe their grievance using the language of *malicious prosecution*. However, although this approach is logically tenable, in practice it will likely prove unsuccessful as well, given the rather stringent prerequisites for such an action. To sustain an action for malicious prosecution in Virginia, the aggrieved party must establish a *concurrence* of (1) actual malice and (2) lack of probable cause; one without the other is insufficient (*Freezer v. Miller*, 1934). Further, "in the context of a malicious prosecution action, *malice* is defined as any controlling motive other than a good faith desire to further the ends of justice, enforce obedience to the criminal laws, suppress crime, or see that the guilty are punished" (*Hudson v. Lanier*, 1998). Since suppressing crime in the form of red light running is the dominant motive in red light camera legislation and its resultant enforcement, it would be extremely difficult to establish actual malice in such cases. And, as we have already seen, the issuance of a summons under Virginia's red light camera statute cannot be assailed for lack of probable cause. Hence, *neither* criterion for malicious prosecution obtains in this situation.

Burden of Proof

The presumption that the owner was also the driver, however, reemerges at the time of trial. Critics allege that red light camera systems are no more than schemes to generate revenue by shifting the burden of proof to the defendant who must stand trial before a tribunal with a monetary interest in holding him or her liable. At this stage, the critics' reproach "What happened to innocent until proven guilty?" resonates with slightly more force. However, this force quickly dissipates when one considers the actual legal implications of a rebuttable presumption like that found in the text of Virginia's red light camera statute.

The text of Va. Code Ann. § 46.2-833.01 characterizes the inference from owner to driver as a "rebuttable presumption," with the emphasis on *rebuttable*. That is, the fact that a person is the registered owner operates merely as *prima facie* evidence that he or she was also the driver at the time of the infraction—*not* as a forgone conclusion. Moreover, under the Virginia statute, this presumption is exceedingly easy to rebut: the owner need only "[file] an affidavit by regular mail with the clerk of the general district court that he was not the operator of the vehicle at the time of the alleged violation" or testify to the same in open court (Va. Code Ann. § 46.2-833.01).

Rebuttable presumptions have been upheld by the Supreme Court against due process challenges, so long as there is a "rational connection" between the basic facts proved by the prosecution and the ultimate fact presumed, and the latter is "more likely than not" to flow from the former (*Ulster County Court v. Allen*, 1979). In *Luria v. United States* (1913), the Court emphasizes the authority of the legislature to enact rules of evidence governing presumptions:

> Legislation providing that proof of one fact shall constitute prima facie evidence of the main fact in issue, is to enact a rule of evidence, and quite within the general power of government . . . That a legislative presumption of one fact from evidence of another *may not constitute a denial of due process* of law or a denial of the equal protection of the law it is only essential that there shall be some *rational connection* between the fact proved and the ultimate fact presumed, and that the inference of one fact from proof of another shall not be so unreasonable as to be a purely arbitrary mandate.

With respect to red light camera legislation, the Court would likely find these conditions satisfied as there does exist a "rational connection" between the basic fact that a given person is a vehicle's registered owner and the presumed fact that that person was the driver of the vehicle, and this is thus not a "purely arbitrary mandate." *Luria* was in fact cited for just this purpose in a recent D.C. case involving red light camera legislation (*Agomo v. Williams,* 2003).

In order to understand the connection between rebuttable presumptions and the burden of proof, we must differentiate between two related but distinct interpretations of the phrase "burden of proof": (1) the "burden of *production*," which is the obligation to make a *prima facie* case, that is, the burden of coming forward with evidence sufficient to enable a rational fact finder to hold that a particular proposition is true, and (2) the "burden of *persuasion*," which is the obligation to introduce evidence that *actually persuades* the fact finder, to the requisite degree of belief, that a particular proposition of fact is true (*City of Hopewell v. Tirpak*, 1998).

These concepts are brought together and linked to the notion of rebuttable presumptions in Federal Rule of Evidence 301, which has been largely adopted by Virginia:

> [A] presumption imposes on the party against whom it is directed the burden of going forward with evidence to rebut or meet the presumption, but does *not* shift to such party the burden of

> proof in the sense of the risk of nonpersuasion, which remains throughout the trial upon the party on whom it was originally cast.

In the red light camera situation, the owner is saddled only with the burden of *production* vis-à-vis a very limited presumption. That is, the owner must produce *some* evidence that he or she was not the driver of the vehicle such that a hypothetical rational fact finder *could* find that this assertion was true. And as we have seen, under Virginia's red light camera statute, the evidence capable of fulfilling this role is quite minimal and can take the form of a simple notarized statement on the part of the defendant. The burden of *persuasion* on the other hand—what most laypeople think of when they use the term "burden of proof"—never shifts from the party on whom it was originally cast, that is, the State. In other words, the State is always responsible for proving to the requisite degree of certainty that the person charged is guilty. Hence, under Virginia's red light camera statue, there exists no assumption of guilt in any sense that would contravene due process.

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APPENDIX I
DETAILS OF THE LITERATURE REVIEW

Tables I1 and I2 list the specific studies that comprised the literature review and the key findings. Table I1 names the studies that are published independently as separate evaluations, and Table I2 lists the studies that were used in the NCHRP Synthesis (McGee and Eccles, 2003).

Table I1. Summary of Studies Used in the Literature Review

Author	Year	Location	Source	Name of study	Summary
Fox	1996	Glasgow, Scotland, UK	The Scottish Office, Central Research Unit	Accidents at Signal Controlled Junctions in Glasgow	Crash reductions at all signalized intersections in Glasgow considering 3-year period before and after automated enforcement. Report mentions other safety initiatives and intersection improvements underway, which may have influenced citywide decline in crashes.
Andreassen	1995	Melbourne, Australia	Australian Road Research Board	A Long-term Study of Red Light Cameras and Accidents	Contains statistical analysis of crash records for intersections in Melbourne, Australia. No long-term reduction in crashes and there continues to be an increase in rear-end and adjacent approach collisions
A Report to Parliament	1993	Perth, Australia	Office of Auditor General	Improving Road Safety: Speed and Red Light Cameras and The Road Trauma Trust Fund, Perth Australia	40% reduction in angle collisions and no increase in rear-end collisions
Hillier, Ronczka, Schnerring	1993	Sydney, Australia	Road Traffic Authority, NSW. Road Safety Bureau	An Evaluation of Red-Light Cameras in Sydney	50% reduction in angle and right-turn opposing collisions, 20-60% increase in rear-end collisions
Mann, Brown, Coxon	1994	Adelaide, Australia	South Australia Department of Transport, Adelaide, South Australia	Evaluation of the Effects of Installing Red Light Cameras at Selected Adelaide Intersections	The sites with red light cameras and other modifications showed significantly greater crash reductions than the control group, but the effect of RLR cameras couldn't be isolated.
	1997	London	London Research Center, Environment and Transport Studies	An Analysis of Accident and Casualty Data 36 Months "After" Implementation and Comparison with the 36 Months "Before" Data,	A 16% reduction in "disobeyed traffic signal" crashes was observed, but it was not statistically significant.
Mullen	2001	City of Edmonton,Alberta, Canada		The City of Edmonton Red Light Camera Program in Review	Average violation frequency decreased from 9 violations per day to 2.5 violations per day after the implementation of the automated enforcement with 6 cameras operating at 12 locations. Overall figures indicate the success of the program in reducing red light violations.
Burkey, Obeng	2004	Greensboro, North Carolina	U.S. Department of Transportation, Research and Special Programs Administration, Washington	A Detailed Investigation of Crash Risk Reduction Resulting From Red Light Cameras in Small Urban Areas	Red light cameras did not reduce crashes or severity; in fact, the report noted that red light cameras, increase crash rates by 40%.

Author	Year	Location	Source	Name of study	Summary
Butler, Pamela Crenshaw	2001	Howard County	Howard University Thesis. Washington, DC:	A Quantifiable Measure of Effectiveness of Red Light Running Cameras at Treatment and Non-Treatment Sites	Contains statistical analysis of right-angle crash experience at two Howard County intersections. Found that reductions in crashes at the intersections were not statistically significant at the 95% confidence level, though they were close. No significant differences between the changes at the RLC and non-RLC intersections in Howard County, or between the non-RLC sites in Howard County and several control sites in Pennsylvania.
BMI	2003	Fairfax County, Virginia		Study to Determine the Safety Effect of Red Light Running Camera Systems Installed at 10 Intersections in Fairfax County, Virginia	A very limited after period and a small sample size suggests a reanalysis of the data in future
Daniel, Ruby, Hobeika	2003	Fairfax County, Virginia	Transportation Research Board, 82nd annual meeting	Assessment of Red Light Running Cameras in Fairfax County, Virginia	Violation rates reduced by 36% over the initial 3 months and by 69% after 6 months of enforcement. The accident data also showed a reduction of 40% in accidents.
McGee, Eccles	2003		TRB, NCHRP	Impact of Red Light Camera Enforcement on Crash Experience (NCHRP synthesis)	Based on the information available through published literature, various websites, and a survey, the report concludes that red light running automated enforcement can be an effective safety countermeasure. However, there is currently insufficient empirical evidence based on statistically rigorous experimental design to state this conclusively.
	2002			Safety Impact of Red Light Camera Enforcement Program	A critical review of the literature dealing with the impacts of red light cameras on crashes
Retting, Ferguson, Hakkert	2002			Effect of Red Light Cameras on Violations and Crashes: A review of International Literature	The studies indicate that, overall, injury crashes, including rear-end collisions, were reduced by 25-30% as a result of camera enforcement.
	2002		IIHS	An Evaluation of the Effectiveness of Red-Light Cameras at Signalized Intersections	This paper brings together literature that has been published on the subject of red-light-running crashes.
Retting, Kyrychenko	2002	Oxnard, California	American Journal of Public Health	Reduction in Injury Crashes Associated with Red Light Camera Enforcement in Oxnard, California	Overall, crashes at signalized intersections throughout Oxnard were reduced by 7% and injury crashes were reduced by 29%. The right-angle crashes were reduced by 32%, and right-angle crashes involving injuries were reduced by 68%.
	2001		IIHS	Crash Reductions Associated with Red Light Camera Enforcement in Oxnard, California	
Retting	2000		ITE Annual Meeting	Reducing Red Light Running Crashes: A Research Perspective	Red light cameras can produce a strong deterrent effect and drivers in urban communities generally support this type of camera enforcement.
Retting, Williams, Farmer, Feldman	1999	Fairfax City, Virginia	ITE Journal	Evaluation of Red Light Camera Enforcement in Fairfax, VA, USA	Overall reductions in violations at the five camera sites were 7% after 3 months and 44% after one year. Overall reductions at the two non-camera sites were 14% after 3 months and 34% after one year. The overall violation rate at the control sites essentially was unchanged. Public support for camera use increased from 75% before enforcement to 84% 1 year after enforcement.

Author	Year	Location	Source	Name of study	Summary
Status Report	2001	Oxnard, California	IIHS	Red Light Cameras Yield Big Reductions in Crashes and Injuries	Installation of red light cameras on only a fraction of the city's intersections reduces serious crashes and injuries at intersections across the city. The article also details a survey showing strong public support for cameras' use and recommends legislative changes to make it easier for localities to install them.
Lum, Wong	2003	Singapore	Journal of Transportation Engineering	Impact of Red Light Camera on Violation Characteristics	Red running violations were substantially reduced by more than 40% at camera approaches. Overall, there was aggregated net reduction of about 7% across all approaches.
	2002		Journal of Safety Research	A Study of Stopping Propensity at matured Red Light Camera Intersections	The propensity to stop at camera approaches was found to be about 17 times more frequent than at non-camera approaches.
	2002		Road and transport research	Effects of Red Light Camera Installation on Driver Behavior at a Signalized Cross-Junction in Singapore	The revealed stopping/crossing decisions of non-platoon vehicle drivers were modeled as they responded to the onset of the yellow signal, along with a number of traffic and behavioral variables.
	1997		Road and Transport Research, Vol. 6, No. 2, 1997, pp. 72–80.	The Impact of Red-Light Surveillance Cameras on Road Safety in Singapore	Right angle collisions and total collisions were reduced by 8 % and 7% respectively with slight increase of 5% in rear-end collisions.
	2002	California	California State Auditor/Bureau of State Audits	Red Light Camera Programs: Although They Have Contributed to a Reduction in Accidents, Operational Weaknesses Exist at the Local level	
		San Diego	PB Farradyne	San Diego Photo Enforcement System Review http://www.sandiego.gov/police/pdf/photochap2.pdf	After six months 20 to 24% reduction in violations that remained same for longer period of camera operation, significant reductions in the accidents attributable to red light running, accident rate is highest where through approach is monitored. Overall accident rate increased by 3% after cameras installation due to increase in rear-end accidents.
Per Garder	2004	Maine (Cameras not present here)	Department of Civil and Environmental Engineering, University of Maine, Orono, Maine	Traffic Signal Safety: Analysis of Red Light Running in Maine	More enforcement by police or automatic surveillance is by the public considered the most effective ways to reduce red-light running. Finally, the most important factor in reducing red-light running frequency, as well as the number of serious crashes caused by red-light running, is never having a posted speed limit greater than 35 mph through a signalized intersection.
U.S. Congress, House. Office of the Majority Leader	2001			The Red Light Running Crisis: Is It Intentional ?	The document concludes: "The only documented benefit to red light cameras is to the pocketbook of local governments who use the devices to collect millions in revenue. We traded away our privacy for this. We gave up our constitutional protections for this. In return, we are less safe. That is the red light camera scam, and it has gone on for far too long"

Table I2: Findings of Crash Evaluations as Reported by Jurisdictions on a Survey Conducted By NCHRP

Location	Type of Evaluation	Findings
Garden Grove, CA	1-yr B/A compared to 5 other high-violation locations	56.2% reduction in right-of-way violation accidents; 1.2% increase in rear-end accidents
Howard County, MD (2 evaluations)	1-yr B/A for 24 intersections	Rear-end collisions increased by 6%; angle collisions decreased by 47%; other collisions decreased by 11%. Reductions in total collisions from 1998 to 2000
	1+-yr B/A for 25 intersections	For all RLR intersections: 30% decrease for rear-end; 42% decrease for angle; 21% decrease for other; 31% decrease total
Laurel, MD		Reduction in number of accidents at all locations
Boulder, CO	32-month after evaluation	57% reduction in red light-related accidents
Los Angeles County, CA		Accident rates for 3 of 5 locations reduced, 4th remained relatively the same, and 5th did not improve
San Francisco City, CA	5-yr B/A for 1st camera in 1996	Red light running collisions declined
Tempe, AZ	4-yr B/A	Collision rate for both intersections has shown increases and decreases since inception
Mesa, AZ	Yearly collision rates	Intersection-related accident rates (per population) have decreased each of 5 years since installation
Baltimore County, MD	1-yr B/A	Total crashes decreased 51%; intersection related decreased 55%; RLR crashes decreased 30%; injury crashes decreased 51%; PDO crashes decreased 51%
Ft. Collins, CO	1 Before for 2.5 yr and after for 5.5 yr	No significant change in accident or injury frequency
Charlotte, NC	B/A for 3 yr for 17 intersections	Overall angle crashes reduced by 37% at intersections with cameras and 60% for approaches with cameras; all crash types reduced by 19%; crash severity reduced by 16%; rear-end crashes increased by 4% on camera approaches
San Diego, CA	B/A for 2 yr at 16 intersections	Injury accidents remained the same at most locations; but incidents of RLR decreased dramatically
Montgomery County, MD	B/A for 2 yr	Overall number of crashes went down slightly, but probably not significant
Sacramento, CA	Comparison of crashes 1 yr B/A	Reductions: 10% for all crashes; 27% for injury crashes; 26% for angle crashes; 12% for rear-end crashes; 39% for red light crashes
Scottsdale, AZ	Comparison of red light running accidents city-wide B/A	Red light running accidents dropped first year after cameras but have crept up but not to the level before installation. RLR accidents at camera locations are too low to make a conclusion. Difficult to isolate RLR camera effect. Summary data provided.
Paradise Valley, AZ	B/A; time frame unknown	Same number of collisions, but reduced severity
Notes: B/A = Before and After; RLR = Red light running; PDO = Property damage only.		

Finally, because the findings of a study by Burkey and Obeng (2004) contrasted with those in the previous literature, the findings were examined closely. Detailed examination of the study raises five key questions that lead one to question the results. These questions do not prove the study has flaws, and the same questions can occur upon reviewing many crash related studies. There existence, however, means that the Burkey and Obeng (2004) report must be viewed in concert with previous literature.

- *Most important, the adequacy of the model may be questioned for two main reasons*. First, the authors used a Poisson distribution for crashes across sites and years, rather than the negative binomial distribution that has typically been used in crash studies. (Although crash counts at a particular intersection may follow the Poisson distribution, studies have also suggested that the distribution of crashes across intersections follows a Gamma distribution, such that the combined distribution of crashes across intersections and across years is the negative binomial distribution.) The authors do not show that the data have the Poisson distribution (rather than negative binomial); instead, the Poisson distribution is used for convenience. In the authors' defense, the Chi-squared result is reported with a p value of 0.00. Second, the pseudo R^2 measures reported in the goodness of fit tests, described in the report as the *RsqP* and *RsqD* variables, are extremely low, with the highest value reported as 0.17 and 0.21 (for crashing into the rear of slowed or stopped vehicles) and dropping to a value of 0.03 and 0.08 for sideswiped crashes in the same direction. Table I3 shows the values from the Burkey and Obeng (2004) report . The pseudo R^2 values are not directly comparable to traditional R^2 values from a linear regression model, and literature on this topic does not give guidance as to what is an appropriate threshold value for accepting the model (Greene, 2000). Given the fact that these are close to 0.0 (with 1.0 being a perfect fit), Table I3 suggests the models may not be a good fit to the data.

Table I3. Goodness of Fit Measures Reported by Burkey and Obeng[a]

Predicted Variable	*RsqP*	*RsqD*
Total crashes	0.19	0.17
Angle crashes	0.05	0.07
Crashes where a vehicle crashed into rear of slowed or stopped vehicles	0.17	0.21
Crashes involving left turning vehicles on different roadways	0.04	0.08
Sideswiped crashes: same direction	0.02	0.08
Crashes involving a left turn in the same direction	0.03	0.07
Other crashes	0.01	0.03

[a]Source: Burkey and Obeng, 2004. Values are rounded to the nearest hundredth.

- *The report relies on one geographical location to construct the underlying crash estimation models*. For example, the report suggests that certain types of crashes increase disproportionately more than a corresponding increase in volume (e.g., it is suggested that a 10% increase in volume leads to a 12.3% increase in crashes.) Yet previous work in 2003 has shown that crash estimation models, when developed for different states for the same type of facility-rural interstate highways with a uniform speed limit, can give very different crash estimation models *for each state*. In that previous work, an increase in volume of 10% is predicted to increase crashes by between 1.3% and 8.3%, depending on the state selected (Garber et al., 2003). This does not mean that the Greensboro figure of 1.23 in itself is wrong; instead, the lesson was that it is important to develop these models for multiple states rather than a single jurisdiction. Had the authors of that 2003 work used only one state's results, they would have overstated the effect of the treatment being studied. It is possible that a similar phenomenon occurs with the 2004 study based on just the single Greensboro area.

- *There is a difference between running traffic control devices and running red lights*. Literature is cited indicating that "running traffic control devices were the primary cause of 22% of all crashes." This statement may be accurate, but it obscures the fact that only a small percentage of crashes are attributable to red light running. Data from Virginia's Department of Motor Vehicles, for example, suggested that in 1998 (a year when no red light cameras were in operation), only 3.3% of all crashes involved a driver who "ran traffic control" (DMV, 1999). When choosing Virginia's most populous county for more detailed analysis, i.e., Fairfax County, data from the Virginia Department of Transportation suggest that 15% of the crashes that occurred *at a traffic signal* involved the offense of "disregarded stop-go light." However, that offense was charged in only 4% of the *total crashes* in Fairfax County in 1998.

- *Some intersections had their amber times changed*. The authors noted that amber times at "several" intersections with red light cameras were shorter than what is specified in North Carolina's legislation, and thus these amber times were increased. Given the authors' use of the word "several," it seems logical that of a total of 303 intersections, this changing of the signal time would not have skewed the data substantially. However, it would be preferable to know either that those intersections where the signal timing was changed were taken out of the study or the number of such intersections was indeed a small percentage of the sample set.

- *The model coefficients in some cases run counter to what would be expected*. Consider, for example, rear-end crashes: it is shown that the presence of no left turn and no right turn increases rear-end crashes. To the authors' credit, they point out that certain variables are merely correlated with crash frequency change rather than causing such a change. Still, the fact that turn prohibitions could increase rear-end crashes is not intuitive; further, the presence of dedicated right-turn lanes does not statistically reduce rear-end crashes ($p = 0.85$), which also runs contrary to expectations.

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