FINAL REPORT

Automated Enforcement of Traffic Signals: *A Literature Review*

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Executive Summary

Implementation of automated enforcement programs for traffic signals is increasing in the United States. Fines assessed by the programs, which are based on photographs or videos captured automatically when a vehicle enters the intersection after the signal has changed to red, range from $50 to $271 dollars. The cameras used in the systems cost about $50,000 to $60,000, with installation, including detectors, equipment cabinet, and mounting pole, adding approximately an additional $25,000. Monthly operating costs are approximately $5,000. In the U.S., a private sector contractor that receives a portion of the fine revenue collected from the systems typically undertakes installation and operation. Public opinion surveys reported in the literature indicate significant public support for the programs. The percentage of survey respondents approving of the systems ranges from approximately 60% to 80%.

Impacts of the systems on the safety of the transportation system are difficult to assess. There is substantial literature documenting a significant decline in the number of vehicles committing traffic signal violations at enforcement sites, ranging from 20% to 87%. However, the few independent analyses of the occurrence of crashes at these sites offer no definitive indication of whether the camera systems impact this important measure of transportation safety. An early Australian study indicated significant reductions in crashes due to implementation of camera enforcement, while a later study found that over time there were no significant changes in crash behavior due to the systems (though the small number of crashes experienced at the studied sites clouded the results). Studies of the systems in use in Scotland found both a significant crash reduction and that the most significant impact on violation behavior was a decrease in vehicles entering the intersection between 0.5 and 5 seconds into the red phase. A study of citywide crashes over the same time period found that red light cameras were likely one of several factors contributing to the overall decline in accidents. A graduate student study of two intersections with automated enforcement in Howard County, Maryland indicated a positive impact of the systems on right-angle crashes. A Mitretek analysis of data provided by Howard County on crash experience at each of the 25 enforced intersections in that county indicated that the reported reduction in both right-angle and rear-end collisions were statistically significant. Several factors were identified that cloud the interpretation of reported safety impacts, including study design issues and the influence of other traffic safety improvements concurrent with the implementation of red light cameras.

This report makes several recommendations for further research into the impacts of red light camera systems. Despite the inherent difficulties of long term transportation safety impact studies, one or more such studies performed by an independent agency on a U.S. red light camera system would provide a better understanding of the impact that red light cameras have on U.S. driver populations. A second effort that may help document any safety impact of these systems would be a detailed review of automatic camera recorded violation data from several jurisdictions to determine if red light violations at particular times during the red phase are more likely to result in crashes, and whether or not red light camera systems in the U.S. are significantly reducing these types of violations. The final recommended area of further research in this area is benefit/cost analysis of the systems. The ability of the systems to reduce crashes should be compared to the costs of operating the systems as well as the total value of fines assessed to signal violators.

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1. Overview

This document presents the result of an extensive review of available documents regarding automated enforcement of traffic signal compliance undertaken by Mitretek Systems. The literature regarding the operation and impacts of systems that automatically enforce driver compliance with the red phase of traffic signals is extensive. However, reviewing the available documents for independent analyses of these systems yields very few examples. Efforts to assess the safety impacts of these systems by independent evaluators (not connected to the agencies or vendors operating the programs) have been made in Australia, the United Kingdom, and, to a lesser extent Howard County, MD. Each of these studies, as well as the remainder of the sources reviewed during this effort, indicate a significant reduction in the number of drivers running the red light. Crash reduction results are mixed and generally inconclusive. An early Australian study (South, *et al*., 1988) indicated significant reduction in crashes several years after the initiation of the program in Melbourne, Australia, while a follow-up study (Andreassen, 1995) several years later found no significant reduction in collisions due to the system. Two studies in Scotland (Halcrow Fox, 1996 and Ray, 1995) indicate significant benefits from the cameras. A graduate student project assessing the system in Howard County, MD (Butler, 2001) also indicated positive impacts of that system on crashes and violations. The remainder of the literature consists primarily of statistics reported by the operating agencies and press reports of camera program results.

The following section of this report describes the operational arrangements surrounding camera programs in the United States, including typical contracting arrangements and the fines and penalties associated with the programs. The third section of the document describes the reported impacts of the systems on violations and collisions, including a more detailed discussion of the few independent analyses of red light camera programs. Next, this report briefly summarizes the results of several public opinion surveys described in the literature. Section 5 lists several research projects regarding red light cameras known to be underway. The body of the report concludes with several recommendations for further research into the impacts of red light cameras. An annotated bibliography of the sources collected in this review follows the body of the report.

2. Operation of Red Light Camera Programs

2.1 Background

States with legislation authorizing the use of photo or automated enforcement of red-light running (RLR) include, but may not be limited to: Arizona, California, Colorado, Delaware, Georgia, Hawaii, Illinois, Maryland, New York, North Carolina, Ohio, Oregon, Texas, Virginia, Washington, and the District of Columbia. Some states (Ohio, for example) have "home rule" wherein a local ordinance is all that is needed to enact a camera enforcement program.

In most cases, once authorized by the state legislature, a municipality determines whether or not to use automated RLR enforcement. Federal Highway Administration guidance recommends that localities perform an engineering review of intersections selected for enforcement, including “approach geometry, signal timing details, and other relevant engineering features.” This review will help ensure that the red light running problem at the identified intersections is due to driver

behavior rather than engineering shortcomings (FHWA, undated). Most municipalities contract with a vendor(s) to install the camera system with associated infrastructure, and to operate the back office processing. A police officer typically reviews violation photos prior to a citation being mailed to the vehicle owner. Requirements for proving and adjudicating the violation vary from state to state. Some states require only pictures taken of the rear of the vehicle while others require rear photos as well as pictures of the driver. These requirements factor into the cost of the camera system and the back office processing. Two-to-three pictures are usually taken of the violation. Some states require that only color photos be taken while others permit color (to prove red phase) and monochrome (vehicle license plate).

2.2 Costs

RLR fines associated with photo enforcement systems vary by state and city. Review of the literature indicates that these fines range anywhere from $50 to $271. Depending on the state's law, a portion of the fine goes to the state treasury with the remainder going to the municipality. The contractor receives a percentage, ranging anywhere from 15% - 56%, of the municipality's portion of the fine in return for installation of the camera system, leasing the equipment, and providing the violation processing. Some states do not receive a portion of the fine, with all revenue going to the municipality and vendor. Some states, California, for instance, use frontal photography to acquire an image of the driver and use this to assess negative points on a driver's driving record for red-light violations.

Most contracts are based on a sliding scale fee wherein as the number of violations processed increase, the percentage of the fine to the contractor decreases. Information is available for fines and percentage paid to vendors as well as for camera system and equipment installation; however, no specific information is available for the cost of the back office processing. The cost of this processing as well as for the camera and associated equipment are folded into the negotiated cost per violation fee charged by the vendor. See Table 1 for additional information. Sources for this cost information can be found in the Bibliography.

Based on Mitretek's literature search, the major vendors active in photo RLR enforcement include: Peek Traffic Inc., EDS, U.S. Public Technologies (USPT) - purchased by Lockheed Martin IMS and soon to be purchased by Affiliated Computer Services (ACS), Traffipax, Redflex Traffic Systems, Nestor Traffic Systems, and LaserCraft. Contractor teams may also form to implement these systems. For example, EDS, whose role tends to be in performing the back office processing, may team with a camera vendor. Camera vendors are typically European including: Gatsometer's Gatso RLC, Robot (distributed in the U.S. by Traffipax), and Peek's Guardian. Lockheed Martin tends to purchase the 35-mm wet film Gatsometer camera systems. Many of the first cameras used for RLR enforcement are 35-mm wet-film; however, the trend is to move to digital technology which alleviates the need to retrieve and replenish film as in the wet-film technology cameras. Peek cameras are digital; Gatso are available in both wet-film and digital. Digital and standard video systems are also available. Nestor Traffic Systems provides video camera detection and photo technologies.

Wet-film, 35-mm red-light cameras range in cost from $50K - $60K. Installation costs are around $25K and include installation of the camera, and associated equipment (e.g., pole, loop detectors, cabinet foundation). Monthly operating costs are approximately $5K per camera

system. The standard digital red-light camera system from Peek Traffic is for a three-lane approach and includes a total of four cameras: 3 monochrome and 1 color. Each of the three monochrome cameras are trained on a single lane, and the color camera is pointed to photograph the entire intersection and to show color of traffic signal. The cost of the camera system is approximately $100K and includes the camera and installation of associated equipment (e.g., poles, loop detectors, cabinet). Costs decrease by $2.5K for a two-lane approach and $5K for a one-lane approach.

Table 1. Operating vendors, fines, and revenue distribution for several U.S. cities with automated RLR enforcement.

Site	Vendor	Fine	Fine Split
Phoenix, AZ	Lockheed Martin	$175	$93 vendor, $82 city
Mesa, AZ	Lockheed Martin	$170	$74.01 state, $95.99 city with $48.50 going to vendor
San Francisco, CA		$271	$123 state, $148 city/county Split to city/county: $48.50 vendor, $99.50 to further program, educational campaign, and equipment vendor
Santa Rosa, CA		$271	$100 vendor
San Diego, CA	Lockheed Martin	$271	$70 vendor
Baltimore, MD	Lockheed Martin	$75	15% - 35% of fine to vendor
Howard County, MD	Traffipax/EDS	$75	Sliding scale. State receives no revenue from fines.
Washington, DC	Lockheed Martin	$75	$26 vendor (as much as 40%), $49 city
Lakewood, WA		$71	
Marietta, GA	LaserCraft	$70	
Garland, TX*	Lockheed Martin	$75	$74.50 vendor, $0.50 city
Wilmington, NC	Peek Traffic	$50	$35 vendor, $15 city
Greensboro, NC	Peek Traffic	$50	$35 vendor, $15 city
High Point, NC	Peek Traffic	$50	$35 vendor, $15 city
Charlotte, NC	Lockheed Martin	$50 $50 $100	1st notice: $28 vendor, $22 city 2nd notice: $23 vendor, $27 city 3rd notice: $76 vendor, $24 city
Oahu, Hawaii*	Lockheed Martin	$77	As much as $50 vendor, $27 city
Fairfax, VA	USPT	$50	$20.85 vendor, $29.15 city

* Automated camera enforcement program in start-up phase.

3. Transportation Safety Impacts of Red Light Cameras

This section discusses the impact of red light camera systems on safety at intersections. The statistics used to describe the performance of the systems are violation and crash reductions. This section first presents reported reductions for many of the locations making use of red light cameras. The section concludes with a review of the few independent analyses of these systems.

3.1 Reported Safety Impacts

Table 2 lists the cited violation and crash reduction figures revealed in this research effort for many of the jurisdictions using red light cameras. Reported violation reductions range from 20% to 87%, with half of the jurisdictions reporting between 40% and 62% reductions in red light violations. The quality of sources for the data in Table 2 varies widely. Violation reduction figures are typically from newspaper or trade press articles, cited as obtained during interviews with representatives of the operating agency, or cited in secondary sources referencing these types of sources. As described in a few of these sources, violation reductions are most often computed by comparing the number of violations recorded by the camera systems during the first months of operation with the same statistics from later time periods. A few of the studies collected data on the number of transgressions prior to commencing enforcement, either with the enforcement camera itself or through review of video recordings of the intersections. Despite the general lack of data collection during a true "before" period, there has been widespread reporting of large violation reductions.

Most of the crash reduction figures cited in Table 2 come from sources similar to those for the violation reductions, and therefore should not be taken as reliable independent evaluations of the systems, with several notable exceptions (discussed in Section 3.2). The agencies responsible for the camera programs in Howard County, MD, Wilmington, NC, and Charlotte, NC, have released documents citing reductions in right-angle collisions at the enforced intersections. Discussions with local transportation engineers in Howard County and Wilmington indicate that these figures were based on review of police reported incidents at the intersections before and after the implementation of the camera systems. The Wilmington data indicates an increase in rear-end collisions at enforced intersections, similar to the impact described by many other locations. Howard County data indicates a reduction in rear-end collisions at the majority of the 25 enforced intersections at that county. In Wilmington, staff reviewed the police reports to eliminate collisions occurring at driveways near the enforced intersection.

While conflicting results sometimes appear in the crash reduction figures cited in Table 2, the majority of the reported cases indicated some reduction in crashes. An important issue clouding the results of these reports is the lack of a significant amount of experience with the camera systems. The figures given are based on one to two years of experience with little to no analysis of trends over time, and therefore cannot reveal whether the programs have a lasting impact. In addition to these local reports, there have been several attempts to independently assess the impacts of red light camera systems on crashes at enforced intersections, as described below.

Table 2. Violation and crash reductions for various RLR enforcement programs.

Site	Violation Reduction	Crash Reduction	Source Type(s)	Source(s)
Arizona				
Scottsdale, AZ	62%		Trade Press Article	"Applications Increase…", 2000
California				
Oxnard, CA	42%[1]	29% reduction injury crashes, 32% reduction right-angle crashes[2]	Insurance Institute for Highway Safety (IIHS) Studies	[1] Retting, 1999 [2] Retting, 2001
San Francisco, CA	42%		Conference Paper	Fleck and Smith, 1999
Santa Rosa, CA	yes	yes	Newspaper Article	"Exposed: SR…", 2001
Los Angeles, CA	75%		Conference Paper	Rocchi, 1999
Colorado				
Boulder, CO	37%	57%	Newspaper Article	"Speeders may be…", 2001
District of Columbia				
Washington, DC	56%		Newspaper Article	"Red-light Cameras.", 2001
Florida				
Polk County, Florida		7.3%	FHWA Synthesis Report	*Synthesis and Evaluation…,* 1999
Fort Meade, FL	50%		Conference Paper	Rocchi, 1999
Maryland				
Howard County, MD	42-62%	21-44% at individual intersections	Agency Data	"Maryland House of Delegates…", 2001
Michigan				
Jackson, MI	83%		Synthesis Report	ITE, 1999
New York				
New York, NY	34%	60-70% reduction in angle crashes at one site	FHWA Website	FHWA, *undated*
North Carolina				
Charlotte, NC	20%	24% reduction at enforced intersections, 20% reduction in crashes caused by RLR	Agency Report	"Safelight Charlotte: First-Year Report.", *undated*
Greensboro, NC	20-25%		Newspaper Article	"Cameras curb red…", 2001
High Point, NC	20%		Newspaper Article	"City Shoots for…", 2001
Wilmington, NC	40-60%	26% reduction in right-angle and 8% increase in rear end, 22% decline in total collisions	Agency Brochure	"Safelight Wilmington: First Year in Review.", 2001
Virginia				
Fairfax, VA	44%		IIHS Study	Retting, August 1999

Table 2. Violation and crash reductions for various RLR enforcement programs. (cont.)

Site	Violation Reduction	Crash Reduction	Source Type(s)	Source(s)
Australia				
Melbourne, Victoria, Australia (1995)		0% reduction in right-angle crashes at enforcement locations, *increase* in rear-end collisions	Independent Evaluation	Andreassen, 1995
Melbourne, Victoria, Australia (1988)		32% decrease in right-angle crashes and 10% decline in injuries	Independent Evaluation	South, 1988
Perth, WA, Aus		40% right-angle crash reduction at enforced intersections, little change in average number of rear-end crashes	Independent Evaluation	Office of the Auditor General, 1996
Queensland, Australia	70%		Agency Website	"Technology versus the Lawbreakers.", *undated*
South Australia		33% reduction in serious right-angle crashes, 5-10% increase in rear-ends	Conference Paper	Rocchi, 1999
Sydney, Australia		50% reduction in angle and right-turn opposing collisions, 20-60% increase in rear-end collisions	Conference Paper	Rocchi, 1999
Victoria, Australia	30%		Synthesis Report	ITE, 1999
Canada				
Victoria, BC	73%		Conference Paper	Rocchi, 1999
Hong Kong				
Hong Kong	40%		Conference Paper	Rocchi, 1999
Singapore				
Singapore	40%		Conference Paper	Rocchi, 1999
United Kingdom				
Essex, England		88% reduction in injury collisions	Conference Paper	Rocchi, 1999
Glasgow, Scotland	69%	62% reduction in injury accidents	Independent Evaluation	Winn, 1995
Nottinghamshire, UK	60%			Rocchi, 1999

3.2 Review of Independent Analyses

An early Australian study (South, *et al*., 1988) indicated significant reduction in crashes two years after the initiation of the program in Melbourne, Australia. This study considered data from five years prior to installation of cameras and two years following installations between August 1983 and November 1984. A follow-up study (Andreassen, 1995) several years later, considering after data through 1989 to provide equal five year "before" and "after" periods, found no significant reduction in collisions due to the system, and an increase in rear-end collisions similar to that described in the first study. The study was based on comparisons of police reported crashes at each of 41 enforcement sites. Due to several changes in the police report format during the study periods, individual crash reports were reviewed to classify crashes appropriately. The study attempted to compare crashes at the selected sites with crashes in all of Victoria; however, problems with the database reports for red light running crashes and crash coding on the reports obtained led the author to conclude that results of this analysis were unreliable. Notably, Andreassen also stated that the low crash frequencies at the camera installations in Melbourne made them poor locations for the assessment of safety impacts due to the camera program.

A report by the Office of the Auditor General for Western Australia (Office of the Auditor General, 1996), describes a significant benefit of a 40% reduction in right angle crashes at the 44 enforced intersections in Perth over a ten-year period. This was compared to very little change in the rate of such collisions over all 920 signalized intersections in the city. The study also found no significant change in the frequency of rear-end collisions at the locations. The report includes a chart presenting the right angle crash frequency at each set of intersections; however, it gives no description of the technique used to develop the statistics presented.

Studies performed in Scotland (Halcrow Fox, 1996 and Winn, 1995) indicate significant benefits from the cameras. The Winn study found a 62% reduction in collisions caused by RLR at camera sites in Glasgow when comparing data from police accident records from "before" and "after" periods of 3 years each. The accident records tallied for each site were filtered to include only those reports that indicated RLR contributed to the crash. A second component of the Winn study was an analysis of the change over time in the number of vehicles violating the signal during various segments of the red phase. The study used data collected by observers and records from the automated camera systems to document the time into the red phase that violations occurred. Data gathered during before, interim, and after surveys periods including manual observation revealed that the decline in violations was most significant during the periods 0.5 to 1 second into the red and in the period 1-5 seconds into the red. These time periods accounted for 42% and 29%, respectively, of the total number of infringements at the sites and the number of infringements in these time bands declined by 69% and 67% between the before and interim surveys. Violation rates remained approximately the same between the interim period, when only warning notices were issued, and after periods. The only time band surveyed that did not show a decline in violations was the period greater than 5 seconds into the red phase. Violations in this segment of the phase accounted for less than 1% of the recorded infringements, while the remaining 29% of violations occurred during the period at the beginning of the red phase (0 to 0.5 seconds into the phase).

The later Halcrow Fox study (Halcrow Fox, 1996), which included a review of police accident reports and traffic volume data covering the period from 1989 to 1995, found that camera enforcement was just one of several traffic safety improvements contributing to a citywide reduction in collisions at signalized intersections in Glasgow. For example, the study notes a significant reduction in accidents caused by pedestrians crossing carelessly, and cites engineering and education efforts as possible reasons for this portion of the overall decline in crashes. With regard to accidents caused by RLR, the study found that both injury and non-injury crashes caused by this behavior declined between 32% and 35% citywide, accounting for a similar percentage of the total crashes in the analysis periods before and after camera enforcement began. The decline in RLR crashes accounted for 20% of the decline in all crashes at signalized intersections. Another notable finding of the study was that "injury accidents caused by red light running declined more sharply at junctions away from the camera sites suggesting that factors such as junction improvement, traffic management and increased vigilance may have been important in reducing red light running accidents across the whole area."

A graduate student thesis assessing the system in Howard County, MD (Butler, 2001) indicated positive impacts of that system on right-angle crashes. This study involved comparison of police reported right-angle collisions at two camera locations for before and after periods of 18 months. The number of crashes occurring at these sites was compared to totals from a sample of non-enforced intersections in Howard County and a "control" group of intersections along arterials of similar traffic volumes and development patterns in Pennsylvania. The study found that the improvement between the before and after period at red light camera (RLC) intersections in the county was not significant at a 95% confidence level, but was significant at the less stringent 90% confidence level. Due to small reductions in the number of crashes at the other sites, the study found no statistically significant differences between the changes at the RLC and non-RLC intersections in Howard County, nor between the non-RLC sites in Howard County and several control sites in Pennsylvania.

Mitretek analysis of data provided by Howard County ("Maryland House of Delegates Commerce and Government Matters Committee Automated Enforcement Review: Red-Light Running Detection Camera Systems", 2001) indicated statistically significant reductions in the total number of both right-angle and rear-end crashes at camera enforced intersections. The analysis excluded 3 atypical intersections located at the terminus of freeway sections (though each of these locations recorded reductions in crashes as well). Telephone interviews with the Howard County Traffic Engineer revealed that the data was obtained from queries of a database of crashes recorded at the enforced intersections. The measured reductions were a 42.5% decline in right-angle collisions and a 29.5% reduction in rear-end crashes at the enforcement sites. Chi-squared and paired-T statistical analysis found these results to be significant at a confidence level of 1%. Chi-squared analysis did not find the 21.8% decrease in "other" types of crashes at the enforced intersections to be statistically significant, however the paired-T test did indicate the change was significant. Data used in this analysis reflected crashes occurring at each site during "before" and "after" periods that varied from one intersection to the next. All "after" time periods concluded on 15 December 2000, while before periods began on appropriate dates before the implementation of cameras in order to provide "before" and "after" periods of equal duration at each site. The date of implementation of the enforcement program at each intersection varied from 18 February 1998 to 26 August 1999, resulting in "before" and "after" periods ranging from 15 to 32 months at each intersection.

4. Public Opinion of Red Light Cameras

Reports in the literature have demonstrated strong public support for red-light camera enforcement programs, ranging from roughly 60% to 80% of survey respondents favoring the systems. Again, the quality of the references providing these statistics varies widely, with few providing details on sample size or survey techniques. Results of an opinion survey of AAA members indicate 77% of the organization's membership supported RLC programs (Anderson). A trade journal article mentions that a 1999 survey found 78% support for RLC enforcement in Scottsdale, Arizona, where cameras have been in operation since 1997 ("Applications Increase for Automated Traffic Violation Enforcement", 2000). Charlotte, North Carolina's first annual report on their red light camera program reported that in 1997, prior to implementation of the program, 80% of Charlotte citizens felt that camera enforcement would be beneficial in reducing red light running ("SafeLight Charlotte: First-Year Report", *undated*).

Random sample surveys conducted by the Insurance Institute for Highway Safety (IIHS) in five cities with RLC programs and five cities without programs found that, in each city, over 75% of respondents favored the camera programs (Retting and Williams, 2000). A 2000 journal article (Wissinger, 2000) cited a 1995 IIHS nationwide survey that found 66% of respondents were in favor of the programs. The most recent national survey identified in this literature review, a 1999 survey sponsored by the organization Advocates for Highway and Auto Safety, found 74% of those surveyed in favor of the programs (Harris, 1999). Reports of public opinion of red light camera enforcement programs in the literature reveal strong support for the programs. However, it is also noteworthy that very few people are undecided about their position on red light cameras. This is reflected in the generally low numbers of people responding with no opinion in the surveys (Polk, 2000).

5. Studies in Progress

The following studies on this subject are known to be in progress as of July 2001:

- NCHRP Synthesis 32-03, "Impact of Red Light Camera Enforcement on Crash Experience" will collect and document the reported impacts of red light camera enforcement on crash experience, both at enforced intersections and areawide.

- A joint FHWA/ITE study entitled "Engineering Safer Intersections to Prevent Red Light Running" is also underway. The study, expected to be available in Spring 2002, will document appropriate methods for improving intersection safety through efforts to curb red light running. The report will identify engineering measures that are necessary prior to the installation of red light cameras.

- The Australian association of transport agencies (Austroads) will soon begin a research project aimed at developing guidelines for setting up and operating intersection signals with red light cameras. The project, expected to take about 12 months to complete, will include a comprehensive review of the literature, analysis of crash data and consultation with experts.

- A survey effort is ongoing in North Carolina to assess the opinions of North Carolina motorists regarding the red light camera enforcement programs in operation in that state.

6. Recommendations for Further Research

Each of the existing independent analysis makes an attempt to assess the long-term impacts of a system that is affected by a variety of external influences that can also impact traffic safety. This is a characteristic of traffic safety impact studies that is probably difficult to overcome. While a long-term study may provide a better indication of any lasting impact of the systems on intersection safety, this longer time frame also allows a greater opportunity for other, necessary, improvements that can also impact safety, such as intersection and pedestrian safety improvements. The result is that the safety impact of the camera systems remains unclear.

Despite the inherent difficulties of long term transportation safety impact studies, one or more such studies performed by an independent agency on a U.S. system would provide a better understanding of the impact that red light cameras have on U.S. driver populations. These studies should include an evaluation of violation and crash trends from several cities, to capture changes in these statistics over time under different driving environments. A second effort that may help document any safety impact of these systems would be a detailed review of automatic camera recorded violation data from several jurisdictions. In a manner similar to the Scottish study (Winn, 1995), such an analysis should review the time into the red-phase that violations are occurring. Reviewing the time of violations would help determine if the violation reductions achieved were impacting all violators, or having a more significant impact on those violating the signal immediately after it changes to red.

Comparisons of violation records with crash data collected after the commencement of camera programs could help better define the relationship between violation reductions and a reduced occurrence of crashes. Reviewing crash records for locations with automated enforcement and associating each crash with a corresponding violation recorded by the camera could determine if red light violations at particular times during the red phase are more likely to result in crashes. Analysis of the change in the number of violations occurring at different time intervals within the red phase could then help determine whether or not red light camera systems in the U.S. are significantly reducing the types of violations most associated with crashes. It is unlikely that a significant number of crashes would occur during video-recorded or manually observed survey periods prior to automated enforcement. Such a study would therefore need to rely on data collected after enforcement begins to assess the relationship between the time of violations and crashes. The study could be enhanced by the collection of violation data before enforcement begins in order to obtain a better "baseline" than is possible when the only violation data collected is done automatically via the camera systems after enforcement begins.

Another area of potential research in this area is benefit/cost analysis of the systems. The research efforts described above could provide an estimate of the impact of the systems in terms of crash reductions. This estimated benefit could be compared to the costs of operating the systems as well as the total value of fines assessed to signal violators.

7. Annotated Bibliography

Government Funded Research, Conference Papers, and Other Technical References

Andreassen, David. *A long term study of Red Light Cameras and Accidents.* Research Report ARR 261. Australian Road Research Board. February, 1995.

- Contains statistical analysis of crash records for sample of intersections in Melbourne, Victoria, Australia. Found no significant decline in right-angle crashes at RLC sites, questioned location of sites given low crash frequency.

Butler, Pamela Crenshaw. "A Quantifiable Measure of Effectiveness of Red Light Running Cameras at Treatment and Non-Treatment Sites." Howard University Thesis. Washington, DC: May, 2001.

- 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, nor between the non-RLC sites in Howard County and several control sites in Pennsylvania.

Datta, Tapan K. *et al*. "Red Light Violations and Crashes at Urban Intersections." Transportation Research Record 1734. pp. 52-58

- Discusses comparative study of intersections with and without all-red intervals, no discussion of RLC impacts

Fleck, Jack L. and Bridget B. Smith. "Can We Make Red Light Runners Stop? Red Light Photo Enforcement in San Francisco, California." San Francisco Department of Parking and Traffic Press Release. March 1999. <http://www.ci.sf.ca.us/dpt/press.htm> (also published as TRB preprint (see ITE report…))

- SF reduction in violations during pilot program, probably original source for 42% figure

Halcrow Fox. "Accidents at Signal Controlled Junctions in Glasgow." The Scottish Office, Central Research Unit. 1996.

- 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.

Hansen, Sharon C. "Photo Enforcement: ITS Meets Controversy." BRW Inc. Phoenix, AZ. *undated*

- Contains results from Mesa, AZ local report (see below)

Harris, Louis. "The Third Survey of Attitudes of the American People on Highway and Auto Safety." Prepared for Advocates for Highway and Auto Safety. September 1999.
- Presents results of nationwide survey questioning 1,005 people over the age of 18. Included a question asking if respondents would favor a statewide law permitting cities in their area to develop red light camera programs.

Hill, Stephen, John McFadden, and Andrew Graettinger. "Methodology for Evaluation the Applicability of the use of Automated Enforcement for Traffic Safety in Alabama." TRB 2001, paper #01-0515.
- Contains lit. review including Howard County figures, also Charlotte data (from 1st year report), though quotation (or data) is inaccurate (quotes 22 crash reduction figures for 20 RLC intersections)

Institute of Transportation Engineers. *Automated Enforcement in Transportation*. ITE Informational Report. December 1999.
- Table of violation reductions.

ITE Technical Council Task Force 4TF-1. Determining Vehicle Signal Change and Clearance Intervals. August 1994.
- "Presents some of the various methods used to determine lengths of yellow change intervals and red clearance intervals."

Kent, S. *et al.* "Red Light Running Behaviour at Red Light Camera and Control Intersections." Monash University Accident Research Centre – Report #73. [*undated executive summary*] <http://www.general.monash.edu.au/muarc/rptsum/es73.htm>
- Report found no statistically reliable differences in red-light encroachments between RLC and non-RLC sites at sample of intersections in Melbourne, also no reliable difference in crashes at the two sets of sites

"Maryland House of Delegates Commerce and Government Matters Committee Automated Enforcement Review: Red-Light Running Detection Camera Systems." Howard County, MD. January 18, 2001.
- Before/after right-angle and rear-end crash data from Howard County

McFadden, John, *et al.* "Implication of Automated Enforcement of Red Light Running on Traffic Records and Law Enforcement. *International Forum on Traffic Records and Highway Information Systems. undated*
- Cites violation results from other reports.

Office of the Auditor General, Western Australia. *Improving Road Safety: Speed and red Light Cameras, The Road Trauma Trust Fund.* Report No. 1. May 1996.
- Discusses operation of speed camera, red light camera, and related Road Trauma Trust Fund programs in and around Perth, Western Australia. Provides statistics on frequency of right-angle and rear-end crashes at enforced intersections and compares to frequency at all Perth intersections. No discussion of methodology for obtaining statistics.

Office of the Auditor General, Western Australia. *Public Sector Performance Report 1998.* Report No. 12 – December 1998.

- Update to 1996 investigation, no data on changes in violations or crashes

Passetti, K. "Use of Automated Enforcement for Red Light Violations." August 1997, CVEN-677 Advanced Surface Transportation Systems, Department of Civil Engineering, Texas A&M University, College Station, Texas.

- Violation reductions from U.S. sites, also findings of no change in violations with initiation of RLR through small programs in the Netherlands (3 sites) and Polk County, Florida (4 sites). 1988 Australian crash reduction findings.

Photo Enforcement of Traffic Laws. NCHRP Synthesis 219. Transportation Research Board, National Research Council. Washington, DC: National Academy Press, 1995.

- Safety impacts chapter discusses safety impact of automated speed enforcement. Literature review during this project found 11 speed camera programs worldwide and stated that these programs were more prevalent than red-light camera systems.

Polk, Amy. "Automated Enforcement: What Works, What Doesn't." ITE Districts 1 & 7 Annual Conference. Niagara Falls, Ontario. 6-10 May 2000.

- Conference presentation reviewing experience with automate enforcement programs.

Porter, Bryan E. "Red Light Running from Virginia to the Nation." Old Dominion University, Department of Psychology. 49th Annual Meeting of the Southern District ITE Conference. Williamsburg, VA. April 23, 2001.

- Discusses impact of education and traditional enforcement programs in Virginia (small percentage changes in violations and crashes *increase* during program, *decline* after)

Public Technology, Inc. "Is Photo Enforcement For You? A White Paper for Public Officials." *undated*

- Discusses the issues surrounding photo enforcement as a solution to red-light running and lists states that have red-light camera legislation.

Red Light Running in Iowa: The Scope, Impact, and Possible Implications. Final Report. Iowa State University, Center for Transportation Research and Education. December 2000.

- Reviewed only table of contents, RLR violation and crash data are in body of report, appears the sections are literature reviews, rather than new data (see summary report).

Red Light Running in Iowa: The Scope, Impact, and Possible Implications. Summary Report. Iowa State University, Center for Transportation Research and Education. December 2000.

- Summary of a larger final report (listed above), contains violation data in form of literature review, but no data from this project

Retting, Richard A., *et al.* "Changes in Crash Risk Following Re-Timing of Traffic Signal Change Intervals." IIHS Report, September 2000.

- Retiming signals to comply with ITE recommended practice yields crash reductions greater than those in a control group.

Retting, Richard A. and Sergey Y. Kyrychenko. *Crash Reductions Associated with Red Light Camera Enforcement in Oxnard, California.* Insurance Institute for Highway Safety Report. Arlington, VA: April 2001.

- Statistical analysis of crash occurrences in four California cities. Oxnard, with RLC, and three others without RLC. Found significant reduction in right-angle and right-angle injury crashes at all intersections in Oxnard, however, these statistics were not computed for other cities. Comparison of citywide crash occurrences found reduction in Oxnard, though the figures for two of the control cities also declined, with Santa Barbara having the largest reduction in crashes.

Retting, Richard A., *et al*. "Evaluation of Red Light Camera Enforcement in Fairfax, Va., USA." *ITE Journal*. August 1999. pp. 30-34

- Violation reductions, public opinion survey. Comparison of violation rates per 10,000 vehicles at enforced sites and in non-enforced (control) sites both in Fairfax and adjacent counties.

Retting, Richard A., *et al*. "Evaluation of red light camera enforcement in Oxnard, California." *Accident Analysis and Prevention 31 (1999).* pp. 169-174.

- Violation reduction, public opinion surveys

Retting, Richard A., *et al*. "Prevalence and characteristics of red light running crashes in the United States." *Accident Analysis and Prevention 31 (1999).* pp. 687-694.

- Discusses demographic characteristics of red light runners

Retting, Richard A., and Allan F. Williams. "Red Light cameras and the perceived risk of being ticketed." looks like Traffic engineering and control Journal from June 2000. TEC 2000.

- Results of telephone surveys on acceptance and awareness of RLC

Retting, Richard A., *et al.* "Red-Light Running and Sensible Countermeasures: Summary of Research Findings." *Transportation Research Record 1640.* Transportation Research Board. Washington, DC: National Academy Press, 1998.

- Literature review of other research, including violation and crash reduction citations, primarily IIHS work.

Retting, Richard A. "Reducing Red Light Running Crashes: A Research Perspective." ITE Annual Meeting 2000. Nashville, TN. August 2000.

- References other IIHS figures, Oxnard, opinion survey

Rocchi, Sarah. "A Review of the Road Safety Benefits of Red Light Cameras." ITE International Conference. Kissimmee, Florida, 1999.

- Tables of violation and collision impacts, varying quality of sources for these figures

Smith, David M. *et al.* "Automated Enforcement of Red Light Running Technology and Programs: A Review." Transportation Research Record 1734. pp. 29-36
- Presents same results data as "Synthesis and Evaluation…" FHWA report

South, D., *et al. Evaluation of the red light camera program and the owner onus legislation.* Road Traffic Authority (Victoria, Australia). Report SR/88/1. 1988
- A copy of this report was not obtained during this literature review. However, it is cited and discussed in numerous other references, most thoroughly in Andreassen, 1995.

Stevens, Sean C. "Benefits from Camera Technology Outweigh Privacy Issues." Georgetown University School of Foreign Service. Program in Science, Technology, and International Affairs.
- Not a scientific paper, more of a discussion of the issues (written in first person)

Synthesis and Evaluation of Red Light Running Automated Enforcement Programs in the United States. FHWA Report [FHWA-IF-00-004]. September 1999.
- Violation reductions from NYC, San Francisco, Polk County, Howard County, reference to crash reduction in Polk County, though authors stress need for additional data

Turner, Shawn, and Amy Polk. "Overview of Automated Enforcement in Transportation." Prepared for publication in ITE Journal. June 1998.
- Primarily summarizes implementation efforts and technologies

Winn, Ray. "Running the red and evaluation of Strathclyde Police's red light camera initiative." The Scottish Office, Central Research Unit. 1995.
- Violation rates and collision reductions at enforced intersections in Glasgow. Violation rates (infringements/infringement opportunities) from observer records, collision reductions from query of crash records for intersections with primary causation being "red light running."

Wissinger, Leanne M. *et al*. "Using Focus Groups to Investigate Issues of Red Light Running." Transportation Research Record 1734. pp.38-45. Washington, DC: 2000
- Lit. review of customer opinion surveys, presents results of focus group efforts

Local Reports

Anderson, Lon. "Candid Camera." *AAA World.* November/December. pg. 7
- Discusses AAA position on red light cameras, cites Fairfax, VA violation reduction and Howard County, MD injury crash reduction.

"Applications Increase for Automated Traffic Violation Enforcement." *The Urban Transportation Monitor*. December 22, 2000. pg.1+
- Describes several ongoing automated enforcement efforts in U.S. Results of public opinion survey in Scottsdale, Arizona.

"Cameras curb red-light violations; officials say 20 percent to 25 percent fewer drivers are running red lights where a camera has been installed." *News & Record*, Greensboro, North Carolina. April 21, 2001.

- Violation reductions for Greensboro program.

"Cameras proving to cut accidents." Editorial. *Wilmington Morning Star.* Wilmington, NC. May 26, 2001.

- Crash reduction quotes from Wilmington traffic engineer.

"Cameras Reduce Accidents, Report Says." *The Washington Post.* Washington, DC. January 29, 2001.

- Mentions new report from Howard County on crash reduction, available February 2001.

"City Shoots for 10 Red Light Cameras." *High Point Enterprise*. High Point, North Carolina. June 9, 2001

- Quote from city traffic engineer gives violation reduction.

"Fewer Collisions, Injuries and Deaths Result from City Crack Down on Red Light Running." San Francisco Department of Parking and Traffic Press Release. April 7, 1998. <http://www.ci.sf.ca.us/dpt/press.htm>

- Series of press releases and copy of a paper regarding San Francisco RLR enforcement and public education effort. Violation, collision reduction and cost information.

FHWA. "Safety – Stop Red Light Running Red Light Camera Effectiveness." FHWA website, *undated*. <http://safety.fhwa.dot.gov/fourthlevel/srlr/effect.htm>

- Crash reduction and violation trends from U.S. and abroad. Few references given.

"Photo Red Light Enforcement Program." City of Fairfax, Virginia. <http://www.ci.fairfax.va.us/police/photoredlightenforcement.htm>

- Gives decline in violations per hour at the 8 monitored intersections. Also cites IIHS study of 44% decline.

"Red-light Cameras." *The Washington Post*. Washington, DC. January 14, 2001.

- Includes violation reduction reference.

"SafeLight Charlotte: First-Year Report." *undated*. <http://www.charmeck.nc.us/citransportation/programs/safelight/report1.htm>

- Violation trends (fluctuations during first year due to increase in number of enforced intersections and improvements in performance of equipment). Crash reductions cited overall and for select intersections. No description of data collection methodology.

"SafeLight Charlotte: Annual Report: August 1999 – July 2000."
<http://www.charmeck.nc.us/citransportation/programs/safelight/report2.htm>

- These reports discuss crashes at enforced intersections before and after program began. However, reporting is incomplete and varies between this annual report and the previous first-year report, making it difficult to draw conclusions from the data presented.

"Safelight Wilmington: First Year in Review." Brochure, City of Wilmington, NC. 2001

- Collision data 1 yr before and after enforcement began at 10 intersections. Spoke with Jim Flechtner, City of Wilmington: crash figures were from reviewed police reports for all 10 enforced intersections.

"Speeders may be on camera." *The Daily Camera.* Boulder, CO. June 14, 2001.

- Includes violation and crash reduction data for red light camera system.

"Support Grows for Cameras at Intersections." *Daily Press Middle Peninsula Edition*. Williamsburg, VA. April 25, 2001.

- Fine, revenue and violation data for Charlotte, NC.

"Technology versus the Lawbreakers." Queensland Police Service. *undated*
<www.police.qld.gov.au/qps/info/technol/p_break.htm>

- Describes program in Queensland Australia, cites violation reduction study by Queensland Department of Transport.

Vinzant, Janet C. and B.J. Tatro. "Evaluation of the Effects of Photo Radar Speed and Red Light Camera Technologies on Motor Vehicle Crash Rates." Prepared for the City of Mesa Police Department. March 1, 1999.
<http://www.ci.mesa.az.us/police/traffic/march_1999_report.htm>

- Report discussing trends in crash rates for two years following implementation of RLC and speed cameras in Mesa. Intersections were divided into four quadrants with implementations of RLC and speed cameras in one quadrant, RLC alone in a second quadrant, speed cameras in another, and no automated enforcement in the fourth quadrant. Crash rates declined in all four quadrants, including the control segment. Study states that it did not attempt to control for other actions that may have improved safety.

"What do red-light cameras see?" *Atlanta Journal and Constitution*. April 23, 2001. pg. 2C.

- Quote on violations and crash rates from Lt. Glenn Hansen of Howard County, MD police.

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Polk, Amy. "Review of Automated Enforcement Programs in the Washington, D.C. Area." ITE International Conference. Kissimmee, Florida, 1999.

"Red Light Cameras Questions and Answers". [Source: 1998, IIHS, 23-Nov-98] [ver. 3/12/99] from the FHWA Safety CBU website.

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"Cameras could be ticket for bad drivers." *The Honolulu Advertiser*. Honolulu, Hawaii. July 2, 2001.

"Cameras curb red-light violations; officials say 20 percent to 25percent fewer drivers are running red lights; where a camera has been installed." *News & Record*, Greensboro, North Carolina. April 21, 2001.

"Cameras still to be installed; City red-light plan unfazed by House." *The Dallas Morning News*. Dallas, Texas. May 18, 2001.

"City Shoots for 10 Red Light Cameras." *High Point Enterprise*. High Point, North Carolina. June 9, 2001

"Click! You're caught! Police turning to cameras to stop red-light running." *The Associated Press*. October 11, 1999.

"Despite rising costs, red-light plan worth it." *The Arizona Republic*. Phoenix, Arizona. May 9, 2001.

"Exposed: SR red-light cameras empty." *The Press Democrat*. Santa Rosa, California. March 29, 2001

"Frederick Police Consider Installing Red-light Cameras." *The Washington Post*. Washington, DC. April 26, 2001.

"Red-light Cameras." *The Washington Post*. Washington, DC. January 14, 2001.

"SafeLight Charlotte: First-Year Report." Report from http://www.charmeck.nc.us/citransportation/programs/safelight/report1.htm. Charlotte, North Carolina.

"SafeLight: State's first photo enforcement program." Press Release from http://www.charmeck.nc.us/citransportation/programs/pressel/press1.html. Charlotte, North Carolina. April 13, 1998.

"Slow: You're on traffic camera." *The News Tribune*. Lakewood, Washington. April 2, 2001.

"Success Spells Loss of City Business For Red-Light Camera Manufacturer." *The Daily Record*, Baltimore, Maryland. December 11, 1999.

"The State: Capturing Red-Light Runners Creates Red-Faced Officials." *Los Angeles Times*. Los Angeles, California. June 3, 2001.

"Traffic light spy cams reduce crashes, study says; 29% drop in injury crashes logged at 11 corners in California city." *Milwaukee Journal Sentinel*. Milwaukee, Wisconsin. May 6, 2001.

"What do red-light cameras see?" *The Atlanta Journal and Constitution*. Atlanta, Georgia. April 23, 2001.

Phone Conversations

Phone conversation with Ian Cardozo, Peek Traffic Inc., June 14, 2001.

Phone conversation with Brenda Black, City of Mesa, Arizona, June 19, 2001.

Phone conversation with David Valle-Schwenk, City & County of San Francisco, Traffic Engineering Division, June 21, 2001.

Phone conversation with George Frangos, Howard County, Maryland, Traffic Engineering Division, June 21, 2001.