The Impact of Red-Light Camera Enforcement on Crash Experience

ALTHOUGH RED-LIGHT CAMERA (RLC) SYSTEMS HAVE BEEN AVAILABLE FOR MORE THAN 30 YEARS, THEY HAVE BEEN USED IN THE UNITED STATES ONLY SINCE 1992. THIS FEATURE SUMMARIZES THE FINDINGS OF A NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM SYNTHESIS PROJECT TO DETERMINE WHAT IMPACT RLC ENFORCEMENT HAS HAD ON CRASHES AND RELATED SEVERITY.

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BACKGROUND

One of the primary causes of crashes at signalized intersections involves a vehicle entering an intersection when the red signal is displayed. This type of collision occurs all too frequently. Red-light running—which reportedly is increasing with other aggressive driving behavior such as speeding and frequent lane changing—has become a national safety problem.

The solution to the red-light running problem lies in the coordinated application of enforcement, engineering and education measures. Traffic laws generally are enforced by police agencies. Police enforcement for red-light running violations traditionally entails monitoring signalized intersections for violators, following an offending vehicle through the intersection, "pulling" the offender off to the side of the street and issuing a citation or warning. This activity is costly and hazardous. Therefore, this type of manual enforcement generally is infrequent and usually does not have a lasting effect.

With readily available vehicle detection and camera surveillance technology, it now is possible to automate this enforcement. Red-light camera (RLC) systems have been available for more than 30 years, but they have been used in the United States only since 1992, when two systems were installed in Jackson, MI. RLC use is increasing slowly but steadily across many states and local jurisdictions. Deployment has been limited due to concerns that affect acceptance by the public and by lawmakers.

One concern relates to the lack of convincing evidence that RLC systems improve safety, not only at the signalized intersections where they are used but throughout jurisdictions. The assumption or hypothesis is that RLC systems reduce incidences of red-light running and thereby reduce the likelihood of related crashes. Under this assumption, angle crashes (a violating vehicle with an adjacent vehicle proceeding through the intersection legally on a green signal display) likely decrease. In addition, crashes in which a left-turning vehicle collides with a vehicle approaching from the opposite direction on the same roadway also decrease. For this scenario, the turning vehicle could be violating the red when the opposite direction has a green signal or vice-versa. However, there is concern that rear-end collisions on the monitored approach increase. Upon seeing a yellow display and knowing there is a camera system, a cautious motorist may stop more abruptly, causing the following motorist, who has not anticipated the need to stop and likely is following too closely, to hit the lead vehicle from behind.

Assuming these crash types produce equal crash severity, a net benefit would accrue if the decrease in angle crashes exceeds any increase in rear-end crashes. In general, angle crashes usually are more severe and, therefore, even a zero change in total crashes may prove safer if there is a smaller proportion of angle crashes to rear-end crashes with the use of cameras.

This feature summarizes the findings of a National Cooperative Highway Research Program (NCHRP) synthesis project undertaken to address this safety issue. The primary objective of the synthesis was to determine what impact RLC enforcement has had on crashes and related severity. This impact was to be identified for intersections where a camera or cameras had been installed and, if possible, area-wide within the jurisdiction or district. Furthermore, it was desirable to identify factors—such as geometry, operations, signage and public outreach—that influenced the observed changes.

As with all NCHRP synthesis documents, this report relied exclusively on available information; no new data collection or analysis was performed. The information base came from published literature, various Internet sites and a questionnaire sent to more than 50 jurisdictions that were known or believed to have installed RLC systems.

AGENCIES USING AUTOMATED ENFORCEMENT SYSTEMS

Table 1 shows U.S. jurisdictions (by city or county) known to use automated enforcement systems for red-light running. It is not known how many signalized intersections are in each jurisdiction. The list was compiled from survey responses and information gathered from recent literature and Web sites. However, the list is more than one year old and it is likely that many more jurisdictions now use these systems. Two primary issues need to be resolved:

- The effect of RLC systems on all signalized intersections rather than only on those equipped with RLC.
- The number or percentage of signalized intersections within a jurisdiction needed to produce a jurisdiction-wide change in driving behavior and crashes.

Table 1. U.S. jurisdictions known to have RLC installations.

City/County	State	Number of intersections with camera(s)	City/County	State	Number of intersections with camera(s)
Chandler	AZ	8	Baltimore City	MD	34
Mesa	AZ	17	Baltimore County	MD	20
Paradise Valley	AZ	2	Bel Air	MD	Unknown
Phoenix	AZ	Unknown	Bladensburg	MD	Unknown
Scottsdale	AZ	9	Charles County	MD	4
Tempe	AZ	2	Cheverly	MD	4
Beverly Hills	CA	6	College Park	MD	Unknown
Culver City	CA	2	Cottage City	MD	Unknown
Cupertino	CA	Unknown	Forest Heights	MD	Unknown
El Cajon	CA	5	Greenbelt	MD	8
Fremont City	CA	8	Hartford County	MD	3
Fresno	CA	Unknown	Howard County	MD	35
Garden Grove	CA	1	Hyattsville	MD	Unknown
Indian Wells	CA	Unknown	Landover Hills	MD	2
Irvine	CA	2	Laurel	MD	5
Long Beach	CA	Unknown	Montgomery County	MD	15
Los Angeles City	CA	8	Morningside	MD	3
Los Angeles County	CA	5	Prince Georges County	MD	26
Oxnard	CA	15	Riverdale Park	MD	4
Poway	CA	8	Charlotte	NC	20
Redwood City	CA	Unknown	Greensboro	NC	20
Sacramento City	CA	10	Fayetteville	NC	Unknown
Sacramento County	CA	5	High Point	NC	10
San Buena Ventura	CA	Unknown	Wilmington	NC	Unknown
San Diego	CA	20	New York City	NY	60
San Francisco	CA	17	Toledo	OH	10
San Juan Capistrano	CA	Unknown	Beaverton	OR	5
West Hollywood	CA	16	Portland	OR	1
Boulder	CO	3	Chattanooga	TN	3
Denver	CO	Unknown	Garland	TX	5
Fort Collins	CO	1	Alexandria	VA	3
Washington	DC	10	Arlington	VA	5
Wilmington	DE	Unknown	Fairfax City	VA	8
Polk County	FL	4	Fairfax County	VA	10
Honolulu City/County	HI	25	Falls Church	VA	Unknown
Overland Park	KS	2	Vienna	VA	3
Annapolis	MD	0	Lakewood	WA	Unknown
Anne Arundel County	MD	5			

For those agencies responding, New York, NY, USA, recorded the first RLC installation, dating back to December 1993. (However, according to *Automated Enforcement in Transportation*, two intersections in Jackson, MI, were equipped with cameras in 1992.)[1] New York also was the first city in the United States with an automated red-light enforcement program to issue citations by mail. The states of California and Maryland had the highest number of jurisdictions with RLC systems, with 22 and 21, respectively.

SUMMARY OF FINDINGS ON CRASH EVALUATIONS

Information on the effect of automated systems on crashes came from published literature and from data and informal reports provided by several agencies that have conducted their own evaluations. Before discussing the literature, some remarks are appropriate. First, it should be recognized that an RLC enforcement program involves more than just implementing camera systems and assessing fines. There are several elements of a program, which include—but are not limited to—education and publicity, level of fines, adjudication, the type of signing (at gateways to jurisdictions versus at equipped intersections), the number of intersections with cameras and the baseline condition of the traffic signal operations, especially yellow change intervals. These elements, which may influence any change in crash experience, are not consistent among the various jurisdictions and, therefore, some variation in automated enforcement effectiveness is to be expected.

At first glance, it would appear simple to determine the safety benefit of using automated systems: Merely compare the number of crashes before installation with the number after installation using the same before-and-after period. However, this type of analysis can lead to erroneous findings. Ample publications in recent years have documented the problem of the regression-to-mean phenomenon. Regression-to-mean refers to the tendency for a fluctuating characteristic of an entity to return to a typical value in the time period after an extraordinary value has been observed.[2] It has been shown that the frequency of crashes can change, sometimes significantly, from year to year without any changes in roadway or traffic conditions. Appropriate controls and comparisons need to be considered so that the effect of a changing condition, such as the use of automated cameras, can be isolated. Unfortunately, in many evaluations, this regression-to-mean effect has not been adequately accounted for and, therefore, the findings must be taken *caveat emptor.*

Good experimental design for treatment evaluation uses a before/after design with a randomized control group.[3] In an ideal experimental design, a group of signalized intersections that are candidates for a treatment—in this case, RLC systems—would be split into portions. One portion would receive the treatment and the others would serve as control sites. The selection of groups would be random, with the intent that both groups would be equal for all factors except the implementation of the treatment. In reality, however, cameras are installed at "problem" locations manifested by high frequencies of violations and/or crashes. An evaluator must then resort to selecting sites that are "comparative." The non-treated comparison sites must have the same level of factors that affect intersection safety—such as geometry, volume and traffic control.

There is another factor that comes into play with respect to what constitutes a true comparison or control site: the so-called "halo" or spillover effect. In their literature review of the effects of RLC systems on violations and crashes, Retting et al. provide convincing data to show that automated enforcement programs are effective in reducing violations at both camera-equipped locations and non-equipped locations.[4] Selecting a non-equipped intersection as a comparison/control site for crash analysis within a community will affect the outcome to the extent that the reduced violations will yield reduced crashes.

Table 2. Summary results of three RLC crash evaluations in the United States.

OXNARD, CA[5]
Camera locations: 11
Findings:
- Reduced total crashes at all signalized intersections by 7 percent and injury crashes by 29 percent
- Reduced total right-angle crashes by 32 percent and right-angle injury crashes by 68 percent
- Increased rear-end crashes by 3 percent (statistically insignificant)

Comments:
- Used three other cities for control
- Concluded that there is a halo effect

MESA, AZ[6]
Camera locations: 18
Findings:
- Reduced average crash rate over two years by 9.7 percent for RLC sites versus 10.7 percent for control sites
- Found a target reduction for sites with both RLC and photo radar speed devices

Comments:
- Design was not adequate for isolating RLC effect

SAN DIEGO, CA[7]
Camera locations: 19
Findings:
- Reduced right-angle and "ran signal" crashes by 30 percent
- Reduced rear-end crashes by 37 percent
- Decreases in right-angle and rear-end crashes were greater for camera-enforced movements

Comments:
- No control or comparison sites
- No statistical testing for changes

Literature from foreign countries and the United States was included in the review in the NCHRP synthesis; however, due to space limitations, only the U.S. experience is discussed here. The summary results of three significant crash evaluations in the United States are presented in Table 2. These published evaluations are the key crash evaluations to date.

In the survey responses, 18 jurisdictions reported that they had conducted crash evaluations. Table 3 provides a summary of those evaluations. The responding jurisdictions used a variety of evaluation types, which can be classified as:

- Monitoring high crash locations to see if camera sites are high on the list
- Monitoring annual crash statistics for all intersections
- Before/after comparisons of crashes for intersections with cameras
- Before/after comparisons of crashes for approaches with cameras
- Before/after comparisons of crashes for intersections with cameras compared with all intersections

For many locations, supporting data were not provided to substantiate the respondents' claims of effectiveness. Due to the many cases of lacking data as well as the less than rigorous evaluation procedures, an overall conclusion cannot be made from the data presented in Table 3. However, it is noteworthy that, in general, nearly all jurisdictions reported favorable results with respect to crash changes.

CONCLUSIONS

The primary objective of the synthesis was to determine what impact RLC enforcement programs have had on crashes and related severity. Specifically, the questions were:

- Do RLC systems reduce or otherwise change crashes at intersections where they are deployed?
- Does the safety effect of automated enforcement at camera-equipped locations spill over to other signalized intersections?
- What factors—related to intersection design or operations, the use of warning signs, the level of fines, or any public outreach—influence any observed changes in crashes?

Are Crashes and Crash Severity Affected by RLC Systems?

While nearly every study and crash analysis reviewed for the synthesis had some experimental design or analysis flaw or deficiency, there was considerable "evidence" that RLC does have a positive overall effect. Most of the various studies and analyses showed "observed" reductions in angle crashes, with some showing smaller increases in rear-end crashes.

Table 3. Findings of crash evaluations as reported by 18 surveyed U.S. jurisdictions.

Location	Number of intersections	Type of evaluation	Findings	Comments
Garden Grove, CA	1	One year before/after compared to five other high violation locations	Right-of-way violation crashes decreased 56.2 percent Rear-end crashes increased 1.2 percent	■
Irvine, CA	2	Annual monitoring	The two locations do not appear in high crash location listing	■
Howard County, MD (two separate evaluations)	35	More than one year before/after for 24 intersections	Rear-end collisions increased 6 percent Angle collisions decreased 47 percent Other collisions decreased 11 percent	■
Howard County, MD	29	More than one year before/after for 25 intersections	For all red-light running intersections: Rear-end crashes decreased 30 percent Angle crashes decreased 2 percent Other crashes decreased 21 percent Total crashes decreased 31 percent	●
Laurel, MD	5	Three years before, after unknown	Number of crashes at all locations decreased	■
Boulder, CO	3	32 months after	Red-light related crashes decreased 57 percent	■
Los Angeles County, CA	5	Not explained	Crash rates decreased for three locations, one remained relatively the same and one did not improve	■
San Francisco, CA	17	Five years before/after for first camera in 1996	Red-light running collisions declined	■
Tempe, AZ	2	Four years before/after	Crash rates showed increases and decreases since inception	■
Mesa, AZ	17	Yearly collision rates	City-wide intersection-related crash rates (per population) decreased for each of five years since installation	▲
Baltimore County, MD	20	One year before/after	All crashes decreased 51 percent Intersection-related crashes decreased 55 percent Red-light running crashes decreased 30 percent Injury and "property damage only" crashes decreased 51 percent	●
Riverdale Park, MD	4	One year before/after for all intersections	Crash data remained consistent	■
Paradise Valley, AZ	2	Before/after (time frame unknown)	Number of collisions remained the same but severity was reduced	■
Scottsdale, AZ	9	Comparison of red-light running accidents city-wide before/after	Red-light running crashes dropped first year after cameras, crept up, but did not meet the pre-camera level Crashes at camera locations were too low to make a conclusion RLC effect was difficult to isolate	■
Sacramento, CA	10	Comparison of crashes one year before/after	All crashes decreased 10 percent Injury crashes decreased 27 percent Angle crashes decreased 26 percent Rear-end crashes decreased 12 percent Red-light crashes decreased 39 percent	○
Montgomery County, MD	15	Two years before/after	Overall crashes decreased slightly, but probably not significant	■
San Diego, CA	20	Two years before/after for 16 intersections	Injury crashes remained the same at most locations Incidents of red-light running decreased dramatically	■
Charlotte, NC	20	Three years before/after for 17 intersections	At camera intersections: Angle crashes decreased 37 percent Severity decreased 16 percent All crashes decreased 19 percent On approaches with cameras: Angle crashes decreased 60 percent Rear-end crashes increased 4 percent	□
Fort Collins, CO	1	2.5 years before, 5.5 years after	No significant change in crash or injury frequency	□

Comments: ■ Supporting data not provided ● Summary data for each intersection provided ▲ Does not distinguish crash rates at RLC intersections ○ Summary data provided □ Supporting data provided

In many cases, the flaw in the analysis was the lack of a proper control group, which would have allowed a valid comparison of the observed changes, increases, or decreases to the changes in signalized intersections that did not have cameras. Cameras tend to be installed at problem locations manifested by higher-than-average crash experience. As discussed earlier, these types of locations can experience reductions in subsequent years even without intervention. To account for regression-to-mean, control sites are needed. In some cases, a reduction was observed that proved statistically insignificant when exposed to statistical testing. This statistically insignificant finding often is attributed to small sample sizes regarding the number of sites and crash frequency at each site.

Is There a Spillover Effect?

Assuming that cameras provide a net safety benefit, it is important to ask whether there is a spillover, or halo, effect for signalized intersections that do not have cameras. This can be used to decide how many intersections that are candidates for cameras need to be equipped to bring about an area-wide change in driving behavior.

The assumption that there can be a spillover effect was inherent in the findings of the Oxnard, CA, USA, study, in which researchers attributed significant crash reductions at 125 signalized intersections to the use of RLC at 11 of the intersections. They based that assumption on the findings of studies on before/after violation changes in Oxnard and Fairfax, VA, USA, where violation reductions were observed at both camera-equipped and non-equipped intersections and differences between camera and non-camera sites were not significant.

This issue should be resolved conclusively because it is a factor to be considered in any evaluation. If indeed there is a spillover effect—which might be expected, especially if there is an aggressive public information campaign—using non-equipped intersections as a control is problematic. Using non-equipped intersections from another jurisdiction or an area out of influence of the red-light running program is preferred for effective evaluations.

What Factors Influence Crash Changes?

To date, there has not been any study following an experimental design that could have answered the aspects of this question. In Glasgow, Scotland, cameras were active for a two-year period, but only warnings were issued because of an error in the act that authorized use of the cameras. The researcher provided data for this interim period in addition to the "official" after period when levies were imposed.[8] Crash reductions, if valid, were observed during the interim and even further reductions were observed during the after period.

Setting aside the deficiencies of that crash analysis, it would appear that imposing fines brings about presumably better compliance and higher crash reductions compared to warnings alone. This conclusion is fairly academic; every agency that uses automated enforcement imposes fines for violations. What would be of interest, however, is the influence of the level of fines. Presumably, as the fine increases the level of non-compliance decreases and, hypothetically, crashes related to red-light running should decrease further. Testing the "elasticity" of fine levels with driver compliance and crash experience is not likely to be undertaken due to political constraints. This aspect of influence is not likely to be answered.

Isolating the influence of other factors may prove difficult because of the experimental design requirements. For example, isolating the influence of warning signs—the question being whether using a sign that warns a motorist of the use of cameras is more effective than no sign—requires a larger sample of locations and the identification of control sites with and without cameras that are similar in all other influencing variables.

During the preparation of the synthesis, the Federal Highway Administration's Joint Programs Office began sponsoring an ongoing effort to develop an experimental design to address these issues. Using this experimental design, a national study is now under way, using data from seven local agencies around the United States. This study will produce an estimate of the crash-related effects of RLC systems, including possible spillover effects on intersections near treated areas, and it will control for other possible related safety treatments, such as lengthening the yellow interval and changing signal phasing. It also will attempt to specify the economic benefits of RLC systems in human capital or comprehensive cost terms.

DISCUSSION

Based on the information that has been acquired and reviewed, it appears that red-light running automated enforcement can be an effective safety countermeasure. The findings of several studies support that, in general, RLC can bring about a reduction in more severe angle crashes with, at worst, a slight increase in less severe rear-end crashes. However, there is not enough empirical evidence based on proper experimental design procedures to state this conclusively.

Red-light running automated enforcement is only one of many countermeasures available to reduce crashes at intersections. Engineers should address design and operational issues that may contribute to these occurrences. There are a variety of engineering countermeasures proven to have an effect on intersection safety that should be considered before automated enforcement, especially in the absence of conclusive evidence on the safety effect.

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