EXECUTIVE
SUMMARY

Safety Evaluation of Red-Light Cameras—Executive Summary

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This document is an Executive Summary of the report *Safety Evaluation of Red-Light Cameras,* FHWA-HRT-05-048, published by the Federal Highway Administration in April 2005.

Abstract

The fundamental objective of this research was to determine the effectiveness of red-light-camera (RLC) systems in reducing crashes. The study involved an empirical Bayes (EB) before-after research using data from seven jurisdictions across the United States to estimate the crash and associated economic effects of RLC systems. The study included 132 treatment sites, and specially derived rear end and right-angle unit crash costs for various severity levels. Crash effects detected were consistent in direction with those found in many previous studies: decreased right-angle crashes and increased rear end ones. The economic analysis examined the extent to which the increase in rear end crashes negates the benefits for decreased right-angle crashes. There was indeed a modest aggregate crash cost benefit of RLC systems. A disaggregate analysis found that greatest economic benefits are associated with factors of the highest total entering average annual daily traffic (AADT), the largest ratios of right-angle to rear end crashes, and with the presence of protected left-turn phases. There were weak indications of a spillover effect that point to a need for a more definitive, perhaps prospective, study of this issue.

Introduction and Background

RLC systems are aimed at helping reduce a major safety problem at urban and rural intersections, a problem that is estimated to produce more than 100,000 crashes and approximately 1,000 deaths per year in the United States.[1] The size of the problem, the promise shown from the use of RLC systems in

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other countries, and the paucity of definitive studies in the United States established the need for this national study to determine the effectiveness of the RLC systems jurisdiction-wide in reducing crashes at monitored intersections. This study included collecting background information from literature and other sources, establishing study goals, interviewing and choosing potential study jurisdictions, and designing and carrying out the study of both crash and economic effects. A description of all project efforts is in the complete report summarized by this document and, to a lesser extent, in two Transportation Research Board (TRB) papers that were also prepared.(2,3)

TRIMARC/Northrop Grumman Mission Systems

Figure 1: A photo taken from a camera of a crash involving red-light running.

A literature review found that estimates of the safety effect of red-light-running programs vary considerably. The bulk of the results appear to support a conclusion that red light cameras reduce right-angle crashes and could increase rear end crashes; however, most of the studies are tainted by methodological difficulties that would render useless any conclusions from them. One difficulty, failure to account for regression to the mean[1] (RTM), can exaggerate the positive effects, while another difficulty, ignoring possible spillover effects[2] to intersections without RLCs, will lead to an underestimation of RLC benefits, more so if sites with these effects are used as a comparison group.

While it is difficult to make definitive conclusions from studies with failed methodology validity, the results of the review did provide some level of comfort for a decision to conduct a definitive, large-scale study of installations in the United States. It was important for the new study to capitalize on lessons learned from the strengths and weaknesses of previous evaluations, many of which were conducted in an era with less knowledge of potential pitfalls in evaluation studies and methods to avoid or correct them.

The lessons learned required that the number of treatment sites be sufficient to assure statistical significance of results, and that the possibility of spillover effects be considered in designating comparison sites, perhaps requiring a study design without a strong reliance on the use of comparison sites. Previous research experience also pointed to a need for the definition of the term, "red-light-running crashes," to be consistent, clear, and logical and for provision of a mechanism to aggregate the differential effects on crashes of various impact types and severities.

Methodological Basics

The general crash effects analysis methodology used is

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[1] "Regression to the mean" is the statistical tendency for locations chosen because of high crash histories to have lower crash frequencies in subsequent years even without treatment.

[2] Spillover effect is the expected effect of RLCs on intersections other than the ones actually treated because of jurisdiction-wide publicity and the general public's lack of knowledge of where RLCs are installed.

different from those used in past RLC studies. This study benefits from significant advances made in the methodology for observational before-after studies, described in a landmark book by Hauer.[4] The book documented the EB procedure used in this study. The EB approach sought to overcome the limitations of previous evaluations of red-light cameras, especially by properly accounting for regression to the mean, and by overcoming the difficulties of using crash rates in normalizing for volume differences between the before and after periods.

The analysis of economic effects fundamentally involved the development of per-crash cost estimates for different crash types and police-reported crash severities. In essence, the application of these unit costs to the EB crash frequency effect estimates. The EB analysis was first conducted for each crash type and severity and site before applying the unit costs and aggregating the economic effect estimates across crash types and severity and then across jurisdictions. The estimates of economic effects for each site allowed for exploratory analysis and regression modeling of cross-jurisdiction aggregate economic costs to identify the intersection and RLC program characteristics associated with the greatest economic benefits of RLC systems.

Details of the development of the unit crash-cost estimates can be found in a recent paper and in an internal report available from FHWA.[5,6] Unit costs were developed for angle, rear end, and "other" crashes at urban and rural signalized intersections. The crash cost to be used had to be keyed to police crash severity based on the KABCO[3] scale. By merging previously developed costs per victim keyed on the AIS injury severity scale into U.S. traffic crash data files that scored injuries in both the Abbreviated Injury Scale (AIS) and KABCO scales, estimates for both economic (human capital) costs and comprehensive costs per crash were produced. In addition, the analysis produced an estimate of the standard deviation for each average cost. All estimates were stated in Year 2001 dollar costs.

Data Collection

The choice of jurisdictions to include in the study was based on an analysis of sample size needs and the data available in potential jurisdictions. It was vital to ensure that enough data were included to detect that the expected change in safety has appropriate statistical significance. To this end, extensive interviews were conducted for several potential jurisdictions known to have significant RLC programs and a sample size analysis was done. The final selection of seven jurisdictions was made after an assessment of each jurisdiction's ability to provide the required data. The jurisdictions chosen were El Cajon, San Diego, and San Francisco, CA; Howard County, Montgomery County, and Baltimore, MD; and Charlotte, NC.

Data were required not only for RLC-equipped intersections but also for a reference group of signalized intersections not equipped with RLCs but similar to the RLC locations. These sites were to be used in the calibration of safety performance functions (SPFs) used in the EB analysis and to investigate possible spillover effects. To account for time trends between the period before the first RLC installation and the period after that, crash and traffic volume data were collected to calibrate SPFs from a comparison group of approximately 50 unsignalized intersections in each jurisdiction.

Following the site/jurisdiction selection, the project team collected and coded the required data. Before the actual data

[3] The KABCO severity scale is used by the investigating police officer on the scene to classify injury severity for occupants with five categories: K, killed; A, disabling injury; B, evident injury; C, possible injury; O, no apparent injury.[7] These definitions may vary slightly for different police agencies.

Table 1. Combined results for seven jurisdictions

	Right-angle crashes		Rear end crashes	
	Total crashes	Definite injury	Total crashes	Definite injury
EB estimate of crashes expected in the after period without RLC	1,542	351	2,521	131
Count of crashes observed in the after period	1,163	296	2,896	163
Estimate of percentage change (standard error)	- 24.6 (2.9)	- 15.7 (5.9)	14.9 (3.0)	24.0 (11.6)
Estimate of the change in crash frequency	- 379	- 55	375	32

Note: A negative sign indicates a decrease in crashes.

analyses, preliminary efforts involving file merging and data quality checks were conducted. This effort included the crash data linkage to intersections and the defining of crashes expected to be affected by RLC implementation. Basic red-light-running crashes at the intersection proper were defined as "right-angle," "broadside," or "right- or left-turning-crashes" involving two vehicles, with the vehicles entering the intersection from perpendicular approaches. Also included were crashes involving a left-turning vehicle and a through vehicle from opposite approaches. "Rear end crashes" were defined as a rear end crash type occurring on any approach within 45.72 m (150 ft) of the intersection. In addition, "injury crashes" were defined as including fatal and definite injuries, excluding those classified as "possible injury."

Results

Because the intent of the research was to conduct a multi-jurisdictional study representing different locations across the United States, the aggregate effects over all RLC sites in all jurisdictions was of primary interest. Table 1 shows the combined results for the seven jurisdictions. There is a significant decrease in right-angle crashes, but there is also a significant increase in rear end crashes. Note that "injury" crashes are defined by severity as K, A, or B crashes; but the frequencies shown do not contain a category for "possible injury" crashes captured by KABCO-level C; thus, these crashes could better be labeled "definite injury" crashes.

As seen in table 2, the direction of these effects (and the magni-

Table 2. Results for individual jurisdictions for total accidents

Jurisdiction number* (in random order)	Percent change in right-angle crashes (standard error)	Percent change in rear end crashes (standard error)
1	- 40.0 (5.4)	21.3 (17.1)
2	0.8 (9.0)	8.5 (9.8)
3	- 14.3 (12.5)	15.1 (14.1)
4	- 24.7 (8.7)	19.7 (11.7)
5	- 34.3 (7.6)	38.1 (14.5)
6	- 26.1 (4.7)	12.7 (3.4)
7	- 24.4 (11.2)	7.0 (18.5)

*The identification of jurisdictions is not provided because of an agreement with the jurisdictions; such information is irrelevant to the findings.

Note: A negative sign indicates a decrease in crashes.

Table 3. Unit crash cost estimates by severity level used in the economic effects analysis

Crash severity level	Right-angle crash cost	Rear end crash cost
O (standard deviation)	$8,673 (1,285)	$11,463 (3,338)
K+A+B+C (standard deviation)	$64,468 (11,919)	$53,659 (9,276)

tude to a lesser degree) was remarkably consistent across jurisdictions. The analysis indicated a modest spillover effect on right-angle crashes; however, that this was not mirrored by the increase in rear end crashes seen in the treatment group, which detracts somewhat from the credibility of this result as evidence of a general deterrence effect.

For the analysis of economic effects, it was recognized that there were low sample sizes of fatal and serious (A-level) crashes in the after period for some intersections. In addition, the initially developed cost estimates for B- and C-level rear end crashes indicated some anomalies in the order (e.g., C-level costs were higher, very likely because on-scene police estimates of "minor injury" often ultimately include expensive whiplash injuries), the B- and C-level costs were combined by Pacific Institute for Research and Evaluation (PIRE) into one cost. Considering these issues and the need to use the same cost categories across all intersections in all seven jurisdictions, two crash cost levels were ultimately used in all analyses: Injury (K+A+B+C) and Non-injury (O). These unit costs are shown in table 3 along with the standard deviation of these costs.

Table 4 shows the results for the economic effects including and excluding property-damage only (PDO) crashes. The latter estimates are included in recognition of the fact that several jurisdictions considerably under-report PDO collisions. Those estimates (with PDOs excluded) show a positive aggregate economic benefit of more than $18.5 million over approximately 370 site years, which translates into a crash reduction benefit of approximately $50,000 per site year. With PDOs included, the benefit is approximately $39,000 per site year. The implication from this result is that the lesser severities and generally lower unit costs for rear end injury crashes together ensure that the increase in rear end crash frequency does not negate the decrease in the right-angle crashes targeted by red-light-camera systems.

Further analysis indicated that right-angle crashes appear slightly more severe in the after period in two jurisdictions, but not in the other five. Because such an effect would mean that the benefits in table 4 are slightly overestimated, an attempt was made to estimate the possible size of the benefit reduction. If such a shift were real, and if its effects could be assumed to be correctly estimated from individual KABCO unit costs already deemed to be inappropriate for such purposes, the overall cost savings reported in the last row of table 4 could be decreased by approximately $4 million; however, there would still be positive economic benefits, even if it is assumed that the unit cost shifts were real and correctly estimated.

Table 4. Economic effects including and excluding PDOs (Using a combined unit cost for K+A+B+C)

	All severities combined			PDOs excluded		
	Right-Angle crash	Rear end crash	All crashes	Right-Angle crash	Rear end crash	All crashes
EB estimate of crash costs before RLC installation	$66,814,067	$69,347,624	$161,843,021	$61,687,367	$52,681,148	$134,407,104
Recorded cost of crashes after RLC installation (370 site years)	$48,319,090	$75,222,780	$147,470,550	$43,868,392	$53,944,539	$115,901,685
Percentage of change in crash cost (s.e.)*	- 27.7 (0.6)	8.5 (0.7)	- 8.9 (0.4)	- 28.9 (0.6)	2.4 (0.8)	- 13.8 (0.5)
Crash cost decrease (per site year)			$14,372,471 ($38,845)			$18,505,419 ($50,015)

* A negative number indicates a decrease.

Examination of the aggregate economic effect per after-period year for each site indicated substantial variation, much of which could be attributable to randomness. It was reasonable to suspect that some of the differences may be due to factors that impact RLC effectiveness; therefore, a disaggregate analysis, which involved exploratory univariate analysis and multivariate modeling was undertaken to try to identify factors associated with the greatest and least economic benefits. The outcome measure in these models was the aggregate economic effect per after period site year.

The disaggregate analysis found that greatest economic benefits are associated with the highest total entering AADTs, the largest ratios of right-angle to rear end crashes, higher proportions of entering AADT on the major road, shorter cycle lengths and intergreen periods, and with the presence of protected left-turn phases. The presence of warning signs and high publicity levels also appear to be associated with greater benefits. These results do not provide numerical guidance for trading off the effects of various factors. The intent of identifying these factors is that in practice RLC implementers would identify program factors such as warning signs that increase program effectiveness and give the highest priority for RLC implementation to the sites with most or all of the positive binary factors present (e.g., left-turn protection) and with the highest levels of the favorable continuous variables (e.g. higher ratios of right-angle to rear end crashes).

Conclusions

This statistically defendable study found crash effects that were consistent in direction with those found in many previous studies, although the positive effects were somewhat lower that those reported in many sources. The conflicting direction effects for rear end and right-angle crashes justified the conduct of the economic effects analysis to assess the extent to which the increase in rear end crashes negates the benefits for right-angle crashes. This analysis, which was based on an aggregation of rear end and right-angle crash costs for various severity levels, showed that RLC systems do indeed provide a modest aggregate crash-cost benefit.

The opposing effects for the two crash types also implied that RLC systems would be most beneficial at intersections where there are relatively few rear end crashes and many right-angle ones. This was verified in a disaggregate analysis of the economic effect to try to isolate the factors that would favor (or discourage) the installation of RLC systems. That analysis revealed that RLC systems should be considered for intersections with a high ratio of right-angle crashes to rear end crashes, higher proportion of entering AADT on the major road, shorter cycle lengths and intergreen periods, one or more left turn protected phases, and higher entering AADTs. It also revealed the presence of warning signs at both RLC intersections and city limits and the application of high publicity levels will enhance the benefits of RLC systems.

The indications of a spillover effect point to a need for a more definitive study of this issue. That more confidence could not be placed in this aspect of the analysis reflects that this is an observational retrospective study in which RLC installations took place over many years and where other programs and treatments may have affected crash frequencies at the spillover study sites. A prospective study with an explicit purpose of addressing this issue seems to be required.

In closing, this economic analysis represents the first attempt in the known literature to combine the positive effects of right-angle crash reductions with the negative effects of rear end crash increases and identify factors that might further enhance the effects of RLC systems. Larger crash sample sizes would have added even more information. The following primary conclusions are based on these current analyses:

Even though the positive effects on angle crashes of RLC systems is partially offset by negative effects related to increases in rear end crashes, there is still a modest to moderate economic benefit of between $39,000 and $50,000 per treated site year, depending on consideration of only injury crashes or including PDO crashes, and whether the statistically non-significant shift to slightly more severe angle crashes remaining after treatment is, in fact, real.

Even if modest, this economic benefit is important. In many instances today, the RLC systems pay for themselves through red-light-running fines generated. However, in many jurisdictions, this differs from most safety treatments where there are installation, maintenance, and other costs that must be weighed against the treatment benefits.

The modest benefit per site is an average over all sites. As the analysis of factors showed, this benefit can be increased through careful selection of the sites to be treated (e.g., sites with a high ratio of right-angle to rear end crashes as compared to other potential treatment sites) and program design (e.g., high publicity, signing at both intersections and jurisdiction limits).

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