Crash Reductions Associated with Red Light Camera Enforcement in Oxnard, California

Richard A. Retting
Sergey Y. Kyrychenko

April 2001

INSURANCE INSTITUTE
FOR HIGHWAY SAFETY

1005 N. GLEBE RD. ARLINGTON, VA 22201-4751
PHONE 703/247-1500 FAX 703/247-1678
website http://www.highwaysafety.org

ABSTRACT

Red light cameras are increasingly being used in communities to deter drivers from running red lights. Numerous studies have established that red light camera enforcement sharply reduces red light violations, but little information is available regarding crash effects. The purpose of this study was to estimate the impact of red light camera enforcement on crashes in one of the first U.S. communities to employ such cameras — Oxnard, California. Crash data from the California Statewide Integrated Traffic Records System were analyzed for Oxnard and for three comparison cities that did not implement red light camera enforcement for a period of 29 months before and after implementation of the program in Oxnard. Changes in crash frequencies after enforcement were compared for Oxnard and control cities, and for signalized and nonsignalized intersections, using a generalized linear regression model.

Overall, crashes at signalized intersections throughout Oxnard were reduced by 7 percent and injury crashes were reduced by 29 percent as a result of red light camera enforcement. Although the crash data did not contain sufficient detail to identify crashes that were specifically red light running events, right-angle collisions — the type of crash most associated with red light violations — were reduced by 32 percent, and right-angle crashes involving injuries were reduced by 68 percent. There was no significant effect on rear-end crashes. Because red light cameras can be a permanent component of the transportation infrastructure, crash reductions attributed to camera enforcement should be sustainable.

INTRODUCTION

Each year in the United States more than 800 people die and an estimated 200,000 are injured in crashes that involve red light running (Retting, Ulmer, et al., 1999). Red light cameras can help reduce red light running by automatically photographing vehicles whose drivers run red lights. A red light camera system is connected to the traffic signal and to sensors that monitor traffic flow. The system continuously monitors the traffic signal, and the camera itself is triggered by any vehicle passing over the sensors above a preset minimum speed and a specified time after the signal has turned red. The camera records the date, time of day, time elapsed since the beginning of the red signal, and the speed of the vehicle. Tickets typically are sent by mail to owners of violating vehicles, based on review of photographic evidence. To date, approximately 50 communities in the United States have implemented red light camera enforcement.

Red light camera enforcement is very effective in reducing red light violations. For example, in both Oxnard, California, and Fairfax, Virginia, red light running violations dropped by about 40 percent during the first year of camera enforcement (Retting et al., 1999a,b). In both cities, reductions in red light violations were nearly identical at intersections equipped and those not equipped with red light cameras, suggesting that camera enforcement produces general changes in motorists' behavior rather than simply encouraging drivers to obey traffic signals at specific locations. Similar reductions in red light violations following implementation of camera enforcement were reported in Australia (Zaal, 1994), Singapore (Chin, 1989), and the United Kingdom (County Surveyors' Society, 1990).

However, less is known about the impact of red light camera enforcement on crashes, the outcome of primary interest. It is expected that such enforcement would reduce the frequency of right-angle collisions at signalized intersections — the principal type of crash associated with red light running. Also, some additional rear-end crashes might result from nonuniform changes in driver behavior. For example, if drivers stop more often for red lights, they may be struck from behind by drivers not intending to stop. Rocchi and Hemsing (1999) identified numerous anecdotal and unpublished reports on reductions in right-angle or "red light running related" crashes following implementation of red light camera enforcement, ranging from 10 percent in New York City to 88 percent in Essex, United Kingdom. In Australia, where red light cameras have been in use for about 20 years, controlled studies in Melbourne, Sydney, and Victoria generally report reductions in right-angle crashes ranging from 32 to 50 percent (Hillier et al., 1993; Ogden, 1996; South et al., 1988). Moderate increases in rear-end crashes were reported in Sydney and Victoria but not in Melbourne.

The purpose of this study was to estimate the impact of red light camera enforcement on intersection crashes in Oxnard, California, one of the first U.S. communities to employ such cameras.

METHOD

Changes in motor vehicle crashes were evaluated in Oxnard, California, which has an estimated population of 156,000 and a land area of 24.4 square miles (U.S. Census Bureau, 1996, 2001). A statewide red light camera law took effect in California in January 1996, permitting municipal governments to establish local red light camera enforcement programs. Under California law, the vehicle driver, if sufficiently identified, is charged with a moving violation. Front photography is used to capture a likeness of the driver and the vehicle's front license plate (if present). In cases where the gender and estimated age of the photographed driver match those of the registered vehicle owner, the owner is presumed to be the driver and is issued a ticket by mail (the registered owner is able to rebut this presumption in court). Under California law, citations issued through red light camera enforcement programs carry the same monetary penalties and license sanctions as those resulting from conventional police traffic stops — currently $271 and 1 driver's license demerit point.

Red light camera enforcement in Oxnard was preceded by a 30-day warning period, during which red light cameras photographed violators, but no tickets were issued. As required by state law, signs advising motorists of photo enforcement of traffic signal laws were posted on major roadways at numerous locations entering the city. In addition, city officials attempted to generate publicity and awareness of the new program by issuing a press release and providing information to local media. Also during the warning period, postcards were sent by mail to residents of Oxnard. Actual enforcement began on July 1, 1997. Eleven intersections in Oxnard were equipped with red light cameras out of approximately 125 intersections with traffic signals. At each camera location, only one of the four intersection approaches was monitored.

To control for potentially confounding external factors such as economic conditions, fuel prices, and weather, which might affect the frequency of motor vehicle crashes, three California cities that did not implement red light camera enforcement during the study period were used as controls. The cities of Bakersfield and San Bernardino were selected because they each have approximately the same number of annual crashes as Oxnard, and their locations (more than 100 miles from Oxnard) made it unlikely that camera enforcement in Oxnard affected driver behavior in these cities. The city of Santa Barbara, located approximately 40 miles north of Oxnard, was selected because of its earlier use as a control for Oxnard in evaluating changes in red light violations following implementation of camera enforcement (Retting et al., 1999a). Red light violation rates did not change in Santa Barbara during the evaluation of the Oxnard red light enforcement program.

Crash data for the four cities were obtained from the California Statewide Integrated Traffic Records System (SWITRS). Crashes were analyzed for 29 months preceding camera enforcement (January 1995 through May 1997) and for 29 months of enforcement (August 1997 through December

1999). The first month of enforcement (July 1997) was excluded from analysis to ensure that drivers were aware of the red light camera program, as was the month prior to the start of enforcement (June 1997) when a warning period announcing the enforcement was in effect. Intersections of each city were divided into two groups: signalized and nonsignalized. Because of the relatively small numbers of crashes associated with the 11 camera enforcement sites in Oxnard, and because prior research documents a large spillover effect of camera enforcement to intersections in the same community not equipped with cameras (Retting et al., 1999a,b), crashes at the 11 camera-equipped intersections were not analyzed separately. (Note that because the before and after time periods include different months, the numbers of crashes for these periods may be somewhat affected by seasonal variations. However, this should not bias estimates of the effect of red light cameras because the statistical model (discussed later) used identical time periods for all four cities and for unsignalized as well as signalized intersections.)

Because SWITRS does not contain a variable to determine whether an intersection is signalized, it was necessary to manually identify all intersections with traffic signals in the four cities, using lists of signalized intersections provided by the cities and the California Department of Transportation (CALTRANS). Any intersection not identified as having a traffic signal was considered nonsignalized. Information provided by the four cities and CALTRANS regarding installation of any new signals during the analysis period was used to eliminate such intersections from the study (a total of 82 new signals were installed during the analysis period — 10 in Oxnard, 41 in Bakersfield, 18 in San Bernardino, and 13 in Santa Barbara).

Changes in crash rates after enforcement were compared for Oxnard and control cities, and for signalized and nonsignalized intersections. Injury crashes were limited to cases with the SWITRS variable for collision severity equal to "fatal," "severe injury," or "other visible injury." The latter two classifications are based on police-reported information. Two types of multiple-vehicle crashes — right-angle and rear-end — were defined using SWITRS variables. Right-angle crashes (expected to be reduced at signalized intersections by red light camera enforcement) were defined as those coded in SWITRS as "broadside" collisions that involved two motor vehicles that were traveling at right angles to each other prior to the crash (based on recorded compass directions). Because of limited crash-type definitions used in SWITRS, it was not possible to categorize crashes specifically as red light running events. The closest category was right-angle collisions, but this also could include some left-turn crashes, because SWITRS does not have a separate category for left-turn crashes, or crashes where drivers may have been exiting from a driveway located close to an intersection. Left-turn crashes typically do not involve red light running. Rear-end crashes, which might increase with red light camera enforcement due to changes in driver behavior with regard to stopping for red lights, were defined as those coded in SWITRS as "rear-end" collisions that involved two motor vehicles traveling in the same direction.

A generalized linear regression model was developed to evaluate changes in total crashes, injury crashes, and specific crash types. The model used the natural logarithm of crash counts as the response variable. Independent variables were city, intersection type (signalized and nonsignalized), and period (before and after enforcement). Two-factor interactions of city-by-period and city-by-intersection type also were included, as crash trends were different in different cities. Analysis of variance was used to test the statistical significance.

RESULTS

Table 1 summarizes changes in the numbers of crashes from the baseline period through the enforcement period, for signalized and nonsignalized intersections. For the three control cities, the frequency of crashes changed roughly in the same way at both signalized and nonsignalized intersections. In Bakersfield and Santa Barbara, the number of crashes declined at both types of intersections; in San Bernardino, they increased. Table 2 summarizes the effect of red light camera enforcement as estimated by the model. It is estimated that red light camera enforcement reduced the number of crashes at Oxnard signalized intersections by 7 percent (with 95 percent confidence limits of 1.3 and 12.5).

Table 1
Total Crashes Before and After Enforcement

City	Type of Intersection	Before	After	Percent Change
Bakersfield	Nonsignalized	760	753	-0.9
	Signalized	771	739	-4.2
San Bernardino	Nonsignalized	1,220	1,283	5.2
	Signalized	1,324	1,400	5.7
Santa Barbara	Nonsignalized	712	622	-12.6
	Signalized	488	438	-10.2
Oxnard	Nonsignalized	994	1,011	1.7
	Signalized	1,322	1,250	-5.4

Table 2
Estimated Effects on Total Crashes

Effect	Degrees of Freedom	Mean Square	F-value	p-value	Estimate	Percent Reduction
Camera	1	0.0013308	11.33	0.0281	-0.07296	7
Error	4	0.00011741				

Table 3 summarizes changes in the number of injury crashes for signalized and nonsignalized intersections in all four cities. As was found for total crashes, the numbers of injury crashes in control cities changed roughly in the same way at signalized and nonsignalized intersections from the baseline period through the enforcement period. Results of the statistical model used to evaluate changes in injury crashes are summarized in Table 4. It is estimated that red light camera enforcement reduced the number of injury crashes at Oxnard signalized intersections by 29 percent (with 95 percent confidence limits of 16.6 and 39.1).

Table 3
Injury Crashes Before and After Enforcement

City	Type of Intersection	Before	After	Percent Change
Bakersfield	Nonsignalized	245	241	-1.6
	Signalized	243	233	-4.1
San Bernardino	Nonsignalized	204	225	10.3
	Signalized	239	246	2.9
Santa Barbara	Nonsignalized	113	115	1.8
	Signalized	89	84	-5.6
Oxnard	Nonsignalized	173	194	12.1
	Signalized	299	239	-20.1

Table 4
Estimated Effects on Injury Crashes

Effect	Degrees of Freedom	Mean Square	F-value	p-value	Estimate	Percent Reduction
Camera	1	0.02865345	35.62	0.004	-0.33855	28.7
Error	4	0.00080437				

Effects on two primary types of multiple-vehicle crashes at intersections — right-angle and rear-end — are summarized in Tables 5-7. Overall, right-angle crashes accounted for approximately 36 percent of all crashes at signalized intersections and 42 percent of all crashes at nonsignalized intersections; rear-end crashes accounted for approximately 9 percent of all crashes at both signalized and nonsignalized intersections. Based on trends in right-angle crashes in the three comparison cities and relative to changes in the frequency of these types of crashes at nonsignalized intersections in Oxnard, the model estimated a significant 32 percent reduction in right-angle crashes at all signalized intersections in Oxnard due to the camera enforcement (with 95 percent confidence limits of 3.2 and 53.0) and a significant 68 percent reduction in right-angle injury crashes at all signalized intersections (with 95 percent confidence limits 56.7 and 76.5). Based on trends in rear-end crashes in the three comparison cities and relative to changes in the frequency of these types of crashes at nonsignalized intersections in Oxnard, the model estimated a nonsignificant 3 percent increase in rear-end crashes at signalized intersections.

Table 5
Estimated Effects on Right-Angle Crashes

Effect	Degrees of Freedom	Mean Square	F-value	p-value	Estimate	Percent Reduction
Camera	1	0.03871492	9.17	0.0388	-0.39352	32.5
Error	4	0.00422139				

Table 6
Estimated Effects on Right-Angle Injury Crashes

Effect	Degrees of Freedom	Mean Square	F-value	p-value	Estimate	Percent Reduction
Camera	1	0.32634352	107.72	0.0005	-1.14253	68.1
Error	4	0.00302947				

Table 7
Estimated Effects on Rear-End Crashes

Effect	Degrees of Freedom	Mean Square	F-value	p-value	Estimate	Percent Increase
Camera	1	0.00022718	0.00418	0.9515 (nonsignificant)	0.030145	3.1
Error	4	0.05430999				

DISCUSSION

Despite the large numbers of communities using red light camera enforcement and a long history of international use, relatively little is known, particularly outside of Australia, about the effect of camera enforcement on motor vehicle crashes. This study provides evidence that red light cameras in the United States can reduce the risk of motor vehicle crashes, in particular injury crashes, at intersections with traffic signals. During the time frame of this study, no other comprehensive traffic safety programs were implemented in Oxnard that could account for these crash reductions.

Crash reductions at signalized intersections were found on a citywide basis, even though cameras were installed at only 11 of 125 signalized intersections in Oxnard. Intersections typically have four approach legs, and red light cameras monitored only one approach leg at each of the 11 enforcement sites, so in Oxnard only about 2 percent of all approaches to signalized intersections were camera enforced. The finding that crash reductions were observed at traffic signals on a citywide basis is consistent with prior behavioral research findings that red light camera enforcement can provide general deterrence against red light violations, with effects not limited to specific intersections with cameras. This is important because the goal of highly conspicuous traffic enforcement is to produce generalized changes in driver behavior with respect to traffic safety laws, not simply to penalize identified violators. And because red light cameras can be a permanent component of the transportation infrastructure, crash reductions attributed to camera enforcement should be sustainable.

Injury crashes may decline more than less severe crashes because of the nature of red light running crashes, which are characterized by more severe side impacts and relatively high impact speeds. The crash reductions estimated by this study may be conservative because the SWITRS data did not contain sufficient detail to identify crashes that were specifically red light running events. Although the findings of a 29 percent reduction in overall injury crashes at signalized intersections and a 32 percent reduction in right-angle crashes are very positive, it is possible that crashes specifically related to red light running declined to an even greater extent.

Changes in motor vehicle crashes associated with red light camera enforcement may differ in other communities because of factors that could influence program effectiveness, including number of cameras, penalty structure, and extent to which camera enforcement is publicized. Publicity about camera enforcement will be important because driver awareness of traffic enforcement is the principal mechanism through which general deterrence is achieved.

Although red light cameras are effective in reducing red light violations and associated crashes, such enforcement should be viewed as a supplement to, and not a substitute for, good engineering design practices that can reduce red light running and enhance intersection safety. These practices include adequately timed yellow signal change intervals, use of all-red clearance intervals, conspicuous traffic signal housings, adequate signal brightness, coordinated signal timing, and use of advance warning signs on high-speed roads or at locations with limited site distances.

ACKNOWLEDGEMENTS

The authors acknowledge contributions to this research made by the cities of Bakersfield, Oxnard, San Bernardino, and Santa Barbara and by the California Department of Transportation. The authors also acknowledge technical contributions by Charles M. Farmer of the Insurance Institute for Highway Safety.

REFERENCES

Chin, H.C. 1989. Effect of automatic red-light cameras on red-light running. *Traffic Engineering and Control* 30:175-79.

County Surveyors' Society. 1990. Traffic signal cameras. Report no. 1/12, Special Activity Group on Accident Reduction. Derbyshire, England.

Hillier, W.; Ronczka, J.; and Schnerring, F. 1993. An evaluation of red light cameras in Sydney. New South Wales, Australia: Roads and Traffic Authority.

Ogden, K.W. 1996. *Safer Roads: A Guide to Road Safety Engineering*. Aldershot: Avebury Technical: 212-213.

Retting, R.A.; Ulmer, R.G.; and Williams, A.F. 1999. Prevalence and characteristics of red light running crashes in the United States. *Accident Analysis and Prevention* 31:687-94.

Retting, R.A.; Williams, A.F.; Farmer, C.M.; and Feldman, A.F. 1999a. Evaluation of red light camera enforcement in Oxnard, California. *Accident Analysis and Prevention* 31:169-74.

Retting, R.A.; Williams, A.F.; Farmer, C.M.; and Feldman, A.F. 1999b. Evaluation of red light camera enforcement in Fairfax, Virginia. *ITE Journal* 69:30-34.

Rocchi, S. and Hemsing, S. 1999. A review of the road safety benefits of red light cameras. *Enhancing Transportation Safety in the 21st Century, ITE International Conference* (CD ROM). Washington, DC: Institute of Transportation Engineers.

South, D.; Harrison, W.; Portans, I.; and King, M. 1988. Evaluation of the red light camera program and the owner onus legislation. Victoria, Australia: Victoria Road Traffic Authority.

U.S. Census Bureau. 1996. Land area, population, and density for places, table 3, California 1990. Washington, DC. Available: http://www.census.gov/population/censusdata/places/06ca.txt.

U.S. Census Bureau. 2001. 1990 to 1996 cities and places population estimates, California. Washington, DC. Available: http://www.census.gov/population/estimates/metro-city/scful/SC99F_CA.txt

Zaal, D. 1994. Traffic law enforcement: a review of the literature. Report no. 53. Victoria, Australia: Monash University Accident Research Centre.