ELSEVIER

Accident Analysis and Prevention 31 (1999) 169–174

ACCIDENT ANALYSIS & PREVENTION

Evaluation of red light camera enforcement in Oxnard, California

Richard A. Retting *, Allan F. Williams, Charles M. Farmer, Amy F. Feldman

Insurance Institute for Highway Safety, 1005 North Glebe Road, Arlington, VA 22201-4751, USA

Received 18 March 1998; received in revised form 20 August 1998; accepted 4 September 1998

Abstract

Red light cameras are increasingly being used to supplement police efforts to enforce against noncompliance with traffic signals—a substantial contributing factor in urban motor vehicle crashes. Camera enforcement is intended to modify driver behavior through both general deterrence and punishment of individual violators. A before/after quasi-experimental design with controls was employed to evaluate the influence of a red light camera enforcement program on red light violation rates in the city of Oxnard, CA. A total of 14 intersections (nine camera sites, three non-camera sites, and two control sites) were studied. Overall, the red light violation rate was reduced approximately 42% several months after the enforcement program began. Increases in driver compliance with red lights were not limited to the camera-equipped intersections but spilled over to nonequipped intersections as well. Results of public opinion surveys conducted approximately 6 weeks before, 6 weeks after, and 6 months after the camera enforcement program began indicated that nearly 80% of Oxnard residents support using red light cameras as a supplement to police efforts to enforce traffic signal laws.

Keywords: Urban crashes; Red light cameras; Red light running; Photo enforcement; Traffic enforcement

1. Introduction

More than 1 million motor vehicle crashes occur annually at traffic signals (US Department of Transportation, 1993, 1994, 1995, 1996, 1997). The number of fatal crashes at traffic signals increased 19% between 1992 and 1996 (US Department of Transportation, 1993, 1997). Traffic signals, through use of time separation, are designed to reduce motor vehicle crashes at intersections involving potentially conflicting traffic movements. High compliance with signals is essential for safe and efficient traffic movement, and noncompliance contributes substantially to urban motor vehicle crashes (Retting et al., 1995).

Motorists are more likely to be injured in crashes involving red light running than in other types of urban crashes. A study of police-reported crashes in four US cities indicated occupant injuries occurred in 45% of the red light running crashes, compared with 30% for other crash types (Retting et al., 1995). This indicates that reductions in red light running crashes would be especially beneficial in reducing urban crash losses.

Efforts to promote traffic law compliance are constrained by limited police enforcement resources, which have been declining in relation to the number of vehicles on the road (Freedman and Paek, 1992). Enforcing traffic signal compliance in urban areas is difficult not only because of limited manpower but because of factors associated with traditional enforcement methods, which in many cases require police to follow a violating vehicle through a red light to stop it. This action, plus pursuit in areas of high vehicle density, can endanger motorists, pedestrians, and police officers. Therefore, conventional traffic enforcement in some communities is being supplemented with advanced technology.

Red light cameras increasingly are being used to help communities enforce against deliberate red light running by automatically photographing vehicles whose drivers run red lights. A red light camera system is connected to the traffic signal system and to sensors buried in the pavement at the crosswalk or stop line. The camera system continuously monitors the traffic signal, and the camera is triggered when any vehicle passes over the sensors faster than a preset minimum speed and at a specified elapsed time after the signal has turned red. A second photograph is taken that shows

* Corresponding author. Tel. +1-703-2471500; Fax: +1-703-2471678; e-mail: iihs@highwaysafety.org.

0001-4575/99/$ - see front matter
PII: S0001-4575(98)00059-1

Table 1
Number of hours observed

	Before	After
Camera sites	1488	1590
Non-camera sites	73	73.5
Control sites	48	47.5

the violator in the intersection. The camera records the date, time of day, time elapsed since the beginning of the red signal, and the speed of the vehicle. The use of a flash produces clear images under a wide range of light and weather conditions. Upon review of photographic evidence and depending on state law requirements, tickets are issued by mail to either vehicle owners or to drivers at the time of the offenses.

Red light camera technology has been in widespread use in many countries since the 1970s (Makinen and Hway-liem, 1992; Blackburn and Gilbert, 1995). The first sustained red light camera enforcement program in the United States was implemented in New York City in 1992, with about a dozen municipal enforcement programs active by 1997.

Some early US red light camera enforcement programs reported a decline in the number of tickets issued over time, suggesting program effectiveness in reducing red light violation rates. For example, San Francisco officials reported that after red light cameras were introduced, the number of violations recorded per 10 000 vehicles at these intersections declined from 11.1 to 6.4 between November 1996 and April 1997 (personal communication, San Francisco Department of Parking and Traffic, August 1997). However, such results are limited because of the absence of violation data for the period prior to camera enforcement and the lack of experimental study designs. Effects on intersections without red light cameras also are unknown.

The present study evaluates the influence of a red light camera enforcement program on red light violation rates and samples public opinion about red light camera use as a supplement to police efforts in the community.

2. Methods

The study was conducted in the city of Oxnard, CA, which has an estimated population of 151 009 and a land area of 24.4 square miles (US Census Bureau, 1996, 1997). A statewide red light camera law took effect in California in January 1996, permitting municipal governments to establish local red light camera enforcement programs. The vehicle driver, if sufficiently identified, is charged with the 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

Table 2
Oxnard red light camera baseline and 4 months after

Site category/intersection	Number of hours		Number of violations		Number of vehicles		Violations per 10 000 vehicles		Percent change
	Before	After	Before	After	Before	After	Before	After	
Camera									
Channel Isl/C St	216	241	69	27	105 936	106 936	6.5	2.5	−62
Channel Isl/Rose	174	174	81	34	46 233	43 945	17.5	7.7	−56
Harbor/Wooley	120	122	53	36	26 784	25 812	19.8	13.9	−30
Rice/Sturgis	142	142	106	49	55 846	50 069	19.0	9.8	−48
Rose/Wooley	176	176	117	87	67 303	63 800	17.4	13.6	−22
Saviers/Pleasant Vly	158	164	32	16	18 142	18 012	17.6	8.9	−49
Ventura/Bay	166	166	66	29	90 996	92 474	7.3	3.1	−58
Ventura/Doris	167	236	153	152	103 858	147 923	14.7	10.3	−30
Ventura/Vineyard	169	169	42	25	43 798	44 366	9.6	5.6	−42
Total	1488	1590	719	455	558 896	593 337	12.9	7.7	−40
Non-camera									
Gonzales/C St	25	25	20	7	11 782	12 939	17.0	5.4	−68
Oxnard/Fourth	24	23	14	7	25 316	22 312	5.5	3.1	−44
Ventura/Devonshire	24	25.5	64	34	23 998	24 900	26.7	13.7	−49
Total	73	73.5	98	48	61 096	60 151	16.0	8.0	−50
Control									
Carillo/San Andrea	24	24	10	8	14 679	14 559	6.8	5.5	−19
Hollister/Puente	24	23.5	12	11	16 556	13 954	7.2	7.9	+10
Total	48	47.5	22	19	31 235	28 513	7.0	6.7	−4

Table 3
Analysis of variance table, camera sites versus non-camera sites

Effect	Degrees of freedom	Mean square	*F*-statistic	*P*-value
Site	11	0.595	17.6	0.0001
After versus before	1	0.944	27.8	0.0004
Camera sites after versus other	1	0.040	1.2	0.3012
Error	10	0.034		

issued a ticket by mail (the registered owner is able to rebut this presumption in court). Violations identified by the cameras carry the same monetary penalties and license sanctions as violations resulting from conventional police enforcement. During the study period, this was a standard fine of $104 plus one demerit point on a driver's license.

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. Actual enforcement began on July 1, 1997.

Baseline red light violation data were collected prior to the warning period and again 3–4 months after actual enforcement began. A total of 14 intersections were included in the study. Nine camera sites were selected by Oxnard police and traffic engineering officials based on what they believed to be a history of police-reported crashes involving red light running (the initial group of intersections where red light cameras were installed during 1997). Three non-camera sites in Oxnard were selected on the basis of allowing safe and unobtrusive observation and data collection and to be representative of camera sites to see if changes in red light running observed at camera sites spilled over to other intersections (no camera installation was, or is, planned for these sites). Two control sites in the city of Santa Barbara, CA, located approximately 40 miles north of Oxnard, also were selected on the basis of allowing safe and unobtrusive observation and data collection. The Santa Barbara sites were selected to control for factors that might affect red light violations, e.g. weather and seasonal variability in travel patterns. Little or no effect at these sites was expected. The nine camera sites were dispersed throughout Oxnard in both commercial and residential districts; the three non-camera sites also were dispersed.

Violation and exposure data for each site were recorded for a single intersection approach. At the camera sites, baseline data were recorded with the same microprocessor-controlled Gatso™ red light cameras that later would be mounted on poles and used for enforcement. During the baseline period, however, special camera housings were installed at ground level to collect data without alerting drivers to the cameras' presence. At the non-camera and control sites, observers deployed video cameras unobtrusively (hidden behind wood poles or other structures) to record traffic approaching and entering these intersections, including a clear view of the signal indication and the stop line or crosswalk.

The time of day and total number of hours observed for baseline and after-measurement periods were matched as closely as possible. The total number of hours observed for the 14 sites is summarized in Table 1. At the camera sites, where violation data were recorded electronically and thus did not require the presence of human observers, far more observations were recorded than at the non-camera and control sites.

A red light violation was defined as a vehicle entering an intersection (as detected by pavement sensors) after the signal light had been red for a minimum elapsed time of 0.4 s—a criterion established for issuing red light camera tickets in Oxnard—and the measured speed of the vehicle was at least 15 mph. Use of a minimum travel speed helped to eliminate false-positives associated with right-turn-on-red movements and emergency vehicles. A trained observer applied these same criteria to red light running events recorded at the non-camera and control sites, employing timecode from videotape to determine elapsed time. Scoring of red light running at all sites was limited to vehicles traveling straight through the intersection.

The duration of yellow traffic signal timing has been found to influence red light running at urban intersections (Retting and Greene, 1997). Therefore, yellow signal timings at the camera sites were checked against an Institute of Transportation Engineers (1985) proposed recommended practice and found to be adequate.

Vehicle exposure was measured at the camera sites with pavement sensors (the same used to detect red light violations) and was estimated at the non-camera and control sites using videotape. Vehicle counts were measured for 5 min of each 15 min study period and extrapolated. At all sites, violation rates per 10 000 vehicles were analyzed using loglinear models. The logarithm of the violation rate at each site was modeled

Table 4
Analysis of variance table, camera and non-camera sites versus control sites

Effect	Degrees of freedom	Mean square	*F*-statistic	*P*-value
Site	13	0.564	16.9	0.0001
After versus before	1	0.004	0.1	0.7266
Camera and non-camera sites after versus other	1	0.294	8.8	0.0118
Error	12	0.033		

as a linear function of the period of observation (after vs. before) and the type of site (camera, non-camera, control). Changes in violation rates after the enforcement program began were compared for the camera versus non-camera sites and then for the camera and non-camera sites versus control sites.

Finally, random sample telephone surveys of Oxnard residents about their awareness and opinions of red light camera enforcement were conducted approximately 6 weeks before, 6 weeks after, and 6 months after the enforcement program began. A ten-question survey was administered to people of driving age (16 years old and older) using a random-digit-dial sampling method. The sample consisted of 500 responses for the baseline survey and 300 responses for each of the subsequent surveys.

3. Results

Red light violation rates per 10 000 vehicles recorded during the baseline period and 3–4 months after the enforcement began at the 14 study sites are summarized in Table 2. Violation rates were lower at all camera and non-camera sites. Overall reductions were 40% at camera sites and 50% at non-camera sites. There was no statistically significant difference between the reduction in violation rates at the camera and non-camera sites ($P = 0.3012$, Table 3). Overall, the violation rate across the camera and non-camera sites was reduced approximately 42%, from 13.2 to 7.7 per 10 000 vehicles. There was a statistically significant difference between the reduction in violation rates at the camera and non-camera sites compared with the control sites ($P = 0.0118$, Table 4). The overall violation rate at the control sites was essentially unchanged at 7.0 during the baseline period and 6.7 after 3–4 months.

Results of the public opinion surveys are summarized in Tables 5–7. A total of 6 weeks before the enforcement program began, 69% of respondents were aware of Oxnard's plan to use red light cameras; 6 weeks into the enforcement program, 84% knew cameras were in use; and 6 months into enforcement, 85% knew about the cameras.

Respondents who knew red light cameras were in use were asked whether they favored or opposed them as a supplement to police efforts to enforce against red light running. Respondents who did not know cameras were in use were asked if they would favor or oppose their use. Respondents who knew cameras were in use were somewhat more favorable about the program than those who did not know. Overall, 79% favored use of red light cameras 6 weeks and 6 months after the program began, compared with 74% 6 weeks before the cameras were installed. Support for camera use generally was lower among males and young respondents (ages 16–29).

4. Discussion

This study found a large and highly significant reduction in red light violations several months after implementation of the red light camera enforcement program in Oxnard, CA. Most Oxnard residents knew about the cameras, and the violation rate across the camera and

Table 5
Among respondents who knew about red light camera use: 'Do you favor or oppose the use of cameras to enforce against red light running in Oxnard, as a supplement to police efforts?' (%)

	6 weeks before ($N = 349$)	6 weeks after ($N = 252$)	6 months after ($N = 255$)
Favor	75	81	80
Strongly favor	51	59	51
Somewhat favor	24	22	28
Oppose	19	15	18
Somewhat oppose	5	6	8
Strongly oppose	14	9	10
Don't know	7	4	3

Table 6
Among respondents who did not know about red light camera use: 'Would you favor or oppose the use of cameras to enforce against red light running in Oxnard, as a supplement to police efforts?' (%)

	6 weeks before ($N = 157$)	6 weeks after ($N = 49$)	6 months after ($N = 45$)
Favor	70	67	76
Strongly favor	39	43	47
Somewhat favor	31	24	29
Oppose	20	18	18
Somewhat oppose	4	4	9
Strongly oppose	16	14	9
Don't know	8	14	7

non-camera sites was reduced by approximately 42%. This finding is not surprising given similar large declines reported after installation of red light camera systems in other countries including England, Scotland, and Singapore (Chin, 1989; Walker, 1993; Scottish Office Central Research Unit, 1995). However, it is likely that effects of red light camera programs in other cities may differ, depending on factors such as the number of cameras deployed and the extent of publicity about them.

Changes in driver compliance with red lights were not limited to camera-equipped intersections and occurred at nearby nonequipped intersections, based on the experience of the three non-camera sites. The presence of cameras may promote a general readiness to stop for red lights. One factor that may promote generalization to non-camera sites in Oxnard is the relatively large number of intersections equipped with cameras (cameras were initially installed at nine of 128 Oxnard intersections with traffic signals). This spillover effect is important because the practice in many communities has been to deploy only a few cameras. For cities with limited resources, use of dummy cameras may be a cost effective way to supplement a small number of working red light cameras.

It is important to determine the long-term effects of red light camera enforcement on violation rates. Meanwhile, the effects in Oxnard will be influenced by substantial statewide increases in red light violation fines that took effect in January 1998. The standard monetary fine increased from $104 to $270. Because of this substantial fine increase and any associated publicity, there was no further evaluation of program effects beyond that reported here. The effects of red light camera enforcement on motor vehicle crashes in Oxnard have yet to be determined. This is important because the ultimate worth of traffic enforcement is to lessen the risk and severity of crashes. Evaluation of crash effects requires experimental design controls and an ample population of relevant crashes, neither of which were available to researchers in Oxnard. South et al. (1988) reported a 32% decrease in right-angle collisions at 46 camera-equipped intersections in Victoria, Australia, for the 3-year period following camera installation. However, subsequent research by Andreassen (1995) that examined crashes during the 5-year period following installation of 41 cameras in Melbourne, Australia, concluded that the cameras were not effective in reducing crashes and that sites with low crash frequencies (apparently characteristic of the Melbourne camera locations) are not good candidates for testing the effectiveness of crash countermeasures. Based on the findings of South et al. and red light running crash data from Birmingham, UK, Lawson (1991) concluded that the costs of installing and maintaining red light cameras at intersections where red light running crashes occur will pay for themselves, assuming crash reductions in the range estimated by South et al.

Both before and during the enforcement program, nearly 80% of motorists in Oxnard said they support red light camera use as a supplement to police efforts to reduce red light running. In a separate national public opinion survey, 61% of respondents said they favor camera use. The highest support was found in large cities, where 83% of respondents favored such a device (Insurance Research Council, 1996). Public opinion surveys in European countries, where automated traffic enforcement has been in use for many years, revealed that the majority of drivers support or accept red light camera use (Muskaug, 1993).

A relatively small but constant number of residents (10–15%) strongly opposed such cameras, largely because of privacy concerns. However, driving is a regulated activity on public roads, and neither the law nor public opinion suggests that drivers should not be observed on the road or have their violations documented. In addition, red light cameras can be designed to photograph only a vehicle's rear license plate, not vehicle occupants, although this may require a change in California law.

Table 7
Among total respondents: 'Do you/would you favor or oppose the use of cameras to enforce against red light running in Oxnard, as a supplement to police efforts?' (%)

	6 weeks before ($N = 506$)	6 weeks after ($N = 301$)	6 months after ($N = 300$)
Favor	74	79	79
Strongly favor	48	56	51
Somewhat favor	26	23	28
Oppose	19	15	18
Somewhat oppose	4	5	8
Strongly oppose	15	10	10
Don't Know	7	6	3

Acknowledgements

The authors gratefully acknowledge the participation and contributions of the following individuals: Steve Casey (Ergonomic Systems Design, Inc.), Zev Fogel (US Public Technologies), Joseph Genovese (City of Oxnard Traffic Engineer), and Ken Klopman (City of Oxnard Police Department). This work was supported by the Insurance Institute for Highway Safety.

References

Andreassen, A., 1995. Long term study of red light cameras and accidents. Research Report no. ARR 261. Australian Road Research Board Ltd, Victoria, Australia.

Blackburn, R.R., Gilbert, D.T., 1995. Photographic enforcement of traffic laws. National Cooperative Highway Research Program, Synthesis of Highway Practice 219. Transportation Research Board, National Research Council, Washington, DC.

Chin, H.C., 1989. Effect of automatic red-light cameras on red-running. Traffic Engineering and Control 30, 175–179.

Freedman, M., Paek, N., 1992. Enforcement resources relative to need: changes during 1978–89. Insurance Institute for Highway Safety, Arlington, VA.

Institute of Transportation Engineers, 1985. Determining Vehicle Change Intervals: A Proposed Recommended Practice. Institute of Transportation Engineers, Washington, DC.

Insurance Research Council, 1996. Public Attitude Monitor 1996, Wheaton, IL.

Lawson, S.D., 1991. Red-Light Running: Accidents and Surveillance Cameras. AA Foundation for Road Safety Research, Basingstoke, UK.

Makinen, T., Hway-liem, O., 1992. Automatic Enforcement of Speed and Red Light Violations. SWOV Institute, Leidschendam, The Netherlands.

Muskaug, R., 1993. Drivers' acceptance of automatic traffic surveillance. Traffic Engineering and Control 34, 243–246.

Retting, R.A., Greene, M.A., 1997. The influence of signal timing on red-light running and potential vehicle conflicts at urban intersections. Transportation Research Record 1595. Transportation Research Board, Washington, DC, pp. 1–7.

Retting, R.A., Williams, A.F., Preusser, D.F., Weinstein, H.B., 1995. Classifying urban crashes for countermeasure development. Accident Analysis and Prevention 27, 283–294.

Scottish Office Central Research Unit, 1995. Running the Red: An Evaluation of the Strathclyde Police Red Light Camera Initiative. Edinburgh, UK.

South, D., Harrison, W., Portans, I., King, M., 1988. Evaluation of the Red Light Camera Program and The Owner Onus Legislation. Victoria Road Traffic Authority, Victoria, Australia.

US Census Bureau, 1996. Land Area, Population, and Density for Places, Table 3, California 1990. http://www.census.gov/population/censusdata/places/06ca.txt.

US Census Bureau, 1997. 1990–1996 Cities and Places Population Estimates, California. http://www.census.gov/population/estimates/metro-city/scts96/sc96t_ca.txt.

US Department of Transportation, 1993. Traffic Safety Facts 1992 (HS-808-022). US Department of Transportation, Washington, DC.

US Department of Transportation, 1994. Traffic Safety Facts 1993 (HS-808-169). US Department of Transportation, Washington, DC.

US Department of Transportation, 1995. Traffic Safety Facts 1994 (HS-808-292). US Department of Transportation, Washington, DC.

US Department of Transportation, 1996. Traffic Safety Facts 1995 (HS-808-471). US Department of Transportation, Washington, DC.

US Department of Transportation, 1997. Traffic Safety Facts 1996 (HS-808-770). US Department of Transportation, Washington, DC.

Walker, D., 1993. Automated Camera Enforcement. Conference Proceedings, TRAFFEX 1993. PTRC Education and Research Services LTD. London, UK.