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16. Abstract

Red light running (RLR) is a dangerous act. Approximately 22% of urban crashes at signalized intersections are caused nationwide by RLR. Nearly 1,036 deaths were caused nationwide by RLR in the year 2000. Indiana had no previous research conducted in this area; therefore, this research was aimed at estimating the RLR problem in Indiana. The other objectives of this research included: learning drivers' opinions on the problem, studying the effectiveness of selected countermeasures, and studying the legal issues related to photo-enforcement.

A crash statistics study, telephone survey, and extended monitoring of a selected intersection were the three major approaches chosen to estimate the magnitude of the problem. The crash statistics for the 1997-1999 period showed that 22% of signalized intersection crashes were caused in Indiana by RLR. RLR preceded 50% of fatal crashes at these intersections. The telephone survey showed that 67% of Indiana drivers felt that RLR was a problem in the state. Twelve percent of them claimed to have been involved in a RLR crash. The extended monitoring of the through movements at the study intersection also recorded a considerable violation rate. These results indicate that RLR may be considered a problem in Indiana.

Traffic at a selected intersection in West Lafayette, Indiana, was videotaped and the video material was used to detect the red light violations. The expected number of drivers arriving at the start of the red signal has been proposed as a true measure of exposure to RLR. We call it an opportunity for RLR. This exposure was used to estimate the RLR rate. The statistical significance of the difference in the RLR rates between different periods was estimated using binomial distribution.

Police enforcement was evaluated and found to reduce the violation rate by approximately 75% in the week immediately after the enforcement. A reduction of 37% was observed after another two weeks. The photo- enforcement reduced the violation rate by 62% during the week of enforcement and by 35% during the week immediately following. Young people violated red lights more frequently than other drivers.

The legal issues that related to RLR and photo-enforcement were studied. The present state law in Indiana does not support the use of photo-enforcement.

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Final Report

FHWA/IN/JTRP- 2002/12

EVALUATION OF SAFETY ENFORCEMENT ON CHANGING DRIVER BEHAVIOR – RUNS ON RED
Volume 1

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1. INTRODUCTION

The main purpose of traffic signals is to ensure smooth flow of traffic thereby promoting safety at intersections. All drivers are expected to obey the rules and to heed traffic signals. It is a common opinion among safety experts that the drivers' compliance with a red signal is deteriorating. The definition of red light running (RLR) varies from region to region, depending on the local laws. **In this research we consider a vehicle to have run a red light if the front of the vehicle crosses the stop bar after the light turns red and the vehicle proceeds through the intersection without stopping.**

Researchers at the Insurance Institute of Highway Safety (IIHS, November 2001) found that deliberate running of red lights is a common and serious violation that contributes to 22% of urban crashes. The Federal Highway Administration (FHWA, 2000A) estimated that 1,036 deaths, 106,000 crashes, and 89,000 injuries were caused by RLR in the year 2000. The economic impact of these violations was also estimated to be $7 billion per year in medical costs, time off work, insurance hikes, and property damage (FHWA 2000B). Officials at the Department of Public Health, San Francisco consider RLR a public health problem similar to not wearing seat belts, not using child car seats, and drunk driving. They consider red light runners as aggressive or distracted drivers. Deutsch, Sameth and Akinyemi (1980) found that only 1.1% of the 90 red light runners in their study wore seat belts, whereas 8.1% of the 160 drivers, who had an opportunity to run a red light but stopped, wore seat belts. They also found that in San Francisco, the violators were mostly professional males over 40 years of age (PhotoCop 2000A), which is quite different from what Retting et al. (1999A) stated in their findings. Twenty-six percent of the violating drivers in Retting's study were under 30 years of age, never wore their seat belts, and had poorer driving records, often being the same drivers who received speeding tickets.

The reasons for running a red signal given by drivers in a survey conducted in Richmond, Virginia varied from "couldn't stop" (41%) to "in a hurry" (21%) (Survey

Research Laboratory, 29 April 1996). The report concludes that congestion, impatience, and reckless driving all contribute to the growing problem of deliberate running of red lights. Another reason for RLR may be that drivers do not recognize the possibly serious consequences of RLR. FHWA (2000C) estimated that the time saved by running a red light is approximately 47 seconds.

Many authors (Tarawneh et al. 1999; Passetti, K.A., August 1997; Retting et al. 1999B) claim that limited municipal budgets do not allow for sufficient police resources to pursue and ticket all red light runners. Further, traffic pursuit can be dangerous to police as well as to other motorists and pedestrians. Many countries and some states in the United States have started RLR campaigns through public education and aggressive enforcement. For example, FHWA encourages communities to participate in "Stop Red Light Running" campaigns. Some states have also introduced special laws that allow automated enforcement to catch red light violators.

Past studies show that RLR is a major community problem. Indiana ranks tenth nationwide by fatality rate. The estimated rate for 1992-1998 is 2.7 fatalities/100,000 people (The Insurance Guide, July 2000). Other states have realized the RLR problem and have taken initiatives to study and mitigate this problem. Because no prior research has been conducted in Indiana on the subject, the Indiana Department of Transportation (INDOT) initiated this study to learn the extent of the problem in Indiana and to help set a course of action if the RLR problem is confirmed.

The major objectives of this research are:

1. To estimate the magnitude of RLR in Indiana,
2. To learn Indiana drivers' opinions on RLR and photo-enforcement,
3. To evaluate selected countermeasures by investigating changes in drivers' behavior,
4. To study the legal issues of RLR and photo-enforcement in other states and in Indiana.

Two Purdue teams - the Civil Engineering (CE) team and the Center for Advanced Traffic Safety (CATS) team conducted the research. Volume 1 of the report presents the CE team's work, which focused on surveying drivers' opinions and on extended monitoring of RLR activities at the Northwestern and Stadium Avenue intersection in West Lafayette, Indiana. Changes in RLR rates at the intersection in response to police enforcement and the presence of photo-equipment were investigated. Volume 2 presents the results of the research conducted by the CATS team.

Volume 1 is divided into eight chapters. The **first chapter** gives a brief introduction to the research problem and the objectives of the research. The **second chapter** briefly describes the research methodology employed to achieve the objectives specified in the first chapter. The **third chapter** focuses on the magnitude of the RLR problem in Indiana. It provides an analysis of crash statistics at signalized intersections in Indiana between 1997 and 1999. It also describes the telephone survey conducted in Indiana, discusses the results obtained, and compares them with similar surveys conducted in other states. The **fourth chapter** focuses on the monitoring methodology. It provides a detailed analysis of the signal timings and enforcement tolerance at the study intersection. The test facility, the monitoring method developed, and its evaluation methodology are also described in chapter four. The **fifth chapter** deals with the effectiveness of RLR-related enforcement. It reports the RLR Crash Reduction Factors for different types of crashes in Howard County, Maryland, as an example of the linkage between enforcement and crash reduction. It also describes the procedure employed to monitor the changes in drivers' behavior during various stages of both police enforcement and photo enforcement. The practical implication and derivation of a new quantitative measure called *opportunity for RLR* or more simply, *opportunity,* which is used to find violation rates, is explained. The results and their statistical significance is also thoroughly discussed. The **sixth chapter** discusses other RLR factors studied in this project: young drivers, time of day, and day of week. The **seventh chapter** gives a summary of the literature review on the legal issues of RLR and photo-enforcement in other states and in Indiana. Finally, the **eighth chapter** gives the conclusions.

2. RESEARCH METHODOLOGY

A literature review about RLR issues was conducted and then a plan of research was developed to address the research objectives outlined in Chapter 1.

The first research objective was to estimate the magnitude of RLR. Three methods were used: crash statistics analysis, drivers' survey, and traffic monitoring. The Indiana crash statistics and the phone survey are described in Chapter 3. Crash data was obtained from INDOT for the period between 1997 and 1999 and was analyzed to find the number and severity of RLR-related crashes.

The survey was used to determine Indiana drivers' opinions on RLR and on photo-enforcement. The previous surveys on RLR were reviewed to help design the Indiana questionnaire. It was decided to make the Indiana questionnaire similar to the ones used for other states to enable comparison. Telephone numbers from around the state were randomly selected to avoid any geographic and demographic biases.

The intersection of Northwestern Avenue and Stadium Street in West Lafayette, Indiana, was selected for traffic monitoring during the research. A detailed analysis of the signal timings at this intersection was done in Chapter 4 to check if they met the design standards. This intersection is equipped with video detection systems and is linked with the Harold L. Michael Traffic Operations Laboratory in the School of Civil Engineering at Purdue University. To facilitate the monitoring, a machine-aided monitoring method was developed and evaluated. The quality of the detection method can be characterized by the following measures of effectiveness:

1. *Detection rate*, which is the fraction of events that are detected, and
2. *False detection rate,* which is the fraction of detections that are false.

Chapter 4 explains this monitoring tool, its evaluation method, and its performance in more detail. Once positively evaluated, it can be used to monitor the intersection for red light violations before, during, and after the implementation of selected enforcement methods. A description of the test facility and the monitoring method is provided in Chapter 4.

RLR can be quantified using different measures. The simplest measure is RLR frequency or the number of RLR per unit time (hour, day, etc.). This measure is particularly useful to any enforcement agency that is looking for location and time when the frequency of RLR is high. Selecting such locations and time is supposed to increase the enforcement efficiency. Another measure that is used frequently is RLR rate. Rates relating RLR to traffic volume or to the number of cycles are commonly used. Normalizing RLR is supposed to enable comparing various locations or different periods.

Deutsch, Sameth and Akinyemi (1980) observed 3,097 drivers at a signalized intersection in Baltimore, Maryland, where they found that 70% of all the signal cycles had at least one red light runner. Ryan and Davis (1982) conducted a study on drivers' behavior at signalized intersections, and found that 19% to 63% of the observed signal cycles had at least one red light violation. A similar study conducted by Retting and Williams (1996) in Arlington County, Virginia, showed that 34% of the 1,373 cycles had at least one red light violation. Porter and England (2000) determined the number of signal cycles that had the last driver enter the intersection during green, yellow, and red. They also studied the similarities between the red light runners and yellow light runners and considered these two groups to have similar behavior, except that their behavior is separated in time. They found that 35% of the cycles observed involved at least one red light violator, or ten violations per hour. Furthermore, they observed that the intersections with high traffic volumes had higher violation rates. In another study conducted by Retting et al. (August 1999), the violation rate was evaluated as the number of violations per 100,000 vehicles. They did not find a statistically significant difference in the reduction of red light violations at the camera and non-camera sites after three months or after one year following camera installation. In a study conducted by FHWA (2000D), the violations were higher for higher traffic volume, and fully actuated signals had 35% more crashes than semi-actuated or pre-timed signals.

All these past studies recognize that the traffic volume and the number of signal cycles influence the opportunity for red signal violations, but none of them fully describes this opportunity. We will introduce a new measure of RLR, called *opportunity*, which is the number of drivers who arrive at the stop bar shortly after the signal turns red and face the dilemma, violate the red signal or stop the car. The concept of opportunity and justification of its use is further explained in Chapter 5.

The RLR frequency and RLR rate were used in this study to investigate the changes in behavior of Indiana drivers in response to RLR-related enforcement and thus to estimate the effectiveness of the implemented countermeasure. Statistical tests based on the Binomial distribution were conducted to determine the significance of the changes in RLR rates.

The final objective of studying the legal issues was achieved by a literature review. The legal issues of RLR and photo-enforcement are discussed in Chapter 7.

3. MAGNITUDE OF RLR IN INDIANA

This chapter investigates the magnitude of the RLR problem in Indiana by analyzing the crash statistics in Indiana and by performing a drivers' survey. The intersection and RLR-related crash statistics between 1997 and 1999 are presented and discussed. The survey added the element of driver perception of RLR issues to this research. The methods employed to conduct the survey and analyze the results are presented in this chapter.

3.1 Crash Statistics Analysis

Crashes are a definitive source of information on the magnitude and severity of a safety problem. Crash data is used to estimate the level of safety for various traffic scenarios and highway improvement projects. In this research, the Indiana crash statistics obtained from Accident Information System of INDOT for the period between 1997 and 1999 were analyzed to give an idea of the magnitude and severity of RLR crashes. Table 3.1 summarizes by severity the crashes that occurred at signalized intersections in Indiana, including the RLR-related crashes. The numbers in the brackets are the percentages of all crashes in the corresponding severity category.

The Indiana crash statistics in Table 3.1 show that 22% of the crashes at signalized intersections in Indiana were caused by RLR (100x15,897/72,991=22). This proportion is equal to the nationwide value reported by researchers at the Insurance Institute for Highway Safety (IIHS, November 2001). It should be mentioned though that the IIHS considered urban crashes only, whereas the Indiana crash data analysis included both urban and rural crashes.

Fifty percent of all fatal crashes at signalized intersections are caused by RLR, 100x71/142=50. Thirty percent of non-RLR crashes are injury/fatal crashes, 100x(16,839+71)/57,094=30, while 44% of RLR crashes are injury/fatal, 100x(6,915+71)/15,897=44. A similar tendency of more frequent severe outcomes of a RLR crash than a non-RLR crash was observed by Retting et al., (1999A). As previously mentioned, Indiana had 2.7 fatalities/100,000 people between 1992 and 1998, and is ranked tenth among the states with high fatality rates (The Insurance Guide, July 2000; Retting et al., 1999A). All the Indiana crash statistics were found to be fairly steady over time.

TABLE 3.1 Crash Statistics at Signalized Intersections in Indiana (1997-1999)

Year	**PDO**	**Injuries**	**Fatal**	**Total**
		All Crashes		
1997	16,094	7,762	39	23,895
1998	16,448	8,213	44	24,705
1999	16,553	7,779	59	24,391
Total	49,095	23,754	142	72,991
		RLR Crashes		
1997	2,984	2,271	21	5,276
1998	2,931	2,377	24	5,332
1999	2,996	2,267	26	5,289
Total	8,911	6,915	71	15,897
		Non-RLR Crashes		
1997	13,110	5,491	18	18,619
1998	13,517	5,836	20	19,373
1999	13,557	5,512	33	19,102
Total	40,184	16,839	71	57,094

3.2 Telephone Survey

A survey of drivers was conducted to estimate the magnitude of RLR perceived by drivers. Since no such survey was conducted previously in Indiana, past surveys on RLR conducted in other states or on the nationwide level were studied to prepare a questionnaire and develop a method to conduct our survey.

The Survey Research Laboratory (Center for Public Policy, Virginia Commonwealth University, April 1996) conducted a survey in Richmond, Virginia. They collected 810 responses from the Richmond Metropolitan area through telephone interviews. GENESYS Sampling Systems, Fort Washington, PA prepared the random sample of telephone numbers. They used a Computer Assisted Telephone Interviewing (CATI) system, which displayed on the screen the questions to be asked by the interviewers. The responses were also entered directly into the computer. This survey reported the following observations with a standard error of 4%. Approximately 27% of respondents said they saw red light violations every day. Sixty-seven percent said that they had never seen anyone being ticketed for RLR. Fifty-nine percent of those who saw people being ticketed for RLR felt that only 10% of the violators are ticketed. Forty-five percent of the respondents said that they had run a red light at least once. Forty-eight percent felt that 10% or fewer cases of RLR would result in a crash.

Public Opinion Strategies of Alexandria, Virginia (FHWA and ATS, July 1998) surveyed 800 licensed drivers across the United States, comparing RLR with other forms of aggressive driving behaviors. They reported the following observations with an error margin of +/- 3.5%. Only 5% of the respondents considered RLR a dangerous act when compared to drunk driving (40%) or speeding (32%). On the other hand, 96% feared they might be in a RLR-related crash, and 91% believed that RLR is "very" to "extremely" dangerous. Nearly 70% supported red light enforcement cameras at intersections. Sixty-three percent stated that they saw RLR a few times a week to once a day, while 65% believed that the RLR problem had not improved over the past few years, rather it had increased. Thirty-two percent of respondents indicated knowing someone who had been injured or killed in a RLR crash.

Porter, Berry and Harlow (1999) conducted a nationwide telephone survey of 5,024 licensed drivers, which was sponsored by DaimlerChrysler Corporation, FHWA, and the American Trauma Society. They concentrated on ten states (4,007 surveys), and 1,017 surveys were collected from the other 40 states. Fifty-eight questions were asked and although the study was designed to examine the extent of the RLR problem, driver characteristics and attitudes were also collected to predict RLR behavior. Fifty-six percent of the respondents reported having run a red light. Young people were found to be more aggressive and violated more frequently, but no difference was observed between the violation rates in big and small cities. Forty percent of the respondents said that they were in a hurry and tried to beat the light. The respondents were also more likely to violate red at intersections closer to their homes. Approximately 11% of the respondents were involved in a RLR-related crash. Thirty-nine percent said increased police enforcement was a good countermeasure to reduce the violation rate.

Retting, et al., (August 1999) conducted a survey in Virginia in which they used a random-dial telephone survey. They found that 75% of the respondents supported cameras before the enforcement program started and 84% supported it one year after the enforcement program.

The following section explains in detail the method employed to conduct the Indiana drivers' survey, discusses the results of the survey, and briefly describes the statistical procedure used to analyze the results.

3.2.1 Survey Methodology

A telephone survey was chosen with a random sample of telephone numbers obtained from the Internet. The main objectives of the survey were:

1. To assess driver behavior in Indiana,
2. To learn drivers' perceptions of the consequences of RLR, and
3. To establish drivers' preferences regarding photo-enforcement in Indiana.

In a random sample, each household in the total population has an equal chance of being selected. The simple random sample requires less knowledge about the population than other techniques, but it does have two major drawbacks. One is that if the population is large, a great deal of time must be spent listing and numbering the members. The other is the fact that a simple random sample will not adequately represent many population characteristics unless the sample is relatively large. We surveyed 150 residents, a manageable sample size for the time and manpower available. The random selection helped to reduce bias in the sample, which in turn reduced the sampling errors.

Major types of sampling errors include random error (even if all aspects of the sample are executed properly, the results will still be subject to a certain amount of error because of random variation), non-inclusive errors (people who should be included in the sample and are not), and non-response errors (members of the sample do not respond, thus changing the characteristics of the sample). It is possible to estimate the range of random error at a particular level of confidence. The confidence interval of this random error is estimated when the survey results are extended to explain the population behavior.

The questionnaires used in other surveys helped us design our questionnaire. The questions were similar to questionnaires used previously in other states so that the results obtained in Indiana and the other states could be compared. Non-technical language was used in the questionnaire. For example, the expression ‘automated photo-enforcement for red light violations’ was rephrased and explained as ‘using cameras at intersections to take photos of red light runners to send tickets.’ The effect of the interviewer was also reduced by not having to rephrase questions. To reduce the likelihood of recording errors, a specially designed spreadsheet was used. The window was split into two parts so that the questions could be viewed and the responses keyed simultaneously into Excel. This saved time in processing the survey results and reduced the possibility of manual errors.

The draft questionnaire was thoroughly discussed by the research team before the final questionnaire was designed. This group also helped in conducting the survey by making calls and collecting the data. The questionnaire was designed to be brief but also collect the required information. The questionnaire is shown in Appendix B. Indiana residents constituted the population for the survey and the telephone numbers were randomly selected from the Internet. The sample covered the entire Indiana population without favoring any particular county or city.

A paper copy of the questionnaire was also given to all of the assistants conducting the survey. The instructions to be followed were provided at appropriate places in the questionnaire. Calls were made on weekdays between 6:00 PM and 8:00 PM, and on Saturdays between 10:00 AM and 8:00 PM. The assistants spent a total of 38 hours conducting the survey and made 583 calls. They encountered 302 unattended calls and 131 calls answered by people who were not willing to participate in the survey. One hundred and fifty respondents (26%) answered the survey. A limited number of telephone numbers were no longer in service, and these calls were not included in the statistics.

Forty-seven percent of the attended telephone calls were answered by people who refused to participate in the survey. While some of them were openly reluctant, others excused themselves or truly could not participate. Due to the large percentage of refusals, the results may be biased if the people refusing participation perceived the survey subject differently from those who responded. This question cannot be answered and almost all surveys face the same problem.

Although the sample was selected randomly, the results were still subject to random error. Increasing the sample size can reduce this inevitable error. If the sample cannot be increased as in our case, at least the error should be estimated. Since our sample size was not large, the random error has been estimated carefully to allow proper conclusions. The standard error, and in some cases the 95% confidence interval, was estimated and reported in the results. By central limit theorem, for a sample size that is sufficiently large, the point estimator p of the true proportion P is normally distributed with (Ronald and Meyers, 1993):

$$\mu = p \tag{3.1}$$

$$\sigma^2 = \frac{pq}{n} \tag{3.2}$$

$$\sigma = \sqrt{pq/n} \tag{3.3}$$

where,

p = proportion of responses (expressed as percentage)

$q = 100 - p$

n = sample size

μ = mean

σ^2 = variance

σ = standard error.

The 95% confidence interval for the true proportion P is:

$$\mu - Z_{\alpha/2} \cdot \sigma < P < \mu + Z_{\alpha/2} \cdot \sigma \tag{3.4}$$

where,

α = level of significance (0.05 is used in this survey)

$Z_{\alpha/2}$ = z – value (assuming normal distribution) at given level of significance.

The confidence interval for the difference in proportions is used in this study to check whether the two proportions are significantly different. A 95% confidence interval for the difference of proportions not including zero value indicates that the difference is significant at the 5% level. The confidence interval for the difference of proportions p_1 and p_2 can be estimated using equation 3.4 with the following changes to the mean and variance:

$$\mu = p_1 - p_2 \tag{3.5}$$

$$\sigma^2 = \frac{p_1 q_1}{n_1} + \frac{p_2 q_2}{n_2} \tag{3.6}$$

Out of 150 respondents, 81 (54%) said that they drive on city roads, 47 (31%) said that they drive on rural roads and 22 (15%) said that they drive on both the city and rural roads equally (see Table 3.2). This may suggest sufficient representation of the city and rural road users in Indiana. With 47% males and 53% females, both genders seem to be adequately represented in the survey. Therefore, the survey seems unbiased in terms of gender and residency of the respondents. One hundred and six respondents were parents with 29 of them having children under 5 years of age, 47 with children between 5 and 16 years of age, and 21 with children between 16 and 19 years of age.

3.2.2 Survey Results

This section discusses the results of the survey and the implication of these results. The comparison of the responses given by the rural, urban, and rural-urban respondents is also included to give INDOT an idea as to where the red light violations are predominant and what programs should be undertaken in the rural and urban regions. Finally, it compares the results obtained from this survey to those obtained from the nationwide survey. The responses given by the Indiana drivers are shown in Appendix C.

TABLE 3.2 Statistics of Respondents

Statistic	All Drivers		Urban Drivers		Rural Drivers		Rural-Urban Drivers	
	%	*Standard Error (%)*	*%*	*Standard Error (%)*	*%*	*Standard Error (%)*	*%*	*Standard Error (%)*
Percentage respondents who are parents	71	3.7	72	5.0	66	6.9	77	9.0
Percentage of respondents who are males	47	4.1	42	5.5	60	7.1	36	10.2
Number of miles driven/year Less than 10,000	30	3.7	32	5.2	30	6.7	23	9.0
Number of miles driven/year 10,000 - 15, 000	30	3.7	31	5.1	28	6.5	32	9.9
Number of miles driven/year 15,001 – 20,000	18	3.1	18.5	4.3	17	5.5	18	8.2
Number of miles driven/year More than 20,000	22	3.4	18.5	4.3	25	6.3	27	9.5
Total Number of Responses	150		81		47		22	

3.2.2.1 Is red light running a problem in Indiana?

There are at least three ways in which one can measure the extent of the RLR problem:

1. Frequency of crashes caused by red signal violation,
2. Frequency of red signal violations, and
3. Public perception of the problem.

The frequency of crashes and relevant citations can be obtained from police records, whereas public opinion can be established from surveys. Although our survey was focused on drivers' perceptions, in one of the questions they were asked about their involvement in crashes caused by red light runners. This question and the crash analysis in section 3.1 help in assessing this problem.

According to the survey, a typical Indiana driver passes 16 signals daily. Almost all drivers (97%) pass at least one signal daily and nearly all respondents indicated within the range between 0 and 50 signals. The exception was professional truck drivers who pass through much more than 50 signals (two cases in the sample). On average, a road user in Indiana encounters a red signal at 60% of the signalized intersections passed (see Table 3.3). The chances of hitting red at rural and urban intersections were similar. The considerable likelihood of hitting a red signal perceived by respondents indicates that drivers in Indiana appear to consider traffic signals a significant travel obstruction.

Ninety-six percent of the respondents felt that RLR is a dangerous act (see Table 3.3), which suggests that Indiana drivers are aware of the potential consequences of RLR. On the other hand, only 66% of the respondents felt that it was a problem in Indiana. This discrepancy does not necessarily indicate inconsistency in the results. Rather, some drivers may not consider RLR a problem in Indiana if they feel that the frequency of such behavior is too low to warrant a concern. This hypothesis is supported by the percent of respondents (44%) who indicated that they seldom or never see RLR (see Table 3.4). This large percentage may explain why 34% of respondents felt that RLR does not cause severe consequences in Indiana despite their belief that RLR is dangerous.

Eighteen respondents (12%) indicated that they had been involved in a crash caused by a red light runner (see Table 3.3). Of these respondents, ten were urban drivers, four were rural drivers, and four were rural/urban drivers. From section 3.1, it can be seen that 22% of crashes at signalized intersections were caused by RLR.

The results of the survey indicate that RLR is a major problem in Indiana, as shown by the frequency of RLR reported by the respondents, the percentage who had been involved in a crash caused by RLR, and the clear majority of drivers who consider the problem serious.

TABLE 3.3 Magnitude of the RLR Problem in Indiana

Statistic	All Drivers		Urban Drivers		Rural Drivers		Rural-Urban Drivers	
	%	*Standard Error (%)*	*%*	*Standard Error (%)*	*%*	*Standard Error (%)*	*%*	*Standard Error (%)*
Average percentage of signals at which a respondent stops	60	4.0	60	5.4	60	7.1	70	9.8
Red light running is a dangerous act	96	0.0	95	2.4	96	2.9	100	0.0
Red light running is a problem in Indiana	66	3.9	62	5.4	64	7.0	82	8.2
Percentage respondents in a crash involving a red light running	12	2.7	12	3.6	9	4.2	18	8.2
Average percentage of red light violators, stopped by police	14	2.8	14	3.9	17	5.5	8	5.8
Total Number of Responses	150		81		47		22	

TABLE 3.4 How Often Do You See Red Light Violations?

Response	All Drivers		Urban Drivers		Rural Drivers		Rural-Urban Drivers	
	%	*Standard Error (%)*	%	*Standard Error (%)*	%	*Standard Error (%)*	%	*Standard Error (%)*
Everyday	27	3.6	34	5.3	23.5	6.2	14	7.4
Few times a week	29	3.7	26	4.9	23.5	6.2	50	10.7
Seldom	39	4.0	34	5.3	49	7.3	36	10.2
Never	5	1.8	6	2.7	4	2.9	0	0.0
Total No. of responses	149		80		47		22	

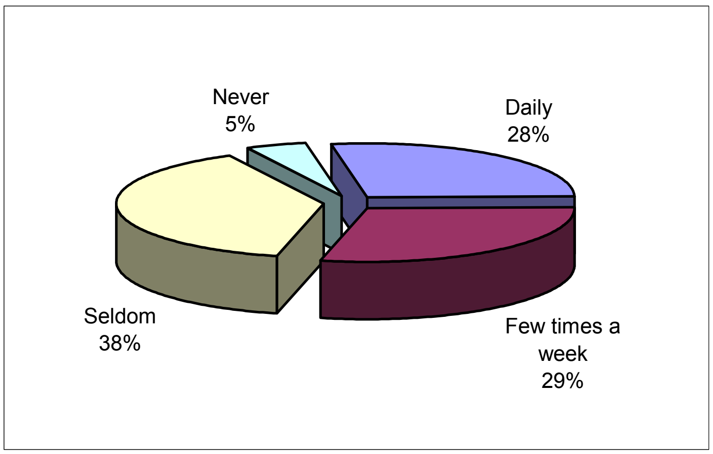


FIGURE 3.1 How often do you see red light violations?

3.2.2.2 Factors that contribute to red light running according to the respondents

Ninety percent of respondents who perceived RLR as a problem indicated that drivers violate red signals because they are in a rush or do not concentrate on the traffic situation. Only 16% indicated that not being able to stop is a frequent cause of running a red signal (see Table 3.5). The total exceeds 100% because respondents had the opportunity to indicate more than one response.

According to the respondents, 14% of red signal violators are stopped and ticketed by the police (see Table 3.3). Nearly 90% thought that out of ten, only two violators or less were ticketed (see Table 3.6). These results indicate disbelief of the respondents in the effectiveness of police enforcement at signalized intersections. A large percentage of respondents were aware that RLR was caused mainly by human behavior, not incorrect design of signals. At the same time, respondents indicated that police enforcement was not effective, and this perception may encourage some drivers to run red lights.

TABLE 3.5 Why Do People Run Red Lights?

Response	All Drivers		Urban Drivers		Rural Drivers		Rural-Urban Drivers	
	%	*Standard Error (%)*	*%*	*Standard Error (%)*	*%*	*Standard Error (%)*	*%*	*Standard Error (%)*
Could not stop in time	16	3.0	12	3.6	30	6.7	0	0.0
Were in a hurry	76	3.5	80	4.4	68	6.8	81	8.3
Not paying attention	35	3.9	31	5.1	41	7.2	41	10.5
Other	8	2.2	6	2.7	12	4.8	5	4.7
Total No. of responses	150		81		47		22	

Note: The percentages and standard errors are calculated for the number of respondents. Hence the sum of percentages may not be equal to 100.

TABLE 3.6 How Many Red Light Runners Out of Ten are Ticketed by the Police?

Response	All Drivers		Urban Drivers		Rural Drivers		Rural-Urban Drivers	
	%	*Standard Error (%)*	*%*	*Standard Error (%)*	*%*	*Standard Error (%)*	*%*	*Standard Error (%)*
0	28	3.7	27	4.9	24	6.2	41	10.5
1	40	4.0	41	5.5	31	6.7	55	10.6
2	21	3.3	22	4.6	28	6.5	0	0.0
≥ 3	11	2.6	10	3.3	17	5.5	4	4.2
Total No. of Responses	150		81		47		22	

3.2.2.3 Measures suggested by the respondents to improve the situation

Respondents were allowed to choose multiple answers to the question about effective methods of dealing with RLR (see Table 3.7), and could add their own ideas. A majority of the respondents felt that increasing fines or police enforcement are good measures to improve the situation. This response agrees with the common belief expressed by the response to another question, i.e., that in most cases, drivers cause the danger. Twenty percent of respondents were concerned about the signals. Some respondents gave more detailed suggestions, such as improve uniformity of signal displays, increase the size of red signals, install more actuated signals, and introduce a flashing yellow signal shortly before red. Ten of those respondents suggested the use of RLR cameras.

TABLE 3.7 Which of the Following Measures Do You Think Help to Reduce RLR?

Response	All Drivers		Urban Drivers		Rural Drivers		Rural-Urban Drivers	
	%	*Standard Error (%)*	*%*	*Standard Error (%)*	*%*	*Standard Error (%)*	*%*	*Standard Error (%)*
More education	16	3.0	16	4.1	17	5.5	13	7.2
Improve stoplights	20	3.3	21	4.6	22	6.0	18	8.3
Increase fines	32	3.8	36	5.3	36	7.0	18	8.3
Police enforcement	46	4.1	49	5.6	42	7.2	45	10.6
Other:	20	3.3	11	3.4	27	6.5	37	10.3
Total No. of responses	150		81		47		22	

Note: The percentages and standard errors are calculated for the number of respondents. Hence the sum of percentages may not be equal to 100

3.2.2.4 Do Indiana drivers support photo-enforcement?

A majority of respondents were inclined to favor photo-enforcement in Indiana, with 54% supporting and 24% strongly supporting the measure (see Table 3.8). Twenty-two percent were against photo-enforcement including 6% strongly opposing it. Many respondents indicated they were aware that photo-enforcement was used in other states.

Previous studies also found that people are receptive to photo-enforcement technology. For example, in a survey conducted by the Insurance Institute for Highway Safety (IIHS, March 1998), 61% percent of all the respondents and 83% of urban respondents supported red light cameras. It also states that 80% of those surveyed in Oxnard, California and Fairfax, Virginia supported photo-enforcement.

TABLE 3.8 Support for Photo-enforcement

Response	All Drivers		Urban Drivers		Rural Drivers		Rural-Urban Drivers	
	%	*Standard Error (%)*	*%*	*Standard Error (%)*	*%*	*Standard Error (%)*	*%*	*Standard Error (%)*
Strongly Support	24	3.5	24	4.7	20	6.0	27	9.5
Support	54	4.1	51	5.6	60	7.3	55	10.6
Oppose	16	3.0	19	4.4	13	5.0	9	6.1
Strongly Oppose	6	2.1	6	2.6	7	3.8	9	6.1
Total No. of responses	148		81		45		22	

3.2.2.5 Indiana vs. other states

The survey sponsored by Daimler-Chrysler (Porter, et al., 1999) included forty states excluding Indiana. Tables 3.9 through 3.13 compare several results obtained in that survey with the results obtained in our survey for Indiana. The average sample size of Daimler-Chrysler's survey (See Table 3.9) is approximately 400 in their ten target states while our sample was 150. Also, the percentage of male respondents in our survey was larger than that for the other states.

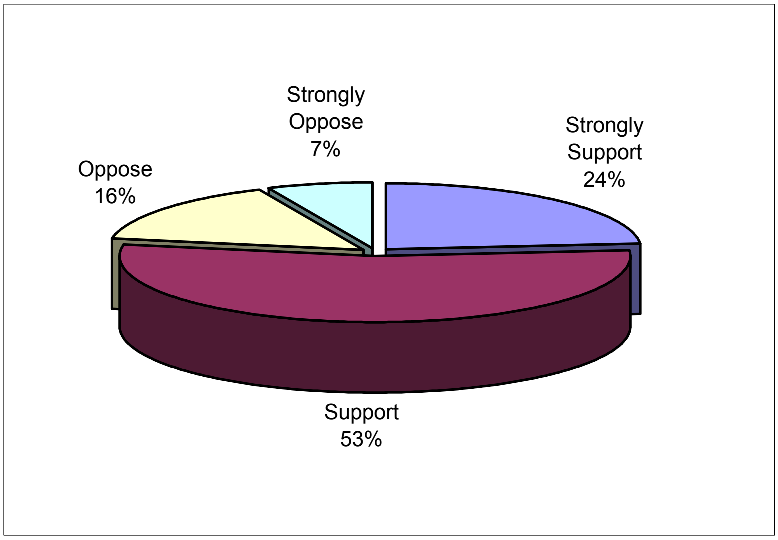


FIGURE 3.2 Support for photo-enforcement

TABLE 3.9 Comparison of Sample Characteristics

State	Sample Size	% Males	% Females	% Parents
Alabama	474	39.5	60.5	79.9
Arizona	410	39.3	60.7	75.9
California	353	41.6	58.4	73.1
Colorado	442	39.6	60.4	72.6
Florida	359	42.1	57.9	79.1
Michigan	460	35.2	64.8	73.9
New Jersey	348	38.2	61.8	73.6
New York	336	40.8	59.2	74.7
South Carolina	432	36.8	63.2	75.5
Texas	393	33.1	66.9	77.1
Comparison 40	1017	35.2	64.8	78.1
Indiana	150	46.6	53.4	70.7

The percentage of people who felt that red light violation is a problem in Indiana is smaller compared to other states (See Table 3.10). The states with comparable percentages of people who felt RLR was a problem in their states were the northern states

(Michigan, New Jersey, and New York). The percentages for New York and New Jersey are significantly higher than that for Indiana. None of the 95% confidence intervals for differences in proportions includes zero, which suggests that the results from our survey are significantly different from the results from the other states. Although the opinion about police effectiveness in enforcing compliance to red signals is the lowest in Indiana (see Table 3.11), the difference between Indiana and other states is small and statistically insignificant.

TABLE 3.10 Is Red Light Running a Problem?

State	**Red Light running – a problem? (% Yes)**	**Difference**	**Confidence interval of the difference**	**Red light Running is Dangerous? (% Yes)**
Alabama	80	14	(6,22)	99
Arizona	87	21	(13, 29)	99
California	84	18	(10, 26)	98
Colorado	85	19	(11, 27)	99
Florida	84	18	(10, 26)	98
Michigan	75	9	(0, 18)	99
New Jersey	78	12	(3, 21)	99
New York	80	14	(5, 23)	99
South Carolina	82	16	(8, 24)	100
Texas	84	18	(10, 26)	98
Comparison 40	77	11	(3, 19)	99
Indiana	66			96

The responses to the question about the measures of reducing RLR (see Table 3.12) cannot be easily compared between Indiana and the other states because the questions were not identical. Although Indiana drivers had an opportunity to give their own suggestions, the Indiana questionnaire had specified the following five choices: more education, police enforcement, increase the fines, improve stoplights, and ‘Other’.

The questionnaires in other states did not offer any choices and relied only on the respondents' suggestions. The percentages shown were calculated per total number of responses. Although the Indiana respondents were given 'more education' in the choices, they did not feel that such a measure would be effective in Indiana. The number of those people who support measures such as 'increase in fines' and 'police enforcement' were significantly higher in Indiana, which could be due to the difference in the design of the question. There is no notable difference in the percentage of respondents who indicated photo-enforcement as an option. Please keep in mind that photo-enforcement was not on the list and was added by the respondents as one of the other measures.

TABLE 3.11 How Many Red Light Violators are Ticketed by the Police?

State	Sample Size	Mean (%)	Standard Deviation (%)
Alabama	474	22	20
Arizona	410	20	20
California	353	17	17
Colorado	442	19	18
Florida	359	17	17
Michigan	460	18	17
New Jersey	348	22	21
New York	336	20	18
South Carolina	432	20	19
Texas	393	20	20
Comparison 40	1017	20	19
Indiana	150	14	16

Other surveys conducted by FHWA (FHWA Press Release, September 1998) found that RLR is a major problem in many communities. The respondents said that they see the violations frequently. The important results, classified by the states, are summarized in Table 3.13 and compared with those obtained in Indiana. The frequency of observing red light runners by Indiana respondents is very low compared to that in other states. A higher percentage of Indiana drivers felt that the violators were in a hurry when compared to the observations made in other states.

TABLE 3.12 Measures to Reduce Red Light Violations

Suggestion	**Indiana (%)**	**Comparison 40 (%)**
No ideas	0	25
More education	12	15
Increase fines	24	11
Police enforcement	35	15
Change signal timings	15	3
Photo-enforcement	5	8
Driver Improvement Clinics	0	2
Other	9	21

TABLE 3.13 Comparison of Selected Responses

State	**Frequently see RLR**	**Know Person Injured in RLR Crash**	**RLR Caused by Rushing**	**RLR did not Reduce**
California	67	34	61	84
Washington DC	67	25	70	89
Florida	75	34	61	85
Illinois	50	25	62	86
Massachusetts	60	25	66	84
Michigan	60	25	55	91
New York	60	25	63	78
Texas	67	34	66	89
Washington	67	34	59	84
US	67	34	60	94
Indiana	27	12 % (Injured themselves)	76	-

Source: FHWA Press Release, 1998

3.3 Summary

The crash statistics and the survey clearly show that a majority of Indiana drivers feel that RLR is a dangerous act and is in fact a problem in Indiana. It has to be added though that the percent of Indiana drivers concerned about RLR is lower than in others states. The crash statistics also showed that 22% of crashes at signalized intersections were caused by RLR, and 30% of all fatal crashes at signalized intersections were caused by RLR. Indiana had 2.7 fatalities/100,000 people caused by RLR between 1992 and 1998, and is ranked tenth among the states with high fatality rates.

Fifty-six percent of the respondents see red light violations at least once a week, and approximately 12% had been involved in a RLR crash, which strengthens the fact that RLR is a major and frequent cause of accidents at intersections.

Ninety percent of Indiana drivers who responded to the survey were aware that the main cause of RLR is drivers who are in hurry or not paying attention. According to the respondents, the police issue tickets only to 14% of red signal violators, a perception that might encourage drivers to violate red signals. Enforcement in the form of increased fees, intensified police enforcement, or photo-enforcement were considered as effective methods of dealing with RLR, and 78% of the respondents supported photo-enforcement when directly asked about it.

The results indicate that the problem of RLR exists in Indiana. Two selected RLR countermeasures were tested and evaluated, which will be discussed in the following chapters. Attempts were also made to identify the effects of some RLR factors – students, time of day, and day of week. Different methods were developed to facilitate this investigation and are discussed in the next chapter.

4. INSTRUMENTATION AND METHODS OF MONITORING RED LIGHT RUNNING

To investigate the changes in driver behavior as a result of various enforcement activities, the red light violations need to be monitored before, during, and after the enforcement measure is applied. Because it is manpower-intensive, a machine-aided technique would significantly reduce the time and labor required to process data. We will attempt to develop a machine-aided method of monitoring RLR for this research.

The Northwestern Avenue and Stadium Avenue intersection in West Lafayette, Indiana was selected for the study. This intersection is signalized and has cameras monitoring all four approaches. Figure 4.1 shows a schematic diagram of the intersection, and includes details such as the phase diagrams, pedestrian phases, and the locations of cameras and traffic cabinets. The Harold Michael Traffic Operations Laboratory and the Transportation Applications Laboratory in the School of Civil Engineering at Purdue University in West Lafayette, Indiana, provided a well-instrumented environment for developing and evaluating a prototype method to monitor RLR.

States that implemented photo-enforcement used cameras and inductive loops in conjunction with the signals to detect the red light violations. The existing photo-enforcement camera principles were employed to develop a prototype method. The prototype method used video cameras to detect the RLR activity continuously during an extended period.

This chapter explains the working principles of existing photo-enforcement cameras and the test facility used to develop our monitoring tool. The procedure used to test and evaluate the machine-aided system with accompanying performance evaluation method and obtained results are also presented.

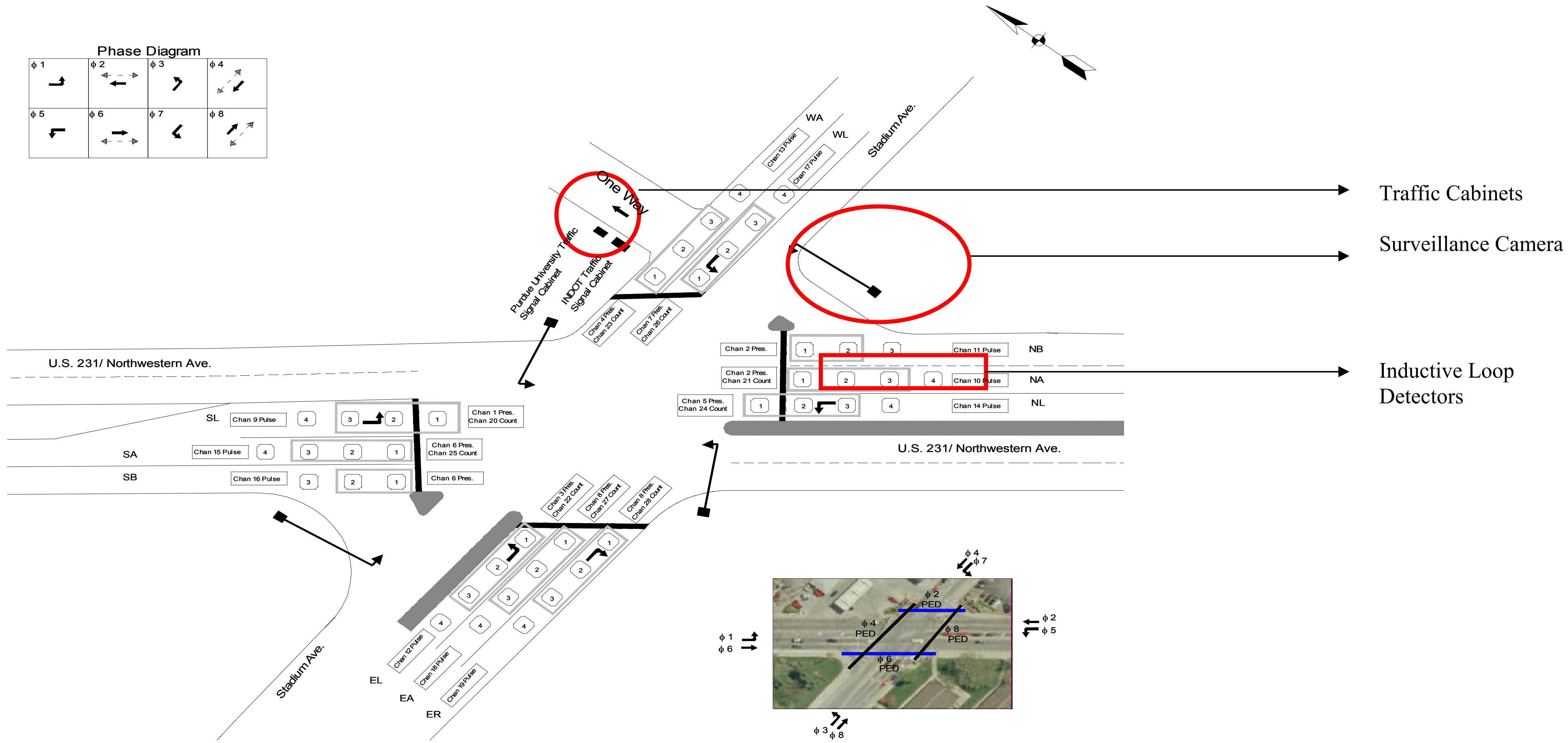


FIGURE 4.1 Details of the Northwestern Avenue and Stadium Avenue intersection
(Source: Grenard, Tarko and Bullock, 2001)

4.1 Principles of Red Light Cameras

Several past studies explained the working principles of traditional red light cameras (Walter, 2000; Stevens, 1999; FHWA 2000E; Passetti, August 1997; Hansen, 2000; Smith et al., July 1999; Sisiopiku et al., January 2002; Kamyab et al., December 2000; Fleck and Smith, March 1999). Four cameras are used at intersections to monitor each approach separately. The system is connected to a traffic signal controller to monitor the red phase of an approach. Figure 4.2 shows the typical location and function of a camera for one approach. The camera system is also connected to inductive loops, or piezoes, in the road to detect the presence and to measure the speed of a vehicle. After the start of the red phase, a fast vehicle traveling over the detectors activates the camera, which takes two photographs - one while the vehicle is at the stop bar and the other when it is beyond the stop bar. The vehicle speed must be higher than a specific threshold to allow camera activation. The speed criterion helps distinguish between fast vehicles moving straight and violating red the signal and slow vehicles legally turning right on red. The time elapsed since the beginning of the red phase is measured and compared with a grace time (typically a fraction of second). Drivers passing a stop bar within the grace time are not ticketed. If a vehicle stops on the loop during the red signal, no photograph is taken.

Color photography helps document that the traffic signal is red. The electronic flash used in the system can produce clear images of vehicles under all light and weather conditions. Each photograph is superimposed with the date and time of the violation, the number of seconds since the signal turned red, and the speed at which the violation occurred. The photos are reviewed and screened by enforcement personnel. The photos may be used as evidence in court if the local law permits.

A central server facility is used to transfer the photos from the intersection to the server, allowing only secured personnel to access the information, send tickets, or produce evidence material for court. A secure server protects the sensitive information and thereby makes the data trustworthy.

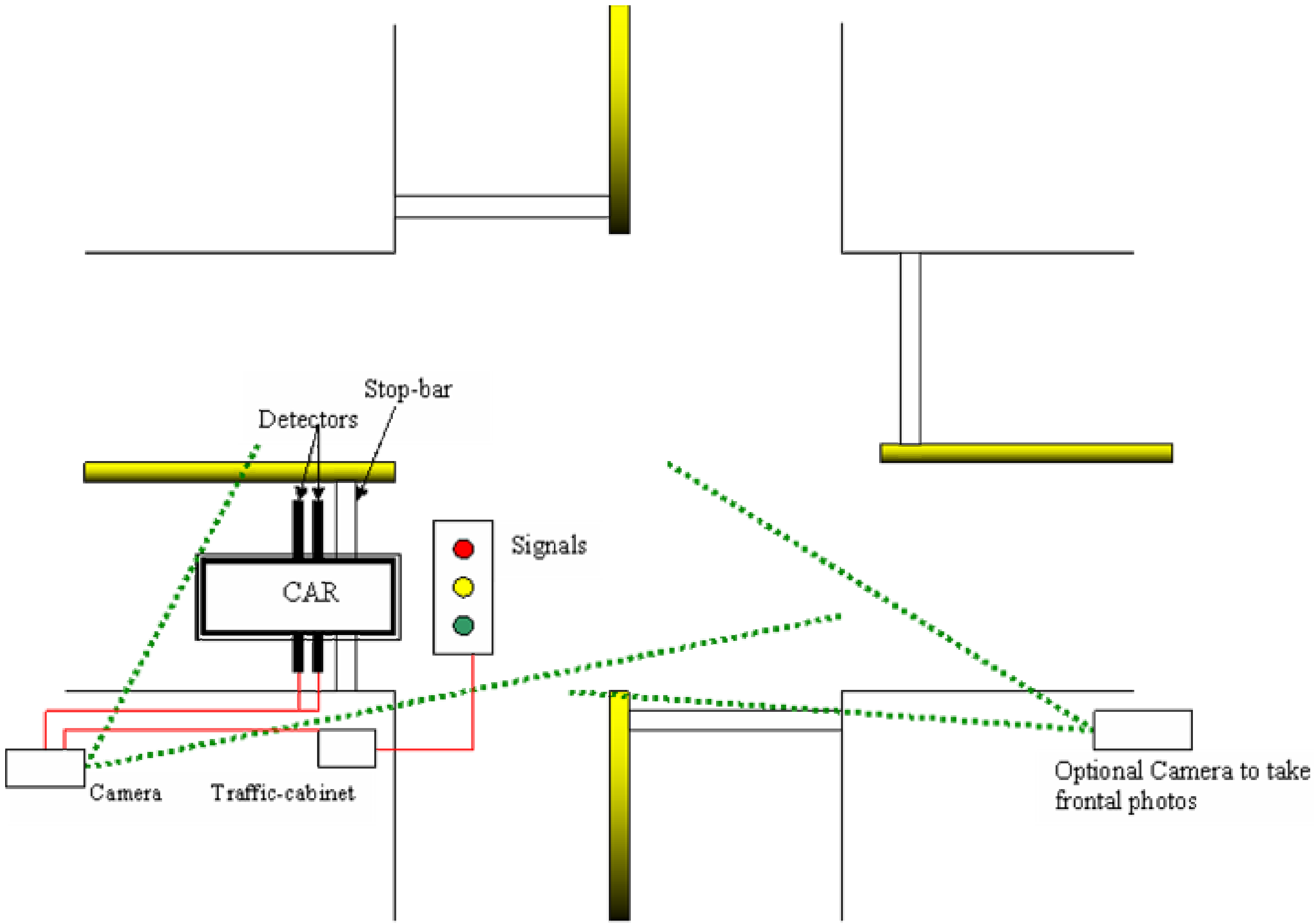


FIGURE 4.2 A typical RLR camera installation

To reduce the system and installation costs, a single red light camera can be used at several properly equipped locations. The camera is moved between sites and drivers do not know where the camera is at any given time. Startup costs can be covered with fines paid by violators. The savings include the cost of prevented crashes and the cost savings by the police.

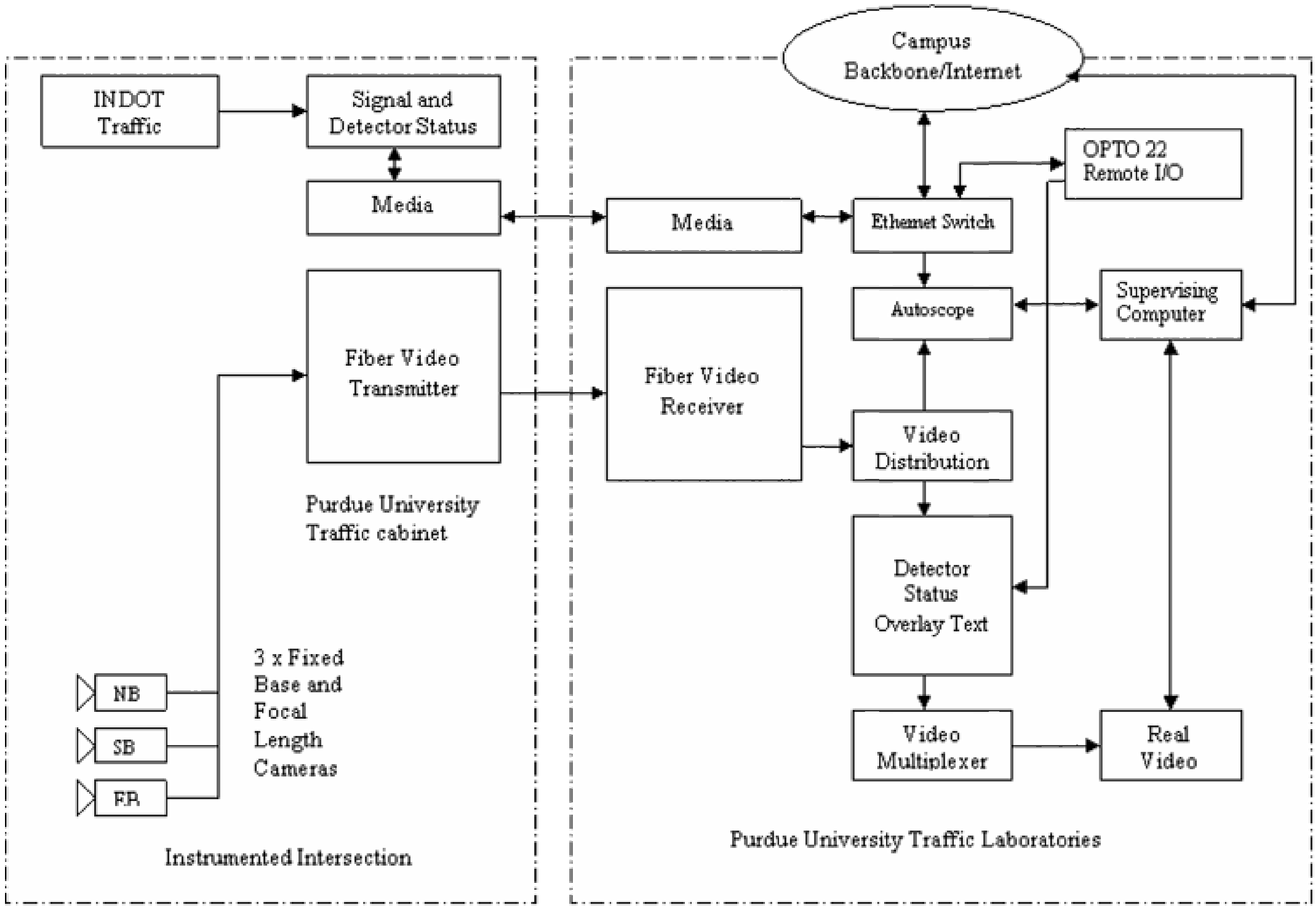
Our research uses three surveillance cameras installed at the selected intersection for monitoring the approaches. Autoscope was used to place virtual detectors that emulate the function of inductive loops. The model developed is only a prototype to detect red light violations, and cannot be used in real-time or to detect license plate numbers**. It has been developed without any Autoscope technical support and for research purposes only. The results related to the system performance do not constitute any basis for evaluating the usefulness of Autoscope and any other video detection system for neither RLR monitoring nor enforcement.** The test facility and the functions of each component are explained in the following section.

4.2 Test Facility Instrumentation

The Harold Michael Traffic Operations Laboratory and the Transportation Applications Laboratory at Purdue University provided an infrastructure needed to develop and evaluate a prototype method to monitor RLR. The joint laboratory equipment used in this project included four components:

1. Instrumented signalized intersection,
2. Intersection-laboratory communication,
3. Autoscope system, and
4. Video acquisition system.

The primary units of the test facility used in this project are presented in Figure 4.3. The real-time video and signal data are sent from the instrumented intersection via fiber optic cable to the Traffic Laboratory and from there via coaxial cables to the Transportation Applications Laboratory. The signals and traffic input from the intersection are analyzed in real-time with the Autoscope 2004 system and raw data files were produced. These data files have to be processed to determine the red light violations.


INDOT
Traffic
Signal and
Detector Status
Media
Fiber Video
Transmitter
Purdue University
Traffic cabinet
NB
SB
EB
3 x Fixed
Base and
Focal
Length
Cameras
Instrumented Intersection
Campus
Backbone/Internet
OPTO 22
Remote I/O
Media
Ethernet Switch
Autoscope
Supervising
Computer
Fiber Video
Receiver
Video
Distribution
Detector
Status
Overlay Text
Video
Multiplexer
Real
Video
Purdue University Traffic Laboratories

4.2.1 Instrumented Intersection

The Northwestern-Stadium intersection equipped with surveillance cameras is a vital component of this research. This intersection is skewed with high vehicular and pedestrian traffic, and traffic volumes vary widely during vacations and athletic events. Considerable pedestrian traffic poses a challenge to video-based monitoring of RLR.

The major components of the instrumented intersection, as shown on the left side of Figure 4.3, include three surveillance cameras, the Purdue University traffic cabinet, and the INDOT traffic cabinet. Figure 4.1 shows a map of the intersection with the locations of these components. Four fixed-base cameras (one for each approach) are currently installed at the intersection, but only three of them (NB, SB, and EB) were used in this research. Figure 4.4 shows a typical surveillance camera used in the research. The video input from these cameras and the signal and detector status data from the INDOT traffic cabinet are transmitted via the Purdue University traffic cabinet and the fiber optic cable to the Traffic Laboratory. The video images and the control signals received in this laboratory are of uncompromised quality.

FIGURE 4.4 Fixed-base surveillance camera

Source: Grenard, Tarko and Bullock, 2001

4.2.2 Intersection-Laboratory Communication

Fiber optic cables were used to carry video input and traffic signal data between the instrumented intersection and the two laboratories. Coaxial cables were used to transmit data within the intersection and within the traffic laboratories. The video and signals data were directly fed to the Autoscope system using the coaxial cables.

4.2.3 Autoscope System

The Autoscope is an image processor, a technology that combines video imaging with pattern recognition. It contains a microprocessor-based CPU, specialized image processing boards, and software to analyze these video images. We used the fourth generation model, Autoscope 2004, for this research, which is depicted in Figure 4.5. The Autoscope processor is fed by the video and traffic signal input coming from the intersection, and the information from the various detectors is combined with logical operations.

The Autoscope system is connected to a supervising computer (see Figure 4.5), which contains software that controls the Autoscope operations and facilitates placing virtual detectors on video images. The detector's operation can be viewed on the screen and the detector can be easily reconfigured if needed. The supervising computer is also used to run the post-processing software for extracting red signal violations from the event files generated by the Autoscope unit.

The following can be measured by placing the appropriate detectors in the field of view: traffic counts and classification, speeds, volumes, occupancy, incident detection, and detection of signals.

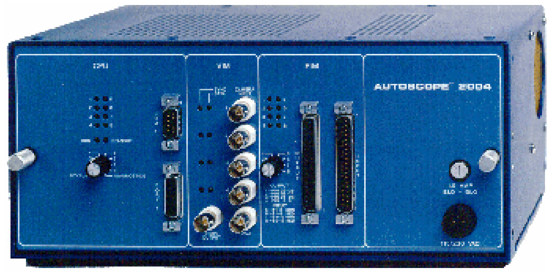


FIGURE 4.5 Autoscope 2004 – Image processor

Source: Grenard, Tarko and Bullock, 2001

4.2.4 Video Acquisition System

The video signal received in the Traffic Laboratory was split between the Autoscope and the Video Acquisition system (Figure 4.3). The Video Acquisition system includes the OPTO 22 server, which produces time stamps and signal status overlay on video images from the four fixed-base cameras. The video images were then sent to the multiplexing unit where they were combined into one image and arranged in quadrants. The multiplexed image was recorded and stored digitally on the supervising computer with the Real Producer software. The quality of these images has been compromised to save the storage demand, but the video signals sent to the Autoscope for real-time processing are of non-compromised quality. Figure 4.6A shows how the four approaches are merged into one image and the text is superimposed over it. Important information like the date, time, directions, and phases can be seen in the image.

4.3 Methods of Monitoring

Two methods were developed to monitor the intersection and to evaluate the effectiveness of the countermeasures. They are:

1. Direct Monitoring Method, and
2. Machine-aided Monitoring Method.

4.3.1 Direct Monitoring Method

As the name suggests, the direct monitoring method involves human observation without the use of any automation techniques. Traffic at the intersection, along with the superimposed signal data was recorded and saved as a video file (*.RM / *.RAM format). This video was later observed to extract the red light violations. With this method the vehicle class could be obtained, but vehicle speed and the time of occurrence of violation from the start of the red could not.

This method required considerable time to watch the video files. On the other hand, it was considered reliable and was used to obtain ground-truth data. Figures 4.6A through 4.6D show a sample case of a car violating a red signal on the NB approach. They also show how the video file looks with the overlaid status of the signal phases, date, time, and directions. The status of the signal phases is denoted by a dot (Red signal), or ‘Y’ (Yellow signal), or ‘G’ (Green signal). From Figure 4.6A, the following information can be obtained.

1. The time was 4:13:10 PM on March 13, 2001.
2. The vehicle was approaching from the NB.
3. Yellow signals were displayed for phase 2 (NB) and phase 6 (SB).

Figure 4.6A shows the car approaching the stop-bar while the signal is yellow (phase 2). Figure 4.6B shows the car inside the stop-bar while the signal now shows red. Figure 4.6C shows the car crossing the stop bar on red. Figure 4.6D shows the car inside the intersection, which means that it has violated the red signal. The car can now be seen in the quadrant marked “WB” in Figure 4.6D, which confirms the violation.

There is a lag of 0.2 seconds between the signal status change and the time it is received in the Traffic Laboratory and superimposed on the video. This lag was assumed to be a tolerance (or grace time) provided to all the drivers and is explained later in section 5.4.

The direct monitoring method could not be easily evaluated because it is considered the most precise method available. All the approaches could be monitored, including the through and turning movements. The false and missed detection rates are expected to be infrequent and attributed to the observer's mistake. There might be cases of misdetection if a vehicle crosses the stop-bar exactly at the beginning of the red signal, which meant that it might or might not be classified as a violation depending on the observer's judgment. To overcome this, a new column was added to the verification file, allowing observer's comments on the violation. The observer may or may not classify it as a violation based on his judgment, but at the same time, a comment was expected stating it was a questionable case.

4.3.2 Machine-aided Monitoring Method

The primary objective of developing the machine-aided method was to reduce the time required to process the information without sacrificing performance of the system. Only the Autoscope standard features were used including directional and input detectors. The system has been designed to detect nearly all red signal violations at the expense of a considerable number of false detections with the intention of removing them by using the direct monitoring afterwards. Therefore, the false detections at the end of the process would technically be zero with a low number of missed detections. The number of detectors was kept as small as possible to avoid too high computational load of the Autoscope processor. Autoscope resolves the computational overload by skipping image frames which reduces the number of pixels to process but increases the risk of missed detections. The detector configuration and the evaluation procedure are explained in the following subsections and the results obtained are discussed as well.

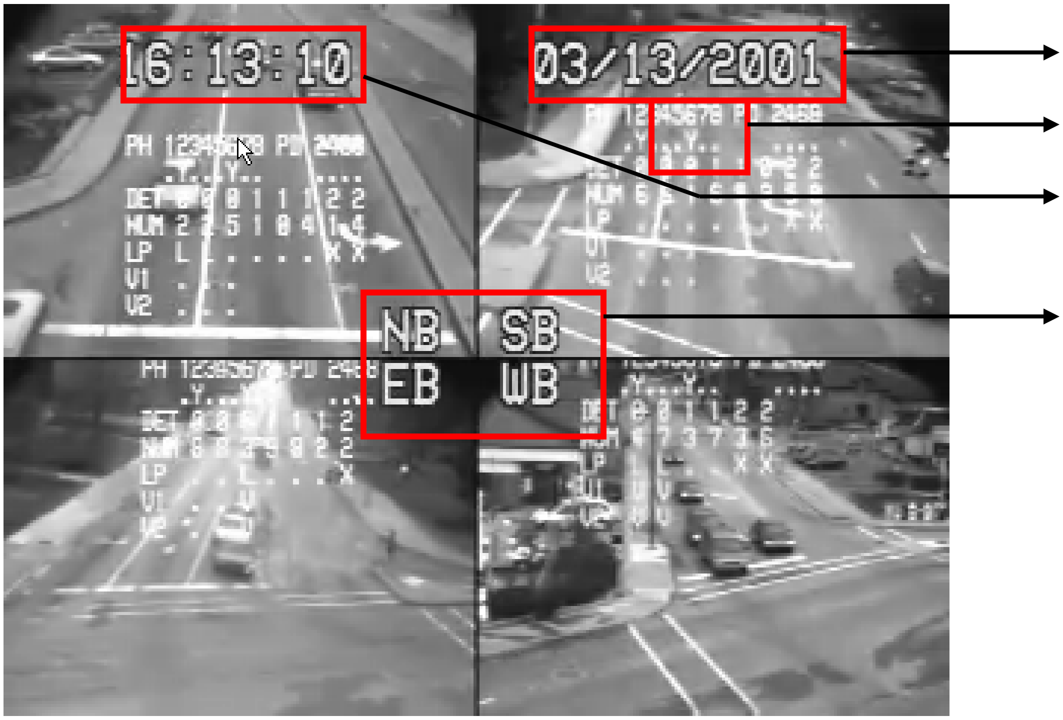


FIGURE 4.6A Snapshot showing a car violating red

FIGURE 4.6B Snapshot showing a car violating red

FIGURE 4.6C Snapshot showing a car violating red

FIGURE 4.6D Snapshot showing a car violating red

It should be noted that the presented tool and its performance cannot be considered a test of the Autoscope ability to detect RLR. As was mentioned, we used the Autoscope system as a research tool to reduce the effort and time required for long-term RLR monitoring. Given the limited resources, only the standard features of the Autoscope were used without the Autoscope vendor involvement.

4.3.2.1 Detector configuration

Developing a suitable and efficient detector layout turned out to be a long and iterative process. The presented final detector layout is supplemented with comments – the lessons learned during its development. In a typical installation, one camera per approach should suffice. Since each lane is monitored separately, it is appropriate to discuss a detector layout for a single lane.

Since the test included the through movements for NB, SB, and EB approaches of the instrumented intersection, three cameras were used, one camera for each approach. Using the fields of view of the cameras, virtual detectors were placed on the images.

The detector layout for a through-lane is as follows and a schematic drawing in Figure 4.7 shows the detector components. A *stop-bar detector* was placed near the stop bar, with a *speed detector* stretching upstream of the stop bar. Strong winds can cause false detections if the count detector is too close to the stop bar. An additional detector, called a *signal detector*, is used to input the status of the red signal, which generates an ON signal as long as a red signal is displayed for the lane. The stop-bar and the signal detectors were connected using a logical operation AND. The corresponding *AND detector* generated the ON signal when a vehicle was detected by the stop-bar detector and at the same time the signal detector showed a red signal. It was found that the configuration of the count and red-signal detectors generated numerous false detection instances. For example, pedestrians crossing the lane, the shadows of vehicles in adjacent lanes, and sunlight glare on vehicles caused frequent false detections. These false cases were later removed after verifying with the video data collected. Another detector called the *station detector* was also connected to the stop-bar detector to collect important interval data (15-minute interval) like volume, density, average speed, average headways, delay, LOS, etc.

Screen capture from the supervising computer (Figure 4.8) shows the detector configuration. The picture shows an image from the NB fixed-base camera, with similar detector configuration as shown in Figure 4.7 on both through lanes of the NB approach.

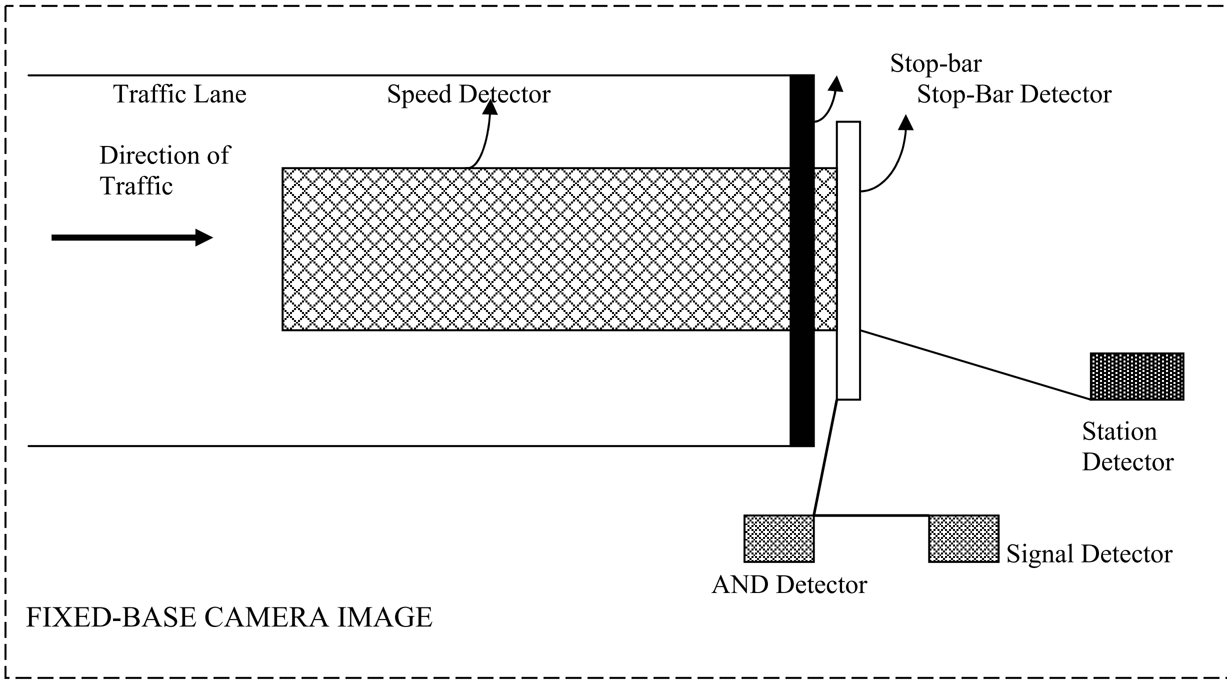


FIGURE 4.7 Typical detector configuration used in the semi-automatic system

4.3.2.2 Detection algorithm

The raw data files obtained from the Autoscope were imported into MS Access and saved in a table named MONDD, where MON stands for the month and DD stands for the date. SQL queries (see Appendix D) were written to extract all the possible cases of violations from the raw data file. Two constraints were used so as to obtain all possible cases of violation:

1. The violation occurred within two seconds of the start of the red.
2. The detector on-time is less than or equal to 1,500 milliseconds.

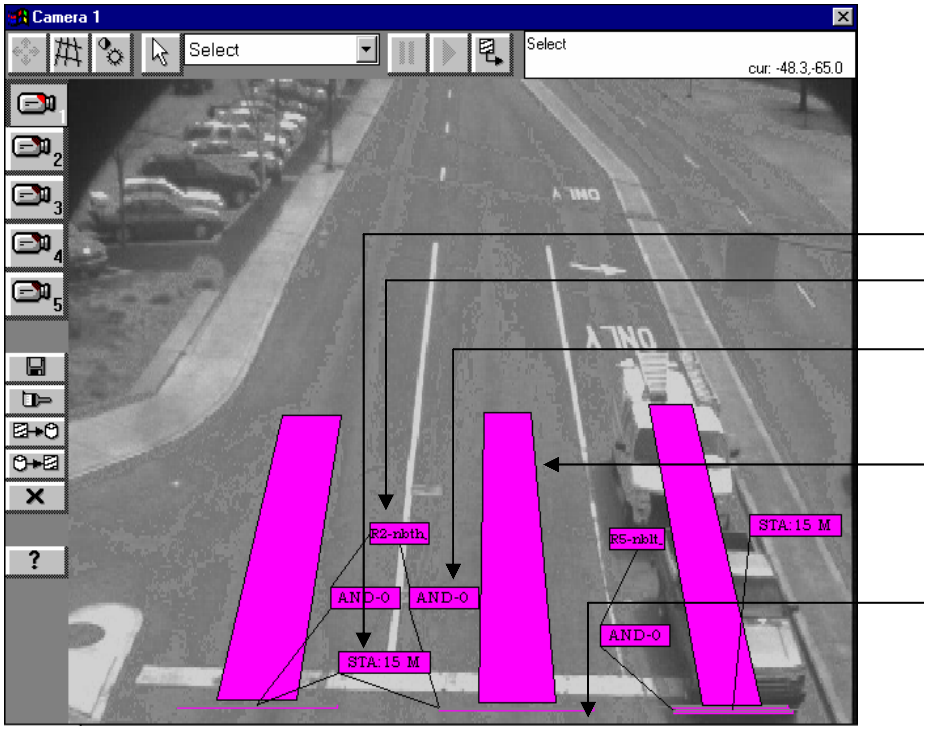


FIGURE 4.8 Snapshots of a typical detector configuration as seen in Autoscope

All of the violations were found to occur during the first two seconds from the start of red. When a three second threshold was used instead of two seconds, no missing detections were observed. Unfortunately, many unwanted false cases were reported, which would significantly increase the time needed to verify the results with video data. A two-second threshold was finally used. In addition, it was observed that moving vehicles do not occupy detectors longer than 1.5 seconds. Hence, the 1.5-second constraint on the detector occupancy time was used to further reduce the number of false detections. These limits were chosen after many observations and also after observing the cases of extracted violations when these limits were changed. Increasing these limits returned a large number of false cases as violations, which would require more time verifying these additional cases reported.

Direct monitoring was used to verify if the reported violation was indeed an actual violation. The query was written to search in a table called “temp” and not directly in MONDD, since this would require us to write a separate query for each day monitored.

So a general name “temp” was used in the query and the name of the table from which we extracted the violation data was changed to “temp”. The table was renamed as MONDD once the violations were extracted and exported to Excel (named as MONDD.xls).

The RLR data obtained from the machine-aided method for the NBTH is shown in Appendix E, and the RLR results obtained by direct monitoring method are shown in Appendix F.

4.3.2.3 Discussion of results

Video material collected between November 6 and December 22, 2001 was used to evaluate the machine-aided monitoring method. A two-hour period of video data, from 3 PM to 5 PM, was observed each day in November and on alternate days in December. Table 4.1 shows the days in which RLR data was collected from the recorded video. All directions and movements were observed to record violations, but only NBTH, SBTH and EBTH were considered for further analysis, since the system was used to monitor only these movements. Approximately 68 hours of video data was observed and 64 violations were recorded for the three through movements.

Violations for the same period were extracted using the machine-aided method and then verified by comparing to the ground-true data. From Table 4.1 it can be seen that the data is not available for three days during Thanksgiving, which is because either the Autoscope data file was corrupted or the video data was not available. If no violations were observed during the two-hour period when the video was watched, such days were not included in calculating the average detection rate since it could skew the results. The SBTH detectors did not function on November 29, and three violations were subsequently missed by the system on that day. Therefore, the detection rate on that day is low. If this day were removed from analysis, the average detection rate would increase considerably. The performance is very poor between November 24 and November 26. The uneven performance of the method with the tendency to decline was the major concern. A significant bias may be introduced to the research results due to the observed tendency.

TABLE 4.1 Evaluation of Machine-aided Monitoring

DATE	Day	No. Of Hrs Observed	Total Violations	No. Of Missed Violations
6-Nov	Tue	2	4	0
7-Nov *	Wed	-	-	-
8-Nov	Thu	2	3	0
9-Nov *	Fri	-	-	-
10-Nov	Sat	1.5	4	0
11-Nov	Sun	2	4	1
12-Nov	Mon	3	6	1
13-Nov	Tue	3	4	1
14-Nov	Wed	3	2	0
15-Nov *	Thu	-	-	-
16-Nov	Fri	3	7	1
17-Nov	Sat	2	2	1
18-Nov **	Sun	2	0	0
19-Nov **	Mon	2	0	0
20-Nov	Tue	2	1	0
21-Nov **	Wed	2	0	0
22-Nov **	Thu	2	0	0
23-Nov **	Fri	2	0	0
24-Nov	Sat	2	1	1
25-Nov	Sun	2	2	1
26-Nov	Mon	2	2	1
27-Nov	Tue	2	1	0
28-Nov	Wed	2	1	0
29-Nov ***	Thu	2	4	3
30-Nov	Fri	2	3	1
1-Dec	Sat	2	1	0
6-Dec	Thu	2	5	4
8-Dec	Sat	2	1	0
10-Dec	Mon	2	1	0
12-Dec	Wed	2	0	0
14-Dec	Fri	2	2	1
16-Dec	Sun	2	0	0
17-Dec	Mon	2	1	0
20-Dec	Wed	2	1	1
22-Dec	Fri	2	1	0
Totals		67.5	64	18

* Video Data was not available or Autoscope data was corrupted.
** Since no violations were observed, these days were not included in finding average violation rate.
*** SBTH and EBTH detectors did not function the whole day and so we have missed 3 violations on these approaches. If we omit this day, the average detection rate is 75%, an increase of about 3%.

Table 4.2 shows the true number of violations, the number of missed violations, and detection rates for the period of evaluation by directional movement. The performance on the NB approach is better than on the other two approaches. The performance on the SB approach is very poor due to the malfunction of the detectors on November 29 as previously mentioned. If this day were removed from the calculations, the detection rate would increase to 75%, an increase of approximately 20%. The poor performance of the system in these directions could be due to the lack of a proper field of view of the camera. The detectors need to be placed in such a way that they are a sufficient distance from the stop bar or pedestrian cross walks so that the camera movement does not cause false violations. They also need to be placed in the path followed by the vehicles from that lane only so that vehicles from other lanes and cross streets do not cause false detections. This restricts the position and size of the virtual detectors placed in the camera's field of view, which could have caused some of these missed detections. The overall detection rate was found to be 72%.

TABLE 4.2 Machine-aided Method Evaluation – by Direction

Direction	**No. Of Violations**	**Missed Violations**	**Detection Rate (%)**
NB	37	7	81
SB	11	5	55
EB	16	6	63
Total	64	18	72

4.3.3 Selected Method of Monitoring

The average detection rate for the machine-aided method was 72%. The system worked well for the NB approach with an 81% detection rate, which might be due to the better field of view of the camera than for other approaches.

The direct monitoring method is more reliable, but it has disadvantages. The correct speed of the vehicle during the course of its violation and the time of occurrence of the violation from the start of red cannot be obtained. However, the high accuracy of the system outweighs its disadvantages, and for that reason the direct monitoring method was selected as the monitoring tool to obtain ground-truth data and to evaluate enforcement measures. Given the evaluation results, the direct observation method of monitoring was used as the leading method. The machine-aided method was utilized only to evaluate the differences in RLR behavior between the daytime and nighttime conditions on the NB approach.

5. EVALUATION OF ENFORCEMENT EFFECTIVENESS

The survey results in Chapter 3 indicated that 78% of the respondents felt that strict enforcement measures were necessary to change driver behavior. It was decided to evaluate the effectiveness of two of these enforcement measures – police enforcement and photo-enforcement. The test bed facility described in the previous chapter was used to monitor the intersection and extract the red light violations. This intersection was monitored for extended periods of time before, during, and after the enforcement. The violation rate and frequency were evaluated. Statistical analysis was done to check the significance of the differences in the violation rates/frequencies between different periods.

This chapter first presents a summary of past research results. The method employed to evaluate the effectiveness of the enforcement measures is then described in detail. A new approach developed as a part of this research to measure RLR, called "opportunity", is also explained. The statistical procedure adopted to find the significance in the observed changes and the obtained results are then discussed thoroughly.

5.1 Past Research

Cooper, P.J., found a significant decrease (~25%) in RLR after implementing police enforcement at selected intersections in Canada. They collected data before, during, and after the enforcement at six selected sites. Tarawneh et al., (January 1999) implemented police enforcement at six signalized intersections where the observed accident rate was high. One officer would stand inconspicuously at the intersection and send messages to another officer if he finds anyone violating the signals. They did not find a significant difference between the effects of public education versus the combined effect of public education and police enforcement. They also cite the work of Marsh, B.W., who reported a 30% reduction in crashes in Jackson, Michigan. He also found that

Evanston, Illinois did not have any fatalities for 199 days. Tarawneh et al., (January 2001) conducted a drivers' survey before and after implementing public education and targeted police enforcement to reduce RLR. They found that the drivers' perception of being caught by police for running a red light increased. Eighty percent of the respondents felt that police catch less than 10% of the violators. After the targeted police enforcement, only 21% felt that police catch less than 10% of the violators, which implies that increased police surveillance can play an important role in reducing red light violations.

Photo technology to enforce traffic regulations has been in use, worldwide, for the past 30 years. It is claimed that its use has contributed to a considerable reduction in the number and severity of traffic collisions in Europe, Australia, and South Africa. No states in the U.S. used photo-enforcement 12 years ago. In 1995 there was only one state using photo-enforcement, and by 2000, 37 communities were using this type of enforcement (IIHS, March 2000). There is an increasing number of states where photo-enforcement is used despite its initial high set-up costs. Among the benefits, proponents of photo-enforcement mention manpower savings, convenience of its use, and improved safety.

Milazzo II et al. (November 2001) considered conditions for drivers to be able to avoid red signal violations. The condition is that the displayed yellow interval is equal to or longer than the minimum value at which a driver can stop the car. The difference between the displayed yellow time and the minimum yellow time is called enforcement tolerance. The authors investigated the effect of speed and the length of yellow interval on enforcement tolerance. They recommended 0.4-second enforcement tolerance. The enforcement tolerance provides a convenient tool to check whether an intersection has properly designed signals. The selected study intersection was checked to make sure that the observed RLR is not caused by incorrect signal timing. Such a condition is necessary for valid investigation of enforcement effectiveness.

RLR programs aim to reduce the number and severity of road traffic collisions and establish a base for a long-term change in driver attitudes. The National Organization for Traffic and Intersection Safety aims to advance traffic intersection safety through the enactment of automated photo-enforcement enabling legislation and other appropriate measures. A report released by the FHWA (February 2000F) says that RLR decreased by as much as 60% at intersections where cameras automatically enforce the law. The photo-camera system installed in Vienna, Virginia predicts the potential red light runners and extends the red light for cross traffic to prevent collisions (IIHS, March 2000).

A brief summary of previous studies done to estimate the effectiveness of photo-enforcement measures (FHWA, September 1998; PhotoCop, 2000; Popolizio, 1995; Retting, et al, 1999B; Smith et al., July 1999; Kamyab et al., December 2000; Hill et al., 2000), as well as the information regarding the states that have tested and have implemented photo-enforcement, is provided below. **The summary reflects the opinions and conclusions expressed in the cited publications.**

New York City, New York started its red light program on June 1, 1993 and installed 15 cameras at signalized intersections. They did not educate the people about the effects of RLR, did not publicize the enforcement program, and did not place warning signs at the intersections. The program operated from the revenue collected from violators. 35-mm cameras were used and Electronic Data Systems Corporation serviced the cameras, processed the film, and prepared violation notices under a contract with New York City. The photographs were digitized and stored on central computers, which were then reviewed by a police representative. Some problems were encountered with the system: parked vehicles blocked the view of the camera, the glare due to the flash, etc. In one year, 175,000 violation notices were issued. The program was effective and the number of violations at each location decreased by an average of 21%. A 60% - 70% decrease in angle crashes was also observed.

Polk County, Florida began its program in 1994. They did not disclose the presence of cameras, but the media discovered them and responded negatively. Signs indicating the presence of cameras were placed later. This county still does not have any photo-enforcement law enacted and therefore issues only warnings. They also used 35-mm film and videotape. Since Florida is a tourist center, the vehicles from different states posed a problem for the state in identifying the violators, and large trucks also blocked the vehicles violating the red light in adjacent lanes. The program has proven to be cost-effective and safe. Polk County’s situation suggests that proper steps should be taken to ensure that the media and the public receive photo-enforcement positively. This could be accomplished by education on the facts related to RLR and clarification of any misconceptions regarding the photo-enforcement cameras. The public needs to be assured that the system will be operated properly and that traffic safety would be improved.

Pasadena, California started its program in 1989 but discontinued it because of technical reasons. *Los Angeles, California* started its program in late 1992 and used photo-enforcement at at-grade crossings. They also used 35-mm film. A large reduction in the number of violations was observed. A telephone survey was also conducted to establish the public's opinion of the problem and the enforcement program. RLR was reduced by 42% after cameras were introduced at nine intersections in *Oxnard, California***.** A similar decline was also noticed at intersections that were not equipped with cameras, called the "spill-over" effect. *San Francisco, California* started the pilot program in 1996. An extensive campaign was conducted to educate the public. The response was positive to the system and the violations decreased by 40%. This community faced some operational problems because many vehicles did not have front license plates, and the process of taking a front-photo also caused glare for the driver.

Arlington, Virginia started its program in 1993 and received support from insurance companies to study RLR factors such as weather, traffic, time of day, and types of vehicles. *Fairfax, Virginia* had a 30-day warning period before beginning the enforcement of its system. Postcards were mailed to residents to publicize the program. Violation data was collected prior to the warning period and then at three months and one year. Two non-camera sites were also observed and a spill-over effect was noticed. They also conducted a telephone survey prior to and after the enforcement program. The study showed that violations declined by 40% after one year of camera enforcement.

Jackson, Michigan was concerned about the negative public response as was seen in Polk County, Florida, but the program did not receive any objections.

Howard County, Maryland field-tested automated enforcement in 1996. They rented the cameras and other equipment and used the "false camera" strategy (placing a box with wires but no camera), which brought down the costs. Educating the drivers and creating public awareness were emphasized. They also encountered the problem of glare due to the flash, and faced added problems with maintenance of cameras and processing of film, which were manpower intensive. Violations decreased by 48% after six months. A decrease in crashes was also observed. The next section shows a brief analysis of the crash statistics obtained from Howard County, before and after the program was started. The statistics prove that the program is effective in reducing RLR-related crashes. Seven counties are now using a total of 168 cameras in Maryland (Washington Post, 2002). These RLR programs are currently monitored by the individual local jurisdictions, but the Maryland Department of Transportation is attempting to standardize the use of these cameras to eliminate the controversy that they are used as revenue generators.

5.2 Crash Reduction Attributed to Photo-enforcement

A study by Andreassen (February 1995) found no reduction in accidents at different signalized intersections in Australia even after photo-enforcement. He noticed an increase in rear-end collisions. Rocci and Hemsing (1999) identified numerous unpublished reports on reductions in RLR-related crashes after photo-enforcement. They found crash reductions of about 88% in Essex (United Kingdom), and 32%-50% in Australia. Retting and Kyrychenko (2001), conducted similar tests in Oxnard, California and found that total crashes at signalized intersections was reduced by 7% with a 29% reduction in injury crashes. They also found that right angle crashes reduced by 32% accompanied by a reduction of 68% in right angle injury crashes. Another important observation in their research was that the crashes were reduced at all signalized intersections, even at intersections not equipped with cameras.

An example of crash data collected before and after installation of red light cameras is shown for Howard County, Maryland (Table 5.1). These data were sent to us by the Howard County traffic engineer. The original data sheets are presented in Appendix A. The data shows a considerable reduction in all types of crashes, particularly angle crashes that are typically associated with RLR. Table 5.1 includes the Crash Reduction Factors (CRF) calculated for each crash type based on the crash statistics. Angle crashes recorded the highest reduction of 39%. Contrary to the belief that photo-enforcement would increase rear-end crashes, Howard County saw a 10% reduction in rear-end crashes, although it increased at some intersections. An average reduction of 17% was observed in total crashes.

The presented CRFs were calculated assuming no increase in traffic volumes. The magnitude of so-called regression-to-mean effect could not be estimated and is not

TABLE 5.1 Crash Reduction Factors in Howard County

#	# Months	Before				After				CRF			
		Rear End	Angle	Other	Total	Rear End	Angle	Other	Total	Rear End	Angle	Other	Total
1	46	31	10	11	52	29	6	11	46	6.5	40	0	11.5
2	46	42	16	9	67	36	10	12	58	14.3	37.5	-33.3	13.4
3	45	31	9	15	55	26	6	16	48	16.1	33.3	-6.7	12.7
4	45	22	9	14	45	15	3	15	33	31.8	66.7	-7.1	26.7
5	45	23	10	8	41	23	5	9	37	0	50	-12.5	9.8
6	45	24	11	7	42	16	5	6	27	33.3	54.5	14.3	35.7
7	44	9	12	7	28	10	7	8	25	-11.1	41.7	-14.3	10.7
8	44	23	10	12	45	22	4	12	38	4.3	60	0	15.6
9	43	21	8	10	39	19	7	12	38	9.5	12.5	-20	2.6
10	43	18	10	9	37	20	4	11	35	-11.1	60	-22.2	5.4
11	41	13	13	14	40	12	10	8	30	7.7	23.1	42.9	25
12	40	16	6	10	32	17	7	8	32	-6.3	-16.7	20	0
13	40	7	13	5	25	3	11	5	19	57.1	15.4	0	24
14	38	10	14	7	31	7	8	5	20	30	42.9	28.6	35.5
15	38	15	9	8	32	15	5	4	24	0	44.4	50	25
16	36	30	17	12	59	27	11	7	45	10	35.3	41.7	23.7
17	36	19	5	7	31	16	4	6	26	15.8	20	14.3	16.1
18	35	21	8	11	40	26	4	8	40	-23.8	50	27.3	0
19	34	19	6	13	38	18	3	12	33	5.3	50	7.7	13.2
20	32	19	10	9	38	15	7	8	30	21.1	30	11.1	21.1
21	30	10	7	8	25	10	4	7	21	0	42.9	12.5	16
22	30	9	7	8	24	9	2	4	15	0	71.4	50	37.5
23	14	5	2	3	10	2	1	1	4	60	50	66.7	60
24	4	1	2	1	4	1	1	1	3	0	50	0	25
25	14	3	3	2	8	2	4	1	7	33.3	-33.3	50	12.5
	908	**441**	**227**	**220**	**888**	**396**	**139**	**197**	**734**	**10**	**39**	**11**	**17**

included. Butler (May 2001) found significant reduction in crashes at other signalized intersections in Howard County that were not equipped with cameras. This result may be interpreted in two contradicting ways. It may indicate the presence of the spill-over effect which increases the overall positive effect of photo-enforcement. On the other hand, if the spill-over effect was not present, then some of the positive safety changes would have to be attributed to other factors and not entirely to the presence of red-light cameras. Regardless of the actual case, the fact that the percent reduction of RLR-related angle crashes is four times the reduction of the other types of crashes indicates that photo-enforcement reduces the frequency of angle crashes.

5.3 Measures of RLR

This section introduces a new measure of RLR which was used in the presented study. One of the RLR measures is RLR frequency (F), which is defined as the number of violations per unit time (hour). RLR frequency is especially useful for law enforcement agencies, since it indicates when and where the frequency of violations observed is high. Enforcement agencies can use this data and enforce the intersections during those hours to get maximum efficiency. RLR frequency can be estimated by dividing the number of red light violations with the number of hours monitored. RLR frequency is the effect of the number of drivers who have an opportunity to violate the red signal (opportunity) and the willingness of the drivers to violate the red signal.

RLR can be calculated using the equation $RLR = E \times R$, where RLR is the number of violations during the period, E is the opportunity for RLR during that period, and R is the RLR rate. RLR rate can be defined as the likelihood that a driver violates the red signal if he/she has an opportunity to do it. It directly represents the drivers' behavior. The exposure measure E is independent of the drivers' behavior. It is defined as the number of drivers who arrive at the intersection during the first few seconds after the signal turns red. Drivers can either violate the red signal or stop and wait until the next green. Only such drivers have the opportunity to violate the red signal. This exposure measure is called *opportunity.* To estimate the RLR rate (R), we need to estimate the opportunity E first. If the number of RLR is known from traffic monitoring, R can be estimated as $R = F / E$ if E is known. This section further explains how to estimate opportunity.

The concept of opportunity can be better explained using Figure 5.1. Let A, B, C, and D letters denote consecutive drivers approaching the intersection stop-bar. Driver A approaches during green and proceeds into the intersection. Driver B approaches during the yellow phase and also proceeds without stopping. Driver C would cross the stop-bar during the red signal if he/she proceeds without stopping and at the approach speed (dotted line C'). In other words, he/she has an opportunity to violate the red signal and has two options. Data collected at the study intersection indicate that practically all the violations occurred during the first two seconds of the red signal. It means that if driver D approaches the intersection later than two seconds after the start of the red signal, then he/she will surely stop the car. The opportunity for violating the red signal was assumed to be only during these first two seconds.

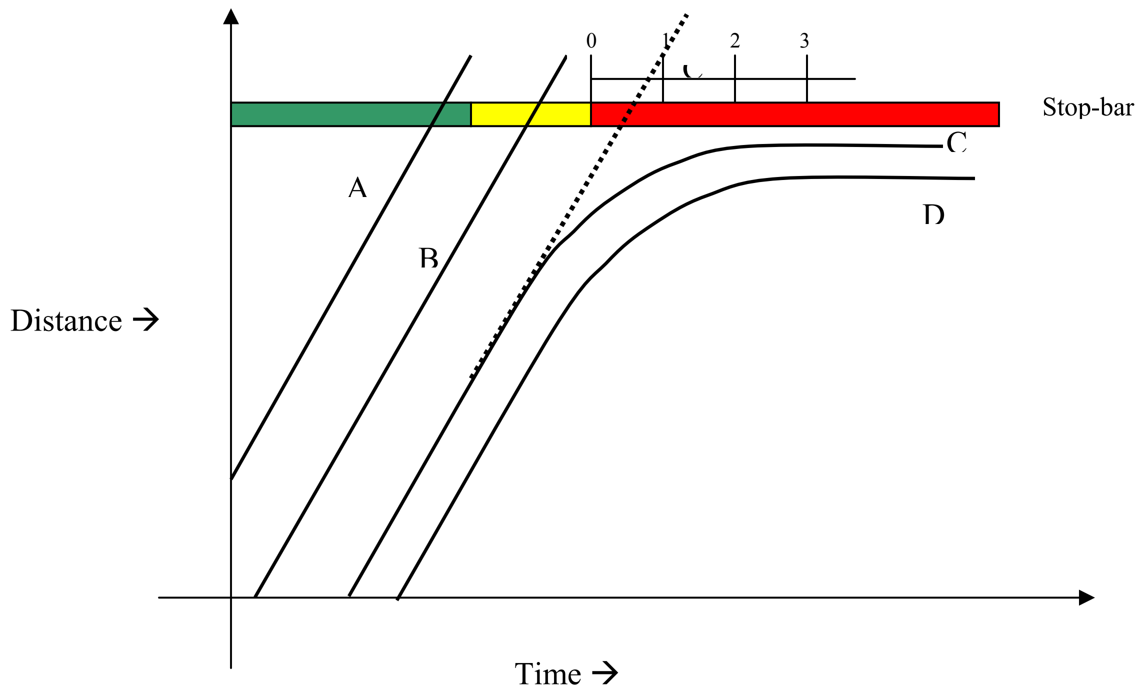


FIGURE 5.1 Diagram to explain opportunity

The main objective in estimating the opportunity is to calculate the expected number of drivers who arrive during the first two seconds of the red signal. To simplify the calculations, it was assumed that the expected number of vehicles in cycles does not change significantly during 15 minutes - the assumption often used in traffic analyses and modeling. In addition, we have assumed that the flow rate at the end of red signals equals the average flow rate over the 15 minutes. Three conditions are needed to make these assumptions acceptable:

1. There is no traffic congestion,
2. There is no coordination with the upstream signals,
3. The intersection does not use advance-detectors that extend green when a vehicle is detected a long distance away from the intersection.

Congestion at the study intersection occurred for through movements on a limited number of days and for a short time. The portion of day with congestion was very low and could be neglected. Although there are two signalized intersections located close to the NB and EB approaches of the study intersections, no fixed relationship between the signals in these intersections was observed. The signal cycle at the studied intersection was closely following changes in the traffic volume. No fixed background cycle was observed. Although the study intersection has advance-detectors, they were not used to actuate traffic signals. It can be concluded that the study intersection meets all of the above conditions, and therefore, the fixed arrival flow assumption is acceptable.

Generally speaking, if one or more of the above conditions are not met, the opportunity and the RLR rate estimates may be biased. To obtain correct opportunity estimate at intersections that do not meet some of the above criteria, the following steps could be taken:

1. If the intersection has congestion problems, use the saturated flow rate instead of the arrival rate for the congested periods.
2. If the second and third criteria are not met, field observations should be conducted. The number of vehicles arriving at the stop-bar during the first two seconds of the red signal must be counted for a considerable number of cycles and adjustment factors should be developed.

Based on the fixed-flow assumption, the number of drivers with RLR opportunity can be estimated as follows. The expected number of drivers with RLR opportunity in one cycle is $Q \times \Delta t$, where Q is the rate of traffic approaching the intersection (veh/s), and Δt is the time at the beginning of the red signal when violations are observed. This time should be set at the lowest value possible but should include all the violations. Table 5.2 shows the distribution of RLRs from the start of red. Table 5.2 and Figure 5.2 reinforce what has already been said. All the violations occur within two seconds after the start of the red signal. Hence Δt was taken as two seconds. The opportunity during a 15-minute interval is calculated as: $N \times Q \times \Delta t$, where N is the number of cycles in the interval.

TABLE 5.2 Distribution of RLRs from Start of Red

Time from Start of Red	# Violations	%Violations	Cumulative % Violations
0	2	0.8	0.8
0.1	9	3.8	4.7
0.2	12	5.1	9.7
0.3	21	8.9	18.6
0.4	24	10.2	28.8
0.5	29	12.3	41.1
0.6	32	13.6	54.7
0.7	25	10.6	65.3
0.8	16	6.8	72.0
0.9	20	8.5	80.5
1	12	5.1	85.6
1.1	4	1.7	87.3
1.2	6	2.5	89.8
1.3	6	2.5	92.4
1.4	3	1.3	93.6
1.5	4	1.7	95.3
1.6	4	1.7	97.0
1.7	2	0.8	97.9
1.8	2	0.8	98.7
1.9	2	0.8	99.6
2	1	0.4	100.0
Total	236	100	

The opportunity for an extended period P is obtained by summing up the opportunities calculated for the 15-minute intervals included in the extended period

$$E = \Delta t \times \sum_{i \in P} N_i \times Q_i \qquad 5.1$$

where, E (expressed in vehicles) is the opportunity for period P, Δt is the initial time of a red signal when the violations occur (2 seconds in this study), N_i is the number of signal cycles in interval i, and Q_i (vehicles/s) is the flow rate in interval i.

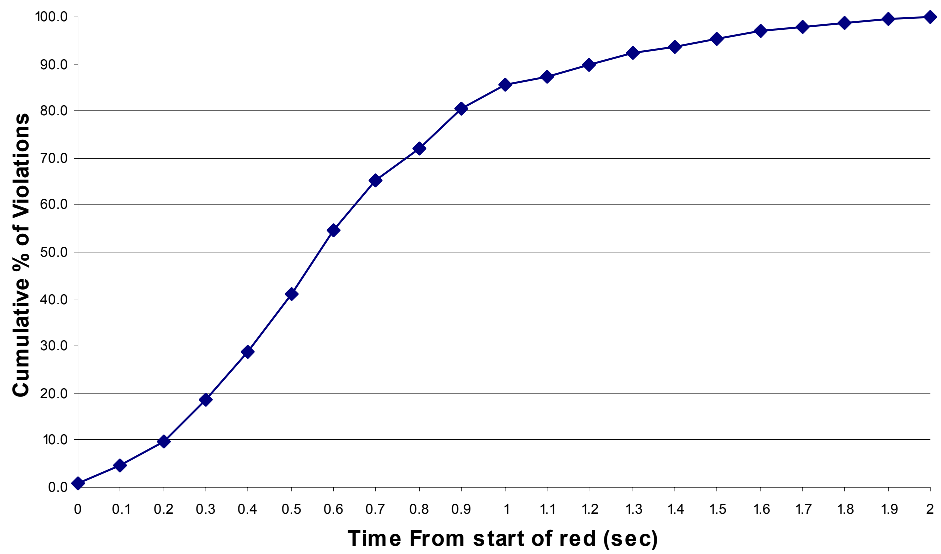


FIGURE 5.2 Distribution of RLRs from start of red

The number of vehicles approaching the intersection during each 15-minute interval was obtained from the Autoscope station detector (see section 4.3.2.1). To obtain the number of cycles in each 15-minute interval, a simple user interface was coded in Visual Basic. The Autoscope data in the Access file format, which was used to extract violations for the machine-aided system, was also used as the input file to obtain the number of signal cycles in each 15-minute interval. These results were saved in an Excel file with the worksheets named after the tables from which the signal cycle data was extracted. The user needed to select the Access file through the interface. The program counted the number of red input detector occurrences for each 15-minute interval and returned it as the number of cycles for that 15-minute interval. Once the volume and the number of signal cycles in each 15-minute interval were obtained, the drivers with RLR opportunity were estimated using equation 5.1.

The police and photo-enforcement were evaluated by observing RLR in three periods – before enforcement, during enforcement, and after enforcement. The volumes and the number of signal cycles in 15-minute intervals were obtained for each period to estimate the total opportunity in these periods. The RLR frequency and the RLR rate were estimated for each period, which were used in evaluating the effectiveness of enforcement measures.

The significance level of the difference in the violation rates between any two periods A and B was estimated using the binomial test. The initial assumption was made that the likelihood that a driver with opportunity for RLR would violate the red signal (rate R) is the same in both periods. The traffic monitoring and the calculations of the opportunity for RLR yielded the following values:

RLR_A = number of RLR observed during period A,

RLR_B = number of RLR observed during period B,

E_A = opportunity during period A, and

E_B = opportunity during period B.

To check the significance level of the reduction in the violation rates during period B compared to period A, it has to be shown that the observed number of violations during period A is too large to be explained with randomness. The following parameters of Binomial distribution are required:

Total number of trials = $RLR_A + RLR_B$, total number of violations,

Number of successes = RLR_A, number of violations in period A,

Likelihood of success = $E_A/(E_A+E_B)$, likelihood that violation occurs in period A if the violation rates in periods A and B are equal.

The likelihood of the occurrence of violations equal to or more than the observed number of violations in period A was evaluated using the Binomial distribution with the listed above parameters. A small likelihood (significance level) indicated that the number of violations in period A was too high to be explained with randomness and that the RLR rate in period A was higher than in period B (or equivalently, that RLR rate in period B was lower than in period A).

5.4 Enforcement Tolerances at the Study Intersection

A detailed analysis of the traffic signals at the study intersection was necessary to check if the signals met the design standards and to make sure that improper signal timing did not cause an excessive number of violations. Proper signal timing justifies an assumption that the observed RLR is the result of drivers' decisions and not an effect of a short yellow signal. The yellow time should be long enough to enable the driver to pass the stop-bar before the signal turns red if stopping is not possible because the driver is too close to the stop-bar. A short yellow time causes a dilemma zone. Drivers in this zone, who see a yellow light, are forced to make unsafe maneuvers regardless of whether they decide to stop, or to proceed. In such cases they would have to decelerate rapidly to stop at the stop-bar or violate the red signal. An analysis of the yellow duration has been done to check if such dilemma zones exist, and if the yellow time is sufficient.

The yellow signals and speeds of vehicles unaffected by signals and other vehicles have been measured at the study intersection. The yellow signal for through vehicles was found to be 3.5 seconds. The speed limit posted on the approaches was 30 mph. Thirty observations of speed were collected on each of the northbound (NB), southbound (SB), and eastbound (EB) approaches. The NB and SB approaches were found to have similar distributions and hence a combined distribution was used for these approaches. Table 5.3 shows the obtained speed distribution parameters. It was found that the average speed on the EB approach (Stadium Avenue, 26 mph) was below the speed limit, while the average speed on the NB+SB approach (Northwestern Avenue, 34 mph) was greater than the speed limit. The 85th percentile speed for Northwestern Avenue was found to be 38 mph, while it was 29 mph for Stadium Avenue. A cumulative percentage of vehicles below a given speed was also estimated for all the approaches (see Tables 5.4 and 5.5).

TABLE 5.3 Variability of Speeds at Study Intersection

Speed (mph)	**NB**	**SB**	**Northwestern Ave (NB+SB)**	**Stadium Ave (EB)**
Average Speed	33	35	34	26
Std Dev	4.0	3.8	4.0	3.7
Max. Speed	43	42	43	34
Min Speed	24	28	24	16
85th percentile speed	-	-	38	29

Enforcement tolerance is the difference between the displayed yellow time and the minimum yellow time required to eliminate a dilemma zone (Milazzo II et al., November 2001). The minimum yellow time was calculated as proposed by the Institute of Transportation Engineers (ITE, 1985):

$$Y = t + \frac{V_o}{2 \times a}, \qquad 4.1$$

where, V_o is the vehicle approach speed (ft/s), a is the standard deceleration rate (10 ft/s^2), t is the standard reaction-perception time (1 second), and Y is the minimum yellow time (seconds). Retting et al. (1997) concluded that the use of yellow signal design standards recommended by the ITE significantly reduces the chance of RLR. The standards specified by ITE were used in this research (Equation 4.1). In our research, a tolerance of 0.2 seconds was added to the calculated tolerances. Therefore, any vehicle violating red during the first 0.2 seconds of the red signal was not counted. The tolerances for various speeds on Northwestern Avenue and Stadium Avenue are shown in Tables 5.4 and 5.5, respectively. The tolerances were calculated for the upper speed limit and then increased by 0.2 seconds. The cumulative distribution of the speeds is also given. The tolerance for the posted speed limit of 30 mph was found to be 0.5 seconds. Milazzo II et al. (November 2001) recommended the use of 0.4 second enforcement tolerance. Thus, a sufficient tolerance has already been provided according to the design standards at the study intersection.

All the vehicles on Stadium Avenue are moving at such speeds that they have at least 0.2 seconds tolerance. Eighty percent of the vehicles on Northwestern Avenue have zero or more tolerance. It should be noted that the speed of the drivers with no tolerance exceed the speed limit. If one assumes that the average deceleration rate acceptable by these aggressive drivers is 11 ft/s^2 instead of 10 ft/s^2 then 97% of the drivers on Northwestern Avenue have above zero tolerance.

The all-red time was found to be 2 seconds, which meets the design standards. The maximum intersection width is 60 ft, which requires a clearance time of 1.5 seconds

(< 2 seconds) at 20 ft/s. Therefore, the all-red is neither too short to pose any safety threat, nor is it too long, making the drivers perceive it to be safe to violate the red and still clear the intersection. Retting et al. (1997) found that the length of the all red signal did not affect RLR.

The presented analysis shows that the signals at the study intersection meet ITE design standards. Thus, this intersection is suitable for enforcement effectiveness evaluation.

TABLE 5.4 Enforcement Tolerances for Different Speeds on Northwestern Avenue

Speed Interval (mph)	# Vehicles	% Vehicles	Cumulative % Vehicles	Enforcement Tolerance (sec)
20-22	0	0	0	1.1
23-25	1	2	2	0.9
26-28	3	5	7	0.6
29-31	12	20	27	0.4
32-34	17	28	55	0.2
35-37	15	25	80	0
38-40	7	12	92	-0.2
41-43	5	8	100	-0.5
Total	60	100		

TABLE 5.5 Enforcement Tolerances for Different Speeds on Stadium Avenue

Speed Interval (mph)	# Vehicles	% Vehicles	Cumulative % Vehicles	Enforcement Tolerance (sec)
11-13	0	0	0	1.7
14-16	1	3	3	1.5
17-19	1	3	7	1.3
20-22	1	3	10	1.1
23-25	6	20	30	0.9
26-28	15	50	80	0.6
29-31	5	17	97	0.4
32-34	1	3	100	0.2
Total	30	100		

5.5 Police Enforcement

The police play an important role in enforcing red signal compliance. The results of the surveys conducted in Indiana and in other states indicated that drivers do not perceive the police to be sufficiently effective in enforcing red light violations. There are several possible explanations: excessive expectations of drivers, limited resources of the police, or a weak effect of the police presence on driver behavior. The last aspect of police enforcement was tested in the presented study.

5.5.1 Police Activity at the Study Intersection

Changes in driver behavior due to frequent police patrolling at the selected Northwestern and Stadium Avenue intersection was observed from November 6 to December 22, 2001. There was no police enforcement between November 6 and November 12, 2001. Police were asked to be present at the intersection for a week from November 12 (Monday) to November 16 (Friday). They were present between 3 PM and 5 PM on these days. There were also two vacation periods during this analysis period, November 21 (Wednesday) to November 25 (Sunday) – Thanksgiving, and December 16 to December 22 – winter break. These vacation periods are also important because the number of vehicles using the intersection changes considerably due to the absence of the students, which would be expected to reduce the frequency of violations. The video data and the Autoscope data were collected during the entire period, and then processed by direct observation for selected time intervals.

Public awareness of the upcoming police enforcement was also an important step in this process. The CATS research team performed the campaign via the local newspaper (Lafayette Journal and Courier) and television (Lafayette Channel-18). The Civil Engineering team requested that the West Lafayette area also be included in the campaign. The Civil Engineering team shared pertinent data with the CATS team. The schedule of the aired campaign on channel-18 is shown in Table 5.6. They were also aired on local radio within 24-hours after being aired on channel-18.

The West Lafayette Police Department (WLPD) was asked to participate in the study. The violations extracted from the video files between April 23 and April 27, 2001 were shared with the WLPD to help them schedule enforcement activities at the study intersection. The WLPD officers were present at the intersection between 3 PM and 5 PM each day from November 12 to November 16, and ticketed the red signal violators. One of the policemen was standing inconspicuously near the intersection watching for red light runners. When a violation was observed he sent a radio message to his partners waiting a short distance from the intersection. These partners were not visible to the drivers from the intersection. If other drivers did see the police stopping the violators, they did not immediately know why the drivers were being stopped. It took time for drivers to learn that the police were enforcing red light violations.

The police issued 51 tickets during the period of enforcement. The summary of the tickets issued during this period is shown in Appendix G.

TABLE 5.6 Campaigning Schedule on Television Channel-18

Day	**Time**
Nov 05	1200, 1700, 1800, 2300
Nov 06	0600
Nov 12	1200, 1700, 1800, 2300
Nov 13	0600

The NBTH, SBTH, and EBTH movements were monitored each day during the period between November 6 and December 22 including a week before the police enforcement, during the one-week enforcement, and four weeks after the enforcement. Traffic was monitored for two hours between 3PM and 5 PM before and after the enforcement week, and for three hours between 3 PM and 6 PM during the week with police enforcement. A few days were excluded from data collection because of equipment failure.

TABLE 5.7 Periods During Police Enforcement

Period #	**Days Included**	**# Hrs**	**Enforcement**	**Vacation**
1	Nov 2001 - 6,8,10,11	7.5	No	No
2	Nov 2001 - 12,13,14,16	11	**Police**	No
3	Nov 2001 - 17,18, 19, 20	8	No	No
4	Nov 2001 - 21, 22,23,24,25	10	No	**Yes**
5	Nov 2001 - 26,27,28,29,30 Dec 2001 - 1,6,8,10,12,14	22	No	No
6	Dec 2001 - 16,18,20,22	8	No	**Yes**
	Total	66.5		

5.5.2 Discussion of Results

The period between November 6 and December 22 was divided into six different sub-periods (Table 5.7). Vacation time and presence of enforcement were the basis to form these periods. The periods have been assigned numbers for easy referring. The dates in each period and the total hours monitored in each period are also shown in the table. A total of 66.5 hours were monitored during the entire period and a total of 61 violations were observed.

The RLR frequencies and the RLR rates in periods 1, 2, 3, and 5 were used to evaluate the police enforcement effectiveness. None of these periods includes vacation time. Fifty-five violations were recorded during the periods included in the evaluation of police enforcement. Table 5.8 shows the opportunity, violations rate, and violation frequency for the four periods. Table 5.9 presents the statistical significance of the differences in the RLR rates.

TABLE 5.8 Evaluation of Police Enforcement

Period#	#RLR	# Hrs	RLR frequency	Opportunity	RLR rate
1	15	7.5	2.0	161.8	0.093
2	18	11	1.6	214.4	0.084
3	3	8	0.4	131.0	0.023
5	19	22	0.9	330.8	0.057
Total	55	48.5			

TABLE 5.9 Significance Levels for Reduction in Violation Rates During Police Enforcement

First Period	RLR rate	Second Period	RLR rate	Total RLR	Prob. Of Success	Significance Level
1	0.093	2	0.084	33	0.430	0.454
1	0.093	3	0.023	18	0.553	0.013
1	0.093	5	0.057	34	0.328	0.113

The RLR rate reduced slightly during the week of the police enforcement (period 2) when compared to the week before the enforcement (period 1). As mentioned earlier, drivers might be learning about the enforcement during period 2 because the police operations were inconspicuous. The RLR significantly decreased by 75% the week after the enforcement (1% significance level) which could have been caused by the message about the enforcement spreading among the drivers. It shows that the police enforcement is able to considerably change the behavior of drivers. The 37% RLR rate reduction (11% significance level) was still present in the last week of the analysis period (period 5). A similar RLR rate reduction, as that observed in period 5, was also observed in March 2002. It might suggest that the enforcement effect was long-term or that the first two weeks before and during police enforcement experienced an unusually large number of red light runners. There is no basis for claiming the latter, though, and it may be concluded that the police enforcement had a lasting impact. A possible additional effect of the aggressive campaign in mass media, associated with the police enforcement, should not be overlooked.

The RLR frequency appears to provide similar information regarding the magnitude of violations as the violation rate. This is because periods with lower volume tend to have more cycles, thus the effects of volume and cycle frequency partly compensate each other. Since this compensation is not perfect, the RLR frequency should not be considered a substitute for the opportunity. A case where RLR frequencies may lead to different conclusions than RLR rates can be seen in the next section when the photo-enforcement periods are analyzed.

The RLR rate presents a more defendable measure of the violation rate than the RLR frequency since it reveals the actual trends in driver behavior. On the other hand, the RLR frequency is of importance to law enforcing agencies as they are interested in identifying intersections and periods with frequent RLR instances. Therefore, both the measures are useful and both are estimated in this study.

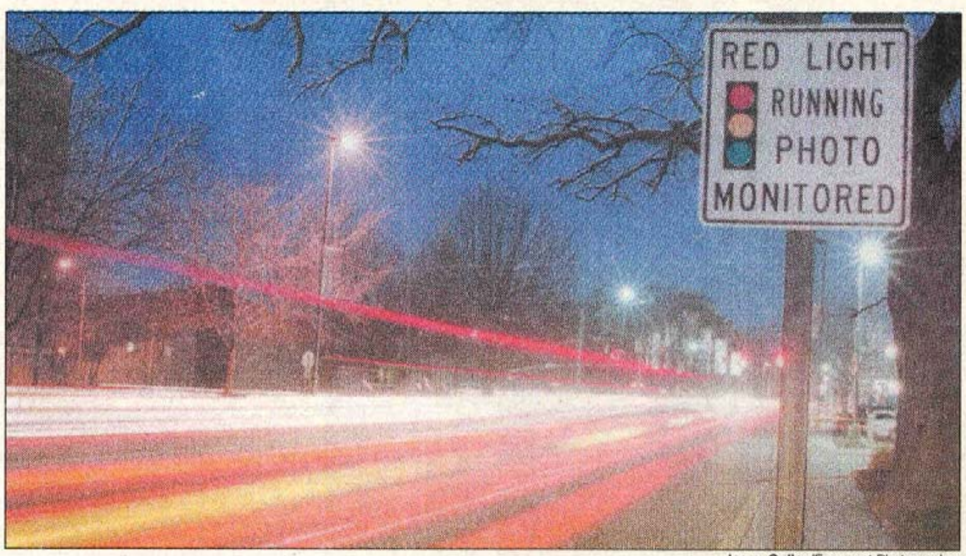
5.6 Photo Enforcement

5.6.1 Simulation of Photo-enforcement

INDOT was requested to provide warning signs to be placed at the study intersection to create public awareness of the presence of the video cameras. The success of the program mainly depended on the extent of public awareness and support. Figure 5.3 shows the warning signs used at the intersection. The word ‘monitored’ was used, since the camera system was not used to enforce the red signal compliance. Also, the video equipment and technology used did not allow us to recognize the license plate numbers.

FIGURE 5.3 Photo-enforcement warning signs

These warning signs themselves created significant concern among drivers, which was reported in the local newspapers. Figure 5.4 shows a photo that appeared in the Purdue Exponent. The text below it misinterprets the signs. Despite our best efforts to send a clear message through the signs, the photo publicized in the newspaper indicates that misinterpretation of the signs by some drivers was possible.


WATCH YOUR SPEED

Jason Gulley/Exponent Photographer

The stop light at the intersection of Northwestern and Stadium Avenues is monitoring traffic speeds. The monitor is part of a vehicle detection study from the civil engineering department at Purdue. A sign has been constructed to notify motorists that their speed is being monitored.

FIGURE 5.4 Article in Purdue Exponent, which misinterprets the warning sign

The warning signs were deemed to be visible enough to inform drivers of the presence of the camera. The signs were placed a good distance from the intersection so drivers could read and understand the signs and have time to react. Figure 5.5A and Figure 5.5B show the warning signs with the test intersection in the background. Figure 5.6 is a schematic of the intersection with the location of these warning signs.

The intersection was monitored between March 6 and March 28, 2002. The signs were placed at the intersection between March 18 (Monday) and March 25 (Monday). The entire period of analysis is divided into four different periods as was done in the case of police enforcement. The direct observation method was used to record the violations. Video material recorded for six hours from 7 AM to 10 AM and from 3 PM to 6 PM was watched for every other day of the study period. Table 5.10 shows the periods, the days with traffic monitored, and other characteristics of the period. A total of 63 hours were monitored during the entire period.

TABLE 5.10 Periods for Studying the Photo-Enforcement Effectiveness

Period#	Dates Included	# Hrs	Photo Enforcement	Vacation
7	Mar 2002 - 6,7,8	9	No	No
8	Mar 2002 - 10,15,16	18	No	**Yes**
9	Mar 2002 - 18,20,22	18	**Yes**	No
10	Mar 2002 - 24,26,28	18	No	No
Total		63		

5.6.2 Discussion of Results

The number of signal cycles in each 15-minute interval was extracted for the entire day as explained previously. The opportunity was then evaluated and the violation rates/frequency were estimated for each period. Only periods 7, 9, and 10 were

EB

The signals are circled

NB

The signals are circled

FIGURE 5.5A Photos of the warning with the intersection in the background

SB

We cannot see the intersection signals here, but the stop can be recognized from the waiting traffic. The first car in the queue is circled.

WB

The signals are circled

FIGURE 5.5B Photos of the warning with the intersection in the background (continued)

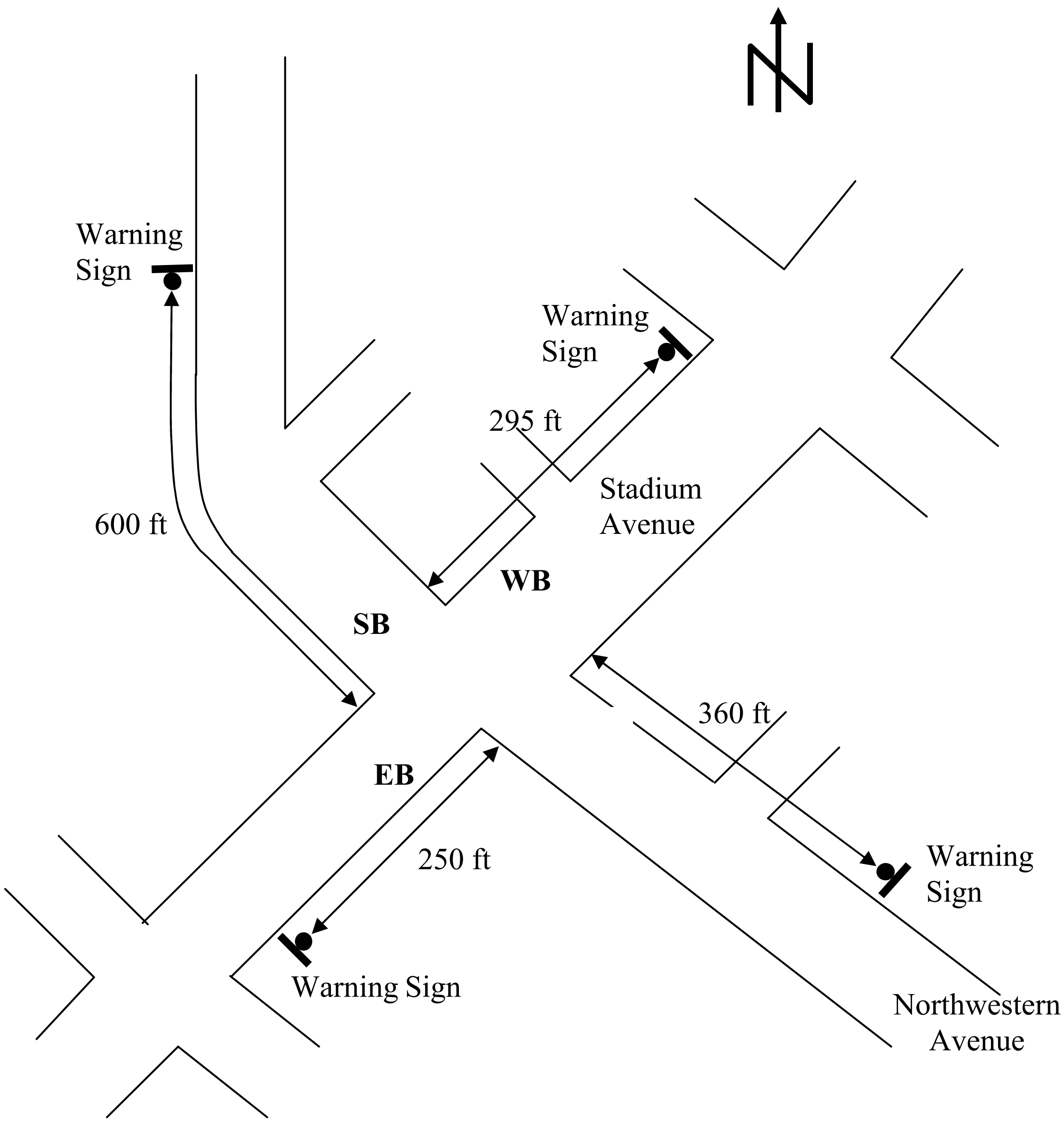


FIGURE 5.6 Schematic representation of the intersection showing the location of warning signs

considered for the evaluation of photo-enforcement. Approximately 45 hours were observed for the photo-enforcement period and 35 violations were recorded. Period 8 was used in the evaluation of the effect of the presence of students on RLR (Chapter 6). The results are shown in Table 5.8. The violation rate reduced 62% during the week of photo-enforcement (2% significance level). Oxnard, California, and Fairfax, Virginia, (FHWA, 2000G) reported a reduction of 40% in the violation rate. While only a 34% reduction was observed in New York, Howard County observed a 58% reduction. These cities also found that the collisions at intersections declined considerably. New York had a 65% reduction while Oxnard and Fairfax had 22% reductions. The reduction in crashes at different intersections in Howard County varied between 18% and 44% (see Section 5.1).

Drivers responded to the warning signs without any delay but they also had a tendency to return to the pre-enforcement behavior faster than in the case of the police enforcement. The RLR rates of periods 7 and 10 indicate that the residual effect a week after the photo-enforcement was 35% of the original value (19% significance level). This difference in driver response can be explained by the conspicuity of the warning signs. The effect of police enforcement appears to have lasted for a longer period of time. The violation rate in period 7 was not only lower than that in period 1 but also nearly equal to that in period 5. The RLR frequency for period 9 was 50% which was considerably higher than the RLR rates. The discrepancy between the trends in the RLR frequencies and rates were larger than for the police enforcement.

TABLE 5.11 Evaluation of Photo-enforcement

Period#	**#RLR**	**# Hrs**	**RLR Frequency**	**Opportunity**	**RLR Rate**
7	13	9	1.4	263.95	0.049
9	10	18	0.6	522.14	0.019
10	12	18	0.7	375.56	0.032
Total	35	45			

TABLE 5.12 Significance Levels for Reduction in Violation Rates During Photo Enforcement

First Period	RLR Rate	Second Period	RLR Rate	Total RLR	Prob. Of Success	Significance Level
7	0.049	9	0.019	23	0.336	0.020
7	0.049	10	0.032	25	0.413	0.187

5.6 Summary

Both the police and photo-enforcement resulted in a significant reduction in the number of violations. Police enforcement resulted in a reduction of only 9% during the week of enforcement, while photo-enforcement showed a reduction of 62%. The reduction in RLR in the period immediately following the police enforcement was 75%, while it was 35% for photo-enforcement. The violation rate in the after-period of photo-enforcement appeared to return to normal at a faster rate than during the police enforcement period, which could be due to drivers' uncertainty about the police presence.

6. OTHER FACTORS OF RED LIGHT RUNNING

Other conditions affecting RLR intensity include population characteristics, day of the week, time of day, weather conditions, intersection characteristics, etc. In this research, the effects of day of the week, time of day, and population characteristics (normal conditions vs. no students) were studied.

6.1 Students

Many researchers agree that young drivers are more aggressive and tend to take more risks compared to older drivers (Retting and Williams, 1996). We studied the effect of the student population to verify this statement. The study intersection was monitored during the presence of students (normal school days) and during the absence of students (vacation days), and the RLR rates were estimated for these periods. Table 6.1 shows the different periods monitored. A total of 67 hours were used in the analysis and 46 violations were observed. Violations were detected using the direct observation method. The number of signal cycles in each 15-minute interval was obtained and the opportunity was estimated. The obtained violation rates are shown in Table 6.1.

The difference in the violation rates between the periods with and without students can be seen easily. The violation rates are higher for the period with students, which supports what Retting and Williams noted in their study. The significance level of these changes is shown in Table 6.2. Binomial distribution was used as in the previous chapters. The effect of students is evident with a significance level ranging between 1% and 8%.

TABLE 6.1 Periods Used to Evaluate the Effect of Students

Period#	Dates Included	# Hrs	#RLR	RLR Frequency	Opportunity	RLR Rate	Vacation
4	Nov 2001 - 21, 22,23,24,25	10	3	0.3	164.63	0.018	**Y**
5	Nov 2001 - 26,27,28,29,30 Dec 2001 - 1,6,8,10,12,14	22	19	0.9	330.80	0.057	N
6	Dec 2001 - 16,18,20,22	8	3	0.4	135.51	0.022	**Y**
7	Mar 2002 - 6,7,8	9	13	1.4	263.95	0.049	N
8	Mar 2002 - 10,15,16	18	8	0.4	564.97	0.014	**Y**
	Total	67	46				

TABLE 6.2 Significance Levels for Reduction in Violation Rates – Effect of Students

First Period	RLR rate	Second Period	RLR rate	Total RLR	Prob. Of Success	Significance Level
5	0.057	4	0.018	22	0.668	0.036
5	0.057	6	0.022	22	0.709	0.081
7	0.049	8	0.014	21	0.318	0.004

6.2 Weekday vs. Weekend

To find the effect of weekdays and weekends, we considered all those periods with:

1. No enforcement
2. No vacations
3. Daylight conditions and no precipitation.

A total of 53 hours were used in the analysis and 55 violations were observed. The RLR rates tend to be lower during weekdays than during weekends. It means that drivers feel less comfortable violating red signals when roads are busy. The significance level of the difference in the RLR rate between weekdays and weekends is 19%. The RLR frequencies were similar on weekdays and on weekends.

TABLE 6.3 Weekday vs. Weekend

Period	# Hrs	#RLR	RLR frequency	Opportunity	RLR rate
Weekday	41.5	43	1.036	882.55	0.049
Weekend	11.5	12	1.043	175.08	0.069
Total	53	55			
Level of Significance	0.19				

6.3 Time of Day

The variation in the number of violations over a day was also evaluated. For this purpose, the results obtained from the machine-aided method for the NBTH approach were used. The violations in each hour during weekdays and weekends from November 6 through December 22, 2001 were obtained. The percentage of violations observed in each hour during the day was calculated (Table 6.4 and Figure 6.1). Due to the rather low number of violations used in this analysis, the pattern is somewhat obscured by randomness. Nevertheless, it may be concluded that the frequency of red signal violations tends to follow the variations in traffic volumes.

TABLE 6.4 Distribution of RLRs over a Day

Hr	Weekday	Weekend	% Weekday	% Weekend
00-01	4	1	2.6	1.4
01-02	1	5	0.6	6.8
02-03	1	0	0.6	0.0
03-04	1	4	0.6	5.4
04-05	0	0	0.0	0.0
05-06	1	0	0.6	0.0
06-07	1	1	0.6	1.4
07-08	9	1	5.8	1.4
08-09	7	5	4.5	6.8
09-10	10	10	6.5	13.5
10-11	14	3	9.0	4.1
11-12	21	3	13.5	4.1
12-13	7	2	4.5	2.7
13-14	10	4	6.5	5.4
14-15	3	8	1.9	10.8
15-16	5	4	3.2	5.4
16-17	12	7	7.7	9.5
17-18	6	1	3.9	1.4
18-19	9	2	5.8	2.7
19-20	5	4	3.2	5.4
20-21	7	0	4.5	0.0
21-22	6	2	3.9	2.7
22-23	5	5	3.2	6.8
23-24	10	2	6.5	2.7
Total	155	74	100.0	100.0

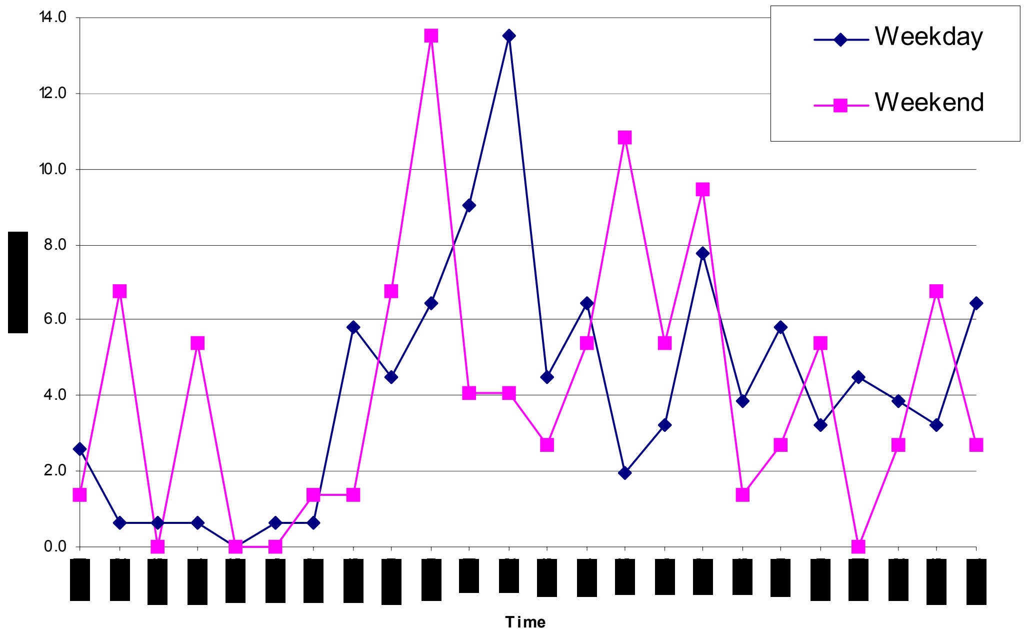


FIGURE 6.1 Daily distribution of RLRs

7. LEGAL ASPECTS OF RED LIGHT RUNNING

Australia and many countries in Europe have implemented photo-enforcement technology. Fourteen states in the Unites States have already used it, while other states are still testing it. The states that permit RLR cameras are *Arizona, California, Colorado, Delaware, Hawaii, Illinois, Maryland, New York, North Carolina, Ohio, Oregon, Virginia, Washington, and the District of Columbia.* In these states, photo-enforcement is defined as an automated system that uses cameras in conjunction with the detector loops and traffic signals at an intersection to photograph the back and/or front of the vehicle during its course of violation and to use the photos to send citations to the drivers.

Law enforcement agencies continue to consider several issues:

- Should a photo of the driver be taken in addition to the vehicle's license plate?
- Who should be ticketed: the owner or the driver of the vehicle?
- Should the issued ticket be equivalent to a ticket for a moving violation or the equivalent of a parking ticket?

7.1 States other than Indiana

The following is a compilation of the information found in several reports published on the Internet by the Federal Railroad Administration, National Highway Traffic Safety Administration, Advocates for Highway and Auto Safety (November 2001), PhotoCop (2000B), and in the report by Hill et al. (2000). The Internet sites were accessed in May 2001.

Arizona

Arizona does not have a specific photo-enforcement law. Some communities like Paradise Valley, Scottsdale, Mesa, and Tempe are using red light cameras. Many other communities including Phoenix are contemplating the use of red light cameras. The state also allows these cameras to be used to enforce speed.

California

The California Legislature successfully extended the authority it granted to use the automated enforcement at railroad grade crossings to using it at signalized intersections, and provisions were made in the California Vehicle Code, section 21455.5 to enforce it.

Provisions made in the legislature for photo-enforcement

The important features of the photo-enforcement laws are:

1. It assigns liability to the driver and not the registered owner of the vehicle. This law came into effect in 1996.
2. It requires a clear frontal photograph of a vehicle, with its license plate and driver. Photos of the driver are compared to driver's license photographs of the vehicle's registered owner. If both photos showed the same person, he/she will be given a moving violation that has the same severity as if a police officer had witnessed the violation and issued a ticket on the scene, as per State Senate Bill 1802.
3. For photo-enforcement citations, Municipal Court Commissioners in San Francisco also required that the address for the registered owner match that from the driver's license file on record with the Department of Motor Vehicles.
4. It allows the 'Notice to Appear' citations for photo-enforcement to be mailed. It should mail the citations within 15 days from the date of violation.
5. It allows a three-year 'sunset' clause allowing the program to be tested for three years from 1996-1998.
6. The California Traffic Control Devices Committee prepared a standard photo-enforcement sign to be used throughout the state. Jurisdictions using automated enforcement must post these signs at each monitored intersection or at all major entrances to the city.
7. In 1999, a registered-owner liability bill was re-introduced. This bill eliminated points when the violation was observed using automated enforcement.

Problems faced

1. It is difficult to obtain a clear photograph of the driver due to glare on windshields, dark interiors, blocking by other vehicles, etc.
2. In cases where the driver is not identifiable, the registered owner does not receive a point against his/her driving record. Discussions continue if points will be assessed to convicted drivers or to eliminate points altogether.

Colorado

The following provisions were made under Colorado Rev. Stat. § 42-4-110.5 to accommodate the use of photo-radar for RLR:

1. The points cannot be added against a license.
2. A warning is issued if it is the driver's first violation.

Delaware

A statewide law (Section 4101, Title 21) was enacted in 1997, which authorizes the use of red light cameras. The main features of the law include:

1. The owner of the vehicle is liable for any violation.
2. The photos from the monitoring system can be used as proof of violation.
3. It cannot be used to convict the owner and is not made part of the operating record of that person. It cannot be used for insurance purposes in the provision of motor vehicle insurance coverage.
4. The monetary penalty imposed should not exceed $50.
5. Summons can be sent through mail.

District of Columbia

1. Violations caught on camera are considered equivalent to a moving violation.
2. The photos from the monitoring system can be used as proof of violation.
3. Owner is liable for the violation unless he produces a statement with the name and address of the driver who was actually operating the vehicle at that time.

Hawaii

The state started a three-year demonstration program in 1998 and made provisions under Act 234 authorizing the use of photo-enforcement.

1. Signs must be placed at the intersections that are monitored by cameras
2. Owner is liable for the violation. He can produce evidence stating the actual driver at the time of violation. The driver would then be sent a citation.

Illinois

1. The frontal picture of the vehicle with the driver and license plate of the vehicle is required.
2. The citation should be issued within 30 days after the violation.
3. The photos obtained from the system can be used to prove the violation.
4. Informative signs must be posted at intersections equipped with cameras.

Maryland

Transportation Act 21.202.1 was enacted in October 1997, which enabled the use of cameras at signalized intersections to catch red light violators. The main features include:

1. The owner of a motor vehicle is subject to a civil penalty and responsible for the violation.
2. Citations must be mailed to offenders within two weeks after the violation.
3. Rear photography of the license plate will be used.
4. Civil penalty should not exceed $100 and citations must be mailed within two weeks of the alleged violation. The current fine is $75, which was set by the Chief Judge of the District Court of Maryland.
5. It is not a moving violation and may be treated as a parking violation.
6. Photos from the system can be used as evidence.
7. There is no sunset provision.
8. A bill was introduced in April 2002, which proposed to standardize the camera enforcement program. Currently the local jurisdictions are operating the RLR photo-enforcement programs according to local laws. This bill would enable similar design

standards and eliminate the controversy that such programs are used as revenue collectors (Washington Post, 2002).

New York

The New York State Law, under Section 1111-A, allows the use of photo-enforcement in the state. The main features of the laws enacted are:

1. Only the vehicle's rear license plate is photographed and a citation is issued to the registered owner of the vehicle.
2. A ticket, called a "Notice of Liability," which is a civil infraction, or the equivalent of a parking ticket, is issued to the owner.
3. The owner of the vehicle is held responsible for violations recorded by automated enforcement systems, but the violation is not a conviction against the owner and cannot become part of the owner's operating record.
4. A sunset provision is also included.
5. Provisions were made to allow for notices of liability to be mailed.
6. A certificate swearing to the violation (after inspecting the photographs) by an authorized person is used as evidence.
7. The issue of driver privacy led to the decision to pursue only rear photography.

City of Toledo, Ohio

1. The City of Toledo Division of Transportation, the Toledo Police Department, and the Toledo Department of Law are responsible for administering the Automated Red Light System.
2. Officials or agents of the City of Toledo shall process "Notice of Liability."
3. The owner of the vehicle is made liable for the violation, but he can produce an affidavit stating the name and address of the person who was actually operating the car at the time of violation.

Virginia

1. Each locality may operate no more than 25 monitoring systems at one time.

2. The owner of the vehicle is considered responsible for the violation, but he can produce a statement with the name and address of the driver operating the vehicle at that time. The operator of a vehicle is liable for the monetary penalty.
3. Information obtained from a monitoring system can be used as proof of a violation. A certificate sworn by an authorized person after inspecting the photographs may be used as evidence.
4. The violation is not a driving conviction and cannot be made a part of the operating record. It cannot be used for insurance purposes.
5. Penalty may not exceed $50.
6. In the case of injuries, the photo evidence also may be used.

Florida

Florida does not currently have a law that permits the issuance of citations for automated enforcement of RLR violations. Legislation has been introduced for five successive sessions of the legislature but has not been successfully enacted. Warning letters are mailed to drivers who are caught running red lights by automated enforcement systems.

7.2 Indiana

The current Indiana state law regarding red light behavior states that vehicles facing a steady red should stop at the stop-line or before the crosswalk on the near side of the intersection. After making a stop, the vehicles can make a right turn or make a left turn if turning from the left lane of a one-way street onto another one-way street with the flow of traffic.

The *State Senate Bill SB 4* (February 2001) addressing photo-enforcement was introduced in the Indiana General Assembly for the first time on February 6, 2001. It could not get the majority of votes to be passed. It was reintroduced after a year, on February 26, 2002 and failed to pass again.

TABLE 7.1 Summary of Photo-enforcement Laws

State	Location	Liability	Image	Penalty	Defenses
Arizona	Phoenix, Tempe	No Specific Statute			
California	Statewide	Owner/Driver	License Plate and Driver	$100	Driver responsible if owner identifies him
Colorado	Statewide	Owner/Driver	License Plate and Driver	$75	Driver responsible if owner identifies him
Delaware	Statewide	Owner	2 or images of vehicle	$75 - $230; Not a conviction and cannot be used for insurance;	Driver responsible if owner identifies him
Dist. of Columbia	Entire Jurisdiction	Owner	N.A	$75	Driver responsible if owner identifies him
Illinois	Municipalities with 1,000,000	N.A	2 or images of vehicle	Maximum $500	Not Addressed (N.A)
Maryland	Statewide	Owner	2 or images of vehicle	Max. $500	Yielding to emergency vehicle; funeral procession; owner identifies driver;
New York	Cities with population 1,000,000; limit 50 intersections	Owner	2 or images of vehicle	Max. $100	Vehicle stolen/leased; owner identifies driver
North Carolina	Only some communities	Owner	2 or images of vehicle	Max. $100	Vehicle stolen/leased; owner identifies driver
Ohio	Toledo	Owner	N.A	Max. $75	N.A
Oregon	Cities with population > 30,000	Owner	2 or images of vehicle	Max. $300	Driver responsible if owner identifies him
Virginia	Statewide; limit 25 intersection	Driver	2 or images of vehicle	Max. $200	Driver responsible if owner identifies him
Washington		Driver	2 or images of vehicle	Max. $250	Driver responsible if owner identifies him

Source: IIHS, June 2002

Features of the bill introduced in Indiana - Automated Traffic Law Enforcement System

An automated traffic law enforcement system is defined as a device that has one or more motor vehicle sensors working in conjunction with a traffic control signal with steady red indication or an illuminated flashing red light and produces a photographically recorded image of a motor vehicle violating the red. The bill that was introduced contains the following provisions:

1. A local authority is allowed to adopt photo-enforcement by virtue of state enactment.
2. The violation notice must clearly indicate the following:
    a. The name and address of the owner of the motor vehicle
    b. The registration number of the motor vehicle
    c. The violation charged
    d. The location of the intersection
    e. The date and time of the violation
    f. A copy of the recorded image
    g. The amount of the civil penalty, not exceeding $100.
3. The warning notices in lieu of imposing a civil penalty can be mailed.
4. A local authority using photo-enforcement must install advance-warning signs along the roadways preceding the intersection at which an automated traffic law enforcement system is located.
5. The owner of the vehicle is given the opportunity to provide to the "ordinance violations bureau" or court that has jurisdiction, within 30 days of receiving notices, the name and address of the person who was operating the vehicle at the time of the alleged violation. A statement would then be issued to the person operating the vehicle.
6. In the following cases, compliance with the red signal is exempted:
    a. An authorized emergency vehicle may proceed past a red or stop signal or stop sign after slowing down as necessary for safe operation.
    b. Traffic control signal lights are giving no indication or conflicting indications.
    c. Vehicles with lighted headlights in a funeral procession.

8. CONCLUSIONS

This research studied the red light running (RLR) problem in Indiana through analyzing crash statistics, conducting a drivers' survey, and monitoring traffic at a selected intersection. A telephone survey was conducted to learn about Indiana drivers' perception of the problem. Changes in the behavior of drivers in response to police enforcement and photo-enforcement implemented at the study intersection were investigated. Two methods, direct observation and the machine-aided method, were used to monitor and record the violations. The machine-aided method was developed using a video detection system. The effects of student population, time of day, and day of the week on RLR were also studied.

This research demonstrates that the magnitude of the RLR problem in Indiana is similar to the RLR problems faced by other states. Nearly 22% percent of all signalized intersection crashes in Indiana are RLR-related, and 50% of all fatal crashes at these intersections are caused by RLR. Sixty-seven percent of Indiana drivers feel that RLR is a problem in Indiana, and only 5% claim that they never see a red light violation. Further, 12% of Indiana drivers claim to have been involved in RLR-related crashes. Nine percent of through drivers arriving at the study intersection during first two seconds of red signal violated the red signal.

A reliable direct observation was used as a leading research tool to evaluate the police and photo-enforcement effectiveness in changing driver behavior. The machine-aided method performed well for selected through-lanes. Its use was limited to studying the difference in driver behavior during daytime and nighttime conditions.

A new concept called *opportunity* for RLR was introduced in this research to improve RLR measurement. Opportunity for RLR is the expected number of drivers arriving at the beginning of a red signal. The opportunity is estimated as the product of traffic volume and the number of signal cycles. It is a true exposure of drivers to RLR.

RLR rate, a measure used in this study, is the proportion of drivers having opportunity for RLR who violate the red signal.

Police enforcement reduced the RLR rate by 75% in the week immediately after the enforcement. This reduction was significant at a level of 1%. A month later, the reduction was found to be 37%, still significant although at the 11% level. Photo-enforcement reduced the RLR rate by 62% during the week of enforcement, which was significant at a level of 2%. The reduction was 35% in the week immediately after the enforcement ended, which was significant at a level of 19%.

There is empirical evidence that reduction of red signal violations translates into reduction in crashes. Crash counts before and after the installment of red-light cameras at intersections in Howard County, Maryland, were analyzed and the crash reduction factors were estimated. The angle crashes were reduced by 40%, while the rear-end rashes were reduced by 10%. A 17% reduction was observed in total crashes. These estimates have not been adjusted for the regression-to-mean effect.

Other potential factors of RLR were also examined. The effect of students on the violation rate was clearly visible. The results support the common opinion that young drivers are more aggressive and are more willing to violate signals than other drivers. Also, violation rates tend to be higher during the weekend than during the weekday. The distribution of violations over a day indicates higher frequency of RLR between 9 AM and 5 PM as expected.

The automated traffic enforcement bill was passed by the Indiana Senate in January 2002 and then tabled in the House of Representatives. The city of Fort Wayne is contemplating the use of photo-enforcement before the enactment of state legislation. The telephone survey of Indiana drivers showed that 78% supported photo-enforcement. This result coincides with the survey results conducted in other states.

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Appendix A

Accident Statistics at Red Light Camera Intersections
Howard County, Maryland

ACCIDENT STATISTICS

*RED-LIGHT CAMERA INTERSECTIONS***

Howard County, Maryland

January 2002

CAMERA LOCATION	LOCATION	INSTALLED	BEFORE INSTALLATION					AFTER INSTALLATION					% CHANGE (+,-)			
			Period	*Rear End*	*Angle*	*Other**	*Total*	Period	*Rear End*	*Angle*	*Other**	*Total*	*Rear End*	*Angle*	*Other**	*Total*
HC 01/600	Eastbound Little Patuxent Parkway @ Columbia Road	2/18/98	***April 1994 to February 1998*** 46 months	31	10	11	52	***February 1998 to December 2001*** 46 months	29	6	11	46	**-6.5**	**-40**	**0**	**-11.5**
HC 02/601	Northbound Broken Land Parkway @ Stevens Forest Road	2/18/98	***April 1994 to February 1998*** 46 months	42	16	9	67	***February 1998 to December 2001*** 46 months	36	10	12	58	**-14**	**-37.5**	**+33**	**-13.5**
HC 03/602	Northbound Broken Land Parkway @ Snowden River Parkway	3/11/98	***June 1994 to March 1998*** 45 months	31	9	15	55	***March 1998 to December 2001*** 45 months	26	6	16	48	**-16**	**-33**	**+6.5**	**-12.5**
HC 04/603	Southbound Broken Land Parkway @ Snowden River Parkway	3/12/98	***June 1994 to March 1998*** 45 months	22	9	14	45	***March 1998 to December 2001*** 45 months	15	3	15	33	**-32**	**-67**	**+7**	**-26.5**
HC 05/604	Southbound Broken Land Parkway @ Cradlerock Way North	3/26/98	***June 1994 to March 1998*** 45 months	23	10	8	41	***March 1998 to December 2001*** 45 months	23	5	9	37	**0**	**-50**	**+12.5**	**-10**
HC 06/605	Southbound Broken Land Parkway @ Stevens Forest Road	3/26/98	***June 1994 to March 1998*** 45 months	24	11	7	42	***March 1998 to December 2001*** 45 months	16	5	6	27	**-33**	**-54.5**	**-14**	**-35.5**
HC 07/606	Northbound Cedar Lane @ Hickory Ridge Road	4/7/98	***August 1994 to April 1998*** 44 months	9	12	7	28	***April 1998 to December 2001*** 44 months	10	7	8	25	**+11**	**-41.5**	**+14**	**-10.5**

**** Valid only for red light camera approach roadways; Howard County Police statistics only**
*** Side swipe collisions, etc.**

FIGURE A1 RLR crash statistics, Howard County

FIGURE A2 RLR crash statistics, Howard County

CAMERA LOCATION	LOCATION	INSTALLED	BEFORE INSTALLATION					AFTER INSTALLATION					% CHANGE (+,-)			
			Period	*Rear End*	*Angle*	*Other**	*Total*	Period	*Rear End*	*Angle*	*Other**	*Total*	*Rear End*	*Angle*	*Other**	*Total*
HC 08/607	Eastbound Governor Warfield Parkway @ Little Patuxent Parkway	4/28/98	*August 1994 to April 1998* 44 months	23	10	12	45	*April 1998 to December 2001* 44 months	22	4	12	38	-4.5	-60	0	-15.5
HC 09/608	Northbound Little Patuxent Parkway @ Governor Warfield Parkway	5/6/98	*September 1994 to May 1998* 43 months	21	8	10	39	*May 1998 to December 2001* 43 months	19	7	12	38	-9.5	-12.5	+20	-2.5
HC 10/609	Southbound Little Patuxent Parkway @ Governor Warfield Parkway	5/6/98	*September 1994 to May 1998* 43 months	18	10	9	37	*May 1998 to December 2001* 43 months	20	4	11	35	-11	-60	+22	-5.5
HC 11/610	Southbound U.S. Route 1 @ Guilford Road	7/17/98	Operated July 1998 to October 2000					Removed from Service October 20, 2000					No Longer in Service			
HC 12/611	Northbound U.S. Route 1 @ Guilford Road	7/17/98	*March 1995 to July 1998* 41 months	13	13	14	40	*July 1998 to December 2001* 41 months	12	10	8	30	-7.5	-23	+42.5	-25
HC 13/612	Southbound U.S. Route 29 @ Rivers Edge Road	7/30/98	*May 1995 to August 1998* 40 months	16	6	10	32	*August 1998 to December 2001* 40 months	17	7	8	32	+6	-16.5	-20	0
HC 14/613	Southbound Cedar Lane @ Freetown Road	7/30/98	*May 1995 to August 1998* 40 months	7	13	5	25	*August 1998 to December 2001* 40 months	3	11	5	19	-57	-15.5	0	-24
HC 15/614	Southbound MD Route 32 @ MD Route 144	11/10/98	*September 1995 to November 1998* 38 months	10	14	7	31	*November 1998 to December 2001* 38 months	7	8	5	20	-30	-42.5	-28.5	-35.5

*** Side swipe collisions, etc.**

FIGURE A3 RLR crash statistics, Howard County

CAMERA LOCATION	LOCATION	INSTALLED	BEFORE INSTALLATION Rear End	Angle	Other*	Total	AFTER INSTALLATION Rear End	Angle	Other*	Total	% CHANGE (+,-) Rear End	Angle	Other*	Total
HC 16/615	Westbound U.S. Route 40 @ Chatham Road	11/19/98	*September 1995 to November 1998* 38 months				*November 1998 to December 2001* 38 months				0	-44.5	-50	-25
			15	9	8	32	15	5	4	24				
HC17/616	Westbound U.S. Route 40 @ Rogers Avenue	12/3/98	*December 1995 to December 1998* 36 months				*December 1998 to December 2001* 36 months				-10	-35	-42.5	-23.5
			30	17	12	59	27	11	7	45				
HC 18/617	Southbound U.S. Route 29 @ MD Route 216	12/9/98	**Operated December 9. 1998 to February 18, 2000**				**Removed from Service February 18, 2000**				**Interchange Project**			
HC 19/618	Southbound Broken Land Parkway @ Hickory Ridge Road	12/18/98	*December 1995 to December 1998* 36 months				*December 1998 to December 2001* 36 months				-15.5	-20	-14.5	-16
			19	5	7	31	16	4	6	26				
HC 20/619	Eastbound Snowden River Parkway @ Oakland Mills Road	1/5/99	*February 1996 to January 1999* 35 months				*January 1999 to December 2001* 35 months				+33	-50	-27	0
			21	8	11	40	28	4	8	40				
HC 21/620	Westbound Snowden River Parkway @ Broken Land Parkway	2/4/99	*May 1996 to February 1999* 34 months				*February 1999 to December 2001* 34 months				-5	-50	-7.5	-13
			19	6	13	38	18	3	12	33				
HC 22/621	Eastbound U.S. Route 40 @ Rogers Avenue	4/6/99	*September 1996 to April 1999* 32 months				*April 1999 to December 2001* 32 months				-21	-30	-11	-26.5
			19	10	9	38	15	7	8	30				
HC 23/622	Westbound Snowden River Parkway @ Oakland Mills Road	6/25/99	*January 1997 to June 1999* 30 months				*June 1999 to December 2001* 30 months				0	-42	-12.5	-16
			10	7	8	5	10	4	7	21				

*** Side swipe collisions, etc.**

FIGURE A4 RLR crash statistics, Howard County

CAMERA LOCATION	LOCATION	INSTALLED	BEFORE INSTALLATION				AFTER INSTALLATION				% CHANGE (+,-)			
			Rear End	*Angle*	*Other**	*Total*	*Rear End*	*Angle*	*Other**	*Total*	*Rear End*	*Angle*	*Other**	*Total*
HC 24/623	Westbound Little Patuxent Parkway @ Columbia Road	6/25/99	***January 1997 to June 1999*** 30 months				***June 1999 to December 2001*** 30 months				**0**	**-71.5**	**-50**	**-37.5**
			9	7	8	24	9	2	4	15				
HC 25/624	Eastbound U.S. Route 40 @ Marriottsville Road	8/26/99	**Operated August 26, 1999 to October 11,2000**				**Removed from Service October 11, 2000**				**No Longer in Service**			
HC 26/625	Eastbound Snowden River Parkway @ Berger Road	10/20/00	***April 1999 to October 2000*** 14 months				***October 2000 to December 2001*** 14 months				**-60**	**-50**	**-67**	**-60**
			5	2	3	10	2	1	1	4				
HC 27/626	Northbound Cedar Lane @ Little Patuxent Parkway	8/23/00	**Operated August 23, 2000 to September 20, 2001**				**Removed from Service September 20, 2001**				**No Longer in Service**			
HC 28/627	Eastbound Little Patuxent Parkway @ Harper's Farm Road	8/23/01	***April 2001 to August 2001*** 4 months				***August 2001 to December 2001*** 4 months				**0**	**-50**	**0**	**-25**
			1	2	1	4	1	1	1	3				
HC 29/628	Northbound MD Route 32 @ MD Route 144	10/20/00	***August 1999 to October 2000*** 14 months				***October 2000 to December 2001*** 14 months				**-33**	**+33**	**-50**	**-12.5**
			3	3	2	8	2	4	1	7				
HC 30/629	Westbound U.S. Route 40 @ North Ridge Road	Pending	**Pending**				**Pending**				**Pending**			

*** Side swipe collisions, etc.**

Source of Data: Office of Howard County Traffic Engineering

Appendix B

Questionnaire used for the Telephone survey

“Red Light Running”

DON'T ASK, Write the ph num: ________________

Hello. My name is **** (Tell your name). I am a Research student at the Transportation Division-Purdue University and we are conducting a research on "***Safety on highways***". The survey will not take more than 5 to 10 minutes. Your responses to this survey are confidential. Can you or someone else in your household who has a driver's license spare a few minutes? **(IF NO, THANK AND TERMINATE.)**
ONCE SUCH A RESPONDENT IS ON THE PHONE AND IS WILLING TO PARTICIPATE: ***Thank you for agreeing to participate in our survey. If anything is not clear to you please ask. Shall we begin the survey?***

The questions:

1. How many stoplights do you pass through daily?

2 At how many of these signals do you need stop? Please estimate

3 Do you consider red light running to be a dangerous act? (1/0)

4 Do you believe that red light running is a problem in Indiana? (1/0)

4A. **(IF YES TO #4)** Why do you think it is a problem? **(DON'T READ, BUT CHECK ALL THAT APPLY)**

1) Causes crashes, injuries, deaths
2) Everyone is doing it
3) Afraid of getting hit at intersections
4) Other:

4B. **(IF NO TO #4)** Why do you think it is not a problem? **(DON'T READ, BUT CHECK ALL THAT APPLY)**

1) Does not lead to many crashes, injuries, deaths
2) Do it all the time and nothing bad happens
3) Light cycles have time built in to allow red light running to occur safely
4) Police don't care because they have more important crimes to deal with
5) Other:

5. How often do you see people running red lights?
   1) Every day
   2) A few times a week
   3) Seldom
   4) Never

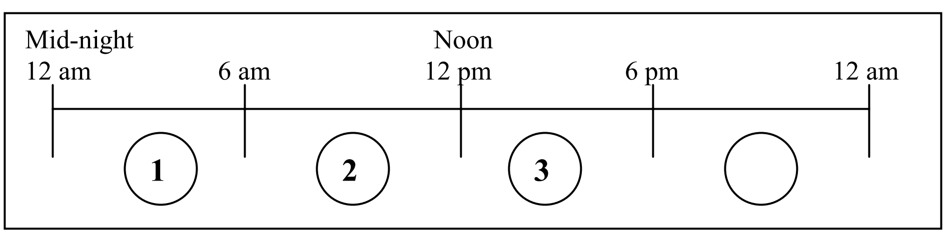
6. Why do you think people run reds?
   1) Couldn’t stop in time
   2) Were in hurry
   3) Weren’t paying attention
   4) Other.

IF OTHER : Can you be more specific?

7. Out of 10 drivers who run a red light, how many do you think will actually be stopped and ticketed by police?

8. Have you ever been in a crash involving a red light runner? (1/0)

9. What time of day are you most likely to see a red light runner? Please give a specific time, like “3:00 p.m.”. **(DO NOT READ LIST)**
   1) 12:01 a.m. – 6:00 a.m.
   2) 6:01 a.m. – 12:00 p.m.
   3) 12:01 p.m. – 6:00 p.m.
   4) 6:01 p.m. – 12:00 a.m.



10 Which of the following measures do you think help to red light running?
   1) More education
   2) Improve stoplights
   3) Increase fines

4) Police enforcement
5) Other:

11 Some states in country are using cameras at intersection to take photos of red light runners to send tickets. If such a measure were introduced in Indiana, which of the following would you do?

1) Strongly support
2) Support
3) Oppose
4) Strongly oppose

12 About how many miles per year do you drive? Please estimate. **(DO NOT READ LIST.)**

1) Less than 10,000
2) 10,000 - 15, 000
3) 15,001 – 20,000
4) More than 20,000

13 On which roads do you drive typically-City or Country-side?

1) City
2) Country-side

14 Are you a parent? (1/0)
IF YES: Do you have any children:

14A Under five years? (1/0)
14B Between 5 and 16 years? (1/0)
14C Between 16 and 19 years? (1/0)

Gender **(DON'T ASK, JUST WRITE IT DOWN 1=M, 0=F):**
Thank you very much for sparing your valuable time and patiently answering to the survey. Your responses are very useful.

SPECIAL INSTRUCTIONS:

- Dial phone number and then dial 8139754
- Enter YES=1, NO=0.
- Go to Tools→ Options → Edit, select "right" in the combo-box. Pressing "Enter" button now, will take you to the cell to the right, so that you can just use the numeric buttons on the right side.
- Questions are inserted as comments so that you can see the question in the excel spreadsheet itself. Split the window into two by going to Window → Split.
- For choices enter the number (1,2...) of the choice, NOT a,b…
- If we can choose more than one choice (1,2,3..), enter the options as number say if they chose 1 and 3 then enter 13
- Enter MALE=1 and FEMALE =0

Appendix C

Reponses of Indiana Drivers to the Survey

TABLE C1 Reponses of Indiana Drivers to the Survey

#	Surveyor	1	2	3	4	4A	4Aother	4B	4Bother	5
1	Brian	30	15	1	1	1				3
2	Brian	1	1	1	0		Could not say - 87 yrs. Old			4
3	Brian	12	6	1	1	2				1
4	Brian	50	25	1	0				Did not have a real answer	1
5	Brian	2	2	1	0		No specific opinion			3
6	Brian	20	6	1	1	1				1
7	Brian	3	1	1	0				Never seen a red light runner	4
8	Brian	2	2	1	1	2				3
9	Brian	5	3	1	1		High volume of traffic			1
10	Brian	30	15	1	1	1				2
11	Brian	10	5	1	1		Dangerous			3
12	Brian	20	10	1	1	1				3
13	Brian	20	15	1	0				Infrequent	3
14	Brian	0	0	1	1		See it frequently			2
15	Brian	3	2	1	1		People not paying attention			1
16	Brian	8	4	1	0				Don't see it often	3
17	Brian	5	2	1	1	1				2
18	Brian	25	12	1	1	1,2				1
19	Brian	10	5	1	1	3				2
20	Brian	20	10	1	1	1				1
21	Brian	4	2	1	1	1				3
22	Brian	30	15	1	1		Everyone in a hurry			1
23	Brian	5	3	1	1		Lax with experience			3
24	Brian	300	210	1	1	1,3				1
25	Brian	15	15	1	1	1				2

TABLE C1 Reponses of Indiana Drivers to the Survey (continued)

#	6	6other	7	8	9	10	10other	11	12	13	14	14A	14B	14C	M/F
1	2		0	1	3	1		2	3	2	1	1	0	0	1
2	2		0	0	4	2	3	1	2	1					1
3	2		2	0	2	4	2	4	1	1					1
4	2		2	0	1	1		2	3	1	1	0	0	0	0
5	2		0	0	3		Cameras	2	2	2	0				0
6	2		1	0	1	4		2	4	1	1	0	1	0	1
7	2		1	0	3	4		2	1	2	0				0
8		Taking chances	2	0	3	3,4		1	1	2	1	0	0	0	0
9	2		0	0	2,3		Better traffic flow	2	3	1	1	0	0	0	1
10	2		4	0	3	3		2	3	1	0				0
11	2		2	0	3	2,4		3	2	1	1	0	1	0	1
12	2,3	Cell phones	2	0	3	2		2	2	1	1	1	1	0	0
13	1		3	0	4	2		4	3	2	1	0	0	1	0
14	2		0	0	3	1,2		2	4	1	0				0
15	2		1	0	2	4		2	4	2	1	0	1	0	0
16	1,2		2	0	2	3,4		4	1	1	0				0
17	2		0	0	3		Camera	2	4	1	1	1	1	0	1
18	2		1	1	2		Cameras	1	4	1	1	1	1	0	1
19	2		2	0	2,3	1		2,3	4	2	1	1	1	0	1
20	2		1	0	2,3	4		3	3	2	1	0	1	1	1
21	3	Stupid	1	0	2	4		2	4	2	1	0	1	0	0
22	2		1	0	3	4		1	3	1	1	0	1	1	1
23	3		4	0	2,3	1,3		2	2	2	1	0	0	0	0
24	2		0	0	2,3	2		2	4	2	1	0	1	0	1
25	2,3		10	0	3	3		1	1	1	1	0	1	0	0

TABLE C2 Reponses of Indiana Drivers to the Survey

#	Surveyor	**1**	**2**	**3**	**4**	**4A**	**4Aother**	**4B**	**4Bother**	**5**
26	Brian	7	3	1	1	1				2
27	Brian	20	12	1	1		Typical of road rage			1
28	Brian	12	6	1	1	1				1
29	Brian	4	2	1	1	1				1
30	Brian	20	15	1	1	1				1
31	Brian	2	2	1	1	1				3
32	Brian	40	20	1	0				Haven't seen it	3
33	Brian	10	5	1	0				Don't see it often	3
34	Brian	3	2	1	1	2				2
35	Brian	4	4	1	0		Doesn't occur often			3
36	Brian	4	1	1	1	3				3
37	Brian	10	5	1	1		People not paying attention			2
38	Brian	5	2	1	1	1				3
39	Brian	2	2	1	0				Don't see it often	3
40	Brian	2	2	1	0				Don't see it often	3
41	Brian	30	15	1	1	1				3
42	Brian	8	6	1	1	1				2
43	Brian	8	2	1	1	2				3
44	Brian	20	10	1	0					1
45	Brian	6	6	1	1	1				1

TABLE C2 Reponses of Indiana Drivers to the Survey (continued)

#	6	6other	7	8	9	10	10other	11	12	13	14	14A	14B	14C	M/F
26	2		4	0	2,3	1,3		2	2	1	1	0	1	0	0
27	2		0	0	3	1		1	4	1	1	0	0	0	1
28	2		1	0	2,3	3,4		1	1	1	0				0
29	2		0	0	2	4		1	4	1	1	0	1	0	0
30	2,3		2	1	3	4		2	3	1	1	0	1	0	0
31	2		0	0	2	3		3	2	2	1	0	1	0	1
32		Shoelaces not tied tight enough? I think this is a saying for not paying attention or obeying the law/	1	0	2,3	3		2	4	1	1	0	1	0	1
33	2		0	0	2,3	1		2	2	2	1	0	0	0	0
34	2		0	0	2	4		1	4	2	0				0
35	2,3		1	0	1		People paying more attention	2	1	1,2	1				0
36	3	Drinking	0	0	1,2,3,4	2,4		2	2	1,2	1				0
37	2		1	0	2	3		2	3	1,2	1	1	1	0	1
38	2		0	1	2	1,4		2	2	1	1	0	0	1	0
39	2		1	0	2,3	2		2	2	1	1	0	1	1	1
40	2		1	0	2,3	2		2	2	1	1	0	1	1	1
41	3		2	0	3	3		2	1	1	1	0	0	0	0
42	2,3		0	0	2,3		No good method	3	4	1,2	1	0	0	1	1
43	2		0	0	3	3		2	2	1	1	0	0	0	0
44	2		1	0	1	3,4		3	3	1	0				1
45	2		0	0	3		Cameras	1	2	1,2	1	1	0	0	0

TABLE C3 Reponses of Indiana Drivers to the Survey

#	Surveyor	1	2	3	4	4A	4Aother	4B	4Bother	5
46	Brian	6	2	1	1	1				2
47	Brian	10	7	1	1	1,3				2
48	Brian	1	1	1	1		People not paying attention			3
49	Brian	4	2	1	1	2				2
50	Brian	50	25	1	0		Not aware of any problem in Indiana			3
51	Brian	5	3	1	1	4	People going through green unprepared for red light runners			3
52	NLKR	7	3	1	1	23				1
53	NLKR	8	7	1	1					4
54	NLKR	8	4	0	0			5	Duty of people to obey them	3
55	Yeq	3	2	1	0			1		3
56	Yeq	25	15	1	0			1	1	1
57	Yeq	too many		1	1	1				14
58	Yeq	6	4	1	0			1		2
59	Yeq	7	4	1	0			3		3
60	Yeq	5	3	1	0			1		2
61	Yeq	12	7	1	0			1		1
62	Yeq	17	11	0	0			4		2
63	Yeq	3	1	0	1	1				1
64	Yeq	9	5	1	0			1		3
65	Yeq	3	1	1	0			3		2

TABLE C3 Reponses of Indiana Drivers to the Survey (continued)

#	6	6other	7	8	9	10	10other	11	12	13	14	14A	14B	14C	M/F
46	2		1	1	2	4	Societal change; persons leaving 5 min. Earlier	3	2	1,2	1	0	1	0	1
47	3		1	0	3	1		2	4	1,2	1	0	0	0	1
48	3		0	0	3	1,4		2	1	1,2	1	1	1	0	0
49	2		0	0	3	4		1	2	1,2	1	0	1	0	0
50	2		1	1	1,4	2		4	4	1,2	1	1	1	0	1
51	2		0	0	3	2		2	1	1,2	1	0	1	0	0
52	2		0	0	3	4		1	2	1	1	1	0	0	1
53	2		1	1	2	3		4	3	1	1	0	1	0	0
54	2		1	0	2	3		2	2	1	1	0	0	0	0
55	2		1	1	2	4		2	2	1	0				0
56	2		1	0	3	4		2	2	1	1	0	1	2	1
57	4	Unreasonable lights	3	0	14	1,2,4		2	4	2	1	0	0	0	1
58	2		1	0	4	2,3		2	3	1,2	0				0
59	1		2	0	1	4		3	2	2	0				1
60	2		1	0	3	3		2	3	1	1		1	1	1
61	3		1	0	2	2		2	2	1	0				1
62	3		2	0	2	3,1		3	3	1	0				0
63	1		2	0	4	2		3	2	1	0				0
64	2		3	0	4	2		2	2	2	1	1			1
65	2		1	0	3	1		2	2	1	0				0

TABLE C4 Reponses of Indiana Drivers to the Survey

#	Surveyor	**1**	**2**	**3**	**4**	**4A**	**4Aother**	**4B**	**4Bother**	**5**
66	Yeq	15	5	1	0			1		2
67	Yeq	8	2	0	1	3				1
68	Yeq	12	6	1	0			1		1
69	Yeq	14	8	1	1	1				2
70	Yeq	9	5	1	0			2		1
71	Yeq	5	4	0	0			1		1
72	Yeq	7	4	1	0			3		1
73	Rob	6	3	1	1	1		2		2
74	Rob	5	5	1	0			2		3
75	Rob	20	6	1	0					3
76	Rob	4	4	1	1	3				1
77	Rob	3	1	1	0			4	People in southern states do it more than up here!	3
78	Rob	12	6	1	0					3
79	Rob	10	9	1	1	1				3
80	Rob	20	12	1	1	34	Children			1
81	Rob	1	1	1	1	4	Not pay attention			3
82	Rob	20	4	1	1	4	Not pay attention, try to beat light			1
83	Rob	10	5	1	0			5	Follow rules of road	3
84	Rob	0	0	1	1	4	Rush			3
85	Rob	30	15	1	0			5	Doesn’t happen at all	3

TABLE C4 Reponses of Indiana Drivers to the Survey (continued)

#	6	6other	7	8	9	10	10other	11	12	13	14	14A	14B	14C	M/F
66	2		1	1	1	1		3	3	1	1		2	1	0
67	1		2	0	3	1		2	3	2	1		1	1	1
68	2		2	0	1	1		2	4	2	0				0
69	2		0	0	4	4		2	1	1	1	1	1		0
70	1		2	0	2	3		2	2	1	0				1
71	3		1	1	1	1,4		2	2	1	1			2	0
72	3		1	0	1	3		3	1	2	0				1
73	1234	Road, icy, weather	3	0	3	24		3	1	1	0	0	0	0	0
74	123		1	0	4	3		3	3	2	1	0	1	1	1
75	123		1	0	2	34		2	2	1	1	0	0	0	0
76	34	Young drivers	2	1	3	3		1	1	2	1	0	0	0	1
77	23		2	0	1	34		2	4	2	0	0	0	0	1
78	3		1	0	4	5	Didn't say!	4	3	2	0	0	0	0	1
79	12		0	0	2	245	Flash yellow before red, like mexico	1	4	2	1	0	1	1	0
80	2		0	0	3	4		3	1	1	1	1	0	0	0
81	3		1	0	3	2	Stoplights need to be more uniform (comment)	2	1	2	1	0	0	0	1
82	34	Try to beat yellow	1	0	2	34		1	3	1	1	1	1	0	1
83	12		0	0	2	5	More actuation at all intersections	2	2	2	0	0	0	0	1
84	23		2	0	2	4		2	2	1	1	0	0	0	0
85	2		1	0	2	34		2	2	1	1	1	0	0	0

TABLE C5 Reponses of Indiana Drivers to the Survey

#	Surveyor	1	2	3	4	4A	4Aother	4B	4Bother	5
86	Rob	10	5	1	1	1				2
87	Rob	10	5	1	1	1				2
88	Rob	1	1	1	0					1
89	Rob	6	3	1	1	2				3
90	Rob	55	10	1	1	2				3
91	Rob	25	6	1	1	1				2
92	Rob	15	10	1	1	2				2
93	Rob	8	7	1	1	1				3
94	Rob	3	1	1	1	14	News			4
95	Rob	5	2	1	1	3				1
96	Rob	20	5	1	1	4	Hurry, take time			2
97	Rob	10	8	1	1	2				3
98	Rob	12	6	1	1	34	Newspaper			2
99	Rob	15	8	1	1	34	Drunks			2
100	Rob	20	15	1	0			5	Don’t see too often	3
101	Rob	15	8	1	1	4	Timed lights, coordination, don't wont to brake			1
102	Rob	30	20	1	1	1				1

TABLE C5 Reponses of Indiana Drivers to the Survey (continued)

#	6	6other	7	8	9	10	10other	11	12	13	14	14A	14B	14C	M/F
86	123		2	0	3	34		2	1	1	1	1	0	0	0
87	2		2	0	2	25	Larger red light (size)	1	2	1	1	0	0	0	1
88	23		1	0	4	4		2	1	1	0	0	0	0	0
89	23		1	0	3	4		n/a	3	2	1	0	0	0	1
90	3		5	0	3	4		2	1	1	1	0	0	0	1
91	123		1	0	2	34		2	4	1	1	1	1	1	0
92	23		0	0	3	3		1	4	1	1	1	1	0	0
93	3		2	1	2	34		3	4	1	1	1	0	0	1
94	34	Get away don’t care	5	0	3	4		2	1	1	1	0	0	0	0
95	12		1	0	2	345	Cameras	1	1	2	1	1	1	0	1
96	23		10	0	3	34		2	4	2	1	0	1	1	1
97	2		1	0	3	2		2	1	2	1	0	0	0	0
98	12		2	0	3	25	Synchronized lights	2	1	2	1	0	0	0	0
99	134	Drunk drivers	4	1	4	25	Greens are too short	2	2	2	0	0	0	0	0
100	23		2	0	3	3		2	1	2	1	0	1	0	0
101	2		2	0	4	45	Nothing will help	1	4	1	1	1	0	0	0
102	24	They no there going to get away with it.	0	0	2	45	Cameras at intersection	1	2	2	0	0	0	0	1

TABLE C6 Reponses of Indiana Drivers to the Survey

#	Surveyor	1	2	3	4	4A	4Aother	4B	4Bother	5
103	Rob	18	10	1	1	4				3
104	Rob	10	5	1	0			5	Don’t see	3
105	Rob	12	4	1	1	2				2
106	Rob	3	2	1	0			5	No answer	3
107	Rob	0	0	1	1	23				2
108	Rob	45	18	1	0			5	Other states more problem	2
109	Rob	5	3	1	1	4	Dangerous intersection close by			2
110	Rob	50	25	1	1	12				1
111	Rob	4	2	1	0			5	Don’t see too often	3
112	Rob	5	2	1	1	4				2
113	Rob	20	10	0	0					2
114	Rob	25	13	1	1	3				1
115	Rob	40	36	1	1	4	Don’t obey rules of road			1
116	Rob	20	10	1	1	4	Hurry			2
117	Rob	5	2	1	1	3				2
118	Rob	40	20	1	0			5	Not many people do it	3
119	Rob	12	4	1	1	2				2
120	Rob	1	1	1	1	2				2

TABLE C6 Reponses of Indiana Drivers to the Survey (continued)

#	6	6other	7	8	9	10	10other	11	12	13	14	14A	14B	14C	M/F
103	123		1	0	2	5		1	1	1	1	1	0	1	0
104	2		1	0	2	4		2	2	2	1	1	1	0	1
105	23		0	0	3	35	More public response, some are too	1	2	2	1	0	0	0	0
106	2		2	0	4	34		2	1	2	1	1	0	0	0
107	23		1	0	3	34		2	4	2	1	0	0	0	0
108	12		1	0	3	12		2	4	1	0	0	0	0	1
109	1		8	0	3	3		3	1	2	1	0	0	0	1
110	125	Blatant abuse	0	0	3	134		1	4	2	0	0	0	0	1
111	2		0	1	3	4		2	1	1	1	0	0	0	1
112	12		2	0	1	34		1	2	2	0	0	0	0	1
113	13		0	0	3	5	Take out red lights	4	3	2	1	0	0	0	1
114	23		1	0	3	23		2	3	1	1	0	1	1	1
115	1234	Better light structure, t-intersections the worst.	2	1	3	35	2-3 week driving school	4	1	2	1	0	0	0	1
116	23		1	0	3	5	Cameras	1	1	1	1	0	0	0	1
117	2		1	0	3	4		2	1	1	1	0	0	0	0
118	23		1	0	4	2		2	2	2	0	0	0	0	1
119	23		3	0	3	5	Penalties harsher, lose license	2	1	2	0	0	0	0	1
120	2		0	0	2	24		4	1	1	1	1	0	0	0

TABLE C7 Reponses of Indiana Drivers to the Survey

#	Surveyor	1	2	3	4	4A	4Aother	4B	4Bother	5
121	Rob	20	10	1	1					3
122	Jeromy	25	10	1	0				Nothing in news about it	2
123	Jeromy	12	6	1	0				Don’t see it often	0
124	Jeromy	1	1	1	0				Don’t drive often enough to see it	3
125	Jeromy	4	2	1	0				Never seen it happen	4
126	Jeromy	45	25	1	1	1				1
127	Jeromy	20	5	1	1	2				1
128	Jeromy	10	6	1	1	1	Just about got hit			3
129	Jeromy	20	15	1	1	2				2
130	Jeromy	10	6	1	1	1				1
131	Jeromy	16	14	1	1		Small cities, no problem; large cities, problem (population)			3
132	Jeromy	6	4	1	1		Everyone in hurry			2
133	Jeromy	4	4	1	1	1	Semis don't stop			2
134	Jeromy	6	3	1	0					3
135	Jeromy	12	6	1	0			5	Never seen it happen	4
136	Jeromy	30	15	1	1		In some areas, pop			3
137	Jeromy	30	10	1	1	2				1
138	Jeromy	10	8	1	0			5	Never seen it happen	3
139	Jeromy	0	0	1	1	2				3
140	Jeromy	30	14	1	1	1				3

TABLE C7 Reponses of Indiana Drivers to the Survey (continued)

#	6	6other	7	8	9	10	10other	11	12	13	14	14A	14B	14C	M/F
121	123		1	0	2	4		2	3	1	1	0	0	0	
122	2		1	0	4	2,3,4		3	1	1	0				0
123		Drunk, stupid, suicidal	2	0	1,4	3		0	2	1	1	0			0
124	2,3		1	0	2,3	3,4		2	1	1,2	1	0	0	0	0
125	3		1	0	2,3	3		3	1	1	1	0	0	0	0
126	2		1	0	3	4	Longer yellow	4	3	1,2	1	0	1	1	0
127	2		1	0	3	3		3	2	1	0	0	0	0	1
128	2		2	0	2	4		1	2	1	1	0	0	0	0
129	2		1	0	3	1		2	4	1,2	0	0	0	0	1
130	2		0	0	2	5	Cameras	1	2	1	1		1		0
131	2	Ignorance	2	0	2	1,2,3,4		1	1	1	1	0	0	0	0
132	2		1	0	3	3,4		2	1	1,2	1	0	0	0	0
133	2,3		0	0	3	4		1	2	1,2	0	0	1	0	0
134	2		0	0	2	1		2	1	1	0	0	0	0	1
135	4	Emergency	0	0	2,3	2		3	3	1	1	0	0	0	1
136	3		1	0	3	5	Less distractions in vehicle	2	4	1,2	1	0	0	0	1
137	2		1	0	3	5	Some lights unnecessary	1	4	1	1	1	0	0	0
138	4	Careless	0	0	2	4		3	1	1	1	0	0	0	1
139	3		2	0	2,3	4		2	1	2	0	0	0	0	0
140	2,3		0	0	2	4		1	2	1,2	0	0	0	0	0

TABLE C8 Reponses of Indiana Drivers to the Survey

#	Surveyor	1	2	3	4	4A	4Aother	4B	4Bother	5
141	Jeromy	6	3	1	0					3
142	Jeromy	4	3	1	1	2				2
143	Jeromy	20	10	1	1	1,3				1
144	Jeromy	13	10	1	0			5	Doesn't see it very often	1
145	Jeromy	5	5	1	1	1				3
146	Jeromy	100	50	1	0			5	Doesn't see it very often	3
147	Jeromy	12	10	1	1	4	See it often			3
148	Jeromy	12	12	1	1	1				2
149	Jeromy	12	2	1	1	2				2
150	Jeromy			1	1	1				1

TABLE C8 Reponses of Indiana Drivers to the Survey (continued)

#	6	6other	7	8	9	10	10other	11	12	13	14	14A	14B	14C	M/F
141	2		5	0	4	4		2	2	1	0	0	0	0	0
142	2,4	Inconsiderate	1	0	2,3	5	Cameras	1	2	1,2	0	0	0	0	0
143	2		1	0	2,3	3		1	4	1	1	1	0	0	1
144	2		0	0	2	4		4	3	1	1	1	1	0	1
145	2		0	1	2,3	5	Cameras	1	1	1	1	0	0	0	1
146	2,3		0	0	2	1		3	4	1	0	0	0	0	1
147	3		0	0	3	4		2	1	1	0	0	0	0	0
148	2		0	1	2	5	Cameras	1	4	1,2	1	0	1	0	0
149	2		5	0	1	4		3	1	1	1	1	0	0	0
150	2		5	1	4	4		2	3	1,2	1				1

Appendix D

MS Access Queries for Extracting Violations on NBTH Approach from Autoscope raw data file – Machine-aided System

Query-1

```
/* Extracts all AND detector records which might possibly indicate a violation.

(SELECT b.*
FROM temp AS a, temp AS b
WHERE a.detnum=109 AND b.detnum=110 AND
(a.hr*3600+a.min*60+a.sec<b.hr*3600+b.min*60+b.sec) AND
(a.hr*3600+a.min*60+a.sec > b.hr*3600+b.min*60+b.sec-2) AND b.ontime<1500)
UNION
(SELECT b.*
FROM temp AS a, temp AS b
WHERE a.detnum=109 AND b.detnum=118 AND
(a.hr*3600+a.min*60+a.sec<b.hr*3600+b.min*60+b.sec) AND
(a.hr*3600+a.min*60+a.sec > b.hr*3600+b.min*60+b.sec-2)
AND b.ontime<1500);
```

Query-2

```
/* Extracts all the COUNT detector records which might possibly indicate a violation.
/* Query-1 is executed before this query. The user need not execute query-1.
/* It is done automatically when query-2 is executed.

SELECT a.*
FROM temp AS a, Violations AS b
WHERE a.ID=b.ID-1;
```

Appendix E

RLR Results Obtained from the Machine-aided System (Only NBTH)

TABLE E1 RLR Results Obtained from the Machine-aided System

Date	Hr	Min	Sec	Detnum	Ontime	Speed	Length	Class	Precipitation	Time from start of red
6-Nov-01	5	50	44.9	103	267	15	5	0	N	0.4
6-Nov-01	6	21	46.874	103	500	30	17	0	N	0.3
6-Nov-01	10	23	9.369	103	734	15	15	0	N	0.4
6-Nov-01	11	47	26.518	103	468	31	18	0	N	0.9
6-Nov-01	12	35	46.596	111	234	27	13	0	N	0.7
6-Nov-01	15	8	28.431	103	401	17	9	0	N	0.5
6-Nov-01	16	0	19.732	103	634	17	14	0	N	0.4
6-Nov-01	16	43	42.991	111	467	34	18	0	N	0.4
6-Nov-01	23	38	21.786	103	234	17	11	0	N	1
7-Nov-01	16	28	51.345	103	334	30	14	0	N	0.3
7-Nov-01	17	50	39.957	103	367	19	10	0	N	1.2
7-Nov-01	21	27	13.052	111	367	23	14	0	N	0.1
7-Nov-01	21	57	29.774	103	367	28	16	0	N	0.4
8-Nov-01	0	8	3.457	103	200	24	6	0	N	0.3
8-Nov-01	9	14	58.114	111	534	8	5	0	N	0.6
8-Nov-01	9	49	12.089	103	600	28	19	0	N	0.4
8-Nov-01	11	46	32.183	103	634	13	11	0	N	1.7
8-Nov-01	11	56	6.343	111	434	18	11	0	N	0.5
8-Nov-01	12	19	59.328	111	501	25	15	0	N	1.6
8-Nov-01	15	23	38.005	103	467	13	8	0	N	0.4
8-Nov-01	20	49	21.32	111	233	28	9	0	N	0.2
8-Nov-01	21	13	21.43	103	134	16	2	0	N	0.5
9-Nov-01	9	36	48.076	103	601	12	10	0	N	0.5
9-Nov-01	16	56	7.987	103	267	23	12	0	N	0.8
9-Nov-01	17	43	1.22	111	400	14	7	0	N	0.9
10-Nov-01	16	5	28.14	103	401	9	4	0	N	0.4
10-Nov-01	16	37	5.991	111	434	12	7	0	N	1.2
10-Nov-01	16	44	21.207	111	300	22	10	0	N	0.3

TABLE E2 RLR Results Obtained from the Machine-aided System

Date	Hr	Min	Sec	Detnum	Ontime	Speed	Length	Class	Precipitation	Time from start of red
10-Nov-01	18	6	21.398	103	167	25	8	0	N	0.4
10-Nov-01	21	40	35.807	103	167	18	3	0	N	1.1
11-Nov-01	9	28	21.72	103	667	28	20	0	N	0
11-Nov-01	9	58	52.116	103	534	2	1	0	N	0.3
11-Nov-01	14	38	2.558	103	501	10	7	0	N	0.6
11-Nov-01	14	38	2.558	111	467	11	6	0	N	0.6
11-Nov-01	14	51	49.657	111	467	13	8	0	N	0.8
11-Nov-01	15	20	43.183	103	567	14	10	0	N	1
11-Nov-01	15	41	5.978	103	300	20	8	0	N	1.3
11-Nov-01	15	44	34.11	111	467	11	7	0	N	0.7
11-Nov-01	21	51	51.998	111	767	12	14	0	N	0.2
11-Nov-01	22	1	32.791	103	301	8	3	0	N	0.5
11-Nov-01	22	5	49.36	111	367	11	8	0	N	0.7
11-Nov-01	22	37	23.083	103	200	32	13	0	N	0.6
11-Nov-01	22	47	36.882	103	233	29	14	0	N	1.3
12-Nov-01	8	6	28.815	103	434	26	15	0	N	0.4
12-Nov-01	16	22	54.655	103	401	23	14	0	N	1.1
12-Nov-01	17	16	32.595	111	334	29	15	0	N	0.6
12-Nov-01	18	51	49.192	103	234	27	8	0	N	0.7
12-Nov-01	19	22	21.88	103	167	12	3	0	N	0.4
12-Nov-01	19	57	13.735	103	167	26	6	0	N	0.4
12-Nov-01	23	5	55.959	103	200	14	4	0	N	0.3
13-Nov-01	1	8	16.828	103	200	29	7	0	N	0.5
13-Nov-01	7	26	39.338	103	801	13	14	0	N	0.5
13-Nov-01	7	36	1.341	103	568	13	10	0	N	0.4
13-Nov-01	7	40	36.469	103	467	25	15	0	N	0.7
13-Nov-01	9	44	11.7	111	767	9	9	0	N	0.4
13-Nov-01	10	45	16.736	103	1235	28	32	1	N	0.6
13-Nov-01	10	45	16.736	103	1235	28	32	1	N	0.6

TABLE E3 RLR Results Obtained from the Machine-aided System

Date	Hr	Min	Sec	Detnum	Ontime	Speed	Length	Class	Precipitation	Time from start of red
13-Nov-01	11	35	32.082	103	601	20	15	0	N	1.8
13-Nov-01	11	35	32.082	103	601	20	15	0	N	1.8
13-Nov-01	13	29	58.867	110	401	25	11	0	N	0.6
13-Nov-01	16	29	6.635	110	668	9	14	0	N	1.9
13-Nov-01	17	5	26.16	110	367	16	12	0	N	0.5
13-Nov-01	19	21	46.789	110	200	14	8	0	N	0.9
13-Nov-01	23	8	34.658	110	467	15	3	0	N	0.1
13-Nov-01	23	14	14.654	110	200	21	12	0	N	0.3
14-Nov-01	0	26	22.851	118	367	26	13	0	N	0.2
14-Nov-01	8	36	5.554	110	367	19	4	0	N	1.2
14-Nov-01	11	48	33.134	110	1268	15	19	0	N	0.6
14-Nov-01	13	35	23.42	110	501	25	11	0	N	0.8
14-Nov-01	16	25	13.486	118	167	9	14	0	N	0.5
14-Nov-01	17	5	56.5	118	400	16	12	0	N	0.5
14-Nov-01	23	11	11.22	110	200	14	8	0	N	0.6
16-Nov-01	8	24	18.749	103	333	25	11	0	N	0.5
16-Nov-01	8	38	18.903	103	1101	9	14	0	N	1.1
16-Nov-01	11	43	3.694	111	567	16	12	0	N	0.5
16-Nov-01	11	44	58.971	111	434	14	8	0	N	0.3
16-Nov-01	16	26	49.095	103	167	15	3	0	N	0.5
16-Nov-01	16	55	39.6	111	333	21	12	0	N	0.6
16-Nov-01	17	28	9.875	103	367	26	13	0	N	0.6
16-Nov-01	17	53	7.541	103	200	19	4	0	N	0.2
16-Nov-01	18	24	2.49	103	1101	15	19	0	N	1.5
16-Nov-01	18	41	58.524	103	167	27	7	0	N	0.4
16-Nov-01	19	48	9.345	111	534	24	32	1	N	0.1
16-Nov-01	21	6	47.668	103	201	32	13	0	N	0.4

TABLE E4 RLR Results Obtained from the Machine-aided System

Date	Hr	Min	Sec	Detnum	Ontime	Speed	Length	Class	Precipitation	Time from start of red
17-Nov-01	0	55	32.628	103	234	29	14	0	N	0.4
17-Nov-01	1	13	27.164	103	166	31	8	0	N	0.1
17-Nov-01	1	18	31.204	103	167	29	9	0	N	0.7
17-Nov-01	1	24	4.362	103	234	18	5	0	N	0.4
17-Nov-01	8	13	30.99	111	301	26	10	0	N	0
17-Nov-01	11	26	47.263	111	400	27	14	0	N	0.7
17-Nov-01	13	47	50.388	103	368	8	3	0	N	0.2
17-Nov-01	14	55	46.303	103	567	20	15	0	N	0.6
18-Nov-01	3	22	20.643	103	201	25	6	0	N	0.5
18-Nov-01	3	39	57.444	103	167	31	7	0	N	0.4
18-Nov-01	8	16	47.395	103	433	5	2	0	N	0.2
18-Nov-01	9	38	56.029	103	534	8	6	0	N	1.5
18-Nov-01	12	38	53.684	103	267	13	4	0	N	0.5
18-Nov-01	14	50	48.609	103	301	22	10	0	N	0.7
18-Nov-01	19	0	54.809	103	200	27	9	0	N	0.3
18-Nov-01	19	11	28.211	111	334	29	15	0	N	0.3
19-Nov-01	0	3	59.654	103	267	24	14	0	N	0.2
19-Nov-01	8	17	12.466	111	500	27	17	0	N	1
20-Nov-01	7	27	53.784	111	1068	13	17	0	N	1.6
20-Nov-01	8	3	30.175	103	500	6	4	0	N	0.1
20-Nov-01	12	32	48.35	111	667	26	19	0	N	0.2
20-Nov-01	16	35	58.147	111	467	21	13	0	N	0.5
20-Nov-01	17	33	36.369	111	300	14	5	0	N	0.8
20-Nov-01	18	18	6.934	103	167	17	5	0	N	0.8
20-Nov-01	19	51	30.511	103	267	21	7	0	N	0.9
21-Nov-01	8	28	8.159	111	668	23	18	0	N	0.6
21-Nov-01	9	52	52.439	111	567	16	12	0	N	0.3
21-Nov-01	10	34	2.453	103	968	15	17	0	N	0.3

TABLE E5 RLR Results Obtained from the Machine-aided System

Date	Hr	Min	Sec	Detnum	Ontime	Speed	Length	Class	Precipitation	Time from start of red
21-Nov-01	12	13	8.486	111	501	27	16	0	N	0.3
21-Nov-01	19	34	24.266	111	200	11	5	0	N	1.5
22-Nov-01	14	0	54.848	103	301	8	2	0	N	0.8
22-Nov-01	18	8	11.346	103	234	33	15	0	N	0.8
22-Nov-01	20	46	14.775	111	334	25	15	0	N	1.6
23-Nov-01	7	24	53.86	111	167	13	3	0	N	0.6
23-Nov-01	7	55	26.297	111	334	26	12	0	N	0.6
23-Nov-01	11	50	20.508	111	300	8	2	0	N	1
23-Nov-01	12	31	49.688	111	400	33	16	0	N	2
23-Nov-01	23	18	27.231	111	267	12	5	0	N	1
24-Nov-01	1	38	38.875	111	968	27	28	1	N	0.1
24-Nov-01	1	52	59.844	103	167	29	7	0	N	0.9
24-Nov-01	9	49	20.557	103	499	12	8	0	N	1.3
24-Nov-01	13	22	14.112	103	434	7	3	0	R	0.6
24-Nov-01	23	0	11.345	111	267	18	6	0	N	0.7
25-Nov-01	16	28	42.229	103	334	17	9	0	N	0.6
26-Nov-01	7	16	14.726	111	701	12	11	0	N	0.3
26-Nov-01	10	4	16.413	103	700	9	9	0	N	0.4
26-Nov-01	16	2	16.996	103	400	14	8	0	N	0.7
26-Nov-01	21	29	24.469	111	267	3	2	0	R	0.6
26-Nov-01	22	20	30.416	103	301	20	11	0	N	0.8
27-Nov-01	7	52	30.706	103	567	11	8	0	N	0.6
27-Nov-01	9	9	6.357	111	300	11	4	0	N	0.7
27-Nov-01	10	34	8.441	103	367	15	7	0	N	0.5
27-Nov-01	13	26	38.702	103	367	24	12	0	N	0.5
27-Nov-01	16	28	48.937	103	233	18	5	0	N	0.7
27-Nov-01	21	20	45.1	111	234	9	4	0	N	0.4

TABLE E6 RLR Results Obtained from the Machine-aided System

Date	Hr	Min	Sec	Detnum	Ontime	Speed	Length	Class	Precipitation	Time from start of red
28-Nov-01	9	42	42.194	111	400	17	10	0	N	0.6
29-Nov-01	11	17	5.638	103	367	11	5	0	N	1.2
29-Nov-01	16	58	55.019	111	501	28	19	0	N	0.3
29-Nov-01	23	14	25.896	103	133	28	4	0	R	0.9
30-Nov-01	12	58	38.669	103	501	15	10	0	N	0.5
30-Nov-01	21	6	59.581	111	234	25	7	0	N	1.9
30-Nov-01	22	11	53.887	103	233	22	6	0	N	1.7
1-Dec-01	3	29	27.154	111	166	26	9	0	N	0.7
1-Dec-01	9	26	11.127	111	534	26	16	0	N	0.8
1-Dec-01	22	22	43.379	103	200	26	13	0	N	0.5
1-Dec-01	23	31	55.483	103	234	23	7	0	N	0.3
2-Dec-01	3	5	6.016	103	233	30	14	0	N	0.9
2-Dec-01	10	26	34.446	111	534	7	4	0	N	0.7
2-Dec-01	11	19	12.668	111	433	12	7	0	N	0.8
2-Dec-01	11	31	36.652	103	434	14	8	0	N	0.7
2-Dec-01	19	43	28.182	103	233	30	9	0	N	0.9
6-Dec-01	8	5	41.522	111	534	23	15	0	N	0.8
6-Dec-01	11	7	20.778	103	400	15	8	0	N	0.7
6-Dec-01	11	11	16.924	111	367	6	2	0	N	0.2
6-Dec-01	14	21	5.097	103	567	13	10	0	N	1.3
6-Dec-01	16	46	35.681	111	400	26	14	0	N	0.8
6-Dec-01	17	4	8.193	103	601	20	15	0	N	0.3
6-Dec-01	18	28	14.346	111	167	28	6	0	N	0.4
6-Dec-01	21	33	57.292	103	166	16	3	0	N	0.8
6-Dec-01	23	42	4.582	111	201	22	8	0	N	0.9
7-Dec-01	3	23	39.352	103	234	25	11	0	N	0.9
7-Dec-01	9	12	56.082	111	401	9	4	0	N	0.5
7-Dec-01	11	6	46.997	103	368	17	8	0	N	0.4
7-Dec-01	22	51	59.265	103	234	31	15	0	N	0.2

TABLE E7 RLR Results Obtained from the Machine-aided System

Date	Hr	Min	Sec	Detnum	Ontime	Speed	Length	Class	Precipitation	Time from start of red
8-Dec-01	8	8	11.361	111	367	7	3	0	N	0.6
8-Dec-01	8	13	20.204	103	334	18	8	0	N	1
8-Dec-01	9	0	47.624	103	500	10	6	0	N	0.5
8-Dec-01	9	42	20.282	103	601	10	7	0	N	0.2
8-Dec-01	10	19	0.675	111	334	9	3	0	N	0.9
8-Dec-01	13	22	22.091	111	434	28	15	0	N	0.9
8-Dec-01	14	59	32.852	111	333	30	13	0	N	0.3
8-Dec-01	16	54	50.814	111	367	17	9	0	N	0.9
9-Dec-01	8	44	0.743	111	534	23	16	0	N	0.3
9-Dec-01	9	56	26.992	103	634	28	20	0	N	0.1
9-Dec-01	12	44	54.116	111	534	28	17	0	N	1.2
9-Dec-01	14	0	5.003	103	467	29	16	0	N	0.9
9-Dec-01	18	11	20.55	103	201	29	7	0	N	0.4
10-Dec-01	0	43	27.049	111	200	25	7	0	N	1
10-Dec-01	7	52	41.62	111	600	28	18	0	N	0.5
10-Dec-01	10	30	4.49	103	667	8	7	0	N	0.1
10-Dec-01	13	28	29.989	111	467	12	7	0	N	0.6
10-Dec-01	13	41	51.417	111	367	25	12	0	N	0.6
10-Dec-01	18	49	43.476	103	200	12	3	0	N	0.5
10-Dec-01	18	49	43.609	111	234	18	5	0	N	0.6
11-Dec-01	13	25	31.279	111	401	15	7	0	N	0.7
11-Dec-01	16	42	51.457	103	201	19	4	0	N	0.5
11-Dec-01	18	35	39.391	103	267	17	6	0	N	0.9
11-Dec-01	21	31	52.533	111	401	26	14	0	N	0.7
12-Dec-01	8	45	0.883	103	601	15	13	0	N	0.2
12-Dec-01	9	50	52.207	103	601	18	14	0	N	0.5
12-Dec-01	10	35	14.556	103	433	13	8	0	R	0.3

TABLE E8 RLR Results Obtained from the Machine-aided System

Date	Hr	Min	Sec	Detnum	Ontime	Speed	Length	Class	Precipitation	Time from start of red
12-Dec-01	11	53	14.951	103	400	23	12	0	N	0.8
12-Dec-01	19	27	13.061	111	234	18	7	0	R	0.9
12-Dec-01	23	27	4.485	103	200	31	9	0	R	1
13-Dec-01	10	28	43.595	111	934	29	26	1	N	0.7
13-Dec-01	14	39	36.899	111	333	26	12	0	N	1
13-Dec-01	15	47	24.235	111	267	14	4	0	N	0.9
13-Dec-01	22	33	10.934	111	267	22	13	0	N	0.7
14-Dec-01	2	35	51.973	103	267	26	15	0	R	0.5
14-Dec-01	13	13	51.737	111	467	19	13	0	N	0.7
14-Dec-01	15	25	10.886	103	400	13	7	0	N	1.1
14-Dec-01	20	13	46.303	111	234	25	8	0	N	0.6
14-Dec-01	20	21	32.098	103	234	24	13	0	N	0.7
14-Dec-01	23	4	8.023	111	467	14	14	0	N	0.7
15-Dec-01	6	17	53.743	103	1001	16	20	0	N	0.1
15-Dec-01	7	17	47.855	103	634	32	21	0	N	1.2
15-Dec-01	9	5	56.503	111	400	30	15	0	N	0.5
15-Dec-01	13	39	13.113	103	367	5	2	0	N	0.6
15-Dec-01	15	3	34.058	103	400	8	4	0	N	0.6
15-Dec-01	16	37	39.887	103	467	16	10	0	N	1.3
15-Dec-01	17	18	57.285	111	367	15	8	0	N	1.6
16-Dec-01	9	21	0.438	111	533	29	18	0	N	1.4
16-Dec-01	10	48	42.556	111	300	30	12	0	R	0.6
16-Dec-01	14	4	39.736	103	835	12	14	0	R	1.5
17-Dec-01	13	55	47.859	103	601	15	12	0	N	0.6
17-Dec-01	18	10	29.304	111	500	8	7	0	N	1
17-Dec-01	20	53	32.221	111	400	13	6	0	N	0.9

TABLE E9 RLR Results Obtained from the Machine-aided System

Date	Hr	Min	Sec	Detnum	Ontime	Speed	Length	Class	Precipitation	Time from start of red
18-Dec-01	8	44	33.437	111	501	5	3	0	N	0.7
18-Dec-01	11	23	1.846	103	1001	28	27	1	N	1
18-Dec-01	11	58	17.232	103	667	20	16	0	N	1.4
18-Dec-01	20	23	8.195	111	233	27	13	0	N	0.5
18-Dec-01	20	55	4.472	103	200	24	6	0	N	0.8
18-Dec-01	22	41	26.42	111	167	29	7	0	N	1
20-Dec-01	8	18	33.228	103	1034	26	28	1	N	1.4
20-Dec-01	9	51	48.659	103	967	12	15	0	N	0.6
20-Dec-01	17	35	43.506	103	634	14	12	0	N	1.3
21-Dec-01	9	46	27.811	103	735	12	14	0	N	0.3
21-Dec-01	11	40	8.635	111	635	30	20	0	N	0.8
21-Dec-01	15	12	17.414	111	467	14	8	0	N	0.9
21-Dec-01	18	48	50.825	103	200	16	7	0	N	0.7
22-Dec-01	16	29	2.969	111	301	34	14	0	R	0.9
22-Dec-01	19	19	45.335	103	467	25	18	0	N	0.6

Appendix F

RLR Results Obtained from the Ground Truth/ Direct Observation Method

TABLE F1 RLR Results Obtained from the Ground Truth/ Direct Observation Method

Date	Day of Week	RLR time			Direction	Day/ Night	Vacation?	Enforcement Type	Precipitation
		Hr	Min	Sec					
6-Mar	Wed	7	26	47	NBTH	D	N	N	None
6-Mar	Wed	7	48	45	NBTH	D	N	N	None
6-Mar	Wed	9	40	55	SBTH	D	N	N	None
7-Mar	Thu	7	56	13	SBTH	D	N	N	None
7-Mar	Thu	9	34	54	NBTH	D	N	N	None
8-Mar	Fri	7	50	58	NBTH	D	N	N	None
8-Mar	Fri	7	50	58	NBTH	D	N	N	None
8-Mar	Fri	7	54	30	NBTH	D	N	N	None
8-Mar	Fri	9	27	13	NBTH	D	N	N	None
8-Mar	Fri	9	35	14	EBTH	D	N	N	None
8-Mar	Fri	9	36	11	NBTH	D	N	N	None
8-Mar	Fri	9	40	54	EBTH	D	N	N	None
8-Mar	Fri	9	51	44	SBTH	D	N	N	None
10-Mar	Sun	10	0	3	SBTH	D	Yes	N	None
10-Mar	Sun	15	36	13	NBTH	D	Yes	N	None
10-Mar	Sun	16	36	35	NBTH	D	Yes	N	None
10-Mar	Sun	17	7	43	NBTH	D	Yes	N	None
10-Mar	Sun	17	9	57	NBTH	D	Yes	N	None
15-Mar	Fri	15	40	38	NBTH	D	Yes	N	None
15-Mar	Fri	17	16	39	SBTH	D	Yes	N	None
16-Mar	Sat	16	7	33	NBTH	D	Yes	N	None
18-Mar	Mon	17	31	13	NBTH	D	N	Video	None
20-Mar	Wed	7	51	17	NBTH	D	N	Video	None
20-Mar	Wed	8	50	59	NBTH	D	N	Video	None
20-Mar	Wed	17	51	39	SBTH	D	N	Video	None
22-Mar	Fri	7	29	1	SBTH	D	N	Video	None
22-Mar	Fri	9	9	51	SBTH	D	N	Video	None
22-Mar	Fri	16	42	25	NBTH	D	N	Video	None
22-Mar	Fri	17	6	31	NBTH	D	N	Video	None
22-Mar	Fri	17	14	35	NBTH	D	N	Video	None
22-Mar	Fri	17	26	2	EBTH	D	N	Video	None
26-Mar	Tue	7	3	31	SBTH	D	N	N	Snow
26-Mar	Tue	7	21	8	SBTH	D	N	N	Snow
26-Mar	Tue	8	58	15	SBTH	D	N	N	Snow
26-Mar	Tue	9	55	37	NBTH	D	N	N	Snow
26-Mar	Tue	17	47	21	EBTH	D	N	N	Snow
28-Mar	Thu	8	52	47	NBTH	D	N	N	None
28-Mar	Thu	9	6	35	NBTH	D	N	N	None
28-Mar	Thu	9	53	1	NBTH	D	N	N	None
28-Mar	Thu	15	1	44	NBTH	D	N	N	None

TABLE F2 RLR Results Obtained from the Ground Truth/ Direct Observation Method

Date	Day of Week	RLR time			Direction	Day /Night	Vacation?	Enforcement Type	Precipitation
		Hr	Min	Sec					
29-Mar	Fri	8	7	0	NBTH	D	N	N	None
29-Mar	Fri	16	12	51	EBTH	D	N	N	Rain
29-Mar	Fri	17	18	26	NBTH	D	N	N	Rain
4-Nov	Sun	15	57	35	EBTH	D	N	N	None
4-Nov	Sun	16	52	50	NBTH	D	N	N	None
5-Nov	Mon	15	54	31	SBTH	D	N	N	None
6-Nov	Tue	15	8	33	NBTH	D	N	N	None
6-Nov	Tue	16	0	24	NBTH	D	N	N	None
6-Nov	Tue	16	6	43	EBTH	D	N	N	None
6-Nov	Tue	16	43	47	NBTH	D	N	N	None
8-Nov	Thu	15	7	57	EBTH	D	N	N	None
8-Nov	Thu	15	10	37	SBTH	D	N	N	None
8-Nov	Thu	15	23	38	NBTH	D	N	N	None
10-Nov	Sat	15	43	17	EBTH	D	N	N	None
10-Nov	Sat	16	5	30	NBTH	D	N	N	None
10-Nov	Sat	16	37	8	NBTH	D	N	N	None
10-Nov	Sat	16	44	23	NBTH	D	N	N	None
11-Nov	Sun	15	20	42	NBTH	D	N	N	None
11-Nov	Sun	15	41	5	NBTH	D	N	N	None
11-Nov	Sun	15	44	34	NBTH	D	N	N	None
11-Nov	Sun	16	17	40	SBTH	D	N	N	None
12-Nov	Mon	15	1	50	EBTH	D	N	P	None
12-Nov	Mon	16	22	52	NBTH	D	N	P	None
12-Nov	Mon	17	5	0	EBTH	D	N	P	None
12-Nov	Mon	17	16	31	NBTH	D	N	P	None
12-Nov	Mon	17	23	10	EBTH	D	N	P	None
12-Nov	Mon	17	41	33	EBTH	D	N	P	None
13-Nov	Tues	16	29	8	NBTH	D	N	P	None
13-Nov	Tues	16	48	54	SBTH	D	N	P	None
13-Nov	Tues	16	59	52	NBTH	D	N	P	None
13-Nov	Tues	17	5	28	NBTH	D	N	P	None
14-Nov	Wed	16	25	15	NBTH	D	N	P	None
14-Nov	Wed	17	5	58	NBTH	D	N	P	None
15-Nov	Thurs	15	44	45	NBTH	D	N	P	None
15-Nov	Thurs	17	0	10	NBTH	D	N	P	None
15-Nov	Thurs	17	42	9	NBTH	D	N	P	None

TABLE F3 RLR Results Obtained from the Ground Truth/ Direct Observation Method

Date	Day of Week	RLR time			Direction	Day/ Night	Vacation?	Enforcement Type	Precipitation
		Hr	Min	Sec					
16-Nov	Fri	15	2	0	EBTH	D	N	P	None
16-Nov	Fri	15	30	1	EBTH	D	N	P	None
16-Nov	Fri	16	26	49	NBTH	D	N	P	None
16-Nov	Fri	16	45	21	SBTH	D	N	P	None
16-Nov	Fri	16	55	39	NBTH	D	N	P	None
16-Nov	Fri	17	28	9	NBTH	D	N	P	None
16-Nov	Fri	17	53	7	NBTH	D	N	P	None
17-Nov	Sat	16	12	53	NBTH	D	N	N	None
17-Nov	Sat	16	59	30	EBTH	D	N	N	None
20-Nov	Tue	16	35	58	NBTH	D	N	N	None
24-Nov	Sat	16	52	50	EBTH	D	N	N	None
25-Nov	Sun	15	0	20	EBTH	D	N	N	None
25-Nov	Sun	15	8	32	EBTH	D	N	N	None
25-Nov	Sun	16	28	46	NBTH	D	N	N	None
25-Nov	Sun	16	39	40	EBTH	D	N	N	None
26-Nov	Mon	15	21	40	EBTH	D	N	N	None
26-Nov	Mon	16	2	17	NBTH	D	N	N	None
27-Nov	Tue	16	28	51	NBTH	D	N	N	None
28-Nov	Wed	15	35	48	SBTH	D	N	N	None
29-Nov	Thu	15	12	37	SBTH	D	N	N	Rain
29-Nov	Thu	16	14	29	SBTH	D	N	N	None
29-Nov	Thu	16	16	19	SBTH	D	N	N	None
29-Nov	Thu	16	58	55	NBTH	D	N	N	None
30-Nov	Fri	15	43	18	NBTH	D	N	N	None
30-Nov	Fri	16	31	44	EBTH	D	N	N	None
30-Nov	Fri	16	37	40	NBTH	D	N	N	None
30-Nov	Fri	16	37	40	SBTH	D	N	N	None
1-Dec	Sat	15	51	48	EBTH	D	N	N	None
6-Dec	Thu	15	35	49	EBTH	D	N	N	None
6-Dec	Thu	15	45	17	NBTH	D	N	N	None
6-Dec	Thu	15	51	15	NBTH	D	N	N	None
6-Dec	Thu	16	46	32	NBTH	D	N	N	None
6-Dec	Thu	16	46	33	NBTH	D	N	N	None
8-Dec	Sat	16	54	55	NBTH	D	N	N	None
10-Dec	Mon	15	3	1	SBTH	D	N	N	None
12-Dec	None					D	N	N	Rain
14-Dec	Fri	15	25	8	NBTH	D	N	N	None
14-Dec	Fri	16	48	41	NBTH	D	N	N	None
16-Dec	None					D	N	N	Rain
17-Dec	Mon	16	25	4	SBTH	D	N	N	None
20-Dec	Thu	16	13	58	NBTH	D	N	N	None
22-Dec	Fri	16	29	1	NBTH	D	Yes	N	None

Appendix G

Summary Sheet of Tickets issued by Police between Nov 12^{th} and Nov 16^{th}, 2001

Dec-06-01 01:08P West Lafayette Police 765-775-5228 P.02

WEST LAFAYETTE POLICE DEPARTMENT

WEST LAFAYETTE POLICE

609 WEST NAVAJO • WEST LAFAYETTE, INDIANA 47906
MAIN PHONE: 765-775-5200 • FAX: 765-775-5228
RECORDS DIVISION: 765-775-5210 • CRIMINAL INVESTIGATION DIVISION: 765-775-5220

12/06/01

Sir,

Below you will find a list of the number of stops that were made each day that was worked. I would like to note that the majority of violations involved vehicles making a left turn once the light had changed.

It should also be noted that the vehicles stopped were not the only vehicles that failed to stop for the automatic signal when required, but they were the only vehicles we were able to stop. This means the numbers below do not represent the total number of vehicles that ran the light only the ones that were documented.

Number of stops	Date	Hours worked
11	11/12/01	1500 to 1700
11	11/13/01	1500 to 1700
7	11/14/01	1500 to 1700
10	11/15/01	1500 to 1700
12	11/16/01	1500 to 1700

Chris Leroux
Deputy Chief

FIGURE G Picture showing the summary of tickets issued by police between November 12th and November 16th, 2001

Appendix H

RLR Data in 15-minute Intervals

TABLE H1 RLR Data in 15-Minute Intervals

Date	Day of Week	Time Interval	Day/night	# RLR	#Cycles	# Vehicles	#Vehicles * #Cycles	Opportunity	Precipitation	Enforcement	Vacation
6-Nov-01	Tuesday	15:00 - 15:15	Day	1	8	430	3440	7.644	None	None	None
6-Nov-01	Tuesday	15:15 - 15:30	Day	0	8	364	2912	6.471	None	None	None
6-Nov-01	Tuesday	15:30 - 15:45	Day	0	8	473	3784	8.409	None	None	None
6-Nov-01	Tuesday	15:45 - 16:00	Day	0	8	231	1848	4.107	None	None	None
6-Nov-01	Tuesday	16:00 - 16:15	Day	2	7	247	1729	3.842	None	None	None
6-Nov-01	Tuesday	16:15 - 16:30	Day	0	7	367	2569	5.709	None	None	None
6-Nov-01	Tuesday	16:30 - 16:45	Day	1	9	390	3510	7.8	None	None	None
6-Nov-01	Tuesday	16:45 - 17:00	Day	0	8	375	3000	6.667	None	None	None
8-Nov-01	Thursday	15:00 - 15:15	Day	2	8	313	2504	5.564	None	None	None
8-Nov-01	Thursday	15:15 - 15:30	Day	1	7	443	3101	6.891	None	None	None
8-Nov-01	Thursday	15:30 - 15:45	Day	0	9	293	2637	5.86	None	None	None
8-Nov-01	Thursday	15:45 - 16:00	Day	0	9	233	2097	4.66	None	None	None
8-Nov-01	Thursday	16:00 - 16:15	Day	0	8	227	1816	4.036	None	None	None
8-Nov-01	Thursday	16:15 - 16:30	Day	0	7	272	1904	4.231	None	None	None
8-Nov-01	Thursday	16:30 - 16:45	Day	0	8	302	2416	5.369	None	None	None
8-Nov-01	Thursday	16:45 - 17:00	Day	0	8	325	2600	5.778	None	None	None
10-Nov-01	Saturday	15:30 - 15:45	Day	1	10	290	2900	6.444	None	None	None
10-Nov-01	Saturday	15:45 - 16:00	Day	0	11	199	2189	4.864	None	None	None
10-Nov-01	Saturday	16:00 - 16:15	Day	1	9	169	1521	3.38	None	None	None
10-Nov-01	Saturday	16:15 - 16:30	Day	0	10	189	1890	4.2	None	None	None
10-Nov-01	Saturday	16:30 - 16:45	Day	2	11	194	2134	4.742	None	None	None
10-Nov-01	Saturday	16:45 - 17:00	Day	0	10	169	1690	3.756	None	None	None
11-Nov-01	Sunday	15:00 - 15:15	Day	0	9	333	2997	6.66	None	None	None
11-Nov-01	Sunday	15:15 - 15:30	Day	1	9	315	2835	6.3	None	None	None

TABLE H2 RLR Data in 15-Minute Intervals

Date	Week	Time Interval	Day/night	# RLR	# Cycles	# Vehicles	* #Cycles	Opportunity	Precipitation	Enforcement	Vacation
11-Nov-01	Sunday	15:30 - 15:45	Day	2	7	336	2352	5.227	None	None	None
11-Nov-01	Sunday	15:45 - 16:00	Day	0	7	285	1995	4.433	None	None	None
11-Nov-01	Sunday	16:00 - 16:15	Day	0	9	247	2223	4.94	None	None	None
11-Nov-01	Sunday	16:15 - 16:30	Day	1	9	193	1737	3.86	None	None	None
11-Nov-01	Sunday	16:30 - 16:45	Day	0	10	196	1960	4.356	None	None	None
11-Nov-01	Sunday	16:45 - 17:00	Day	0	11	230	2530	5.622	None	None	None
12-Nov-01	Monday	16:00 - 16:15	Day	0	8	134	1072	2.382	None	Police	None
12-Nov-01	Monday	16:15 - 16:30	Day	1	7	313	2191	4.869	None	Police	None
12-Nov-01	Monday	16:30 - 16:45	Day	0	8	335	2680	5.956	None	Police	None
12-Nov-01	Monday	16:45 - 17:00	Day	0	8	390	3120	6.933	None	Police	None
12-Nov-01	Monday	17:00 - 17:15	Day	1	7	260	1820	4.044	None	Police	None
12-Nov-01	Monday	17:15 - 17:30	Day	2	7	334	2338	5.196	None	Police	None
12-Nov-01	Monday	17:30 - 17:45	Day	1	7	344	2408	5.351	None	Police	None
12-Nov-01	Monday	17:45 - 18:00	Day	0	7	347	2429	5.398	None	Police	None
13-Nov-01	Tuesday	15:00 - 15:15	Day	0	9	481	4329	9.62	None	Police	None
13-Nov-01	Tuesday	15:15 - 15:30	Day	0	8	536	4288	9.529	None	Police	None
13-Nov-01	Tuesday	15:30 - 15:45	Day	0	7	282	1974	4.387	None	Police	None
13-Nov-01	Tuesday	15:45 - 16:00	Day	0	9	246	2214	4.92	None	Police	None
13-Nov-01	Tuesday	16:00 - 16:15	Day	0	7	182	1274	2.831	None	Police	None
13-Nov-01	Tuesday	16:15 - 16:30	Day	1	7	259	1813	4.029	None	Police	None
13-Nov-01	Tuesday	16:30 - 16:45	Day	0	7	318	2226	4.947	None	Police	None
13-Nov-01	Tuesday	16:45 - 17:00	Day	2	8	288	2304	5.12	None	Police	None
13-Nov-01	Tuesday	17:00 - 17:15	Day	1	8	250	2000	4.444	None	Police	None
13-Nov-01	Tuesday	17:15 - 17:30	Day	0	7	268	1876	4.169	None	Police	None
13-Nov-01	Tuesday	17:30 - 17:45	Day	0	8	353	2824	6.276	None	Police	None

TABLE H3 RLR Data in 15-Minute Intervals

Date	Day of Week	Time Interval	Day/night	# RLR	# Cycles	# Vehicles	#Cycles	Opportunity	Precipitation	Enforcement	Vacation
13-Nov-01	Tuesday	17:45 - 18:00	Day	0	7	287	2009	4.464	None	Police	None
14-Nov-01	Wednesday	15:00 - 15:15	Day	0	9	289	2601	5.78	None	Police	None
14-Nov-01	Wednesday	15:15 - 15:30	Day	0	8	362	2896	6.436	None	Police	None
14-Nov-01	Wednesday	15:30 - 15:45	Day	0	9	291	2619	5.82	None	Police	None
14-Nov-01	Wednesday	15:45 - 16:00	Day	0	8	241	1928	4.284	None	Police	None
14-Nov-01	Wednesday	16:00 - 16:15	Day	0	8	204	1632	3.627	None	Police	None
14-Nov-01	Wednesday	16:15 - 16:30	Day	1	6	212	1272	2.827	None	Police	None
14-Nov-01	Wednesday	16:30 - 16:45	Day	0	7	283	1981	4.402	None	Police	None
14-Nov-01	Wednesday	16:45 - 17:00	Day	0	8	277	2216	4.924	None	Police	None
14-Nov-01	Wednesday	17:00 - 17:15	Day	1	8	238	1904	4.231	None	Police	None
14-Nov-01	Wednesday	17:15 - 17:30	Day	0	6	295	1770	3.933	None	Police	None
14-Nov-01	Wednesday	17:30 - 17:45	Day	0	6	313	1878	4.173	None	Police	None
14-Nov-01	Wednesday	17:45 - 18:00	Day	0	8	320	2560	5.689	None	Police	None
16-Nov-01	Friday	15:00 - 15:15	Day	1	6	388	2328	5.173	None	Police	None
16-Nov-01	Friday	15:15 - 15:30	Day	0	6	411	2466	5.48	None	Police	None
16-Nov-01	Friday	15:30 - 15:45	Day	1	7	339	2373	5.273	None	Police	None
16-Nov-01	Friday	15:45 - 16:00	Day	0	7	278	1946	4.324	None	Police	None
16-Nov-01	Friday	16:00 - 16:15	Day	0	6	217	1302	2.893	None	Police	None
16-Nov-01	Friday	16:15 - 16:30	Day	1	6	280	1680	3.733	None	Police	None
16-Nov-01	Friday	16:30 - 16:45	Day	0	6	275	1650	3.667	None	Police	None
16-Nov-01	Friday	16:45 - 17:00	Day	2	7	290	2030	4.511	None	Police	None
16-Nov-01	Friday	17:00 - 17:15	Day	0	7	317	2219	4.931	None	Police	None
16-Nov-01	Friday	17:15 - 17:30	Day	1	6	310	1860	4.133	None	Police	None
16-Nov-01	Friday	17:30 - 17:45	Day	0	7	341	2387	5.304	None	Police	None
16-Nov-01	Friday	17:45 - 18:00	Day	1	6	296	1776	3.947	None	Police	None

TABLE H4 RLR Data in 15-Minute Intervals

Date	Day of Week	Time Interval	Day/night	# RLR	# Cycles	# Vehicles	* #Cycles	Opportunity	Precipitation	Enforcement	Vacation
17-Nov-01	Saturday	15:00 - 15:15	Day	0	12	234	2808	6.24	None	None	None
17-Nov-01	Saturday	15:15 - 15:30	Day	0	10	193	1930	4.289	None	None	None
17-Nov-01	Saturday	15:30 - 15:45	Day	0	4	177	708	1.573	None	None	None
17-Nov-01	Saturday	15:45 - 16:00	Day	0	5	232	1160	2.578	None	None	None
17-Nov-01	Saturday	16:00 - 16:15	Day	1	6	211	1266	2.813	None	None	None
17-Nov-01	Saturday	16:15 - 16:30	Day	0	7	206	1442	3.204	None	None	None
17-Nov-01	Saturday	16:30 - 16:45	Day	0	8	178	1424	3.164	None	None	None
17-Nov-01	Saturday	16:45 - 17:00	Day	1	7	179	1253	2.784	None	None	None
18-Nov-01	Sunday	15:00 - 15:15	Day	0	9	238	2142	4.76	None	None	None
18-Nov-01	Sunday	15:15 - 15:30	Day	0	9	247	2223	4.94	None	None	None
18-Nov-01	Sunday	15:30 - 15:45	Day	0	9	152	1368	3.04	None	None	None
18-Nov-01	Sunday	15:45 - 16:00	Day	0	7	125	875	1.944	None	None	None
18-Nov-01	Sunday	16:00 - 16:15	Day	0	9	134	1206	2.68	None	None	None
18-Nov-01	Sunday	16:15 - 16:30	Day	0	9	147	1323	2.94	None	None	None
18-Nov-01	Sunday	16:30 - 16:45	Day	0	9	128	1152	2.56	None	None	None
18-Nov-01	Sunday	16:45 - 17:00	Day	0	10	136	1360	3.022	None	None	None
19-Nov-01	Monday	15:00 - 15:15	Day	0	9	354	3186	7.08	None	None	None
19-Nov-01	Monday	15:15 - 15:30	Day	0	7	451	3157	7.016	None	None	None
19-Nov-01	Monday	15:30 - 15:45	Day	0	7	269	1883	4.184	None	None	None
19-Nov-01	Monday	15:45 - 16:00	Day	0	8	195	1560	3.467	None	None	None
19-Nov-01	Monday	16:00 - 16:15	Day	0	8	165	1320	2.933	None	None	None
19-Nov-01	Monday	16:15 - 16:30	Day	0	6	235	1410	3.133	None	None	None
19-Nov-01	Monday	16:30 - 16:45	Day	0	8	278	2224	4.942	None	None	None
19-Nov-01	Monday	16:45 - 17:00	Day	0	8	269	2152	4.782	None	None	None
20-Nov-01	Tuesday	15:00 - 15:15	Day	0	8	406	3248	7.218	None	None	None

TABLE H5 RLR Data in 15-Minute Intervals

Date	Week	Time Interval	Day/night	# RLR	# Cycles	# Vehicles	* #Cycles	Opportunity	Precipitation	Enforcement	Vacation
20-Nov-01	Tuesday	15:15 - 15:30	Day	0	7	472	3304	7.342	None	None	None
20-Nov-01	Tuesday	15:30 - 15:45	Day	0	8	259	2072	4.604	None	None	None
20-Nov-01	Tuesday	15:45 - 16:00	Day	0	7	250	1750	3.889	None	None	None
20-Nov-01	Tuesday	16:00 - 16:15	Day	0	7	281	1967	4.371	None	None	None
20-Nov-01	Tuesday	16:15 - 16:30	Day	0	7	283	1981	4.402	None	None	None
20-Nov-01	Tuesday	16:30 - 16:45	Day	1	7	308	2156	4.791	None	None	None
20-Nov-01	Tuesday	16:45 - 17:00	Day	0	7	280	1960	4.356	None	None	None
21-Nov-01	Wednesday	15:00 - 15:15	Day	0	10	736	7360	16.356	None	None	Yes
21-Nov-01	Wednesday	15:15 - 15:30	Day	0	11	545	5995	13.322	None	None	Yes
21-Nov-01	Wednesday	15:30 - 15:45	Day	0	12	271	3252	7.227	None	None	Yes
21-Nov-01	Wednesday	15:45 - 16:00	Day	0	14	164	2296	5.102	None	None	Yes
21-Nov-01	Wednesday	16:00 - 16:15	Day	0	13	144	1872	4.16	None	None	Yes
21-Nov-01	Wednesday	16:15 - 16:30	Day	0	15	212	3180	7.067	None	None	Yes
21-Nov-01	Wednesday	16:30 - 16:45	Day	0	11	175	1925	4.278	None	None	Yes
21-Nov-01	Wednesday	16:45 - 17:00	Day	0	16	192	3072	6.827	None	None	Yes
22-Nov-01	Thursday	15:00 - 15:15	Day	0	17	96	1632	3.627	None	None	Yes
22-Nov-01	Thursday	15:15 - 15:30	Day	0	17	107	1819	4.042	None	None	Yes
22-Nov-01	Thursday	15:30 - 15:45	Day	0	14	45	630	1.4	None	None	Yes
22-Nov-01	Thursday	15:45 - 16:00	Day	0	13	41	533	1.184	None	None	Yes
22-Nov-01	Thursday	16:00 - 16:15	Day	0	13	53	689	1.531	None	None	Yes
22-Nov-01	Thursday	16:15 - 16:30	Day	0	14	48	672	1.493	None	None	Yes
22-Nov-01	Thursday	16:30 - 16:45	Day	0	15	59	885	1.967	None	None	Yes
22-Nov-01	Thursday	16:45 - 17:00	Day	0	17	56	952	2.116	None	None	Yes
23-Nov-01	Friday	15:00 - 15:15	Day	0	16	226	3616	8.036	None	None	Yes
23-Nov-01	Friday	15:15 - 15:30	Day	0	16	158	2528	5.618	None	None	Yes

TABLE H6 RLR Data in 15-Minute Intervals

Date	Day of Week	Time Interval	Day/night	# RLR	Cycles	Vehicles	* #Cycles	Opportunity	Precipitation	Enforcement	Vacation
23-Nov-01	Friday	15:30 - 15:45	Day	0	11	109	1199	2.664	None	None	Yes
23-Nov-01	Friday	15:45 - 16:00	Day	0	11	104	1144	2.542	None	None	Yes
23-Nov-01	Friday	16:00 - 16:15	Day	0	19	88	1672	3.716	None	None	Yes
23-Nov-01	Friday	16:15 - 16:30	Day	0	15	75	1125	2.5	None	None	Yes
23-Nov-01	Friday	16:30 - 16:45	Day	0	14	92	1288	2.862	None	None	Yes
23-Nov-01	Friday	16:45 - 17:00	Day	0	18	96	1728	3.84	None	None	Yes
24-Nov-01	Saturday	15:00 - 15:15	Day	0	19	114	2166	4.813	Rain	None	Yes
24-Nov-01	Saturday	15:15 - 15:30	Day	0	16	117	1872	4.16	Rain	None	Yes
24-Nov-01	Saturday	15:30 - 15:45	Day	0	15	68	1020	2.267	Rain	None	Yes
24-Nov-01	Saturday	15:45 - 16:00	Day	0	19	57	1083	2.407	Rain	None	Yes
24-Nov-01	Saturday	16:00 - 16:15	Day	0	19	80	1520	3.378	None	None	Yes
24-Nov-01	Saturday	16:15 - 16:30	Day	0	19	54	1026	2.28	None	None	Yes
24-Nov-01	Saturday	16:30 - 16:45	Day	0	17	70	1190	2.644	None	None	Yes
24-Nov-01	Saturday	16:45 - 17:00	Day	1	18	67	1206	2.68	None	None	Yes
25-Nov-01	Sunday	15:00 - 15:15	Day	1	12	180	2160	4.8	None	None	Yes
25-Nov-01	Sunday	15:15 - 15:30	Day	0	15	185	2775	6.167	None	None	Yes
25-Nov-01	Sunday	15:30 - 15:45	Day	0	11	65	715	1.589	None	None	Yes
25-Nov-01	Sunday	15:45 - 16:00	Day	0	8	100	800	1.778	None	None	Yes
25-Nov-01	Sunday	16:00 - 16:15	Day	0	8	147	1176	2.613	None	None	Yes
25-Nov-01	Sunday	16:15 - 16:30	Day	1	10	172	1720	3.822	None	None	Yes
25-Nov-01	Sunday	16:30 - 16:45	Day	0	11	116	1276	2.836	None	None	Yes
25-Nov-01	Sunday	16:45 - 17:00	Day	0	13	101	1313	2.918	None	None	Yes
26-Nov-01	Monday	15:00 - 15:15	Day	0	9	246	2214	4.92	None	None	None
26-Nov-01	Monday	15:15 - 15:30	Day	1	7	301	2107	4.682	None	None	None
26-Nov-01	Monday	15:30 - 15:45	Day	0	8	185	1480	3.289	None	None	None

TABLE H7 RLR Data in 15-Minute Intervals

Date	Day of Week	Time Interval	Day/night	# RLR	Cycles	Vehicles	* #Cycles	Opportunity	Precipitation	Enforcement	Vacation
26-Nov-01	Monday	15:45 - 16:00	Day	0	8	181	1448	3.218	None	None	None
26-Nov-01	Monday	16:00 - 16:15	Day	1	8	195	1560	3.467	None	None	None
26-Nov-01	Monday	16:15 - 16:30	Day	0	8	214	1712	3.804	None	None	None
26-Nov-01	Monday	16:30 - 16:45	Day	0	9	213	1917	4.26	None	None	None
26-Nov-01	Monday	16:45 - 17:00	Day	0	8	239	1912	4.249	None	None	None
27-Nov-01	Tuesday	15:00 - 15:15	Day	0	8	360	2880	6.4	None	None	None
27-Nov-01	Tuesday	15:15 - 15:30	Day	0	8	348	2784	6.187	None	None	None
27-Nov-01	Tuesday	15:30 - 15:45	Day	0	8	126	1008	2.24	None	None	None
27-Nov-01	Tuesday	15:45 - 16:00	Day	0	10	165	1650	3.667	None	None	None
27-Nov-01	Tuesday	16:00 - 16:15	Day	0	7	180	1260	2.8	None	None	None
27-Nov-01	Tuesday	16:15 - 16:30	Day	1	6	204	1224	2.72	None	None	None
27-Nov-01	Tuesday	16:30 - 16:45	Day	0	7	236	1652	3.671	None	None	None
27-Nov-01	Tuesday	16:45 - 17:00	Day	0	8	249	1992	4.427	None	None	None
28-Nov-01	Wednesday	15:00 - 15:15	Day	0	9	279	2511	5.58	None	None	None
28-Nov-01	Wednesday	15:15 - 15:30	Day	0	8	294	2352	5.227	None	None	None
28-Nov-01	Wednesday	15:30 - 15:45	Day	1	8	174	1392	3.093	None	None	None
28-Nov-01	Wednesday	15:45 - 16:00	Day	0	8	238	1904	4.231	None	None	None
28-Nov-01	Wednesday	16:00 - 16:15	Day	0	7	157	1099	2.442	None	None	None
28-Nov-01	Wednesday	16:15 - 16:30	Day	0	7	174	1218	2.707	None	None	None
28-Nov-01	Wednesday	16:30 - 16:45	Day	0	7	206	1442	3.204	None	None	None
28-Nov-01	Wednesday	16:45 - 17:00	Day	0	9	233	2097	4.66	None	None	None
29-Nov-01	Thursday	15:00 - 15:15	Day	0	7	159	1113	2.473	Rain	None	None
29-Nov-01	Thursday	15:15 - 15:30	Day	0	7	171	1197	2.66	Rain	None	None

TABLE H8 RLR Data in 15-Minute Intervals

Date	Day of Week	Time Interval	Day/night	RLR	Cycles	Vehicles	* #Cycles	Opportunity	Precipitation	Enforcement	Vacation
29-Nov-01	Thursday	15:30 - 15:45	Day	0	7	89	623	1.384	None	None	None
29-Nov-01	Thursday	15:45 - 16:00	Day	0	9	91	819	1.82	None	None	None
29-Nov-01	Thursday	16:00 - 16:15	Day	0	8	81	648	1.44	None	None	None
29-Nov-01	Thursday	16:15 - 16:30	Day	0	7	87	609	1.353	None	None	None
29-Nov-01	Thursday	16:30 - 16:45	Day	0	8	99	792	1.76	None	None	None
29-Nov-01	Thursday	16:45 - 17:00	Day	1	7	152	1064	2.364	None	None	None
30-Nov-01	Friday	15:00 - 15:15	Day	0	7	383	2681	5.958	None	None	None
30-Nov-01	Friday	15:15 - 15:30	Day	0	6	372	2232	4.96	None	None	None
30-Nov-01	Friday	15:30 - 15:45	Day	1	6	270	1620	3.6	None	None	None
30-Nov-01	Friday	15:45 - 16:00	Day	0	6	321	1926	4.28	None	None	None
30-Nov-01	Friday	16:00 - 16:15	Day	0	7	280	1960	4.356	None	None	None
30-Nov-01	Friday	16:15 - 16:30	Day	0	6	273	1638	3.64	None	None	None
30-Nov-01	Friday	16:30 - 16:45	Day	3	6	247	1482	3.293	None	None	None
30-Nov-01	Friday	16:45 - 17:00	Day	0	6	273	1638	3.64	None	None	None
1-Dec-01	Saturday	15:00 - 15:15	Day	0	6	477	2862	6.36	None	None	None
1-Dec-01	Saturday	15:15 - 15:30	Day	0	5	450	2250	5	None	None	None
1-Dec-01	Saturday	15:30 - 15:45	Day	0	5	154	770	1.711	None	None	None
1-Dec-01	Saturday	15:45 - 16:00	Day	1	5	162	810	1.8	None	None	None
1-Dec-01	Saturday	16:00 - 16:15	Day	0	6	205	1230	2.733	None	None	None
1-Dec-01	Saturday	16:15 - 16:30	Day	0	6	187	1122	2.493	None	None	None
1-Dec-01	Saturday	16:30 - 16:45	Day	0	9	174	1566	3.48	None	None	None
1-Dec-01	Saturday	16:45 - 17:00	Day	0	10	156	1560	3.467	None	None	None
6-Dec-01	Thursday	15:00 - 15:15	Day	0	7	412	2884	6.409	None	None	None
6-Dec-01	Thursday	15:15 - 15:30	Day	0	8	392	3136	6.969	None	None	None
6-Dec-01	Thursday	15:30 - 15:45	Day	1	7	169	1183	2.629	None	None	None

TABLE H9 RLR Data in 15-Minute Intervals

Date	Day of Week	Time Interval	Day/night	# RLR	Cycles	# Vehicles	* #Cycles	Opportunity	Precipitation	Enforcement	Vacation
6-Dec-01	Thursday	15:45 - 16:00	Day	2	7	163	1141	2.536	None	None	None
6-Dec-01	Thursday	16:00 - 16:15	Day	0	6	197	1182	2.627	None	None	None
6-Dec-01	Thursday	16:15 - 16:30	Day	0	6	271	1626	3.613	None	None	None
6-Dec-01	Thursday	16:30 - 16:45	Day	0	7	253	1771	3.936	None	None	None
6-Dec-01	Thursday	16:45 - 17:00	Day	2	7	229	1603	3.562	None	None	None
8-Dec-01	Saturday	15:00 - 15:15	Day	0	8	293	2344	5.209	None	None	None
8-Dec-01	Saturday	15:15 - 15:30	Day	0	7	249	1743	3.873	None	None	None
8-Dec-01	Saturday	15:30 - 15:45	Day	0	9	118	1062	2.36	None	None	None
8-Dec-01	Saturday	15:45 - 16:00	Day	0	11	154	1694	3.764	None	None	None
8-Dec-01	Saturday	16:00 - 16:15	Day	0	10	129	1290	2.867	None	None	None
8-Dec-01	Saturday	16:15 - 16:30	Day	0	10	144	1440	3.2	None	None	None
8-Dec-01	Saturday	16:30 - 16:45	Day	0	11	129	1419	3.153	None	None	None
8-Dec-01	Saturday	16:45 - 17:00	Day	1	8	129	1032	2.293	None	None	None
10-Dec-01	Monday	15:00 - 15:15	Day	1	7	434	3038	6.751	None	None	None
10-Dec-01	Monday	15:15 - 15:30	Day	0	8	499	3992	8.871	None	None	None
10-Dec-01	Monday	15:30 - 15:45	Day	0	9	181	1629	3.62	None	None	None
10-Dec-01	Monday	15:45 - 16:00	Day	0	8	191	1528	3.396	None	None	None
10-Dec-01	Monday	16:00 - 16:15	Day	0	8	193	1544	3.431	None	None	None
10-Dec-01	Monday	16:15 - 16:30	Day	0	8	223	1784	3.964	None	None	None
10-Dec-01	Monday	16:30 - 16:45	Day	0	8	240	1920	4.267	None	None	None
10-Dec-01	Monday	16:45 - 17:00	Day	0	8	260	2080	4.622	None	None	None
12-Dec-01	Wednesday	15:00 - 15:15	Day	0	7	346	2422	5.382	Rain	None	None
12-Dec-01	Wednesday	15:15 - 15:30	Day	0	7	326	2282	5.071	Rain	None	None
12-Dec-01	Wednesday	15:30 - 15:45	Day	0	8	173	1384	3.076	Rain	None	None
12-Dec-01	Wednesday	15:45 - 16:00	Day	0	8	198	1584	3.52	Rain	None	None

TABLE H10 RLR Data in 15-Minute Intervals

Date	Day of Week	Time Interval	Day/night	# RLR	Cycles	# Vehicles	* #Cycles	Opportunity	Precipitation	Enforcement	Vacation
12-Dec-01	Wednesday	16:00 - 16:15	Day	0	7	186	1302	2.893	Rain	None	None
12-Dec-01	Wednesday	16:15 - 16:30	Day	0	6	204	1224	2.72	Rain	None	None
12-Dec-01	Wednesday	16:30 - 16:45	Day	0	6	208	1248	2.773	Rain	None	None
12-Dec-01	Wednesday	16:45 - 17:00	Day	0	7	205	1435	3.189	Rain	None	None
14-Dec-01	Friday	15:00 - 15:15	Day	0	6	350	2100	4.667	None	None	None
14-Dec-01	Friday	15:15 - 15:30	Day	1	7	359	2513	5.584	None	None	None
14-Dec-01	Friday	15:30 - 15:45	Day	0	7	246	1722	3.827	None	None	None
14-Dec-01	Friday	15:45 - 16:00	Day	0	8	222	1776	3.947	None	None	None
14-Dec-01	Friday	16:00 - 16:15	Day	0	7	244	1708	3.796	None	None	None
14-Dec-01	Friday	16:15 - 16:30	Day	0	7	240	1680	3.733	None	None	None
14-Dec-01	Friday	16:30 - 16:45	Day	0	7	210	1470	3.267	None	None	None
14-Dec-01	Friday	16:45 - 17:00	Day	1	7	274	1918	4.262	None	None	None
16-Dec-01	Sunday	15:00 - 15:15	Day	0	15	181	2715	6.033	None	None	Yes
16-Dec-01	Sunday	15:15 - 15:30	Day	0	15	174	2610	5.8	None	None	Yes
16-Dec-01	Sunday	15:30 - 15:45	Day	0	15	88	1320	2.933	None	None	Yes
16-Dec-01	Sunday	15:45 - 16:00	Day	0	12	76	912	2.027	None	None	Yes
16-Dec-01	Sunday	16:00 - 16:15	Day	0	16	85	1360	3.022	None	None	Yes
16-Dec-01	Sunday	16:15 - 16:30	Day	0	15	89	1335	2.967	None	None	Yes
16-Dec-01	Sunday	16:30 - 16:45	Day	0	11	98	1078	2.396	None	None	Yes
16-Dec-01	Sunday	16:45 - 17:00	Day	0	12	147	1764	3.92	None	None	Yes
17-Dec-01	Monday	15:00 - 15:15	Day	0	15	243	3645	8.1	None	None	Yes
17-Dec-01	Monday	15:15 - 15:30	Day	0	14	202	2828	6.284	None	None	Yes
17-Dec-01	Monday	15:30 - 15:45	Day	0	14	148	2072	4.604	None	None	Yes
17-Dec-01	Monday	15:45 - 16:00	Day	0	13	154	2002	4.449	None	None	Yes

TABLE H11 RLR Data in 15-Minute Intervals

Date	Day of Week	Time Interval	Day/night	# RLR	Cycles	Vehicles	* #Cycles	Opportunity	Precipitation	Enforcement	Vacation
17-Dec-01	Monday	16:00 - 16:15	Day	0	15	160	2400	5.333	None	None	Yes
17-Dec-01	Monday	16:15 - 16:30	Day	1	14	207	2898	6.44	None	None	Yes
17-Dec-01	Monday	16:30 - 16:45	Day	0	14	185	2590	5.756	None	None	Yes
17-Dec-01	Monday	16:45 - 17:00	Day	0	12	213	2556	5.68	None	None	Yes
20-Dec-01	Thursday	15:30 - 15:45	Day	0	16	107	1712	3.804	None	None	Yes
20-Dec-01	Thursday	15:45 - 16:00	Day	0	15	115	1725	3.833	None	None	Yes
20-Dec-01	Thursday	16:00 - 16:15	Day	1	15	149	2235	4.967	None	None	Yes
20-Dec-01	Thursday	16:15 - 16:30	Day	0	16	130	2080	4.622	None	None	Yes
20-Dec-01	Thursday	16:30 - 16:45	Day	0	15	158	2370	5.267	None	None	Yes
20-Dec-01	Thursday	16:45 - 17:00	Day	0	16	149	2384	5.298	None	None	Yes
22-Dec-01	Saturday	15:00 - 15:15	Day	0	17	145	2465	5.478	None	None	Yes
22-Dec-01	Saturday	15:15 - 15:30	Day	0	18	180	3240	7.2	None	None	Yes
22-Dec-01	Saturday	15:30 - 15:45	Day	0	15	77	1155	2.567	None	None	Yes
22-Dec-01	Saturday	15:45 - 16:00	Day	0	17	94	1598	3.551	None	None	Yes
22-Dec-01	Saturday	16:00 - 16:15	Day	0	20	85	1700	3.778	None	None	Yes
22-Dec-01	Saturday	16:15 - 16:30	Day	1	16	94	1504	3.342	None	None	Yes
22-Dec-01	Saturday	16:30 - 16:45	Day	0	15	87	1305	2.9	None	None	Yes
22-Dec-01	Saturday	16:45 - 17:00	Day	0	18	79	1422	3.16	None	None	Yes
6-Mar-02	Wednesday	7:00 - 7:15	Day	0	18	228	4104	9.12	None	None	None
6-Mar-02	Wednesday	7:15 - 7:30	Day	1	11	248	2728	6.062	None	None	None
6-Mar-02	Wednesday	7:30 - 7:45	Day	0	12	257	3084	6.853	None	None	None
6-Mar-02	Wednesday	7:45 - 8:00	Day	1	10	262	2620	5.822	None	None	None
6-Mar-02	Wednesday	8:00 - 8:15	Day	0	10	380	3800	8.444	None	None	None
6-Mar-02	Wednesday	8:15 - 8:30	Day	0	8	407	3256	7.236	None	None	None

TABLE H12 RLR Data in 15-Minute Intervals

Date	Day of Week	Time Interval	Day/night	# RLR	# Cycles	Vehicles	* #Cycles	Opportunity	Precipitation	Enforcement	Vacation
6-Mar-02	Wednesday	8:30 - 8:45	Day	0	10	390	3900	8.667	None	None	None
6-Mar-02	Wednesday	8:45 - 9:00	Day	0	12	351	4212	9.36	None	None	None
6-Mar-02	Wednesday	9:00 - 9:15	Day	0	11	322	3542	7.871	None	None	None
6-Mar-02	Wednesday	9:15 - 9:30	Day	0	10	339	3390	7.533	None	None	None
6-Mar-02	Wednesday	9:30 - 9:45	Day	1	12	339	4068	9.04	None	None	None
6-Mar-02	Wednesday	9:45 - 10:00	Day	0	15	296	4440	9.867	None	None	None
7-Mar-02	Thursday	7:00 - 7:15	Day	0	15	275	4125	9.167	None	None	None
7-Mar-02	Thursday	7:15 - 7:30	Day	0	12	286	3432	7.627	None	None	None
7-Mar-02	Thursday	7:30 - 7:45	Day	0	11	306	3366	7.48	None	None	None
7-Mar-02	Thursday	7:45 - 8:00	Day	1	7	275	1925	4.278	None	None	None
7-Mar-02	Thursday	8:00 - 8:15	Day	0	10	373	3730	8.289	None	None	None
7-Mar-02	Thursday	8:15 - 8:30	Day	0	10	282	2820	6.267	None	None	None
7-Mar-02	Thursday	8:30 - 8:45	Day	0	10	313	3130	6.956	None	None	None
7-Mar-02	Thursday	8:45 - 9:00	Day	0	8	265	2120	4.711	None	None	None
7-Mar-02	Thursday	9:00 - 9:15	Day	0	9	311	2799	6.22	None	None	None
7-Mar-02	Thursday	9:15 - 9:30	Day	0	9	243	2187	4.86	None	None	None
7-Mar-02	Thursday	9:30 - 9:45	Day	1	13	241	3133	6.962	None	None	None
7-Mar-02	Thursday	9:45 - 10:00	Day	0	11	226	2486	5.524	None	None	None
8-Mar-02	Friday	7:00 - 7:15	Day	0	14	259	3626	8.058	None	None	None
8-Mar-02	Friday	7:15 - 7:30	Day	0	12	209	2508	5.573	None	None	None
8-Mar-02	Friday	7:30 - 7:45	Day	0	11	259	2849	6.331	None	None	None
8-Mar-02	Friday	7:45 - 8:00	Day	3	8	234	1872	4.16	None	None	None
8-Mar-02	Friday	8:00 - 8:15	Day	0	9	343	3087	6.86	None	None	None
8-Mar-02	Friday	8:15 - 8:30	Day	0	10	327	3270	7.267	None	None	None

TABLE H13 RLR Data in 15-Minute Intervals

Date	Day of Week	Time Interval	Day/night	# RLR	# Cycles	# Vehicles	#Cycles	Opportunity	Precipitation	Enforcement	Vacation
8-Mar-02	Friday	8:30 - 8:45	Day	0	12	374	4488	9.973	None	None	None
8-Mar-02	Friday	8:45 - 9:00	Day	0	13	301	3913	8.696	None	None	None
8-Mar-02	Friday	9:00 - 9:15	Day	0	11	328	3608	8.018	None	None	None
8-Mar-02	Friday	9:15 - 9:30	Day	1	10	337	3370	7.489	None	None	None
8-Mar-02	Friday	9:30 - 9:45	Day	3	9	385	3465	7.7	None	None	None
8-Mar-02	Friday	9:45 - 10:00	Day	1	11	393	4323	9.607	None	None	None
10-Mar-02	Sunday	7:00 - 7:15	Day	0	7	82	574	1.276	None	None	Yes
10-Mar-02	Sunday	7:15 - 7:30	Day	0	7	104	728	1.618	None	None	Yes
10-Mar-02	Sunday	7:30 - 7:45	Day	0	4	177	708	1.573	None	None	Yes
10-Mar-02	Sunday	7:45 - 8:00	Day	0	9	71	639	1.42	None	None	Yes
10-Mar-02	Sunday	8:00 - 8:15	Day	0	9	296	2664	5.92	None	None	Yes
10-Mar-02	Sunday	8:15 - 8:30	Day	0	13	610	7930	17.622	None	None	Yes
10-Mar-02	Sunday	8:30 - 8:45	Day	0	7	522	3654	8.12	None	None	Yes
10-Mar-02	Sunday	8:45 - 9:00	Day	0	13	587	7631	16.958	None	None	Yes
10-Mar-02	Sunday	9:00 - 9:15	Day	0	14	654	9156	20.347	None	None	Yes
10-Mar-02	Sunday	9:15 - 9:30	Day	0	9	342	3078	6.84	None	None	Yes
10-Mar-02	Sunday	9:30 - 9:45	Day	0	12	575	6900	15.333	None	None	Yes
10-Mar-02	Sunday	9:45 - 10:00	Day	1	16	591	9456	21.013	None	None	Yes
10-Mar-02	Sunday	15:00 - 15:15	Day	0	13	996	12948	28.773	None	None	Yes
10-Mar-02	Sunday	15:15 - 15:30	Day	0	18	1048	18864	41.92	None	None	Yes
10-Mar-02	Sunday	15:30 - 15:45	Day	1	17	982	16694	37.098	None	None	Yes
10-Mar-02	Sunday	15:45 - 16:00	Day	0	16	869	13904	30.898	None	None	Yes
10-Mar-02	Sunday	16:00 - 16:15	Day	0	17	554	9418	20.929	None	None	Yes
10-Mar-02	Sunday	16:15 - 16:30	Day	0	15	440	6600	14.667	None	None	Yes

TABLE H14 RLR Data in 15-Minute Intervals

Date	Day of Week	Time Interval	Day/night	# RLR	# Cycles	# Vehicles	#Cycles	Opportunity	Precipitation	Enforcement	Vacation
10-Mar-02	Sunday	16:30 - 16:45	Day	1	14	253	3542	7.871	None	None	Yes
10-Mar-02	Sunday	16:45 - 17:00	Day	0	16	71	1136	2.524	None	None	Yes
10-Mar-02	Sunday	17:00 - 17:15	Day	2	18	53	954	2.12	None	None	Yes
10-Mar-02	Sunday	17:15 - 17:30	Day	0	18	50	900	2	None	None	Yes
10-Mar-02	Sunday	17:30 - 17:45	Day	0	17	61	1037	2.304	None	None	Yes
10-Mar-02	Sunday	17:45 - 18:00	Day	0	13	57	741	1.647	None	None	Yes
15-Mar-02	Friday	7:00 - 7:15	Day	0	16	219	3504	7.787	None	None	Yes
15-Mar-02	Friday	7:15 - 7:30	Day	0	18	157	2826	6.28	None	None	Yes
15-Mar-02	Friday	7:30 - 7:45	Day	0	14	157	2198	4.884	None	None	Yes
15-Mar-02	Friday	7:45 - 8:00	Day	0	12	192	2304	5.12	None	None	Yes
15-Mar-02	Friday	8:00 - 8:15	Day	0	15	278	4170	9.267	None	None	Yes
15-Mar-02	Friday	8:15 - 8:30	Day	0	17	221	3757	8.349	None	None	Yes
15-Mar-02	Friday	8:30 - 8:45	Day	0	17	186	3162	7.027	None	None	Yes
15-Mar-02	Friday	8:45 - 9:00	Day	0	15	165	2475	5.5	None	None	Yes
15-Mar-02	Friday	9:00 - 9:15	Day	0	17	165	2805	6.233	None	None	Yes
15-Mar-02	Friday	9:15 - 9:30	Day	0	18	153	2754	6.12	None	None	Yes
15-Mar-02	Friday	9:30 - 9:45	Day	0	18	177	3186	7.08	None	None	Yes
15-Mar-02	Friday	9:45 - 10:00	Day	0	15	161	2415	5.367	Rain	None	Yes
15-Mar-02	Friday	15:00 - 15:15	Day	0	13	211	2743	6.096	None	None	Yes
15-Mar-02	Friday	15:15 - 15:30	Day	0	15	232	3480	7.733	None	None	Yes
15-Mar-02	Friday	15:30 - 15:45	Day	1	13	241	3133	6.962	None	None	Yes
15-Mar-02	Friday	15:45 - 16:00	Day	0	12	230	2760	6.133	None	None	Yes
15-Mar-02	Friday	16:00 - 16:15	Day	0	14	241	3374	7.498	None	None	Yes
15-Mar-02	Friday	16:15 - 16:30	Day	0	13	279	3627	8.06	None	None	Yes

TABLE H15 RLR Data in 15-Minute Intervals

Date	Day of Week	Time Interval	Day/night	# RLR	# Cycles	# Vehicles	#Cycles	Opportunity	Precipitation	Enforcement	Vacation
15-Mar-02	Friday	16:30 - 16:45	Day	0	14	234	3276	7.28	None	None	Yes
15-Mar-02	Friday	16:45 - 17:00	Day	0	12	191	2292	5.093	None	None	Yes
15-Mar-02	Friday	17:00 - 17:15	Day	0	13	178	2314	5.142	Rain	None	Yes
15-Mar-02	Friday	17:15 - 17:30	Day	1	12	215	2580	5.733	Rain	None	Yes
15-Mar-02	Friday	17:30 - 17:45	Day	0	13	192	2496	5.547	Rain	None	Yes
15-Mar-02	Friday	17:45 - 18:00	Day	0	15	181	2715	6.033	Rain	None	Yes
16-Mar-02	Saturday	7:00 - 7:15	Day	0	8	63	504	1.12	None	None	Yes
16-Mar-02	Saturday	7:15 - 7:30	Day	0	9	66	594	1.32	None	None	Yes
16-Mar-02	Saturday	7:30 - 7:45	Day	0	16	49	784	1.742	None	None	Yes
16-Mar-02	Saturday	7:45 - 8:00	Day	0	16	52	832	1.849	None	None	Yes
16-Mar-02	Saturday	8:00 - 8:15	Day	0	11	63	693	1.54	None	None	Yes
16-Mar-02	Saturday	8:15 - 8:30	Day	0	15	75	1125	2.5	None	None	Yes
16-Mar-02	Saturday	8:30 - 8:45	Day	0	17	69	1173	2.607	None	None	Yes
16-Mar-02	Saturday	8:45 - 9:00	Day	0	18	102	1836	4.08	None	None	Yes
16-Mar-02	Saturday	9:00 - 9:15	Day	0	14	125	1750	3.889	None	None	Yes
16-Mar-02	Saturday	9:15 - 9:30	Day	0	14	89	1246	2.769	None	None	Yes
16-Mar-02	Saturday	9:30 - 9:45	Day	0	15	110	1650	3.667	None	None	Yes
16-Mar-02	Saturday	9:45 - 10:00	Day	0	16	128	2048	4.551	None	None	Yes
16-Mar-02	Saturday	15:00 - 15:15	Day	0	14	220	3080	6.844	None	None	Yes
16-Mar-02	Saturday	15:15 - 15:30	Day	0	14	191	2674	5.942	None	None	Yes
16-Mar-02	Saturday	15:30 - 15:45	Day	0	10	219	2190	4.867	None	None	Yes
16-Mar-02	Saturday	15:45 - 16:00	Day	0	14	327	4578	10.173	None	None	Yes
16-Mar-02	Saturday	16:00 - 16:15	Day	1	18	172	3096	6.88	None	None	Yes
16-Mar-02	Saturday	16:15 - 16:30	Day	0	16	226	3616	8.036	None	None	Yes

TABLE H16 RLR Data in 15-Minute Intervals

Date	Day of Week	Time Interval	Day/night	# RLR	# Cycles	# Vehicles	#Cycles	Opportunity	Precipitation	Enforcement	Vacation
16-Mar-02	Saturday	16:30 - 16:45	Day	0	17	177	3009	6.687	None	None	Yes
16-Mar-02	Saturday	16:45 - 17:00	Day	0	18	109	1962	4.36	None	None	Yes
16-Mar-02	Saturday	17:00 - 17:15	Day	0	18	68	1224	2.72	None	None	Yes
16-Mar-02	Saturday	17:15 - 17:30	Day	0	17	75	1275	2.833	None	None	Yes
16-Mar-02	Saturday	17:30 - 17:45	Day	0	19	102	1938	4.307	None	None	Yes
16-Mar-02	Saturday	17:45 - 18:00	Day	0	17	68	1156	2.569	None	None	Yes
18-Mar-02	Monday	7:00 - 7:15	Day	0	13	227	2951	6.558	None	Video	None
18-Mar-02	Monday	7:15 - 7:30	Day	0	10	192	1920	4.267	None	Video	None
18-Mar-02	Monday	7:30 - 7:45	Day	0	9	289	2601	5.78	None	Video	None
18-Mar-02	Monday	7:45 - 8:00	Day	0	7	252	1764	3.92	None	Video	None
18-Mar-02	Monday	8:00 - 8:15	Day	0	9	347	3123	6.94	None	Video	None
18-Mar-02	Monday	8:15 - 8:30	Day	0	8	351	2808	6.24	None	Video	None
18-Mar-02	Monday	8:30 - 8:45	Day	0	10	332	3320	7.378	None	Video	None
18-Mar-02	Monday	8:45 - 9:00	Day	0	12	250	3000	6.667	None	Video	None
18-Mar-02	Monday	9:00 - 9:15	Day	0	11	256	2816	6.258	None	Video	None
18-Mar-02	Monday	9:15 - 9:30	Day	0	9	277	2493	5.54	None	Video	None
18-Mar-02	Monday	9:30 - 9:45	Day	0	12	292	3504	7.787	None	Video	None
18-Mar-02	Monday	9:45 - 10:00	Day	0	14	247	3458	7.684	None	Video	None
18-Mar-02	Monday	15:00 - 15:15	Day	0	8	279	2232	4.96	None	Video	None
18-Mar-02	Monday	15:15 - 15:30	Day	0	7	298	2086	4.636	None	Video	None
18-Mar-02	Monday	15:30 - 15:45	Day	0	8	384	3072	6.827	None	Video	None
18-Mar-02	Monday	15:45 - 16:00	Day	0	9	429	3861	8.58	None	Video	None
18-Mar-02	Monday	16:00 - 16:15	Day	0	8	360	2880	6.4	None	Video	None
18-Mar-02	Monday	16:15 - 16:30	Day	0	6	339	2034	4.52	None	Video	None

TABLE H17 RLR Data in 15-Minute Intervals

Date	Day of Week	Time Interval	Day/night	# RLR	# Cycles	# Vehicles	#Cycles	Opportunity	Precipitation	Enforcement	Vacation
18-Mar-02	Monday	16:30 - 16:45	Day	0	7	393	2751	6.113	None	Video	None
18-Mar-02	Monday	16:45 - 17:00	Day	0	8	339	2712	6.027	None	Video	None
18-Mar-02	Monday	17:00 - 17:15	Day	0	7	199	1393	3.096	None	Video	None
18-Mar-02	Monday	17:15 - 17:30	Day	0	7	263	1841	4.091	None	Video	None
18-Mar-02	Monday	17:30 - 17:45	Day	1	8	288	2304	5.12	None	Video	None
18-Mar-02	Monday	17:45 - 18:00	Day	0	8	250	2000	4.444	None	Video	None
20-Mar-02	Wednesday	7:00 - 7:15	Day	0	14	206	2884	6.409	None	Video	None
20-Mar-02	Wednesday	7:15 - 7:30	Day	0	10	234	2340	5.2	None	Video	None
20-Mar-02	Wednesday	7:30 - 7:45	Day	0	10	241	2410	5.356	None	Video	None
20-Mar-02	Wednesday	7:45 - 8:00	Day	1	7	260	1820	4.044	None	Video	None
20-Mar-02	Wednesday	8:00 - 8:15	Day	0	10	350	3500	7.778	None	Video	None
20-Mar-02	Wednesday	8:15 - 8:30	Day	0	7	312	2184	4.853	None	Video	None
20-Mar-02	Wednesday	8:30 - 8:45	Day	0	11	362	3982	8.849	None	Video	None
20-Mar-02	Wednesday	8:45 - 9:00	Day	1	13	270	3510	7.8	None	Video	None
20-Mar-02	Wednesday	9:00 - 9:15	Day	0	13	272	3536	7.858	None	Video	None
20-Mar-02	Wednesday	9:15 - 9:30	Day	0	9	271	2439	5.42	None	Video	None
20-Mar-02	Wednesday	9:30 - 9:45	Day	0	11	292	3212	7.138	None	Video	None
20-Mar-02	Wednesday	9:45 - 10:00	Day	0	12	227	2724	6.053	None	Video	None
20-Mar-02	Wednesday	15:00 - 15:15	Day	0	10	258	2580	5.733	None	Video	None
20-Mar-02	Wednesday	15:15 - 15:30	Day	0	8	274	2192	4.871	None	Video	None
20-Mar-02	Wednesday	15:30 - 15:45	Day	0	8	361	2888	6.418	None	Video	None
20-Mar-02	Wednesday	15:45 - 16:00	Day	0	11	417	4587	10.193	None	Video	None
20-Mar-02	Wednesday	16:00 - 16:15	Day	0	9	322	2898	6.44	None	Video	None
20-Mar-02	Wednesday	16:15 - 16:30	Day	0	8	347	2776	6.169	None	Video	None

TABLE H18 RLR Data in 15-Minute Intervals

Date	Day of Week	Time Interval	Day/night	# RLR	# Cycles	# Vehicles	#Cycles	Opportunity	Precipitation	Enforcement	Vacation
20-Mar-02	Wednesday	16:30 - 16:45	Day	0	9	417	3753	8.34	None	Video	None
20-Mar-02	Wednesday	16:45 - 17:00	Day	0	8	367	2936	6.524	None	Video	None
20-Mar-02	Wednesday	17:00 - 17:15	Day	0	7	166	1162	2.582	None	Video	None
20-Mar-02	Wednesday	17:15 - 17:30	Day	0	6	199	1194	2.653	None	Video	None
20-Mar-02	Wednesday	17:30 - 17:45	Day	0	7	222	1554	3.453	None	Video	None
20-Mar-02	Wednesday	17:45 - 18:00	Day	1	7	275	1925	4.278	None	Video	None
22-Mar-02	Friday	7:00 - 7:15	Day	0	14	179	2506	5.569	None	Video	None
22-Mar-02	Friday	7:15 - 7:30	Day	1	11	196	2156	4.791	None	Video	None
22-Mar-02	Friday	7:30 - 7:45	Day	0	11	284	3124	6.942	None	Video	None
22-Mar-02	Friday	7:45 - 8:00	Day	0	8	301	2408	5.351	None	Video	None
22-Mar-02	Friday	8:00 - 8:15	Day	0	9	382	3438	7.64	None	Video	None
22-Mar-02	Friday	8:15 - 8:30	Day	0	9	408	3672	8.16	None	Video	None
22-Mar-02	Friday	8:30 - 8:45	Day	0	13	387	5031	11.18	None	Video	None
22-Mar-02	Friday	8:45 - 9:00	Day	0	13	313	4069	9.042	None	Video	None
22-Mar-02	Friday	9:00 - 9:15	Day	1	12	274	3288	7.307	None	Video	None
22-Mar-02	Friday	9:15 - 9:30	Day	0	8	417	3336	7.413	None	Video	None
22-Mar-02	Friday	9:30 - 9:45	Day	0	11	485	5335	11.856	None	Video	None
22-Mar-02	Friday	9:45 - 10:00	Day	0	13	375	4875	10.833	None	Video	None
22-Mar-02	Friday	15:00 - 15:15	Day	0	9	1137	10233	22.74	None	Video	None
22-Mar-02	Friday	15:15 - 15:30	Day	0	6	1082	6492	14.427	None	Video	None
22-Mar-02	Friday	15:30 - 15:45	Day	0	6	1476	8856	19.68	None	Video	None
22-Mar-02	Friday	15:45 - 16:00	Day	0	7	1275	8925	19.833	None	Video	None
22-Mar-02	Friday	16:00 - 16:15	Day	0	7	1047	7329	16.287	None	Video	None
22-Mar-02	Friday	16:15 - 16:30	Day	0	6	1060	6360	14.133	None	Video	None

TABLE H19 RLR Data in 15-Minute Intervals

Date	Day of Week	Time Interval	Day/night	# RLR	# Cycles	# Vehicles	#Cycles	Opportunity	Precipitation	Enforcement	Vacation
22-Mar-02	Friday	16:30 - 16:45	Day	1	7	696	4872	10.827	None	Video	None
22-Mar-02	Friday	16:45 - 17:00	Day	0	7	531	3717	8.26	None	Video	None
22-Mar-02	Friday	17:00 - 17:15	Day	2	7	234	1638	3.64	None	Video	None
22-Mar-02	Friday	17:15 - 17:30	Day	1	7	222	1554	3.453	None	Video	None
22-Mar-02	Friday	17:30 - 17:45	Day	0	7	311	2177	4.838	None	Video	None
22-Mar-02	Friday	17:45 - 18:00	Day	0	8	208	1664	3.698	None	Video	None
26-Mar-02	Tuesday	7:00 - 7:15	Day	1	15	124	1860	4.133	snow	None	None
26-Mar-02	Tuesday	7:15 - 7:30	Day	1	9	134	1206	2.68	snow	None	None
26-Mar-02	Tuesday	7:30 - 7:45	Day	0	7	189	1323	2.94	snow	None	None
26-Mar-02	Tuesday	7:45 - 8:00	Day	0	7	249	1743	3.873	snow	None	None
26-Mar-02	Tuesday	8:00 - 8:15	Day	0	7	130	910	2.022	snow	None	None
26-Mar-02	Tuesday	8:15 - 8:30	Day	0	6	124	744	1.653	snow	None	None
26-Mar-02	Tuesday	8:30 - 8:45	Day	0	7	180	1260	2.8	snow	None	None
26-Mar-02	Tuesday	8:45 - 9:00	Day	1	6	141	846	1.88	snow	None	None
26-Mar-02	Tuesday	9:00 - 9:15	Day	0	6	153	918	2.04	snow	None	None
26-Mar-02	Tuesday	9:15 - 9:30	Day	0	7	155	1085	2.411	snow	None	None
26-Mar-02	Tuesday	9:30 - 9:45	Day	0	7	119	833	1.851	snow	None	None
26-Mar-02	Tuesday	9:45 - 10:00	Day	1	7	143	1001	2.224	snow	None	None
26-Mar-02	Tuesday	15:00 - 15:15	Day	0	9	366	3294	7.32	snow	None	None
26-Mar-02	Tuesday	15:15 - 15:30	Day	0	11	318	3498	7.773	snow	None	None
26-Mar-02	Tuesday	15:30 - 15:45	Day	0	10	466	4660	10.356	snow	None	None
26-Mar-02	Tuesday	15:45 - 16:00	Day	0	10	424	4240	9.422	snow	None	None
26-Mar-02	Tuesday	16:00 - 16:15	Day	0	9	660	5940	13.2	snow	None	None
26-Mar-02	Tuesday	16:15 - 16:30	Day	0	8	276	2208	4.907	snow	None	None

TABLE H20 RLR Data in 15-Minute Intervals

Date	Day of Week	Time Interval	Day/night	# RLR	# Cycles	# Vehicles	#Cycles	Opportunity	Precipitation	Enforcement	Vacation
26-Mar-02	Tuesday	16:30 - 16:45	Day	0	9	538	4842	10.76	snow	None	None
26-Mar-02	Tuesday	16:45 - 17:00	Day	0	9	384	3456	7.68	snow	None	None
26-Mar-02	Tuesday	17:00 - 17:15	Day	0	11	125	1375	3.056	snow	None	None
26-Mar-02	Tuesday	17:15 - 17:30	Day	0	8	145	1160	2.578	snow	None	None
26-Mar-02	Tuesday	17:30 - 17:45	Day	0	9	182	1638	3.64	snow	None	None
26-Mar-02	Tuesday	17:45 - 18:00	Day	1	8	131	1048	2.329	snow	None	None
28-Mar-02	Thursday	7:00 - 7:15	Day	0	14	156	2184	4.853	None	None	None
28-Mar-02	Thursday	7:15 - 7:30	Day	0	10	186	1860	4.133	None	None	None
28-Mar-02	Thursday	7:30 - 7:45	Day	0	10	196	1960	4.356	None	None	None
28-Mar-02	Thursday	7:45 - 8:00	Day	0	8	311	2488	5.529	None	None	None
28-Mar-02	Thursday	8:00 - 8:15	Day	0	9	404	3636	8.08	None	None	None
28-Mar-02	Thursday	8:15 - 8:30	Day	0	9	260	2340	5.2	None	None	None
28-Mar-02	Thursday	8:30 - 8:45	Day	0	9	267	2403	5.34	None	None	None
28-Mar-02	Thursday	8:45 - 9:00	Day	1	8	305	2440	5.422	None	None	None
28-Mar-02	Thursday	9:00 - 9:15	Day	1	12	272	3264	7.253	None	None	None
28-Mar-02	Thursday	9:15 - 9:30	Day	0	11	286	3146	6.991	None	None	None
28-Mar-02	Thursday	9:30 - 9:45	Day	0	12	289	3468	7.707	None	None	None
28-Mar-02	Thursday	9:45 - 10:00	Day	1	12	292	3504	7.787	None	None	None
28-Mar-02	Thursday	15:00 - 15:15	Day	1	9	323	2907	6.46	None	None	None
28-Mar-02	Thursday	15:15 - 15:30	Day	0	8	372	2976	6.613	None	None	None
28-Mar-02	Thursday	15:30 - 15:45	Day	0	8	317	2536	5.636	None	None	None
28-Mar-02	Thursday	15:45 - 16:00	Day	0	9	304	2736	6.08	None	None	None
28-Mar-02	Thursday	16:00 - 16:15	Day	0	9	307	2763	6.14	None	None	None
28-Mar-02	Thursday	16:15 - 16:30	Day	0	7	295	2065	4.589	None	None	None

TABLE H21 RLR Data in 15-Minute Intervals

Date	Day of Week	Time Interval	Day/night	# RLR	# Cycles	# Vehicles	#Cycles	Opportunity	Precipitation	Enforcement	Vacation
28-Mar-02	Thursday	16:30 - 16:45	Day	0	8	437	3496	7.769	None	None	None
28-Mar-02	Thursday	16:45 - 17:00	Day	0	9	448	4032	8.96	None	None	None
28-Mar-02	Thursday	17:00 - 17:15	Day	0	7	207	1449	3.22	None	None	None
28-Mar-02	Thursday	17:15 - 17:30	Day	0	8	248	1984	4.409	None	None	None
28-Mar-02	Thursday	17:30 - 17:45	Day	0	8	194	1552	3.449	None	None	None
28-Mar-02	Thursday	17:45 - 18:00	Day	0	7	185	1295	2.878	None	None	None
29-Mar-02	Friday	7:00 - 7:15	Day	0	15	136	2040	4.533	None	None	None
29-Mar-02	Friday	7:15 - 7:30	Day	0	13	149	1937	4.304	None	None	None
29-Mar-02	Friday	7:30 - 7:45	Day	0	9	200	1800	4	None	None	None
29-Mar-02	Friday	7:45 - 8:00	Day	0	9	188	1692	3.76	None	None	None
29-Mar-02	Friday	8:00 - 8:15	Day	1	9	309	2781	6.18	None	None	None
29-Mar-02	Friday	8:15 - 8:30	Day	0	10	307	3070	6.822	None	None	None
29-Mar-02	Friday	8:30 - 8:45	Day	0	10	278	2780	6.178	None	None	None
29-Mar-02	Friday	8:45 - 9:00	Day	0	11	229	2519	5.598	None	None	None
29-Mar-02	Friday	9:00 - 9:15	Day	0	10	227	2270	5.044	None	None	None
29-Mar-02	Friday	9:15 - 9:30	Day	0	10	260	2600	5.778	None	None	None
29-Mar-02	Friday	9:30 - 9:45	Day	0	10	269	2690	5.978	None	None	None
29-Mar-02	Friday	9:45 - 10:00	Day	0	12	253	3036	6.747	None	None	None
29-Mar-02	Friday	15:00 - 15:15	Day	0	7	379	2653	5.896	Rain	None	None
29-Mar-02	Friday	15:15 - 15:30	Day	0	6	336	2016	4.48	Rain	None	None
29-Mar-02	Friday	15:30 - 15:45	Day	0	6	398	2388	5.307	Rain	None	None
29-Mar-02	Friday	15:45 - 16:00	Day	0	6	400	2400	5.333	Rain	None	None
29-Mar-02	Friday	16:00 - 16:15	Day	1	7	409	2863	6.362	Rain	None	None
29-Mar-02	Friday	16:15 - 16:30	Day	0	7	360	2520	5.6	Rain	None	None

TABLE H22 RLR Data in 15-Minute Intervals

Date	Day of Week	Time Interval	Day/night	# RLR	# Cycles	# Vehicles	#Vehicles * #Cycles	Opportunity	Precipitation	Enforcement	Vacation
29-Mar-02	Friday	16:30 - 16:45	Day	0	7	375	2625	5.833	Rain	None	None
29-Mar-02	Friday	16:45 - 17:00	Day	0	8	377	3016	6.702	Rain	None	None
29-Mar-02	Friday	17:00 - 17:15	Day	0	7	180	1260	2.8	Rain	None	None
29-Mar-02	Friday	17:15 - 17:30	Day	1	8	192	1536	3.413	Rain	None	None
29-Mar-02	Friday	17:30 - 17:45	Day	0	8	186	1488	3.307	Rain	None	None
29-Mar-02	Friday	17:45 - 18:00	Day	0	8	181	1448	3.218	Rain	None	None

Final Report

FHWA/IN/JTRP- 2002/12

EVALUATION OF SAFETY ENFORCEMENT ON CHANGING DRIVER BEHAVIOR – RUNS ON RED

Volume 2

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Introduction

"Red light running" (RLR) is defined as a driver entering the intersection subsequent to the traffic control light turning red. The encroachment action on the part of the violating driver not only increases the risk of a crash, but because of the crash dynamics involved, the likelihood for serious injury is increased. A unique attribute of intersection crashes versus other crash types is that two or more vehicles may have a legal right to the same spot in the road—but not at the same time. While all intersection crashes cannot be attributed to red light running, the number of intersection crashes in Indiana in 1995 totaled 58,433, or approximately 23.7 percent of the total crashes that occurred. Intersection crashes accounted for 164 fatal crashes, or 19.1 percent of the fatal crashes in 1995. In 1999, the total number of crashes had decreased by 12.1 percent from 1995, while intersection crashes decreased by only 0.7 percent for that same period of time. However, from 1995 to 1999, the number of fatal intersection crashes increased from 164 to 202, representing a 23.2 percent increase. Not all of these fatal intersection crashes necessarily can be attributed to red light running. For example, during the same period of time, the number of licensed drivers only increased 0.4 percent, from 3,860,329 (1995) to 3,876,908 (1999). However, the number of miles driven by these drivers increased from 645.41 (100 million miles) to 714.59 (100 million miles), representing an increase of 10.7 percent. The potential for danger is further heightened because new or expansive roadway construction has not kept pace with the increase in travel miles. In many cases, the chosen traffic control solution to increased driving as related to congested intersections has been a progression from no signage to yield/stop signs to signalized traffic controls.

Unfortunately, increased congestion also brings traffic delays and increased transit time. On the part of the driver, this can manifest itself as increased impatience, additional risk taking, and aggressive driving actions. While the increased miles driven can be quantified (above), there is certainly the perception that there has been an increase in "aggressive" driving behaviors, although this behavior is difficult to quantify.

In general terms, there is the belief that the incidence of red light running has increased, but little empirical or practical research has been conducted to identify and quantify any particular characteristics or attributes of red light runners. As a result, various alternatives have been evaluated and tested to reduce the incidence of red light running, and the potentially fatal causing crashes that can result. Traffic signal controls are primarily designed to provide for smooth traffic flow without causing an increased risk of a crash. Signal modifications have been tested and introduced, such as increasing the length of the yellow signal, utilizing an all red signal, and increasing the length of the all red signals to reduce the risk of intersection crashes. Even with these modifications, signalized intersections are not designed as a deterrent to red light running.

Historically, the principal deterrents have been law enforcement officers visually observing the infraction and then pursing the offender. Increasing law enforcement patrols have proven to be relatively ineffective and expensive as a deterrent to red light running. The presence of an officer, only if he or she is in the "right" position and if visible to a potential offender, is a deterrent. Otherwise, the officer may observe a red light running offender, but in many cases, is not in a safe roadway position to be able to make a traffic stop without creating a more hazardous traffic situation. As a result, the development and use of cameras as a means to combat red light running have been tested and introduced in a number of communities as one alternative. Results have been mixed, primarily not because of technology issues, but because of political issues. These issues have included involvement of the American Civil Liberties Union focused upon the issue of "big brother," the distribution of revenues received from citations, and ensuring that the actual offender receives the citation (not just the registered owner of the vehicle), among other issues.

Review of Literature

A considerable amount of research and expense has been appropriated to the cause, impact, and potential for deterring red light running. Numerous communities, both nationally and abroad, have funded an array of investigations, with the end results equally varied. Kent, Corben, Fildes, and Dyte (1995) undertook one such study in and around Melbourne, Australia. The intent of the study was to measure the nature and extent of red light running (RLR) occurrences at camera-equipped intersections versus comparably-designed non-camera-equipped intersections. A total of six approaches were used in the study utilizing the following setups: three intersection approaches fully equipped with RLR signage and RLR detection cameras; the opposite (oncoming) approaches to the same three intersections were equipped with RLR camera warning signs, but no cameras; and three similarly designed intersections also were observed that had no signage or cameras in place. The study found that 93 percent of RLR violations occurred during the all-red signal phase, with the authors concluding that the probability of conflicting traffic (chance of crashing) is lowest during this phase. Further, the findings also indicated that a significant number of RLR occurrences involved right-turn movements, rather than throughway violations. This finding was especially true for speed zones marked 60 km/h or higher. Most notable was that observed RLR violations occurred at comparable rates whether enforcement cameras were present at the approach or not. Although the authors concluded that red light encroachments were rather rare events and of little risk of danger, large trucks were found to be over-represented offenders during the all-red interval. While right-turn RLR violations were higher than throughway violations, the study found that right-turn encroachments decreased in general when all approaching lanes to the intersection had fully-controlled right-turn phases. No differences in RLR violations could be determined between camera and non-camera approaches, for which the authors recommended further investigation into the current operational mode of the Melbourne camera program. Specifically, an investigation into increasing the duration of the all-red phase by one or two seconds should be considered and evaluated as an inexpensive, less obtrusive mechanism of decreasing the incidence of red light run-involved crashes.

The Melbourne study above cited a previous long-term investigation of red light running crash incidents as related to the presence of red light cameras conducted by Andreassen (1995). Andreassen's analysis included an examination of the long-term effects of crashes at 41 signalized intersections where red light cameras were in use beginning in 1984. The accident reports covered a period of 1979 to 1989, and considered the relationship of RLR crash occurrence to the introduction of red light cameras for all camera sites collectively and compared the changes over time throughout Melbourne and the rest of the state, including sites without cameras. Other analyses included categorizing each occurrence by crash type, as well as further categorizing by crash location and whether the crash occurred on the side in which red light cameras were installed. Further analyses included reviewing the frequency of RLR-related crashes prior to the introduction of red light cameras to those RLR-related crashes that occurred after the cameras were installed. A fifth analysis included a review of the selected camera approach as compared to the initial frequency of RLR violations that had been determined, while a final analysis compared the overall resultant changes obtained at the red light camera sites to sites without cameras in place. Andreassen's study found that three-quarters of the sites chosen for red light camera installation had two or less reported adjacent approach crashes. As a result of his study, Andreassen determined that low frequency sites are not good choices for crash countermeasures effectiveness testing. The introduction of RLR cameras at the sites he investigated was found to have no determinable reduction in the number of crashes. But rather, Andreassen noted that those sites experienced increases in rear-end and adjacent approach collisions when he compared the before and after effect of camera installation. It was his opinion that use of red light running cameras at the 41 signalized intersections reviewed demonstrated no measurable value as an effective countermeasure to combat red light running.

In addition to Australia, photo enforcement likewise has been implemented over the past several years throughout parts of Canada, Europe, and Asia, as well as locally within the following states: Arizona, California, Colorado, Delaware, Illinois, Maryland, New York, North Carolina, Oregon, Hawaii, Georgia, Texas, Virginia, Washington State, and Washington, D.C. The city of Charlotte, North Carolina instituted the *Safe*Light Program in August 1998. According to the Charlotte Department of Transportation (DOT) (2001), a comparison using three years of pre-camera crash statistics with three years of post-camera data revealed that angle crashes, typical of RLR crashes as well as causing greater injury severity, were reduced by 37 percent at those intersections where cameras were installed. Overall, all crash types experienced a 19 percent reduction at RLR camera approaches, with crash injury severity experiencing a 16 percent reduction. However, when the crash data was reviewed for crash type, an overall increase of 4.3 percent for rear end crashes was observed among the camera approach lanes at the Charlotte sites over the three-year period, a trend that also was observed in Melbourne. The Charlotte DOT speculated that perhaps the incidence of rear end collisions has increased due to motorists' expectations that the driver ahead will run the red light, but unexpectedly stops for it. Finally, the Charlotte report states that the overall residual crash impact for all intersections and all crash types has only decreased by less than one percent. Of the original 20 locations at which red light enforcement cameras were installed, only 17 remain, and of those 17, only 12 experienced a reduction in crash occurrence on the camera approach lanes. Despite the lack of large reductions in the overall statistics, camera approach crashes were reduced at those sites where red light enforcement was in place, and injury severity was diminished at those locations as well, which is an indication of progress.

The Insurance Institute for Highway Safety (IIHS) released a *Status Report* earlier this year on the topic of red light running, and the inconsistencies in which the findings are measured, evaluated, and analyzed from one study to the next. Institute researchers compiled and critically analyzed the literature and research methodologies that have been representative of red light running knowledge and findings. As previously discussed, the effectiveness of red light camera enforcement varies widely across a multitude of reports. One Australian evaluation reported that enforcement cameras reduced injury crashes by seven percent, while another reported a reduction of 46 percent. A critical flaw uncovered by the Institute is that much of the research contains methodological problems; these problems have resulted in the variability observed within the findings. The IIHS states that an increase in rear end crashes is not a surprising phenomenon, citing that rear end crashes are a result of more people stopping for a red light that are subsequently hit from behind by a distracted driver, or a driver who was following too closely.

The Institute's review process included studies conducted in Australia, Singapore, and the United States. As a requirement for inclusion in the assessment, each study had to include pre- and post-camera crash data within its analysis. Moreover, data from non-camera sites had to be included for comparisons. As a result of the assessment, the Institute discovered that many of the studies conducted on red light running did not control for the statistical tendency regression to the mean. This error was introduced in situations where red light cameras were placed at the worst intersections with the highest crash frequencies, then compared to intersections where crash rates were not as high, and no interventions were introduced. According to Susan Ferguson, IIHS Senior Vice President for Research, sites that have an unusually high crash rate will normalize or decline over time, with or without intervention, secondary to regression towards the mean. Studies that do not control for regression to the mean, or are not compared to similar characteristic sites most likely overestimate the crash reduction achieved. Another common bias noted in the review was not controlling for the spillover effects achieved by the presence of enforcement cameras. It has been observed that photo enforcement impacts upon a driver's general driving behavior in such a way that violations and crash occurrences decrease at not only the camera site, but at the surrounding intersections as well. Unless the spillover effect of red light cameras is included in the final data analysis, crash reductions are most likely under-reported. Nonetheless, the Institute holds that overall crash reductions are achieved with the introduction of enforcement cameras.

The IIHS report cites that none of the Australian studies controlled for regression to the mean, nor the spillover effect. A re-calculation and analysis of the combined findings obtained in those reports indicate a 39 percent decrease in injury crashes at enforcement sites overall. Another group of studies were found to have controlled partially for regression to the mean by utilizing non-camera sites that were similar in design, crash rates, and RLR rates to the camera sites for comparison. However, these same studies failed to control for spillover, resulting in a statistically non-significant ten percent reduction in injury crashes. Among these studies were two conducted in Australia and another from Singapore.

A single study, conducted in Oxnard, California, controlled for both regression to the mean as well as spillover effect. This study reviewed the crashes that occurred at camera-enforced sites, and also the overall changes in crashes at signalized and non-signalized intersections throughout the area. Additional comparisons also were made to three other California cities where no red light enforcement cameras were in place. The Institute found that as a result of this study, a 29 percent overall reduction in injury crashes was achieved throughout all of Oxnard's 125 signalized intersections. This large reduction, as did all the studies reviewed by the Institute, coincided with an increase in rear end crashes at camera-equipped intersections. Ferguson cites that even with the small increases experienced in rear end collisions, the research indicates that RLR cameras decrease injury crashes by an estimated 25 to 30 percent.

Another important aspect brought about from the re-analysis of the Oxnard data revealed that the contributing circumstances assigned by the investigating officer at the crash scene also provides pertinent clues as to the success or failure of a photo enforcement campaign. Simply stated, not all crashes that are due to red light running are cited as such; some crashes are attributed to failure to yield, driver inattention, speeding, and so forth. During the re-evaluation process of the Oxnard, California data, IIHS researchers discovered that when they compared pre-camera crash data to post-camera crash data, injury crashes at signalized or sign posted intersections decreased by 46 percent, and for all crash types, the reduction was 20 percent. The original California study had determined that injury crashes were reduced by only 29 percent, and seven percent for all crash types. While the California study's original results are impressive alone, it excluded a large number of crashes that actually were associated with a red light running violation, thus underestimating the impact of the photo enforcement campaign.

In another study based upon the Oxnard evaluation, Retting, Williams, Farmer, and Feldman (1999) conducted public opinion surveys at various intervals throughout the study's duration. The initial survey was administered approximately six weeks prior to the installation of photo enforcement, another approximately six weeks after installation, and a third survey was conducted approximately six months following the start of the red light running campaign. Results revealed that nearly 80 percent of the respondents in the Oxnard study supported the use of photo enforcement cameras to assist in law enforcements' efforts to combat red light running.

One other factor discussed in the *Status Report* is the question of photo enforcement's constitutionality. The 2001 highly publicized lawsuit that was filed against San Diego, California, against the use of photo enforcement cameras was specifically decided on the administrative application of the law, not its constitutionality. The Superior Court judge who heard the case upheld that red light cameras are not a violation of privacy, but because of the manner in which the citations were issued and the camera vendor received compensation for each citation written, the city was found at fault. Although the ruling led to the dismissal of approximately 300 red light running violations in San Diego, the law itself was upheld, and San Diego was provided a legally-sound model on which to base their photo enforcement campaign. However, after suspending the program in June 2001, crashes due to red light running increased across the city by 14 percent, according to data obtained by the California State Auditor (2002), thus lending further proof that the San Diego photo enforcement program was achieving successful, injury-reducing results. Richard Retting, the IIHS senior transportation engineer, commented that the primary intention of using photo enforcement is to deter red light running, as opposed to writing citations. If the program is working optimally, there would be no violations, and thus no tickets issued.

An analysis of the changes in crash risk associated with traffic signal re-timing was conducted by Retting, Chapline, and Williams (2002). The authors found that there currently exists no universal methodology for determining or modifying a signal change interval at a signal controlled intersection. Some intersections are set for a brief all-red phase for all lanes of traffic, while others switch from yellow to red for north/south traffic and simultaneously from red to green for east/west traffic. Moreover, the authors determined that relatively little is known as to what influence altering the signal change interval has upon crash risk. Using values and proposed practices recommended by the Institute of Transportation Engineers, it was hypothesized that traffic signal re-timing, extending the yellow phase and/or adding an all-red phase would reduce crash risk and injury rates. Their study selected 122 intersections that were randomly assigned to experimental and control groups. The experimental group consisted of 51 eligible sites, of which 40 underwent signal sequence changes, followed by a three-year period of data collection. At the end of the study period, the experimental sites reported an eight percent reduction in the total number of crashes, and a 12 percent reduction in the number of injury crashes, as compared to the control sites where no signal changes were made. The researchers also found that crashes involving pedestrians and bicyclists decreased 37 percent at the re-timed sites compared to the control sites.

Approximately 40 percent of motor vehicle crashes occur at intersections, with signalized intersection crashes posting the largest increases. A number of these crashes are attributed to the driver disregarding a traffic signal. A national study of RLR crashes was conducted by Retting, Ulmer, and Williams (1999), and compared drivers of RLR crashes to drivers in non-RLR crashes. The analysis revealed that overall, RLR drivers were more likely to be male, under 30 years of age, and possess an invalid driver's license. These violators had higher rates of prior moving violations and previous convictions for driving while intoxicated than non RLR-involved drivers. In addition, the violator group had greater frequencies of alcohol consumption prior to running the red light that caused their crash. The authors also compared red light run crashes based upon daytime or nighttime hours. As before, a higher number of nighttime RLR violators were young, male, and highly intoxicated at the time of the crash.

Porter and Berry (2001) conducted a telephone survey using a national probability sample of 880 licensed drivers. Generally speaking, the majority of respondents acknowledged that red light running is a dangerous traffic safety problem. However, approximately 20 percent of the respondents self-reported having run one or more red lights within the past ten signalized intersections they had driven through. As found in the previous study, offenders were more often younger in age, were usually alone in the vehicle at the time of the violation, and admitted to being in a hurry and sped up to beat the red light. As has been found in similar surveys, other aggressive driving behaviors, such as speeding, weaving through traffic, and tailgating, were supplemental predictors of the respondent's willingness to run a red light. Less than six percent of those interviewed reported ever receiving a citation for RLR, and the majority of drivers believed that the likelihood of being caught and sanctioned was small. A number of respondents suggested and supported legal sanctions to deter red light running violations.

Previous research has indicated that RLR interventions have had an impact on crash rates. Still, the reported impact has varied greatly, and methodological issues have been raised with the previous studies. Thus, based upon the findings uncovered in the review of literature presented here, additional research into the problem of red light running is needed to accurately assess the degree of interventions necessary to deter red light running, as well as measuring a program's success (or failure) rate. The Purdue study was designed to model other surveys, while incorporating the findings and suggestions made by other researchers. Specifically, controlling for regression to the mean and spillover, along with comparably-designed, randomly selected sites were utilized. Moreover, numerous observations across multiple times of day and day of week were conducted to control for anomalous results.

Project Objectives

While the issues of red light running have been raised on a national front, only minimal data is available in Indiana. The objectives of this research project included an assessment of the seriousness of the issue in Indiana, and, if an issue, to quantify any particular measures to assist law enforcement agencies in their enforcement activities. Tippecanoe County and its signalized intersections were used as the primary research area.

To evaluate the seriousness of the issue in Indiana, a phone survey and a series of observational surveys were constructed. The phone survey provided a statewide assessment of the issue as measured by Indiana licensed drivers. The survey also was intended to measure the frequency and seriousness of red light running. The observational surveys were restricted to Tippecanoe County. Tippecanoe County has approximately 143 signalized intersections that can be categorized by several criteria (speed limit, number of travel lanes, type of signal arrangement, etc.) to identify over-represented design characteristics that might affect the incidence rate of red light running. A parallel study also was designed to take advantage of a Purdue University monitored intersection located in West Lafayette. Through the use of this intersection, 24-hour monitoring provided data relative to the time of day and the day of the week.

The third component of the project was to evaluate the effectiveness of a media campaign by itself against a media campaign combined with increased enforcement to reduce the incidence of red light running. Independent of the above research and data collection, an analysis of intersection crashes was performed to identify any over-represented characteristics. The results of this analysis have been compared with the observational data for common attributes. The final component of the project included the development of a model for enforcement agencies that could lead to more effective utilization of traffic patrols to reduce the incidence of red light running. This model is based upon the results gained from the research within Tippecanoe County and may offer the potential to be tested in other counties or areas in Indiana.

Research Procedures

In order to develop a statistically sound survey, a complete inventory of the signalized intersections in Tippecanoe County had to be developed. Using data provided by the Indiana Department of Transportation (InDOT), the Tippecanoe Highway Department, and the cities of West Lafayette and Lafayette, Indiana, a preliminary listing of the signalized intersections was developed. To validate the data, a university researcher visited each intersection, and, in turn, categorized the intersections using several attributes. These included the number of lanes, speed limit, presence (or lack thereof) of left turn lanes (dedicated or not), right turn on a red light allowed (or not allowed), left turn arrows (or no arrows), and the intersection configuration. Intersection configurations included the number of lanes, one way streets, "tee" intersections, and "5-way" intersections, as examples. Where available, traffic volume rates were obtained from InDOT to gain an appreciation for the effects of volume. A total of 149 signalized intersections were identified. Of the 149 sites, six sites were eliminated because of construction activity, flashing signals, or other activity that would minimize/eliminate the ability for a driver to run a red light. The complete listing of these intersections is shown in Appendix A.

Because neither design criteria for sample size determination nor existing data were available for the local sites, a decision was made to over-sample. Data was collected over an eleven consecutive day period. In taking this approach, a balance was provided between weekdays and weekends, with four days of the week being observed twice. The rationale for sampling these four days twice was that doing so might reveal either the randomness or perhaps, patterns of red light running related to days of the week. For each day, seven time slots were established that allowed for a cross-section of observation time over the period from 6:00

AM to 8:45 PM. The combination of eleven days and seven time slots per day provided a total of 77 observation periods. All 143 sites were eligible to be drawn. Sample slots were filled sequentially (day one, time slot one through day eleven, time slot seven). Because so little was known about the potential patterns of red light running, it was determined that the same site could be used up to two times, as it might provide insights into red light running behaviors according to different times and different days of the week. Once a site had been drawn twice, that site was no longer eligible for further sampling. Sixty-one different sites were drawn with 16 sites also selected for a second observation slot. The site schedule and results for all observational results are included in the appendix and labeled as Appendix B.

Observation protocols paralleled those used by CATS for the Annual Statewide Observational Seat Belt Survey design. A red light observation form was designed, in addition to a site summary sheet. A five minute pre-survey vehicle count and a five minute post survey vehicle count were used to determine traffic volume. Red light running violations were then tracked as they occurred. For each violation, the type of vehicle, driver gender, estimated driver age, driver race, and vehicle action were captured. Vehicle action included whether the offending vehicle turned left, went straight through the intersection, or made a right hand turn. Upon completion of the first wave of sampling, the results were sorted by the incidence of red light runners for each selected observation time slot. By design of the survey, the results could be categorized using a number of sorting criteria to yield data that could be used from throughout the entire survey. For example, gender, approximate age, and vehicle type could be totaled from all of the observational periods, and yielded the greatest amount of data. Data from a particular day also could be totaled to address patterns that may be occurring on certain days. Likewise, data collected during the same observation hours could be totaled to develop patterns by time of day. However, individual site data for the sites sampled a single time may or may not be representative of typical results at that site. Because of this last possibility, a second round of observational surveys was conducted using a subset of the first survey sites. Sixteen sites were randomly selected. In addition, from the first round of surveys, two patterns were observed that also warranted further evaluation in the second round. When looking at time of day, incidences of red light running appeared to be over-represented during the typical lunch hours (11:00 AM–1:00 PM). Secondly, the incidence of red light running appeared to increase as the workweek progressed. For example, a higher incidence of red light runs was observed on Fridays than on Wednesdays. Therefore, the second round survey design, while again randomly distributing the sites over all observation hours and days of the week, additional surveys were included during the 11:00 AM–1:00 PM time slot and on Friday.

From the results of the first and second surveys, specific sites were selected to monitor during the periods of increased media and enforcement. The sites, times, and days were based upon an identification of over-represented red light running incidences. With the completion of the second round of surveys, the objective was to reveal any evidenced patterns of higher incidences of red light running (by site, time of day, and day of week), and to evaluate the effectiveness of a media campaign followed by the increased presence of enforcement. The media phase utilized local television and newspapers to make the public aware of the issues of red light running, as well as to also inform the public that local law enforcement would be increasing traffic patrols specifically focused on red light runners. Patterns of red light running were shared with the media, but specific site information initially was not divulged. Following the media awareness campaign, a weeklong enforcement campaign was conducted by the Lafayette Police Department, with the site locations eventually revealed to measure subsequent change in the incidence of red light running. Upon completion of these phases of research, the intent was to develop a model to be provided to local enforcement agencies to allow for a more effective way to deploy traffic patrols. As envisioned, this model would be based upon a distribution of the red light running infractions.

As a potential validation and support tool, the results of the observational surveys were correlated with both citation and crash data. These data, combined with the observational data may provide even further insights into the pattern and/or behavior of red light runners.

Data Collection Process

To minimize any variances imposed by the individual collecting the data, only three observers were used. Each of the three individuals was trained in data collection procedures including appropriate safety precautions. Criteria were established to ensure that all observers understood what constituted a red light running infraction. Prior to the actual collection of data, a data collection form and site summary form were developed. Both forms were field tested prior to the actual start of data collection. Copies of each of these forms and the observation protocols are included in the appendix and labeled as Appendix C and Appendix D, respectively.

Observers were assigned specific sites at specific times and on specific days. Observers were instructed to arrive at the site with sufficient time allowed to establish an observation point and complete necessary pre-site documentation. Because vehicle miles traveled were available for only a few of the sites, a five-minute pre-survey count was conducted, followed by the 45-minute observation cycle, and finally, a five-minute post-survey vehicle count.

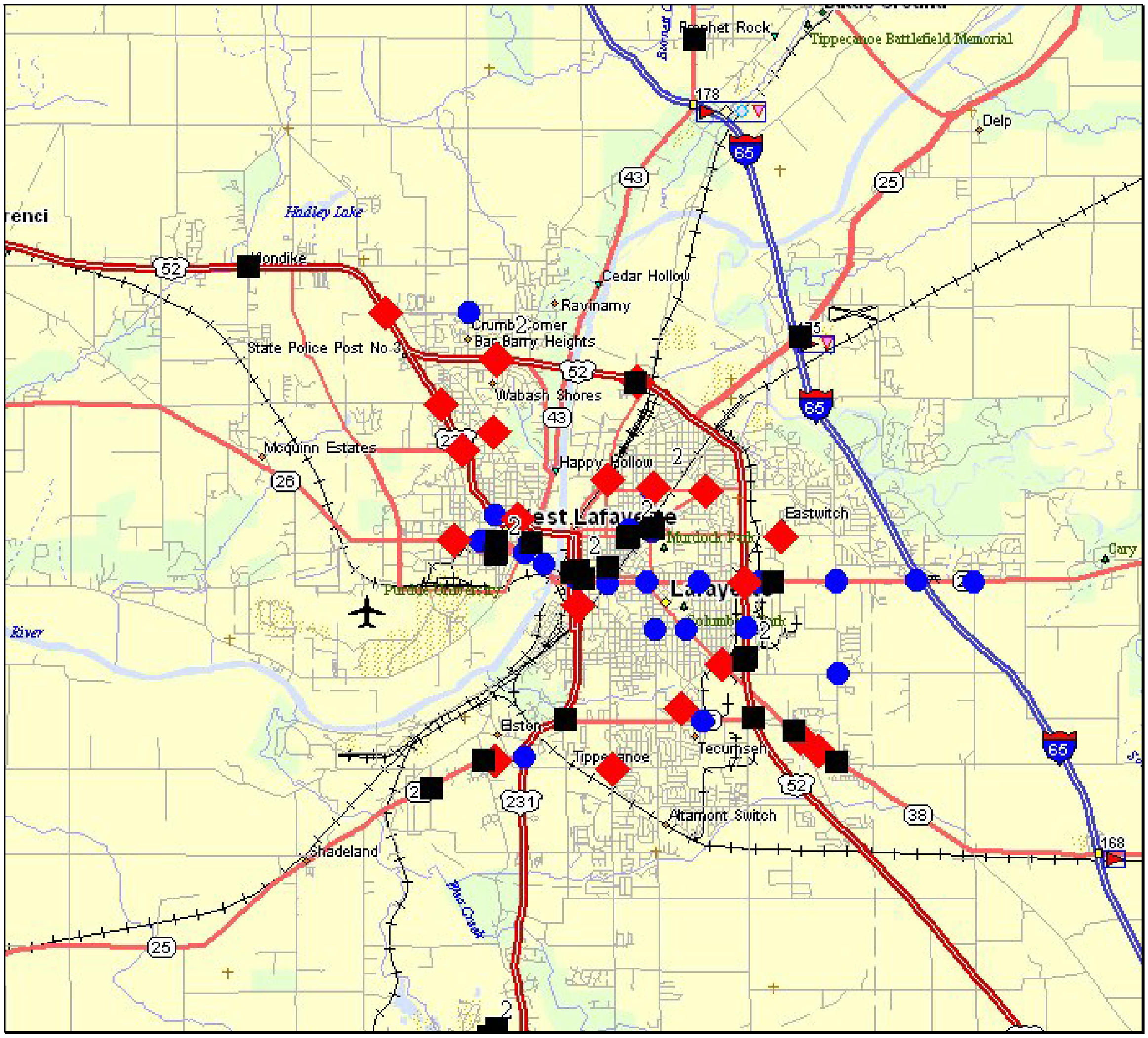
At each change of the light cycle, vehicles were observed as to their traffic pattern regarding running through a red light. For each red light running incident observed, the vehicle type, driver gender, approximate driver age (young, average, or older), the presence of passengers in the vehicle, and, if so, the gender of the passenger, and the type of violation (turning left, straight through intersection, or turning right) were collected. Upon completion of the post-survey vehicle count, the observer completed the site summary sheet, entering the appropriate data, and validating the accuracy of the data.

Data Summary

Data in Appendix A lists details about the initial observations on 75 sites. It includes the site location, functional class codes, intersection types, data collection dates and number of observed red light runs, as well as citations and crashes for the year 2000. The sites are sorted by observed RLR occurrences, by citations and by crashes.

The sites are also mapped below, according to the following color criteria, which is based upon the number of observed RLR violations: blue represents 3 or more, red represents 1 or 2, and black represents no violations during the observation period.

Figure 1: RLR Observations



A comparison between Figure 1 and Figure 2 reveals that the sites that had a higher number of observed RLR infractions (blue dots at the SR 26 corridor in Lafayette) do not coincide with the sites that received the greater number of citations (blue stars in West Lafayette). Although this trend could raise the question as to whether the incidence of higher enforcement is lowering the number of occurrences, the number of observations available was too small to be used conclusively.

Figure 2: RLR Citations

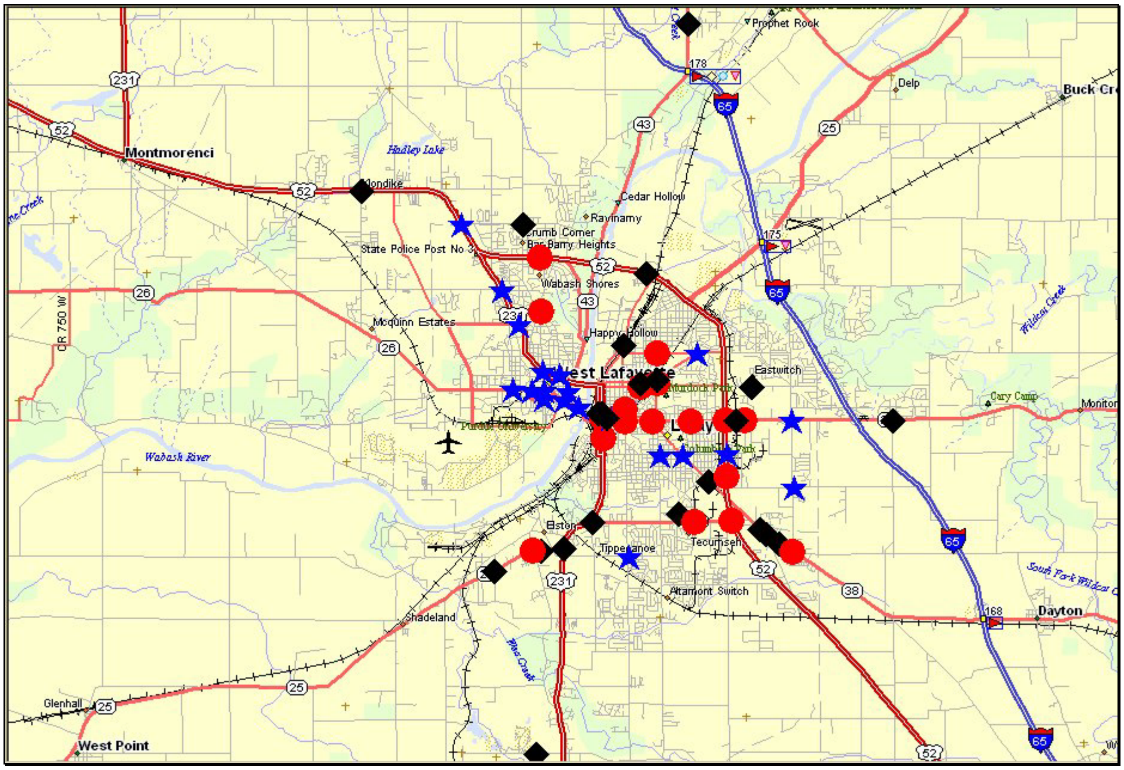
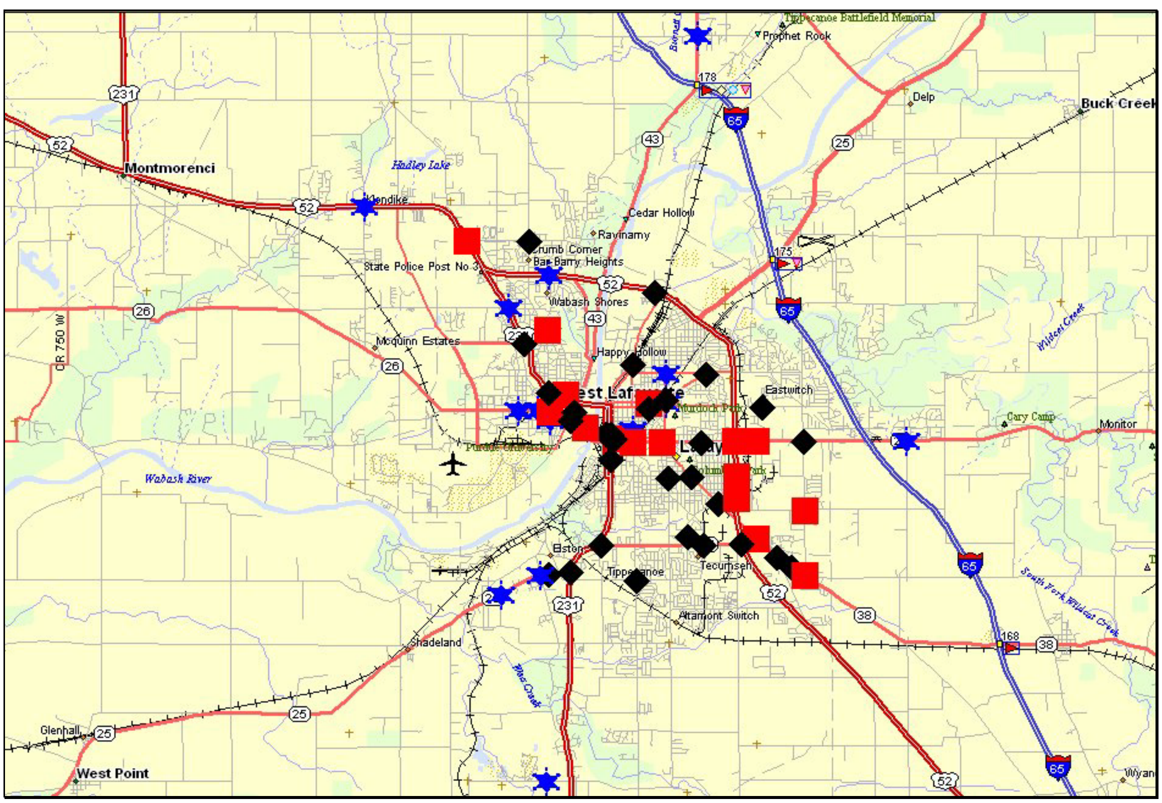


Figure 3: RLR Crash Occurrences



Observation Schedules and Results

Table 1 below shows the observation schedule for the final selection of sites, with the allocations of site visits by day of the week. Table A-2, in the Appendix, displays the same breakdown but by time of day instead.

Table 1 – RLR Occurrences by Site by Time of Day and Date

Site Number		Date of Survey	Mon	Tue	Wed	Thu	Fri	Sat	Sun	Total number of RLRs
8	DATE	26-Mar-01	5							5
	Total		5							5
15	DATE	29-Mar-01				4				4
	Total					4				4
17	DATE	31-Mar-01						1		1
		07-Sep-01					7			7
		10-Sep-01	5							5
		11-Sep-01		3						3
		12-Sep-01			6					6
		13-Sep-01				5				5
		14-Sep-01					5			5
		15-Sep-01						1		1
		30-Oct-01		1						1
		31-Oct-01			15					15
		02-Nov-01					13			13
		05-Nov-01	11							11
		07-Nov-01			15					15
		09-Nov-01					8			8
		12-Nov-01	8							8
		14-Nov-01			13					13
		16-Nov-01					17			17
	Total		24	4	49	5	50	2		134
21	DATE	27-Mar-01		1						1
	Total			1						1
30	DATE	27-Mar-01		7						7
	Total			7						7
31	DATE	22-Mar-01				6				6
	Total					6				6
34	DATE	21-Mar-01			3					3
	Total				3					3
35	DATE	26-Mar-01	3							3
		30-Mar-01					3			3
	Total		3				3			6
36	DATE	30-Mar-01					4			4
	Total						4			4
41	DATE	21-Mar-01			5					5
	Total				5					5
43	DATE	28-Mar-01			3					3
		30-Mar-01					12			12
	Total				3		12			15

Site Number		Date of Survey	Mon	Tue	Wed	Thu	Fri	Sat	Sun	Total number of RLRs
47	DATE	23-Mar-01					1			1
		12-Sep-01			3					3
		14-Sep-01					1			1
		15-Sep-01						3		3
	Total				3		2	3		8
53	DATE	08-Sep-01						1		1
		11-Sep-01		1						1
		19-Sep-01			1					1
		21-Sep-01					1			1
	Total			1	1		1	1		4
58	DATE	23-Mar-01					8			8
	Total						8			8
61	DATE	24-Mar-01						3		3
		09-Sep-01							2	2
		13-Sep-01				4				4
		18-Sep-01		3						3
	Total			3		4		3	2	12
65	DATE	21-Mar-01			2					2
		07-Sep-01					2			2
		09-Sep-01							3	3
		10-Sep-01	9							9
		13-Sep-01				7				7
		15-Sep-01						1		1
		18-Sep-01		6						6
		19-Sep-01			7					7
		21-Sep-01					8			8
		29-Oct-01	27							27
		31-Oct-01			34					34
		02-Nov-01					30			30
		05-Nov-01	37							37
		07-Nov-01			44					44
		09-Nov-01					70			70
		12-Nov-01	32							32
		14-Nov-01			34					34
		16-Nov-01					64			64
		19-Nov-01	15							15
		23-Nov-01					22			22
	Total		120	6	121	7	196	1	3	454
72	DATE	29-Mar-01				7				7
		07-Sep-01					2			2
		16-Sep-01							8	8
		18-Sep-01		4						4
		20-Sep-01				4				4
	Total			4		11	2		8	25

Site Number		Date of Survey	Mon	Tue	Wed	Thu	Fri	Sat	Sun	Total number of RLRs
75	DATE	21-Mar-01			6					6
		10-Sep-01	6							6
		12-Sep-01			3					3
		15-Sep-01						6		6
		21-Sep-01					1			1
	Total		6		9		1	6		22
76	DATE	23-Mar-01					4			4
	Total						4			4
77	DATE	07-Sep-01					20			20
		08-Sep-01						3		3
		09-Sep-01							3	3
		10-Sep-01	5							5
		11-Sep-01		4						4
		13-Sep-01				5				5
		14-Sep-01					1			1
		19-Sep-01			6					6
	Total		5	4	6	5	21	3	3	47
78	DATE	25-Mar-01							3	3
	Total								3	3
79	DATE	30-Mar-01					2			2
	Total						2			2
82	DATE	31-Mar-01						1		1
	Total							1		1
84	DATE	28-Mar-01			2					2
		07-Sep-01					1			1
		10-Sep-01	5							5
		11-Sep-01		3						3
		19-Sep-01			1					1
		21-Sep-01					2			2
	Total		5	3	3		3			14
86	DATE	28-Mar-01			1					1
	Total				1					1
87	DATE	21-Mar-01			5					5
		07-Sep-01					6			6
		08-Sep-01						4		4
		10-Sep-01	4							4
		19-Sep-01			5					5
	Total		4		10		6	4		24
88	DATE	30-Mar-01					2			2
	Total						2			2
89	DATE	22-Mar-01				2				2
		23-Mar-01					2			2
	Total					2	2			4
90	DATE	22-Mar-01				1				1
	Total					1				1

Site Number		Date of Survey	Mon	Tue	Wed	Thu	Fri	Sat	Sun	Total number of RLRs
97	DATE	25-Mar-01							3	3
	Total								3	3
100	DATE	22-Mar-01				6				6
		28-Mar-01			4					4
	Total				4	6				10
115	DATE	25-Mar-01							4	4
	Total								4	4
117	DATE	29-Mar-01				1				1
		07-Sep-01					1			1
		12-Sep-01			4					4
	Total				4	1	1			6
119	DATE	24-Mar-01						2		2
		31-Mar-01						5		5
	Total							7		7
120	DATE	27-Mar-01		2						2
	Total			2						2
122	DATE	29-Mar-01				1				1
	Total					1				1
123	DATE	21-Mar-01			1					1
	Total				1					1
127	DATE	22-Mar-01				2				2
		09-Sep-01							1	1
		10-Sep-01	2							2
		12-Sep-01			4					4
		14-Sep-01					5			5
		15-Sep-01						1		1
		18-Sep-01		1						1
	Total		2	1	4	2	5	1	1	16
129	DATE	23-Mar-01					7			7
	Total						7			7
135	DATE	21-Mar-01			2					2
		07-Sep-01					4			4
		13-Sep-01				3				3
		18-Sep-01		1						1
		20-Sep-01				2				2
		23-Sep-01							3	3
	Total			1	2	5	4		3	15
137	DATE	26-Mar-01	2							2
		10-Sep-01	2							2
		14-Sep-01					4			4
		21-Sep-01					3			3
	Total		4				7			11
139	DATE	26-Mar-01	5							5
	Total		5							5

Site Number		Date of Survey	Mon	Tue	Wed	Thu	Fri	Sat	Sun	Total number of RLRs
140	DATE	23-Mar-01					4			4
		29-Mar-01				1				1
		07-Sep-01					12			12
		08-Sep-01						2		2
		10-Sep-01	2							2
		18-Sep-01		1						1
		19-Sep-01			1					1
		20-Sep-01				3				3
		30-Sep-01							2	2
	Total		2	1	1	4	16	2	2	28
141	DATE	07-Sep-01					2			2
		08-Sep-01						1		1
		10-Sep-01	3							3
		12-Sep-01			2					2
		20-Sep-01				7				7
	Total		3		2	7	2	1		15

Analysis of Results

Passenger cars accounted for 55 percent of red light run observations. Pickup trucks accounted for 18.7 percent, and Minivans and Sport Utility Vehicles scored around 10 percent each. All other types of vehicles, including motorcycles, represented the final 5.4 percent.

Table 2 – Number of RLRs Observed by Vehicle Type

Vehicle Type	Counts	Percent
Passenger Cars	526	55.0%
Pickup Trucks	179	18.7%
Mini or Large Vans	100	10.4%
Sport Utility Vehicles	100	10.4%
Motorcycles	9	0.9%
Other Vehicle Types	43	4.5%
Total	**957**	**100.0%**

Male drivers were responsible for 64.2 percent of the RLR occurrences, females accounted for 34 percent, and the rest were of unknown gender. Caucasians made up 87.6 percent of the collected data, 3.2 percent were African American, and another 4.9 percent were classified as other. The remaining drivers either were not classified (one survey set did not collect race data) or were coded as unknown. Of the African American drivers observed, 74.2 percent were male, and 25.8 percent were female. For Caucasians, the ratio changed to 64.7 percent for males, and 35 percent females. The rest were counted as unknowns.

Table 3 – Number of RLRs by Driver Race

Race	Counts	Percent
Caucasian	838	87.6%
Other	47	4.9%
African American	31	3.2%
Unknown	21	2.2%
Data Not Collected	20	2.1%
Total	**957**	**100.0%**

Overall, it was found that 15.7 percent of the RLR drivers were considered young (<21), 76 percent of the drivers were considered average age (21-64 years of age), and 5.7 percent were older (65+). Among young drivers, 45.2 percent were female, while 54.8 percent were male. For the average age adult drivers, a much smaller female ratio of 33.2 percent was found. Similarly, only 31.5 percent of older drivers were female. It seems that young females are more aggressive drivers as a group when compared to older female drivers.

Table 4 – Number of RLRs by Driver Gender and Age Group

Driver Gender*	Young*	Average*	Older*
Female	45.2%	33.2%	31.5%
Male	54.8%	66.8%	68.5%

*Drivers of Unknown Age and/or Gender were omitted.

The majority of vehicles (53.4 percent) observed running a red light were going straight ahead, followed by vehicles executing a left turn (33.4 percent) or a right turn (13.2 percent). Van drivers seemed to have a slightly higher tendency to commit RLR left turns. Perhaps the bulkiness of the vehicle increases the degree of safety experienced by those drivers.

Figure 4 – Number of RLRs by Type of Vehicle Maneuver

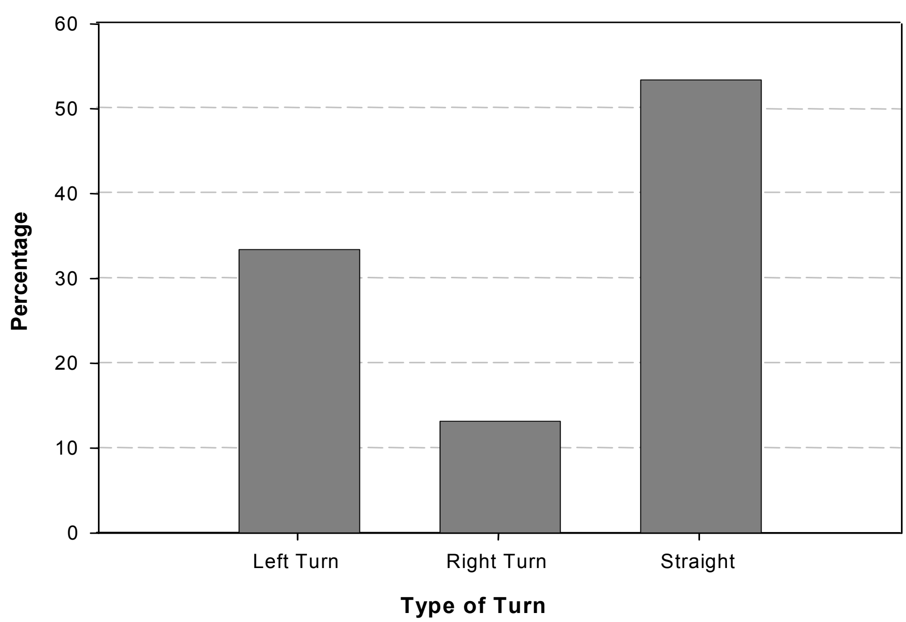


Table 5 – Number of RLRs by Type of Vehicle Maneuver

Vehicle Type	Vehicle Maneuver		
	Left	Right	Straight
Passenger Cars	34.7%	11.3%	54.0%
Pickup Trucks	33.1%	16.1%	50.8%
Mini & Large Vans	37.1%	12.9%	50.0%
Others	25.0%	15.9%	59.1%
Sport Utility Vehicles	29.2%	16.7%	54.2%
Total for All Vehicles	33.4%	13.2%	53.4%

During the October collection period, traffic volumes were monitored, and 5-minute traffic counts were determined at the beginning and end of the collection periods. Figure 5 below displays the correlation between observed RLR violations and averaged 5-minute traffic counts were observed. It appears that there is a linear and rapid increase in the number of red light run infractions at lower traffic volumes. As the volume of traffic increases, the RLR growth seems to slow down, perhaps due to gridlock-type congestion. Also notice that variability in the occurrence rate also increases at high vehicle counts. The trend is displayed in Figure 5.

Figure 5 – Number of RLR Violations by Traffic Volume

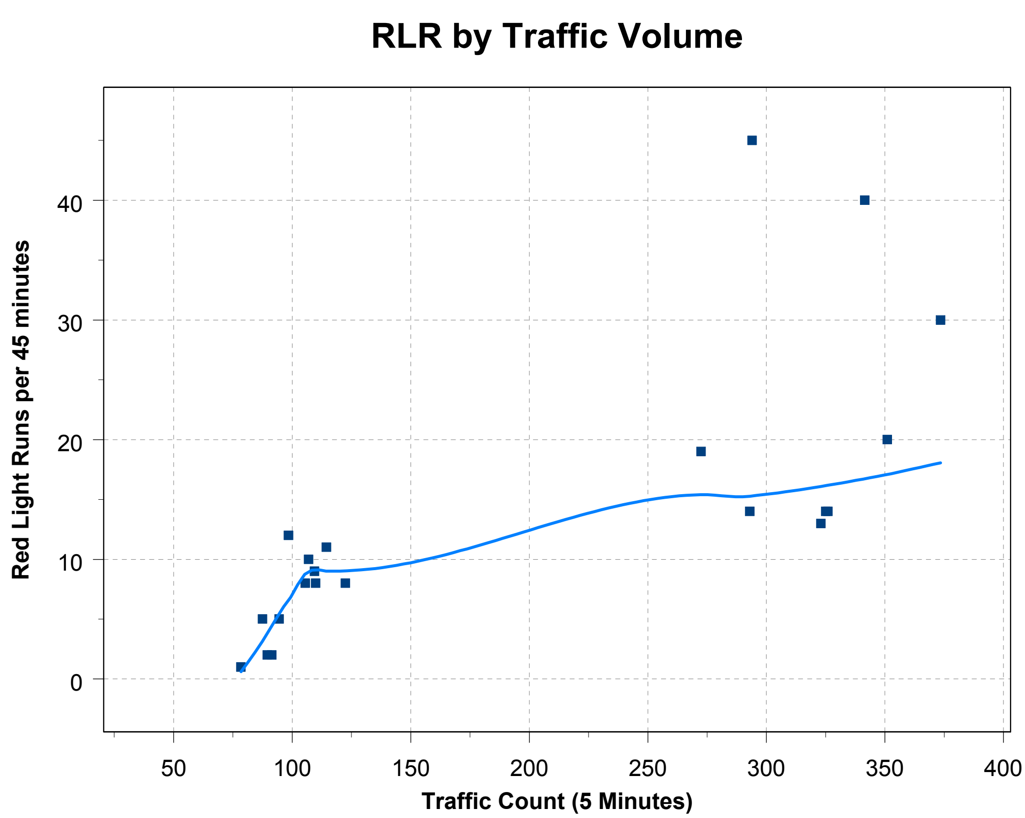
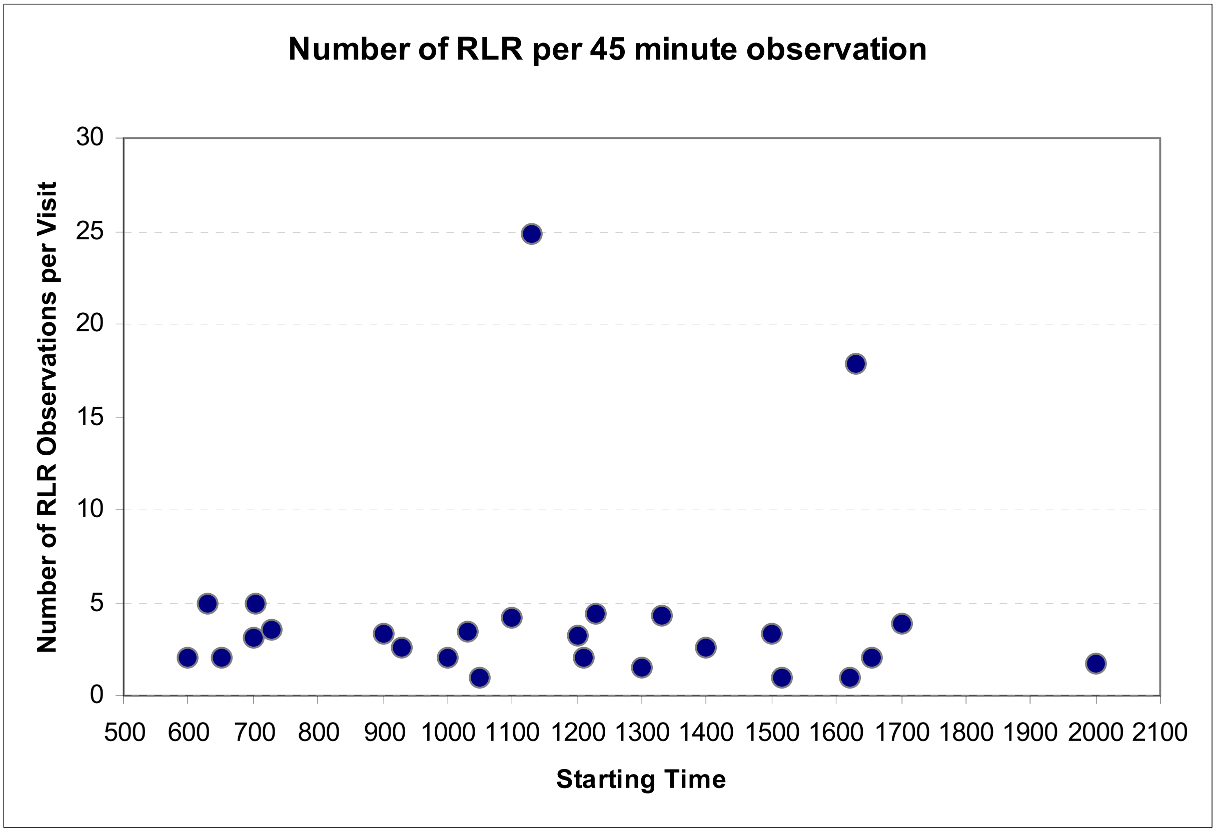


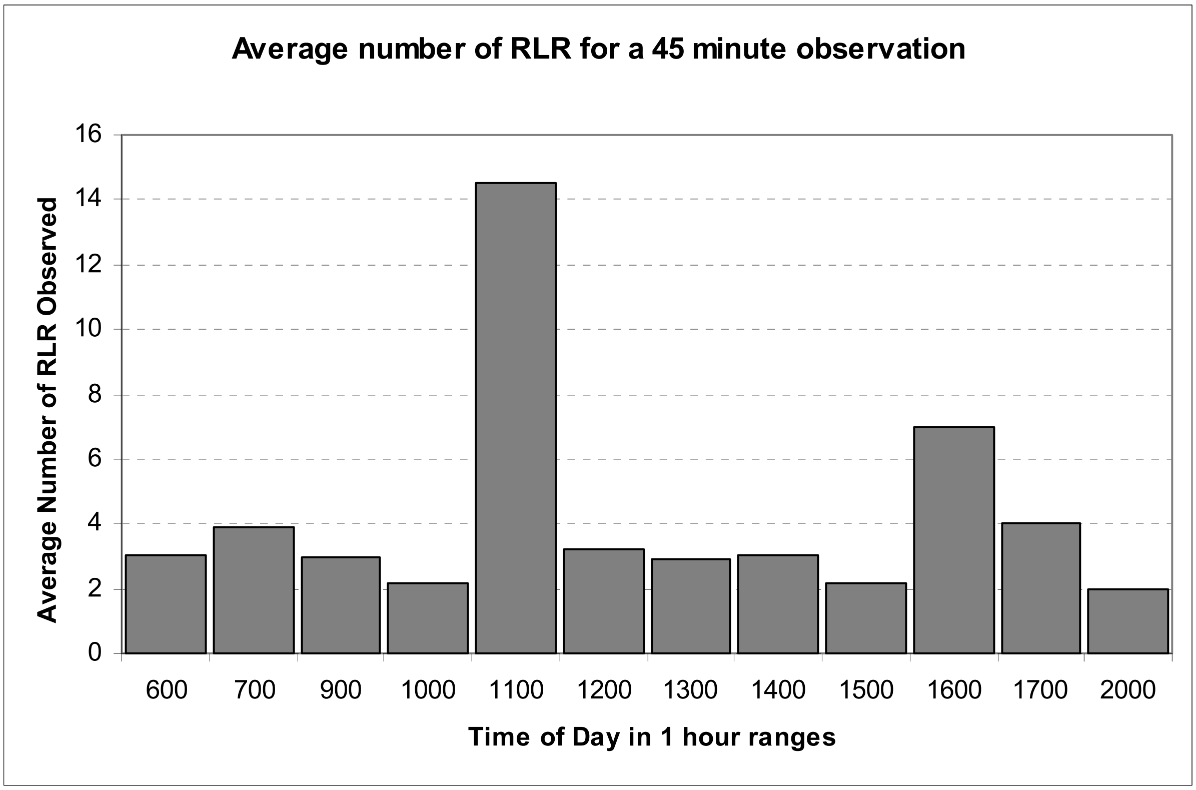
Figure 6 –Number of RLRs per 45-Minute Observation Period by Observation Starting Time



Figures 6 and 7 identify the time periods when the highest incidence of RLR was detected. Figure 6 displays the average number of observations in a 45-minute time period starting at the time charted. Figure 7 averages those observations according to the number of visits taking place in hourly intervals. The averages shown account for all observation visits that took place starting at that same time (Figure 6), or within that hourly interval (Figure 7). While there seems to be a constant rate between 2 and 3 observations every 45 minutes throughout the whole day, it becomes clear that during the typical lunch period, the incidence of RLR substantially increases. The same phenomenon is also observed close to the 5:00 p.m. rush hour, albeit on a smaller scale. Generally speaking, these data suggest that an individual positioned at one of the monitored intersections during a 45-minute period any time between 6:00 a.m. and 8:00 p.m. will see an average of three red light runs. If the observation period begins between 4:00 p.m. and 5:00 p.m., the average will increase to around 7 RLR. If the observation period starts between 11:00 a.m. and 12:00 p.m., that average will jump to around 14 occurrences. It can be implied that there seems to be a definite Red Light Running problem in the Lafayette area.

During the heightened enforcement period, the two intersections (based upon observational survey results) that had shown the highest incidence of red light running, were selected for the use of saturation patrols. During saturation patrols, officers in the area increase their patrols through the selected intersections. Hopefully, through this increased presence, potential offenders are deterred from running a red light. However, because of the movement of traffic through an intersection, traffic arriving at the intersection just moments after an officer has passed through that same intersection, have no knowledge that an officer is even in the area. Therefore, the officer's value is limited to only when that officer is highly visible. As a result, the presence of law enforcement as a deterrent to red light running throughout the entire observational period was effective only when the officer's marked car was highly visible to motorists at that intersection. However, once that vehicle was no longer visible to motorists, the incidence of red light running reappeared.

Figure 7 – Average Number of RLR per 45-Minute Observation Period



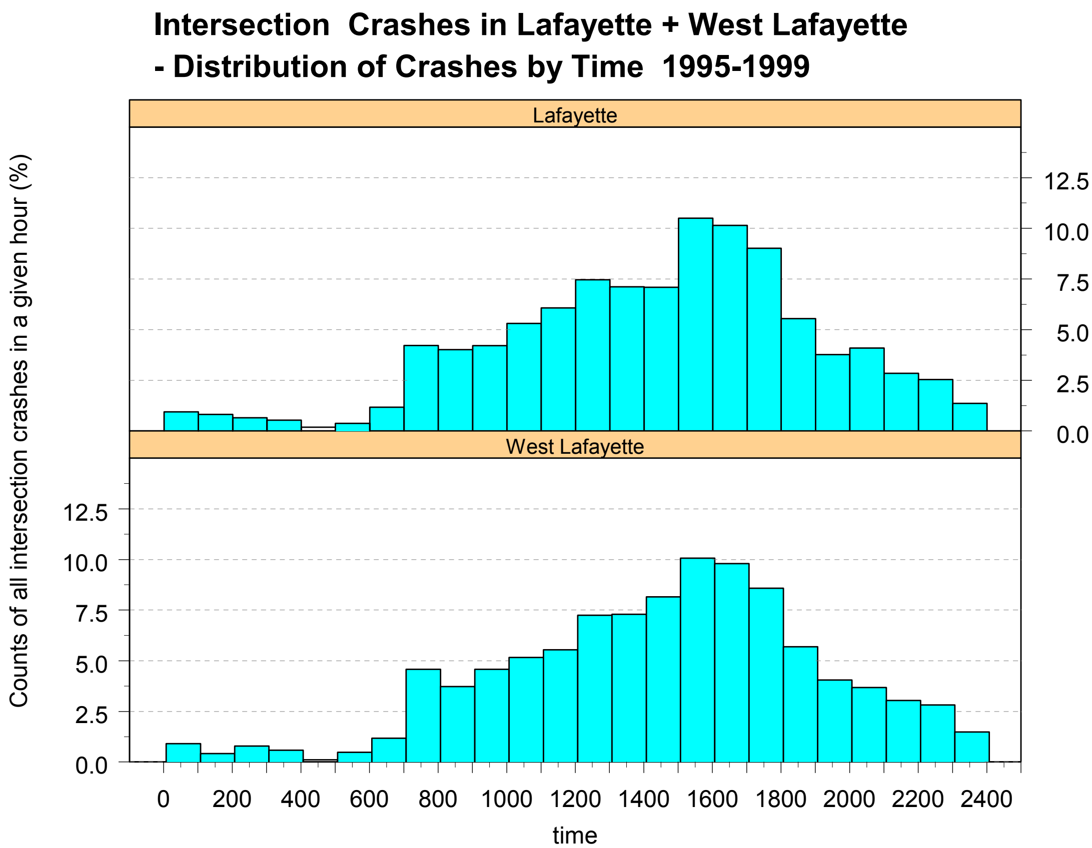
Red Light Running Crashes in Lafayette/West Lafayette

To further investigate the patterns of Red Light Running in Tippecanoe County, and complement the observed RLR data, all ISP crash data for the period of 1995 to 1999 (most current available data) was investigated. To extract the potential RLR crashes, the search criteria was defined as "Intersection crashes, with an operational traffic light present" and a main contributing circumstance of "ignored traffic sign." It is suspected that this definition undercounts the actual number of RLR crashes—thus, it is a conservative measure. The crashes queried also were restricted to the cities of Lafayette and West Lafayette.

The dataset of RLR crashes presented in this report is a subset of RLR occurrences; therefore, it should be stated that RLR crash patterns do not need to closely match RLR occurrence patterns. This is due to the fact that crashes probably involve other aspects, including stress and fatigue levels that have an impact upon driver performance, and a driver's attention level. These influences may not be present in RLR occurrences that did not result in a crash. It is expected, nevertheless, that there should be a correlation between the two groups. The findings of this crash analysis are grouped in five different areas:

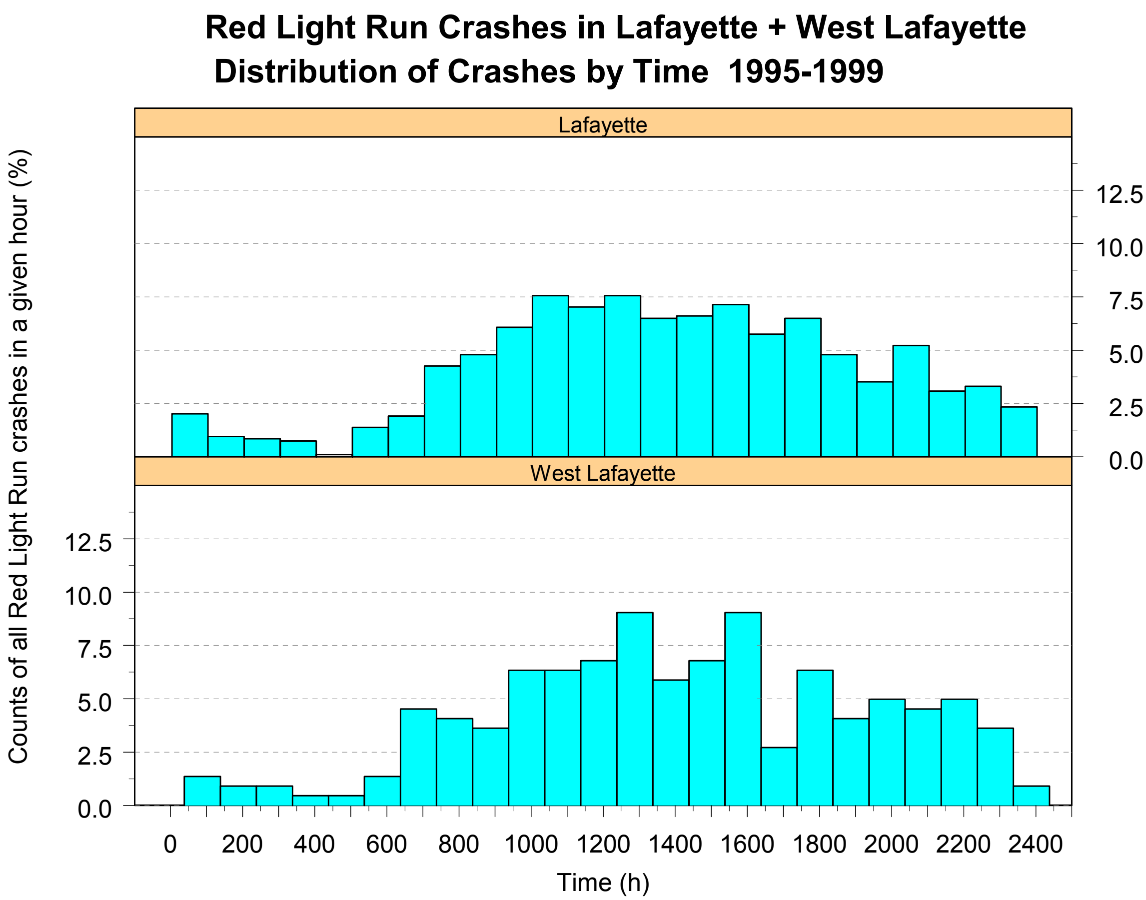
All Intersection Crashes vs. RLR Crashes By Time of Day

Figure 8 – Distribution of Intersection Crashes by Time of Day in Lafayette and West Lafayette for 1995-1999



In this study, the hourly distribution of all intersection crashes versus the distribution exclusively for RLR crashes was compared. The results are displayed in Figures 8 and 9. As shown in Figure 8, intersection crashes have their peak during the 5:00 p.m. rush hour. It is theorized that the accumulative effect of the stress of the day, added to the high volume of traffic is a primary contributing factor. Conversely, when only red light running crashes are examined, we find a substantially different pattern (Figure 9). It was noted that the highest incidence of RLR crashes occur around lunchtime, as can be seen in the figure below. It could be argued that the rush to return to work or to complete errands over the lunch rush hour is the mitigating factor. The major difference in driver behavior could come from a lack of attention or slow reaction time due to fatigue in the first case, versus a real aggressive driving pattern in the second.

Figure 9 – Distribution of RLR Crashes by Time of Day in Lafayette & West Lafayette for 1995-1999



All Intersection Crashes vs. RLR Crashes by Day of Week

During this phase, the first study was repeated except that the day of the week was examined instead of hourly ones. Different patterns in the distribution of all intersection crashes and RLR-only crashes across different weekdays also were investigated. During this portion of the study, no visible differences were observed. The distributions for both all intersection crashes (Figure 10) and for RLR-only crashes (Figure 11) were found to be very constant across all days of the week. The only observed pattern of note was that the number of intersection crashes seemed to be lower during Sundays and Mondays. Drivers are probably fresher and more relaxed at the beginning of the week, which would validate that stress and mental fatigue is a factor in intersection crashes. Still, RLR crashes don't show any particular difference between Monday or any other day. It also was observed that Saturdays seem to consistently have the highest rates of crashes for both groups. Further understanding of traffic patterns is needed to help explain this finding.

Figure 10 – Distribution of Intersection Crashes by Day of Week in Lafayette and West Lafayette for 1995-1999

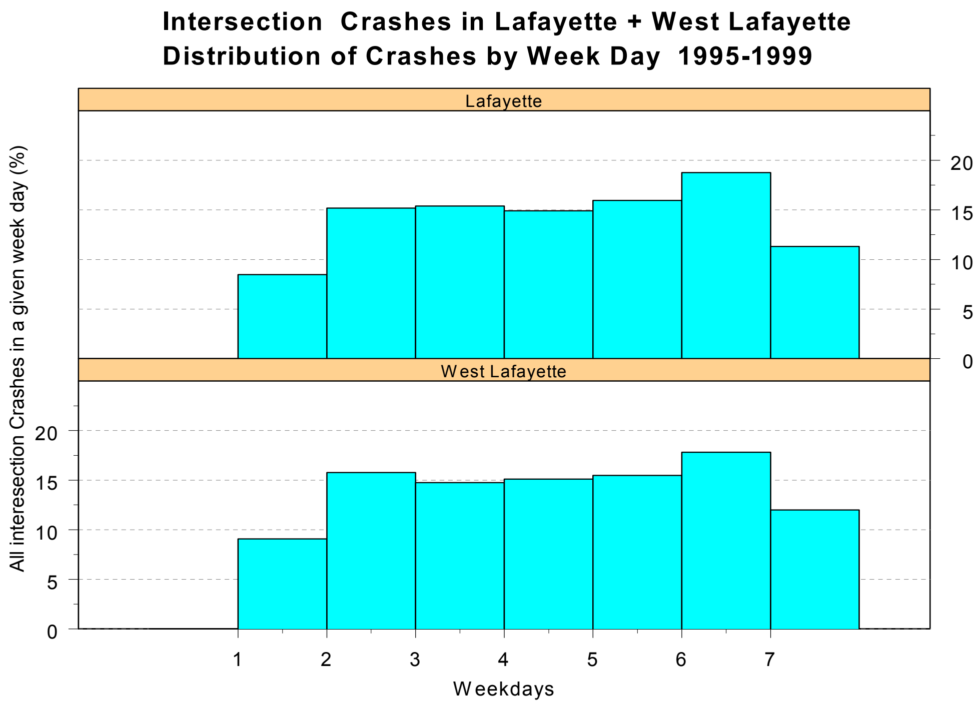
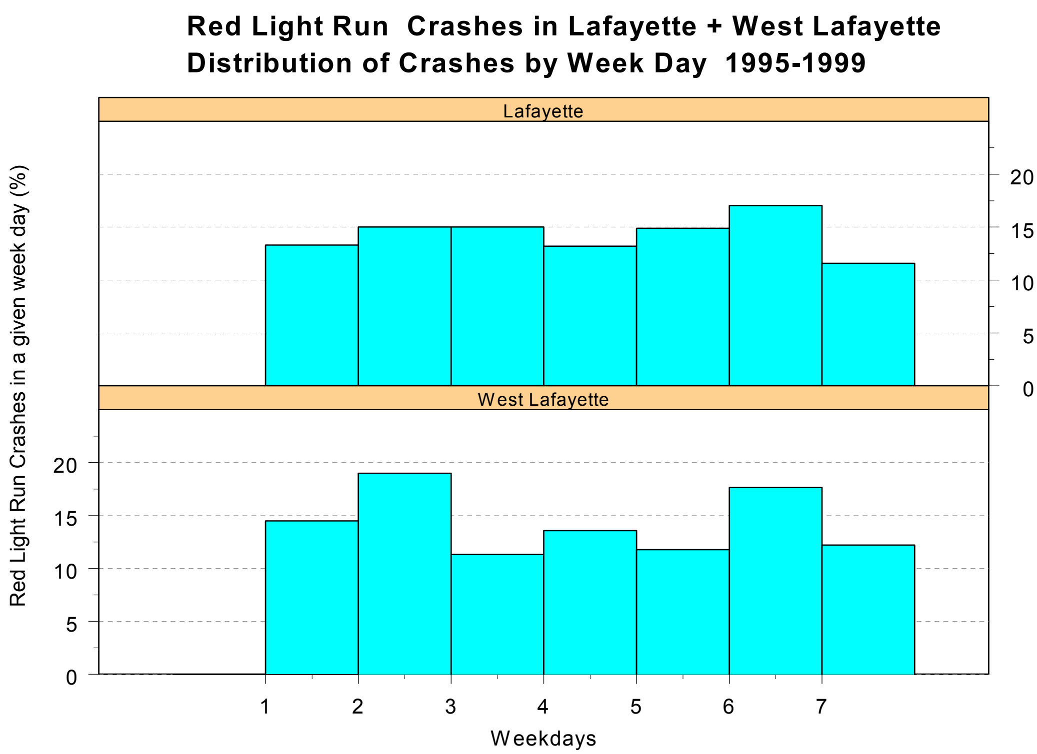


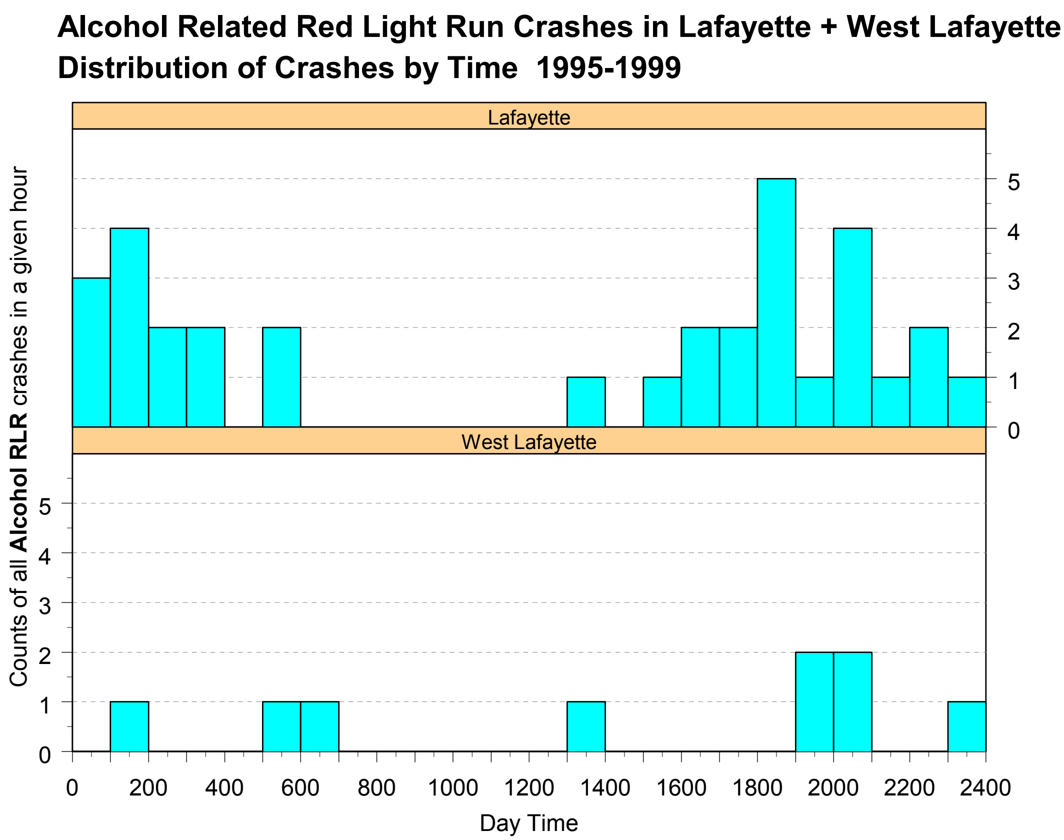
Figure 11 – Distribution of RLR Crashes by Day of Week in Lafayette & West Lafayette for 1995-1999



Alcohol-Related Red Light Running Crashes

Despite an attempt to examine if alcohol was a contributing factor in the incidence of red light running in the two cities, the numbers were too small to prove (or disprove) any significant influence (Figure 12). It was discernible, nonetheless, that late evening and early morning are the primary hours for alcohol-related RLR to occur, a finding that concurs with other studies on alcohol-related crashes.

Figure 12 – Alcohol-Related RLR Crashes by Time in Lafayette & West Lafayette for 1995-1999



Percentage of Signaled Intersection Crashes Due to Red Light Running

The final index that was investigated was the percentage of crashes in signaled intersections that were due to red light runs. A high percentage of RLR crashes would support the assumption that RLR is presently a problem in Tippecanoe County, and the findings proved to be revealing. Although similar numbers were found for past years, this report presents only the crash data for 1999. The intention is to display the most current crash percentages while taking into account any increases in traffic volume and signaled intersections between the two cities that could potentially affect direct comparisons with older data.

Table 6 displays the breakdown of all signaled intersection crashes in 1999, by time of day and weekday for Lafayette and West Lafayette. For the sake of tabulation, the times were lumped into eight groups. Table 7 shows the same breakdown for RLR-only crashes, but displayed as a percentage of all the intersection crashes.

Table 6 – Signalized Intersection Crashes in Lafayette and West Lafayette in 1999

Signalized Intersection Crashes in Lafayette

TIME OF CRASH	SUNDAY	MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SATURDAY	TOTAL
12:00am-6:29am	5	2	0	1	5	5	5	23
6:30am-9:00am	4	8	5	8	13	8	3	49
9:00am-10:59am	5	9	13	7	15	14	5	68
11:00am-12:59pm	11	11	10	11	24	8	8	83
1:00pm-2:59pm	9	13	15	12	14	20	8	91
3:00pm-4:59pm	10	19	16	15	14	24	13	111
5:00pm-6:29pm	3	5	11	8	12	13	9	61
6:30pm-11:59pm	15	20	23	23	21	24	8	134
Unknown	0	0	0	0	0	0	1	1
TOTAL	**62**	**87**	**93**	**85**	**118**	**116**	**60**	**621**

Signalized Intersection Crashes in West Lafayette

TIME OF CRASH	SUNDAY	MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SATURDAY	TOTAL
12:00am-6:29am	5	0	1	1	3	4	4	18
6:30am-9:00am	0	4	4	4	3	1	1	17
9:00am-10:59am	1	9	2	1	3	3	2	21
11:00am-12:59pm	6	5	4	7	6	8	1	37
1:00pm-2:59pm	6	6	1	5	6	8	4	36
3:00pm-4:59pm	3	6	5	8	5	6	12	45
5:00pm-6:29pm	6	3	9	5	3	5	1	32
6:30pm-11:59pm	7	5	14	6	8	13	11	64
Unknown	1	0	2	1	1	2	1	8
TOTAL	**35**	**38**	**42**	**38**	**38**	**50**	**37**	**278**

Table 7 reveals that in Lafayette, 27.4 percent of the signaled intersection crashes are attributed to red light running. West Lafayette has a much lower overall rate of 13.3 percent, but it reaches 27 percent during lunch hour.

The crashes were collapsed in certain hour groups, differently from the hourly histogram displayed before. Nevertheless, patterns across the times of day seem to validate that the critical times when RLR occurs is mid day, slowing down later in the afternoon. These numbers are high enough to support the statement that Red Light Running is a problem in Tippecanoe County.

Table 7 – Percentage of Signalized Intersection Crashes Due to RLR in Lafayette and West Lafayette in 1999

Signalized Intersection Crashes in Lafayette

TIME OF CRASH	SUNDAY	MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SATURDAY	TOTAL
12:00am-6:29am	60.0%	100.0%	0.0%	100.0%	40.0%	60.0%	40.0%	56.5%
6:30am-9:00am	100.0%	37.5%	20.0%	37.5%	38.5%	37.5%	66.7%	42.9%
9:00am-10:59am	20.0%	33.3%	23.1%	28.6%	40.0%	42.9%	40.0%	33.8%
11:00am-12:59pm	27.3%	45.5%	40.0%	36.4%	25.0%	12.5%	12.5%	28.9%
1:00pm-2:59pm	22.2%	46.2%	26.7%	8.3%	7.1%	25.0%	25.0%	23.1%
3:00pm-4:59pm	0.0%	15.8%	12.5%	26.7%	14.3%	16.7%	15.4%	15.3%
5:00pm-6:29pm	33.3%	0.0%	18.2%	37.5%	33.3%	7.7%	11.1%	19.7%
6:30pm-11:59pm	33.3%	35.0%	47.8%	21.7%	14.3%	25.0%	25.0%	29.1%
TOTAL	30.6%	33.3%	29.0%	27.1%	24.6%	25.0%	23.3%	27.4%

Signalized Intersection Crashes in West Lafayette

TIME OF CRASH	SUNDAY	MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SATURDAY	TOTAL
12:00am-6:29am	20.0%	0.0%	0.0%	100.0%	33.3%	25.0%	0.0%	22.2%
6:30am-9:00am	0.0%	25.0%	0.0%	50.0%	0.0%	0.0%	100.0%	23.5%
9:00am-10:59am	100.0%	11.1%	0.0%	0.0%	0.0%	0.0%	0.0%	9.5%
11:00am-12:59pm	50.0%	40.0%	25.0%	28.6%	0.0%	25.0%	0.0%	27.0%
1:00pm-2:59pm	50.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	8.3%
3:00pm-4:59pm	0.0%	0.0%	0.0%	0.0%	20.0%	16.7%	8.3%	6.7%
5:00pm-6:29pm	0.0%	0.0%	0.0%	0.0%	0.0%	20.0%	0.0%	3.1%
6:30pm-11:59pm	14.3%	40.0%	14.3%	16.7%	12.5%	23.1%	0.0%	15.6%
TOTAL	25.7%	15.8%	7.1%	15.8%	7.9%	16.0%	5.4%	13.3%

Conclusion

This study approached the assessment and determination of red light running as a problem from two different perspectives: on site human-conducted observations of RLR violations, and a detailed analysis of attributed and suspected red light run caused traffic crashes. The on site visual inspection survey pointed to an average of three red light runs every 45 minutes, occurring across all times of day, with peaks up to 14 infractions during the typical lunch period.

The introduction of a red light media campaign, even through the combined use of three media elements – radio, television, and newspaper, had no effect on reducing red light running. It is believed that unless the motorist was stopped at an intersection and at that time, heard the media activity regarding red light running, media messages are otherwise ineffective, especially when provided only for a short time period. The combination of a media campaign coupled with increased presence of law enforcement had no noticeable results. During the heightened enforcement period, the two intersections (based upon observational survey results) that had shown the highest incidence of red light running, were selected for the use of saturation patrols. Hopefully, through this increased presence, potential offenders are deterred from running a red light. However, because of the movement of traffic through an intersection, traffic arriving at the intersection just moments after an officer has passed through that same intersection, have no knowledge that an officer is even in the area. Therefore, the officer's value was limited to only when that officer is highly visible. As a result, the presence of law enforcement as a deterrent to red light running throughout the entire observational period was effective only when the officer's marked car was highly visible to motorists at that intersection. However, once that vehicle was no longer visible to motorists, the incidence of red light running reappeared. For Tippecanoe County, the study did identify a pattern of higher frequencies of red light running to allow the West Lafayette and Lafayette Police Departments to increase their traffic patrols during those peak periods.

The results of the study would support that the use of saturation patrols is not a cost effective approach to reducing red light running.

The analysis of the crash database indicates that between 13 percent and 27 percent of crashes at signaled intersections occur due to red light runs. These numbers support the presence of a Red Light Running problem in Tippecanoe County. Additionally, based upon this research, and findings from the Melbourne study, traffic signal re-timing could be a viable, cost-effective treatment for reducing crash occurrence and injury severity, while at the same time remain in conformance with the values and recommended practices of the Institute for Transportation Engineers.

Recommendations

While the study focused only on one county (Tippecanoe), the results from the study could logically be applied to other Indiana counties having a large urban representation (therefore, a higher number of traffic signals). A logical next step is to validate both the methodology and results through a similar study in two – three different counties. One of the four largest counties (Marion, Allen, St. Joseph, and Lake) and a second county with a population density close to that of Tippecanoe County would be recommended. Through counties conducting similar studies, "hot spots and times" could be shared with the driving public to raise their awareness and caution when approaching a signalized intersection.

The introduction of media to raise driver awareness level of red light running had only a marginal, if any, impact on observed driving behavior. However, the media campaign lasted only one week and, therefore, may not have been as effective as possible. In order to more effectively utilize a media campaign, the campaign should be extended to a longer time period and also include signage, particularly in the areas of the high RLR intersections.

The study did not evaluate citation data and drivers' histories. Research into these areas would provide a factual base to assess and quantify the impact of sanctions applied to red light runners and presence of repeat offenders for the same or similar violations.

Finally, data and analysis from this study could provide a foundation to raise the awareness level of Indiana legislators as to the seriousness and frequency of red light running and the value of enforcement alternatives, such as the installation of red light running cameras. While red light running cameras may have their own issues, the study results would not support that the use of saturation patrols as a cost effective approach to reducing red light running.

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Intersection #	Name of Street 1	St 1 #	Name of Street 2	St 2 #	# N/S Lanes	# N/S Lanes ABC	Speed Limit N/S	Speed Limit N/S AB	# E/W Lanes	# E/W Lanes ABC	Speed Limit E/W	Speed Limit E/W AB	Name of Street 3- for Odds	Vehicle Count	Location	NOTE
1	14th	1	Union	2	3	A	<40	A	2	A	<40	A		16,529	L	
3	9th	3	Greenbush	4	5	C	<40	A	4	B	<40	A		21,643	L	
4	3rd	5	Main	6	2	A	<40	A	3	A	<40	A		2,816	L	
5	18th	7	Elmwood	8	4	B	<40	A	2	A	<40	A		2,816	L	
6	21	9	Elmwood	10	3	A	<40	A	4	B	<40	A		12,475	L	
7	Creasy Lane	11	SR 38	12	6	C	<40	A	8	C	<40	A		26,480	L	Under Const.
8	Creasy Lane	13	McCarty	14	6	C	>40	B	6	C	<40	A		53,999	L	
9	Creasy Lane	15	Sam's/Cat.	16	7	C	>40	B	3	A	<40	A		26,480	L	
10	US 52	17	Wabash National	18	5	C	>40	B	4	B	<40	A		16,416	L	
11	6th	19	Ferry	20	2	A	<40	A	4	B	<40	A		2,158	L	
12	2nd	21	South (SR 26)	22	4	B	<40	A	2	A	<40	A		14,371	L	
13	2nd	23	Columbia (SR 26)	24	4	B	<40	A	2	A	<40	A		15,650	L	
14	9th	25	Salem	26	3	A	<40	A	3	A	<40	A		11,427	L	
15	18th	27	Salem	28	4	B	<40	A	2	A	<40	A		8,594	L	
16	26th	29	Union	30	3	A	<40	A	5	C	<40	A		4,371	L	Under Const.
17	Greenbush	31	Elmwood	32	odd	O	odd	O	odd	O	odd	O	27th	3,771	L	
18	Creasy Lane	33	Union	34	6	C	<40	A	6	C	<40	A		25,793	L	
19	US 52	35	Greenbush	36	8	C	>40	B	4	B	<40	A		28,578	L	
20	US 52	37	Union	38	8	C	>40	B	5	C	<40	A		39,946	L	Under Const.
21	US 52	39	Duncan	40	5	C	>40	B	8	C	<40	A		8,919	L	
22	US 52	41	SR 25/Schuyler	42	5	C	<40	A	9	C	>40	B		9,258	L	
23	Earl	43	Union	44	2	A	<40	A	4	B	<40	A		34,085	L	
24	9th	45	Union	46	3	A	<40	A	3	A	<40	A		27,110	L	
25	18th	47	Union	48	4	B	<40	A	3	A	<40	A		22,693	L	
26	9th	49	Ferry	50	4	B	<40	A	4	B	<40	A		7,908	L	
27	9th	51	Main	52	6	C	<40	A	4	B	<40	A		5,107	L	
28	9th	53	Kossuth	54	odd	O	odd	O	odd	O	odd	A	Highland	21,414	L	
29	9th	55	Teal	56	4	B	<40	A	4	B	<40	A		28,575	L	
30	9th	57	South	58	4	B	<40	A	3	A	<40	A		12,538	L	
31	18th	59	Kossuth	60	4	B	<40	A	4	B	<40	A		40,848	L	
32	18th	61	South	62	odd	O	odd	O	odd	O	odd	A	Lincoln	30,428	L	
33	18th	63	Main	64	odd	O	odd	O	odd	O	odd	A	Douglas	41,807	L	
34	26th	65	South	66	5	C	<40	A	4	B	<40	A		10,007	L	
35	Main	67	Kossuth	68	4	B	<40	A	4	B	<40	A		40,697	L	
36	26th	69	Sequoya/Teal	70	5	C	<40	A	6	C	<40	A		20,163	L	
37	Earl	71	Main	72	5	C	<40	A	4	B	<40	A		44,678	L	
38	Earl	73	Kossuth	74	4	B	<40	A	4	B	<40	A		11,369	L	
39	Earl	75	Ferry	76	4	B	<40	A	4	B	<40	A		7,539	L	
40	Earl	77	South/SR 26	78	5	C	<40	A	6	C	<40	A		9,766	L	
41	US 52	79	Kossuth	80	7	C	>40	B	4	B	<40	A		8,979	L	
42	US 52	81	McCarty	82	8	C	>40	B	4	B	<40	A		17,251	L	
43	Creasy Lane	83	SR 26	84	7	C	<40	A	8	C	>40	B		26,480	L	
44	30th	85	Teal	86	2	A	<40	A	5	C	<40	A		5,824	L	
45	4th	87	Owen	88	2	A	<40	A	2	A	<40	A		5,622	L	
46	Farabee	89	SR 26	90	4	B	<40	A	8	C	>40	B		8,668	L	
47	9th	91	Canal	92	3	A	<40	A	2	A	<40	A			L	
48	3rd	93	Ferry	94	2	A	<40	A	4	B	<40	A			L	
49	4th	95	Main	96	3	A	<40	A	3	A	<40	A			L	
50	6th	97	Main	98	2	A	<40	A	4	B	<40	A			L	
51	6th	99	South (SR 26)	100	3	A	<40	A	3	A	<40	A			L	
52	3rd	101	South (SR 26)	102	3	A	<40	A	3	A	<40	A			L	
53	6th	103	Columbia (SR 26)	104	4	B	<40	A	3	A	<40	A			L	

Intersection #	Name of Street 1	St 1 #	Name of Street 2	St 2 #	# N/S Lanes	# N/S Lanes ABC	Speed Limit N/S	Speed Limit N/S AB	# E/W Lanes	# E/W Lanes ABC	Speed Limit E/W	Speed Limit E/W AB	Name of Street 3- for Odds	Vehicle Count	Location	NOTE
54	3rd	105	Columbia (SR 26)	106	2	A	<40	A	3	A	<40	A			L	
55	5th	107	Columbia (SR 26)	108	2	A	<40	A	1	A	<40	A			L	
56	5th	109	South (SR 26)	110	2	A	<40	A	2	A	<40	A			L	
57	Salem	111	Fallon	112	2	A	<40	A	2	A	<40	A			L	
58	14th	113	Salem	114	2	A	<40	A	2	A	<40	A			L	
59	9th	115	Columbia (SR 26)	116	4	B	<40	A	3	A	<40	A			L	
60	18th	117	Hyatt	118	4	B	<40	A	3	A	<40	A			L	
61	Main	119	South (SR 26)	120	odd	O	odd	O	odd	O	odd	O	16th		L	
63	US 52	121	SR 38	122	8	C	>40	B	6	C	>40	B			L	
64	US 52	123	Teal	124	8	C	>40	B	7	C	<40	A			L	
65	US 52	125	SR 26	126	6	C	>40	B	6	C	<40	A			L	
67	4th	127	Teal	128	odd	O	odd	O	odd	O	odd	A	Poland Hill		L	
68	US 231	129	Elston	130	4	B	>40	B	3	A	<40	A			L	
69A	Old US 231	131	SR 25	132	6	C	>40	B	4	B	>40	B			L	
69B	New US 231	133	SR 25	134	2	A	>40	B	5	C	>40	B				
70	US 231	135	Beck Lane	136	4	B	>40	B	4	B	<40	A			L	
71	Red Cloud	137	SR 26	138	4	B	<40	A	8	C	>40	B			L	
72	US 26	139	I-65 SB	140	2	A	<40	A	6	C	>40	B			L	
73	36th	141	SR 26	142	4	B	<40	A	8	C	>40	B			L	
74	4th	143	Ferry	144	3	A	<40	A	4	B	<40	A			L	
75	SR 26	145	Post Office	146	4	B	<40	A	8	C	>40	B			L	
76	Tapawingo	147	State	148	2	A	<40	A	6	C	<40	A		3,775	WL	
77	State	149	Grant	150	3	A	<40	A	3	A	<40	A		7,321	WL	
78	Grant	151	Northwestern	152	odd	O	odd	O	odd	O	odd	O	Wiggins	7,434	WL	
79	State	153	Russell	154	5	C	<40	A	3	A	<40	A		**31,520**	WL	
80	State	155	University	156	0	A	<40	A	4	B	<40	A		3,632	WL	Univ @ State: 0
81	Yeager	157	Northwestern	158	6	C	<40	A	2	A	<40	A		12,867	WL	
82	Northwestern	159	Lindberg	160	7	C	<40	A	4	B	<40	A		7,819	WL	
83	Salisbury	161	Kalberer	162	4	B	>40	B	4	B	<40	A		6,441	WL	
84	Grant	163	Salisbury	164	3	A	<40	A	2	A	<40	A		**31,704**	WL	
85	Navajo	165	Salisbury	166	7	C	<40	A	4	B	<40	A		6,051	WL	
86	Northwestern	167	Cherry	168	5	C	<40	A	2	A	<40	A		6,750	WL	
87	Salisbury	169	Cumberland	170	4	B	<40	A	4	B	<40	A		11,760	WL	
88	Salisbury	171	Fowler	172	4	B	<40	A	4	B	<40	A		12,092	WL	
89	US 52	173	Nighthawk	174	4	B	<40	A	7	C	>40	B		6,156	WL	
90	US 52	175	Cumberland	176	8	C	>40	B	6	C	<40	A		4,751	WL	
91	Vine	177	Wiggins	178	2	A	<40	A	2	A	<40	A		404	WL	
93	*Fowler*	179	*Vine*	180	*2*	*A*	<40	A	*2*	*A*	<40	*A*		*404*	*WL*	*Possible Elim.*
94	Stadium	181	Northwestern	182	8	C	<40	A	4	B	<40	A		21,952	WL	
95	Stadium	183	University	184	odd	O	odd	O	odd	O	odd	O	Stadium Mall	4,941	WL	
96	US 52	185	Morehouse	186	4	B	<40	A	7	C	>40	B			TC	
97	State	187	River Rd.	188	odd	O	odd	O	odd	O	odd	A	Brown		WL	
98	Grant	189	Wood	190	3	A	<40	A	3	A	<40	A			WL	
99	Wood	191	Chauncey	192	1	A	<40	A	3	A	<40	A			WL	
100	State	193	Memorial Mall	194	3	A	<40	A	5	C	<40	A			WL	
101	State	195	Intramural	196	4	B	<40	A	4	B	<40	A			WL	
103	Salisbury	197	Lindberg	198	5	C	<40	A	5	C	<40	A			WL	
104	State	199	Northwestern	200	odd	O	odd	O	odd	O	odd	A	South		WL	
105	SR 25	201	I-65 NB	202	7	C	>40	B	3	A	>40	B			TC	
106	SR 25	203	CR 300N	204	6	C	>40	B	2	A	>40	B			TC	
107	US 52	205	Yeager	206	5	C	<40	A	6	C	>40	B			WL	
108	Wiggins	207	Salisbury	208	3	A	<40	A	4	B	<40	A			WL	

Intersection #	Name of Street 1	St 1 #	Name of Street 2	St 2 #	# N/S Lanes	# N/S Lanes ABC	Speed Limit N/S	Speed Limit N/S AB	# E/W Lanes	# E/W Lanes ABC	Speed Limit E/W	Speed Limit E/W AB	Name of Street 3-for Odds	Vehicle Count	Location	NOTE
109	University	209	3rd	210	2	A	<40	A	3	A	<40	A			WL	
110	US 52	211	Salisbury	212	6	C	<40	A	7	C	>40	B			WL	
111	Stadium	213	Russell	214	3	A	<40	A	4	B	<40	A				
112	Robinson	215	N.River Rd (231)	216	3	A	<40	A	5	C	<40	A				
115	Howard	217	N.River Rd (231)	218	5	C	<40	A	2	A	<40	A				
116	16th St.	219	Kossuth	220	2	A	<40	A	4	B	<40	A				
117	Hiatt Dr.	221	22nd St.	222	4	B	<40	A	3	A	<40	A				
118	Greenbush	223	Shenandoah Dr.	224	2	A	<40	A	4	B	<40	A				
119	18th	225	Greenbush	226	4	B	<40	A	4	B	<40	A				
120	9th St.	227	Beck Lane	228	6	C	<40	A	4	B	<40	A				
121	18th St.	229	Beck Lane	230	4	B	<40	A	4	B	<40	A				
122	Main	231	ALCOA	232	4	B	<40	A	2	A	<40	A				
123	36th/Eastwich	233	Union	234	2	A	<40	A	5	C	<40	A				
124	SR 26	235	Catapillar	236	3	A	<40	A	7	C	>40	B				
125	SR-25(Teal)	237	18th	238	5	C	<40	A	5	C	<40	A				
126	SR-25(Teal)	239	22nd St.	240	2	A	<40	A	4	B	<40	A				
127	US-231(4th)	241	Romig	242	2	A	<40	A	2	A	<40	A				
128	SR-26(South)	243	4th	244	2	A	<40	A	2	A	<40	A				
129	SR-26(Columbia	245	4th	246	3	A	<40	A	3	A	<40	A				
130	US-231(3rd)	247	Greenbush	248	6	C	<40	A	2	A	<40	A				
131	US-231(3rd)	249	Salem	250	2	A	<40	A	3	A	<40	A				
132	US-52	251	Creasy/Brady	252	6	C	>40	B	6	C	>40	B				
133	US-52	253	Target Plaza	254	7	C	>40	B	4	B	<40	A				
134	SR-38	255	Laf Market Place (K-Mart)	256	7	C	>40	B	6	C	<40	B				
135	SR-38	257	Maple Pt.	258	8	C	>40	B	4	B	<40	B				
136	US-52	259	Maple Pt.	260	6	C	>40	B	2	A	<40	B				
137	SR-38	261	Kingsway	262	4	B	>40	B	6	C	<40	B				
138	Old US-231	263	350S	264	4	B	>40	B	5	C	>40	A				
139	SR-26	265	500E	266	2	A	>40	B	4	B	>40	A				
140	US 231	267	SR 25S	268	2	A	>40	B	6	C	>40	A				
141	SR 25S	269	Old Romney Road	270	3	A	>40	B	2	A	<40	B				
142	US 65	271	SR 38	272	2	A	>40	B	6	C	>40	A				
143	SR 25S	273	100W	274	4	B	>40	B	4	B	<40	B				
144	New 231	275	500S	276	7	C	>40	B	6	C	>40	A				
145	Concord	277	350S	278	4	B	>40	B	4	B	>40	A				
146	SR38	279	475E	280	4	B	>40	B	8	C	>40	A				
147	43N	281	St. Police Post	282	2	A	>40	B	3	A	<40	B				
148	Kondike	283	US 52	284	3	A	>40	B	6	C	>40	A				
149	State	285	Airport	286	4	B	>40	B	4	B	<40	B				

DATE * TIME * SITE Crosstabulation

Count

			TIME																										Total
SITE			600	630	650	700	705	730	900	930	1000	1030	1050	1100	1130	1200	1210	1230	1300	1330	1400	1500	1515	1620	1630	1655	1700	2000	
8	DATE	26-Mar-01						5																					5
	Total							5																					5
15	DATE	29-Mar-01						4																					4
	Total							4																					4
17	DATE	31-Mar-01						1																					1
		07-Sep-01							7																				7
		10-Sep-01												5															5
		11-Sep-01																		3									3
		12-Sep-01																		6									6
		13-Sep-01																5											5
		14-Sep-01																									5		5
		15-Sep-01								1																			1
		30-Oct-01							1																				1
		31-Oct-01							5						10														15
		02-Nov-01							5						8														13
		05-Nov-01							2						9														11
		07-Nov-01							4						11														15
		09-Nov-01													8														8
		12-Nov-01													8														8
		14-Nov-01							1						12														13
		16-Nov-01							4						13														17
	Total							1	29	1				5	79			5		9							5		134
21	DATE	27-Mar-01						1																					1
	Total							1																					1
30	DATE	27-Mar-01												7															7
	Total													7															7
31	DATE	22-Mar-01												6															6
	Total													6															6
34	DATE	21-Mar-01	3																										3
	Total		3																										3
35	DATE	26-Mar-01												3															3
		30-Mar-01						3																					3
	Total							3						3															6
36	DATE	30-Mar-01												4															4
	Total													4															4
41	DATE	21-Mar-01					5																						5
	Total						5																						5
43	DATE	28-Mar-01						3																					3
		30-Mar-01																12											12
	Total							3										12											15
47	DATE	23-Mar-01	1																										1
		12-Sep-01										3																	3
		14-Sep-01																			1								1
		15-Sep-01																3											3
	Total		1									3						3			1								8
53	DATE	08-Sep-01							1																				1
		11-Sep-01																							1				1
		19-Sep-01								1																			1
		21-Sep-01												1															1
	Total								1	1				1											1				4
58	DATE	23-Mar-01						8																					8
	Total							8																					8
61	DATE	24-Mar-01																				3							3
		09-Sep-01									2																		2
		13-Sep-01																									4		4
		18-Sep-01				3																							3
	Total					3					2											3					4		12

SITE			TIME																										Total
			600	630	650	700	705	730	900	930	1000	1030	1050	1100	1130	1200	1210	1230	1300	1330	1400	1500	1515	1620	1630	1655	1700	2000	
65	DATE	21-Mar-01												2															2
		07-Sep-01							2																				2
		09-Sep-01												3															3
		10-Sep-01								9																			9
		13-Sep-01				7																							7
		15-Sep-01				1																							1
		18-Sep-01																									6		6
		19-Sep-01																7											7
		21-Sep-01																8											8
		29-Oct-01													13										14				27
		31-Oct-01													14										20				34
		02-Nov-01																							30				30
		05-Nov-01													14										23				37
		07-Nov-01													19										25				44
		09-Nov-01													40										30				70
		12-Nov-01													15										17				32
		14-Nov-01													14										20				34
		16-Nov-01													28										36				64
		19-Nov-01													15														15
		23-Nov-01													22														22
	Total					8			2	9				5	194			15							215		6		454
72	DATE	29-Mar-01																7											7
		07-Sep-01															2												2
		16-Sep-01										5													3				8
		18-Sep-01																			4								4
		20-Sep-01																		4									4
	Total											5					2	7		4	4				3				25
75	DATE	21-Mar-01																6											6
		10-Sep-01												6															6
		12-Sep-01														3													3
		15-Sep-01												6															6
		21-Sep-01								1																			1
	Total									1				12		3		6											22
76	DATE	23-Mar-01												4															4
	Total													4															4
77	DATE	07-Sep-01																							20				20
		08-Sep-01										3																	3
		09-Sep-01																			3								3
		10-Sep-01														5													5
		11-Sep-01							4																				4
		13-Sep-01																			5								5
		14-Sep-01																1											1
		19-Sep-01												6															6
	Total								4			3		6		5		1			8				20				47
78	DATE	25-Mar-01																									3		3
	Total																										3		3
79	DATE	30-Mar-01																									2		2
	Total																										2		2
82	DATE	31-Mar-01																				1							1
	Total																					1							1
84	DATE	28-Mar-01												2															2
		07-Sep-01											1																1
		10-Sep-01																									5		5
		11-Sep-01										3																	3
		19-Sep-01				1																							1
		21-Sep-01		2																									2
	Total			2		1						3	1	2													5		14
86	DATE	28-Mar-01																1											1
	Total																	1											1
87	DATE	21-Mar-01																				5							5
		07-Sep-01												6															6
		08-Sep-01																		4									4
		10-Sep-01		4																									4
		19-Sep-01																									5		5
	Total			4										6						4		5					5		24
88	DATE	30-Mar-01																										2	2
	Total																											2	2
89	DATE	22-Mar-01																2											2
		23-Mar-01																2											2
	Total																	4											4
90	DATE	22-Mar-01																				1							1
	Total																					1							1
97	DATE	25-Mar-01												3															3
	Total													3															3
100	DATE	22-Mar-01																									6		6
		28-Mar-01																				4							4
	Total																					4					6		10

			TIME																										Total
SITE			600	630	650	700	705	730	900	930	1000	1030	1050	1100	1130	1200	1210	1230	1300	1330	1400	1500	1515	1620	1630	1655	1700	2000	
115	DATE	25-Mar-01																4											4
	Total																	4											4
117	DATE	29-Mar-01																					1						1
		07-Sep-01																	1										1
		12-Sep-01																							4				4
	Total																		1				1		4				6
119	DATE	24-Mar-01																2											2
		31-Mar-01																									5		5
	Total																	2									5		7
120	DATE	27-Mar-01																									2		2
	Total																										2		2
122	DATE	29-Mar-01																									1		1
	Total																										1		1
123	DATE	21-Mar-01																						1					1
	Total																							1					1
127	DATE	22-Mar-01																										2	2
		09-Sep-01														1													1
		10-Sep-01				2																							2
		12-Sep-01							4																				4
		14-Sep-01				5																							5
		15-Sep-01																			1								1
		18-Sep-01												1															1
	Total					7			4					1		1					1							2	16
129	DATE	23-Mar-01																				7							7
	Total																					7							7
135	DATE	21-Mar-01																										2	2
		07-Sep-01														4													4
		13-Sep-01												3															3
		18-Sep-01								1																			1
		20-Sep-01							2																				2
		23-Sep-01				3																							3
	Total					3			2	1				3		4												2	15
137	DATE	26-Mar-01																				2							2
		10-Sep-01							2																				2
		14-Sep-01												4															4
		21-Sep-01																									3		3
	Total								2					4								2					3		11
139	DATE	26-Mar-01																									5		5
	Total																										5		5
140	DATE	23-Mar-01																									4		4
		29-Mar-01																										1	1
		07-Sep-01		12																									12
		08-Sep-01			2																								2
		10-Sep-01																	2										2
		18-Sep-01																1											1
		19-Sep-01																			1								1
		20-Sep-01										3																	3
		30-Sep-01																									2		2
	Total			12	2							3						1	2		1						6	1	28
141	DATE	07-Sep-01																								2			2
		08-Sep-01																						1					1
		10-Sep-01																			3								3
		12-Sep-01		2																									2
		20-Sep-01																							7				7
	Total			2																	3			1	7	2			15

Red Light Running Project - CATS Page___of___

Site Observation Form for Intersection #_________

Observer_________________________________ Date____

Street 1_________________________________ Beginning Time__________________________________

Street 2_________________________________ Day____

Veh	Driver	Race	Age	Passenger				Notes
	M F	W A O	Y A O	M F	N E S W	N E S W	N E S W	
	M F	W A O	Y A O	M F	N E S W	N E S W	N E S W	
	M F	W A O	Y A O	M F	N E S W	N E S W	N E S W	
	M F	W A O	Y A O	M F	N E S W	N E S W	N E S W	
	M F	W A O	Y A O	M F	N E S W	N E S W	N E S W	
	M F	W A O	Y A O	M F	N E S W	N E S W	N E S W	
	M F	W A O	Y A O	M F	N E S W	N E S W	N E S W	
	M F	W A O	Y A O	M F	N E S W	N E S W	N E S W	
	M F	W A O	Y A O	M F	N E S W	N E S W	N E S W	
	M F	W A O	Y A O	M F	N E S W	N E S W	N E S W	
	M F	W A O	Y A O	M F	N E S W	N E S W	N E S W	
	M F	W A O	Y A O	M F	N E S W	N E S W	N E S W	
	M F	W A O	Y A O	M F	N E S W	N E S W	N E S W	
	M F	W A O	Y A O	M F	N E S W	N E S W	N E S W	
	M F	W A O	Y A O	M F	N E S W	N E S W	N E S W	
	M F	W A O	Y A O	M F	N E S W	N E S W	N E S W	
	M F	W A O	Y A O	M F	N E S W	N E S W	N E S W	
	M F	W A O	Y A O	M F	N E S W	N E S W	N E S W	
	M F	W A O	Y A O	M F	N E S W	N E S W	N E S W	
	M F	W A O	Y A O	M F	N E S W	N E S W	N E S W	
	M F	W A O	Y A O	M F	N E S W	N E S W	N E S W	
	M F	W A O	Y A O	M F	N E S W	N E S W	N E S W	
	M F	W A O	Y A O	M F	N E S W	N E S W	N E S W	
	M F	W A O	Y A O	M F	N E S W	N E S W	N E S W	
	M F	W A O	Y A O	M F	N E S W	N E S W	N E S W	

CODES:

VEH:	COMM. CODES:	DRIVER:	RACE:	AGE:	DIRECTION:
C=Car	1=Comm. Pickup/Van/Car	M=Male	W=White	Y=Young(<21)	N=North
T=Pickup	2=1 to 5 Ton Box Truck	F=Female	A=Af-Amer	A=Average	E=East
V=Mini-van	3=Semi Tractor Rig		O=Other	O=Older(>65)	S=South
X=Full Size Van	4=School Bus				W=West
Z=SUV					
MC=Motorcycle; (MP=Moped)					

TOTALS:

Cars_______ Pickup_______ Mini-van_______ Full Size Van__________ SUV_______ MC__________ MP____________

Comm Pickup___________ 1 to 5 Ton______________ Semi-Tractor_______________ School Bus____________

Veh Count # 1_________

Veh Count # 2_________

Appendix D

CATS Red Light Running Project – Form Instructions

Site Observation Form

Introduction

The Observation Form is used to record red light running incidents at selected intersections in the study area. The observations will report on the red light running incident with the observer noting on the form characteristics of the target vehicle, operator and the behavior of the vehicle at the time of the incident. The instructions will detail the information to be recorded on the observation form by filling in the appropriate blanks or by circling appropriate code letters.

Page____of_____

Experience has shown that for 30 and 45-minute observation periods, reports will result in only one page being used. Should the need arise, however, space is provided to indicate the use of more than one sheet. This blank space should be filled in regardless of number of sheets to remove any doubt as to quantity of pages.

Site Observation Form for Intersection #__________

Each intersection to be observed has a number assigned. This will be included on the schedule and the intersection number of the intersection being observed should be placed in this blank.

Observer__________________

First initial and last name of observer should be entered in this blank.

Street 1_____________________

First of the streets as they appear on the intersection list should be placed here.

Street 2_____________________

Second of the streets as they appear on the intersection list should be placed here.

Date_______________________

Date of observation should be entered here.

Beginning Time

Beginning time of the observation period should be placed here. Military time is preferred to avoid confusion about time of day.

Day

Day of week of observation should be placed in this blank

The body of the observation report is organized in columns with each row representing one observation. Each column of the row should be coded as follows under the column heading. "Unknowns" or "Unsures" will be assumed if no circles are made in the areas requiring a code letter to be circled. Instructions for coding the body of the Observation Form are as follows:

Veh

Codes are defined at the bottom of the observation form and should be entered for the vehicle being observed running the red light. Vehicle codes can be found in one of two groupings of privately owned or commercially owned vehicles. Motorcycles, mopeds, and bicycles are included in the privately owned grouping column and distinctions should be made between motorcycles-"MC" (ridden with one leg on each side of the engine compartment), mopeds-"MP" (also known as motorized bicycles generally ridden with both feet together on a foot board in front of the engine), and bicycles- "B" which are foot powered regardless of number of wheels in contact with the ground. Under commercial vehicles, "1 to 5 ton" trucks would include any commercial truck larger than a pickup but smaller than a semi-tractor rig.

Driver

The observer should circle M for male or F for female for the vehicle operator according to gender observed. Leave codes un-circled if gender of operator is not known.

Race

Circle W for White, A for African American, or O for Other to reflect the observer's best understanding of the race of the vehicle operator.

Age

Age refers to approximate age of the observed vehicle operator and must be estimated according to appearance. If the operator appears to be under 21 years of age, "Y" (younger) should be circled. If the operator appears to be over 65, "O" (older) should be circled and any other age should result in circling "A" for average.

Passenger

If a passenger is riding in the vehicle being observed, note that fact be circling "M" (for male) or "F" (for female) in the passenger column of the row for the vehicle being observed. If the gender of the passenger cannot be determined but the presence of a passenger is clear, circle both "M" and "F".

Noting for the presence of a passenger should be done whether the passenger is in the front seat or somewhere else in the observed vehicle.

Direction of Travel

Arrows head the columns for noting direction of travel for the observed vehicle. The arrows indicate a direction of travel for the vehicle being coded as making a left turn, going straight through the intersection, or making a right turn. The direction of travel should be noted by circling one of the direction indicators (North, East, South, or West) for vehicle travel AFTER the vehicle has passed through the intersection. Thus, the direction of the turn and subsequent travel will be indicated. For example, if a vehicle is traveling in the northbound lane of street A, enters the intersection disregarding a red traffic signal and makes a left turn, the new direction of travel would then be west and a "W" should be circled in the left turn column of the observation report. A compass rose is included at the top of the "Site Summary Form" to help avoid confusion regarding directions.

Notes

This column should be used for the observer's notes regarding the vehicle being coded. This space could also be used for special notes regarding the intersection or traffic in relation to the vehicle under observation.

Legend

The bottom of the observation form contains the definitions for the codes being used in the body of the form. Blanks are also located here so the total number of each vehicle type can be tabulated and entered into the blank spaces. Totals are arrived at by tallying the numbers for each vehicle type observed during the observation period and placing the numbers for each category in the appropriate blanks.

Veh Count # 1 and #2__________

Vehicle counts are conducted for five minutes prior to the observation period and for five minutes following. All vehicles regardless of type should be counted as they traverse the intersection during each 5-minute count period. The totals for each period should be entered in the appropriate blank.

Light Cycles__________

During the observation period, the observer should keep as careful a count as possible of the number of the times the traffic signal cycles. The number of cycles during the observation period should be entered in the blank space provided on the left bottom of the form.