2007

The effectiveness of Iowa's automated red light running enforcement programs

Eric John Fitzsimmons
Iowa State University

The effectiveness of Iowa's automated red light running enforcement programs

by

Eric John Fitzsimmons

A thesis submitted to the graduate faculty

in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

Major: Civil Engineering (Transportation Engineering)

Program of Study Committee:
Shauna Hallmark, Major Professor
Reginald R. Souleyrette
David J. Plazak
Neal Hawkins

Iowa State University

Ames, Iowa

2007

UMI Number: 1446132

ProQuest Information and Learning Company
300 North Zeeb Road
P.O. Box 1346
Ann Arbor, MI 48106-1346

DISCLAIMER

This document was used in partial fulfillment of the requirements set forth by Iowa State University for the degree of Master of Science. The numerical results and conclusions made in this report regarding "system effectiveness" are interim steps for a final report and should not reflect the final and / or current views of the Iowa Department of Transportation (Iowa DOT), The Center for Transportation Research and Education (CTRE), or Iowa State University (ISU). Further research involving the effectiveness of Iowa's automated red light running enforcement programs performed by CTRE and / or the Iowa DOT may alter the results as reported herein.

DEDICATION

Dedicated to the lives in Iowa saved or will be saved by automated red light running enforcement.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF EQUATIONS

ACKNOWLEDGEMENTS

First, I would like to thank my program of study committee members. Without their support, guidance, expertise, and recommendations this project would have never come together.

Dr. Shauna Hallmark - Associate Professor, CCE E
Dr. Reginald R. Souleyrette – Professor, CCE E
David J. Plazak – Adjunct Assistant Professor, Community and Regional Planning
Neal Hawkins - CTRE, Associate Director of Traffic Operations

I would like to thank the Iowa Department of Transportation for funding this project and David Matulac with the Iowa DOT Office of Traffic Safety for monitoring this project. Without the Iowa DOT's funding and interest in saving lives with automated enforcement, this project and thesis would not have been possible. I would also like to thank my family for understanding my commitment towards education and research in civil engineering.

I also would like to thank the following individuals for extensive help and contributions made to this document.

Ann K. Staudt – Editing, Descriptive Statistics, and Friend
Andrew K. Gay – Editing, Hill & Knowlton, New York, NY
David Andersen – Field data collection
Caroline Kinzenbaw – Field data collection
Massiel A. Orellana – Statistics
Tom McDonald – CTRE, Safety Circuit Rider
Dr. Linda A. McGuire – Associate Dean for Public Service, The University of Iowa College of Law
Dr. Tom Stout – Editing
Linda Hedberg & Kathy Wellik – Iowa State University Transportation Services
CTRE Students – Victor Lund, Justin Jackson, Josh Hinds, Craig Mizera, Dan Ormand, Jon Wiegand, Greg Karssen, Xudong Chai, and Hillary Isebrands
CTRE Staff

Finally, I would like to thank the following individuals for local and national technical expertise.

Richard A. Retting – Insurance Institute for Highway Safety
Tom Welch – Iowa DOT Office of Traffic Safety
Dr. Michael Pawlovich – Iowa DOT Office of Traffic Safety
Ronald Bunting – Iowa DOT
Dennis Henderson – City of Clive City Manager
Pamela L. Shannon – City of Clive City Clerk
Chief Robert P. Cox – Chief of Police, City of Clive
Jim Dewitt – City of Clive Public Works Operation Supervisor
Sgt. John Brodersen – City of Clive Police Department
John B. Larson – City of Urbandale Assistant Director of Engineering
Eric R. Petersen – City of West Des Moines Associate Traffic Engineer
Tom Dozler – City of Ankeny Public Works
Ray Weiser – Scott County GIS Office
Lt. Michael G. Venema – City of Davenport Police Department
Al Berg – City of Davenport Finance Department
Gary Statz – City of Davenport Traffic Engineer
Gregory Reeder – City of Council Bluffs Public Works Director
Mark Franz – City of Council Bluffs Traffic Superintendent
Dennis Kroeger – CTRE Transportation Research Specialist
Dr. Tom Maze – Professor, CCE E
Ron Johnson – Iowa Signal, for the City of Waukee

ABSTRACT

One of the most controversial topics facing traffic engineers, city councils, and public awareness groups is the implementation of automated red light running enforcement camera systems at signalized urban intersections. Red light running is a significant safety problem as drivers become more aggressive on roads, and become impatient waiting for a traffic signal to change. Red light running camera systems are automated enforcement systems which detect and capture the image and license plate of vehicles which run a red light and then issue a citation. They are becoming widely used in the US to reduce the number and severity of red light running crashes. The effectiveness of automated red light running enforcement is constantly debated among government officials and citizens who see cameras as either “intrusive” or “constitutionally illegal” to an extent. In some cases, it has been argued that automated red light running enforcement increases the percentage of rear-end collisions.

In 2004, the state of Iowa reported over 2,900 crashes (approx. 4.9% of all reported crashes) involving “failure to yield right of way making right turn on red signal” and “ran traffic signal” both of which constitute a driver being involved in a red light running collision. This thesis presents the interim results of a research project which evaluated the effectiveness of Iowa’s currently deployed automated red light running camera systems in: Council Bluffs, Davenport, and Clive. Violation data were collected from each community and system effectiveness was evaluated through a before and after study and comparing enforced intersections with similar intersections where the automated enforcement system is not expected to have any spillover effects. The before and after data study investigated reductions in total crashes, red light running-related crashes (crashes where either the officer or crash narrative indicated red light running had been a factor in the crash), crash severity, and then a statistical model was developed to determine the expected crash frequencies for each automated enforced intersection. The findings of all three studies were compared to each other and initial conclusions were made as to how effective each red light running camera system is, and if all three systems were an effective means at reducing red light running and saving lives in Iowa.

Key Words: automated enforcement-red light running camera effectiveness-crash study-violations study-high speed intersection crashes-public acceptance-history of automated enforcement-Iowa automated enforcement-Bayesian hierarchical model-Poisson linear regression

CHAPTER 1: INTRODUCTION

1.1 INTRODUCTION

Red light running (RLR) is a significant safety problem as drivers become more aggressive and distracted on city roads, and become impatient waiting for a traffic signal to change. As a result as agencies have struggled to find ways to address the issue, they have increasingly turned to the use automated RLR camera enforcement systems at urban signalized intersections. RLR camera systems are a form of automated enforcement which detect, determine, and capture images of vehicles that run a red light to later issue a citation. In most cases the systems are operated by a private corporation. However the use of RLR cameras is one of the most controversial topics facing drivers, traffic engineers, city councils, and public awareness groups. The effectiveness of automated RLR enforcement cameras in reducing crashes is questioned and in some cases, it has been argued that automated RLR enforcement increases the percentage of rear-end collisions. The legality and acceptability of the systems are also constantly debated among government officials and citizens who see cameras as either "intrusive" or "constitutionally illegal" to an extent.

1.1.1 Civilization Versus "Big Brother is Watching You" Versus Safety

We live in a time and age where cameras are predominantly watching society as a means of security. George Orwell's novel *1984* painted a dark terrifying picture, damning surveillance by a nation-state and promoted images of "Big Brother is watching you" which many people have referred to as an example when responding to automated RLR enforcement. Regardless, whether camera surveillance is used for RLR enforcement, speeding, or congestion; the means of automatically capturing and ticketing will always be questioned.

Cameras are constantly among us, from dressing rooms to airport security lines, automated teller machines to department stores, city buses to grocery stores, to even our home security systems. Video recording of humans through the use of cameras have proven valuable in capturing people in their everyday lives, whether for good, protection, or the purpose of evidence. Another recent advancement in camera technology in the transportation field is the constant evolution of Intelligent Transportation Systems (ITS). Most major metropolitans have a central traffic operation center with hundreds of cameras monitoring and recording ordinary citizens traveling down a highway, entering an intersection, and occasionally helping when major crashes occur.

Moreover, the question arises of how RLR camera enforcement privacy differs from existing automated technology currently deployed (except that a camera located at an intersection can capture a vehicle and / or a human actually breaking the law). Three communities in Iowa have deployed automated RLR camera systems to help prevent potentially dangerous crashes and to notify violators through a civil fine that they were captured performing a dangerous movement with their vehicle. As expressed by RLR camera opponent groups in Iowa, the RLR camera systems are an illegal way to generate funds, are invasive of privacy, and certain ordinance cannot supersede state laws; but how far can one argue these technicalities if a RLR camera prevents one unnecessary death?

1.2 PROBLEM STATEMENT / STATEWIDE ANALYSIS

In 2004, the State of Iowa reported over 2,900 crashes (approx. 4.9% of all reported crashes) involving "failure to yield right of way making right turn on red signal" and / or "ran traffic signal" both which indicate a potential RLR crash. Since 2004, three communities in Iowa have implemented RLR camera systems and several others have considered them. In the absence of definitive studies to quantify the effectiveness of the cameras, the Iowa Department of Transportation (Iowa DOT) was interested in evaluating the experience in Iowa so that other Iowa agencies have additional information to determine whether the RLR camera systems offer a viable and effective solution to RLR.

To gain an understanding of the magnitude of RLR in the state of Iowa, a crash analysis for the entire state was assessed for 2001 to 2006. Locations of signalized intersections in the state were determined using a database based on the Iowa DOT GIMS database. The Iowa DOT crash database (version "crashes (2001 2005) Jan 2006" for 2001 to 2005 and "statewide20012006(April2007)" for 2006) was used. Crashes were spatially located and those crashes within 25 meters of each signalized intersection were extracted for each year. RLR and RLR type crashes were then summarized from those signalized intersection crashes.

A statewide intersection database was developed for Iowa based on the 1999 GIMS snapshot linework from the Iowa DOT. This database represents the intersection of any location where 3 or more approaches join. No statewide inventory of signalized intersections exists. In order to determine where signalized intersections were located, a database created by Dr. Michael Pawlovich of the Iowa DOT was used. Crashes from 2001 to 2005 which were within 25 meters of an intersection node in the statewide intersection database were extracted. Total number of crashes was summed for each location. The number of crash cases that have some indication that a traffic signal was present from the Traffic Controls crash option were recorded in one field. The total number of crash cases where a traffic signal was indicated in either the Traffic Controls crash option or Contributing Circumstances, Driver crash option were summarized. This indicated that the reporting officer had indicated presence of a traffic signal. Officers may not always fill in either option when reporting a crash. The point ID was related to the point ID from the statewide intersection database. An intersection was determined to be signalized if the following conditions were met:

- 2 to 4 crashes had occurred and a signal was indicated for at least 2 crashes
- 6 or 7 crashes had occurred and a signal was indicated for at least 3 crashes
- 8 or more crashes had occurred and a signal was indicated for at least 4 crashes

RLR crashes were defined as crashes where the officer indicated "ran traffic signal" or "failure to yield right of way on right turn on red" as the major cause. Since the officer may not always indicate cause, the numbers of crashes with collision types which are indicative of RLR were also evaluated. These include angle—on-coming left turn, broadside, head-on, and sideswipe—opposite direction. These crashes are referred to as “RLR type crashes”.

The number of RLR crashes for each year from 2001 to 2006 and the number RLR type crashes for each year from 2001 to 2006 are shown in Figure 1. As indicated, from 1,290 to 1,994 RLR crashes per year occur. This resulted in an annual average of 1,764 RLR crashes. RLR type crashes range from 3,120 to 4,708 with an annual average of 4,055 crashes. Additionally, an annual average of 68 fatal and major injury RLR crashes and 123 fatal or major injury RLR type crashes occurred.

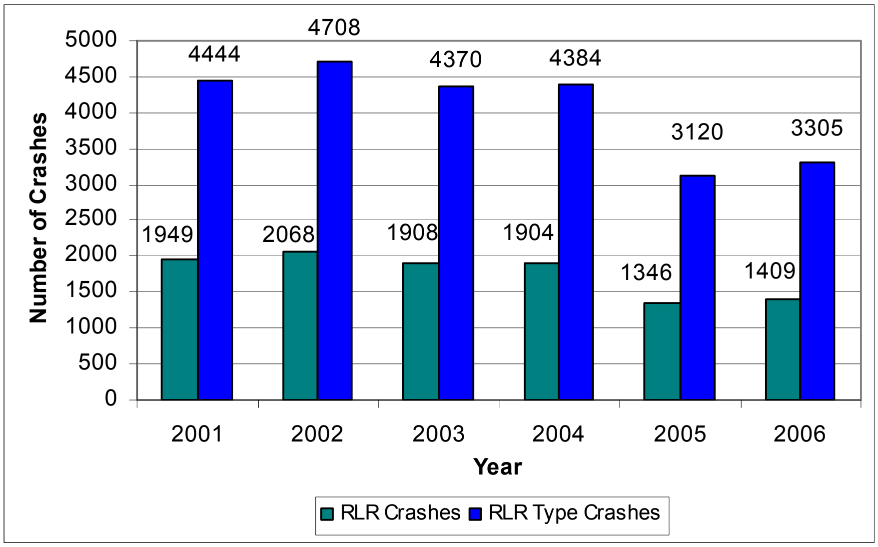


Figure 1. RLR and RLR type crashes in Iowa from 2001 to 2006.

An average of 8,162 total crashes occurred at signalized intersections in Iowa per year. RLR crashes account for 21.6% of all crashes at signalized intersections and RLR type crashes account for 49.7% of all signalized intersection crashes annually. Additionally, RLR crashes account for 35.0% of the fatal and major injury crashes at signalized intersections and RLR type crashes account for 63.6% of fatal and major injury crashes at signalized intersections.

1.3 RESEARCH OBJECTIVES

This thesis presents the results of an Iowa Department of Transportation (Iowa DOT) sponsored research project which evaluated the effectiveness of Iowa’s currently deployed automated RLR camera systems in: Council Bluffs, Davenport, and Clive. Along with investigating the change in RLR crashes, the investigation will examine how each city began their programs and evaluate the intersections, payment structure, and legal concerns.

Known violation data were collected for all three cities and crash data was extracted from the Iowa DOT’s crash data base. A simple before-after data study investigated the reduction in total accidents, RLR related crashes (e.g. broadside, right-angle, and rear-end, non-RLR related crashes, and total number of crashes), crash severity, and reduction in violations. The findings were compared to other communities around the nation to see how Iowa's automated red light running enforcement system measured up on a national level.

CHAPTER 2: LITERATURE REVIEW

This section of the thesis discusses the history, applications, and effectiveness of Red Light Running (RLR) camera systems. This literature review cites sources from newspapers, local jurisdictions, academic and professional journals, magazines, vendors, interviews, historical documents, and research records. It includes information pertaining to:

- The history of automated enforcement, and development of the RLR camera system
- How a red light camera system works with examples cited from cities in the United States
- Camera, film type, and vendor information
- Case studies of United States cities where RLR systems have been installed and studied
- Legal and legislative concerns

This literature review consists of the most recent information and statistics for automated RLR enforcement and is divided into eight main sections:

2.0 Introduction to RLR enforcement and the toll of RLR on society
2.1 Characteristics of RLR drivers and intersections
2.2 Possible RLR countermeasures
2.3 Description of automated Enforcement
2.4 How automated RLR cameras work
2.5 Summary of notable RLR programs
2.6 System Effectiveness
2.7 Legality of automated enforcement with specific court cases

2.0 BACKGROUND

RLR is an ever-increasing problem in urban areas of the United States, as well as many nations around the world. Many times it results in dangerous rear-end collisions and sometimes fatal side impact, right-angle collisions. Any vehicle that has crossed the approach stop bar and enters a signalized intersection after the beginning of the red phase has run a red light; these vehicles have become a potential safety hazard for other vehicles. The Federal Highway Administration (FHWA) estimates in 2002, there were 207,000 RLR-related crashes at signalized intersections, an economic loss of over $14 billion per year with more than 1,000 deaths *(1)*. A study performed by Bonneson et al. determined the average cost per RLR-related crash in the state of Texas for the year 2003; results are shown in TABLE 1.

TABLE 1 Cost of Red-Light-Related Crashes in Texas for 2003 (2)

Severity*	Crash Cost [40a]	Annual Crashes	Crash Dist.,%	Annual Injuries	Annual Cost
K	3,237,000	121	0	133	$431,000,000
A	224,000	1439	4	2047	$458,000,000
B	45,000	5493	15	8987	$404,000,000
C	24,000	11,798	31	24,802	$595,000,000
PDO	2,500	18,851	50	0	$94,000,000
Total:	**--**	**37,702**	**100**	**35,969**	**$1,982,000,000**
		Average Cost per Red-Light-Related Crash:			**$52,600**

* K: Fatal Injury, A: Incapacitating Injury, B: Non-incapacitating Injury, C: Possible Injury, PDO: Property Damage Only ($ per vehicle)

The large numbers shown in Table 1 demonstrate that RLR is a serious issue. Bonneson et al. also estimated the state of Texas averages about $2 billion each year in lost societal cost due to drivers running red lights *(2, 3)*. RLR costs society more money and lives each year due to an ever-increasing volume of traffic on local roads. Many city jurisdictions and state law enforcement agencies are constantly under public pressure to combat this trend either by making engineering improvements to intersections or by installing automated enforcement systems.

As of October 2006, the Insurance Institute of Highway Safety (IIHS) reported that over 170 communities in 22 states and the District of Columbia have implemented RLR programs. These states include Arizona, California, Colorado, Delaware, District of Columbia, Georgia, Illinois, Iowa, Maryland, Massachusetts, Minnesota, Missouri, New Mexico, New York, North Carolina, Ohio, Oregon, Pennsylvania Rhode Island, South Dakota, Tennessee, Texas, and Washington *(4)*. Despite the growing number of communities with RLR enforcement cameras, implementing such a program can be a daunting task for any traffic engineer, local city and law official, or a state legislature. Often, the blame for implanting a system is placed on specific engineering problems at the intersections. However, with proper engineering, public education, and law enforcement tactics, a RLR program can have substantial results and save lives.

2.1 DRIVER AND INTERSECTION CHARACTERISTICS

2.1.1 Legal Explanation of a Change Interval

In 1962, a modification in the Uniform Vehicle Code allowed vehicles to enter into an intersection legally when a yellow and clear the intersection when a red signal is displayed in the approach leg *(5,7g)*. As stated in a recent ITE report, “Determining Vehicle Changing Intervals,” a state has a “permissive yellow rule” or “restrictive yellow rule” to define a RLR violation. A permissive yellow rule allows vehicles to enter the intersection on yellow while using caution. The restrictive yellow rule states that vehicles cannot enter the intersection on a yellow light unless it is unsafe to come to a complete stop *(6).* A yellow light’s main purpose is to alert drivers that the green light is about to turn red. If a poor choice in the duration of the yellow interval, an area before the stop bar called the dilemma zone in which a vehicle can neither stop safely before the intersection nor clear the intersection without speeding up. When a vehicle does speed up to clear the intersection, this could lead to a potentially dangerous situation.

2.1.2 Determining the Factors of Crash Frequency

RLR is a complicated traffic problem with many possible variables that might attribute RLR to a specific action, person, or situation resulting in a crash. Vehicles running a red light vary day to day, intersection to intersection, and from person to person. Any driver may run a red light due to inattention; however most red light running is due to aggressive driving. Various research studies have identified the behavior of the average violator and the intersection characteristics in where violations are more likely to occur. A summary of all of the known current research conducted on what elements influence RLR violators and the studies' conclusions are shown in TABLE 3.

2.1.3 Characteristics of Red Light Runners

In 1996, Retting et al. performed a study to identify the characteristics of red light runners. This study was conducted at an eight-lane, east-west intersection in Arlington County, Virginia. Using automated camera systems and human observers, Retting recorded 1,373 cars over a period of time. Of these recorded cars, 462 ran the red light, and 911 complied with the yellow light and came to stop at the stop bar. These figures equated to two red light runners per hour. Violating drivers were classified by the length of time the light had been red before the car crossed the stop bar, and times were recorded from 0.5 to 2.0 seconds. Drivers had minimal influence on these times because there were no correlations, so the data was grouped for the study. Shown below in TABLE 2 and TABLE 4, are the results of this study.

TABLE 2 Percentage of Passenger Cars by Size for Red Light Violators and Compliers (7d)

	Small (Wheelbase ≤99 inches)	Midsize (Wheelbase 100-109 inches)	Large (Wheelbase >109 inches)	Total
Violators	49	45	6	100
Compliers	40	49	10	100

As shown in TABLE 2, Retting was able to conclude that red light runners generally drove small and midsize cars, although no particular make or model of car was identified in the study. Also, RLR violators were less likely to drive cars manufactured after 1991. This might be a result that drivers with newer automobiles did not want to take the chance with an accident and a new car, although this was not researched in this study.

As shown in TABLE 4, Retting categorized red light violators as to how many prior moving convictions the drivers had and what age range the violators were. To find this information, license plates numbers were matched with driving records and cross-verified using the car's vehicle identification number (VIN).

TABLE 3 Summary of the Most Recent Driver Behavior Studies (7)

Element	Variable	Key Finding	Reference
Driver	Age	The older groups accounted for a relatively small portion of red light running crashes compared to the younger age	[Kraus and Quiroga, 2004] (7a)
		Younger drivers between the ages of 18-25 years old are more likely to run red lights compared to other age groups.	[Porter and Berry, 2001] (7b)
		Red light runners tend to be drivers under 30 years old.	[Retting et al., 1999; Retting Williams, 1996] (7c)(7d)
	Gender	Red light runners are more likely than non-runners to be male.	[Retting et al.; 1999] (7c)
	Occupancy	Drivers have higher probablility of running red lights when driving alone compared to when passengers are in their vehicles.	[Porter and Berry, 2001] (7b)
	Safety Belt	Red light runners are less likely to wear safety belts.	[Porter and England, 2000; Retting and Williams, 1996] (7c)(7d)
	Driving Record	Red light runners are more likely than non-runners to be driving with suspended or revoked driver's licenses.	[Retting et al.; 1999] (7c)
		Drivers with poor driving records and driving smaller and older cars have a high tendency to run red light.	[Retting and Williams, 1996] (7d)
Intersection	Signal Timing	The frequency of red light running increases when the yellow interval is less than 3.5 seconds.	[Brewer et al., 2002] (7e)
		Longer yellow intervals will cause drivers to enter intersection later and lengthening the all-red intervals caters to red light violators.	[Eccles and McGee, July 2001] (7f)
	Stopping Distance	Probability of a vehicle stopping for traffic light decreases as its distance from the intersection decreases.	[Chang et al., 1985] (7g)
	Approach Speed	Probablility of a driver stopping for a traffic light decreases as the approach speed to the intersection increases.	[Chang et al., 1985] (7g)
	Grade	Probability of a driver stopping for a traffic light increases as the approach grade to intersection increases.	[Chang et al., 1985] (7g)
	Intersection Width	Drivers tend to stop for traffic lights more at wider intersections than at narrower intersections.	[Chang et al., 1985] (7g)
Traffic & Environment	Approach Volume	Higher red light running rates were observed in cities with wider intersections and higher traffic volumes.	[Porter and England., 2000] (7h)
		The red light running frequency increases as the approach traffic volume at intersection increases.	[Brewer et al., 2002] (7e)
	Time of Day	Higher red light violations occur during the time period of 3:00 PM to 5:00 PM.	[Kamyab, et al., 2002 Kamyab, et al., December 2000] (7i)(7j)
		The average number red light violations are higher during AM and PM peak hours compared to other times of the day.	[Retting et al., 1998] (7k)
	Day of the Week	There are more red light violations on weekdays compared to weekends.	[Lum and Wong, 2003; Kamyab, et al., 2002; Kamyab, et al., December 2000; Retting et al., 1998] (7j)(7i)(7J)(7k)
	Weather	The influence of rainfall on red light running behavior is insignificant.	[Retting et al., 1998] (7k)

TABLE 4 Driver Characteristics of Violators and Compliers (7d)

	Percent of Driver			Mean			
	Age <30	2+ Speed Convictions	3 + Speed Convictions	Age	Speed Convictions	Total Convictions	Point Balance
Virginia, Maryland, and Washington, DC - 36-Month Driver Records							
Violators	26	14	16	36	0.58	1.2	-
Compliers	14	4	6	42	0.25	0.67	-
Virginia Only - 60-Month Driver Record							
Violators	29	22	22	35	0.96	1.83	-0.88
Compliers	14	7	12	42	0.40	0.93	+1.18

As shown in TABLE 4, Retting concluded that red light runners generally are younger, under the age of 30, with prior moving violations. Seat belt usage was observed in the field as well: 74 percent of compliers were found wearing seatbelts, while 33 percent of violators were wearing seatbelts. These studies also suggested that since red light violators are younger and already put in a higher-risk driving group, this merits more enforcement resources such as cameras, police officers, and education *(7d)*.

2.1.4 Intersection Characteristics and RLR

Other contributing factors to a driver running a red light are the wide array of intersection characteristics that might be aiding in the violation. Not all intersections are uniform depending on when the intersection was built or what standards were used when designing the intersection. Certain designs and configurations may lead to reduced reaction and stopping times, driver confusion, or limited views of the traffic signals. Many times, a simple engineering analysis of the troubled intersection could help the situation before the implementation of a RLR system *(8)*.

- **Grade**

  The grades approaching the intersection may significantly affect the time needed for a vehicle to stop. Grades in excess of 5 percent may affect the driver's desire to stop for a red light. A study conducted in 1985 concluded that more drivers will tend to stop at an intersection that is on an uphill grade, but tend to run the red lights on a downhill grade. It was also recommended by this research group that having a longer all-red clearance interval on down grades would counterbalance this effect to prevent potential accidents *(8g)*. In another report, the weight and downhill momentum of a vehicle affects a driver's ability to safely stop at an intersection *(9)*.

- **Poor Visibility**

  Drivers are not able to notice and react to traffic control devices that cannot be seen when approaching the intersection. Obstructions could include overhanging vegetation, billboards, large trucks, commercial signs, low pressure sodium lights, or awkward geometric alignment of the road *(9)*.

- **Roadside Obstructions**

  Roadside obstructions such as parked vehicles, vegetative growth, pedestrians, and billboards may block motorists' view of signs, traffic control devices, or other vehicles *(10)*. Intersections with such approaches should be engineered so roadside parking does not interfere with sign visibility *(11)*. Traffic control devices and signs should be regularly cleared of vegetation over-growth and / or vandalism *(12)*.

- **Line of Sight**

  Line of sight is critical to a driver approaching an intersection. Obstructions beside the vehicle (i.e. a tree or building) or an obstruction in front of the vehicle (i.e. a large truck or trailer) may reduce reaction time and/or affect driver behavior. The worst case for line of sight obstruction is the intersection located at the base of a hill where the traffic signal is partially or completely hidden from the driver's view until reaching the top *(11)*.

- **Approach Volumes**

  Multiple research studies have indicated that RLR may be influenced by the time or day of the week *(13)*. During peak hours of the day, traffic volumes and congestion will influence the number of red lights run. Drivers who commute or run errands during these times will experience considerable delays. This is especially true if signals are not properly timed or coordinated, resulting in adverse driver behavior *(10)*. On the other hand, many drivers will travel before peak hour congestion when there is little volume on the road. In some cases, traffic signals might be non-traffic actuated signals, making drivers wait for extended periods of time for no vehicles, thus occasionally resulting in red lights being run *(10)*.

2.1.5 Traffic and Environment

- **Weather**

  A RLR survey study performed by the Old Dominion's Department of Psychology concluded weather is not an important predictor of RLR *(13)*. However, it is reasonable to assume that water, snow, or fog cover will affect the dynamics of the vehicle and the driver's ability to control the vehicle without distractions. Poor visibility resulting from severe weather, sun glares, particulate matter, and debris may also affect the driver's sight distance and reaction time when approaching an intersection *(11).*

- **Vehicle type**

  The type of vehicle may contribute too many RLR cases where drivers don't completely understand their vehicles' dynamics or how quickly they can stop. According to a report by Lenard Evans, vehicles that carry heavy loads require additional time to slow and stop when traffic signals change to yellow. Drivers of vehicles carrying heavy loads with a greater amount of mass may forget these variables resulting in RLR violations *(14)*.

2.2 RLR COUNTERMEASURES

RLR countermeasures can be divided into three groups, which consist of the "Three Es" engineering, education, and enforcement, to combat some of the issues listed in the driver behavior section. However, the

Three Es may not work for every case, and ultimately an automated enforcement system might be installed. A good starting point is to attempt to find deficiencies in the driver or intersection. Shown in TABLE 5 are the reasons found by an unpublished FHWA report as to why red light runners ran the red light and what countermeasure would be most appropriate for that cause *(15)*.

TABLE 5 Possible Causes and Appropriate Countermeasures (16)

Possible Causes of Red-Light Running	Engineering	Enforcement	Education
1. Did not see signal	◊		
2. Tried to beat yellow	●	◊	◊
3. Reported they had green	◊		
4. Intentional violation	●	◊	◊
5. Unable to stop vehicle	●		
6. Followed another vehicle	◊	◊	
7. Confused by Signal	◊		

◊ = Likely Countermeasure ● = Possible Countermeasure

As shown in TABLE 5, engineering countermeasures could help, or at least help a jurisdiction take a first step in reducing RLR before deploying an automated camera system.

2.2.1 Engineering

Although driver behavior is a key element in determining whether someone will run a red light, intersections factors such as an inadequate change signal, sight distance issues, or significant delay may also contribute to RLR; it sometimes and can be solved by less expensive countermeasures than automated enforcement *(16)*. Bonneson et al. classified engineering countermeasures into three categories based on the method of implementation. "Signal operation" countermeasures include modifications to signal timing, type of signal, cycle length, and change interval. "Motorist information" countermeasures are modifications to advanced warning devices such as signs or flashing lights, as to warn drivers of a signalized intersection ahead. "Physical improvements" countermeasures involve sometimes-extensive modifications to an intersection to solve dangerous safety concerns or operational problems *(17)*.

Signal Operations

Increased Yellow Interval

Two known studies have evaluated the effectiveness of extending the duration of the yellow interval. Retting and Greene cited numerous sources where extending the yellow time will reduce RLR and right-angle crashes *(18)*. Another study, performed by Van der Horst and Wilimink, found a relationship between RLR and yellow duration at 11 test intersections. Their conclusions found that yellow intervals of at least 3.5 seconds are associated with minimal RLR cases *(19)*. Bonneson et al. concluded that increasing the yellow time was inversely related to the frequency of RLR and found this decreased RLR 50 to 70 percent *(17)*. Although this method proved successful, researchers noted that if yellow interval extensions are increased too much, the capacity of the intersection might decrease and delay will increase *(16)*. Since delay has been cited as a factor in RLR, the benefits may be offset.

Provide Green-Extension

Advanced detection devices are used before major intersections with actuated traffic signals to extend green time or change the signal phase by sending an advance signal. Once a vehicle passes the detection device (Autoscope or inductive loops), a signal is sent to the traffic signal to extend the green time or change the cycle phase. Zegeer and Dean concluded that extending the green time would reduce the frequency of RLR by as much as 65 percent *(20,17)*. Although many communities have implemented green extension by advance warning devices, it can also increase RLR if driver expectancy is altered for regular users of the intersection.

Coordination

A common practice among cities is to coordinate traffic signals along a corridor to provide less delay, thus resulting in less RLR violations. Although improving the flow of traffic along a corridor, Van der Horst and Wilmink concluded that there is a greater chance that a platoon of vehicles formed by signal coordination will run a red light if the platoon arrives close to the end of the green cycle *(19, 17)*. It was also noted the potential of RLR violations may decrease with traffic signal coordination if cycle lengths were adjusted *(19, 17)*.

Motorist Information

Improved Traffic Signal Visibility

One of most common claims for RLR is the complaint that a driver was not able to see the traffic signal or mistaking the color of the signal *(16)*. Although many times these claims prove false, traffic signals should be visible far enough upstream for a vehicle to safely stop. A FHWA study recommended the following improvements that would help traffic signal visibility to drivers approaching the intersection *(16):*

- *Lens Size and Type:* Increasing the diameter of the signal head from 8” to 12” will improve the visibility of the traffic signal. An unpublished research study conducted in Winston-Salem, NC showed a 47 percent decrease in RLR right angle crashes at intersections with 12” lenses using a simple before-and-after study *(16, 21)*. The same FHWA report also suggests using Light Emitting Diodes (LED) for traffic signal lenses. LEDs are tiny electronic lights that emit a signal color which is amplified with lenses to create a brighter light than the traditional 135-watt incandescent lights which are traditionally used in traffic signals *(16)*. LEDs last 4-5 years longer and use 90% less energy that traditional traffic signal lights *(16)*. Furthermore, preliminary studies have shown LED lights activate much quicker, giving drivers fractions of a second more to react to the change in color *(22)*.

- *Backplates:* Backplates are common at most traffic signals, and are particularly helpful if a vehicle is traveling east-west to combat possible sun glare. In many communities, it is now standard practice to place backplates on every traffic signal to improve visibility for all directions *(16)*. The Manual on Uniform Traffic Control Devices (MUTCD) in section 4D.18 requires the front (view towards oncoming traffic) of the backplate to be a dull black to minimize light reflection and provide a contrast to the three traffic signal colors *(12)*. Polanis investigated the effect backplates had on crash frequency and found they decreased right-angle crashes by 32 percent *(21)*.

In 1998, a research study conducted in British Columbia, Canada by Miska, de Leur, and Sayed investigated the effects of installing yellow reflective tape on the edge of the backplates to combat various claims of not being able to visually see the traffic signals at studied intersection. As shown below in Figure 1, a 75mm reflective 3M tape border was installed on single heads of six traffic signals at six intersections. The cost of installation was minimal at $35 per signal and around $420 per intersections. Miska, de Leur, and Sayed concluded that the numbers of claims were reduced up to 60% *(23, 24)*.

Figure 2. Signal with high intensity yellow retroreflective tape on backplate (23).

- *Placement:* Although the MUTCD does not specify or require that the traffic signals be over each lane and be attached to a pole, studies in Iowa and Missouri have shown 32 and 25 percent reductions in crashes at intersections with traffic signals attached to mast and poles *(16)*. An FHWA report states that traffic signals located above each lane overcome three important obstacles that median or roadside traffic signals have: (1) they generally do not provide good conspicuity, (2) mounting locations may not provide a display with clear meaning and (3) motorists' line-of-sight blockage to the signal head due to other vehicles, particularly trucks, in the traffic stream *(16)*. Shown below in Figure 3 is a typical high speed intersection in Colorado where 12" diameter traffic signal heads are located over each travel lane. Also note the 8"diameter pole mounted signal head to aid vehicles that cannot see the overhead traffic signals due to blockage from trucks or other large vehicles.

Figure 3. CDOT specified high-speed intersection traffic signal (25).

Shown below in TABLE 6 are a summary of the effectiveness of some typical countermeasures to improve signal visibility at intersections.

TABLE 6 Effectiveness of Countermeasures Intended to Improve Signal Visibility and / or Conspicuity (26)

Countermeasure	Measure of Effectiveness	Reduction due to Implementation	Sample Size	Reference
Increase signal lens from 8 to 12 in.	Right-angle crash	47	55 intersections	[Polanis, 2002][58]
Add back plates to signal heads	Right-angle crash	32	6 intersections	[Polanis, 2002][58]
Add supplemental signal heads	Right-angle crash	47	11 intersections	[Polanis, 2002][58]
Add a second red indication to each head	Right-angle crash	33	9 intersections	[Polanis, 2002][58]
Add LED signal lenses	Red light running frequency	54	1 intersection	[Bonneson, 2002][2]
Add a strobe light in the red indication	Right-angle crash	15	6 intersections	[Cottrell, 1995][61]

Addition of Advance Warning Signs

One of the most commonly used countermeasures to warn drivers of an approaching intersection are advance warning signage, as shown in Figure 4. The sign on the left, a W3-3, is typical in urban areas where advance warning may sometimes be needed in heavy congestion. Secondly, these signs can be accompanied by flashing warning lights or flags attached to the sign. In a study conducted by Polanis, it was found the W3-3 warning signs reduced right-angle crashes by 44 percent at signalized intersections *(21)*.

Figure 4. Advance intersection warning signs (12).

Another type of advance warning device is also shown in Figure 4, which is the "Be Prepared to Stop" (W3-4) sign. This sign can be used as a stand-alone warning sign for either signalized intersections or conventional four-way stops *(12)*. In some cases, flashing lights have been attached to this sign and coordinated with intersections to flash during the green phase of the approach leg. Bonneson et al. states that this sign has been found to particularly reduce RLR-associated crashes up to 67 percent *(17)*.

Physical Improvements

Removal of Unneeded Traffic Signals

Removal of traffic signals at low volume intersections can be an effective countermeasure if safety and intersection operation is not degraded. This idea works well at low volume side streets where traffic is directed to main arterial corridors. In a study performed by Retting et al., 199 signals were removed from signalized intersections in Philadelphia, Pa., and it was found that crashes were reduced by 24 percent *(7k)*.

Added Capacity with Additional Lanes

Another factor contributing to RLR is the congestion at signalized intersections. Sometimes intersections may not be built to handle peak-hour traffic either as a result of physical or economic constraints. Many times, drivers have no intentions of running a red light but are forced to do so if they are making a left turn in the intersection when the phase change happens. Although many jurisdictions recognize that vehicles in the intersection are not running red lights, drivers of vehicles behind the stop bar may be persuaded to run the red light behind the vehicles that is in the intersections. The first correction that should be considered is adjusting the phasing, which many times can greatly improve traffic congestion *(17)*. The second, more costly option is to add additional lanes, whether it is through or turning lanes, or alternatively, converting the intersection to a roundabout.

Adjust Curve Geometry

Intersections can be complicated by horizontal or vertical curves, which can lead to a higher frequency of RLR crashes. Vertical curves can affect drivers in both uphill and downhill conditions. This may cause the driver to misjudge the stopping distance or prevent the driver from being able to fully see the traffic signals before approaching the intersection *(17)*. Sharp horizontal curves place high demands on the driver to accurately drive through the curve and negotiate a possible traffic signal at the same time *(17)*.

2.2.2 Public Education

Public awareness campaigns are crucial at the beginning of a red light enforcement program, and their implementation is a productive way to gain public awareness when there is a problem in a jurisdiction. According to a FHWA Red Light Running Camera's Operational Guidelines, one of the key messages for a RLR education campaign should be the fatality and injury consequences and resulting emotional and economical tolls of RLR *(27)*.

2.2.3 Enforcement

Rat Box Light Enforcement

"Rat Boxes", "White Light Enforcement", or also referred to as "The Tattler" are a form of enforcement that are simple and cost effective and can be integrated into an existing traffic signal system. Constructed for about $100, a rat box consists of a small LED or incandescent light that is placed on the backside or underneath a traffic signal as shown in Figure 5. Once the approach traffic signal turns red, the light will activate and will turn off during the green and yellow interval. The system is designed so that a single police officer can sit downstream of the intersection and catch RLR violators while watching each approach stop bar when its designated traffic signal turns red and the rat box illuminates.

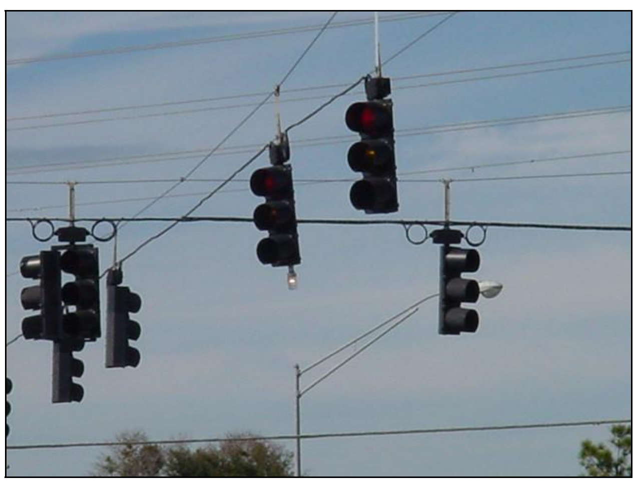


Figure 5. White enforcement light in Hillsborough County, Florida (28).

White light enforcement is heavily used in the state of Florida. A 2003 report states that intersections with the system installed showed a 50% decrease in RLR violations and an 11% decrease in crashes over a 3-month period in 2001 *(28)*.

Targeted Police Enforcement

Enforcement countermeasures require either the use of police officers or automated enforcement at intersections. Bonneson et al. states that police presence have shown to have a significant short-term effect on reducing crash frequency; however, having a police officer at an intersection for long periods of time would be costly and may pose a risk to bystanders if a police chase is needed *(17)*.

Automated Enforcement

The final and most controversial countermeasure is automated enforcement, whether it is RLR cameras or photo-radar speed cameras. Although automated enforcement has shown to reduce right-angle crashes by 32 to 42 percent, legal battles, public opposition, and upfront costs have prevented many cities from implementing such a system *(7k)*.

2.3 AUTOMATED ENFORCEMENT

Today's RLR camera systems date back to previous technology known as photo-radar which is currently used heavily outside of the United States as a form of automated enforcement. Photo-radar enforcement is a derived technology from several pieces of technology such as a camera, radar, and electronic controls. Using these known instruments, automated enforcement began with crude and questionable testing to slow drivers, eventually capturing the violator on film.

The first recorded method of primitive automated enforcement in the United States dates back to the year 1902 in Westchester County, New York. This simple yet highly effective system consisted of three tree trunks located along a road at one-mile intervals. A police officer was concealed at each tree trunk with a stop watch (Panther Speed Device) and telephone. Once the violator passed the first trunk, the police officer telephoned the time to the second officer at the next tree trunk, and then computed the speed for the one mile interval. If the vehicle was exceeding the speed limit, the second officer would contact the third officer via a telephone to stop the vehicle with a giant pole that was lowered across the road. This method was constantly questioned in court because each officer had to testify in court regarding their recorded time and associated calculations *(29)*.

While the concept of modern photo-radar automated enforcement is relatively common technology, it is not the first speed detection device to use a camera. In 1910, Massachusetts researchers created a device known as a photo speed recorder which consisted of a camera synchronized with a stopwatch. The camera took pictures of vehicles at a measured time interval. The speed of the passing vehicle was determined by mathematical calculations after viewing the vehicle's size in multiple photos taken by the camera in progression *(29)*.

Photo-radar, law enforcement's latest innovation, is a combination of these two previous technologies, minus the human factor. Introduced to society in the 1940s, photo-radar technology uses automated electronic controls, which are activated when radar detects a vehicle. A camera, also activated by the electronic controls, can take pictures at multiple zooms and angles depending on its use. With this technology constantly improving, inventors such as Maurice Gatsonides were able to find new uses for it, including RLR cameras, the predecessor of the automated photo-radar speed cameras.

2.4 AUTOMATED RED LIGHT CAMERAS

2.4.1 Early Camera Technology

The modern automated RLR camera system was invented by Maurice Gatsonides, a Dutch citizen and world-renowned race and rally car driver. Born in 1911 in Gombong, Java, he was the son of a Holland diplomat. As an aspiring KLM Airlines pilot, Gatsonides entered motor sports which led him to British auto racing and winning the Monte Carlo race in 1953. After retiring from the circuit in the mid-1960s, Gatsonides used his vast knowledge of driving and electronics to create the Netherlands-based company Gatsometer (now Gatso BV). The original company invented two products, which are still used in the transportation field to this day *(30)*.

Figure 6. First mobile Gatsometer (31).

Figure 7. First Gatso mobile camera system (32).

Maurice Gatsonides' first invention to capture drivers was the speed camera system, shown in Figure 6. First tested in 1958, it later proved to be the most reliable in the industry. Comprised of a moped, camera, two road tubes, and a mechanical stopwatch, the system was moved easily to different intersections or road segments depending on the client's need. The original intent of this system was to develop a technology to show Gatsonides his speed as his car raced around a corner using the pneumatic road tubes. After the photo camera was activated by a human, a fast speed study was performed by a mechanical stopwatch, which used the pulses from the road tubes at intersections. Gatsometer's second breakthrough product is shown in Figure 7, which were the first speed flash camera invented in 1971, using radar technology to capture RLR and speeding violators. Later, this same technology would be implemented into a camera system that would capture vehicles running a red light based on its approach speed. Gatsometer has been a leader in the RLR camera technology, having made great progress in automated enforcement including mobile cameras, hidden camera technologies, toll booth enforcement, and cameras to capture the driver's face as shown in Figure 8 and Figure 9.

Figure 8. Gatso driver face camera (31).

Figure 9. Gatso RLR camera system (31).

2.4.2 Modern Camera Technology

RLR cameras serve three purposes. First, RLR cameras are used to enforce traffic signal compliance. Second, the cameras can reduce the frequency of RLR violations and have proven effective in reducing fatal collisions. Last, RLR cameras generate a revenue for the city which in many cases fund enforcement programs or investing in the community (e.g. parks, recreation, fire department) *(4j)*. The success of these three functions is dependent on how the camera is set up and the technology that is in place.

Gary Erikson, a researcher in RLR camera technology at Eastman Kodak, cites the following nine requirements that automated enforcement systems should include *(33)*:

- The ability to capture, transmit, process, store, and recover captured images so data may be managed in an efficient manner
- Sufficient resolution to satisfy court standards for the image-reading of vehicle license plates, clear detail of the vehicle, and identification of the vehicle operator, if necessary
- The capability to prevent the spreading of overexposure portions of an image (anti-blooming) that may result from vehicle headlights or sunlight from highly reflective surfaces
- Adequate differentiation of light to dark areas within an image to provide necessary details (also referred to as contrast latitude)
- The ability to detect at varying levels of light
- Image enhancement circuitry to eliminate major sensor defects such as bright or dark columns which detract from the visible presentation of an image
- Continuous read-out of images to support monitoring along with single frame capture capability for recognizing several successive vehicles committing a violation
- The ability to be moved to different locations or to be mounted into a permanent position; and
- Environmentally friendly components

A typical red light camera system can cost $50,000 or more depending on the intersection and number of cameras *(4j)*. For many communities, a $50,000 system might be too expensive for operating and maintenance for the amount of enforcement needed at the intersection. An option to offset the cost of the system is using a portable camera system and a "dummy" flash system. The portable camera system can be moved between multiple intersections if the camera is mounted in a vehicle, or can be mounted on existing structures. The dummy flash system is a camera flash that is mounted next to an empty camera box and flashes if there is a red light violator, fooling the driver to think he or she was caught by a RLR camera *(7j)*.

Figure 10. Gatso RLR camera system (Atlanta, GA).

Figure 11. Transol RLR camera (Davenport, IA).

RLR cameras are located typically in weatherproof, vandalism-protected metal boxes. Placed close to the intersection on hinged poles or fixed onto a traffic signal structure, these boxes are mounted 10-15 feet in the air as shown in Figure 10. Other RLR camera systems are integrated into the existing traffic signal hardware as shown in Figure 11. The red light camera system is typically connected both to the traffic signal controller and to dedicated inductive loops in the pavement at or before the stop bars or to the auto scopes at the intersection. Although many traffic equipment vendors claim one automated enforcement camera system can monitor four lanes of traffic, studies performed in New York City have shown accurate photography can only be accomplished in three travel lanes *(34)*. Typically the RLR camera inductive loop system is separate from signal control inductive loops so that minimal interference will occur.

When a traffic signal switches to a red phase, the automated enforcement system is activated, and the camera is ready to take a picture. Violating vehicles will cross a trigger mechanism, which could include road tubes, inductive loop sensors, piezoelectric strips (pressure sensors), radar, or lasers. A minimum time period and preset speed limit are built into the trigger mechanism, allowing the system to differentiate between vehicles attempting to make a stop, turn, or run through the intersection. This grace period is typically 3/10 of a second with a typical minimum speed limit of 15-20 mph *(34)*. A second photo of the violating vehicle is taken seconds after the first photo showing the traffic signal color and offending vehicle in the middle of the intersection. In some cases, a third photograph is taken to capture the offending vehicle's license plate.
Two pictures taken from the Mesa, Arizona red light automated enforcement system are shown in Figure 12 and Figure 13. These two picture were originally taken in high resolution color, but were rendered to a lower resolution for the reproduction in this report. The City of Mesa, Arizona uses advanced digital camera systems, which are estimated to have over a 10 mega pixels resolution with zoom capabilities to identify humans in the car and license plate numbers. The magnified pictures are not presented in this report for legal reasons.

Figure 12 shows the sport utility vehicle (SUV) has clearly passed the stop bar and is currently proceeding through the crosswalk. The black bar at the top of the photo displays current information about the picture frame. The date, time, and location are current to the image. The recorded speed is shown at 46 mph, and the current signal phase is "R" or red. RTIME, short for "red time," is shown as 0.2 or two-tenths seconds after the traffic signal had turned red. Also shown is the lane number; this number tells which lane the offending vehicle is in. Typically the lanes are counted from the inside out in one direction if more than one camera is present. Lastly, the frame tells the reader which picture is being shown; for example frame A equals picture 1, while frame B equals picture 2.

Figure 13 is the second photo taken by the Mesa, Arizona red light enforcement system, showing the SUV clearly inside the intersection. As shown in the photo's black box at the top, much of the information has remained constant except the time and the red time, which is currently at 0.95 seconds. By viewing both Figures 6 and 7, a Mesa, Arizona police officer can conclude that the SUV entered the intersection illegally 0.2 seconds after the traffic signal had turned red.

Depending on the type of automated enforcement system, photographic evidence of the violating driver will be electronically or physically sent to a photo-processing center where each offending photo is reviewed by a police officer. If the officer concludes that a moving violation has occurred, the owner of the offending vehicle will be issued and mailed a moving citation, municipal citation, or a traffic citation depending on the state legislation.

Figure 12. First picture taken by an automated RLR enforcement camera (Mesa, AZ).

Figure 13. Second picture taken by an automated RLR enforcement camera (Mesa, AZ).

2.4.3 Camera Systems & Plate Identification Systems

Currently, there are three different types of mediums to capture red light runners. Depending on how new the system is and whether or not the photos will be captured digitally determines what kind of photography will be used. Today, there are three different types of cameras available:

- 35-millimeter Wet Film imagery
- Video imagery
- Digital imagery

Although these mediums are used for RLR enforcement, these systems have also been proven successful for railroad crossing, speed detection, and traffic studies. All three types of cameras are able to produce blur-free, shock resisted images in all weather and lighting conditions. Along with the camera unit, many accessories such as various flash types, filters, and lenses can be added depending on the brightness and photo required for the intersection.

35-millimeter Cameras

35-millimeter "wet film" camera technology is the oldest and most common form of automated enforcement of RLR technology. Wet film photographs can be taken either in black and white or in full color. Many jurisdictions prefer color photographs to indicate which phase the traffic signal was in during the violation and the color of the vehicle. However, these photos are generally more expensive and time consuming to process. 35-millimeter cameras typically sit on adjusting poles which make collecting film and maintenance easier.

Typical 35-millimeter RLR cameras capture two succeeding images per second with a shutter speed of 1/1000 of a second. 35-millimeter cameras automatically adjust light input and focusing to capture the best image possible *(35)*. It is estimated that 35-millimeter red light camera systems cost approximately $5,000 per camera to operate *(36)*. The main benefit of using wet film technology is the difficulty in tampering with the equipment or film. However, there are numerous disadvantages to this technology, which include the manual labor involved in collecting, processing, preparing, and mailing of citations.

Video Cameras

Autoscope technology is widely used in the transportation field as a cost-effective medium to study and manage traffic. Many video detection camera systems can be seen high above intersections controlling traffic signals by use of observing vehicles and the changing pixels, but they are not used for capturing red light violators. The use of video recording such as this as evidence in court is not permitted in many states *(34)*.

Video camera technology is very much the same as a digital image or 35-millimeter image when the system is used to capture individual vehicles. A typical video camera enforcement system typically includes constantly recording video in color or black and white, and it is normally outlined with a box to activate the RLR system established by computer software *(4j)*. Once a traffic signal turns red and a vehicle enters the outlined box, another software package recognizes the license plates, and it runs a computer software program performing automatic vehicle identification. The main advantage of the video camera system is it does not need activation devices such as inductive loops or laser detectors. Also, issuing tickets is simplified due to having a full length video instead of two static pictures.

Because of legal concerns attached to video recording, many jurisdictions use video camera systems to record intersections over a long period of time to study the severity of RLR and use video evidence as support to implementing a RLR enforcement program.

Digital Cameras

The use of digital camera systems for RLR technology is the newest method in capturing vehicle images. The first commercially available digital camera was sold in 1991 by Kodak Eastman for $13,000, and it offered 16 megabits of memory with resolution of 1.3 mega pixels. The introduction of the digital camera opened a new door for groups beyond commercial camera users, particularly the transportation industry. Digital cameras use the same hardware mounting equipment as traditional 35-millimeter cameras, and these systems can be installed in existing cabinets along with existing inductive loop systems. Traffipax, a vendor in the digital red light camera industry, offers a camera system with 10.7 mega pixels (4008 x 2672) resolution and a 250 gigabyte hard drive that can monitor four lanes of traffic on a single approach. In addition, this new technology combines digital video recording, which can be used for secondary evidence or incident management if needed by police officials *(37)*.

Along with producing and recording better vehicle images, better processing and dissemination of citations are the main improvements for digital enforcement cameras. Digital camera systems have the technology to have dedicated phone lines to download photography every day to processing centers nearly anywhere. This method streamlines the traditional processing method of having personnel remove film from the cameras, develop the film, run license plate matching algorithms, and prepare to mail tickets to city police officials before mailing the ticket to the driver *(34)*. Ultimately, this system is designed to reduce human error by having digital imagery which can be examined by computer software and reduce the overall time from picture capture to ticket delivery.

2.5 RLR PROGRAMS

In 1992, in a response to the high percentage of intersection crashes, the Federal Highway Administration (FHWA) began a campaign to increase public awareness of about RLR. Six city and county jurisdictions, including Los Angeles County, Calif., Polk County, Fla., Howard County, Fla., Howard County, Md., Charleston, S.C., and Washington, D.C., received grants to test and evaluate wet film camera technology to catch RLR violators *(38)*.

Since the implementation and study of the six original cities, the FHWA has given out 32 additional grants to numerous cities and counties, and as of 2000 the use of RLR cameras has risen considerably throughout the United States. Today, over 110 cities in 20 states use a RLR system, which includes cameras and/or warning signs *(39)*. Although the technology has greatly improved over the years, it is still a costly and time-consuming project for many cities. Case studies in this section were selected based on the amount of information available and the positive impact the RLR program had on society.

2.5.1 New York City, New York

New York City has one of the largest RLR automated enforcement systems in the United States with over 50 cameras in place. Legislation was just signed to add 50 more, bringing the enforcement up to 100 intersections. Mr. Rudolph E. Popolizo, P.E., chief of the New York City RLR program, has published numerous articles and papers defending the city's view and history of this program, which has proven to be controversial. The New York City Department of Transportation started researching RLR technology in 1983 to better understand the technology being used in Europe and Australia *(40)*.

With the start of this large research undertaking, the city of New York took an unconventional approach by allowing three RLR camera vendors to demonstrate the potential technology. This demonstration processed proved to be a successful event and piqued interest throughout the government.

In March of 1989, a request for information (RFI) was issued with two major guidelines attached to it. The first guideline stated that the red light camera system had to be a stand-alone operation that did not interact with any other existing summonsing or tracking process. The second guideline stipulated that two pictures must be taken to validate a violation actually occurred *(40)*. By having the camera system exist as a stand-alone operation, the system was allowed to accurately track and record each Notice of Liability (NOL) and eliminate administrative error on the part of the city.

The camera system test had initial problems, including blocked line-of-sight, especially due to large, parked delivery trucks in nearby lanes. To counteract this, the camera systems were placed higher on mast arms, 16 feet high and 8 feet from the curb. Another problem involved glares in the photographs from the flash mounted next to the camera. This problem occurred during different times of the day and also when the weather deteriorated *(41)*.

Finally, in July of 1989, a request for proposals (RFP) was issued and included a "sunset provision," which states the following:

- The City is empowered to install and operate devices at no more than 25 intersections; (b) the registered owner of the vehicle in violation shall be sent a NOL by first class mail; (c) a liable owner may be assessed a monetary fine of $50 (N.Y. Vehicle and Traffic Law §1111-a); (d) original determination of liability shall be made by a technician based upon inspection of photographs; (e) a person charged with liability shall have the opportunity to contest the charge. This sunset provision has been extended indefinitely with the option for more than 100 intersections instead of the original 25 *(40)*.

Because of the city's fiscal constraints, Electronic Data Systems (EDS) won the RFP and stated the company could provide the service for "no cost to the city" as stated by EDS *(40)*. After months of negotiations and intersection demonstrations, the city of New York agreed on an $8,440,000 contract with a city cost of $5,460,000 for a total contract cost of $13,900,000 *(40)*.

Over the last decade, the camera system in New York City has proven successful. During the 2003 fiscal year, the city of New York issues 308,100 red light camera violations *(42)*, while overall violations have decreased 38 percent since the program started *(41)*. It is also worth noting that over a three-year revenue study conducted by the city of New York, revenues from ticket violations came to a total of $18.5 million, while the cost of the program for the same three years cost the city $15.5 million, which gave the city a $3 million profit *(41)*.

2.5.2 San Francisco, California

In 1996, the City of San Francisco started a RLR study to see whether a system could combat the ever-increasing number of violators. Three vendors were invited to participate in the study, although one declined the offer. Electronic Data Systems and US Public Technologies, both currently owned by Lockheed Martin, each set up cameras at two intersections. Each company was paid $30,000 by the city for the study, and tickets costing $17.50 were issued for each violation. By March 1997, over 2,500 citations had been issued, and only US Public Technologies was the prime contractor *(43)*.

San Francisco started its RLR program after a high profile crash that sparked a media frenzy to have the city take action. In October 1994, a driver ran a red light near The San Francisco University. Swerving to miss another vehicle, the driver lost control of the automobile, injuring 13 students waiting for a bus *(44)*.

This incident also prompted the city to start a massive media campaign, which included billboards, TV commercials, radio announcements, and catchy slogans such as "RED Means STOP." This campaign was generally accepted by the community and local media. This incident also prompted the California State Legislature to amend the California Vehicle Code in 1996 (SB833), which permits the use of "automated enforcement" for RLR violations *(45)*. With the passing of Senate Bill 833, the California Vehicle Code was amended to make running a red light a moving violation in which a fine and points were assessed to the driver. Another important legislative bill passed in California was Assembly Bill 1191, commonly known as "The Shelly Bill," in 1998. Assembly Bill 1191 passed with overwhelming success, which provided $80 out of a $271 ticket to cover the cost of existing automated enforcement and provide funding for 25 new RLR camera systems *(34)*.

TABLE 7 Collisions Caused by Red Light Violations in San Francisco, 1992-1997 (46)

Year	Injury Collisions	Fatalities	Total Injured
1992	780	3	1367
1993	779	5	1320
1994	781	4	1293
1995	809	4	1343
*1996	780	5	1297
1997	724	1	1198

*1996: RLR system is activated

The 1996 San Francisco RLR campaign was a success. Between 1996 and 1999, the city issued over 10,000 citations that were captured by cameras and recorded an average of 20,000 citations reported by officers in the field *(44)*. The most noticeable impacts of the RLR campaign was a 42 percent decrease in red light runners and a 9 percent citywide reduction in collisions and injuries in 1997 *(44)*. Shown in TABLE 7 are the decrease in collisions and injuries around the time of the RLR cameras installation *(46)*. With these numbers set in 1997, city officials submitted a RFP to expand the program by 20 intersections by 1998 which resulted in the passing of The Shelly Bill.

2.5.3 Portland, Oregon

Portland, Ore., started its automated enforcement program in 1995 when the state legislature allowed the cities of Portland and Beaverton to test photo-radar equipment for speeding. After overwhelming success with this pilot program, which lasted until 1997, the photo-radar program was extended indefinitely. Automated RLR enforcement was requested after the city of Portland reported 12,000 collisions per year caused by RLR *(47)*. The city of Portland cited that because of the rapidly growing population, city police officials could not enforce all parts of the city with their limited budget. Portland city officials also cited that automated enforcement would be an inexpensive and safe way to enforce problem intersections.

As of 2003, the City of Portland has six operational RLR cameras at five intersections. These intersections were selected due to a high rate of observed red light runners which ranged from 2.3 to 3.7 violations per hour prior to the installation of the system. During the study period from October 2001 to August 2002, the five intersections reported a 60 to 87 percent decline in violations, and over 150,000 red light violations were avoided *(48)*. Shown below in TABLE 8 are the results of this study for the five intersections.

TABLE 8 Portland Monthly Red Light Camera Analysis, Violations per Hour per Month (48)

Location	Prior to Cameras	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	1st Month vs. Aug. % Change	Prior vs. Aug. % Change
NE 39th & Sandy														
Violations per Hour	**2.92**	0.53	0.45	0.53	0.38	0.41	0.3	0.41	0.44	0.39	0.36	0.37	**-30%**	**-87%**
NE 39th & Sandy														
Violations per Hour	**3.71**	1.73	1.47	1.37	1.21	1.25	1.42	1.41	1.28	1.35	1.3	1.21	**-30%**	**-67%**
E Burnside & Grand														
Violations per Hour	**2.21**	0.21	0.26	0.27	0.2	0.25	0.22	0.18	0.28	0.42	0.59	0.39	**86%**	**-82%**
W Burnside & 19th														
Violations per Hour	**3.04**	n/a	n/a	n/a	1.26	1.19	1.13	1.2	1.17	1.24	1.27	1.22	**-3%**	**-60%**
SE Grand & Madision														
Violations per Hour	**2.33**	n/a	n/a	n/a	0.43	0.66	0.72	0.67	0.65	0.7	0.77	0.62	**44%**	**-73%**

As illustrated, every intersection had a substantial decrease in violations per hour over the eleventh - and eight -month study periods between October 2001 through August 2002. The City of Portland attributes the success of the system to the extensive public outreach used to inform drivers of the new system being installed at these intersections.

In 1995, Portland started its public outreach campaign to the community by educating drivers about the photo-radar system which was the first of the two implemented programs. It was found that the public supported the initiative and a post-survey demonstrated that drivers showed a high awareness of the program *(48)*. In

1996, Portland joined the national "Stop! For Red Lights Campaign" and informed the public using such mediums as television, newsletters, and neighborhood association flyers *(47)*. Once the city gained support of the public, Portland sought legislative approval for the red light camera enforcement, which passed in the 1999 session of Congress. This program has been highly successful, and as of 2006, the city of Portland is looking to expand its RLR and photo-radar enforcement program.

2.6 SYSTEM EFFECTIVENESS

Automated RLR enforcement camera effectiveness is constantly debated among government officials and citizens who see cameras as either "intrusive" or "constitutionally illegal" to an extent *(49)*. While less controversial than speed enforcement programs found in Europe and various U.S. cities, RLR camera programs are not entirely without controversy or questioning *(50)*. In some cases, it has been argued that automated red light running enforcement increases the percentage of rear end collisions *(49, 51b)*. It is necessary to conduct effectiveness studies on any type of countermeasure to determine the validity of its intended use. Very few research studies have fully explained the effectiveness of automated RLR cameras within a certain city while taking other variables into consideration such as spillover effects, regression to the mean bias, and the use of control / comparison intersections. Based on available literature sources at the time of this study, it was determined that there were no other studies performed using multiple RLR programs in the same state to compare programs and determine their effectiveness. A statewide effectiveness study could be useful for such agencies as other cities investigating the possible use of automated enforcement, or a state department of transportation to quantify the safety benefits. Automated RLR camera enforcement effectiveness can be determined by use of various methods depending on the amount of data available, and the length of time the system has been in place. In an FHWA report, researchers found through an extensive literature review that many factors should be taken into consideration when performing an automated red light running effectiveness study *(50)*:

- Number of treatment sites
- Spillover effects in the same city
- Differences in accident investigation and reporting practices between cities
- Defining "RLR crash"
- RLR camera effects on rear end crashes
- Exposure changes between before-and-after periods
- Regression to the mean effects
- Yellow interval improvements at the time of installation
- Disaggregate effects by signalization variables
- Effects of signage
- Public education level
- Type of ticketing

- Definition of a RLR violation

2.6.1 Spillover Effects

A spillover or "halo" effect is a phenomenon that can occur in any before and after experimental study where a treatment or countermeasure in a small area can affect a larger area. In cases of RLR enforcement, it is all too common for jurisdictions to report to the public the positive effects of RLR cameras without investigating nearby intersections or using control intersections without cameras to compare results. There is some recent evidence that RLR systems not only deter motorists from breaking the law by running a red light, but can also modify driver behavior at nearby intersections without RLR systems within a certain distance of the intersection with camera enforcement *(49)*. If an aggressive public awareness or education campaign happened prior to the installation of the camera system or public legal battles after installation, the spillover effect would be expected to significantly impact results in effectiveness *(49)*. In an effectiveness study conducted by Retting and Kyrychenko for the City of Oxnard, California, significant evidence of spillover was found using control sites: reductions in violations at similar intersections showing a positive effect on the entire community *(52, 49)*. It is recommended by the NCHRP Synthesis 310 to use non-RLR equipped intersections from other jurisdictions for effectiveness studies along with non-RLR equipped control intersections within the same city as RLR equipped intersections *(49)*. A study conducted by Cunninghman and Hummer of the Institute for Transportation Research and Education at North Carolina State University recommends two criteria for selecting comparison intersections for spillover effects: (1) The comparison site is to be located within 1 mile of the intersections with cameras, and (2) the comparison intersection must lie on the same corridor *(53)*.

2.6.2 RLR Performance Measures

To properly evaluate the frequency of red light violators, whether looking at an intersection or a countermeasure, a consistent unit of measure must be used. Shown in TABLE 9, Quiroga et al. created a table which defines RLR measures of effectiveness and what units should be used.

TABLE 9 RLR Performance Measures (26)

Incident	Frequency-Based Measure	Rate Expressions	Location
Entry during yellow interval	1. Vehicles entering during the yellow interval. 2. Cycles with one or more entries on yellow.	…per hour …per cycle	…per lane …per approach
Entry during red interval	3. Vehicles entering during the red interval. 4. Cycles with one or more entries on red. 5. Vehicles in intersection after end of all-red. 6. Vehicles entering in first "X" seconds of red.	…per vehicle	…per intersection
Conflict due to red light running	7. Vehicle-vehicle conflict.		

[1]"Per vehicle" relates to the total number of vehicles counted for the subject location
[2]If the numerator and denominator have common units, the ratio is often expressed as a percentage

As shown in the second column of TABLE 9, number 6 uses "X" as a variable for the number of seconds passed when the vehicle has entered the intersection on the red phase. By dividing the frequency-based measure by the normalizing factor (or rate expression), the recorded number of incidents is converted into a rate-based measure *(26)*. Bonneson et al. indicate a combined use of the terms "per cycle" and "per vehicle" into the most appropriate frequency measurement unit of "RLR per 100,000 vehicle-cycles." *(17)*

2.6.3 Violation and Crash Studies

To evaluate the safety benefits of a RLR camera system at an intersection, corridor, or system as a whole, one must first establish whether the RLR camera system will produce desired or undesired results. Burkey and Obeng states that the goals of a safety program can be measured in terms of compliance with the law (e.g. seatbelts, speed reduction, child safety seats), or it can be measured as to how many crashes resulting in fatalities, injuries, and property damage the system can reduce *(54)*. To measure the effects on reducing crashes, two data collection methods can be used to evaluate and measure the system's effectiveness with the aid of various statistical methods. Although the NCHRP Synthesis 310 recommends many ways to evaluate effectiveness using real or collected data, other methods such as surveys, interviews, or annual revenue generated can also give insight into effectiveness *(49)*.

RLR Violation Study

Data Collection

Violation studies are a common method to determine the effectiveness of a countermeasure. As mentioned previously, violation studies can be performed with a variety of photographic technology including video, digital, and wet film photography *(4j)*. Video is typically taken at intersections of interest, with multiple cameras looking at approaching lanes and traffic signals for a certain time duration or at peak hours. The most widely used technology in capturing violating vehicles is Autoscope technology.

Autoscope technology was first introduced in the early 1970's by University of Minnesota researchers as proposed video technology to study traffic flow, automatic surveillance, incident management, and signal control *(55)*. Mass production of Autoscope technology started as a joint venture between the University of Minnesota and Econolite Control products in 1984, and advanced software packages were created as a computer overlay program to video taken in the field to evaluate speed, counts, and even operate traffic signal at intersections *(55)*. In a violation study performed by Kamyab and McDonald in 2000, two methods of video recording were tested, including a trailer-mounted Autoscopes and a wireless Autoscope system. As shown below in Figure 14, two Autoscope cameras were mounted on a 35 foot pneumatic mast pole and were connected to recording devices located inside the trailer *(4j)*.

Figure 14. Mobile Autoscope trailer (CTRE, Iowa State University).

Kamyab and McDonald concluded that the Autoscopes mounted on the trailer were not flexible enough to provide a clear image of an intersection without a zoom lens. It was also noted that the apparatus at the intersection would counteract the study by distracting drivers approaching the intersection *(4j)*.

The second method used by Kamyab and McDonald included unattended wireless Autoscopes that recorded both the traffic signal and approach leg of the intersection. Two cameras were installed at intersections; of interest, one camera monitored the approach traffic signal, and the other camera watched the approaching stop bar from the front. As shown in Figure 15, both cameras used spread spectrum frequencies to transmit video signals to a receiver, and a quad splitter projected both camera images on the same screen. The VCR used in the study was wired to the traffic signal cabinet and started recording when the traffic signal turned yellow, and paused when the green phase started *(4j)*.

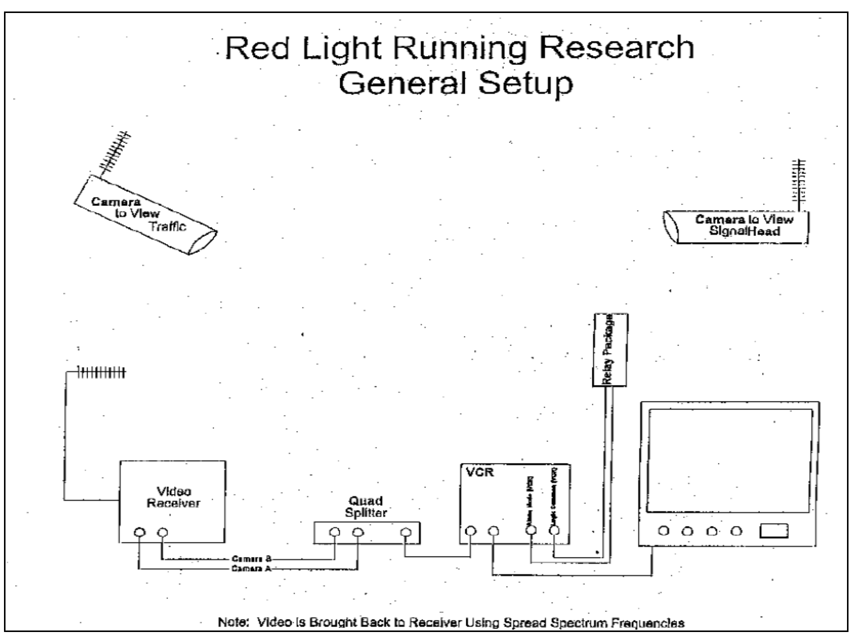


Figure 15. Wireless Autoscope system (4j).

In a similar study performed in 2007 by Retting, Ferguson, and Farmer, wireless Autoscopes were used to capture violating vehicles for the first 5 seconds of the red phase. A consistent problem found in this study involved a 0.5 second signal time delay for the video recording unit to switch from "pause" to "record," which resulted in possible violating vehicles not being captured *(56)*.

Data Analysis

Two methods can be used to extrapolate RLR violations from recorded video at an intersection *(57)*. They are:

1. Direct monitoring method
2. Machine-aided monitoring method

The Direct Monitoring Method is considered the most precise evaluation method available, but can be time-consuming and mistakes can be easily made by the evaluator depending on his or her judgment of a violation *(57)*. Shown below in Figure 16, from the Center for Transportation Research and Education at Iowa State University, a split screen was used to record RLR violations. The top picture shows a truck crossing the stop bar while the traffic signal shown below the picture is red. The research team recorded the time movement of each violation *(4j)*.

Figure 16. Direct monitoring combined camera view (CTRE, Iowa State University).

The machine-aided monitoring method's objective is to reduce the time needed to evaluate an approach with the sacrifice of minimal errors in the evaluation *(57)*. As shown below in Figure 17, Purdue University researchers used Autoscope software to detected RLR vehicles at a single intersection approach while determining entering vehicle counts and approaching vehicle speeds. Tarko et al. concluded that all violations occurred during the first 2 seconds of the red phase. Although this method proved to save considerable time extracting violations, it was determined that the video data needed to be screened a second time to verify that the software captured the violations *(57)*.

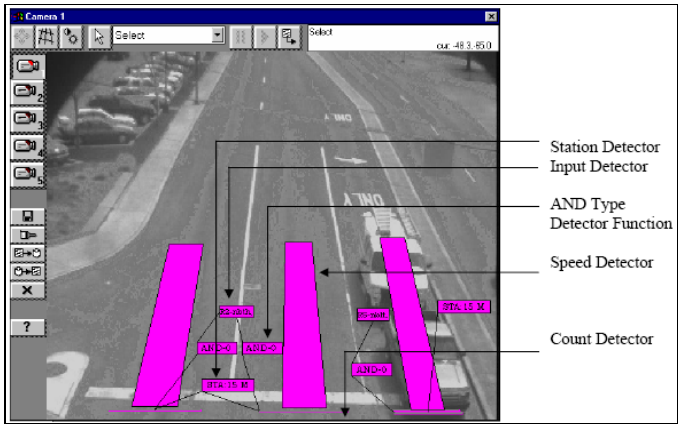


Figure 17. RLR Autoscope computer program approach overlay (57).

In a research project conducted by Washburn and Courage at the University of Florida, a third method to evaluate RLR violators was created. Red Light Running Analysis Package (RLRAP) was developed to enable users to monitor two items simultaneously, vehicles entering the intersection and the current signal status, displayed using colors while only using one video feed of the entire intersection as shown in Figure 18.

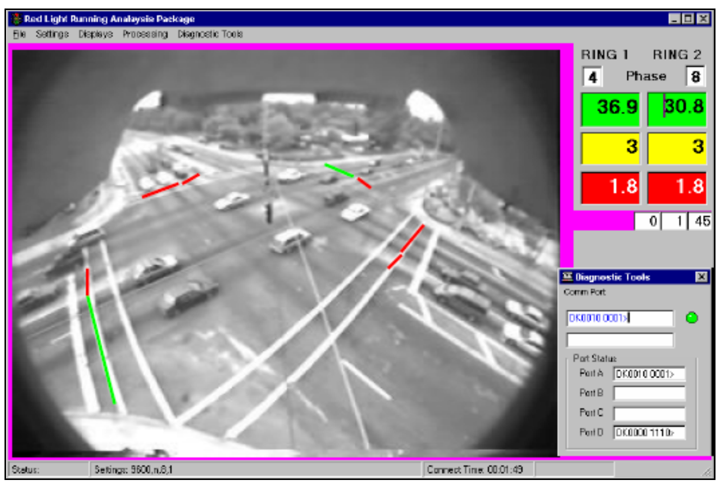


Figure 18. RLRAP monitoring an intersection (58).

Although the RLRAP software package does not include a counting program similar to that used in the Purdue study, the goal of this project was to measure the accuracy of phase timing measurements and the repeatability of those measurements over multiple playbacks of the videotape *(58)*.

Violation data collected by any of the above methods will result in a total number of RLR violators for a certain movement at an intersection. Frequency of RLR can easily be obtained by adding the total number of violations over the period of time the study took place. The rate of RLR violation rates can provide a greater insight into the overall problem. In a report by Washburn and Courage, the following equations to find RLR violation rate were suggested *(58)*:

$$RLR\ Rate(\%) = \frac{N_R \times 100}{V} \quad \textbf{[2-1]}$$

$$RLR\ Rate(TEV) = \frac{N_R \times 1000}{V} \quad \textbf{[2-2]}$$

where:

RLR Rate (%) = Average percentage of hourly volume running a red light

RLR Rate (TEV) = Average number of red light runners per thousand entering vehicles

N_R = Average number of red light runners in analysis hour

V = Peak hour volume

$$Avg.\ RLRs\ per\ Cycle = \frac{\overline{N_R}}{\overline{N_C}} \quad \textbf{[2-3]}$$

where:

$\overline{N_R}$ = Average percentage of hourly volume running a red light

$\overline{N_C}$ = Average number of cycles in analysis hour

RLR Crash Study

Crashes are the ultimate measure of safety effectiveness *(49)*. Performing a crash study to evaluate the effectiveness of RLR camera systems could include using all of the crashes occurring at the intersection or crashes on certain approaches if only certain approaches have a camera system. By evaluating the crash rate, a judgment can be made if the RLR camera system is effective in reducing crashes for a certain number of daily entering vehicles. Even though overall crash data for a certain intersection can reveal the RLR camera effectiveness, it is suggested that certain crash scenarios (types of crashes) and results (crash severity) may provide a more targeted answer for effectiveness *(49)*. NCHRP Synthesis 310 suggests five different types of study designs to measure RLR camera effectiveness based on crash data that are available. These designs include (1) before-and-after study with control group, (2) before-and-after study with comparison group, (3) simple before-and-after study, (4) cross-sectional evaluation, and (5) trend analysis *(49)*.

RLR Violation Frequency and Crash Relationship

A study performed by Bonneson et al. developed and tested a regression model to express the relationship between total crashes recorded and red light violation frequency for an approaching leg on an intersection *(17)*.

$$C_3 = m_y e^{b_0} ADT_S^{b_1} ADT_c^{b_2} RLR_r^{b_3} \quad \textbf{[2-4]}$$

where:

C_3 = Three-year count of right-angle and left-turn crashes

m_y = Number of years associated with the crash data

ADT_s = Average daily traffic volume on a subject approach

ADT_c = Average daily traffic volumes on the cross street

RLR_r = RLR rate on the subject approach, number of red-light-running events per 1000 vehicles

b_i = Regression coefficients (where i=0,1,2,…)

The above model was calibrated and tested using data obtained from 12 Texas intersection approaches. The resulting equation to model this test is shown below.

$$C_1 = 0.00278 ADT_C^{0.614} RLR_r^{0.387} \qquad \textbf{[2-5]}$$

C_1 in the above equation is the predicted annual crash frequency rate (crashes per year, right-angle plus left-turn) for a typical intersection approach. The studied intersections approach term (ADT) was not used in the final model calculation because its regression coefficient (b_1) was close to zero *(2)*. It was also found that the variable b_3, which is associated with RLR rate, had a large standard deviation in the model.

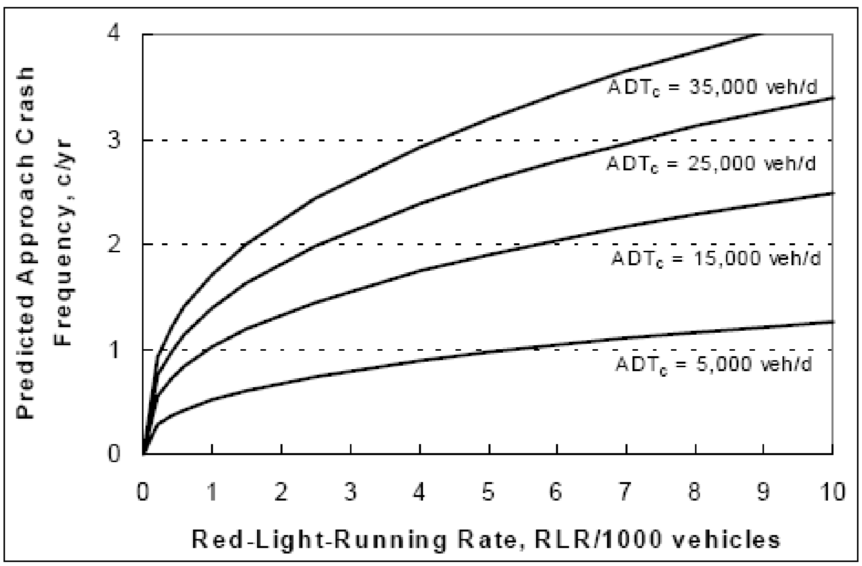


Figure 19. Predicted effect of RLR on intersection crash frequency (17).

Bonneson et al. concluded "the crash frequency increases with increasing cross-street volume and RLR rate." This conclusion is illustrated in Figure 19; as ADT increases, the crash frequency and RLR rates increase logarithmically.

2.6.4 International Results

Australia

In 1981, G.E. Maisey conducted the first research in Australia to determine the effectiveness of RLR cameras *(59)*. Although this report was not able to be obtained, another research report was able to explain Maisey's findings *(49)*. Maisey's research focused on one intersection in Perth, Australia for one year, beginning in July 1979. South et al. reported Maisey suggested that the RLR camera increased rear-end collisions and reduced right angle collisions *(51b)*. To confirm Maisey's findings, South et al. performed a second study from 1979 to 1984 and 1984 to 1986 in the city of Melbourne, Australia to evaluate the effectiveness of the RLR cameras *(49)*. South et al.'s research included 46 intersections with cameras and 50 control intersections without cameras. Their results are shown in TABLE 10. As shown, right-angle crashes decreased by as much as 32 percent, while rear-end collisions both increased and decreased. The difference in percentages are due to the definition of the rear-end event. "Rear-end" specifically refers to a vehicle that collides with the rear of another vehicle, while "rear end (turn)" refers to a rear-end collision in which the front vehicle was intending to make a turning movement at the intersection *(49)*.

TABLE 10 Results of Red Light Camera Use in Sydney (49, 51b)

Accident Type	Change (%)
Right angle	-32.0
Right angle (turn)	-25.0
Left against through	+2
Rear end	-30.8
Rear end (turn)	+28.2
Other	-2.2
All crashes	-6.7
No. of casualties	-10.4

In 1993, Hiller et al., along with the New South Whales Road and Traffic Authority, conducted a research study to determine the effectiveness of RLR cameras installed in Sydney, Australia in 1987-1989. The difference between this report and the previously mentioned reports were Hiller et al. selected 16 intersections with cameras and matched them with 16 other control intersections based on crash history. After two-year pre- and post-studies, Hiller et al. concluded the following points about RLR cameras *(51a, 49)*:

- Red light cameras, in general, appeared to reduce right-angle and right- (left-) turn against crashes, and to increase rear-end crashes. The overall crash severity was reduced.
- Red light camera hardware (signposting, signs, and housing for cameras) appeared to be effective at reducing right-angle and right- (left-) turn against crashes, even when seldom used as active sites.
- Other suitable countermeasures to the targeted crash types, such as turning lanes, S-lanes, and additional signal phases, also appear to be as effective as RLR cameras.
- Because "most-used control sites" did not demonstrate any significant reduction, Hiller et al. suggested there might not be any spillover (or halo) effect on RLR crashes at non-camera sites.

As explained in the above Australian research reports, there are a lot of possible holes in the research. However, from the research conducted, conclusions could be drawn upon the reduced crash severity (49).

Great Britain

In 2000, the United Kingdom's Department for Transport (DfT) created a pilot partnership between cities to evaluate the effectiveness of photo-radar cameras to capture speeding and RLR violators. This partnership was created with the DfT and the following communities: Cleveland, Essex, Lincolnshire, Northants, Nottingham, South Wales, Thames Valley, and Strathclyde. However, many more communities joined the partnership during the evaluation period and data was added to the four-year evaluation report. In a report for the DfT, the following was concluded after four years of study *(60)*.

- **Vehicle speeds were down** – Average vehicles speeds at speed camera sites, including red light enforcement cameras, had dropped by around 6 percent, and at new sites there was a 31 percent reduction in speeding. It was concluded that overall drivers traveling 15 mph or more over the speed limit fell 91 percent at permanent camera sites and 36 percent at mobile camera sites.
- **Both casualties and deaths were down –** After allowing for selection effects (i.e. regression to the mean) there was a 22 percent reduction in personal injury collisions where cameras were introduced. The number of people killed or seriously injured dropped by 42 percent, and 100 fewer fatalities were recorded per year per intersection. Furthermore, 1,745 fewer people were killed, and 4,230 fewer injuries were reported in 2004 alone.
- **A cost to benefit ratio of 2.7:1** – A recorded benefit to society in four years was £258 million with a total cost of £96 million for law enforcement.

Another area of Great Britain that has had success in the RLR camera field is Scotland. A study performed by R. Winn in 1993 evaluated Glasgow, Scotland's RLR system that was installed in 1991. During this time, only warnings were given to violators until 1993. Winn reported in a preliminary 1992 report that RLR was considered the primary cause of 17 percent of all crashes reported at signalized intersections. In the same study, Winn also reported a 69 percent reduction in the total RLR violations, and the violation rate (percentage of the number of violation opportunities) fell from 6.1 to 2.2 percent with the installation of RLR enforcement cameras *(49)*. Winn also published a second questionable follow-up report in 1993 which found there was a 62 percent reduction in the number of injury accidents at six signalized intersections *(51o)*. Although this number seems valid, it was also discovered that Winn showed no indication that six control intersections were used, thus making the report inconclusive *(49)*.

In 1996, Fox conducted a more complete study over three separate periods to investigate Glasgow's RLR cameras. Three main objectives were outlined in the research, which included the following *(37n)*:

- Determine characteristics and frequency of crashes at pedestrian crossings before and after the camera installation.
- Investigate the impact on all of Glasgow's signalized intersections with pedestrian crossings of the installation of RLR cameras.
- Examine results of similar regional research to see if any trends may be responsible for observed changes.

The analysis took place between 1989 and 1995. Warnings were only given at the designated intersections *(49)*. Shown in TABLE 11 11 are Fox's results from the study. The time periods, as shown in

Table 11 are the three designated study periods: (1) Before – January 1989 through June 1991, (2) Interim- July 1991 through March 1993, and (3) After- April 1993 through November 1995.

TABLE 11 Accident Severity at Signalized Junctions by Time Period (Rate per Month) (49, 51n)

	Time Period			*After-Before Change*	
Accident Severity	**Before**	**Interim**	**After**	**Difference**	**%**
Fatal per month	0.8	0.5	0.3	-0.5	-67
Serious per month	12.9	8.6	7.8	-5.2	-40
Slight per month	46.3	38.5	33.2	-13.1	-28
Noninjury per month	127.2	109.2	98.8	-28.4	-22
Grand total per month	187.1	156.9	139.9	-47.2	-25

Fox, unlike previous Glasgow researchers, performed a "spillover study," which looked at four areas of Glasgow. Two of these areas had RLR cameras while the third study area was adjacent to study areas with cameras. The fourth study area was all of Glasgow. Shown in TABLE 12 are the results of Fox's spillover test *(49, 51n)*.

TABLE 12 Changes in the Number of Personal Injury Accidents (per Month) at Signalized Junctions by Area of Incidence, Primary Causation, and Time Period (49, 51n*)*

	ALL PIAs			*RLR PIAs*			**No. of**
Area	**Before**	**After**	**%Difference**	**Before**	**After**	**%Difference**	**Junctions**
1	10.9	7.9	-27.6	3.2	2.4	-25.4	53.0
2	0.8	0.4	-51.8	0.3	0.9	-38.9	3.0
3	28.4	19.8	-30.2	3.9	3.1	-21.1	169.0
4	20.0	16.1	-19.5	3.1	2.1	-32.7	143.0

Two conclusions were made from the spillover study, as shown in TABLE 12. Fox noticed the -32.7 percent change in personal injury accidents, outside of the areas with the RLR cameras. In the report, Fox concluded that this number "demonstrates that other factors such as junction (intersection) improvements, local traffic management, and increased pedestrian and driver vigilance may have been important in reducing RLR crashes across the whole area [of Glasgow] *(51n)*." The second conclusion Fox found during this study was a significant reduction in RLR crashes involving professional drivers, such as trucks and taxis *(49)*. An informal conclusion might consider professional drivers more aware of automated enforcement and apply it to their jobs wherever they are working.

<u>*Singapore*</u>

One of the most congested cities in the world, Singapore has one of the most extensive RLR camera enforcement programs dating back to 1986. It was reported in 1997 by Ng et al. that one in five intersections was enforced by one to three cameras *(51h)*. Ng et al. conducted two research studies a period, of nine years. The first study was to evaluate and review the crash trends for 125 intersections over the period. The results of this study are shown in Figure 20 *(49)*. As shown, there has been a significant decline in annual accident counts per junction after the installation of the red light camera systems in 1986. Ng et al. also notes in the research report that this decline happened even with a 22 percent vehicle growth rate and generally flat crash trends among the signalized intersections *(51h)*.

The second analysis performed by Ng et al. was the evaluation of the before and after change in crash types at 42 signalized intersections with cameras and 42 similar intersections without cameras, but with similar crash rates. The study lasted for two three-year periods, which included before and after data for each three year analysis periods. The results of this analysis are shown in TABLE 13 *(51h, 49)*.

TABLE 13 Crash Rate Change for Camera Enforced Intersections in Singapore (51h)

Type of Crash	Before	After	Change (%)
Angle	1.73	1.43	-1.73
Rear end	0.4	0.4	0
Head on/sideswipe	0.37	0.27	-27
Others	0.47	0.4	-14.9
All crashes	2.97	2.5	-15.8

Although Ng et al. had a strong case in having control sites, research has shown that Ng et al. did not fully account or adjust for possible regression to the mean, because the comparison intersections had different volumes and were located far away from the intersections with cameras *(51h)*.

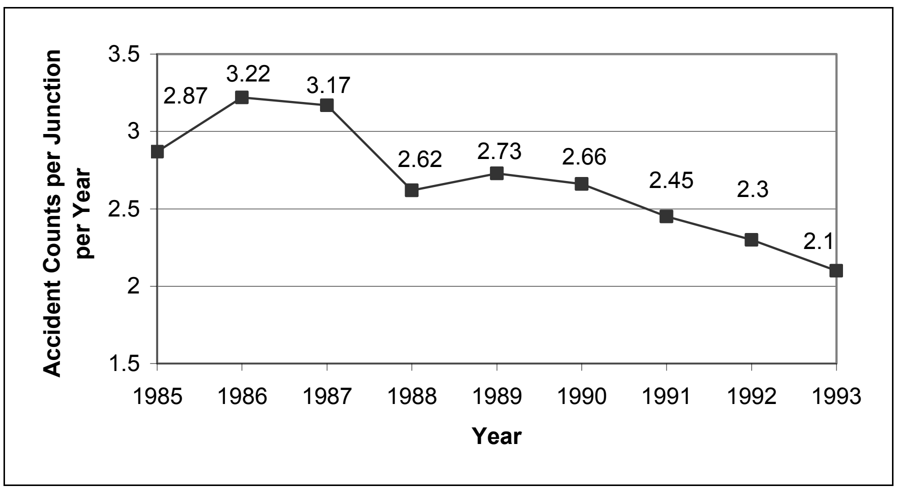


Figure 20. Average annual accident counts at Singapore camera enforced junctions (49, 51h).

2.6.5 United States Results

<u>*Oxnard, California*</u>

One of the best known studies conducted to evaluate the effectiveness of RLR cameras was conducted by Retting and Kyrychenko of the Insurance Institute for Highway Safety in 1998 in Oxnard, Calif. *(52)*. This study evaluated 11 out of the 125 camera-equipped signalized intersections in Oxnard and three California control cities: Bakersfield, San Bernardino, and Santa Barbara. The unique feature of this investigation included the lack of isolation of the 11 intersections located in residential and commercial areas, but also looking at nearby intersections to see if any spillover affects happened. As a control, Retting and Kyrychenko investigated non-signalized intersections in every town in the study, which included three non-signalized intersections in Oxnard *(52)*. After a 29-month study, the results of total crashes and injury crashes can be found in TABLE 14 below. As shown, total crashes and injury crashes both decreased during the study period.

TABLE 14 Crashes Before and After Enforcement in Oxnard, California (52)

City	Type of Intersection	Total Crashes			Injury Crashes		
		Before	After	Percent Change	Before	After	Percent Change
Bakersfield	Non-signalized	760	753	-0.9	245	241	-1.6
	Signalized	771	739	-4.2	243	233	-4.1
San Berinardino	Non-signalized	1220	1283	+5.2	204	225	+10.3
	Signalized	1324	1400	+5.7	239	246	+2.9
Santa Barbara	Non-signalized	712	622	-12.6	113	115	+1.8
	Signalized	488	438	-10.2	89	84	-5.6
Oxnard	Non-signalized	994	1011	+1.7	173	194	+12.1
	Signalized[1]	1322	1250	-5.4	299	239	-20.1

[1]Signalized intersections had RLR enforcement

After the data was processed, a generalized linear regression model was created to evaluate the crash data, and an analysis of variance was used to test the statistical significance. It was concluded by the researchers that Oxnard's RLR camera system reduced the number of crashes by 7 percent with 95 percent confidence intervals of 1.3 to 12.5 percent *(49, 52).*

TABLE 15 Estimated Effects on Right-Angle, Right-Angle Injurys, and Rear-End Crashes in Oxnard, California (52)

Effect	Degrees of Freedom	Mean Square	F value	P value	Estimate	Change (%)
Right-angle crashes						
Camera	1	0.03871492	9.17	0.0388	-0.39352	**-32.5**
Error	4	0.00422139				
Right-angle injury crashes						
Camera	1	0.3264352	107.72	0.0005	-1.14253	**-68.1**
Error	4	0.00302947				
Rear-end crashes						
Camera	1	0.00022718	0.00418	.9515*	0.030145	**+3.1**
Error	4	0.05430999				

* Non significant

Another analysis was performed with the data collected in Oxnard, which is summarized in TABLE 15. This analysis looked at the two more common types of intersection crashes, which include right-angle and rear-end collisions. Right-angle crashes accounted for approximately 36 percent of all crashes at signalized intersections, while rear-end collisions accounted for 9 percent *(52).* Using a model developed by Retting and Kyrychenko, the percent changes were estimated for intersections with camera enforcement, and results were promising. Based on the results of this study, it was concluded by Retting and Kyrychenko that this study "provides evidence that red light cameras in the United States can reduce the risk of motor vehicle crashes, in particular injury crashes, at intersections with traffic signals *(52)*." Although this significant conclusion may hold true to many situations, depending on multiple variables, RLR camera systems may have different effects on different signalized intersections.

2.6.6 Effectiveness Literature Review Conclusions

TABLE 16 recapitulates most of the major reports evaluating the effectiveness of automated RLR camera enforcement in major international and U.S. cities. As noted by Burkey and Obeng, estimates of crash reduction and an increase in rear end collisions raise many questions about the validity of recent studies which could include *(54)*:

- Are these studies controlled for other safety improvements, programs, and changes in automobile safety features that occur with RLR camera programs?
- Are there some intersection characteristics that may influence the effectiveness of RLR cameras in increasing safety?
- Are these changes biased because of regression to the mean effects?
- Are the effects of the cameras limited to monitored intersections or are there some spillovers?

Further explanation shows many jurisdictions will place camera systems at problematic locations that have high crash rates than other intersections *(49)*. Moreover, many cities will be influenced by the camera system vendor, political pressure, or enforcement history which could result in potential ineffectiveness. In an extensive literature review written by Mccubbin, Staples, and Salwin and quoted by Burkey and Obeng, it was concluded that *(36, 54)*:

> Each of the existing independent analyses makes an attempt to assess the long-term impacts of a system that is affected by a variety of external influences that can also impact traffic safety. This is a characteristic of traffic safety impact studies that is probably difficult to overcome. While a long-term study may provide a better indication of any lasting impact of the systems on intersection safety, this longer time frame also allows a greater opportunity for other, necessary, improvements that can also impact safety, such as intersection and pedestrian safety improvements. The result is that the safety impact of the camera system remains unclear. *(36)*

2.7 LEGAL AND SOCIAL CONCERNS

The key to a successful automated RLR camera program is the complete understanding of the legal aspects associated with any form of automated enforcement. By understanding what constitutional rights citizens have and what possible arguments could be made in court, any jurisdiction is helped to overcome gray areas when a violator contests their violation photos. This section briefly explains some research that was found to understand what laws are out to help automated enforcement.

2.7.1 Constitutional Privacy Laws

Many opponents of automated enforcement argue that capturing a vehicle and/or a person with cameras is unconstitutional. The IIHS reports that state courts in California, Colorado, Oregon, and North Carolina, including the United States Ninth Circuit Court of Appeals and Superior Court of the District of Columbia, have rejected constitutional challenges. However, some courts have asked cities to make changes in operational issues to settle disputes *(61)*.

TABLE 16 Summary of Findings from Past Studies (51)

City	Camera Sites	Comparision / reference group	Crash type studied and estimated effects (negative indicates reduction)		Comments	Reference
Sydney, Australia	Installed at 16 Intersections	16 Signalized intersection	Right-angle and left-turn opposed	-50%	Regression to the Mean (RTM) bias possible; spillover may have affected comparision sites; results confounded by adjustment to signal timing in middle of study period	[Hiller, et al., 1993][(37a)]
			Rear end	25% to 60%		
Melbourne, Australia	Installed at 46 Intersections	50 signalized instersections	No Significant results. Looked at right angle, right angle (turn), right against through, rear end, rear end (turn), other, all crashes, number of casualties, no signigicant results		RTM possible, no accounting for changes in traffic volumes; comparison sites possibly affected by spillover and other treatments	[South, et al., 1988][(37b)]
Victoria, Australia			No Significant results		Lack of an effect could be that the sites studied tended to have few red light-running related accidents; comparision sites may have been affect by spill over	[Andreassen, 1995][(37c)]
Melbourne, Australia	3 intersections approaches at different intersections	Noncamera approaches	No significant relationship between the frequency of crashes at RLC and non RLC sites and difference in red-light-running behavior		Cross-sectional design is problemematic; likely spillover effects to the noncamera approaches at the same intersection	[Kent, et al., 1995][(37d)]
Adelaide, Australia	Installed at 13 intersections	14 signalized intersections	Reductions at the camera sites were not statistically different from the reductions at the comparision sites		RTM and spillover to comparision sites are issues not addressed	[Mann, et al., 1994][(37e)]
London, U.K.	RLC at 12 intersections and 21 speed cameras	Citywide effects examined	No significant results		The results are confounded because two programs are evaluated	[London Accident Analysis Unit, 1997][(37f)]

TABLE 16 (continued)

City	Camera Sites	Comparision / reference group	Crash type studied and estimated effects (negative indicates reduction)		Comment	Reference
Various cities in England and Wales	Installed at 78 intersections		All injury	-18%	A simple before-and-after comparision not controlling for effectes of other factors, RTM and traffic volume changes; therefore there is limited confidence in the results	[Hooke, et al., 1996][37g]
Singapore	Installed at 42 intersections	42 signalized intersections	All	-7%	RTM and spillover effects at comparision sites are issues	[Ng, et al., 1997][37h]
			Right angle	-8%		
Oxnard, CA	Installed at 11 intersections	Unsignalized intersections in Oxnard and signalized intersecions in 3 similarly sized cities	All	-7%	Looked at citywide effects, not just at RLC sites 29 months of before-and-after data used	[Retting and Kyrychenko, 2001][37i]
			All injury	-29%		
			Right angle	-32%		
			Right-angle injury	-69%		
			Rear end	3% (non-significant)		
Charlotte, NC	Installed at 17 intersections	no comparison group	Angle - all approaches	-37%	Probable RTM in site selection	[SafeLight, Charlotte][37j]
			Angle - camera approaches	-60%		
			All - camera approaches	-19%		
			Rear end - camera approaches	4%		
			All	<-1%		
Howard County, MD	Installed at 25 intersections		Rear end	-32%	Probably RTM in stie selection	[Maryland House of Delegates, 2001][37k]
			Right angle	-42%		
			Other	-22%		

TABLE 16 (continued)

City	Camera Sites	Comparision / reference group	Crash type studied and estimated effects (negative indicates reduction)		Comment	Reference
San Francisco, CA	Installed at 6 Intersections	Citywide effects examined	Citywide injury collisions caused by red-light violators; unclear how these were defined	-9%	Question on definition of RLC crashes; did not examine specific effects at treated sites	[Fleck and Smith, 1998][(37l)]
Mesa, AZ	6 intersections with RLC only, 6 intersections with RLC plus photo speed enforcement	6 signalized intersections	Total crash rates-crashes per million entering vehicle at each intersection		It is unclear if the assignment of treatment of treatment/no treatment to the four quandrants was random	[Vinzant and Tatro, 1999][(37m)]
			Comined-treatment quadrant	-15.9%		
			photo-radar quandrant	-7.5%		
			RLC quadrant	-9.7%		
			Control Quandrant	-10.7%		
Glasgow, Scotland	Installed at 8 intersections and 3 "pelican" crossings	Area wide effects on injury crashes examed	Crossing carelessly	-54.0%	RTM effects likely because the decreases in non-RLR crashes are greater than the RLR decreases at times, it is difficult to say what citywide effect the cameras have.	[Fox, 1996][(37n)]
			Unsafe right turn	-29.0%		
			Failure to keep distance	8.0%		
			Other	-29.0%		
			All per month	-32.0%		
Glasgow, Scotland	6 locations on 1 approach	Various	Injury crashes related to RLR violations	-62.0%	Probable RTM effects	[Winn, 1995][(37o)]

Passetti notes that although there are no First Amendment cases that define or argue the right to privacy in a vehicle, the Supreme Court has defined privacy for marriage and/or a family. On the other hand, driving is considered a privilege, and not everyone is entitled or guaranteed to drive a vehicle *(34)*. The act of driving is performed on public roads in front of the public eye, thus raising the question whether any constitutional privacy laws protect a driver. Every driver receives a state driver's license by taking a driving exam of some sort. Therefore the driver must abide by certain rules set by the state and federal government including abiding by traffic signals and regulatory traffic control devices. These driving laws are in place not only to protect the driver, but also to protect the public. In 1986, a court statement from NY v. Class (1986) read "Automobiles are justifiably the subject of pervasive regulation by the state. Every operator of a motor vehicle must expect that the State, in enforcing its regulations, will intrude to some extent upon that operator's privacy *(61)*." The result of this lawsuit included the United States Supreme Court determining it was legal for a police officer to search databases for drivers based on the Vehicle Identification Number (VIN) and did not violate the Fourth Constitutional Amendment (search and seizure) *(62)*.

In a landmark District of Columbia Supreme Court case, the plaintiff's taxi-leasing company, Auto Ward, Inc., and Emelike U. Agomo filed a class action lawsuit against then Mayor Anthony A. Williams. Agomo was charged for 11 moving violations, which were captured by automated enforcement systems. Auto Ward, Inc. is a taxi-leasing firm in the District of Columbia, which was served with at least 57 moving violations that totaled $6,675.00. This lawsuit assumed the presumption of guilt violates the due process rights of the plaintiffs and an estimated 100,000 registered automobile owners. The main complaint in this lawsuit was a third-party company was hired by the District of Columbia to try and identify the owners of each of the automobiles involved in the class action lawsuit. Furthermore, it was argued that this third-party company accurately described the movement of the vehicle, and accurately described the date, time, and license plate number. However, the plaintiffs believed capturing, identifying, and charging drivers violated the Fifth Constitutional Amendment (trial and punishment, compensation for takings), which the District of Columbia ruled constitutional *(63)*.

Quoted by the Insurance Institute for Highway Safety, it also noted in 2003 remark that a judge in the District of Columbia made during Agomo v. Williams (2003):

> [The] fact that there are a high number of persons photographed running the traffic signal or operating at excessive speeds is an example of the magnitude of the problem facing city officials trying to correct a growing situation. Although cameras operated by the Government are a concern regarding privacy issues, those concerns are outweighed by the legitimate concerns of safety on our public streets. *(61)*

2.7.1 Admissibility Issues with Automated Enforcement

According to a report by Blackburn et al., the general public and most courts will accept photography as evidence under two theories, the first being the picture testimony and the second being the "silent witness theory" *(61)*. The silent witness theory has become more prevalent in court cases due to an increased use of various technologies to monitor or capture evidence. Essentially, the picture speaks for itself. The silent witness is an automated enforcement photograph of a person, object, or scene that can be used in the court of law without in-court testimony. The second theory of picture testimony includes such items as maps, photographs, or drawings, which can serve as evidence without in-court testimony *(64)*.

In the case People v. Pett (1958), the issue of photo-radar automated enforcement was questioned when Louis Pett was charged for driving 41 mph in a 30-mph speed zone in the village of Garden City, N.Y. Mr. Pett's vehicle was captured with a photo-radar device, which also recorded his license plate. The court found Mr. Pett guilty beyond reasonable doubt, and it was stated by the court, "We have passed the horse and buggy days and are living in a new era. The question is, did the defendant do it and was there sufficient proof offered to find the defendant guilty beyond reasonable doubt?" This case, although early in the era of automated enforcement, questioned the scientific reliability of a photograph of a vehicle *(61)*.

In 1973, Thomas J. Goger presented a paper that explained three steps for photographic radar to be considered evidence in a court of law. He said a scientific principle must be applied for an instrument to be scientifically reliable *(50)*. It was recommended by Goger that radars used for speed enforcement be properly tested with duel tuning forks *(65)*. To this day, modern radar units used for traffic enforcement are calibrated with tuning forks to 77.6 (5589 HZ) and 33.2 (2391 HZ) miles per hour before usage.

Passetti explains that if a jurisdiction decides to use automated RLR enforcement, a calibrated instrument must be used to sequence a series of events. These tasks include taking a photograph or video of the offending vehicle and stamping it with the time and date. Furthermore, if a jurisdiction uses photographic evidence against a driver in a moving violation, a photograph of the driver must be taken as well *(34)*.

2.7.3 Commercial RLR Camera Countermeasures

People have gone to extensive lengths to protect their privacy from what is dubbed "Big Brother is watching you." Shown in Figure 21 and Figure 22 are two commercial products advertised in magazines such as "Motor Trend" and "Popular Science" to help drivers avoid being caught by RLR cameras. Figure 21, sold under the name "Photoblocker," is a spray that is applied to the front and rear license plates. The company website explains that once the spray is applied, a high gloss will reflect camera flashes, resulting in a white square when the photo is taken *(66)*.

Photoshield, shown in Figure 22, is also sold by the same website. It is simply a clear plastic film to cover both the front and rear license plates which is manufactured by the 3M Corporation and sold under a different name. The website additionally claims radar gun, laser gun, and infrared cameras cannot lock onto the license plates. Both of these products claim to save millions in possible "illegal" tickets *(66)*. The effectiveness of these products have not been researched or verified.

Figure 21. Photoblocker spray (66).

Figure 22. Photoshield cover (66).

CHAPTER 3: A VIOLATION STUDY OF CLIVE, IOWA

3.1 DESCRIPTION OF CLIVE, IOWA

The City of Clive had its beginnings in 1880 when the area known as Flynn Farm was established and eventually filed as the city's first official plat of land on January 18, 1882. Clive was developed into a city by two businessmen, Jefferson Polk and Frederick Hubbell, who owned the Des Moines-based Union Land Company. Their company's theory, "to purchase coal lands, stone quarries, land for town sites, and land generally in the state of Iowa" brought an influx of various developments to the area which in turn helped create a railroad stop on the St. Louis-Des Moines Northern Railway which traveled through Clive to Boone, Iowa.

The first post office depot opened on February 8, 1882, which brought a community of about twenty families together that started building infrastructure around the post office, including two general stores and a blacksmith shop. By 1923, the City of Clive had grown to over 150 permanent residents, and on August 18, 1956, Clive officially became a city after much pressure from the City of West Des Moines who was in discussion of annexation.

According to local records, there is no exact explanation where the name "Clive" came from. The city's website currently proposes two possible explanations. The first account involved a gentleman by the name of General Robert Clive who helped establish the British Empire in India. The second thought states "Clive" was the name of a section gang foreman at the local rail yard. It is thought that when a rail car was fully loaded with rails, ties, and spikes, the workers were told to get the car out to Clive.

The City of Clive is located in Western Polk County between the rapidly growing Des Moines suburbs of West Des Moines, Urbandale, and Windsor Heights. The city has a population of over 14,000 residents, and an area of about 1200 acres *(67)*.

3.2 BACKGROUND OF CLIVE'S RLR PROGRAM

3.2.1 Instrumentation

On December 18, 2005, the Clive City Council voted unanimously to enter into an exploratory contract with Redflex Traffic Systems of Scottsdale, Arizona after company representatives contacted city officials who were interested in the possibilities that automated enforcement could offer. The initial contract with Redflex included a study that investigated Clive's high speed intersections on Hickman Road and University Avenue for potential automated RLR enforcement camera systems. The City Council's goal in implementing the cameras was to reduce the number of drivers running red lights, to improve safety not only on Hickman Road, but throughout the entire city. They were careful not to give the public the impression that the purposes of the cameras were not to generate a "profit from citizen's misbehavior" as quoted by one city council member during a public meeting. Hickman Road and University Avenue were the two study corridors considered by Redflex and the Clive Police Department.

The City of Clive is situated between the cities of Urbandale and West Des Moines. Three major east-west roads of Hickman Road, University Avenue, and Douglas Avenue divide the three cities. Although the

City of Clive owns the south lanes of Hickman Road and the north lanes of University Avenue, video was taken at all approaches of the designated intersections. Redflex recorded eight to twelve hour videos at twenty eight approaches at eleven potential intersections. The videos were analyzed by Redflex employees in Arizona and a report was submitted to the city council which included the number of RLR violations at each studied approach. The report showed six high violation approach locations along Hickman Road with 6 to 11 violations in an eight to twelve hour video study period. Shown below, in TABLE 17, are the high values Redflex found at the studied intersections and each approach. The approaches in bold currently have RLR camera systems installed.

TABLE 17 Redflex's Initial Study and the Number of Violations for Each Approach

		RLR Violation			
Intersection	**Approach**	**Left Turn**	**Through**	**Right Turn**	**Total**
Harbach & 86th	Northbound	1	3	1	**5**
	Southbound	0	2	0	**2**
Hickman & 100th	**Northbound**	**2**	**6**	**0**	**8**
	Southbound	3	1	1	**5**
	Eastbound	1	3	0	**4**
	Westbound	2	3	1	**6**
Hickman & 128th	**Northbound**	**0**	**3**	**6**	**9**
	Eastbound	**0**	**11**	**4**	**15**
	Westbound	1	7	1	**9**
Hickman & 142nd	**Eastbound**	**0**	**11**	**6**	**17**
	Westbound	0	15	3	**18**
Hickman & 156th	**Northbound**	**2**	**1**	**5**	**8**
	Southbound	1	3	1	**5**
	Eastbound	**0**	**6**	**3**	**9**
	Westbound	0	0	0	**0**
Hickman & 86th	Northbound	5	0	5	**10**
	Eastbound	0	2	0	**2**
Hickman & I-35/80	Eastbound	0	5	0	**5**
University & 100th	Northbound	1	0	0	**1**
	Southbound	0	0	0	**0**
	Eastbound	0	1	4	**5**
	Westbound	0	2	0	**2**
University & 114th	Eastbound	0	5	1	**6**
	Westbound	0	0	3	**0**
University & 86th	Northbound	0	2	0	**2**
	Southbound	0	3	0	**3**
University & I-35/80	Eastbound	3	11	1	**15**
	Westbound	0	3	2	**5**

[1]Numbers and approaches in bold are the approaches were RLR cameras were installed

Based on the video study performed and analyzed by Redflex, a list of recommended intersections was given to the city to evaluate. The following intersections and approaches were selected by the Clive City Council to implement a RLR camera system:

- 86th Street, northbound approach, at Hickman Road
- 100th Street, northbound approach, at Hickman Road
- Hickman Road, eastbound approach, at 128th Street
- Hickman Road, eastbound approach, at 156th Street
- 156th Street, northbound approach at Hickman Road

The City of Clive decided to precede with the locations recommendations except for the 86th Street and Hickman Road northbound approach because an intersection reconstruction project was scheduled for 2007. In addition to the recommended locations, a RLR camera was installed at the northbound approach of 128th Street and Hickman Road, which is currently being expanded to a divided four-lane road collector from an existing two lane road because of the increase in residential and commuter traffic volume. For the City of Clive to implement the Hickman Road RLR enforcement program, the city had to amend Chapter 61 of the 2000 Clive Code Ordinances which specified the use of city traffic control devices.

On March 30, 2006, City Ordinance No. 851 was enacted with a four to one vote amending Chapter 61 of the 2000 Clive Code of Ordinances to include a section that allows automated RLR enforcement, and the violation to be considered a civil infraction. The City of Clive defines a red light runner in this ordinance as a vehicle that crosses a stop line at the intersection when the traffic signals are showing a red light or arrow. Ordinance 851 also provided a framework for rules, how contracts should be managed between the vendor, and a set fine of $75 for issued citations. The City of Clive entered into an official agreement with Redflex, which includes the following key points:

- A five year contract with the option to purchase two additional years after the expiration of the agreement.
- Redflex will install, maintain, and provide technical service within 24 hours of equipment failure, ensure proper communication between Redflex and the camera system, and process violations.
- Redlfex will provide 3 months of training for up to 15 city officials for 16 hours each,
- Redflex will provide a lockbox system to deposit fines for the city.
- Redflex will be provided information by Clive to Department of Motor Vehicle records data.
- Clive may terminate the agreement if state statutes are amended to prohibit operation of the enforcement system.
- Redflex will not open the traffic controller box without a city traffic engineer present.

3.2.2 Payment Structure

As part of the agreement, Redflex and the City of Clive set up two possible payment methods based on the number of citations taken in by the camera systems. Between August 2006 and March 2007, the City of Clive has solely used payment method one.

Method 1

- Clive shall pay Redflex an operating flat fee of $4,870 per month per approach.
- If monies collected from citations exceed the operating flat fee, Clive will receive the difference as revenue.

- If the city does not collect the operating amount, the difference will be carried over to the next month.
- The operating cost flat fee will increase based on the consumer price index.
- If a termination of agreement were to take place because of an overturned state law or court ruling, Clive would not be held responsible for any debt accumulated previous to the system shutdown.

Method 2

Assuming the City of Clive is collecting a consistent amount of paid citations, the city can switch to the second method after the first or third year anniversaries of the program. Any debt owed to Redflex will be paid with violations until the debt is paid off and the city will collect the following amounts based on the number of citations paid per day as shown in TABLE 18.

TABLE 18. Method two Redflex Proposed Payment Structure (fee per citation)

Tier	Citations Paid (Average Per System per Month)	Fee
Tier 3	6+ Citations fully paid per day (181+ per month)	$28
Tier 2	3-6 citations fully paid per day (91 to 180 per month)	$38
Tier 1	1-3 citations fully paid per day (up to 90 per month)	$48

As shown in TABLE 18, the more citations issued per day will lower the fee Redflex would collect from the $75 citation. Although method two would work on a large scale operation quite well, the city has determined that currently the number of citations paid per month has not reached the equivalent of Tier 1.

Redflex also explains in the terms of agreement that the City of Clive can move up tiers based on the number of citations paid per month. The difference between method one and two involves how Redflex is paid based on the number of citations issued per month. Redflex will continue to have the flat operating fee per approach as stated in method one, but the City of Clive is held responsible for covering the charge each month if the number of citations are met; or a 1.5% monthly late fee is applied after 60 days of not paying the due balance following the proposed tiers. Finally, the fee assessed by Redflex and operating charge increases each year based on the consumer price index.

To extend regulation involving automated RLR enforcement, the City of Clive passed Ordinance 858 on June 15, 2006 with a unanimous vote. Ordinance 858 gives the owner of the violating vehicle an opportunity to identify the driver of the vehicle at the time of the violation. Ordinance 858 was aimed towards fleet owners such as rental car companies, limousine services, and taxi service companies where fleet vehicles were operated by employees.

Ordinance 863 passed by a five to one vote on December 21, 2007, redefining RLR for right and left turning movements. It states, “if the vehicle owner’s vehicle fails to obey an official traffic control device and crosses a marked stop line of the intersection plane at a given location or fails to come to a complete stop before cautiously entering the intersection to make a right turn from the right lane of traffic or a left turn from a one-way street onto another one-way street when the traffic signal for the vehicle's direction is emitting a steady red light or red arrow is then considered a Municipal traffic offense."

3.2.3 Functionality of System

The Redflex camera systems installed at the four Clive intersections and all of the Council Bluffs intersections face the rear of vehicles and results in not being able to photograph the driver's face. The camera system connects directly to the roadside traffic control cabinet to synchronize with the signal timing plan. The camera system houses a vehicle detection system separate than that of the traffic signal detection system. This system includes the actual video camera, video detection system, communication system, and two cameras that take still photos. The vehicle detection system takes a still image of the roadway with no traffic on it and the image is compared with live vehicle traffic that runs the red light. This system utilizes many of the same technologies found at intersections with video vehicle detection where the operator can place vehicle detection squares via a computer program which overlap continuous live video.

To capture a vehicle potentially going running a red light, many steps must be completed in the matter of seconds by the automated RLR camera system to photograph the violation. Using live video detection, 4 preset points prior to the stop bar are defined by the vehicle detection system as points to collect the vehicles speed as it approaches the intersection. Towards the end of the green phase through the yellow phase, the vehicle detection system monitors vehicles passing the four detection points. Using live video, the camera's computer makes a determination of the vehicle's speed based on the time it takes for pixels to change in the live video to make a judgment if violating vehicle is traveling at velocity that would hinder it from stopping before the red phase. There is also a threshold to this process, a 25 mph threshold speed is built into the system whereas if the vehicle detection system captures a vehicle traveling above 25 mph, it will assume the vehicle is traveling too fast to be able to stop before the stop bar. Once the computer determines a vehicle is traveling too fast to be able to stop for the red light, it will activate the video and still-photo camera firing sequence.

Having the still-photo and video camera firing sequence ready, the RLR camera system will receive the same electrical signal that is given out by the Clive intersection traffic controller that turns the traffic signals red. Once the RLR computer receives the red call from the traffic signal controller, the camera system will wait for 1 second before taking the three photos and short video. This amnesty period is built in to the camera system to give any benefit of doubt to the driver to stop before taking the picture and to let the traffic signal fully illuminate. Once the amnesty runs out three digital photographs are taken and 6 seconds of buffer video is captured.

Three images are taken of the potential violator: 1) an image which shows the vehicle behind the stop bar with a red traffic indication shown in the background which indicates that the vehicle crossed into the intersection after the red indication was given, 2) a high resolution image of the license plate, and 3) an image of the vehicle in the intersection (the system uses images 1 and 3 to determine speed and time elapsed since the vehicle crossed into the intersection). Figure 22 shows how these photos are used in a mailed citation from Redflex. The Clive RLR camera system also incorporates a continuous video system. When a potential violation occurs, the cameras fire a sequence of six seconds of live video which is converted by Redflex to a 12 second video by way of an file unzipping process to accompany the violation images. If a person receiving a ticket wishes to dispute the ticket they are able to go to the Clive Police Department and view the 12 second video and the three official images. The City indicated that in most cases after people view the video it is pretty clear that they ran the red light and they end up not disputing the ticket. The video can also be accessed as evidence. All images are stored on a local system hard drive and are later transmitted to Redflex via a dedicated T1 phone line.

3.2.4 Ticket Issuing

Upon receiving images from the camera, Redflex performs initial filtering which removes photos that have the following characteristics:

- The vehicle cannot be identified due to vehicle obstruction or plate obstruction.
- Police rejections which could include funeral processions, yielding to an emergency vehicle, invalid offense, or a safe turn on red.
- Registration issues which could include temporary paper license plates, inability of the software to identify the state the license plate is from, out of the country license plates, or the driver information has been obtained from a certain jurisdiction.

System issues may also require Redflex or a police officer to reject the ticket. These issues usually involve a malfunction of the physical system in the field and are typically filtered out by Redflex before the police officer is able to view the violation. Variables in rejecting an image based on a system malfunction could include the following:

- Camera malfunction which could include digital distortion
- missing images
- blurry image of the license plate
- no flash in one of the three photographs

The city police may reject an image that Redflex does not catch which includes no transmitted imagery or video, an unclear scene, or a vehicle that is on the stop bar or past the stop line and came to a complete stop.

CITY OF CLIVE, IA
RED LIGHT PHOTO
ENFORCEMENT PROGRAM
NOTICE OF VIOLATION

NOTICE NUMBER: CLR00001050

The City of Clive has a red light photo enforcement program in effect to reduce the number of red light running violations. As you can see from the photos to the right, a vehicle registered in your name and described below appears to have run a red light.

DATE OF VIOLATION	TIME OF VIOLATION
September 19, 2006	**07:45 AM**

NAME (FIRST, MIDDLE, LAST): [redacted]

ADDRESS (STREET, APT #): [redacted]

CITY	STATE	ZIP CODE
[redacted]	[redacted]	[redacted]

VEH. LIC.NO [redacted]	STATE IA	VEH. YEAR [redacted]
VEH. MAKE [redacted]	BODY STYLE [redacted]	REG. YEAR
PENALTY AMOUNT **$ 75.00**	ORDINANCE **Section 61.05 of the Clive Code of Ordinances**	DESCRIPTION **Failure to Obey a Traffic Control Device**

LOCATION OF VIOLATION
Hickman Rd & 156th St EB

YOU MUST RESPOND TO THIS NOTICE ON OR BEFORE:
DATE: **10/25/2006**

REGISTERED OWNER (FIRST, MIDDLE, LAST): [redacted]

ADDRESS (STREET, APT #): [redacted]

CITY	STATE	ZIP CODE
[redacted]	[redacted]	[redacted]

PLEASE NOTE THAT RECORDED IMAGES CONSTITUTE EVIDENCE OF A VIOLATION OF THE SECTION 61.05 OF THE CLIVE CODE OF ORDINANCES.

THIS VIOLATION WAS NOT COMMITTED IN MY PRESENCE. BASED UPON MY REVIEW AND INSPECTION OF THE RECORDED IMAGES, I STATE THAT A VIOLATION OF SECTION 61.05 DID OCCUR.

I DECLARE UNDER PENALTY OF PERJURY UNDER THE LAWS OF THE STATE OF IOWA THE FOREGOING IS TRUE AND CORRECT.

[redacted]	[redacted]	[redacted]
DATE ISSUED	**CLIVE POLICE DEPARTMENT**	**BADGE NO.**

NOTE: As the registered owner of the vehicle described in this Notice, you are responsible for paying this fine by 10/25/2006.

Failure to respond to this notice will result in a Civil Infraction Citation being issued to you. You will then be required to appear in person in court and may be assessed an additional charge of at least $50.00 in court costs (and $15.00 in police service fees). Failure to pay the fine or appear in court will result in a judgment being issued against you and liens registered in the Polk or Dallas County Courts.

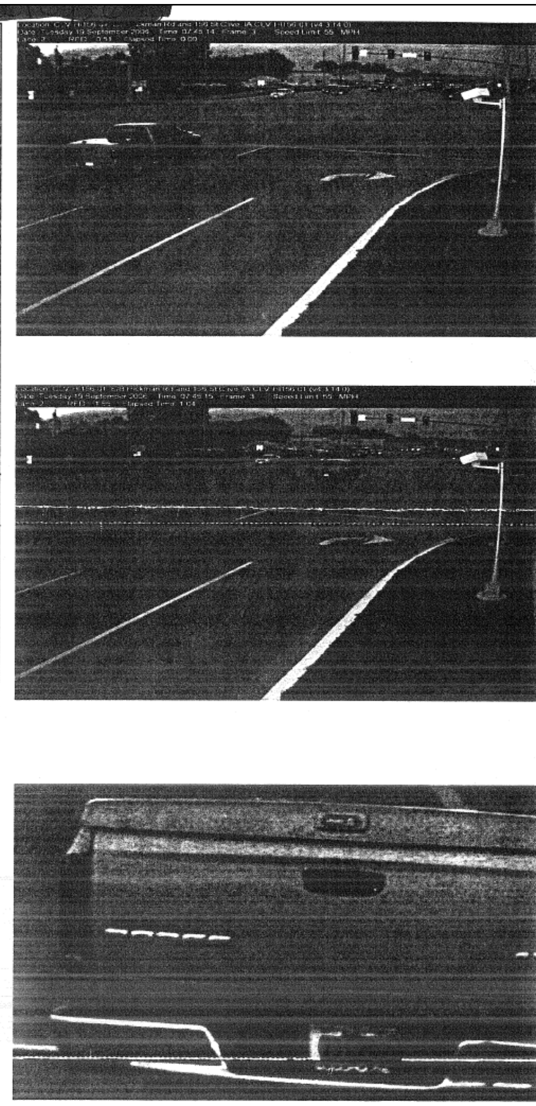


Figure 23. A Notice of Violation for Clive, Issued by Redflex.

Illustrated in Figure 23 is a ticket that was issued to a RLR violator in Clive, and the most of the information about the violator has been redacted to protect confidentiality. As shown in the images on the left, the vehicle was clearly captured by the camera system and the license plate number can easily be read by a computer program or human. Also shown is the signature of the Clive Police Officer that verified the violation and his or her badge number. Shown in Figure 24 is the second page of the ticket that describes the violator's options upon receiving a RLR citation.

OPTIONS PAGE

OPTION A: PAYMENT COUPON — **CLIVE RED LIGHT PHOTO ENFORCEMENT PROGRAM**

Notice #: CLR00001050

Issued To: DCFS TRUST

☐ Check or Money Order

Please make check or Money Order Payable to "Clive Red Light Photo Enforcment Program"
(ensure address on reverse side appears in the window of the envelope)

☐ Credit Card: ☐ VISA ☐ MASTERCARD

Name as it appears on card (Print): ____________ First ____________ Last

Card #: ____________ Expiration Date: Month ______ Year ______ Security Code #: ______

Mailing Address: ____________ Street ____________ City / State / Zip Code

Phone Number: (   ) ____ - ______ Signature: ____________ Date: __/__/__

Total Amount Due: $75.00

Amount Enclosed: ____________

DCFS TRUST
400 HORSHAN RD
HORSHAM, PA 19044

Tear Here *Tear Here* *Tear Here*

OPTION B: AFFIDAVIT — **CLIVE RED LIGHT PHOTO ENFORCEMENT PROGRAM** — **Notice #: CLR00001050**

Issued To: DCFS TRUST

CHECK ONE:

☐ I sold the vehicle prior to the violation date to the person named below.

☐ The person named below was the driver of the vehicle.
NOTE: The identification of another person as the vehicle driver does not relieve the vehicle owner of liability for the civil penalty, unless the vehicle driver pays the civil penalty under Option A.

☐ The vehicle or license plate(s) were stolen at the time of the violation.

Print Actual Driver/New Owner's Name: ____________

Address: ____________ City, State, ZIP Code: ____________

The stolen or illegally taken vehicle was reported to ____________ Police Dept. on __/__/__.

Police Report No. ____________.

DECLARATION
I CERTIFY UNDER PENALTY OF PERJURY THAT THE FOREGOING IS TRUE AND CORRECT.

Signature: ____________ Print Name: ____________

Phone Number: (   ) ____ - ______ Date: __/__/__

IMPORTANT:

- This Affidavit must be returned by 10/25/2006.

Tear Here *Tear Here* *Tear Here*

OPTION C: TRIAL REQUEST — **CLIVE RED LIGHT PHOTO ENFORCEMENT PROGRAM**
(Complete ONLY if you want a hearing)

Notice #: CLR00001050 **Issued To: DCFS TRUST** **Date of Violation: 09/19/2006**

Print Name: ____________ First ____________ Last

Address: ____________ Street ____________ City, State, ZIP Code

Phone Number: ____________

Signature: ____________ Date: __/__/__

IMPORTANT:

- This trial request must be returned by 10/25/2006.

Figure 24. Mailed Ticket With Driver Options.

The ticket is issued to the person who owns the vehicle. As shown, the owner/violator has three options. As shown, Figure 25 is the third page of the ticket and explains each option in detail.

CITY OF CLIVE **INSTRUCTION PAGE** **RED MEANS STOP**

1. **Reason You Received This Notice:**
   A vehicle registered in your name was photographed running a red light or the registered owner of the vehicle depicted on this Notice has submitted an Affidavit naming you as the driver of the vehicle at the time of the violation. This is a violation of Section 61.05 of the Clive Code of Ordinances.

2. **View Violation on the Internet**
   - The violation has been captured on video and is available to be viewed on the Internet at: **www.photonotice.com (Enter City Code: CLIVE)**. The video is available online for 60 days from the date of violation.
   - If you do not have access to a computer, computers are available at the Public Libraries. Please refer to your phone book for the library most convenient to you.
   - Upon request, you may also view the images and video at the Clive Police Department, 8505 Harbach Blvd, Clive, IA 50325. Call 515-278-1312 to schedule an appointment. You will be notified of a date and time to appear.

3. **You Must Select One of the Following Options. Complete the coupon on the Options Page for the option you select and return the coupon in the enclosed envelope. Make sure the mailing address on the reverse side of the coupon appears in the window of the enclosed envelope.**

   A. **Payment Methods.** As the registered owner or nominated driver of the vehicle described on this Notice, we have no choice but to hold you liable for paying this civil penalty by 10/25/2006. No points will be assessed to your driving record and no record of this violation will be sent to your insurance company or the Department of Motor Vehicles.

   - Please do not send cash.
   - Make Check or Money Order payable to "Clive Red Light Photo Enforcement Program".
   - Payments by Personal Check, Money Order or Visa/MasterCard are accepted. Please mail in the enclosed envelope along with the payment coupon found on Option A of page 2.
   - A $30.00 administrative fee will be assessed for rejected or declined payments.

   B. **Affidavit: Identify another Driver, Vehicle Sold or Stolen.** Under Section 61.05 of the Clive Code of Ordinances, the owner of the vehicle that ran the red light is liable for the payment of the civil penalty. However, the owner may identify the person who was driving at the time of the violation and request that the driver assume liability for the civil penalty by completing if the Affidavit of Non-Responsibility (Option B of the mail-in coupon on page 2) and returning it within the enclosed envelope by 10/25/2006. You may mail the Affidavit of Non-Responsibility **in the enclosed envelope** or fax it to the Clive Police Department, 8505 Harbach Blvd, Clive, IA 50325. Fax # (515) 278-6066.
   PLEASE NOTE that the identification of another person as the driver of the vehicle at the time of the violation does NOT relieve the owner of liability for the civil penalty. If the driver does not pay the civil penalty, the vehicle owner is responsible to pay the civil penalty.

   - If the vehicle was sold prior to the date of violation, please include a copy of the transfer of sale.
   - If the vehicle or license plate was reported stolen at the time of the violation, please include a copy of the police report.
   - No record of this violation will be sent to your insurance company or to the Department of Motor Vehicles.
   - Please do not nominate another driver if you are paying the fine.

   C. **Right to a Trial.** You have the right to a trial to contest this notice:

   To schedule a trial and have the matter reviewed by a Magistrate you MUST do the following:

   1. Complete Option C (Request for Trial Coupon on page 2) and mail it to the Clive Police Department, 8505 Harbach Blvd, Clive, IA 50325 or fax it to (515) 278-6066 by 10/25/2006. Please include your phone number. The Polk or Dallas County Court will notify you of a date and time to appear.
   2. Trials are held at Polk County Clerk of the Court, River Point Office Center, 500 SW 7th Suite 100, Des Moines, IA 50309 or the Dallas County Court, 801 Court, Adel, IA 50003.
   3. If the violation is contested in court, $50.00 in filing fees, a $15.00 police service fee and any additional costs will be assessed if you are found liable. If you fail to appear, you will be responsible for paying the assessment. If you are found not liable, the fees will be waived.

4. Failure to respond to this notice will result in a Civil Infraction Citation being issued to you. An additional $50.00 in court costs, a $15.00 police service fee and any additional costs will be assessed whether you appear in court on your court date or if you pay the fine before your court date. Failure to pay the fine or appear in court will result in a judgment being issued against you and liens registered in the Polk or Dallas County Courts.

For questions regarding payment, contact Clive Red Light Photo Enforcement Program Customer Service Call Center toll free at 1-877-847-2338 between 9:00am and 4:00pm (MST).

Figure 25. Instructions for payment of ticket, nomination of another driver, or right to trial instructions.

The first option is to pay the $75.00 ticket by detaching and returning the top portion. If the owner was not driving the vehicle when the violation happened, they may name the individual who was driving the vehicle at the time of the violation so that the violation can be assigned to that person. They may also state that the vehicle or license plates were stolen prior to the time of the violation and as a result were not in their possession. If the owner names the offending driver, a citation will be mailed to that individual by Redflex. The third option is to ask for a court hearing. With this option, the processed forms are mailed back to Redflex and the company notifies the city that the third option was selected by the owner/violator.

The RLR cameras were installed by June 28, 2006 at the intersection approaches selected by the city. During the following month of operation the City issued 499 warning tickets to violators. After August 1, 2006, ticketing took effect and violators were charged the $75 fine. The Clive Police Department estimated that approximately 300 tickets were issued per month. Photography and video evidence of violating drivers are kept for 30 days or until all challenges are completed. The only recorded malfunction of the RLR camera system came during a heavy snowstorm in 2006 when the camera could not determine the speeds of cars due to heavy snowflakes obscuring the vehicle detection system. In 2007, Redflex installed an inductive loop vehicle detection system, separate from the city's loops detection system, to detect vehicle speeds rather than relying on the speeds computed using the video detection system.

3.2.5 Revenue

Since August 2006, when the City of Clive began issuing tickets to violators, 2440 citations have been paid to Redflex. Redflex sends monthly statements to the City indicating which citations have been processed. Since the beginning of issuing citations, the Clive City Clerk has received statements of funds received ranging from $50 to $125. Shown below in TABLE 19 are the citations paid per by city the vehicle is registered in and the percent of the total number of citations paid per month from August 2006 through March 2007.

TABLE 19 Number and Percentage of Paid Citations Based on Violator's City

Month	Clive	Urbandale	West Des Moines	Waukee	Windsor Heights	Des Moines	Other[1]
Jul-06	Warning Period						
Aug-06	5	7	6	5	0	8	18
Sep-06	14	22	33	17	0	63	57
Oct-06	17	31	46	32	1	66	109
Nov-06	22	31	38	27	0	70	92
Dec-06	27	30	9	23	1	51	86
Jan-07	41	40	48	32	0	70	118
Feb-07	59	51	64	50	1	132	146
Mar-07	68	65	61	49	3	145	133
Total	**253**	**277**	**305**	**235**	**6**	**605**	**759**
% of Total Paid Citations	**10.37%**	**11.35%**	**12.50%**	**9.63%**	**0.25%**	**24.80%**	**31.11%**

[1]Cities located outside of the Des Moines area or vehicles registered in another state

As shown in TABLE 19, most of the paid citations have come from outside of the of the City of Clive, and over 50% of the total paid citations have come from cities outside of the west Des Moines area which includes other Iowa cities or vehicles that from a different state.

Illustrated below in TABLE 20 are the numbers of citations paid per camera at each of the six approaches. As shown, the northbound camera at 100th Street and Hickman Road received the most paid citations, and the Clive City Clerk reported the fewest number of citations paid for the eastbound approach camera at 256th Street and Hickman Road. As illustrated in TABLE 20, the numbers of citations paid have increased over the time of enforcement.

TABLE 20 Number of Paid Citations per Approach per Month Received by the City

Month	100th (NB)	128th (NB)	128th (EB)	142nd (EB)	156th(NB)	156th(EB)
Jul-06			Warning Period			
Aug-06	8	9	13	11	5	3
Sep-06	29	20	65	38	32	22
Oct-06	61	16	94	49	46	36
Nov-06	61	20	85	58	30	26
Dec-06	62	13	68	41	27	16
Jan-07	137	50	74	24	42	22
Feb-07	160	107	62	24	140	10
Mar-07	177	111	73	36	107	20
Total	**695**	**346**	**534**	**281**	**429**	**155**

After reviewing the paid citation data provided by the Clive City Clerk per camera, the total amount of revenue generated per camera is shown below in TABLE 21. As shown, the RLR camera located at the northbound approach of 100th Street and Hickman Road generated the most ticket revenue based on the number of paid citations for the entire enforcement period.

TABLE 21 Total Collected Amount Before Redflex Collects Surcharges

Month	100th (NB)	128th(NB)	128th(EB)	142nd (EB)	156th (NB)	156th (EB)
Jul-06			Warning Period			
Aug-06	$600.00	$675.00	$975.00	$825.00	$375.00	$225.00
Sep-06	$2,175.00	$1,500.00	$4,875.00	$2,850.00	$2,400.00	$1,650.00
Oct-06	$4,577.95	$1,202.95	$7,105.90	$3,675.00	$3,450.00	$2,708.85
Nov-06	$4,610.90	$1,502.95	$6,358.85	$4,212.95	$2,252.95	$1,955.90
Dec-06	$4,655.90	$1,005.00	$5,116.80	$3,030.90	$2,057.95	$1,232.95
Jan-07	$10,289.75	$3,774.75	$5,564.75	$1,800.00	$3,158.85	$1,652.95
Feb-07	$12,000.40	$7,982.45	$4,658.85	$1,830.00	$10,523.60	$827.95
Mar-07	$13,334.25	$8,347.30	$5,483.85	$2,702.95	$8,129.50	$1,511.80
Total	**$52,244.15**	**$25,990.40**	**$40,139.00**	**$20,926.80**	**$32,347.85**	**$11,765.40**

Over the eight month citation period, the City has taken in $182,502 and has been charged a service charge of $235,943, resulting in a net loss of $53,441 as shown in TABLE 22. Also shown in TABLE 22 in the subtotal column is the accumulating debt that is carried over from the previous month if the city does not collect enough revenue to cover the $29,000 service charge. The deduction column is how much the city receives as profit if revenues are greater than the service charge. Unfortunately, because Clive has such a large debt load, the profit towards the city has been paying off the net loss as shown in column labeled “Total”. Furthermore, Redflex adjusts its service charge based on the change of the consumer price index for all urban consumers (CPI-U) for the U.S. City Average for all items.

TABLE 22 Total RLR Camera Revenue as Reported by the City of Clive

Month	Revenue	Service Charge	Subtotal	Previous Balance	Deduction	Total
Jul-06	$0.00*	$1,947.96	($1,947.96)	$0.00	$0.00	($1,947.96)
Aug-06	$3,525.00	$29,220.00	($25,695.00)	($1,947.96)	$0.00	($27,642.96)
Sep-06	$15,581.64	$29,220.00	($13,638.36)	($27,642.96)	$0.00	($41,281.32)
Oct-06	$22,573.42	$29,220.00	($6,646.58)	($41,281.32)	$0.00	($47,927.90)
Nov-06	$20,346.26	$29,240.00**	($8,894.39)	($47,927.90)	$0.00	($56,822.29)
Dec-06	$17,141.67	$29,240.65	($12,098.98)	($56,822.29)	$0.00	($68,921.27)
Jan-07	$26,001.79	$29,249.50**	($3,247.71)	($68,921.27)	$0.00	($72,168.98)
Feb-07	$37,823.25	$29,276.05**	$8,547.20	($72,168.98)	$8,547.20	($68,621.78)
Mar-07	$39,509.65	$29,329.15**	$10,180.50	($68,621.78)	$10,180.50	**($53,441.28)**

*Warning month; no revenue collected by the city, minimal service charge
**Increase based on the Consumer Price Index for All Urban Consumers (CPI-U) for the U.S. City Average for All Items

3.2.6 Legal Proceedings

In October 2006, Tim Steinmeyer of Urbandale, Iowa was photographed by a red light running camera at 100th street and Hickman Road traveling northbound while making a right turn onto Hickman Road. Steinmeyer thought the arrow was green, but the ticket showed the light above the arrow was red. After reviewing the ticket received from Redflex, Steinmeyer concluded that the photographs were inconclusive and after reviewing the video and noticing the adjacent vehicles running the red light as well. Steinmeyer decided to contest the violations in front of Polk County Magistrate Jeffery Lipman on January 24, 2007. Steinmeyer cross-examined Sergeant Vernon Lukehart from the City of Clive Police Department and Redflex training manager Tony Parrino. The City of Clive asked the court to consider not only the merits of Steinmeyer's claim, but the also the constitutionality of the City's Chapter 61 Ordinances.

On March 26, 2007, in a 26 page disposition, Magistrate Lipman cited that video recording is accepted evidence in the State of Iowa and cited the Iowa court case Hutchinson v. Am. Family Mut. Ins. Co., 514 N.W.2d 882, 890 (Iowa 1994). This case involved Connie Lee Hutchinson's family who brought American Family Mutual Insurance Company to the Iowa Supreme Court appealing their first district court ruling seeking underinsured motorist benefits. A video tape used in the district court included computer animation which depicted how close-head injury could affect the brain, as suffered by Ms. Hutchinson. The Iowa Supreme Court ruled that the video tape "did not purport to recreate Ms. Hutchinson's particular accident", but showed an overview of what could happen. It was also ruled that a motion picture [to be] "admissible [it] must be authenticated, although no particular methodology is required." It was also noted that "when the posed photographs go no further in the undisputed testimony, their admission has long been generally approved." In the case City of Clive v Steinmeyer (2007), Mr. Steinmeyer was found to have run a red light and the photographs were captured by sensors and do not impact the legitimacy of the evidence, and that the RLR cameras systems and each captured images is certified by an internal certificate.

Although, Magistrate Lipman ruled that use of the cameras was admissible, he also cited Iowa Code 364.2(2) which states "The enumeration of a specific power of a City does not limit or restrict the general grant of home rule power conferred by the constitution of the State of Iowa. A City may exercise its general powers subject only to limitations expressly imposed by a state or city law." Two procedural challenges face the City of

Clive in response to Iowa Code 364.2(2). Citing the court case City of Vinton v. Engledow 258 Iowa 861, 140 N.W.2d (Iowa 1966), where [any] “ordinances passed under statute providing that cities and towns shall have to restrain and regulate the riding and driving of horses, livestock, fast or immoderate riding or driving within such limits must comply with requirements of statutes requiring traffic laws to be uniform and requiring ordinances to be consistent with statutes.” As specified in the disposition, the City of Clive had violated this statement by establishing a civil fine of $75 that differed from a scheduled fine of $35. The $35 fine was established by the City of Clive if a police officer pulls over a RLR violator, which totals $96.20 including court cost and taxes, and is reported to the Iowa Department of Transportation as specified by Iowa Code 321.491. It states, “Within ten days after the conviction or forfeiture of bail of a person upon a charge of violating any provision of this chapter or other law regulating the operation of vehicles on highways, every magistrate of the court or clerk of the district court of record in which the conviction occurred or bail was forfeited shall prepare and immediately forward to the department an abstract of the record of the case.” Magistrate Lipman noted the same ruling in the district court case City of Davenport v. Monique D. Rhoden (Iowa 2007).

In summary, Magistrate Lipman stated that RLR cameras were sound technology which are admissible in the court of law and recognized that the City of Clive has the authority to regulate traffic signal offenses. In response to this ruling, the Clive City Council voted unanimously on March 29. 2007 to suspend Ordinances 851, 858, and 863 until the matter can be settled in a district appeals court later this year. In summary, the two main issues that were found by Magistrate Lipman were first; the City of Clive violated Chapter 364.2(2) of the Iowa (2006) by setting a separate fine schedule for RLR violations an existing established scheduled fine of $35 for an officer observing a RLR violation. The second issue mentioned was that RLR was considered a criminal traffic violation as specified in Iowa Code Chapter 321.491 which states that a criminal traffic violation it must be reported to the Iowa DOT. Currently, an automated RLR ticket is considered a civil fine which is not reported to the Iowa DOT.

3.3 VIOLATION STUDY

This section discusses a violation study that compared the red light violations at the instrumented intersections against a set of control intersections. RLR data for non-instrumented intersections were collected by setting up a video camera during peak hours of the day and recording vehicle behavior through the intersection. The number of violations that occurred at instrumented versus non-instrumented intersections is presented.

3.3.1 Site Selection

Data were collected from 11 selected intersections; 4 intersections were camera enforced and 7 intersections were used as control sites. 6 intersections were located in nearby cities including Clive, Urbandale, West Des Moines, and Waukee. One intersection was selected outside of the nearby study area in the City of Ankeny.

When selecting comparison intersections, three main criteria were used to determine which intersections and approaches were to be used in this study. The first criterion involved gathering information from the city and determining if the control intersections had similar approach geometry, traffic signal configuration, signage, daily entering vehicles, and signal timing. The second criterion was based on city traffic engineer and police department recommendations. After an initial interview with city representatives prior to the field investigations, recommended RLR "hot spots" were given to the research team based on the number of issues citations for drivers running a red light. The third criterion used to determine control intersections was based on a violation study performed by Cunningham and Hummer where the researchers believed that a comparison site must lie on the same corridor within a one-mile radius. Cunningham and Hummer believed that drivers would forget about automated enforcement after leaving the one mile buffer zone and revert to normal driving habits *(53)*. As shown in Figure 26, all but one of the comparison sites are located within the one-mile radius, 86th and Douglas was selected based on a recommendation from multiple city officials as a well known RLR intersection. The final sites used for the violation study include:

- North- and eastbound 156th Street & Hickman Road (Clive, Iowa)
- Eastbound 142nd Street & Hickman Road (Clive, Iowa)
- North- and eastbound 128th Street & Hickman Road (Clive, Iowa)
- Northbound 100th Street & Hickman Road (Clive, Iowa)
- North- and eastbound 86th Street & Hickman Road (Clive, Iowa)
- South- and westbound 86th Street & Douglas Avenue (Urbandale, Iowa)
- North-, east-, and westbound 100th Street & Douglas Avenue (Urbandale, Iowa)
- Eastbound North Warrior Lane & Hickman Road (Waukee, Iowa)
- West – and southbound 35th Street & University Avenue (West Des Moines)
- North-, west- and eastbound 60th Street & University Avenue (West Des Moines)
- East-, and northbound Oralabor Road & State Street (Ankeny, Iowa)

3.3.2 Site Descriptions

Details about each of the selected intersections and approaches are shown in the following pages. Approach and aerial images were acquired from local GIS departments and field images were taken during data collection. At each intersection, it was noted what businesses were surrounding the area and if the pedestrian count was high. Other important information collected included peak hour volumes for each turning movement, signal timing for left turning and through movements, and identifying if a lane had a dedicated movement or if it shared a movement (e.g. a though and right turning movement for one lane, this would be specified as "shrd" in the table). The approach speed limit was also recorded as each approach had a different posted speed limit. The last aspect recorded was whether the intersection were actuated, pre-timed, or in coordination with nearby intersections. Actuated means the traffic signal will change for a maximum time if a vehicle is detected by either video or an inductive loop.

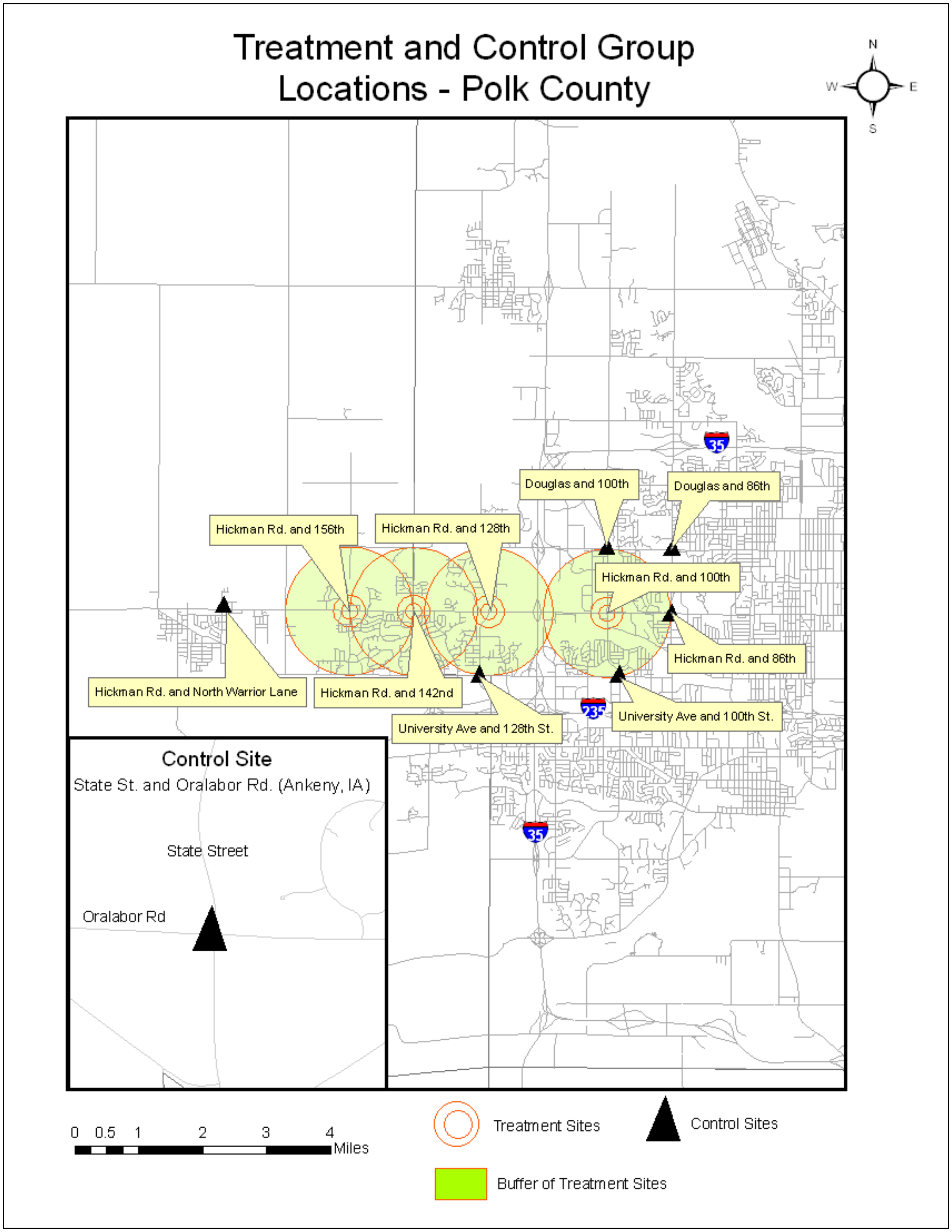


Figure 26. Violation Study Intersections with Buffer Zones.

Typically the minor street is actuated when the second street is a major street such as Hickman Road. Free loops, similar to actuated means that all approaches are managed like an actuated signal where the traffic signal will change its phase before the maximum is up for a vehicle that is detected. Pre-timed signals do not involve vehicle detection devices and are pre-programmed by the traffic engineer to keep a consistent time of green for each approach for a certain period of the day. Finally, a coordinated signal is typically found in a corridor where multiple traffic signals are located on a major road. The traffic engineer may wish to coordinate multiple signals so that drivers have all green phases while traveling the corridor at or below the posted speed limit. Coordination plans can be very complicated and can adjust multiple times during the day to accommodate different volumes of traffic.

156th Street & Hickman Road

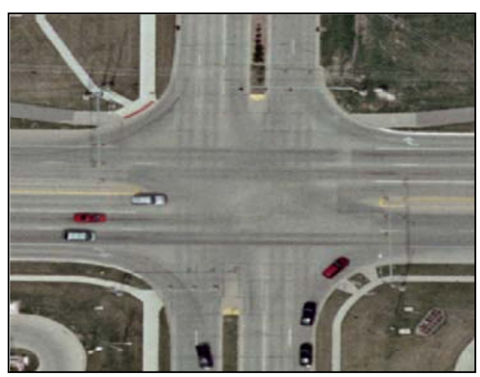
The intersection at 156th Street and Hickman Road is the farthest west camera enforced intersection in Clive and is also the last major intersection before the City of Waukee which is located just west of Clive. On the southeast side of the intersection is a Dahl's grocery store which is surrounded by residential developments. On the southwest side are a gas station and small commercial businesses. On the northwest side of the intersection is a commercial development and on the northeast side are private residences. This intersection is also has significant pedestrian and bicycle traffic on the north side traveling east and west. 156th Street connects to Douglas Avenue to the north and University Avenue to the south. Characteristics about each intersection are provided in TABLE 23 through TABLE 32.

TABLE 23 Roadway, Traffic, and Signal Timing Characteristics for 156th St. & Hickman Road

Intersection	156th Street & Hickman Road (Clive, Iowa)
RLR Camera Approach	Eastbound Hickman Road and Northbound 156th Street
N-S Street:	156th Street
E-W Street:	Hickman Road
Peak Periods	7:00 - 9:00 AM, 11:00 AM - 1:00 PM, 4:00 - 6:00 PM

	NB			EB		
	L	T	R	L	T	R
Lanes	1	2,3	4	1	2	shrd
Posted Speed (mph)	35			50		
Peak Hour Volumes						
7:00-9:00 AM	211	229	70	338	2586	262
11:00 AM -1:00 PM	316	272	163	161	1553	150
4:00-6:00 PM	424	726	298	140	2006	160
Cycle Length (sec.)						
6:00 AM - 3:30 PM	100	100		100	100	
3:30 PM - 7:00 PM	120	120		120	120	
7:00 AM - 6:00 AM	Free Loops			Free Loops		
Green Interval (sec.)						
6:00 AM - 3:30 PM	30	20		30	50	
3:30 PM - 7:00 PM	20	50		15	60	
7:00 AM - 6:00 AM	Free Loops			Free Loops		
Yellow Interval (sec.)	3.5	4.0		3.5	5.1	
All-Red Interval (sec.)	1.5	2.4		1.5	2.4	

*Actuated and Coordinated with Hickman Road Progression



Aerial View of 156th St. & Hickman Rd.

Figure 27. 156th St. & Hickman Rd. (eastbound).

Figure 28. 156th St. & Hickman Rd. (northbound).

142nd Street & Hickman Road

Located one mile east of the intersection of 156th Street and Hickman Road, the intersection of 142nd and Hickman Road has less commercial development, but more private residences south of Hickman Road t. A large church is located on the southeast side of the intersection, and significant pedestrian and bicycle traffic continue on the north side of the intersection on an 8 foot wide paved trail. 142nd Street connects to both University Avenue to the south and Douglas Avenue to the north.

TABLE 24 Roadway, Traffic, and Signal Timing Characteristics for 142nd St. & Hickman Rd.

Intersection	142nd Street & Hickman Road (Clive, Iowa)
RLR Camera Approach	Eastbound Hickman Road
N-S Street:	142nd Street
E-W Street:	Hickman Road
Peak Periods	7:00 - 9:00 AM, 11:00 AM - 1:00 PM, 4:00 - 6:00 PM

	NB		
	L	**T**	**R**
Lanes	1	2,3	4
Posted Speed (mph)	55		
Peak Hour Volumes			
7:00-9:00 AM	123	2583	333
11:00 AM -1:00 PM	470	1020	321
4:00-6:00 PM	512	1411	485
Cycle Length (sec.)			
Peak Hours	100		
Off-Peak Hours	100		
Green Interval (sec.)			
Peak Hours	20	50	
Off-Peak Hours	30	60	
Yellow Interval (sec.)	3.5	5.1	
All-Red Interval (sec.)	1.5	1.2	

*Actuated and Coordinated with Hickman Road Progression

Aerial View of 142nd St. & Hickman Rd.

Figure 29. 142nd St. & Hickman Rd. (eastbound).

128th Street & Hickman Road

The intersection of 128th Street and Hickman Road is the only camera enforced intersection in Clive that is located on a minor road. At the time of the study the intersection is under construction, being upgraded from a two-lane to a four-lane road. From field investigations, this intersection and appears to be a main connecting road for commuters traveling north to south. Due to its greater distance from residential areas, less pedestrian and bicycle traffic occurs here and truck traffic is heavy due to Interstate 80 / 35 being a mile east of this intersection. Two banks are located on the north side of the intersection (one on each side) and there are residential areas behind. Campbell Recreation Area is located on the southeast side of the intersection.

TABLE 25 Roadway, Traffic, and Signal Timing Characteristics for 128th St. & Hickman Rd.

Intersection	128th Street & Hickman Road (Clive, Iowa)
RLR Camera Approach	Eastbound Hickman Road and Northbound 128th Street
N-S Street:	128th Street
E-W Street:	Hickman Road
Peak Periods	7:00 - 9:00 AM, 11:00 AM - 1:00 PM, 4:00 - 6:00 PM

	NB			EB		
	L	**T**	**R**	**L**	**T**	**R**
Lanes	1	2	shrd	1	2,3	4
Posted Speed (mph)	35			50		
Peak Hour Volumes						
7:00-9:00 AM	211	229	70	338	2588	262
11:00 AM -1:00 PM	316	272	163	161	1553	150
4:00-6:00 PM	424	726	298	140	2006	160
Cycle Length (sec.)						
Peak Hours	100			100		
Off-Peak Hours	100			100		
Green Interval (sec.)						
Peak Hours	30	50		30	50	
Off-Peak Hours	27	30		20	50	
Yellow Interval	3.5	3.6		3.5	5.0	
All-Red Interval	1.5	2.6		1.5	1.4	

*Actuated and Coordinated with Hickman Road Progression

Aerial View of 128th St. & Hickman Rd.

Figure 30. 128th St. & Hickman Rd. (northbound).


Figure 31. 128th St. & Hickman Rd. (eastbound).

100th Street & Hickman Road

The intersection of 100th Street and Hickman Road is located in a large commercial area which includes Betts Auto Campus and this intersection is the most eastern location with automated camera enforcement. 100th Street serves as a large collector street for Clive, Urbandale, and West Des Moines. One mile south of this intersection is Valley West Mall, and one mile west is Interstate 80. Less than one mile north of this intersection is an active railroad line connecting to local factories. There is also considerable pedestrian and bicycle traffic north and south which connects to a local trail network.

TABLE 26 Roadway, Traffic, and Signal Timing Characteristics for 100th St. & Hickman Rd.

Intersection	100th Street & Hickman Road (Clive, Iowa)
RLR Camera Approach	Northbound 100th Street
N-S Street:	100th Street
E-W Street:	Hickman Road
Peak Periods	7:00 - 9:00 AM, 11:00 AM - 1:00 PM, 4:00 - 6:00 PM

	NB		
	L	**T**	**R**
Lanes	1	2,3	4
Posted Speed (mph)	35		
Peak Hour Volumes			
7:00-9:00 AM	189	698	199
11:00 AM -1:00 PM	70	1020	321
4:00-6:00 PM	512	1411	485
Cycle Length (sec.)			
Peak Hours	100		
Off-Peak Hours	100		
Green Interval (sec.)			
Peak Hours	35	45	
Off-Peak Hours	30	35	
Yellow Interval (sec.)	3.0	4.5	
All-Red Interval (sec.)	2.0	1.5	

*Actuated and Coordinated with Hickman Road Progression


Aerial View of 100th St. & Hickman Rd.

Figure 32. 100th St. & Hickman Rd. (northbound).

<u>86th Street & Hickman Road</u>

The intersection of 86th Street and Hickman Road is one mile east of 100th street and reconstruction is planned for the near future. Plans include signal coordination, access management along 86th Street, and longer turning bays. On the southwest side of the intersection is a Dahl's grocery store, and on the southeast side is an auto parts store. On the northeast side of the intersection is a small strip mall, and on the northwest side is a Perkins Restaurant with a frontage road. This frontage road serves as a shortcut for many commuters when the intersection is at capacity.

TABLE 27 Roadway, Traffic, and Signal Timing Characteristics for 86th St. & Hickman Road

Intersection	86th Street & Hickman Road (Clive, Iowa)
Video Camera Location	Northbound 86th Street and Eastbound Hickman Road
N-S Street:	86th Street
E-W Street:	Hickman Road
Peak Periods	7:00 - 9:00 AM, 11:00 AM - 1:00 PM, 4:00 - 6:00 PM

	NB			**EB**		
	L	**T**	**R**	**L**	**T**	**R**
Lanes	1	2	shrd	1	2	shrd
Posted Speed (mph)		30			40	
Peak Hour Volumes						
7:00-9:00 AM	184	696	116	227	758	198
11:00 AM -1:00 PM	208	1168	233	427	993	174
4:00-6:00 PM	325	1495	346	50	1641	149
Cycle Length (sec.)						
Peak Hours		100			100	
Off-Peak Hours		100			100	
Green Interval (sec.)						
Peak Hours	30	40		25	40	
Off-Peak Hours	40	40		40	40	
Yellow Interval (sec.)	3.0	3.5		3.0	3.9	
All-Red Interval (sec.)	1.5	1.8		1.5	1.6	

Aerial View of 86th Street & Hickman Road

Figure 33. 86th St. & Hickman Rd. (southbound).

86th Street & Douglas Avenue

Located north of the Hickman Road corridor in the city of Urbandale is the intersection of 86th Street and Douglas Avenue. This intersection moves east- and westbound traffic to the north and south with double left turn lanes. On the northwest side of the intersection is a HyVee grocery store, and on the northeast side of the intersection is a Wells Fargo Bank and various commercial businesses. On the southeast side is a commercial development and on the southwest side is the Urbandale Administration Building and Public Library.

TABLE 28 Roadway, Traffic, and Signal Timing Characteristics for 86th St. & Douglas Ave.

Intersection	86th Street & Douglas Avenue (Urbandale, Iowa)					
Video Camera Location	Westbound Douglas Ave. and Southbound 86th Street					
N-S Street:	86th Street					
E-W Street:	Douglas Avenue					
Peak Periods	7:00 - 9:00 AM, 11:00 AM - 1:00 PM, 4:00 - 6:00 PM					
	SB			**WB**		
	L	**T**	**R**	**L**	**T**	**R**
Lanes	1	2,3	4	1,2	3	shrd
Posted Speed (mph)	35			45		
Peak Hour Volumes						
7:00-9:00 AM	187	1320	302	279	1089	137
11:00 AM -1:00 PM	281	1119	253	375	880	283
4:00-6:00 PM	341	1341	365	341	1341	360
Cycle Length (sec.)						
7:00-9:00 AM	90			90		
11:00 AM -1:00 PM	100			100		
4:00-6:00 PM	100			100		
Green Interval (sec.)						
7:00-9:00 AM	9.6	32.2	44.8	6.0	23.5	9.6
11:00 AM -1:00 PM	11.8	38.6	51.5	10.6	26.0	10.5
4:00-6:00 PM	12.7	32.5	47.5	11.9	27.9	10.5
Yellow Interval (sec.)	3.0	3.6	3.0	3.0	4.0	3.0
All-Red Interval (sec.)	1.0	2.1	1.0	1.0	2.1	1.0

*Actuated and Coordinated with 100th Street & Douglas Avenue

Aeral View of 86th St. & Douglas Ave.

Figure 34. 86th St. & Douglas Ave. (southbound).

<u>100th Street & Douglas Avenue</u>

One mile west of 86th Street and one mile north of Hickman Road is the intersection of 100th Street and Douglas Avenue. Located in an industrial area of Urbandale, this intersection moves traffic northbound and southbound from the east. Located on the northeast side of the intersection is a 28-pump QuikTrip and several fast food establishments. On the northwest side of the intersection are various commercial developments. On the southwest side of the intersection are heavy commercial businesses with a railroad track running diagonal to the west and northbound approaches. On the southeast side of the intersection are residential areas and small businesses. This intersection experiences school bus blockage in the morning and afternoon due to the railroad tracks.

TABLE 29 Roadway, Traffic, and Signal Timing Characteristics for 100th St. & Douglas Ave.

Intersection	100th Street & Douglas Avenue (Urbandale, Iowa)								
Video Camera Location	Northbound 100th Street and East and Westbound Douglas Avenue								
N-S Street:	100th Street								
E-W Street:	Douglas Avenue								
Peak Periods	7:00 - 9:00 AM, 11:00 AM - 1:00 PM, 4:00 - 6:00 PM								
	NB			**WB**			**EB**		
	L	**T**	**R**	**L**	**T**	**R**	**L**	**T**	**R**
Lanes	1	2,3	4	1,2	3	shrd	1	2	shrd
Posted Speed (mph)	35			45			45		
Peak Hour Volumes									
7:00-9:00 AM	171	477	183	466	1047	220	277	591	93
11:00 AM -1:00 PM	261	835	451	544	862	260	378	901	265
4:00-6:00 PM	204	1162	672	518	801	256	414	1305	241
Cycle Length (sec.)									
7:00-9:00 AM	100			100			120		
11:00 AM -1:00 PM	100			100			120		
4:00-6:00 PM	100			100			120		
Green Interval (sec.)									
7:00-9:00 AM	38.8	31.4	49.4	14.0	29.8		15.5	31.3	
11:00 AM -1:00 PM	44.3	34.6	52.9	14.3	24.9		16.3	27.0	
4:00-6:00 PM	42.8	34.7	54.1	15.4	29.8		24.7	39.1	
Yellow Interval (sec.)	4.0			4.0			4.0		
All-Red Interval (sec.)	1.0			1.0			1.0		

*Actuated and Coorindated with 86th Street & Douglas Avenue

Figure 35. 86th St. & Douglas Ave. (northbound).

Figure 36. 86th St. & Douglas Ave. aerial view.

35th Street & University Avenue

Located in the north part of the city of West Des Moines, the intersection of 35th Street (Valley West Drive) and University Avenue is located next to Valley West Mall and several large commercial developments including Target, Best Buy, Home Depot, and many others which are located on the south side of the intersection. On the north side of the intersection are small commercial developments surrounded by residential areas. Half of this intersection is located in the City of Clive, but the West Des Moines Traffic Operations Center controls the traffic signals at this intersection.

TABLE 30 Roadway, Traffic, and Signal Timing Characteristics for 35th St. & University Ave.

Intersection	35th Street & University Avenue (West Des Moines, Iowa)
Video Camera Location	Westbound University Avenue and Southbound 35th Street
N-S Street:	35th Street
E-W Street:	University Avenue
Peak Periods	7:00 - 9:00 AM, 11:00 AM - 1:00 PM, 4:00 - 6:00 PM

	SB			WB		
	L	T	R	L	T	R
Lanes	1	2	shrd	1	2	shrd
Posted Speed (mph)	35			35		
Peak Hour Volumes						
7:00-9:00 AM	217	516	227	196	415	102
11:00 AM -1:00 PM	331	461	319	296	664	279
4:00-6:00 PM	271	704	294	273	781	248
Cycle Length (sec.)						
7:00-9:00 AM	100-110			100-110		
11:00 AM -1:00 PM	105-110			105-110		
4:00-6:00 PM	105-110			105-110		
Green Interval (sec.)						
7:00-9:00 AM*	18-20	28-30**		18-20	40-45**	
11:00 AM -1:00 PM*	20-22	29-30**		18-20	36-45**	
4:00-6:00 PM*	20-22	29-30**		18-20	36-45**	
Yellow Interval	4.0	4.0		4.0	4.0	
All-Red Interval	1.0	2.0		1.0	2.0	

* Actuated Through Maximum Values, **Minimum values

Aerial view of 35th Street & University Ave.

Figure 37. 35th St. & University Ave. (southbound).

<u>128th Street & University Avenue</u>

Located west of Interstate 80 and one mile south of Hickman Road is the intersection of 128th Street and University Avenue. This intersection is also surrounded by commercial development. On the southwest side of the intersection is the Lakeview Medical Park. Biaggi's restaurant is located on the southeast side with a Walgreens on the northeast side, and Granite City Brewing Company on the northwest side. This intersection moves many commuters off and on Interstate 80 / 35 in the mornings and evenings. To the north of the intersection, 128th Street is currently a two-lane road passing through residential areas; the City of Clive is in the process of making the road a divided four-lane arterial.

TABLE 31 Roadway, Traffic, and Signal Timing Characteristics for 60th St. & University Ave.

Intersection	60th Street & University Avenue (West Des Moines, Iowa)								
Video Camera Location	Westbound University Avenue and Southbound 60th Street								
N-S Street:	60th Street								
E-W Street:	University Avenue								
Peak Periods	7:00 - 9:00 AM, 11:00 AM - 1:00 PM, 4:00 - 6:00 PM								
	NB			**SB**			**WB**		
	L	**T**	**R**	**L**	**T**	**R**	**L**	**T**	**R**
Lanes	1	2	shrd	1	2	shrd	1	2	shrd
Posted Speed (mph)	35			35			45		
Peak Hour Volumes									
7:00-9:00 AM	172	318	205	270	397	352	424	939	108
11:00 AM -1:00 PM	219	403	333	201	257	276	419	1188	245
4:00-6:00 PM	373	588	316	202	389	208	363	1399	444
Cycle Length (sec.)									
Free Loops Actuated	110			110			110		
7:15 AM - 10:00 PM	110			110			110		
Green Interval (sec.)									
Free Loops Actuated	Actuated			Actuated			Max Time		
7:15 AM - 10:00 PM	16*	28*		16*	26*		24*	48**	
Yellow Interval (sec.)	3.6	3.6		3.6	3.6		4.4	4.4	
All-Red Interval (sec.)	2.4	2.4		2.2	2.2		1.8	1.8	

* Actuated with additional times going to coordnated phase

** Coordnated phase Maximum

Figure 38. 86th St. & University Ave. (westbound).

Figure 39. 86th St. & University Ave. aerial view.

<u>Oralabor Road & State Street</u>

Oralabor Road and State Street was one of two control sites used in the violation study. This high-speed intersection is located in Ankeny about 15 miles northeast of the Hickman Road corridor. There are not currently any businesses or residential developments at the corners of the intersection, but future developments are moving closer. Many morning and evening commuters travel through this intersection to Interstate 35 which is located a short distance east, or they travel south of State Street to north Des Moines.

TABLE 32 Roadway, Traffic, and Signal Timing Characteristics for Oralabor Rd. & State St.

Intersection	Oralabor Road & State Street (Ankeny, Iowa)					
Video Camera Location	Northbound State Street and Eastbound Oralabor Road					
N-S Street:	State Street					
E-W Street:	Oralabor Road					
Peak Periods	7:00 - 9:00 AM, 11:00 AM - 1:00 PM, 4:00 - 6:00 PM					
	NB			**EB**		
	L	**T**	**R**	**L**	**T**	**R**
Lanes	1	2,3	4	1	2,3	4
Posted Speed (mph)	55			55		
Peak Hour Volumes						
7:00-9:00 AM	211	399	339	187	1128	550
11:00 AM -1:00 PM	154	307	362	105	720	190
4:00-6:00 PM	577	1203	710	291	1210	256
Cycle Length (sec.)						
5:30 - 9:00 AM	90-110			90-110		
9:00 AM - 2:30 PM	80-100			80-100		
2:30 -5:30 PM	90-110			90-110		
5:30 -11:50 PM	Fully Actuated			Fully Actuated		
11:50 PM - 5:30 AM	60-80			60-80		
Green Interval (sec.)						
5:30 - 9:00 AM	27	110		80	110	
9:00 AM - 2:30 PM	76	100		76	100	
2:30 -5:30 PM	80	110		33	110	
5:30 -11:50 PM	25*	45*		25*	45*	
11:50 PM - 5:30 AM	76	110		76	110	
Yellow Interval (sec.)	4.0			4.0		
All-Red Interval (sec.)	2.0			2.0		

Aerial view of Oralabor Road & State Street

* Coordinated with Oralabor Progression

*Max Green

Figure 40. Oralabor Rd. & State St. (northbound).

North Warrior Lane & Hickman Road

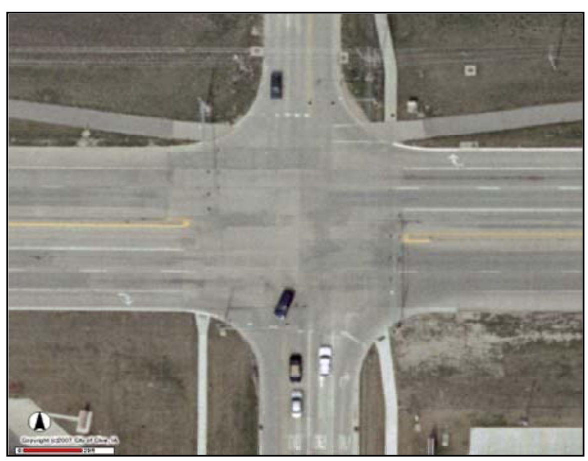
The second control site used in the violation study was the intersection of North Warrior Lane and Hickman Road located in Waukee. This intersection is located 2 miles west of the 156th Street intersection and the approaches speed limit are 10 mph lower at 45 mph. North Warrior Lane is one of three major roads that lead into the City of Waukee and is surrounded by new commercial and light industrial businesses. On the southwest corner of the intersection is a 16-pump Casey's General Store which serves as a morning and afternoon staging area for Waukee school buses. Traffic volume is expected to increase over the next 10 years due to expanding development from the Des Moines area.

TABLE 33 Roadway, Traffic, and Signal Timing Characteristics for N. Warrior Ln. & Hickman Rd.

Intersection	North Warrior Lane & Hickman Road (Waukee, Iowa)
Video Camera Location	Eastbound Hickman Road
N-S Street:	North Warrior Lane
E-W Street:	Hickman Road
Peak Periods	7:00 - 9:00 AM, 11:00 AM - 1:00 PM, 4:00 - 6:00 PM

	EB		
	L	**T**	**R**
Lanes	1	2,3	4
Posted Speed (mph)	45		
Peak Hour Volumes			
7:00-9:00 AM	39	1329	71
11:00 AM -1:00 PM	39	767	82
4:00-6:00 PM	52	921	74
Cycle Length (sec.)			
Actuated	45-50	45-50	
Green Interval (sec.)			
Actuated	15**	15**	
Yellow Interval (sec.)	4	4.2	
All-Red Interval (sec.)	1.0	1.0	

* Fully Actuated
** Minimum Green Time



Aerial View of North Warrior Lane & Hickman Road

Figure 41. N. Warrior Ln. & Hickman Rd. (eastbound).

3.4 DATA COLLECTION

The ideal way to evaluate the effectiveness of red light running cameras is to evaluate the before and after crash reduction. However, since the cameras in Clive weren't installed until the end of 2005, only one year of after data was available which is not sufficient to conduct a crash analysis *(49)*. As a result, the only way to evaluate the effectiveness of Clive's automated RLR enforcement system was to perform a cross-secitonal analysis that compared RLR violations at camera instrumented intersections to a group of control intersections. The number of red light running citations issued and additional collected data for the instrumented intersections were provided by the City of Clive and are presented in the following sections. Field studies were conducted at the control intersections to collect violation data on a randomly sampled day of the week between Tuesday and Thursday. Since it is difficult to visually monitor an intersection for red light running violations, approaches were videotaped and the numbers of red light violations were extracted from a review of the captured video.

3.4.1 Equipment Feasibility

Initially, the team planned to video tape intersections using a video monitoring system owned by CTRE which consists of two black and white Autoscopes mounted on a telescoping arm which is mounted on a trailer. The mast can be raised to 35 feet. The system was first tested for feasibility on February 21, 2007. CTRE's mobile Autoscope system was deployed at the intersection of Airport Road and US 69 in Ames to evaluate how well it served. The Autoscope trailer was set up at the northwest side of the intersection behind the Wiley Ford dealership sign shown in Figure 42 marked by a red circle. The Autoscope was raised 35 feet into the air and only one camera was used to monitor the intersection due to the other camera not being able to pan correctly.

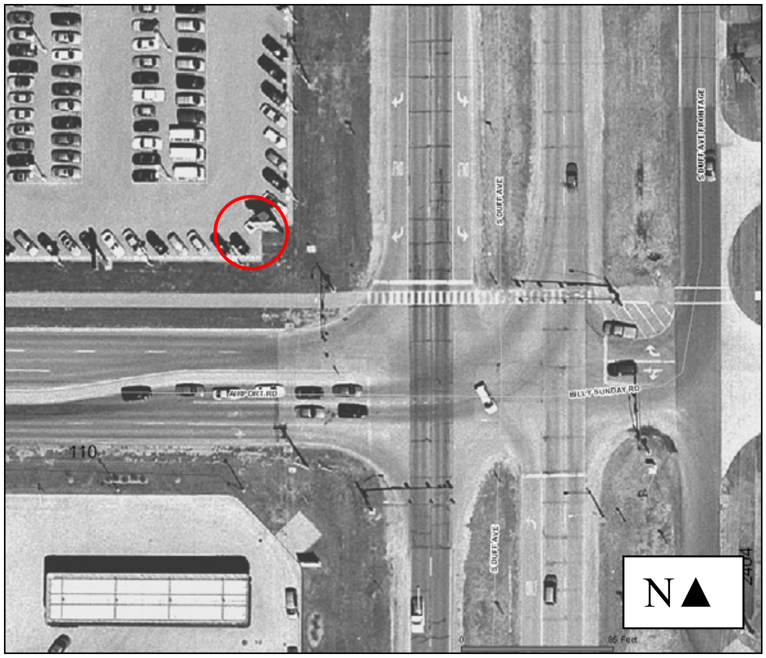


Figure 42. Test Location in Ames, Iowa (Image: Ames Assessors Office).

Black and white video was recorded for the three peak hours of 7:00 AM – 9:00 AM, 11:00 AM – 1:00 PM, and 4:00 PM – 6:00 PM, and the mast was lowered between recording sessions. The eastbound and southbound approaches were the only approaches studied. The videos were post-processed the following day. Shown in Figure 43 and Figure 44 are the respective 4:00 PM – 6:00 PM and 11:00 AM – 1:00 PM resulting video images.

Figure 43. Autoscope image of test location in Ames looking eastbound at 4:52 PM.

Figure 44. Autoscope image of test location in Ames, looking eastbound at 11:04 AM.

As shown in Figure 43 and Figure 44, it was nearly impossible to view the traffic signal phase for the entire day because of sun glare, shadows, wind, and the type of equipment. Additionally, the trailer/camera/mast arm configuration is rather obvious and it was not certain whether the data collection equipment would affect driver behavior. As a result, the research team decided to use ground level wide-angle Digital Versatile Disc (DVD) cameras instead. In addition to these cameras being less obvious to drivers, they can be positioned to minimize glare and shadows and also detect the color of the traffic signal quite easy.

3.4.2 Field Data Criteria

Control intersections were selected that were similar to the camera instrumented locations. Several locations in Clive, West Des Moines, and Urbandale were chosen based on the following characteristics:

- Average daily entering vehicle counts were similar
- Geometric characteristics were similar
- Approaching posted speed limits were similar
- Signal timing was similar
- Lane configuration was similar

Along with these initial criteria, location and approach type were taken into consideration. The intersections selected were within one mile of an intersection on Hickman Road with camera enforcement, and the approaches studied at these intersections were either: (1) in the City of Clive (one direction: University and Douglas), or (2) the approach direction was the same as the camera approach upstream or downstream or (3) the field team determined that there was a high number of RLRs in a specified approach direction. Permission was granted from the Cities of West Des Moines, Clive, Urbandale, Waukee, Ankeney to park and video tape on city owned right-of-way. In addition to the control intersections around the RLR camera locations, two additional intersections were selected outside of Clive, West Des Moines, and Urbandale to ensure that some of the control locations were not influenced by the RLR cameras or corridor. The two intersections were at

Oralabor Road and State Street in Ankeny and North Warrior Lane and Hickman Road in Waukee. Both intersections had many of the same characteristics of intersections along Hickman Road including 45 and 55 mph posted approach speeds and similar traffic movements.

3.4.3 Field Data Collection Methodology

Video was taken using two DVD-R digital cameras mounted on two tripods in the bed of an Iowa State University pickup truck as shown in Figure 45.

Figure 45. Collecting data at 86th Street and Douglas Avenue.

Since the self-contained camera battery was limited to 90 minutes; a car battery unit and a D/C power converter were used to supply power so that the intersection could be monitored for an entire day. Since the cameras needed to be near the data collection vehicle for power, this constrained how far apart the cameras could be placed, thus eliminating ground use or the ability to hide the cameras behind obstructions. The truck was parked close enough to the intersection so that drivers could identify the “Iowa State University” logo on the truck and (presumabley) continue driving normally. The cameras were positioned high on the tripods which could see the stop bar and traffic signal in the same frame. Peak hour videos were taken between the hours of 7:00 AM – 9:00 AM, 11:00 AM – 1:00 PM, and 4:00 PM – 6:00 PM. Each DVD-R disk recorded thirty minutes of raw video; thus, the need to change disks resulted in a small amount of lost recording time. Early morning sunlight limited the available viewing angle if video was taken of an eastbound approach. Video recording was halted two times due to heavy rains in March and a late April snowstorm.

DVDs were viewed using the computer program Power DVD where zoom and frame-by-frame capabilities could be used to determine if a red light running violation occurred. Although the frame-by-frame feature added a more exact way to measure car position in relevance to the yellow and red light, some experimental error was expected. Shown in Figure 46 is a frame of the DVD video of the recorded intersection.

Figure 46. Captured video of N. Warrior Lane and Hickman Road.

A RLR violation was considered to occur if: the front of the vehicle crossed the stop bar or end of the center median (if no stop bar was present) after the red indication was given. Figure 46 illustrates a silver SUV stopped prior to the intersection before the edge of the median and behind the crosswalk (which cannot be seen in this image). This assumption was mainly used for the through and protected / permitted left turning movements. For vehicles making a right turn on a red, a RLR violation was counted if the vehicle did not come to a complete stop or close to a complete stop before making the right turn as specified by all three cities' municipal codes.

Another variable that was needed in the analysis was the traffic volume for each intersection. The Cities of West Des Moines and Urbandale had vehicle counts per lane at each of the control intersections, while the City of Clive had no traffic counts for Hickman Road. Manual counts at the camera enforced approaches at each intersection were performed during the peak hours of either Tuesday, Wednesday, or Thursday. Vehicle counts were recorded on Jamar Technologies DB-400 Turning Movement Counter, and then later downloaded using the computer program PETRAPro.

Video recording took place from March, 2007 through April 2007 at the comparison intersections. Due to the court ruling, the RLR cameras were on hiatus during this study period so the random day of March 6, 2007 was chosen and violation data was collected from the City of Clive and compared to the video violation counts.

3.5 RESULTS

For each intersection, peak hours were defined as Morning Peak (7:00 AM – 9:00 AM), Mid Day (11:00 AM – 1:00 PM), and Evening Peak (4:00 PM – 6:00 PM). At each designated approach, two hours of video data and traffic volumes were taken during each peak period. Data were collected one day per intersection for one or two approaches on either Tuesday, Wednesday, or Thursday. The results of the data collection are as follows.

3.5.1 RLR Frequency and Rate

One measure to determine the effectiveness of a RLR camera system is to find a common value to compare other intersections or approaches to. A University of Florida study performed by Washburn and Courage in 2004 also evaluated RLR violations in the Florida area and suggested the use of the following three metrics.

- Frequency: The number of RLR violations per peak hour per approach. This was performed by visual inspection of the DVD video, sometime frame by frame to see if a violating vehicle cross the stop bar prior to or after the traffic signal turned red.
- RLR Rate: The ratio of red light running violations to total approach volume, expressed as a percent. The two equations were used to find the average percentage of hourly volume running red lights (Equation 3-1), and the average number of red light runners per thousand entering vehicles (Equation 3-2). The two equations are as follows.

$$RLR\ Rate\ (\%) = \frac{N_R \times 100}{V} \qquad \textbf{[3-1]}$$

$$RLR\ Rate\ (TEV) = \frac{N_R \times 1,000}{V} \qquad \textbf{[3-2]}$$

Where:

RLR Rate (%) = Average percentage of hourly volume running a red light

RLR Rate (TEV) = Average number of red light runners per thousand entering vehicles

N_R = Number of red light runners during each peak hours

V = Average analysis hour volume (as provided by the city of field counts)

- Average RLRs per Cycle: The average RLRs per cycle was calculated by taking the average number of recorded RLR violations divided by the average number of cycles during the peak hour (Equation 3).

$$Avg.\ RLRs\ per\ Cycle\ =\ \frac{\overline{N_R}}{\overline{N_C}} \qquad \textbf{[3-3]}$$

Where:

$\overline{N_R}$ = Average number of red light runners during the recorded peak hour

$\overline{N_C}$ = Average number of cycles during the peak hour

The three metrics were calculated for each approach where data collection occurred. The following nine tables present the results at each approach of each intersection at both camera enforced approaches and non-camera approach intersections for each peak hour. The number of RLRs per peak hour is also listed but caution should be used in comparing frequency of violations since this metric provides no indication of volume. TABLE 34, TABLE 35, and TABLE 36 show the results from the camera enforced intersections; TABLE 37, TABLE 38, and TABLE 39 show the results from the non-camera enforced intersections; and TABLE 40, TABLE 41, and TABLE 42 show the results from the intersection located in Ankeny. In addition to the calculated results, the initial study results from Redflex, and the peak hour volume for each turning movement is listed in the all of the following tables.

TABLE 34 RLR Violation Statistics for Morning Peak Hours at Camera Enforced Intersections

Approach	Movement	RLR Rate (%)	RLR Rate (TEV)	Number of RLR / Cycle	Number of RLR / Peak Hour	Redflex Before Count*	Peak Hour Volume
156th Street & Hickman Road (Clive)							
EB	Left	0.00%	0.0	0.00	**0**	0	94
EB	Through	0.00%	0.0	0.00	**0**	6	2040
EB	Right	0.00%	0.0	0.00	**0**	3	139
NB	Left	0.00%	0.0	0.00	**0**	2	71
NB	Through	0.00%	0.0	0.00	**0**	1	129
NB	Right	0.00%	0.0	0.00	**0**	5	269
142nd Street & Hickman Road (Clive)							
EB	Left	0.00%	0.0	0.00	**0**	0	356
EB	Through	0.00%	0.0	0.00	**0**	11	698
EB	Right	0.00%	0.0	0.00	**0**	6	199
128th Street & Hickman Road (Clive)							
EB	Left	0.29%	2.9	0.03	**1**	0	338
EB	Through	0.00%	0.0	0.00	**0**	11	2586
EB	Right	0.00%	0.0	0.00	**0**	4	262
NB	Left	0.00%	0.0	0.00	**0**	0	211
NB	Through	0.00%	0.0	0.00	**0**	3	229
NB	Right	1.41%	14.1	1.41	**1**	6	70
100th Street & Hickman Road (Clive)							
NB	Left	1.05%	10.5	0.05	**2**	2	189
NB	Through	0.00%	0.0	0.00	**0**	6	698
NB	Right	0.00%	0.0	0.00	**0**	0	199

* Redflex before count was based on total observed violations in a 12 hour period

TABLE 35 RLR Violation Statistics for Mid-Day Peak Hours at Camera Enforced Intersections

Approach	Movement	RLR Rate (%)	RLR Rate (TEV)	Number of RLR / Cycle	Number of RLR / Peak Hour	Redflex Before Count*	Peak Hour Volume
156th Street & Hickman Road (Clive)							
EB	Left	0.00%	0.0	0.00	**0**	0	124
EB	Through	0.08%	0.8	0.02	**1**	6	1202
EB	Right	0.00%	0.0	0.00	**0**	3	202
NB	Left	0.00%	0.0	0.00	**0**	2	185
NB	Through	0.00%	0.0	0.00	**0**	1	188
NB	Right	0.00%	0.0	0.00	**0**	5	204
142nd Street & Hickman Road (Clive)							
EB	Left	0.00%	0.0	0.00	**0**	0	470
EB	Through	0.00%	0.0	0.00	**0**	11	1020
EB	Right	0.00%	0.0	0.00	**0**	6	321
128th Street & Hickman Road (Clive)							
EB	Left	0.00%	2.0	0.00	**0**	0	161
EB	Through	0.06%	0.6	0.03	**1**	11	1553
EB	Right	0.00%	0.0	0.00	**0**	4	150
NB	Left	0.00%	0.0	0.00	**0**	0	316
NB	Through	0.00%	0.0	0.00	**0**	3	272
NB	Right	0.00%	0.0	0.00	**0**	6	163
100th Street & Hickman Road (Clive)							
NB	Left	1.27%	12.7	0.17	**6**	2	470
NB	Through	0.00%	0.0	0.00	**0**	6	1020
NB	Right	0.00%	0.0	0.00	**0**	0	321

* Redflex before count was based on total observed violations in a 12 hour period

TABLE 36 RLR Violation Statistics for Evening Peak Hours at Camera Enforced Intersections

Approach	Movement	RLR Rate (%)	RLR Rate (TEV)	Number of RLR / Cycle	Number of RLR / Peak Hour	Redflex Before Count*	Peak Hour Volume
156th Street & Hickman Road (Clive)							
EB	Left	0.00%	0.0	0.00	**0**	0	118
EB	Through	0.00%	0.0	0.00	**0**	6	1534
EB	Right	0.00%	0.0	0.00	**0**	3	225
NB	Left	0.00%	0.0	0.00	**0**	2	306
NB	Through	0.00%	0.0	0.00	**0**	1	404
NB	Right	0.00%	0.0	0.00	**0**	5	232
142nd Street & Hickman Road (Clive)							
EB	Left	0.00%	0.0	0.00	**0**	0	512
EB	Through	0.00%	0.0	0.00	**0**	11	1411
EB	Right	0.00%	0.0	0.00	**0**	6	485
128th Street & Hickman Road (Clive)							
EB	Left	0.00%	0.0	0.00	**0**	0	140
EB	Through	0.00%	0.0	0.00	**0**	11	2006
EB	Right	0.00%	0.0	0.00	**0**	4	160
NB	Left	0.00%	0.0	0.00	**0**	0	242
NB	Through	0.00%	0.0	0.00	**0**	3	726
NB	Right	0.67%	6.7	0.06	**2**	6	298
100th Street & Hickman Road (Clive)							
NB	Left	0.58%	5.8	0.08	**3**	2	512
NB	Through	0.00%	0.0	0.00	**0**	6	1411
NB	Right	0.61%	6.1	0.08	**3**	0	485

* Redflex before count was based on total observed violations in a 12 hour period

As shown in TABLE 34, TABLE 35, and TABLE 36 the number of recorded violations for March 6, 2007 is minimal, and has decreased from Redflex's initial twelve-hour study prior to the cameras installation. The two locations with the highest number or captured RLR violations happened at the intersections of 100th Street and Hickman Road and 128th Street and Hickman Road, which are close to Interstate 80 / 35.

Shown in TABLE 37, TABLE 38, and TABLE 39 are the results of the video violation study performed during the peak hours at nearby intersections within one mile of camera enforced intersections on Hickman Road. All of the video recorded intersections had a much higher peak hour violation rate for all approach movements. Another interesting result involved the intersection of 86th Street and Hickman Road. This intersection showed a substantial violation increase from Redflex's initial 12-hour study. As reported, the number of violations captured in the morning peak hour was equal to or greater than the entire initial study performed by Redflex.

TABLE 37 RLR Violations Statistics for Morning Peak Hours at the Control Intersections

Approach	Movement	RLR Rate (%)	RLR Rate (TEV)	Number of RLR / Cycle	Number of RLR / Peak Hour	Redflex Before Count	Peak Hour Volume
North Warrior Lane & Hickman Road (Waukee)							
EB	Left	0.00%	0.0	0.00	**0**		39
EB	Through	0.07%	0.7	0.02	**1**	N/A	1329
EB	Right	7.04%	70.4	0.09	**5**		71
86th Street & Hickman Road (Clive & Urbandale)							
EB	Left	0.88%	8.8	0.07	**2**	0	227
EB	Through	0.39%	3.9	0.11	**3**	2	758
EB	Right	2.02%	20.2	0.14	**4**	0	198
NB	Left	2.71%	27.1	0.17	**5**	5	184
NB	Through	0.28%	2.8	0.07	**2**	0	696
NB	Right	4.31%	43.1	0.17	**5**	5	116
86th Street & Douglas Avenue (Urbandale)							
WB	Left	0.00%	0.0	0.00	**0**		279
WB	Through	0.92%	9.2	0.15	**9**	N/A	1089
WB	Right	2.92%	29.2	0.06	**29**		137
SB	Left	0.00%	0.0	0.00	**0**		187
SB	Through	1.36%	13.6	0.26	**13**	N/A	1320
SB	Right	2.31%	23.1	2.31	**23**		302
100th Street & Douglas Avenue (Urbandale)							
EB	Left	0.36%	3.0	0.01	**3**		277
EB	Through	0.50%	5.0	0.04	**5**	N/A	591
EB	Right	7.52%	75.0	0.09	**75**		93
WB	Left	1.28%	12.8	0.08	**6**		466
WB	Through	0.38%	3.8	0.05	**4**	N/A	1047
WB	Right	3.18%	31.8	0.09	**7**		220
NB	Left	0.00%	0.0	0.00	**0**		171
NB	Through	0.21%	2.1	0.01	**2**	N/A	477
NB	Right	3.82%	38.2	0.09	**38**		183
35th Street & University Avenue (Clive & West Des Moines)							
WB	Left	0.51%	5.1	0.00	**1**		196
WB	Through	0.72%	7.2	0.15	**3**	N/A	415
WB	Right	3.84%	38.4	0.06	**4**		102
SB	Left	2.30%	23.0	0.10	**5**		217
SB	Through	0.00%	0.0	0.00	**0**	N/A	516
SB	Right	3.52%	35.2	0.16	**8**		227
60th Street & University Avenue (Clive & West Des Moines)							
WB	Left	0.00%	0.0	0.00	**0**		424
WB	Through	0.00%	0.0	0.00	**0**	N/A	939
WB	Right	0.92%	9.2	0.01	**1**		108
NB	Left	1.74%	17.4	0.05	**3**		172
NB	Through	0.94%	9.4	0.05	**3**	N/A	318
NB	Right	4.87%	48.7	0.16	**10**		205
SB	Left	1.11%	11.1	0.05	**3**		270
SB	Through	0.75%	4.5	0.05	**3**	N/A	397
SB	Right	3.97%	39.7	0.23	**14**		352

* Redflex before count was based on total observed violations in a 12 hour period

TABLE 38 RLR Violation Statistics for Mid-Day Peak Hours at the Control Intersections

Approach	Movement	RLR Rate (%)	RLR Rate (TEV)	Number of RLR / Cycle	Number of RLR / Peak Hour	Redflex Before Count*	Peak Hour Volume
North Warrior Lane & Hickman Road (Waukee)							
EB	Left	2.56%	25.6	0.02	**1**		39
EB	Through	0.00%	0.0	0	**0**	N/A	767
EB	Right	1.21%	12.1	0.02	**1**		82
86th Street & Hickman Road (Clive & Urbandale)							
EB	Left	4.45%	44.5	0.68	**19**	0	427
EB	Through	0.20%	2.0	0.07	**2**	2	993
EB	Right	2.80%	28.0	0.18	**5**	0	174
NB	Left	1.44%	14.4	0.11	**3**	5	208
NB	Through	0.77%	7.7	0.32	**9**	0	1168
NB	Right	3.43%	34.3	0.29	**8**	5	233
86th Street & Douglas Avenue (Urbandale)							
WB	Left	2.66%	26.6	0.15	**10**		375
WB	Through	0.57%	5.7	0.07	**5**	N/A	880
WB	Right	1.41%	14.1	0.06	**4**		283
SB	Left	1.77%	17.7	0.07	**5**		281
SB	Through	0.18%	1.8	0.03	**2**	N/A	1119
SB	Right	3.55%	35.5	0.13	**9**		253
100th Street & Douglas Avenue (Urbandale)							
EB	Left	5.55%	55.5	0.28	**21**		378
EB	Through	0.44%	4.4	0.05	**4**	N/A	901
EB	Right	2.64%	26.4	0.09	**7**		265
WB	Left	0.36%	3.6	0.02	**2**		544
WB	Through	0.23%	2.3	0.02	**2**	N/A	862
WB	Right	5.00%	50.0	0.18	**13**		260
NB	Left	1.14%	11.4	0.04	**3**		261
NB	Through	0.47%	4.7	0.05	**4**	N/A	835
NB	Right	3.76%	37.6	0.23	**17**		451
35th Street & University Avenue (Clive & West Des Moines)							
WB	Left	2.66%	26.6	0.15	**8**		296
WB	Through	0.57%	5.7	0.07	**1**	N/A	664
WB	Right	2.15%	21.5	0.06	**6**		279
SB	Left	1.51%	15.5	0.31	**5**		331
SB	Through	0.21%	2.1	0.02	**1**	N/A	461
SB	Right	5.02%	50.2	0.33	**16**		319
60th Street & University Avenue (Clive & West Des Moines)							
WB	Left	0.00%	0.0	0.00	**0**		419
WB	Through	0.08%	0.8	0.01	**1**	N/A	1188
WB	Right	0.81%	8.1	0.03	**2**		245
NB	Left	0.91%	9.1	0.03	**2**		219
NB	Through	0.99%	9.9	0.06	**4**	N/A	403
NB	Right	3.90%	39.0	0.21	**13**		333
SB	Left	0.49%	4.9	0.01	**1**		201
SB	Through	0.38%	3.8	0.01	**1**	N/A	257
SB	Right	4.34%	43.3	0.20	**12**		276

* Redflex before count was based on total observed violations in a 12 hour period

TABLE 39 RLR Violation Statistics for Evening Peak Hours at the Control Intersections

Approach	Movement	RLR Rate (%)	RLR Rate (TEV)	Number of RLR / Cycle	Number of RLR / peak hour	Redflex Before Count*	Peak Hour Volume
North Warrior Lane & Hickman Road (Waukee)							
EB	Left	0.00%	0.0	0.00	**0**		52
EB	Through	0.00%	0.0	0.00	**0**	N/A	921
EB	Right	5.40%	5.4	0.07	**4**		74
86th Street & Hickman Road (Clive & Urbandale)							
EB	Left	3.33%	33.3	0.54	**15**	0	450
EB	Through	0.36%	3.6	0.21	**6**	2	1641
EB	Right	2.68%	26.8	0.14	**4**	0	149
NB	Left	1.84%	18.4	0.21	**6**	5	325
NB	Through	0.47%	4.7	0.25	**7**	0	1495
NB	Right	3.17%	31.7	0.39	**11**	5	346
86th Street & Douglas Avenue (Urbandale)							
WB	Left	1.88%	18.8	0.10	**7**		371
WB	Through	0.35%	3.5	0.06	**4**	N/A	1124
WB	Right	4.76%	47.6	0.26	**18**		378
SB	Left	1.17%	11.7	0.06	**4**		341
SB	Through	0.52%	5.2	0.10	**7**	N/A	1341
SB	Right	3.88%	38.8	0.21	**14**		360
100th Street & Douglas Avenue (Urbandale)							
EB	Left	5.07%	50.7	0.66	**21**		414
EB	Through	0.38%	3.8	0.04	**5**	N/A	1305
EB	Right	4.14%	41.4	0.54	**10**		241
WB	Left	0.57%	5.7	0.05	**4**		204
WB	Through	0.12%	1.2	0.05	**4**	N/A	1162
WB	Right	2.34%	23.4	0.40	**29**		672
NB	Left	1.96%	19.6	0.57	**3**		518
NB	Through	0.34%	3.4	0.12	**1**	N/A	801
NB	Right	4.31%	43.1	2.34	**6**		256
35th Street & University Avenue (Clive & West Des Moines)							
WB	Left	5.12%	51.2	0.10	**14**		273
WB	Through	0.51%	5.1	0.06	**4**	N/A	781
WB	Right	7.25%	72.5	0.26	**18**		248
SB	Left	1.11%	11.1	0.06	**3**		271
SB	Through	0.71%	7.1	0.14	**5**	N/A	704
SB	Right	5.44%	54.4	0.33	**16**		294
60th Street & University Avenue (Clive & West Des Moines)							
WB	Left	0.55%	55.0	0.03	**2**		363
WB	Through	0.00%	0.0	0.00	**0**	N/A	1399
WB	Right	4.27%	42.7	0.31	**19**		444
NB	Left	1.07%	10.7	0.16	**4**		373
NB	Through	2.04%	20.4	0.20	**12**	N/A	588
NB	Right	1.58%	15.8	0.25	**5**		316
SB	Left	0.00%	0.0	0.00	**0**		202
SB	Through	2.05%	20.5	0.13	**8**	N/A	389
SB	Right	8.17%	81.7	0.28	**17**		208

* Redflex before count was based on total observed violations in a 12 hour period

TABLE 40, TABLE 41, and TABLE 42 are the results from the video violation study performed at the control intersection of Oralabor Road and State Street located in south Ankeny. Not expected by the research team, the results showed consistently high right turning violation rates during all peak hours. The geometry of the intersection was quite similar to the automated enforced and non-automated enforced intersections, except for the fact the right turn radius was much larger, thus resulting in the turning movement acting like a free right turn. This could explain the high number of right turn violations.

TABLE 40 RLR Violation Statistics for Morning Peak Hours at the Ankeny Control Intersection

Approach	Movement	RLR Rate (%)	RLR Rate (TEV)	Number of RLR / Cycle	Number of RLR / peak hour	Redflex Before Count	Peak Hour Volume
ORALABOR ROAD & STATE STREET (Ankeny)							
EB	Left	2.67%	26.7	0.05	**5**		187
EB	Through	0.62%	6.2	0.07	**7**	N/A	1128
EB	Right	5.45%	54.5	0.33	**30**		550
NB	Left	0.00%	0.0	0.00	**0**		211
NB	Through	0.50%	5.0	0.02	**2**	N/A	399
NB	Right	17.10%	171.0	0.65	**58**		339

TABLE 41 RLR Violation Statistics for Mid-Day Peak Hours at the Ankeny Control Intersection

Approach	Movement	RLR Rate (%)	RLR Rate (TEV)	Number of RLR / Cycle	Number of RLR / peak hour	Redflex Before Count	Peak Hour Volume
ORALABOR ROAD & STATE STREET (Ankeny)							
EB	Left	1.90%	19.0	0.02	**2**		105
EB	Through	0.27%	2.7	0.02	**2**	N/A	720
EB	Right	14.21%	142.1	0.30	**27**		190
NB	Left	0.64%	6.4	0.64	**1**		154
NB	Through	33.00%	3.3	0.33	**1**	N/A	301
NB	Right	9.11%	91.1	9.11	**33**		362

TABLE 42 RLR Violation Statistics for Evening Peak Hours at the Ankeny Control Intersection

Approach	Movement	RLR Rate (%)	RLR Rate (TEV)	Number of RLR / Cycle	Number of RLR / peak hour	Redflex Before Count	Peak Hour Volume
ORALABOR ROAD & STATE STREET (Ankeny)							
EB	Left	0.34%	3.4	0.01	**1**		291
EB	Through	0.41%	4.1	0.05	**5**	N/A	1210
EB	Right	8.20%	82.0	0.23	**21**		256
NB	Left	0.86%	8.6	0.05	**5**		577
NB	Through	0.49%	4.9	0.67	**6**	N/A	1203
NB	Right	10.70%	107.0	0.85	**76**		710

To accurately display the above data to the Iowa Department of Transportation, a map was created using Autodesk 2004 version of Land Desktop and is shown in Figure 47. Data for each movement was collected and analyzed which included: before violation data from Redflex, field data for three peak hours, traffic counts, and the number of cycles.

3.6 DAY OF THE WEEK STUDY

In addition to performing a study looking solely into violations at camera enforced intersections and control intersections, the research team was interested as to what kind of data was behind each violation at the camera enforced intersections. Along with the actual violation count for the entire enforcement period, day of the week data were also obtained from the Clive police records via Redflex as to what day of the week violations occurred the most. A common misconception by many media outlets is that RLR occurs most frequently on the weekends when drivers are away from the office; however, countrary to this theory, RLR studies have concluded that RLR violations occur most frequently during the working days of the week when traffic volumes are higher and schedules are tighter. Using RLR data obtained from the Clive Police Department, TABLE 43 lists the total number of violations for the entire enforcement period per day of the week and the rank of each day depending on this value for all of the intersections in Clive with RLR cameras.

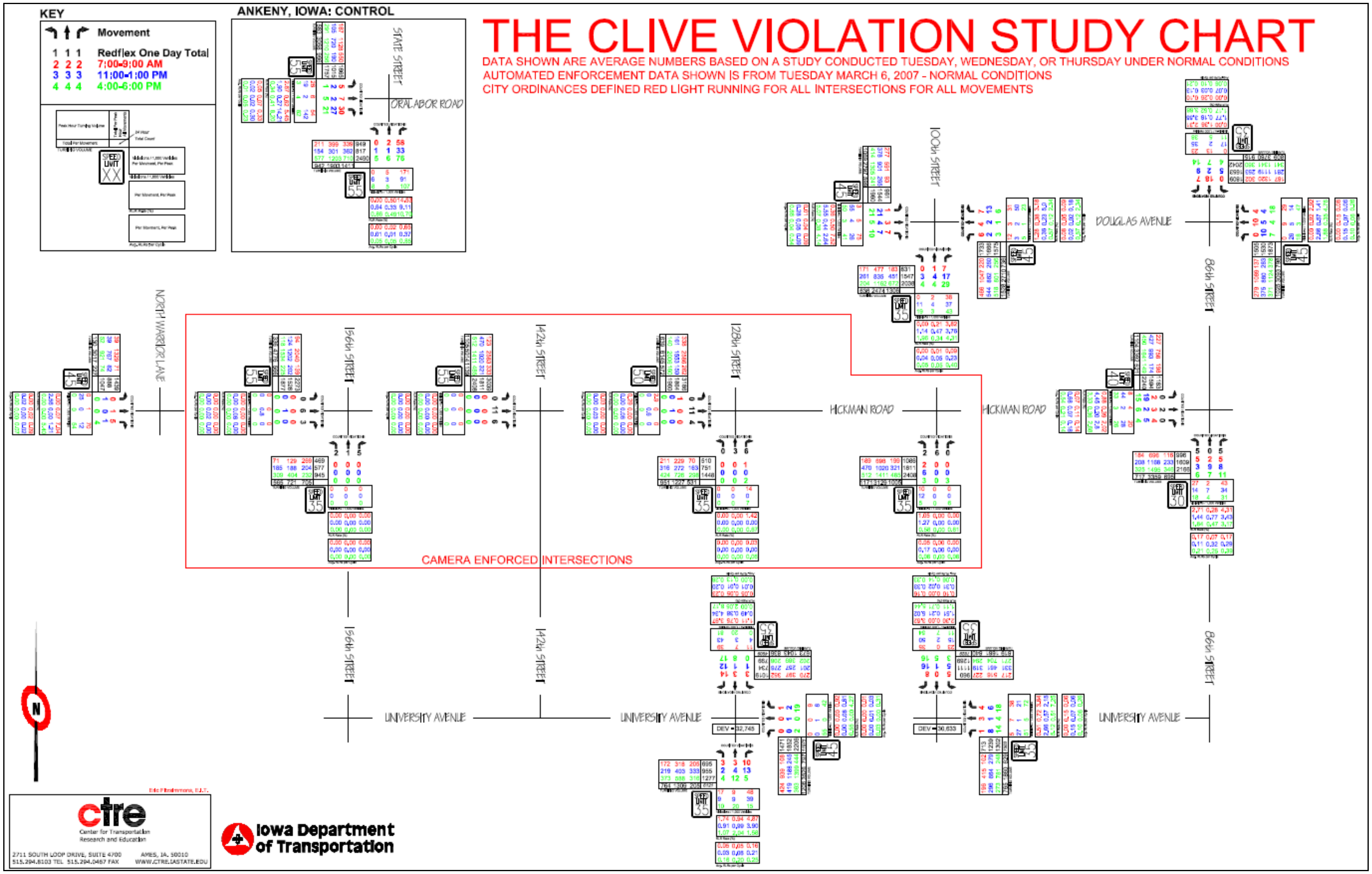


Figure 47. Violation study map and results per intersection.

TABLE 43 Rank of Each Day of the Week Based on the Total Number of RLR Violations

Rank	Day of the Week	Total Violations
1	Friday	1406
2	Tuesday	1333
3	Monday	1262
4	Wenesday	1255
5	Thursday	1209
6	Saturday	1115
7	Sunday	960

As listed in TABLE 43, Friday had the highest number of violations for the entire enforcement period in Clive, followed by Tuesday and Monday consistent with past studies. The lowest numbers of RLR violations occurred on Saturday and Sunday. Over the entire enforcement period per, the largest daily violation counts for each camera enforced approach total values were matched with the associated day of the week and are shown in TABLE 44.

TABLE 44 Total Violation Count Associated with the Day of the Week and Intersection Approach

Intersection	Highest Total Violation Count	Day of the Week
NB 100th St. & Hickman Rd.	327	Friday
NB 128th St. & Hickman Rd.	169	Friday
EB 128th St. & Hickman Rd.	317	Tuesday
EB 142nd St. & Hickman Rd.	136	Friday
NB 156th St. & Hickman Rd.	410	Saturday
EB 156th St. & Hickman Rd.	129	Monday

As listed, not all of the camera enforced intersection approaches had the highest total number of violations on Friday. Furthermore, early week days such as Monday and Tuesday had high total number of violations for two eastbound approaches. The only approach that had a high total number of violations on a weekend was northbound 156th Street and Hickman Road. One possible external variable that could have affected these numbers and days of the week is what type of zoning that surrounds the intersection within the one mile buffer (e.g. residential, commercial, industrial, interstate, car dealerships, grocery store, etc.). Along with associating the largest number of total violations to a specific day of the week, daily totals for each intersection approach were associated with each day of the week and are illustrated in Figure 48.

Although some individual intersection approaches did not peak on Friday as seen in Figure 48 the highest total number of violations occurred on Friday. To evaluate the number of violations per day of the week for each approach lane, data were separated for each camera enforced approach and are shown in Figure 49 through Figure 54.

Figure 49 illustrates the number of violators per day of the week for the northbound approach at the intersection of 100th Street and Hickman Road. As shown, the left turn movement had the highest number of violators each day of the week with the highest number of violations occurring on Friday. The number of through movement violations stayed consistent throughout the week, the right turning movement had its highest number of violations on Thursday.

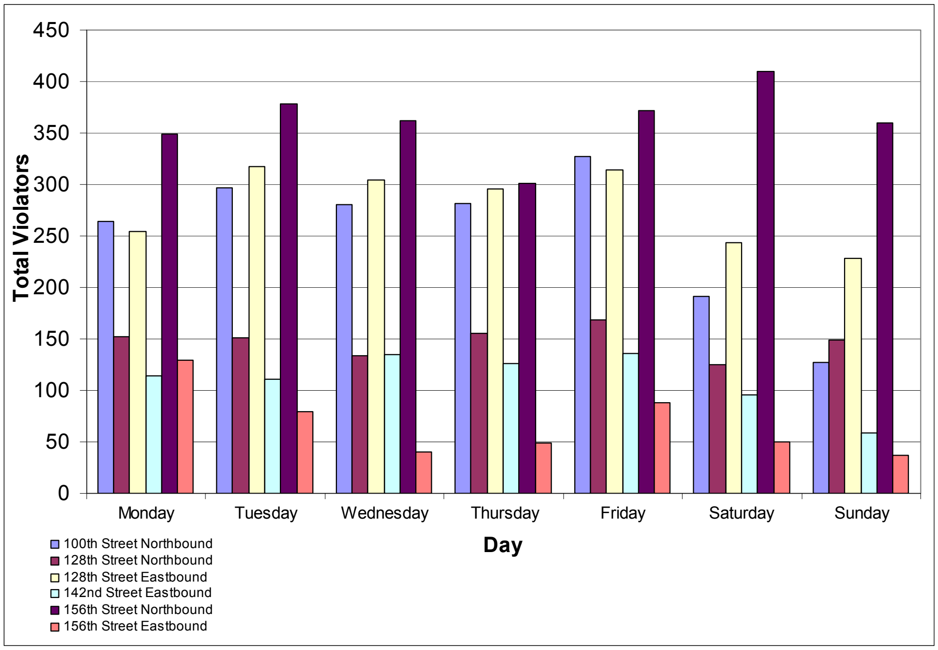


Figure 48. Total violations per day of the week at each camera enforced intersection.

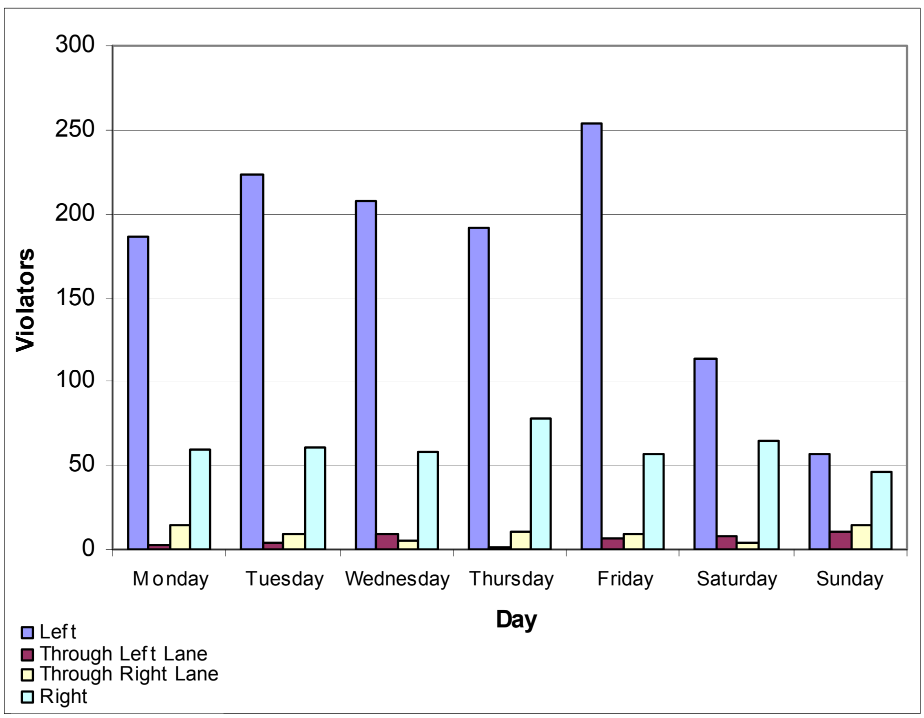


Figure 49. Total violations per day of the week at 100th St. northbound and Hickman Rd.

As shown in Figure 50, the northbound approach at the intersection of 128th Street and Hickman Road had its highest violation total on Friday. Also, Figure 50 illustrates that the right turning movement had the highest number of violation each day of the week.

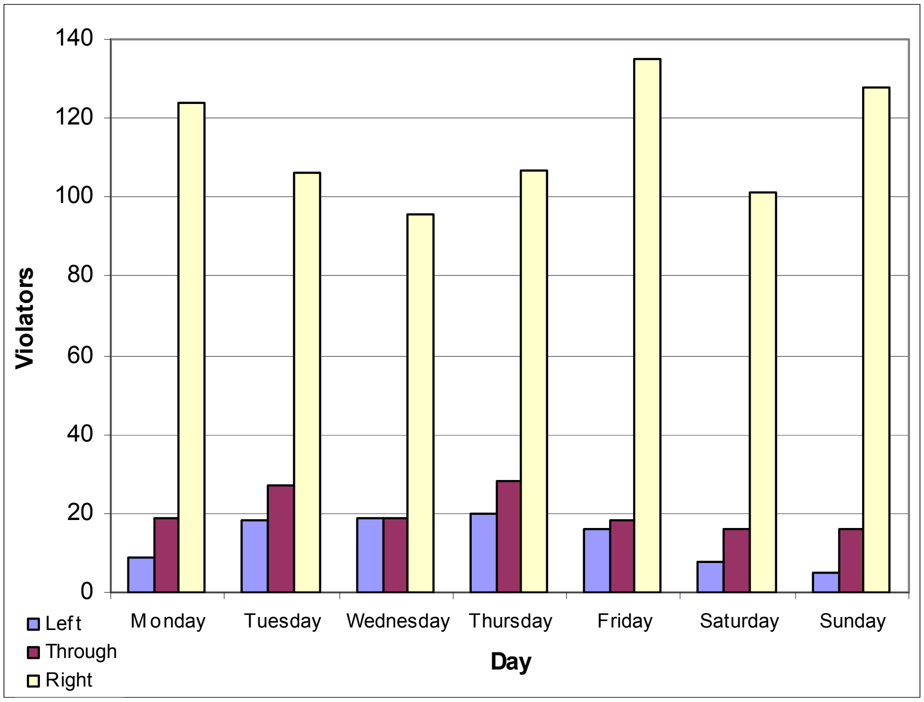


Figure 50. Total violations per day of the week per lane at 128th St. northbound and Hickman Rd.

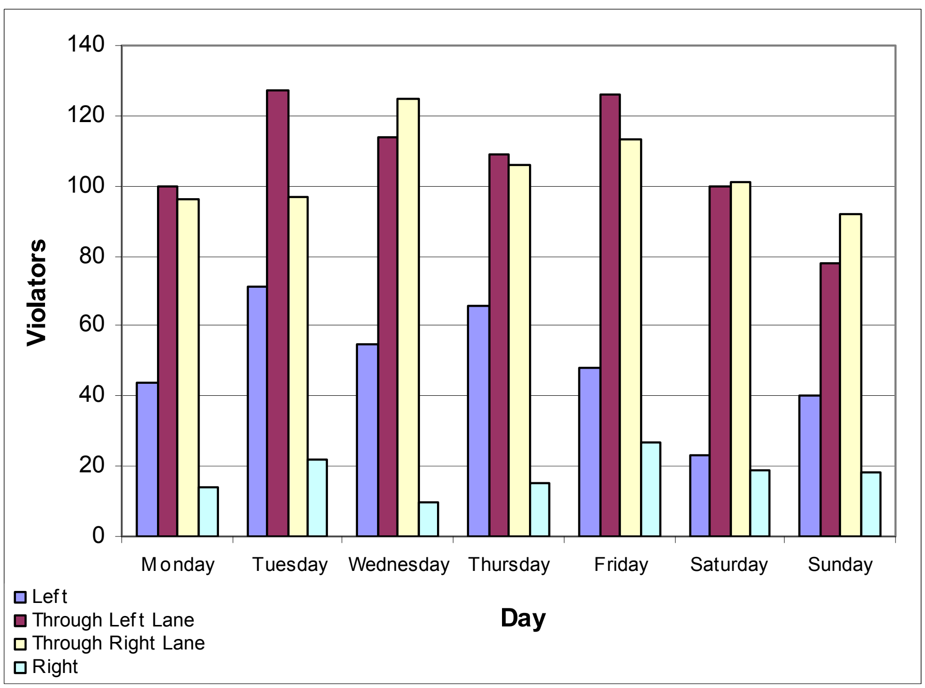


Figure 51. Total violations per day of the week per lane at 128th St. eastbound and Hickman Rd.

As listed in TABLE 43, the eastbound approach at 128th Street and Hickman Road had its highest total number of violations on Tuesday. Figure 51 illustrates that through movement violations are frequent every day of the week at this intersection, with more through movement violations occurring on Tuesday, Wednesday, and

Friday. The highest number of left turning violations occurred on Tuesday, contributing to the highest total number of violations at this intersection

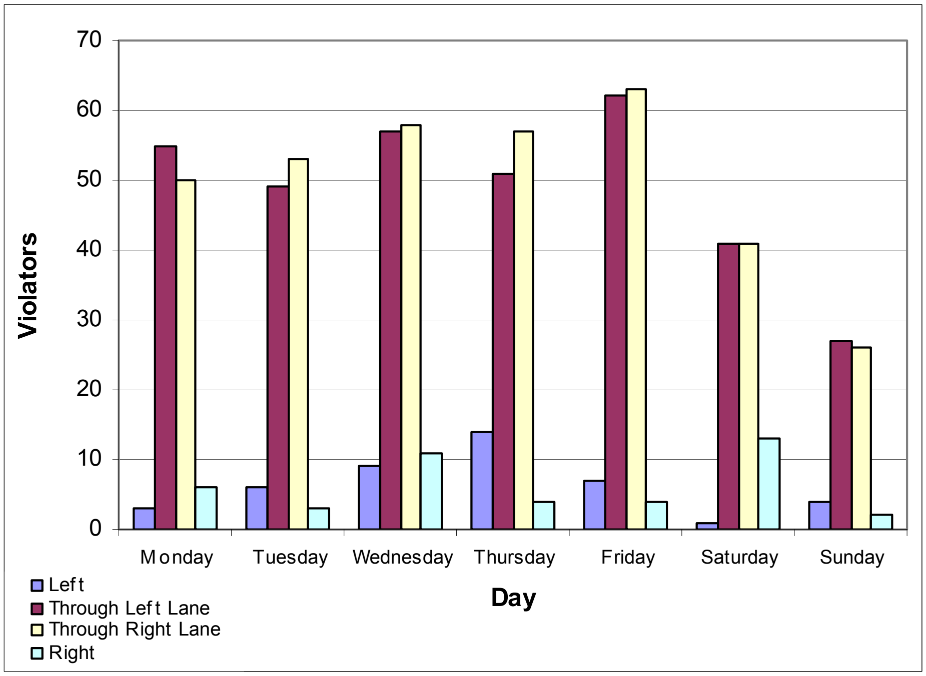


Figure 52. Total violations per day of the week per lane at 142nd St. eastbound and Hickman Rd.

As shown in Figure 52, the eastbound approach at 142nd Street and Hickman Road experienced most RLR violations in the through lanes, every day of the week. The left turning movement had its highest high violation count on Thursday, and the right turning movement had its highest number of violations on Saturday. As indicated in TABLE 43, the highest total number of violations at this intersection occurred on Friday.

From TABLE 43, the northbound approach at the intersection of 156th Street and Hickman Road saw the highest violation count on Saturday as shown in Figure 53. As shown, the right turning movement had the highest number of violations overall every day of the week.

As shown in Figure 54 and listed in TABLE 43, the eastbound approach at the intersection of 156th Street and Hickman Road had the highest total number of violations on Monday, as the right turning movement on Monday was extremely high compared to the through and left turning movements for the entire week. The through movement had the highest number of violations on Friday, while the left turning movement had its highest number of violators on Monday.

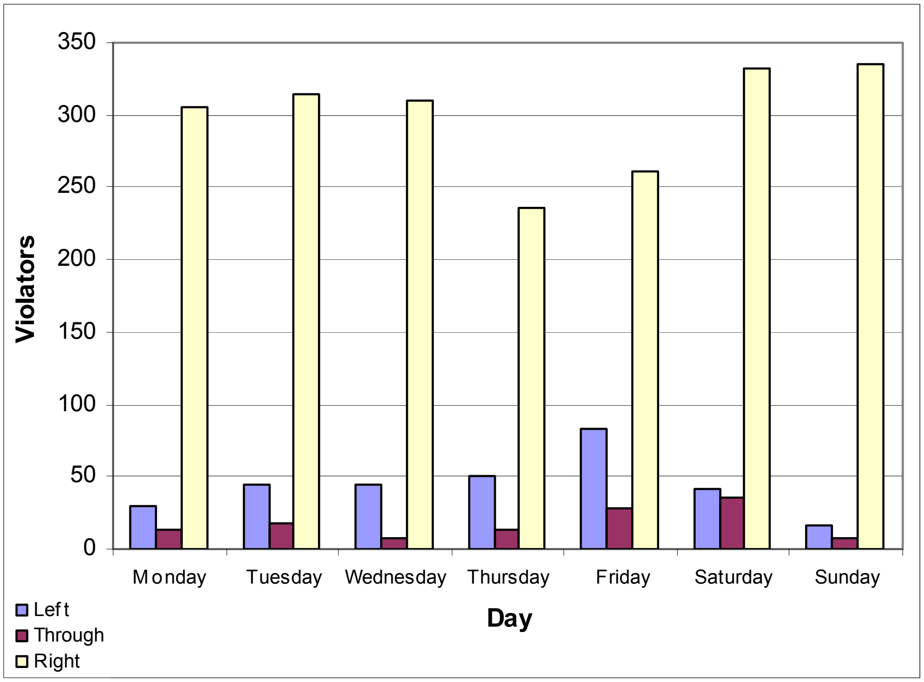


Figure 53. Total violations per day of the week per lane at 156th St. northbound and Hickman Rd.

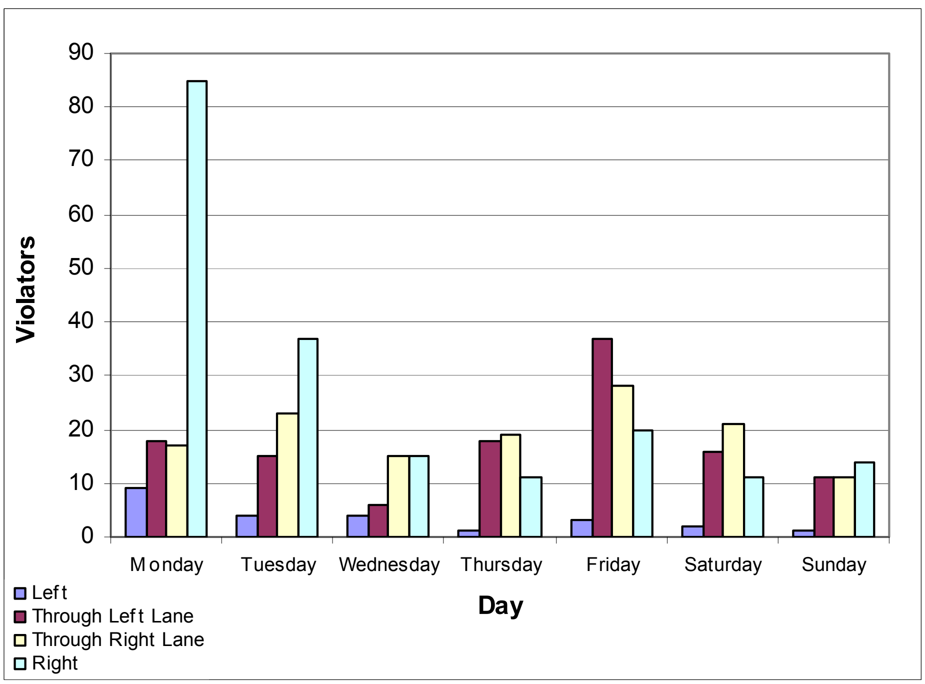


Figure 54. Total violations per day of the week per lane at 156th St. eastbound and Hickman Rd.

3.7 TIME OF THE DAY STUDY

Data were also obtained from Clive regarding the hour of day that violations occurred. As studies mentioned in the literature review, RLR violations typically occurred during the morning and afternoon peak hours when drivers tended to run red lights due to lateness for work, dropping children off at schools, or congestion *(13)*. Using the collected data from each camera enforced approach in Clive, the total number of violations per movement was summed and plotted for each hour of the day, and is illustrated in Figure 55.

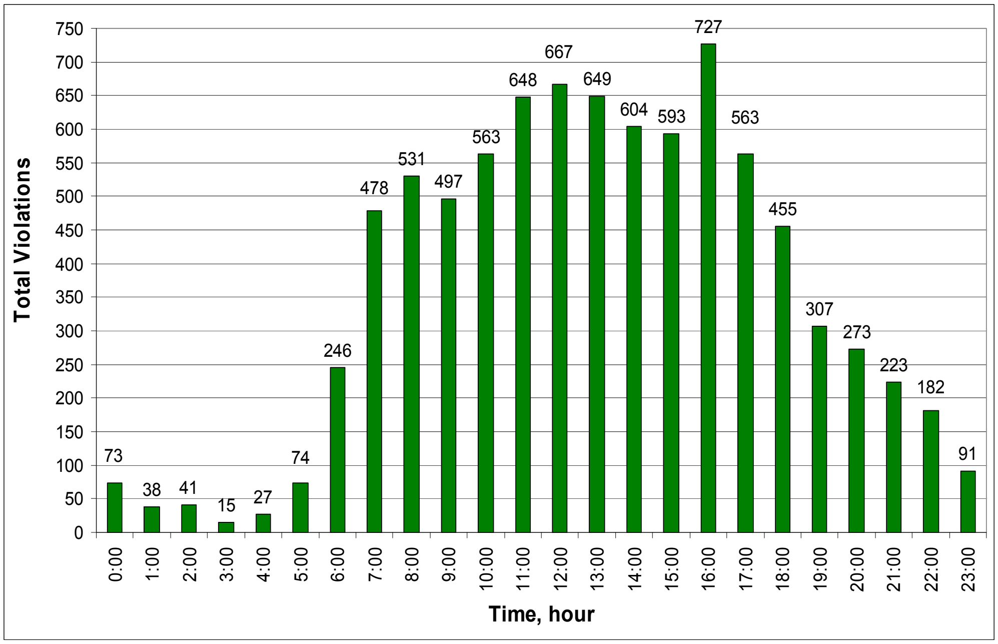


Figure 55. Total RLR violations in Clive by hour of the day, all intersections combined.

As shown in Figure 55, the highest combined total number of violations occurred between 4:00 PM and 5:00 PM; the second highest numbers was between 12:00 PM and 1:00 PM. Unlike other RLR studies performed across the nation, the City of Clive didn't see its highest number of violation during the morning peak hours of 7:00 AM to 9:00 AM. Breaking down the data into intersections approaches, Figure 56 was created showing which intersection had the highest number of RLR violation per hour of the 24-hour day.

As illustrated, most of the RLR occurred during the middle of the 24 hour day between the hours of 7:00 AM and 5:00 PM with some of the highest number of violations occurring between 11:00 AM and 5:00 PM. Northbound 156th Street had the highest number of violations between 7:00 AM and 1:00 PM, while northbound 100th Street had the highest number of violations between 4:00 PM and 5:00 PM.

Figure 57 illustrates the total number of violations per hour of day for each northbound movement at 100th Street and Hickman Road. As shown, the left lane had the highest number of violations from 6:00 AM to 9:00 PM. Due to surrounding businesses and location of this camera, it is believed that most of the vehicles running the left turn were either commercial vehicles or private vehicles heading towards Interstate 80, located west (left turning movement) of 100th Street and Hickman Road. The right turning movement had the second highest number of violators and its trend follows closely that of the left turning movement at a lower number of total violations.

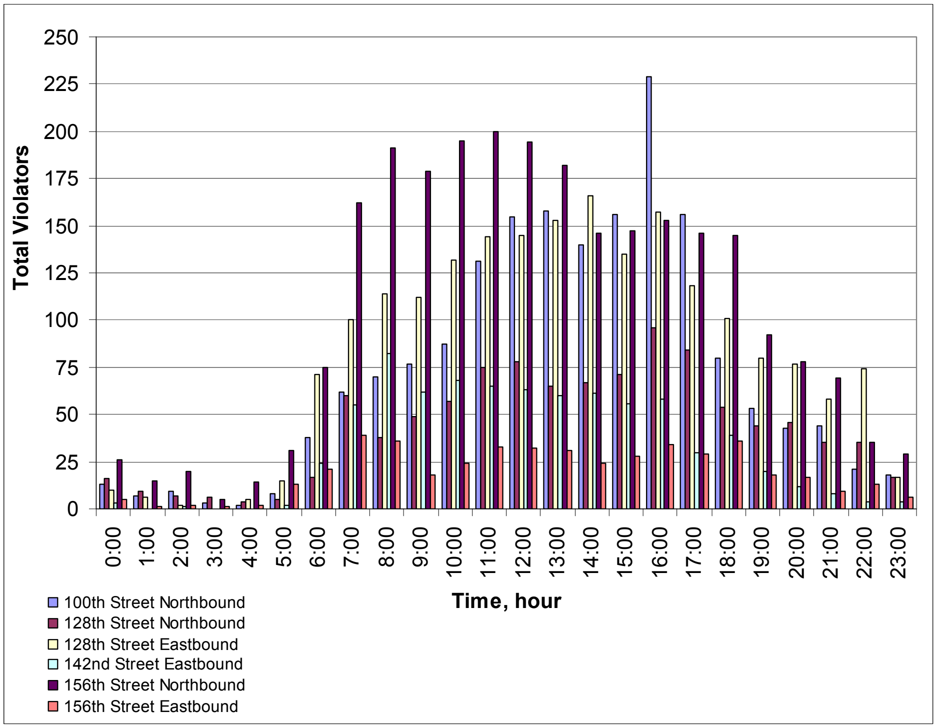


Figure 56. Total violations at all individual enforced intersections over a 24 hour period.

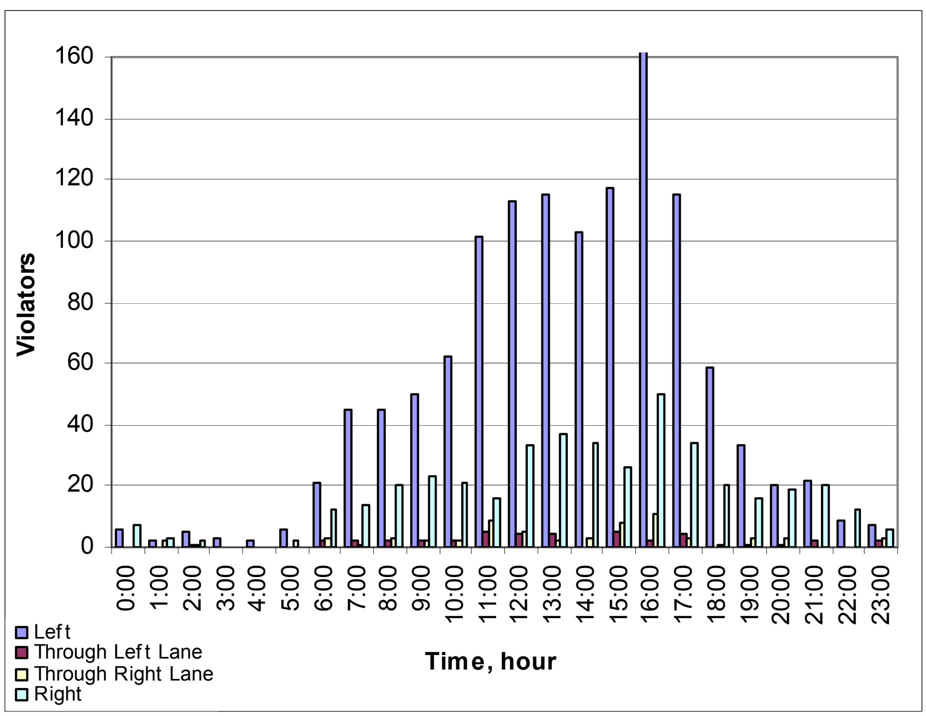


Figure 57. Total violations at northbound 100th Street and Hickman Road over a 24 hour period.

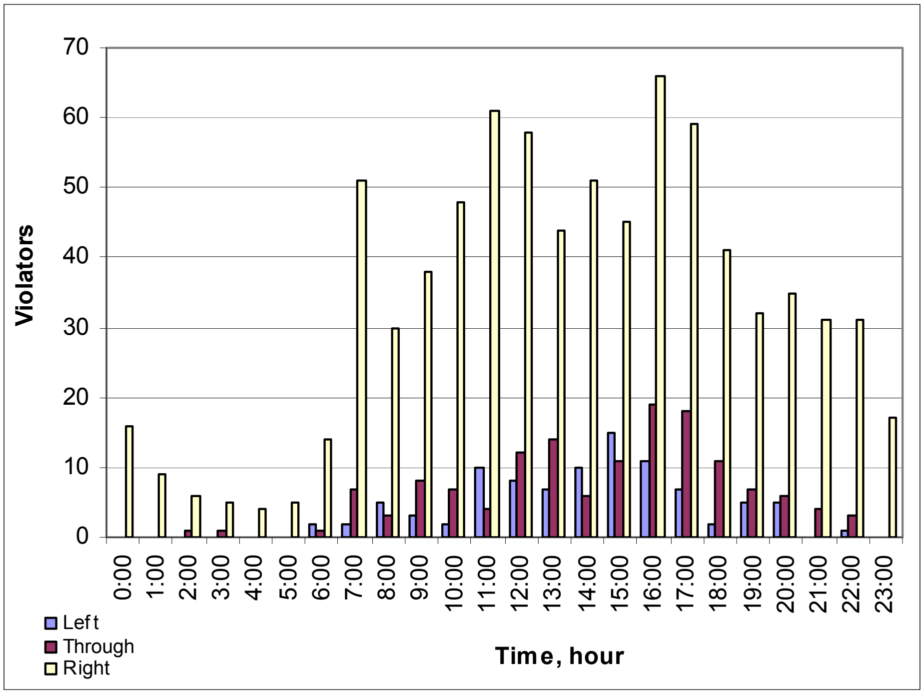


Figure 58. Total violations at northbound 128th Street and Hickman Road over a 24 hour period.

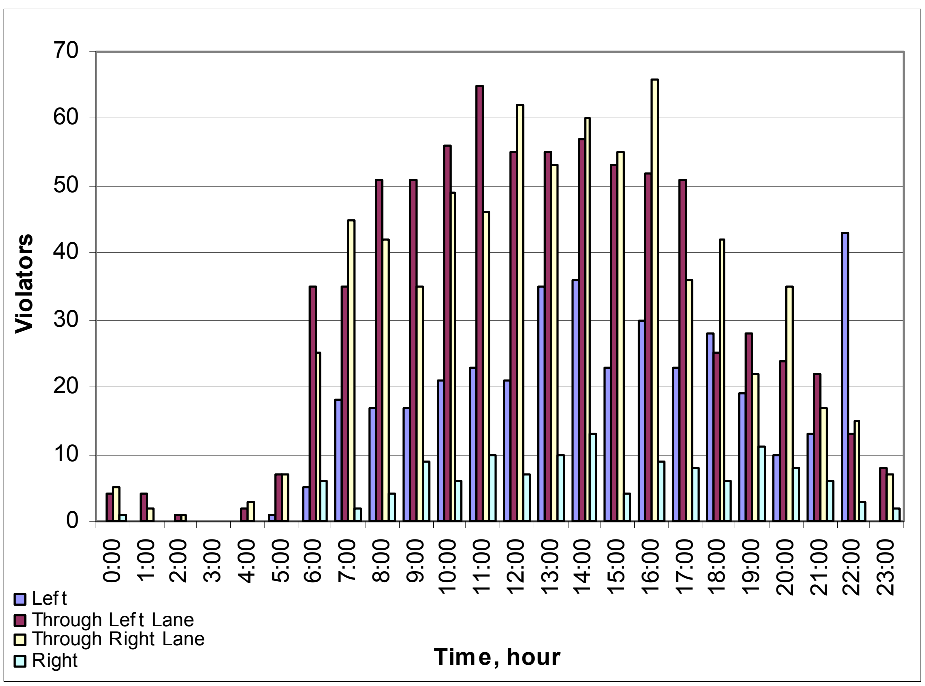


Figure 59. Total violations at eastbound 128th Street and Hickman Road over a 24 hour period.

Figure 58 illustrates the total number of violations by hour of day for each northbound movement at 128th Street and Hickman Road. As shown, the right turning movement had the highest number of violations for every hour of day. Due to this intersection being located west of Interstate 80, most of the right turning vehicles are traveling towards the interstate throughout the day.

Figure 59 illustrates the total number of violations per hour of day for each eastbound movement at 128th Street and Hickman Road. As shown, the majority of the RLR violations happened between 6:00 AM and 11:00 PM, with both through movements having the highest number of violations. Also shown, the left turning movement had an unusually high number of violations at 10:00 to 11:00 PM compared to the trend of all other movements.

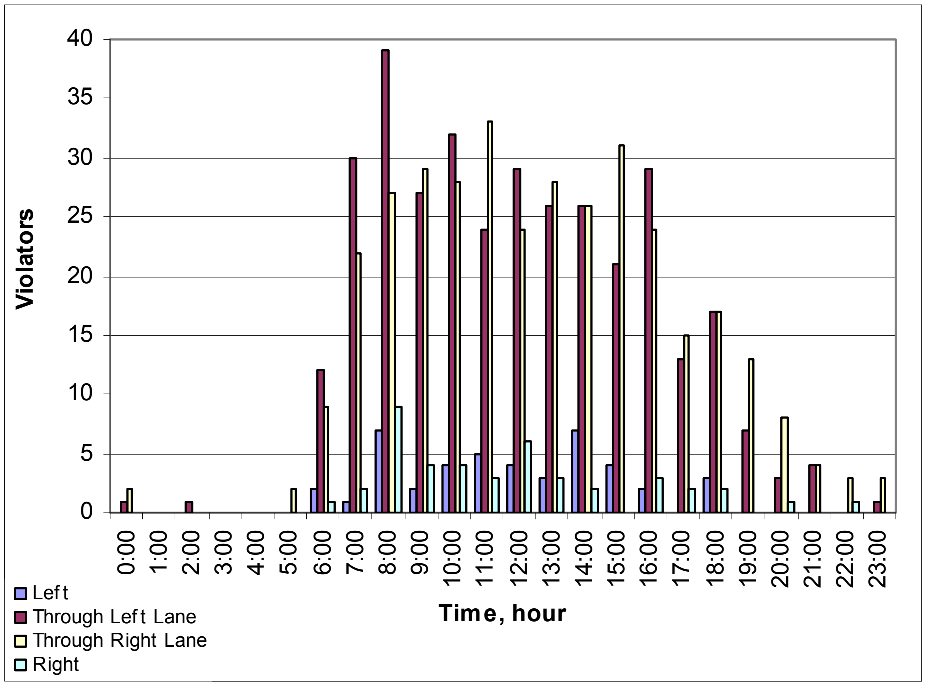


Figure 60. Total violations at eastbound 142nd Street and Hickman Road over a 24 hour period.

Figure 60 illustrates the total number of violations per hour of day for each eastbound movement at the intersection of 142nd Street and Hickman Road. As shown, the through movements had the highest number of total violations from 7:00 AM to 11:00 AM. The trend shown in Figure 5 is similar to national trends where RLR frequency increased during the morning and evening peak hours when drivers drove to and from work. 142nd Street and Hickman Road is also different from the other Clive camera enforced intersections in that the north- and southbound approaches had considerably less traffic than east- and westbound Hickman Road.

Figure 61 illustrates the total number of violations per hour of day for each northbound movement at 156th Street and Hickman Road. As shown, the right turning movements had the highest number of violators over all of the 24 hours, but were especially high between 8:00 AM and 1:00 PM. One possible reason for this might be the Dahl's grocery store that has an access point on northbound 156th Street, and these times might correlate to when people go to the grocery store. Also shown, left and through movements had a gradual increase in RLR during the hours of 12:00 PM through 6:00 PM, likely due to commuters running a red light on their way home from work.

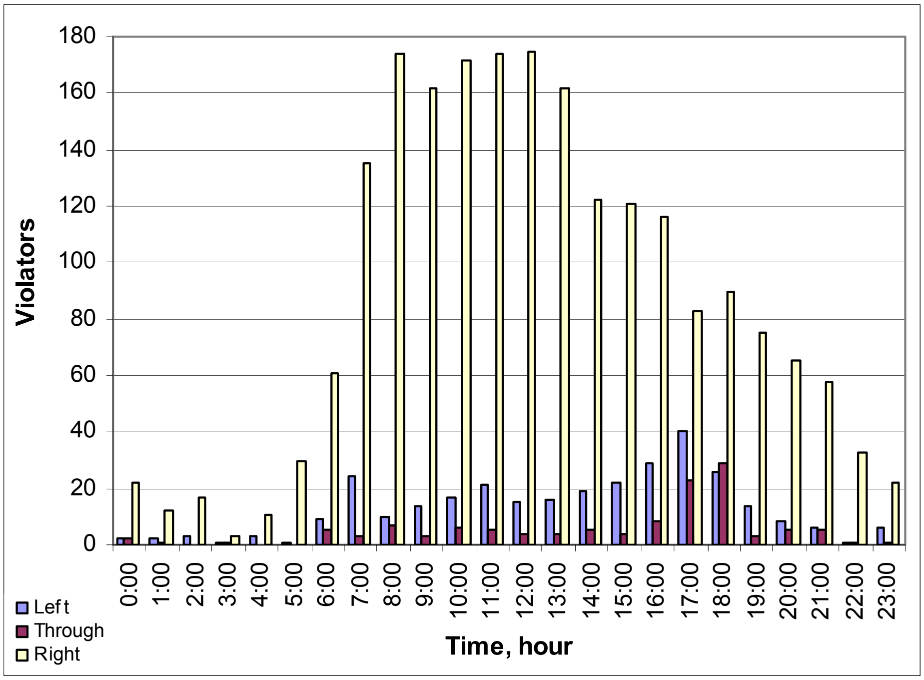


Figure 61. Total violations at northbound 156th Street and Hickman Road over a 24 hour period.

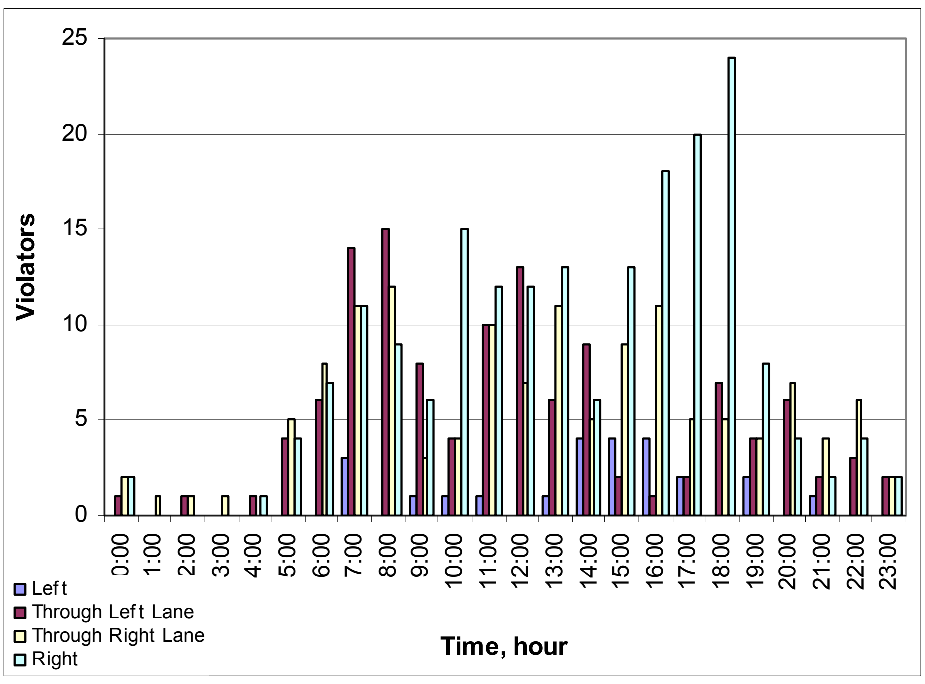


Figure 62. Total violations at eastbound 156th Street and Hickman Road over a 24 hour period.

Figure 62 illustrates the total number of violations per hour of day for each eastbound movement at 156th Street and Hickman Road. As shown, the total number of violations spike at different times of the day for different movements. From the data available, through movement violations occur the most frequently between 7:00 AM and 8:00 AM, and then again between 11:00 AM and 12:00 PM. The right turning movement had the highest number of RLR violators in the afternoon between 3:00 PM and 6:00 PM, while through movement violations are minimal at this time.

3.8 RLR SEVERITY STUDY

A measure to evaluate the potential severity of a RLR crash is by measuring how long after the onset of red a violating vehicle enters the intersection. The longer this time the greater the potential risk and severity *(53)*. Presented in the following plots are the numbers of violations and their associated times into the red phase data collected by Clive's automated RLR camera system over the entire enforcement period. Also shown are red lines indicating the city's preset all-red phase (or all-red clearance interval) for left and through / right turning movements. Many jurisdictions will include an optional all-red phase into intersection signal timing; this duration, which is usually around two seconds, is based on intersection geometrics, collision experience, pedestrian activity, approach speed, local practices, and engineering judgment *(71)*. Vehicles entering the intersection a second or less after the onset of the red phase may pose less of a hazard to serious crashes because of the perception, reaction, and start-up time of possible conflicting vehicles that are currently stopped at the intersection. Although RLR at any time following the onset of the red phase is a concern, a particularly alarming issue found at almost every intersection in Clive was the high number of violators entering the intersection after 2.1+ seconds into the red phase. Illustrated in Figure 63 is the total number of violators for every movement at each intersection. An average all-red time was calculated by averaging the left turn all-red times with the through / right turn all-red times, and an average of 1.675 seconds was determined by averaging the all-red clearance interval for all of the camera enforced approaches.

Although many violators ran the red light during the 1.675 average all-red phases, a majority of the RLR occurred after 2.1+ seconds on the red phase as shown in Figure 63. The highest number of 2.1+ second violators occurred at northbound 156th Street with over 1900 violations happening at 2.1+ seconds. To explore the reason behind why drivers might enter the intersection so late in the red phase, each movement for each intersection was studied in order to find an explanation or movement that contributed to when the driver entered the intersection. Figure 64 through Figure 69 present the times for each lane of the enforced approaches in Clive. As illustrated in Figure 64, the left and right turning movements had the highest number of violators for all of the measured times after the onset of the all-red phase at the intersection of 100th Street and Hickman Road. This intersection had the longest all-red clearance interval of Clive's camera enforced intersections. It was also found that this approach had the second highest number of violators between 0.1 and 2.0 seconds, but just the fourth highest number of violators that entered the intersection after 2.1+ seconds. Figure 65 and Figure 66 illustrate the RLR severity at the intersection of 128th Street and Hickman Road

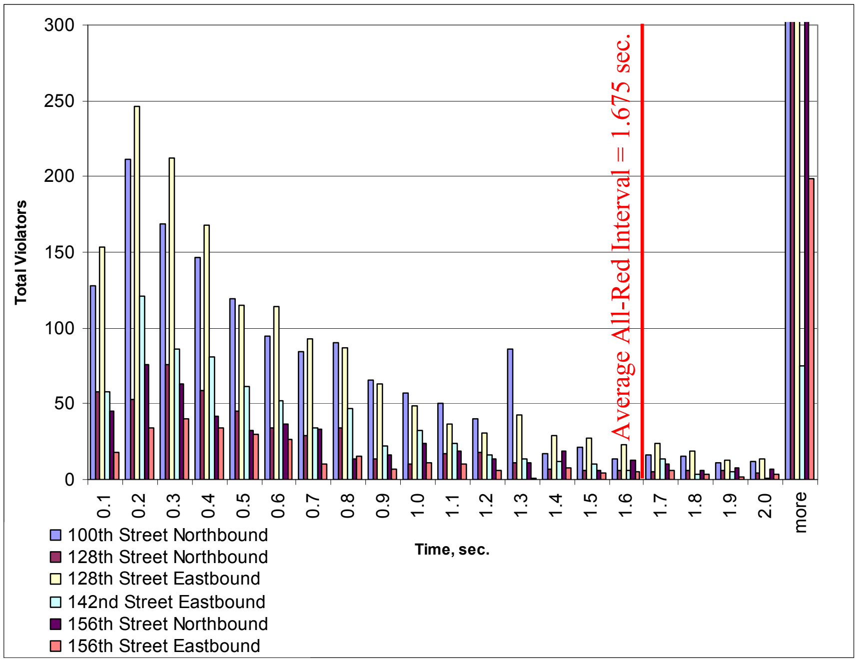


Figure 63. RLR severity Totals at all camera enforced intersections.

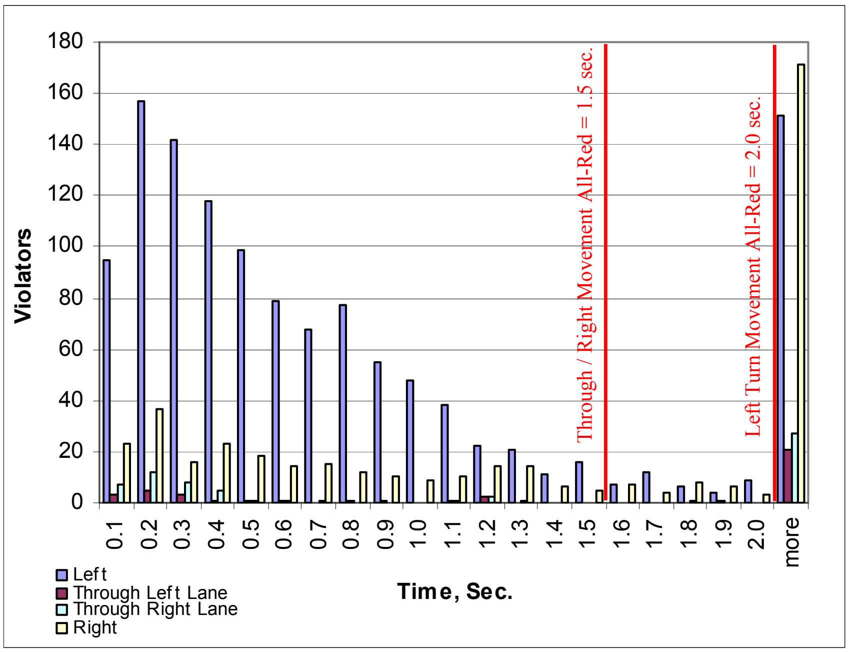


Figure 64. RLR severity at 100th St. northbound and Hickman Road by lane.

.

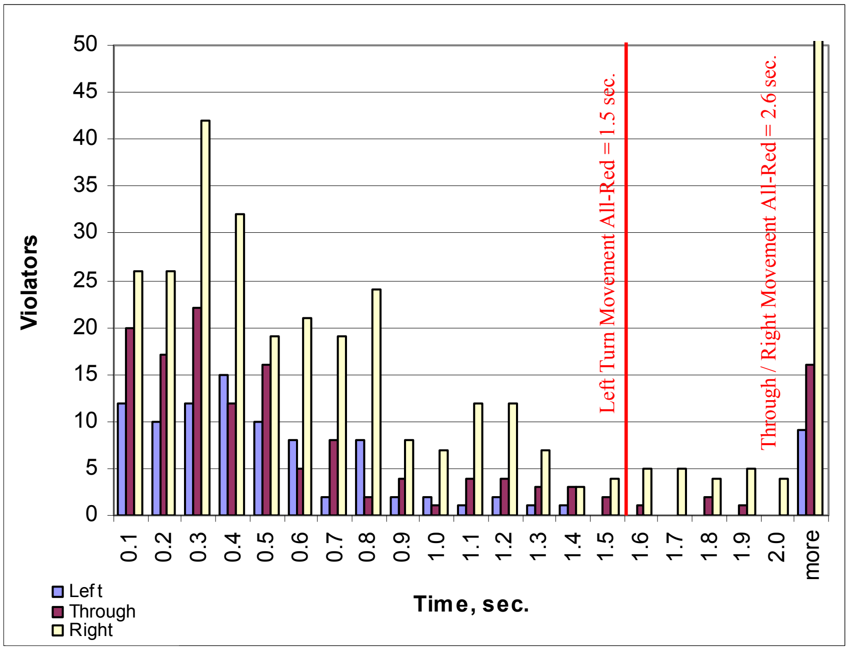


Figure 65. RLR severity at 128th St. northbound and Hickman Rd. per lane.

As illustrated in Figure 65, the right turning movement had the highest number of vehicles entering the intersection for all times past the onset of the all-red phase of the northbound approach at 128th Street and Hickman Road. Field observations had shown that many vehicles traveling north on 128th Street make a right turn towards Interstate 80 at all parts of the signal cycle. Vehicles for all movements entering the intersection between 0.1 through 0.8 seconds after the red phase are believed to be the end of a platoon since the Hickman Road corridor is coordinated.

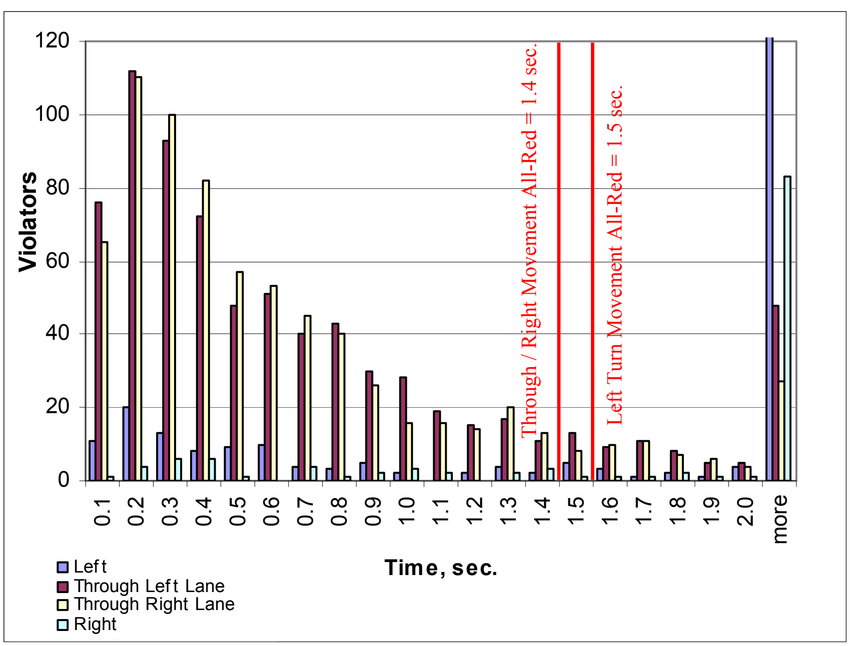


Figure 66. RLR severity at 128th St. eastbound and Hickman Rd. per lane.

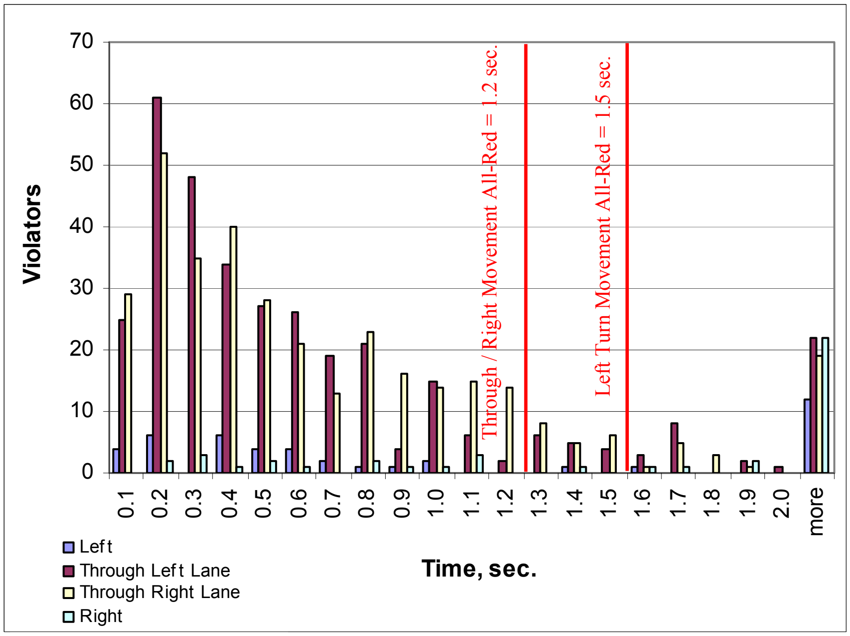


Figure 67. RLR severity at 142nd St. eastbound and Hickman Rd. by lane.

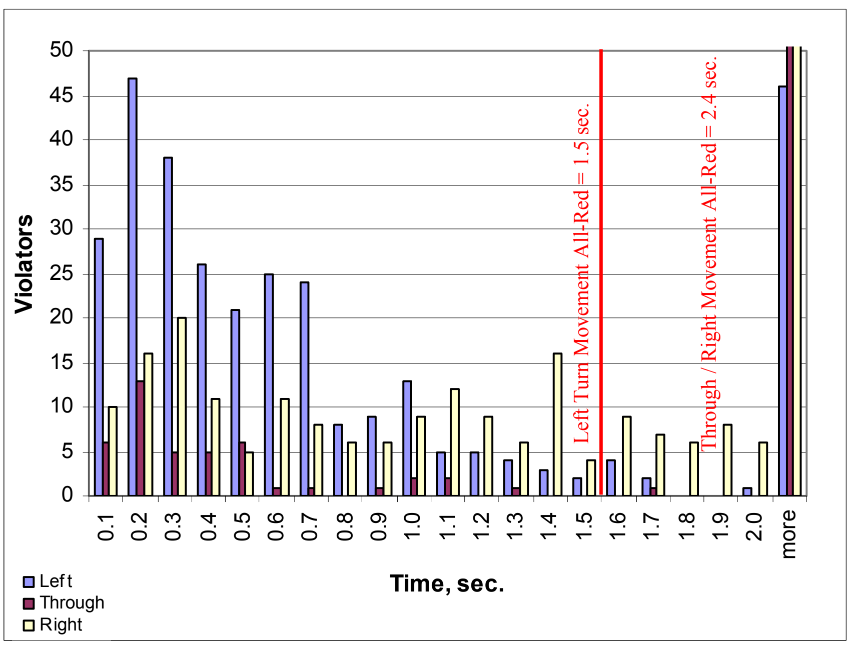


Figure 68. RLR severity at 156th St. northbound and Hickman Rd. by lane.

Contrary to the northbound approach illustrated in Figure 65, the eastbound approach traveling through the intersection of 128th Street and Hickman Road had a significantly higher number of through movement violators between 0.1 through 2.0 seconds as shown in Figure 66. The left turning movement had the highest number of violators past the 2.1+ second mark, and it is believed that these violators entered the intersection at the end of a platoon. Figure 67 illustrated the RLR severity at the intersection of 142nd Street and Hickman Road.

As shown in Figure 67, 142nd Street eastbound had the greatest percentage of violators entering the intersection prior to 1.0 second of red phase, and fewer violators entering the intersection after 2.1+ seconds. The right turning movement increase after 2.1+ seconds was believed to be vehicles making right turns onto 142nd Street with the assumption that there are no vehicles traveling through the intersection as 142nd Street have a lower overall volume. Figure 68 and Figure 69 illustrate the RLR severity at the intersection of 156th Street and Hickman Road.

As illustrated in Figure 68, the northbound approach at 156th Street and Hickman Road had the highest number of RLR violators enter the intersection after 2.1+ seconds of red. This approach also had the longest all-red interval for the through and right turning movements for all of the camera enforced intersections. From Figure 68, it was concluded that the high number of vehicles entering the intersection between 0.1 and 0.7 seconds were the result of long queues for the left turning movement. Furthermore, with over 1800 right turn violations, geometry, signal timing, or close proximity of a large grocery store might have contributed to the high numbers.

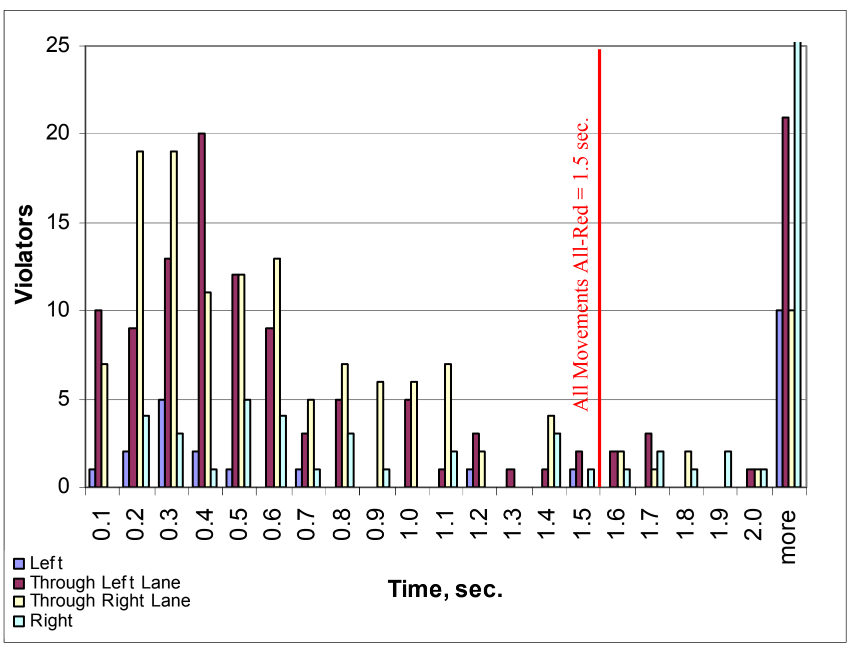


Figure 69. RLR severity at 156th St. eastbound and Hickman Rd. by lane.

The eastbound approach at 156th Street and Hickman Road had the lowest total number of RLR violations. As shown in Figure 69, both through lanes have the highest number of violators between 0.1 and 2.0 seconds, while the right turning movement had the highest number of violators entering the intersection after 2.1+ seconds into the red phase. A hypothesis of why this might be happening is drivers wanting to get to Dahl's grocery store or back to their homes a little faster and proceeding to turn right during the red phase without stopping.

3.9 CLIVE RLR STATISTICS

3.9.1 Data Description

To find a statistical relationship between the intersections in Clive with RLR cameras and the selected control intersections, a statistical model was created by Iowa State University statistics graduate student Massiel Orellana using the data collected in the field. A total of 11 intersections and 21 approaches were evaluated for RLR using video recordings and traffic volumes collected either in the field or through the city agencies. The following explanatory variables of each equation was collected and considered for a statistical model.

- *Camera:* Presence or absence of camera at each approach
- *Approach:* East, west, north, or southbound
- *Posted Speed Limit:* 30, 35, 40, 45, 50 or 55 mph
- *Movement:* Right, left, or through movements
- *Time:* 7:00- 9:00 AM, 11:00 AM – 1:00 PM, and 4:00 – 6:00 PM
- *Violations:* The number of vehicles that ran a red light
- *Volume:* Traffic volume by movement per peak hour

Illustrated in Figure 70 are the distribution of violations for all of the intersections which was the response variable.

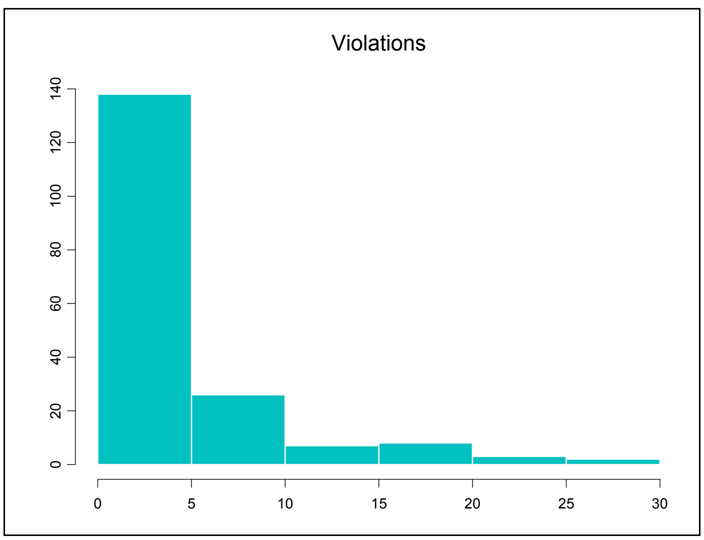


Figure 70. Histogram of the number of violations.

As shown, this histogram suggests that assuming a Poisson distribution for the response variable would be appropriate. Since the number of approaches observed changed from one intersection to another depending on whether a camera was present or not, a new defined "site" variable was created to indicate a particular approach and its associated characteristics based on the listed of possible explanatory variables. The Clive violation study had 21 sites, or 21 studied approaches. Each intersection characteristic was assigned a numbers to be inputted into the statistical model. For example, the intersections were identified by the numbers 1 through 11 (100th Street = 0, 128th Street = 1,128th Street = 2,…, etc.), each site was also defined by the numbers 1 through 4 (eastbound = 1, westbound = 2, northbound = 3, southbound = 4), and finally movement was defined by numbers 1 through 3 (left = 1, through = 2, right = 3) . Camera presence at a site was indicated with either a “0” for no camera and “1” for camera enforcement. All of the explanatory variables listed at the beginning of this section were taken into consideration for the analysis except the posted speed limit because it varied at all of the studied sites. Using two of the explanatory variables “Volume” and “Violations”, a scatter plot was created to illustrate the number of violations at each site to the volume of traffic at each site and can be seen in Figure 40.

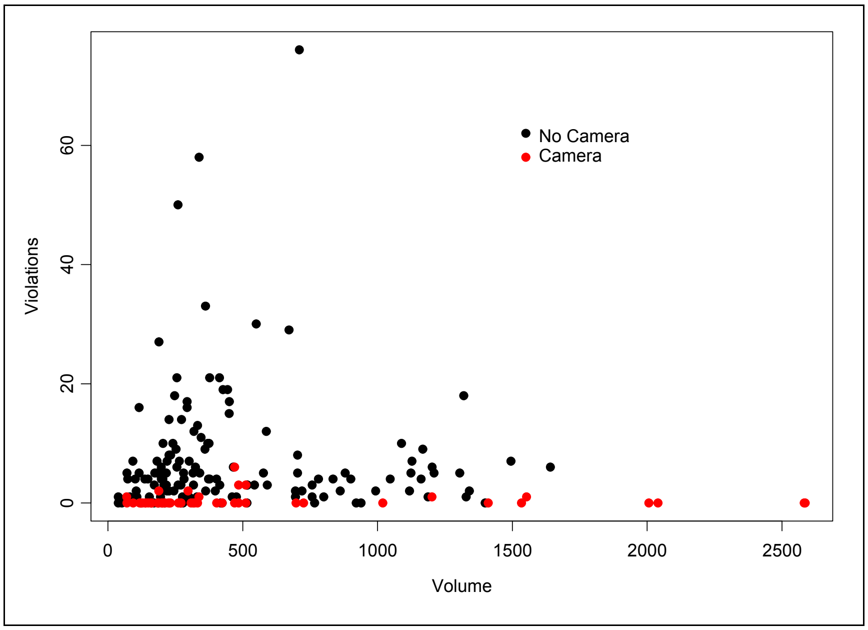


Figure 71. Scatter plot of sites with camera or no cameras vs. site traffic volume.

As illustrated, the sites without cameras tend to have a higher number of violations than sites with cameras. Also shown, even sites with RLR cameras and high traffic volume resulted in low violation counts. It was found that the maximum number of violations for a randomly selected day for the intersection with RLR cameras was 6. The maximum number of violations at the control intersections on a randomly sampled day was 76 violations. On average, sites with RLR cameras have 0.3 violations while sites without RLR cameras have 7.46 violations. Based on these numbers, it was apparent that the cameras had an impact on RLR behavior.

3.9.2 Model Fitting

From the violation analysis in section 3.9.1 it was clear that the statistical model to be used for the analysis could not assume a normal distribution. A suitable approach for the given data was to use a Poisson regression, which is a statistical model in the class of Generalized Linear Models that are an extension of classical linear models. The proposed Poisson model was defined as the following:

$$y_{ij} = \textit{number of violations at intersection i, approach j} \qquad \textbf{[3-4]}$$

The number of violations at a given approach followed the Poisson distribution with the parameter μ, where this parameter represented both the mean and variance of the violation distribution. Since the traffic volume at each approach differed, it was expected that the mean at every approach would also be different. The mean of distribution at each approach was adjusted to its traffic volume by multiplying the traffic volume with a certain parameter λ, where log-lambda represented the linear combination of the explanatory variables listed in section 8.3.1 that were taken into consideration. By finding log-lambda, a way to express the violation average at each approach as a function of the explanatory variables at each approach as shown below.

$$y_i \sim Poisson(\mu)$$
$$\mu = \lambda * volume \qquad \textbf{[3-5]}$$
$$\log(\lambda) = \mathbf{X\beta}$$

Where:

$\mathbf{X}$ is a matrix containing the information of the covariates, and $\boldsymbol{\beta}$ is a vector of parameters.

A SAS procedure known as GLIMMIX was used to fit a generalized linear model to the violation data allowing the inclusion of random effects. Including random effects was important because the observations were not independent. Observations at the same intersection were correlated, and observations at the same created site variable were also correlated so these two variables were included at random. The following final statistical model was used to evaluate the data.

$$Violation_{ij} \sim Poisson(\mu_{ij})$$
$$\mu_{ij} = \lambda_{ij} * volume \qquad \textbf{[3-6]}$$
$$\log(\lambda_{ij}) = \beta_1 * \text{Camera} + \beta_2 * \text{Movement} + \text{b}_1 * \text{Intersection} + \text{b}_2 * \text{Site}$$

Where:

$b_1 \sim N(0, \sigma^2_{b_1})$ and $b_2 \sim N(0, \sigma^2_{b_2})$

3.9.3 Results

For the statistical model, two fixed variables were considered which included camera presence and movement. The variable “movement” was first taken into consideration with three possible outcomes (left, through, and right). To test the significance of this variable, an F-test was performed which concluded that “movement” was a significant variable. To further examine the movement variable, multiple comparisons were used which resulted in all three movement types being different leading the researchers to conclude that more data was needed to determine the RLR camera effectiveness per movement.

The second fixed variable considered was camera presence where no camera = 0 and yes camera =1. Using least means square, two intercepts where found to fit the following model to find a violation mean.

$$Violation\ Mean = Intercept + Camera*X + Movement*X \qquad \textbf{[3-7]}$$

Where:

It is assumed that all other explanatory variable values were held constant and “X” would be represented by the camera presence label. Movement was not taken into consideration for this analysis.

The resulted output of the lease means square test suggested that approaches without RLR camera present had a slope of -4.24 with the confidence interval between -4.52 and -3.95. Intersection approaches with RLR cameras had a slope of -7.46 with the confidence interval between -8.12 and -6.80. It can also be noted that the two confidence intervals do not cross at any point, and the camera presence slope is almost double of the non-camera slope. By assuming the values of -4.24 and -7.46 the result showed that camera presence had the lower violation mean of 3.22 as shown in Appendix C. It can be concluded by this statistical model that RLR cameras substantially reduce the number of violations.

3.10 SUMMARY OF FINDINGS

Automated RLR enforcement began in July, 2006 as a means to improve safety on the busy Hickman Road corridor. Six automated RLR cameras were installed at intersections identified by Redflex, a RLR camera system vendor as potential candidates. The City of Clive entered into a 5 year contract with Redflex to rent each camera for $29,000 a month. In March, 2007 a Polk County Magistrate’s ruling put Clive’s camera enforcement on hiatus until a district court of appeal ruling or an Iowa Supreme Court ruling would help define automated enforce as it relates to Chapter 321 of the Iowa Code. A study conducted by the Center for Transportation Research and Education at Iowa State University was performed as an Iowa DOT projects to evaluate the effectiveness of Iowa’s three communities that currently have automated RLR enforcement. A violation study was selected as the method to evaluate Clive’s system because only several months of crash data were available after the cameras were installed and this was not sufficient to conduct a crash analysis. Field data were collected between March 2007 and May 2007 with the use of video recording and analysis, along with collecting data from the police department. This data included camera enforced intersections, surrounding control intersections, and an intersection 20 miles away to investigate how widespread the cameras effected the driver’s behavior when it came to RLR.

The data was analyzed using two methods, the first method involved descriptive statistics which found that the camera enforced approaches had a much lower RLR rate than other intersections within a 1 mile radius of the camera enforced intersections. The second of analysis involved using a generalized linear model to evaluate the differences in means between locations with RLR cameras and control intersections. This final statistical model investigated the significance of each approach or site depending if a camera was present at the site or not. Also included in the final model were the possible explanatory variables “traffic volume” and “time”. It was decided by the researchers that “Time” could not be considered, and “traffic volume could be used in the final model as an offset, but not a covariate.

Similar to the descriptive statistics, the results of the statistical model indicated violations at a given approach at a given intersection with automated RLR cameras showed a significant reduction in violations as compared to the control intersections. Since most of the control intersections were locations in the same area as the intersections with RLR cameras, it was concluded that the cameras were not modifying driver behavior within a 1 mile radius as hypothesized by Cunningham and Hummer (2004) in a violation study performed in North Carolina.

Data were also extracted from the Clive Police Department's Redflex data as to the characteristics of the violations for the entire enforcement period. Some characteristics of the RLR violations in Clive include the following.

- Most violations occurred on a Friday with the fewest occurring on Sunday.
- Eastbound cameras recorded the most violations in the through movement lanes.
- Northbound cameras recorded the most violations in the left and right turning movements depending if the intersection is located to the west or east of Interstate 80 / 35.
- The most recorded RLR violations occurred between 4:00 PM through 5:00 PM.
- A majority of the dangerous violations occurred 2.1+ seconds after the light had turned red (which surpasses the all-red clearance time), although many occurred between 0.1 second until the end of the all-red clearance time.
- Most of the violators were driving late model vehicles.
- Many left turning RLR violations occurred due to operating at a lower intersection level of services during peak hours.
- It was observed by the researchers in the field but not quantified that most of the RLR violators were using a cell phone or were distracted during the violation.

CHAPTER 4: A STUDY OF THE RLR PROGRAM IN COUNCIL BLUFFS, IOWA

4.1 DESCRIPTION OF COUNCIL BLUFFS, IOWA

The City of Councils Bluffs, referred to as the "Gateway to the American West" or "Kanesville," was settled in the mid 1800's by over 30,000 Mormon refugees on their way to what is known today as Salt Lake City. Kanesville was an optimal resting place for the California gold rush traveling population of 1849 was later renamed in 1853 to Council Bluffs in honor of the scenic bluffs surrounding the city.

Rail service came to Council Bluffs in 1862 after a visit by Abraham Lincoln and presidential advisor Grenville M. Dodge in 1859 to establish an official eastern transcontinental rail terminal. Council Bluffs' became the central hub to seven rail lines and in 1954, over a quarter of Council Bluffs population was supported by the fifth largest rail center in the nation.

City of Council Bluffs has a population of over 58,000 people with a 7% population growth over the previous ten years. The city shares its borders with Omaha, Nebraska, bringing a wealth of economic development to the area including gambling and technology industries *(68)*.

4.2 BACKGROUND OF COUNCIL BLUFFS RLR PROGRAM

4.2.1 Instrumentation

On May 9, 2005, the Council Bluffs City Council authorized the Mayor and City Clerk to execute an agreement with Redflex Traffic Systems, Inc. for an automated RLR system. On March 14, 2005, the City of Council Bluffs voted 3 to 1 for the required third time to consider an ordinance to change Chapter 9.16 of the Council Bluffs 2000 Municipal Code to add a section that explains automated enforcement which includes photographic, video, and electronic cameras. On October 10, 2005 a second ordinance to amend Chapter 9.16 of the 2000 Council Bluffs Municipal code was passed by a 3 to 1 vote which specifies where the civil fines are to be paid to. Unlike the cities of Davenport and Clive, Council Bluffs does not have the option for a vehicle's owner to nominate an offending driver if he or she is caught by the system while driving the registered owner's vehicle (i.e. limousine company, fleet vehicle, rental car, etc.).

Identical to the City of Clive terms of agreement, the City of Council Bluffs signed a terms of agreement with Redflex in May 2005 to establish key guidelines for the RLR program. Noted in the terms of agreement include the following points:

- A five year contract with Redflex with the option to purchase two additional years after the expiration of the agreement.
- For the first six months, Redflex will provide an expert witness for Council Bluffs to use in prosecuting violations.
- Redflex will install, maintain, and provide technical service within 24 hours of equipment failure, ensure proper communication between Redflex and the camera system, and process violations.
- Redlfex will provide 3 months of training for up to 15 city officials for 16 hours each,

- Redflex will provide a lockbox system to deposit fines for the city.
- Redflex will be provided access by Council Bluffs to Department of Motor Vehicle records data.
- Council Bluffs may terminate the agreement if (1) the state statutes are amended to prohibit operation of the enforcement system, (2) any court having jurisdiction over City rules, or state or federal statute declares, that results from the Redflex system of photo red light enforcement are inadmissible in evidence, or (3) either party commits any material breach as specified by the terms and agreements.
- Redflex will not open the traffic controller box without a city traffic engineer present.

The City of Council Bluffs has had continued success with the RLR camera program with the help of extensive public support from the community and local media. Currently, there is no class action lawsuits brought against the program, and Council Bluffs RLR program is the only automated enforcement program currently operating as of this report in July 2007.

4.2.2 Payment Structure

It is assumed according to the automated enforcement ordinance that the driver operating the vehicle is the owner since the cameras do not capture face image so the $65 ticket is sent to the registered owner of the vehicle via a license plate identification program. Similar to Clive, Redflex initially reviews each potential violation before sending them on the city. A Council Bluffs sworn police officer reviews each potential violation and makes the final determination about whether a RLR violation had occurred before an owner is issued a ticket by Redflex. The vehicle owner has a chance to witness 12 seconds of video of the infraction either on the web or at the police station, and also may appeal to the city attorney's office. Council Bluffs receives an average of $16 per paid citation, but the overall monthly income from tickets are based on a sliding scale depending on how many tickets are issued each month at each intersection as described below in TABLE 45.

TABLE 45 Tiered Payment Structure Based on the Number of Collected Citations

Tier	Per Approach Average	Fee	Redflex Revenue	City Revenue
1	Citations 0-3 Per Day	76.9%	$49.98	$15.02
2	Citations 4-6 Per Day	61.5%	$39.97	$25.03
3	Citations 7+ Per Day	46.0%	$29.90	$35.10

Council Bluffs also has the option to switch methods of payment on the anniversary of the original terms of agreement. Redflex requires written notice by the city and any debts must be paid off before the payment method switches. The second method of payment requires a fixed monthly rental fee of $5,170 per camera enforced approach. If Council Bluffs were to elect this method of payment, a fixed rental fee of $36,190 per month would be assessed to the city.

Council Bluffs decided to compensate Redflex using the slide tiered system instead of the monthly rental fee. Although the tiered system provides some leverage as to how many tickets are collected, Redflex does have an underlying service fee that the city must meet each month. If for some reason no citations are collected in one month at one approach, the city must cover the balance or a 1.5% monthly late fee is applied to service fee after 60 days. Finally, the fee assessed by Redflex and operating charge increases each year based on the consumer price index.

4.2.3 Functionality of System

As specified by the initial terms and agreement with the vendor, Redflex Traffic Systems studied 20 potential candidate intersections with high traffic volumes for automated enforcement. A five year contract with Redflex was signed for seven approaches at five intersections which include:

- Willow Way, southbound approach, at 7th Street
- Kanesville Blvd., westbound approach, at 8th Street
- Kanesville Blvd., eastbound approach, at 8th Street
- Broadway, westbound approach, at 16th Street
- Broadway, eastbound approach, at 16th Street
- Broadway, westbound approach, at 21st Street
- Broadway, eastbound approach, at 35th Street

These intersections, along with the control intersections listed below are illustrated in Figure 72. Similar to Clive, it was assumed that the camera enforced intersections would have an affect on driving behavior within 1 mile of the enforced intersection. The control intersections selected for this study include the following.

- Broadway and 1st Street
- Broadway and Kanesville Boulevard
- 35th Street and Nebraska Avenue
- 24th Street and 27th Avenue

As shown in Figure 72, two of these intersections lie within the 1 mile buffer zone of the camera enforced intersection and two lie outside of this zone.

Automated enforcement began on August 4th, 2005 with a 15-day warning period given to violators before regular ticketing began. Written notices were mailed to owners by Redflex and a large public campaign was kicked off. In general, the public appeared to support the new enforcement system. City officials also commented that the local media initially tried to highlight public disproval, but once they realized the level of support the cameras were receiving, the media started to criticize the nearby city of Omaha, Nebraska for not implementing a similar program. Advance "photo enforced" signs constructed by Council Bluff's sign shop as shown in Figure 73, were also installed prior to the intersection on each approach in which a camera system was installed. The automated enforcement system went online August 4, 2005 at five signalized intersections, each with one or two approaches being monitored by cameras.

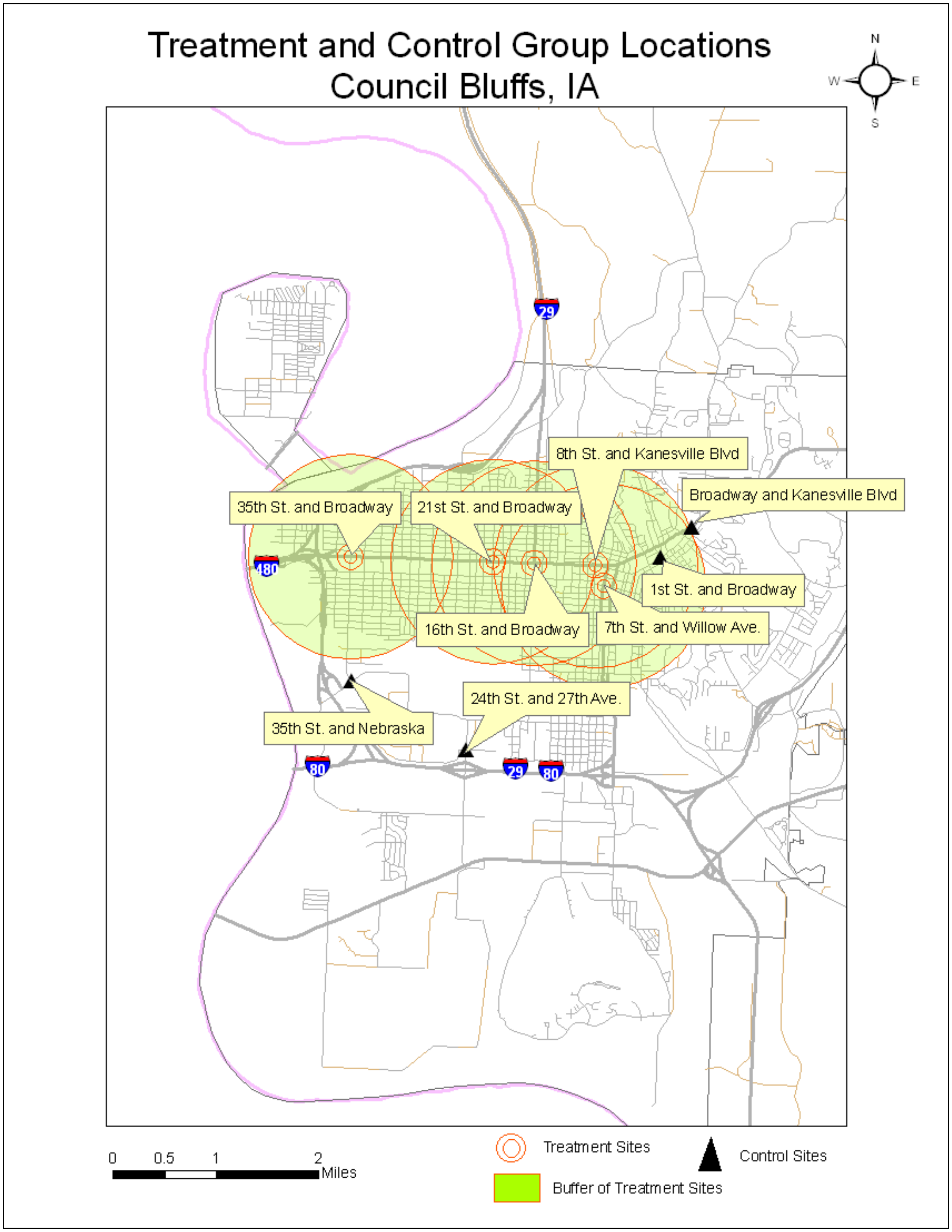


Figure 72. Location of Camera enforced and control intersections in Council Bluffs.

Figure 73. Advance Warning Signs.

The Redflex camera system installed in Council Bluffs works exactly the same as the Clive camera system, described in the previous section. The city considers a vehicle running a red light when it crosses into the intersection after the light has turned red, upon which three digital images are taken along with a 12 second digital video. Vehicles in the intersection or waiting for a gap to make a safe turn are not considered running a red light. Under the new city automated enforcement ordinance, a vehicle's driver who runs a red light, if sufficiently photographed and reviewed, will receive a civil infraction which is not reported to the Iowa DOT. Similar to Clive, Council Bluffs set the cameras minimum threshold speed to 15 miles per hour with a 0.10 second amnesty period before the triggering sequence. Also, the RLR camera system does not pick up the free right turn on the westbound approach of Kanesville Boulevard and 8^{th} Street. Council Bluffs has reported no vandalism to the camera system, but notes that there are many maintenance problems which Redflex is called out to solve including motherboard and vehicle detection failures

The City of Council Bluffs Police Department has not changed enforcement tactics, but overall has noticed a decrease in accidents city wide and a decrease in RLR at the enforced intersections. Redflex acquired access to the Nebraska Department of Motor Vehicles records, but as of the time of this report does not have records from Missouri or South Dakota from which to identify violating vehicles from these states. Council Bluffs would like to expand its automated enforcement system to another part of town but is waiting for new state legislation and future Iowa Supreme Court ruling.

4.2.4 Site Description

Details about each of the selected intersections and approaches are shown in the following pages. Approach and aerial images were acquired from local GIS departments and field images were taken during data collection. At each intersection, it was noted what businesses were surrounding the area and if pedestrian count was high. Other important information collected included peak hour volumes for each turning movement, signal timing for left turning and through movements, and identifying if a lane had a dedicated movement or if it shared a movement (e.g. a though and right turning movement for one lane, this would be specified as "shrd" in the table). The approach speed limit was also recorded as each approach had a different posted speed limit. The last aspect recorded was weather the intersection was actuated, free loops, pre-timed, or in coordination with nearby intersections.

Broadway (US 6) and 35th Street

The intersection of Broadway and 35th Street is located less than one mile east of Interstate 29 and is the first major intersection east of downtown Omaha, Nebraska. Much like three other camera enforced intersections, Broadway and 35th Street is located in a heavily commercial area. On the northeast side of the intersection is Automart 150, and on the northwest side is Fleming Motor Company. On the southeast side of the intersection is a Sonic and to the southwest is an empty parcel of land. All four businesses have multiple access points on both 35th Street and Broadway.

TABLE 46 Roadway, Traffic, and Signal Timing Characteristics for Broadway and 35th Street

Intersection	Broadway (US 6) and 35th Street (Council Bluffs, Iowa)
RLR Camera Approach	Eastbound Broadway
N-S Street:	35th Street
E-W Street:	Broadway
Peak Periods	7:00 - 9:00 AM, 11:00 AM - 1:00 PM, 4:00 - 6:00 PM

	EB		
	L	**T**	**R**
Lanes	1	2	shrd
Posted Speed (mph)	35		
Peak Hour Volumes			
7:00-9:00 AM	162	1468	30
11:00 AM -1:00 PM	304	1528	106
4:00-6:00 PM	312	1639	114
Cycle Length (sec.)			
Free Loops / Actuated	70		
6:30 AM - 11:00 PM*	70		
Green Interval (sec.)			
Free Loops / Actuated	25	20	
6:30 AM - 11:00 PM*	10	25	
Yellow Interval (sec.)	3.5		
All-Red Interval (sec.)	1.2		

*Signals are coordinated from 6:30 AM to 11:00 PM

Aerial View of Broadway and 35th Street

Figure 74. Broadway and 35th St. (eastbound).

Broadway (US 6) and 21st Street

Located one half-mile west of Broadway and 16th Street is the intersection of Broadway and 21st Street. This intersection is also surrounded by commercial developments including a building on the northeast side of the street with many small businesses. On the northwest side of the intersection is Glass Doctor. On the southwest side of the intersection is a large Tires Plus building, and finally on the southeast side of the intersection is Auto Connection. These businesses have multiple access points on both 21st Street and Broadway.

TABLE 47 Roadway, Traffic, and Signal Timing Characteristics for Broadway and 21st Street

Intersection	Broadway (US 6) and 21st Street (Council Bluffs, Iowa)
RLR Camera Approach	Westbound Broadway
N-S Street:	21st Street
E-W Street:	Broadway
Peak Periods	7:00 - 9:00 AM, 11:00 AM - 1:00 PM, 4:00 - 6:00 PM

	EB		
	L	T	R
Lanes	1	2	shrd
Posted Speed (mph)	35		
Peak Hour Volumes			
7:00-9:00 AM	46	1200	24
11:00 AM -1:00 PM	88	1818	32
4:00-6:00 PM	191	2328	9
Cycle Length (sec.)			
Free Loops / Actuated	70		
6:30 AM - 11:00 PM*	70		
Green Interval (sec.)			
Free Loops / Actuated	30	20	
6:30 AM - 11:00 PM*	12	32-36	
Yellow Interval (sec.)	3.5		
All-Red Interval (sec.)	1.2		

*Signals are coordinated from 6:30 AM to 11:00 PM

Aerial View of Broadway and 21st Street

Figure 75. Broadway and 21st St. (westbound).

Broadway (US 6) and 16th Street

The intersection of Broadway and 16th Street is centrally located in Council Bluffs' commercial area located one half-mile west of the intersection of Kanesville Blvd. and 8th Street. Many commercial businesses surround this intersection with multiple access points on both roads. The north side of the intersection includes a British Petroleum gas station to the east and a Peoples National Bank to the west. The south side of the road includes two fast food establishments, Burger King and McDonalds, that have high turning volumes during the lunch peak hour.

TABLE 48 Roadway, Traffic, and Signal Timing Characteristics for Broadway and 16th Street

Intersection	Broadway (US 6) and 16th Street (Council Bluffs, Iowa)
RLR Camera Approach	Eastbound and Westbound Broadway
N-S Street:	16th Street
E-W Street:	Broadway
Peak Periods	7:00 - 9:00 AM, 11:00 AM - 1:00 PM, 4:00 - 6:00 PM

	EB			WB		
	L	T	R	L	T	R
Lanes	1	2	3	1	2,3	4
Posted Speed (mph)	35			35		
Peak Hour Volumes						
7:00-9:00 AM	138	1037	75	352	1457	121
11:00 AM -1:00 PM	270	1668	151	507	1664	218
4:00-6:00 PM	292	2052	125	761	1589	153
Cycle Length (sec.)						
Free Loops / Actuated	111 to 126			111 to 126		
6:30 AM - 11:00 PM*	111 to 126			111 to 126		
Green Interval (sec.)						
Free Loops / Actuated	20	27		20	27	
6:30 AM - 11:00 PM*	16	37-50		15	37-51	
Yellow Interval (sec.)	3.5			3.5		
All-Red Interval (sec.)	1.2			1.2		

*Signals are coordinated from 6:30 AM to 11:00 PM

Aerial View of Broadway and 16th Street

Figure 76. Broadway & 16th St. (eastbound).

Figure 77. Broadway & 16th St. (westbound).

Kanesville Boulevard & 8th Street

Located on the east side of the Broadway commercial corridor, the intersection of Kanesville Boulevard and 8th Street is situated at the base of a bridge to the west and includes a free eastbound right turn that is not monitored by the camera system. The road divides on the east side of the intersection into Kanesville Blvd. to the north and Broadway continuing to the south. On the north side of the intersection is an open tract and private residences. On the southwest side of the intersection are Kelly's Furniture and Kelly's Carpet, with access points on 8th Street. On the southeast side of the intersection a commercial strip mall which includes Firestone, Ace Hardware, Hy-Vee, and Jensen Auto Care, with access points on both 8th Street and Broadway.

TABLE 49 Roadway, Traffic, and Signal Timing Characteristics for Kanesville Blvd. and 8th Street

Intersection	Kanesville Blvd. (US 6) and 8th Street (Council Bluffs, Iowa)
RLR Camera Approach	Eastbound and Westbound Kanesville Blvd.
N-S Street:	8th Street
E-W Street:	Broadway
Peak Periods	7:00 - 9:00 AM, 11:00 AM - 1:00 PM, 4:00 - 6:00 PM

	EB			WB		
	L	T	R	L	T	R
Lanes	1	2	shrd	1	2,3,4	free
Posted Speed (mph)	35			35		
Peak Hour Volumes						
7:00-9:00 AM	138	1037	75	352	1457	121
11:00 AM -1:00 PM	270	1668	151	507	1664	218
4:00-6:00 PM	292	2052	125	761	1589	153
Cycle Length (sec.)						
Free Loops / Actuated	111 to 126			111 to 126		
6:30 AM - 11:00 PM	111 to 126			111 to 126		
Green Interval (sec.)						
Free Loops / Actuated	20	27		20	27	
6:30 AM - 11:00 PM	16	37-50		15	37-51	
Yellow Interval (sec.)	3.5			3.5		
All-Red Interval (sec.)	1.2			1.2		

*Signals are coordinated from 6:30 AM to 11:00 PM

Aerial View of Broadway & 8th Street

Figure 78. Kanesville Blvd. & 8th St. (eastbound).

Figure 79. Kanesville Blvd. & 8th St. (westbound).

7th Street (IA 192) & Willow Avenue

Located southwest of Kanesville Blvd. and 8th Street is the residential intersection of 7th Street and Willow Avenue. This intersection, surrounded by many places of worship and educational institutions, is a one-way street intersecting a local arterial. On the southeast side of the intersection is St. John Lutheran Church; on the southwest side is Bloomer Elementary School. On the northwest side of the intersection is St. Francis Academy and on the northeast side is a local funeral home. All of these buildings surrounding the intersection have various access points and street parking on either 7th Street or Willow Avenue. The advance warning signs shown in Figure 1 are located at the beginning of the camera enforced approach block.

TABLE 50 Roadway, Traffic, and Signal Timing Characteristics for 7th Street and Willow Avenue

Intersection	7th Street and Willow Avenue (Council Bluffs, Iowa)
RLR Camera Approach	Southbound 7th Street
N-S Street:	7th Street
E-W Street:	Willow Avenue
Peak Periods	7:00 - 9:00 AM, 11:00 AM - 1:00 PM, 4:00 - 6:00 PM

	SB	
	L	R
Lanes	shrd	shrd
Posted Speed (mph)	25	
Peak Hour Volumes		
7:00-9:00 AM	1166	
11:00 AM -1:00 PM	1742	
4:00-6:00 PM	1753	
Cycle Length (sec.)		
24 Hour Coordination	60	
Green Interval (sec.)		
24 Hour Coordination	30	
Yellow Interval (sec.)	3.0	
All-Red Interval (sec.)	1.0	

*One way Left Turn Protected / Permitted

Aerial View of 7th Street and Willow Ave.

Figure 80. Advance warning sign (southbound).

Figure 81. 7th St. and Willow Ave. (southbound).

4.3 VIOLATION STUDY

Violation data were obtained through the Council Bluffs Police Department for the entire enforcement period although such variables as day of the week, time of the day, and time into red could not be obtained. The police department did provide monthly data as to how many violations the RLR cameras captured and the number of valid citations were issued out of the number of possible violations. Similar to Davenport and Clive, Redflex and the city perform a filtering process that checks the validity of each violation captured by the camera system. As shown in Figure 82, the city started issuing citations in August 2005 and is still continuing issuing tickets as of this study. The two colored bars in Figure 82 chart represent the number of recorded citations by the camera system per month and the actual number of mailed citations that were approved by a city police officer out of the original total number of citations.

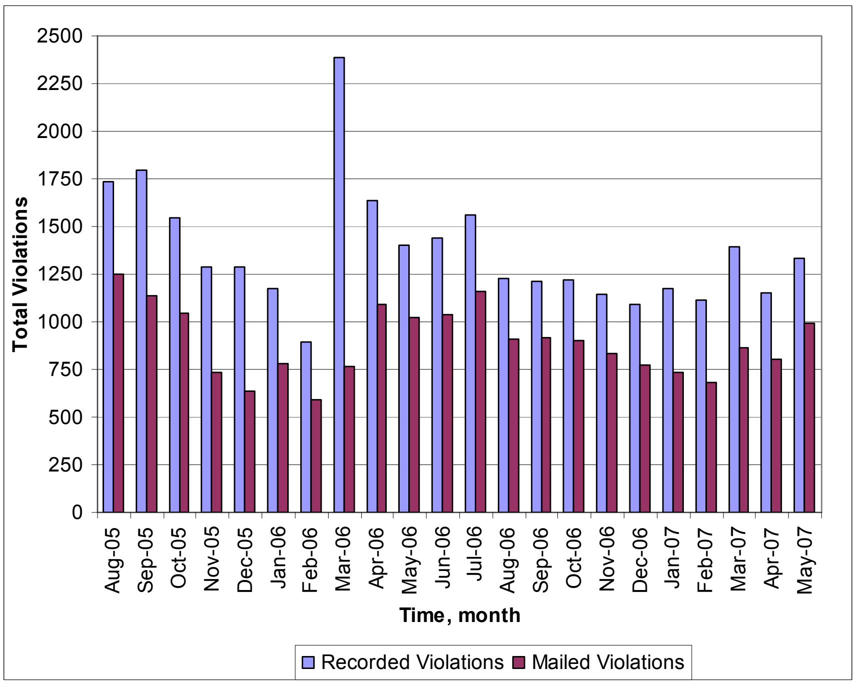


Figure 82. Monthly total violations versus mailed violations.

Current trends in the number of potential violations to actual issued citations average a combined 33.5% rejection rate per month by both Redflex and the police department. As shown, the number of recorded violations during the month of March 2006 differed greatly from the actual mail violations because of bad weather (snow and ice on the roads) and equipment problems (motherboard failures) from which many photographs were filtered out by Redflex, and safe turns on red which were filtered by the police department.

From the monthly violation data collected from the City of Council Bluffs, the total number of issued violations per intersection between the months of August 2005 and May 2007 were graphed and are shown in Figure 83.

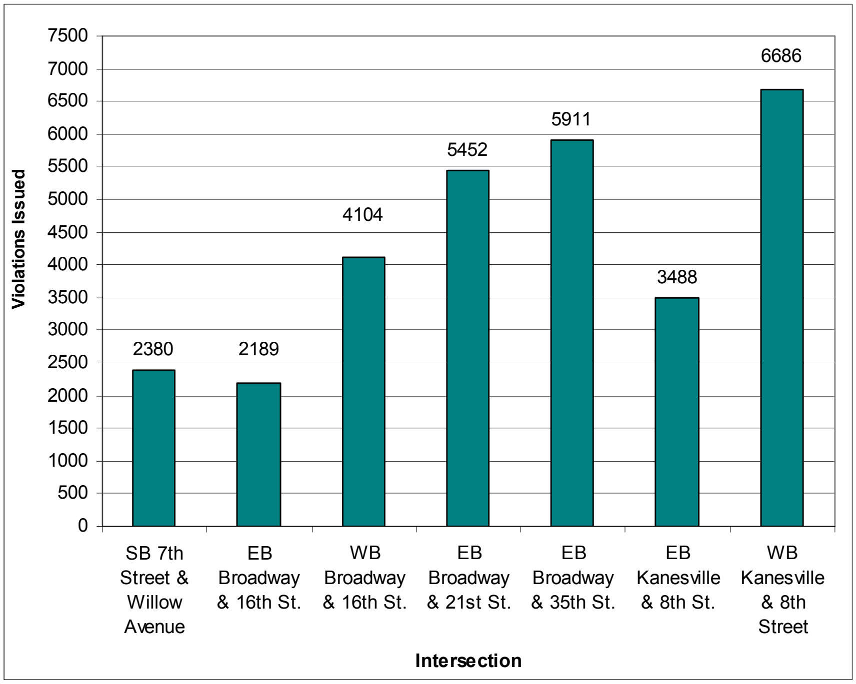


Figure 83. Total violations per enforced intersection between August 2005 and May 2007.

As shown in Figure 83, the westbound approach of Kanesville Blvd. and 8th Street had the most violations while on the other hand, the eastbound approach of the same intersection had almost half the number of issued citations. From the results shown in Figure 83, the most violations were at intersections on the east and west ends of the Broadway corridor while intersections located between the two had moderate to lower number of violations. Using RLR data obtained from the City of Council Bluffs, the team investigated the average percentage decrease in overall violations, monthly data from each intersection approach with a RLR camera system was plotted and linear equation and trend line was found using Excel and the results are presented in Figure 84 through Figure 88.

As shown in Figure 84, the average percentage decrease in violations is -4.31% and violations for 2007 have consistently held at 60 to 80 violations per month. As noted previously, this intersection is located off of the Broadway corridor where the other RLR cameras are located thus it could be assumed to local drivers are getting used to the enforced intersections.

Figure 85 has the linear regressions for both westbound and eastbound approaches of Broadway and 16th Street. As shown, both directions have seen a decrease in the overall number of violations per month with the westbound approach having an average decrease of -11.09% and the eastbound approach had an average decrease of 2.0%.

As shown in Figure 86, the eastbound approach of Broadway and 21st Street has seen the greatest overall average decrease of -17.49% over the entire enforcement period.

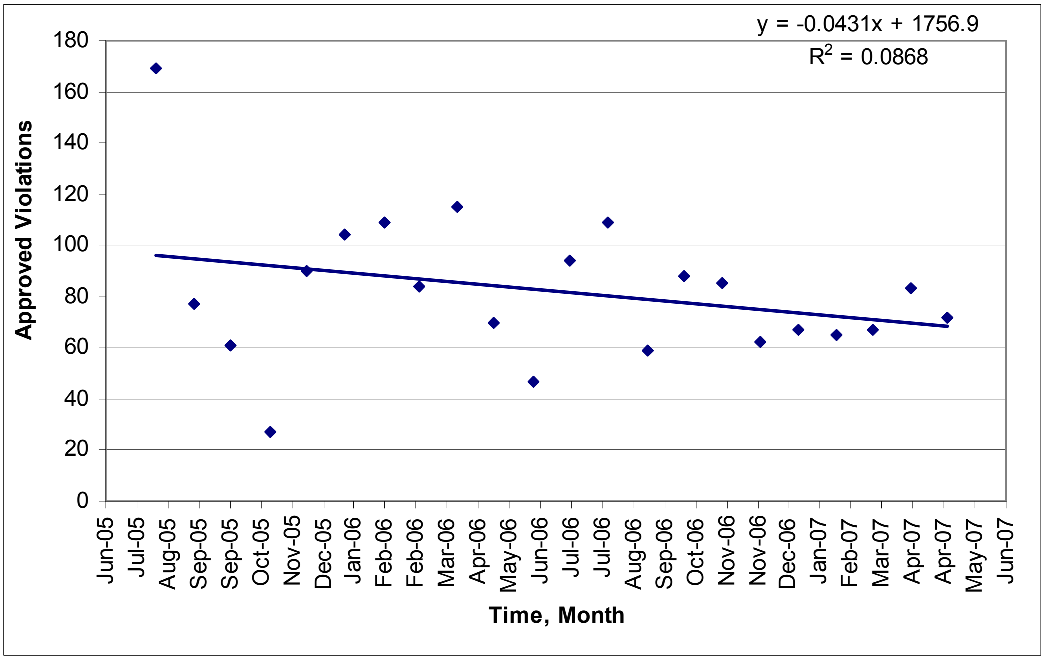


Figure 84. Linear regression of violations for 7th St. & Willow Ave.

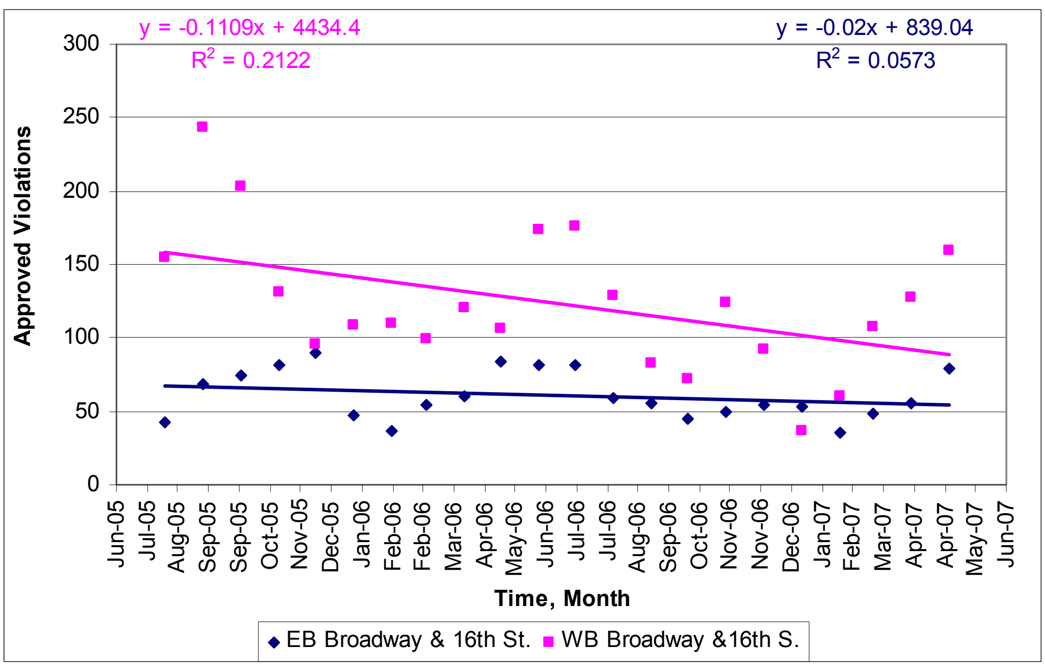


Figure 85. Linear regression of violations for Broadway & 16th St.

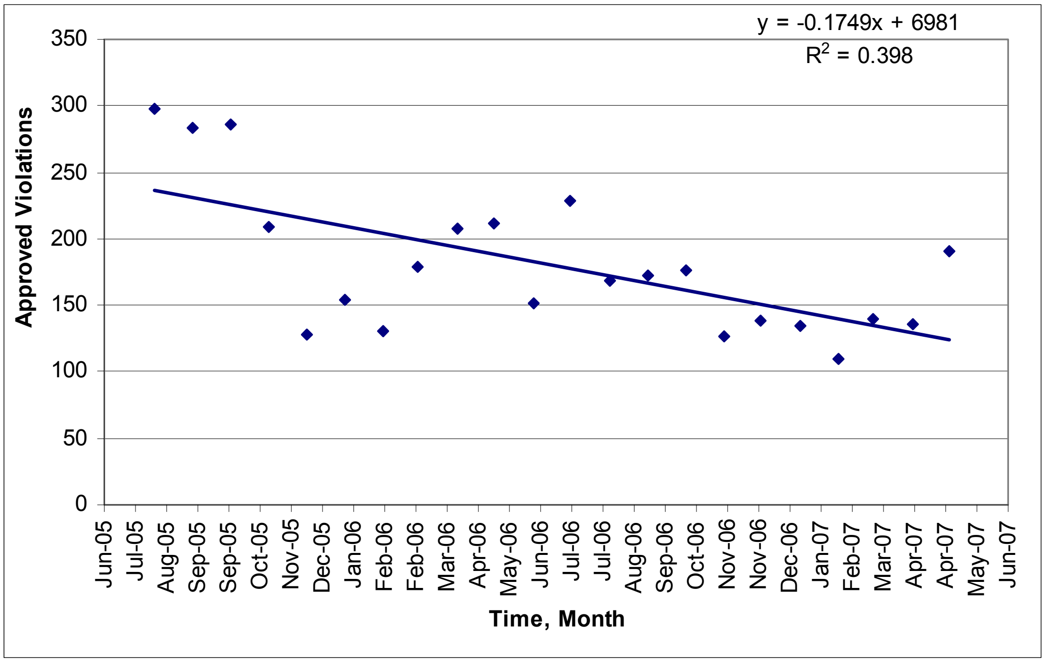


Figure 86. Linear regression of violations for Broadway & 21st St.

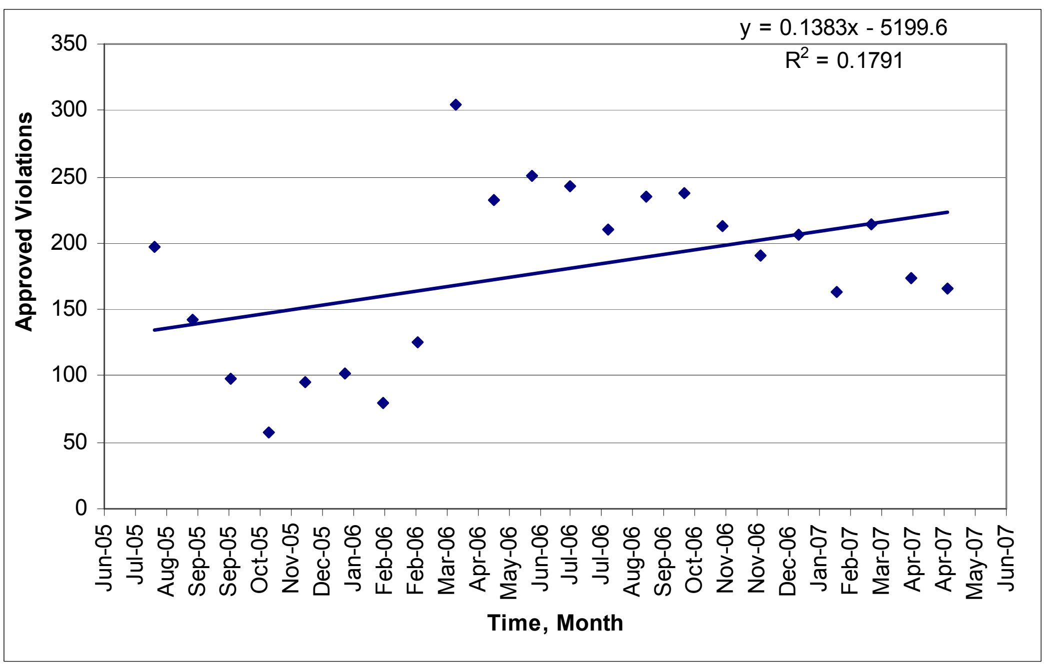


Figure 87. Linear regression of violations for Broadway & 35th St.

The only intersection that currently shows an increase in the average number of violations is the eastbound approach of Broadway and 35th Street which has a percentage increase of +13.83% and is shown in Figure 87. This intersection also has the second highest number of overall RLR violations.

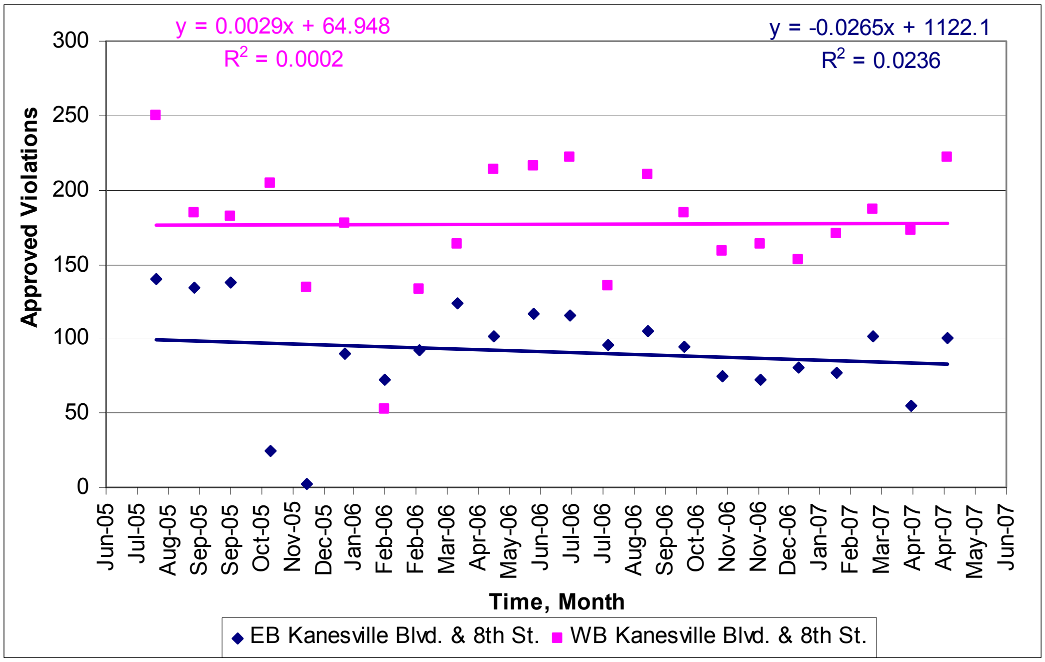


Figure 88. Linear regression of violations for Kanesville Blvd. & 8th St.

Figure 88 shows the linear regression for both the eastbound and westbound approaches for the intersection of Kanesville Blvd. and 8th Street. The westbound approach of this intersection has the highest number of RLR violations in Council Bluffs due to either drivers entering Council Bluffs from Omaha or interstate drivers who have exited the interstate. The eastbound approach is the fifth highest approach out of seven approaches with RLR violators.

4.4 CRASH STUDY METHODOLOGY AND RESULTS

The analysis methodology and results of the crash study performed for Council Bluffs can be found in Chapter 6.

CHAPTER 5: A STUDY OF THE RLR PROGRAM IN DAVENPORT, IOWA

5.1 DESCRIPTION OF DAVENPORT, IOWA

The City of Davenport, named after Colonel and fur trader George Davenport, and is part of the Iowa area known as "The Quad Cities" which is made up of Moline, IL; Rock Island, IL; Bettendorf, IA; and Davenport, IA surrounding the Mississippi River. Centuries ago, this area was home to the Sauk, an Indian tribe which inhabited parts of Iowa and Wisconsin. At the same time, the United States purchased what is known today as The Rock Island and built Fort Armstrong as a fur trading outpost, which later became a modern military institution.

Saukenuk, a major village across from Fort Armstrong, was home to the Native American Black Hawk. Black Hawk had great animosity towards American western expansion during the 1800's; the small and unsuccessful war against the Americans known as "The Black Hawk War" resulted in his capture in 1838 and the Sauk moving to parts of Oklahoma. In 1862, the United States Congress passed legislation to establish the Rock Island Arsenal. During the Civil War over 12,000 Confederate soldiers were imprisoned on the island; later during World War I, World War II, and the Korean Conflict, it became one of the largest weapons manufacturers for the conflicts.

Also during the 1800's, the Quad Cities saw an influx of immigrants traveling up the Mississippi River to find new homes in America. Germans, Belgians, and Swedes were attracted to the area because of military, lumber, and manufacturing. In 1848, famous entrepreneur John Deere opened his first steel manufacturing factory in Moline, Illinois known as Deere & Company, which took advantage of the river to power much of its heavy manufacturing equipment *(70)*. Davenport was also dubbed "Washing Machine Capital of the World" and "Cigar Making Capital of the Midwest" as other large commercial ventures began there *(69)*.

In 1854, Davenport saw the first of 3 railroad companies and first of many bridges which would connected Rock Island to Davenport. The area also saw an economic boom with stiff competition between the railroad companies and steamboat companies. Ironically, just two weeks after the first railroad bridge was opened the steamship Effie Afton collided with the bridge causing both to burn. In 1863, the case between the rail company and the steamship company over the accident was brought before the U.S. Supreme Court and ruled in favor of the rail company allowing bridges to span across the Mississippi River.

Today, the City of Davenport is home to just under 100,000 residents that spread over 39,000 acres. The City of Davenport, along with the area known as the quad cities have experienced great economic development due to the increase in high tech, commercial, and river transport companies. *(69)*

5.2 BACKGROUND OF DAVENPORT'S RLR PROGRAM

5.2.1 Instrumentation

On January 21, 2004, the City of Davenport signed a beta test agreement with the automated enforcement company Transol USA Inc., based in Chandler, Arizona. A beta test agreement in this case was for Transol USA to test its latest RLR camera technology in Davenport. Prior to the signing the agreement with

Transol, the Davenport City Engineering Office along with the Traffic Enforcement Department of the Davenport Police Department studied intersections for possible automated enforcement based on the total number of crashes as shown below in TABLE 51. Most of the high-crash intersections were selected, although a few were not due to planned construction or other constraints that would not allow an automated enforcement system.

The City of Davenport signed the terms and agreement to start an automated enforcement program after extensive signal progression and engineering countermeasures failed to lower the number of red light runners at high volume intersections. As stated in the terms of agreement, the city believed an automated enforcement system would benefit the public's health, safety, and welfare, and help reduce potentially dangerous crashes.

In 2004, the Davenport City Code section on traffic control devices was amended to add Section 10.16.070 which specified city ordinances 2004-35 and 2005-361 on automated RLR and speed enforcement. One key element to this section is that the violating driver does not have the opportunity to nominate the driver of the vehicle, and the vehicle's registered owner would receive the $65 civil fine. The city also established an automated speed enforcement program with Redflex Technologies in 2005 to capture drivers exceeding the posted speed limit by 10 mph on major roads throughout the city. Unlike a fixed fine schedule with RLR violations, the civil speeding ticket is based on a tier system ranging from $5 to $120 based on the number of miles per hour over the speed limit. The City of Davenport also has one mobile speed van which is deployed in strategic places throughout the city where automated enforcement cannot be placed.

Davenport's terms of agreement are much different than Clive and Council Bluffs and include:

- A camera system may be added or subtracted from a location after 1 year of operation
- The City of Davenport agrees to pay Transol a fee for installation, operation, and maintenance, by one of two payment plans as specified by Transol
- The City of Davenport agrees to enter into a 5-year contract with Transol and can be dissolved if automated enforcement is no longer legally enforceable by State Law, or if legislation or court decisions make it reasonably impossible to operate the system. The entire red light running program will end 30 days after the city notifies the company of the changes in law.
- Every year on the anniversary of the original contract, the city shall review the effectiveness of the RLR system and will have the option to terminate the program at Transol's expense. Furthermore, each year the city may elect to switch payment plans as described later in this section.
- Transol shall keep the premises around the camera systems clean and free from debris. If necessary, the city may clean the area and may deduct expenses from the monthly fee owed to Transol.

TABLE 51 Davenport Intersections Based on the Highest to Lowest Average Number of Crashes

	Intersection		2003	2002	2001	Average
	Kimberly	**Welcome Way**	**9**	**10**	**6**	**8.3**
	Kimberly	**Elmore**	**11**	**7**	**5**	**7.7**
	Kimberly	Main (mall ent.)	9	8	2	6.3
	Harrison	**35th**	**4**	**3**	**9**	**5.3**
	Division	**4th**	**5**	**4**	**6**	**5.0**
*	53rd	Welcome Way	1	6	5	4.0
*	Kimberly	Marquette	2	5	5	4.0
	Kimberly	Fairmount	3	5	3	3.7
**	Kimberly	Division	3	5	3	3.7
	Division	36th	1	4	6	3.7
	Kimberly	**Brady**	**3**	**4**	**3**	**3.3**
*	53rd	Brady	4	0	6	3.3
	53rd	Elmore Circle	2	5	3	3.3
	Locust	Harrison	0	6	3	3.0
	Locust	Brady	1	2	6	3.0
*	Lombard	Marquette	2	2	5	3.0
	Division	3rd	2	3	3	2.7
	Kimberly	Pine	3	2	2	2.3
	53rd	Elmore Avenue	3	3	1	2.3
	Locust	Marquette	2	2	3	2.3
	Locust	Lincoln	3	1	3	2.3
	Brady	35th	1	5	1	2.3
	Locust	Division (5 pts)	1	4	1	2.0
	Kimberly	NW Blvd	1	3	2	2.0
	Kimberly	Jersey Ridge	1	3	2	2.0
	53rd	Jersey Ridge	3	3	0	2.0
	Central Park	Marquette	3	0	3	2.0
	Locust	Iowa	1	3	2	2.0
	Locust	Grand	0	5	1	2.0
	42nd	Welcome Way	2	1	3	2.0
	53rd	Division	2	1	2	1.7
	53rd	NW Blvd	1	3	1	1.7
	Locust	Gaines	1	2	2	1.7
	53rd	Lorton	1	2	N/A	1.5
	Central Park	Division	3	0	1	1.3
	Locust	Bridge	1	2	1	1.3
	Kimberly	Spring	1	1	1	1.0
	Central Park	Brady	1	1	1	1.0
	Central Park	Harrison	1	0	2	1.0
	Locust	Clark	2	1	0	1.0
	Locust	Washington	1	0	2	1.0
	Central Park	Hickory Grove	2	1	0	1.0
	Locust	Eastern	1	2	0	1.0
	53rd	Utica Ridge	0	1	2	1.0
	Brady	29th	2	1	0	1.0
	Brady	46th	1	2	0	1.0
	46th	Welcome Way	2	1	0	1.0
	53rd	Eastern	1	1	0	0.7
	Locust	Main	1	1	0	0.7
	53rd	Corp. Park Dr	1	1	0	0.7
*	River	Concord	0	1	0	0.3
	River	Stark	1	0	0	0.3
	53rd	Tremont	0	1	0	0.3
	Central Park	Lincoln	1	0	0	0.3
***	Kimberly	Eastern	0	N/A	N/A	0.0
	Central Park	Clark	0	0	0	0.0
	50th	Welcome Way	0	0	0	0.0

*Intersection reconstruction in the next 2 years
**Intersection reconstruction in the next 3-5 years
***Intersection was reconstructed in 2002

The RLR camera system began on August 25, 2004 at the intersections of 4th Street and Division Street and 35th and southbound Harrison Street. The second installation occurred during the months of September and October, 2004 at the following intersection approaches.

- Brady Street, northbound approach, at Kimberly Road
- Elmore Street, eastbound approach, at Kimberly Road
- Elmore Street, westbound approach, at Kimberly Road
- Welcome Way, southbound approach, at Kimberly Road

Unlike the camera systems in Council Bluffs and Clive, individual lanes are monitored by a single video camera and flash as shown in Figure 89. Advance warning signs with orange flags alert approaching vehicles of automated enforcement. Video is constantly dumped by the computer system until a violating vehicle's speed is detected by inductive loops (or the video detection system) triggering the video capturing sequence. There is no grace time built into the system and no approaching vehicle threshold speed to give the benefit of doubt to the driver. Short videos that are captured are transmitted to Transol in Arizona via a dedicated T1 phone line and are processed and filtered before sending images back to the Davenport Police Department for approval. Once a police officer has reviewed the video and license plate photo, approved violations are sent back to Transol and mailed to the owner of the vehicle. Unlike Clive, Davenport does not have a driver nomination ordinance to ticket the drivers of the registered vehicle.

Figure 89. Davenport RLR and Automated Speed Camera System.

5.2.2 Payment Structure

The City of Davenport activated intersections individually with a 30 day warning period at each intersection. Transol charged $5.00 per warning citation issued and no monthly fee was charged to the city. Much like Clive and Council Bluffs, two payment options were established by Transol which can be adjusted every year on the anniversary of the original contract. Described below are the two payment structures the city was presented with.

Method 1

The City of Davenport will rent the camera systems at 5 intersections and 9 approaches. The amount requested by Transol was $4,800 per intersection per month which added up to $24,000 per month.

Method 2

The second method requires the City of Davenport to pay a fee per violation of $32.00 per ticket out of the $65 civil fine charged to the owner of the vehicle that ran the red light. If the violator wishes to challenge the offense and a court rules in favor of the person cited, the $32.00 fee will be dismissed.

5.2.3 Reorganization

On September 1, 2005, the City of Davenport signed a memorandum of understanding with Nestor Traffic Systems, Inc. of Providence, Rhode Island, which took over Transol's RLR operations. Prior to this time, Nestor already had a contract with Davenport similar to Redflex to use automated LIDAR technology speed enforcement at the intersections with red light running cameras. The memorandum of understanding signed by city officials with Nestor included the same terms of agreement made with Transol. With a new contract in place, the fee to Nestor changed from the original $32 to $24 per violation, with the city receiving $41 per violation. Between the January and February 2006, Nestor switch the system over which resulted in minimal violation capturing this can clearly be seen in Figure 90.

During the same time period, an effectiveness study was performed by both Nestor and the City of Davenport to determine the effectiveness of the RLR cameras presently installed. In June, 2006 one set of cameras was moved from 4th Street and Division Street to Lincoln Avenue and Locust Street due to no significant decrease in crashes. In addition to the equipment move, the City of Davenport requested approval form the Iowa DOT to add east- and westbound enforcement at Kimberly Road and Brady Street, which was approved January 23, 2006. Currently, RLR cameras are installed at the following locations.

- Brady Street, northbound approach, at Kimberly Road
- Brady Street, eastbound approach, at Kimberly Road
- Brady Street, westbound approach, at Kimberly Road
- Elmore Avenue, eastbound approach, at Kimberly Road
- Elmore Avenue, westbound approach, at Kimberly Road

- Welcome Way, southbound approach, at Kimberly Road
- North Harrison Street, southbound approach, at West 35th Street
- Locust Street, eastbound approach, at North Lincoln Avenue
- Locust Street, westbound approach, at North Lincoln Avenue

Shown in Figure 91 are the location of the camera enforced intersections and the selected control intersections. Similarly to Clive and Council Bluffs, it was assumed that driver behavior would change within the 1 mile radius buffer zone. The intersections selected as control intersections include the following.

- Pine Street and Kimberly Road
- 53rd Street and Elmore Avenue
- Locust Street and Brady Street
- Locust Street and Hickory Grove
- North Division Street and Central Park Avenue

5.2.4 Revenue

The City of Davenport views automated enforcement as a balancing act between public acceptance and safety. The police department had hoped that revenue generated from the automated RLR and speed enforcement camera systems could benefit Davenport's citizens by creating such programs as alcohol safety, a juvenile crime unit, neighborhood enforcement, and possibly hiring more police officers. Since the beginning of the RLR enforcement program in 2004, the City of Davenport has collect over $260,000 in paid citations to help public safety in Davenport. Shown in Figure 90 is the revenue collected by Nestor / Transol and the City of Davenport which showed almost a 50 / 50 split with revenue.

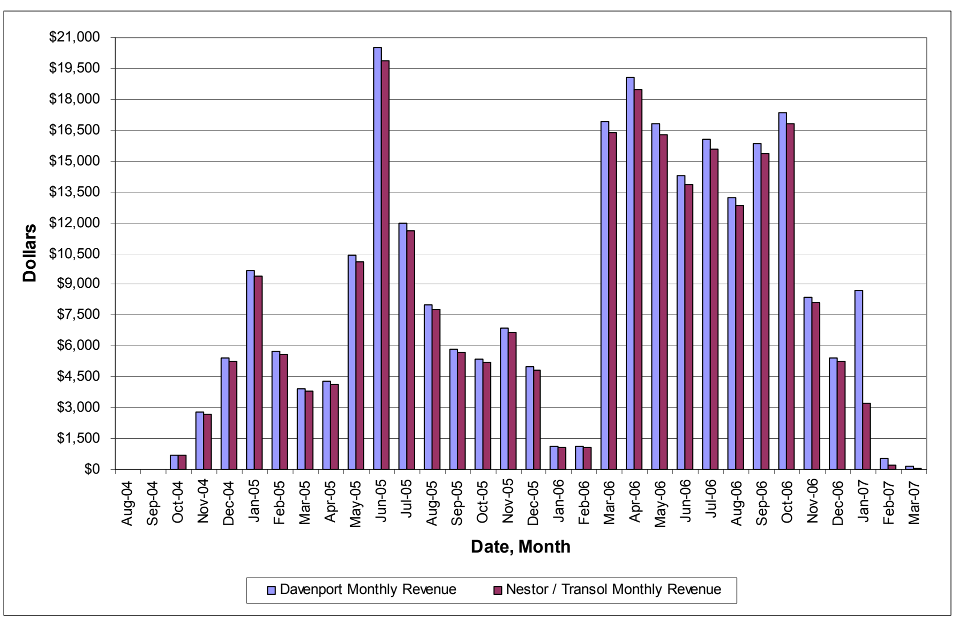


Figure 90. Total monthly revenue split between Davenport and Nestor each month of RLR enforcement.

As illustrated, revenue took a sudden decline between the months January 2006 through February 2006 when the enforcement program changed companies from Transol to Nestor.

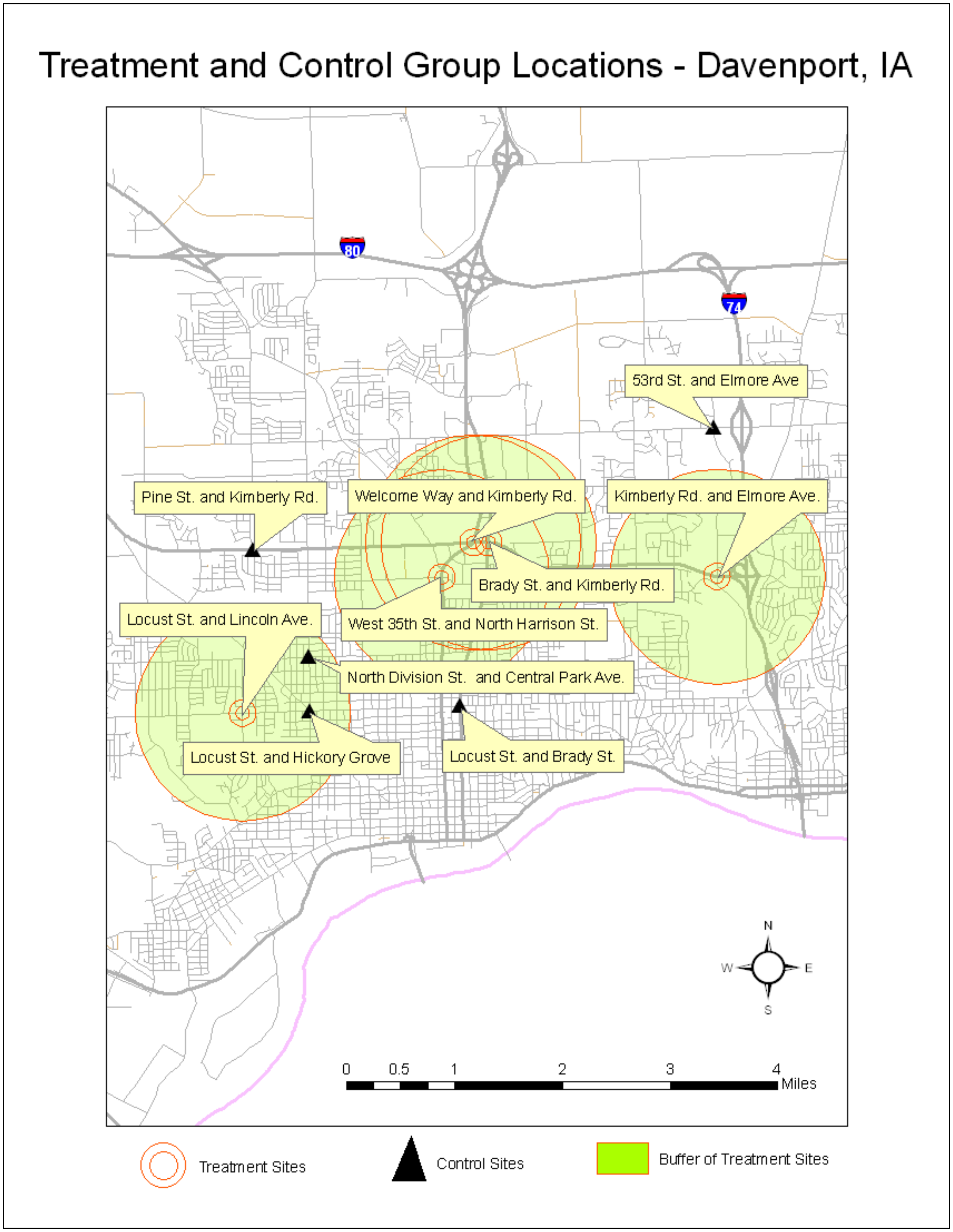


Figure 91. Camera enforced and control intersections in Davenport.

Also, the automated enforcement program went on hiatus in between February and March due to contract reorganization which resulted in minimal revenue.

5.2.5 Legal Proceedings

Davenport's automated enforcement systems have come under scrutiny twice since enforcement began in 2004. The first lawsuit against the city came when Thomas Seymour disputed the constitutionality behind automated enforcement. The American Civil Liberties Union (ACLU) of Iowa backed Seymour's dispute as test case that argued the constitutionality of the camera system and how the cameras unfairly put a burden of proof of innocence on those who get captured by the cameras. On July 18, 2006 Scott County Magistrate Kyle Williamson denied the motion to dismiss the charges against Seymour and ordered him to pay the $125 ticket. Furthermore, Magistrate Williamson cited in his ruling that such automated speed enforcement is not illegal under the Iowa Constitution. The Iowa Supreme Court has accepted the appeal by the ACLU on behalf of Seymour, and will hear the case in 2008.

On October 17, 2006, Monique Rhoden and Curt Canfield challenged the automated enforcement system when her 2000 Cadillac was ticketed by the automated speed enforcement camera system traveling 46 mph in a posted 35 mph zone. District Court Judge Gary McKenrick heard arguments against the system where the plaintiff argued that Section 10.16.070 of the Davenport Municipal Code violates established provisions of Chapter 321 of the Iowa Code (2006). The plaintiff also asserts that the same section of the Davenport Municipal Code is an illegal tax or revenue generator. District Court Judge McKenrick sited that municipal infractions are authorized under Section 364.22(2) of the Iowa Code (2005): an ordinance established by the city may provide that a violation of this ordinance is a municipal infraction and may not exceed $1,000 as stated by Section 364.22(1) of the Iowa Code (2005). Judge McKenrick found that the city was not illegally collecting fines or taxes because Section 463.22(1) of the Iowa Code (2005) authorizes it. Chapter 321 of the Iowa Code explains that disobedience of a traffic control device or speeding is considered a state scheduled violation which is accompanied by a scheduled fine (Sections 805.8(1), 805.8A(5), and 805.8A(8) of the Iowa Code (2005)). Thus, Judge McKenrick stated that Davenport did not follow the Iowa Code by having a separate automated enforcement schedule that differs from state scheduled violation fines.

Davenport Municipal Code Section 10.16.070 states that citations will not be sent to the Iowa Department of Transportation and will not be added to the violator's driving record. McKenrick notes that this violates Section 321.491 of the Iowa Code (2005) that requires a person who is charged with a violation be reported to the Department of Transportation within 10 days of conviction.

Responding to the ruling on January 2, 2007 the City of Davenport's corporate attorney Mary Thee proposed three paths the city could take with the district court ruling. The first path includes an appeal to the ruling in front of Scott County District Court or Iowa Supreme Court; the second path involves the City Council weakening the ordinance to comply with Chapter 321 of the Iowa Code, or the third path is to heavily lobby state legislators. The appeal process for this ruling is expected to take 12 to 18 months.

Starting in late January 2007, the City Alderman decided to take on all three described paths even with the court ruling setback. The City of Davenport plans to appeal to the Iowa Supreme Court in January 2008 while modifying the ordinance and readjusting its fine structure. The recommended proposed fine change brings an automated RLR enforcement from $65 to $35 and would be reported to the Iowa DOT. Passed with a vote of 7-3 on January 24, 2007, the city ordinance was changed; the cameras continued to capture violators and ticket drivers until March 31, 2007 when the both the automated speeding and RLR cameras were put on hiatus by the city until the various lawsuits could be settled.

On April 20, 2007 Scott County Judge Gary McKenrick ruled the lawsuits to stop Davenport's [speeding and RLR] cameras could become a class action case where refunds would be awarded to drivers caught speeding or running a red light which could cost the city in the millions of dollars. Judge McKenrick wrote in his ruling that "[automated enforcement fines were] illegal exaction, unjust enrichment and restitution." On May 4, 2007 the City of Davenport hired Attorney Craig Levien of Betty, Neuman, and McMahon of Davenport to appeal the court ruling in front of the Iowa Supreme Court which agreed to here the case in January 2008. The City of Davenport is heavily lobbying both Iowa House and Senate transportation standing committee to pass automated enforcement legislation to continue RLR and speed camera enforcement.

5.2.6 Site Description

Details about each of the selected intersections and approaches are shown in the following pages. Approach and aerial images were acquired from local GIS departments and field images were taken during data collection. At each intersection, it was noted what businesses were surrounding the area and if pedestrian counts were high. Other important information collected included peak-hour volumes for each turning movement, signal timing for left turning and through movements, and identifying if a lane had a dedicated movement or if it shared a movement (e.g. a though and right turning movement for one lane, this would be specified as "shrd" in the table). The approach speed limit was also recorded as each approach had a different posted speed limit. The last aspect recorded was weather the intersection was actuated, free loops, pre-timed, or in coordination with nearby intersections.

<u>Kimberly Road & Brady Street</u>

Considered one of Davenport's busiest downtown intersections, Kimberly Road and Brady Street is unique in that Brady Street is a one way street traveling north that eventually meets Interstate 80. The intersection is surrounded by many businesses and restaurants including Toys 'R' Us on the northwest side, a British Petroleum station on the northeast side, a small commercial development on the southeast side, and the popular restaurant Los Agaves Mexican Grill on the southwest. Although Brady Street has a wide cross section and many access points, coordination between signals located to the north and south are timed quite well, helping control congestion. Kimberly Road is one of many busy east-west corridors in Davenport and carries a heavy volume of traffic in both directions.

TABLE 52 Roadway, Traffic, and Signal Timing Characteristics for Kimberly Road and Brady Street

Intersection	Kimberly Road (US 6) and Brady Street (Davenport, Iowa)							
RLR Camera Approach	Eastbound and Westbound Kimberly Road, Northbound Brady Street							
N-S Street:	Brady Street							
E-W Street:	Kimberly Road							
Peak Periods	7:00 - 9:00 AM, 11:00 AM - 1:00 PM, 4:00 - 6:00 PM							
	EB			**WB**		**NB**		
	L	**T**	**R**	**T**	**R**	**L**	**T**	**R**
Lanes	1,2	3,4	shrd	1,2	shrd	1, shrd	2,3	shrd
Posted Speed (mph)		35		35			35	
Peak Hour Volumes								
7:00-9:00 AM	237	1306		1302	281	301	1333	223
11:00 AM -1:00 PM	410	2108		2348	531	837	1758	445
4:00-6:00 PM	540	2459		2699	666	918	2221	517
Cycle Length (sec.)								
7:00-9:00 AM		110		110			110	
11:00 AM -1:00 PM		110		110			110	
4:00-6:00 PM		110		110			110	
Green Interval (sec.)								
7:00-9:00 AM		60		60			40	
11:00 AM -1:00 PM		60		60			40	
4:00-6:00 PM		60		60			40	
Yellow Interval (sec.)		4.0		4.0			4	
All-Red Interval (sec.)		1.0		1.0			1.0	

Figure 92. Kimberly Rd. & Brady St. (eastbound).

Figure 93. Kimberly Rd. & Brady St. (westbound).

Figure 94. Kimberly Rd. & Brady St. (northbound).

Figure 95. Kimberly Rd. & Brady St. aerial view.

<u>West 35th Street & North Harrison Street</u>

Located south of the camera-enforced intersection of Welcome Way and Kimberly Road is the intersection of 35th Street and Harrison Street. Harrison is a one-way southbound street that carries the combined volume of Welcome Way and Harrison Street from where the two roads meet north of this intersection. Located on the both the southeast and southwest of the intersection is a city park. On the northwest side of the intersection is a fire station and on the northeast side is a busy bank that has a driveway less than 30 feet away from the intersection. 35th Street is a high volume arterial that serves many nearby residential areas and terminates at Division Street a couple of miles west of this intersection.

TABLE 53 Roadway, Traffic, and Signal Timing Characteristics for 35th Street and N. Harrison Street

Intersection	35th Street and North Harrison Street (Davenport, Iowa)
RLR Camera Approach	Southbound Harrison Street
N-S Street:	Harrison Street
E-W Street:	35th Street
Peak Periods	7:00 - 9:00 AM, 11:00 AM - 1:00 PM, 4:00 - 6:00 PM

	SB		
	L	**T**	**R**
Lanes	shrd	2,3	shrd
Posted Speed (mph)	35		
Peak Hour Volumes			
7:00-9:00 AM	99	2122	201
11:00 AM -1:00 PM	155	2437	239
4:00-6:00 PM	238	2896	352
Cycle Length (sec.)			
7:00-9:00 AM	110		
11:00 AM - 1:00 PM	110		
4:00-6:00 PM	110		
Green Interval (sec.)			
7:00-9:00 AM	57		
11:00 AM - 1:00 PM	57		
4:00-6:00 PM	57		
Yellow Interval (sec.)	4.0		
All-Red Interval (sec.)	1.0		

*Coordinated with Welcome Way Progression

Aerial View of 35th Street & North Harrison St.

Figure 96. 35th St. & Harrison St. (southbound).

Figure 97. 35th St. & Harrison St. (northbound).

Welcome Way & Kimberly Road

Located less than a half-mile west of Brady Street and Kimberly Road and less than a mile north of 35th Street and Harrison Street, Welcome Way and Kimberly Road is another busy intersection with Welcome Way being a one-way street leading in from Interstate 80. This intersection handles heavy volumes of traffic, particularly turning traffic with dual left and right turning lanes. On the northwest side of the intersection is a multiple-story bank and on the northeast side of the intersection is the back of Toys ‘R’ Us. On the southwest side of the intersection is a Lexus car dealership with multiple access points on both Kimberly Road and Welcome Way.

TABLE 54 Roadway, Traffic, and Signal Timing Characteristics for Welcome Way and Kimberly Road

Intersection	Welcome Way and Kimberly Road (Davenport, Iowa)
RLR Camera Approach	Southbound Welcome Way
N-S Street:	Welcome Way
E-W Street:	Kimberly Road
Peak Periods	7:00 - 9:00 AM, 11:00 AM - 1:00 PM, 4:00 - 6:00 PM

	SB		
	L	T	R
Lanes	1	2,3,4	5,6
Posted Speed (mph)	35		
Peak Hour Volumes			
7:00-9:00 AM	351	1316	209
11:00 AM -1:00 PM	638	1358	394
4:00-6:00 PM	645	1571	402
Cycle Length (sec.)			
7:00-9:00 AM	110		
11:00 AM - 1:00 PM	110		
4:00-6:00 PM	110		
Green Interval (sec.)			
7:00-9:00 AM	60		
11:00 AM - 1:00 PM	60		
4:00-6:00 PM	60		
Yellow Interval (sec.)	4.0		
All-Red Interval (sec.)	1.0		

*Coordinated with Welcome Way Progression

Aerial View of Welcome Way & Kimberly Road

Figure 98. Welcome and Kimberly Road (sb east).

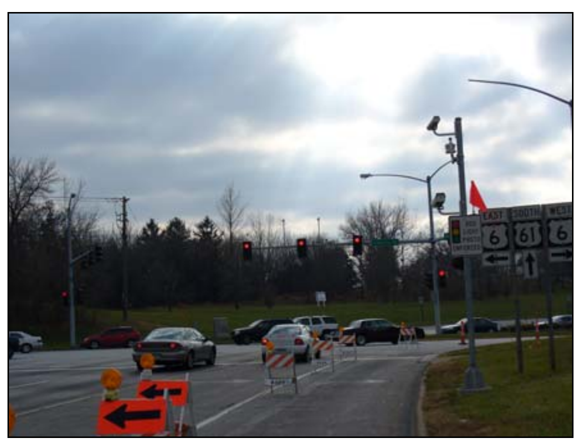


Figure 99. Welcome and Kimberly Road (sb west).

Lincoln Avenue & Locust Street

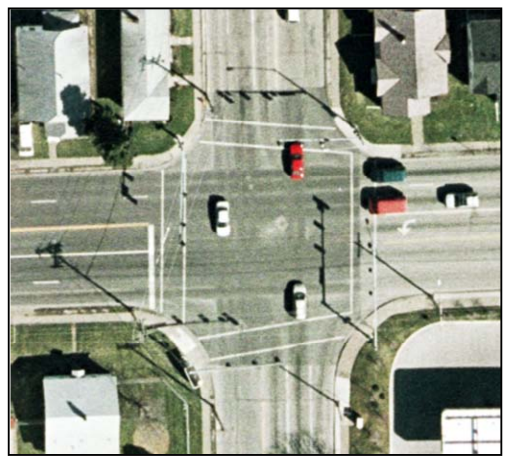
Located west of the other three camera enforced intersections is the intersection of Lincoln Avenue and Locust Street. This heavy volume intersection has a Hy-Vee grocery store on its southeast side with multiple access points onto Locust Street. Private residences surround both the north and southwest side of the intersection. The intersection at Lincoln Avenue and Locust Street experiences significant pedestrian traffic in all four directions during peak hours.

TABLE 55 Roadway, Traffic, and Signal Characteristics for Lincoln Avenue and Locust Street

Intersection	Lincoln Avenue & Locust Street (Davenport, Iowa)
RLR Camera Approach	Eastbound and Westbound Locust Street
N-S Street:	Lincoln Avenue
E-W Street:	Locust Street
Peak Periods	7:00 - 9:00 AM, 11:00 AM - 1:00 PM, 4:00 - 6:00 PM

	EB			WB		
	L	T	R	L	T	R
Lanes	1	2,3	shrd.	1	2,3	shrd.
Posted Speed (mph)	35			35		
Peak Hour Volumes						
7:00-9:00 AM	1909			1954		
11:00 AM - 1:00 PM	1723			1832		
4:00-6:00 PM	2123			2297		
Cycle Length (sec.)						
7:00-9:00 AM	100-110			100-110		
11:00 AM - 1:00 PM	100-110			100-110		
4:00-6:00 PM	100-110			100-110		
Green Interval (sec.)						
7:00-9:00 AM	10.0-35.0			10.0-35.0		
11:00 AM - 1:00 PM	10.0-35.0			10.0-35.0		
4:00-6:00 PM	10.0-35.0			10.0-35.0		
Yellow Interval (sec.)	4.0			4.0		
All-Red Interval (sec.)	1.0			1.0		

*Acutated



Aerial View of Lincoln Ave. & Locust St.

Figure 100. Lincoln Ave. & Locust St. (eastbound).

Figure 101. Lincoln Ave. & Locust St. (westbound).

Kimberly Road & Elmore Avenue

Located on the east side of Davenport the intersection of Kimberly Road and Elmore Avenue is the first intersection west of Interstate 74 and the City of Bettendorf. Private residences can be found on the west side of the intersection. Commercial developments, including banks and shopping centers, can be found on the east side of the intersection. There is pedestrian traffic on the single crosswalk due to complicated signal timing that makes crossing the intersection a challenge. The traffic engineering department has stated that this is a heavy volume intersection and congestion happens during both the morning and afternoon peak hours. Multiple signal timing updates have happened at this intersection in the past two years helping improve traffic flow.

TABLE 56 Roadway, Traffic, and Signal Timing Characteristics for Kimberly Road and Locust Street

Intersection	Kimberly Road & Elmore Avenue (Davenport, Iowa)
RLR Camera Approach	Eastbound and Westbound Kimberly Road
N-S Street:	Elmore Avnue
E-W Street:	Kimberly Road
Peak Periods	7:00 - 9:00 AM, 11:00 AM - 1:00 PM, 4:00 - 6:00 PM

	EB			WB		
	L	T	R	L	T	R
Lanes	1,2	2,3	4	1	2,3	4
Posted Speed (mph)	45			45		
Peak Hour Volumes						
7:00-9:00 AM	257	1323	190	196	1770	410
11:00 AM - 1:00 PM	724	1486	360	281	1691	741
4:00-6:00 PM	629	2038	398	383	2302	623
Cycle Length (sec.)						
7:00-9:00 AM	100-110			100-110		
11:00 AM - 1:00 PM	100-110			100-110		
4:00-6:00 PM	100-110			100-110		
Green Interval (sec.)						
7:00-9:00 AM	15-45 max			15-45 max		
11:00 AM - 1:00 PM	15-45 max			15-45 max		
4:00-6:00 PM	15-45 max			15-45 max		
Yellow Interval (sec.)	4.5			4.5		
All-Red Interval (sec.)	1			1		

Aerial View of Kimberly Road & Elmore Ave.

Figure 102. Kimberly & Elmore Ave (westbound).

Figure 103. Kimberly & Elmore Ave. (eastbound).

5.3 VIOLATION STUDY

Data were collected from the Davenport Police Department for the total number of issued citations during the enforcement period that both Transol and Nestor held a contract with the city and the results are shown in TABLE 57. The numbers from 2004 can be misleading because intersections came online at various times during this year. These numbers were collected from the City of Davenport Police Department citation statements.

TABLE 57 RLR Citations per Year as a Percent of the Total Citywide Issued Citations

Citations	2004	2005	2006
Total RLR Issued Citations	585	3,442	6,610
Total Citywide Citations	15,298	22,508	48,734
Percent of Total Citations	**3.8%**	**15.3%**	**13.6%**

* All possible municipal citations

Figure 104 illustrates the number of mailed citations by type of automated enforcement that is used in Davenport. All three systems were operating after Nestor took over the RLR camera system in January 2006; monthly data were collect by both the Police Department and Nestor. Data prior to January 2006 could not be obtained from either the City of Davenport or Nestor because Transol disposed of them once it went out of business.

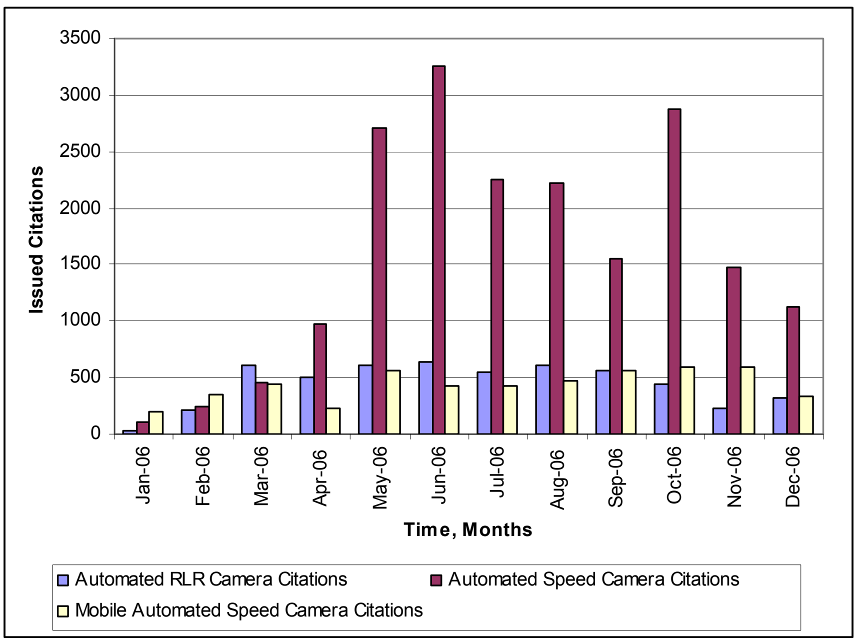


Figure 104. Total monthly mailed citations based on type of automated enforcement.

As shown in Figure 104, the largest number of citations was issued by the fixed speed enforcement camera system, collecting over 3,000 citations in the month of June 2006 alone. The Davenport Traffic Engineering Department explains that some of the differs in total monthly violations occurred because of improved progression along Kimberly Way, as well as other signal timing improvements to other intersections around the Kimberly Way / Welcome Way corridors.

For this study, limited citation data were obtained for each intersection and are presented in Figure 105. As illustrated, the through movement at each enforced intersection had the highest count of possible and issued citations compared to left and right turning movements. The westbound approach at Kimberly Road and Brady Street and southbound approach at Welcome Way and Kimberly Road also reported high right turn RLR. Adding the total mailed citations for each of the nine enforced intersections, southbound approach at Welcome Way and Kimberly Road had the highest number of mailed citations which is currently 1,192. The intersection with the lowest number of total mailed citations is eastbound approach at Lincoln Avenue and Locust Street with 193 citations currently.

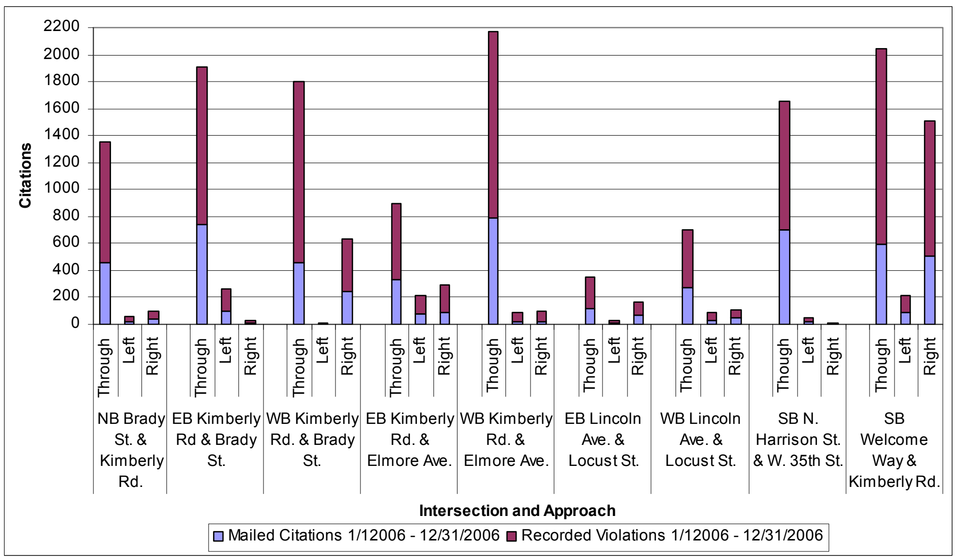


Figure 105. Recorded violations versus mailed citations at all RLR enforced intersections and approaches.

Also illustrated in Figure 105 are the differences between violations and citations. These differences are the number of rejected violations either by Nestor or the police department. To have a RLR violation be rejected by Nestor or the Davenport Police Department, there are three categories of rejection variable: discretionary factors, controllable factors, or uncontrollable factors. Discretionary factors include items that the police department will generally dismiss, variables such as construction, funeral processions, grace period, an officer directing traffic, a leased or rental vehicle, or an out of state vehicle that cannot be identified. Controllable factors are typically filtered by Nestor after the video has been transmitted to the company in which required elements, which the police would need to fully consider the offense RLR, are missing. Uncontrollable factors include such variables that neither Nestor or the police can control such as plate obstruction, sun glare, signal obstruction, speed change, no DMV record for the vehicle, or a sudden lane change. The average violation rejection rate was calculated to be 53.6% and the intersection with the highest violation rejection rate is southbound Harrison and 35th Street with a 69.9% violation rejection rate for the entire enforcement period. Westbound Kimberly Road and Elmore Avenue had the lowest average violation rejection rate of 36.9%.

5.4 CRASH STUDY METHODOLOGY AND RESULTS

The analysis methodology and results of the crash study performed for Davenport can be found in Chapter 6.

CHAPTER 6: RLR CRASH STUDY METHODOLOGY AND ANALYSIS FOR DAVENPORT AND COUNCIL BLUFFS, IOWA

Presented in Chapter 6 are the methodologies, analysis, and results for the RLR programs in Council Bluffs and Davenport using the Iowa DOT's crash database. The number of crashes and crash rates per intersection, per quarter for both cities can be found in Appendix A and B, respectively.

6.1 PREVIOUS STUDIES

The effectiveness of RLR programs are usually evaluated by either comparing the reduction in total crashes from the before to after period or selecting some subset of crashes that appear to be RLR related. Use of total crashes is the most easily obtained and easily explained to lay persons. However, some studies have suggested that while RLR cameras reduce broad-angle crashes, rear-end crashes may increase *(51)*. Consequently, the net result may be little or no change in the total number of crashes. Other studies have attempted to identify RLR crashes. Studies have evaluated right angle crashes, angle crashes, injury right angle, rear-end crashes, and injury rear-end crashes *(72, 51, 51i)*. However, as indicated by Bonneson and Zimmerman in a study conducted in 2006, it is difficult to identify actual RLR crashes since RLR is not indicated on the crash form of most states. Even when crash form attributes are available that indicate some type of disregard for traffic signal, officers may not take the time to determine whether the crash was RLR related. For instance, an officer reporting an angle-oncoming left turn crash at a signalized intersection may just assume that the left turning vehicle failed to select an adequate gap rather than attempting to determine if one of the drivers ran the red light.

In the same study, Bonneson and Zimmerman listed the following common attributes to identify red light running crashes:

- Intersection relationship: "at" the intersection;
- Crash type: right angle; and
- First contributing factor: "disregard of stop and go signal"

They evaluated these attributes to identify RLR related crashes at 70 signalized intersections in three Texas cities for a 3-year period. Using these criteria, they found 274 crashes with all three attributes. After reviewing officer reports for 3,338 crashes at those intersections, they found that 232 red light related crashes were missed while only four of the 274 were determined to be "not red light running related." In many cases, "left-turn opposing" crashes resulted from failure to yield right of way during a permissive indication and were not typically considered to be red light running related. However, they found that 75 "left-turn opposing" crashes were in fact RLR related. Their conclusions were that RLR crashes are not always coded as right-angle crashes and police officers may designate disregard of traffic signal in different manners.

6.2 CRASH DATA EXTRACTION

Based on the results of other studies, it was determined that the most effective approach was to attempt to identify RLR crashes for analysis. RLR rear-end crashes and other RLR crashes (which included any crash indicated as RLR except for rear-end crashes), hereafter referred to as “RLR other crashes,” were extracted and analyzed separately. For each community, several intersections with similar crash history and volumes which were not likely to have been influenced by the locations with cameras were selected as control sites.

Extraction of RLR crashes for the Davenport and Council Bluffs intersections with cameras and control intersections without cameras was completed using the following methodology. The Iowa DOT crash database, which includes spatial referencing, was used to select crashes which occurred within 25 meters of the intersection. This is the method that the Iowa DOT uses to identify an intersection crash. Crashes were extracted from 2001 to 2006. Next, crashes in which the officer had indicated “Ran Traffic Signal” as the major cause were selected as RLR crashes. This included all crash types and accounted for a total of 247 crashes (237 RLR other and 10 RLR rear end crashes). Since officers may not always use the designation “Ran Traffic Signal” to indicate the major cause, or may not take the time to determine whether the crash was due to one vehicle running a red light, the crash report for each crash which was not indicated as having “Ran Traffic Signal” as the major cause was reviewed. Crashes where an officer or witness indicated that at least one vehicle involved had ran the red light were coded as RLR. Crashes where the crash diagram geometry and/or narrative indicated that a collision had occurred between two vehicles that were initially coming from perpendicular approaches were also included as RLR. For instance, a right angle crash between a vehicle which was going straight westbound and a vehicle going straight west bound would have entailed one of the vehicles running the red light.

Rear-end crashes were also evaluated to determine whether they were RLR related. There is some speculation that installation of red light running cameras may actually increase rear end crashes. In some studies, total rear end crashes are included in the analyses. However, not all rear end crashes at intersections are related to a leading vehicle coming to an abrupt stop for a red signal and being rear ended by a following vehicle. Rear end crashes which were coded with a major cause of “Ran Traffic Signal” were included. The crash record for the remaining rear end crashes was evaluated. Rear-end crashes were discarded from this group when an officer or witness indicated that the rear-end crash had not been the result of a red light. For instance, in a number of cases, it was indicated that the light had just turned green and the following vehicle started up faster than the lead vehicle. In several other cases, a read end occurred during a lane change which was not related to a red light and in several others, a rear end crash occurred when vehicles slowed due to downstream congestion or a vehicle turning into a driveway.

6.3 DESCRIPTIVE STATISTICS METHODOLOGY

Descriptive statistics are used to describe the basic statistical features of a set of data in a study, although not as power as a statistical model. Descriptive statistics for this study were determined as a way to express the effectiveness of the RLR system at camera enforced intersections compared to specified control intersections in Council Bluffs and Davenport. Using the crash data extrapolated from the Iowa DOT's database and verification of each RLR crash, the data were sorted into four subgroups as described in Section 6.2.

- Total Crashes
- RLR Rear-End Crashes
- RLR Other Crashes
- Not a RLR Crash

A means of comparison between the four subgroups was made by taking into consideration the change in crash rates before and after the RLR camera installation for both the camera enforced intersections and the control intersections. To perform this task, crash rates for each subgroup per intersection were determined using equation 6-1 found in the ITE Traffic Engineering Handbook 5th Edition.

$$Crash\ Rate\ per\ MEV = (a \times 1,000,000) \div (b \times 365) \qquad \textbf{[6-1]}$$

Where:

a = number of accidents in one year
b = 24-hr total intersection entering volume

Equation 6-1 was adjusted to reflect crashes per quarter since crash data were analyzed by quarter. Equation 6-2 were used to determine the DEV per quarter for both the before and after periods minus the quarter the RLR camera was installed.

$$DEV\ per\ Quarter\ (before\ or\ After) = \frac{\sum \begin{matrix}[(Yearly_{Before\ or\ After\ installation}\ DEV \times 365\ Days)] \\ +[(DEV_{Installation\ Year} \times 365\ Days)/\#\ Quarters_{Before\ or\ After\ Quarter\ of\ Installation}]\end{matrix}}{\#\ of\ Quarters_{Before\ or\ After\ Installation}}$$

[6-2]

Once the quarterly and yearly DEV were found for the before and after periods, the total number before and after crashes for each subgroup were totaled for each year and both numbers were entered into equation 6-1 to find before and after crash rate for each intersection. The following descriptive statistics methodology explains the procedure used for both cites.

6.3.1 The Number of Crashes

A total of 1,291 crash reports for both RLR other and RLR rear end crashes were evaluated for Davenport and Council Bluffs for both treatment and control intersections. This process yielded 10 additional RLR other crashes for a total of 258 and an additional 80 red light related rear end crashes for a total of 90 crashes.

Total number of crashes, total number of RLR other crashes, and total number of RLR rear end crashes were separated by quarter for each intersection. Quarters were used rather than years so that the quarter when the camera was installed could be excluded from the analysis, rather than excluding an entire year. It should be noted that it was extremely difficult to determine whether left turn oncoming and right turn on red crashes were a result of RLR if they were not indicated with a major cause of "Ran Red Light." Review of the crash reports indicates that in most cases it did not appear that the officer had attempted to distinguish whether the vehicle involved in a right turn on red accident had slowed or stopped and simply failed to see oncoming traffic or whether they did not slow and were involved in the crash because they ran the red light. The same applied to left turn oncoming. In most cases the officer indicated that one or more drivers had failed to yield right of way but did not appear to attempt to determine whether the left turn driver had a permissive signal and simply failed to select an appropriate gap or whether the driver had a red indication and ran the signal.

6.3.2 Determining Intersection Daily Entering Vehicles

To determine the exposure rate for second half of the crash rate equation, a daily entering vehicle count was needed. With the aid of ArcView and the Iowa DOT's state road, intersection, and city databases, a GIS project for Council Bluffs and Davenport was created. The steps to determine the DEV for each intersection per year can be found in Appendix D. Once the DEV and the number of crashes were found for each of the camera enforced and control intersections, the data were inputted into equation 6-2 and eventually into equation 6-1 for each intersection per quarter for a before and after time period; and the results for each intersection and all-crash and all-DEV combined crashes rates are presented in section 6.4.

6.4 COUNCIL BLUFFS DESCRIPTIVE STATISTICS RESULTS

Shown below in TABLE 58 are the before and after crash rates (MEV) associated with each intersection that was studied in Council Bluffs. A common misconception made is that if the number of crashes are decreasing, then the RLR camera system is effective without taking into consideration the before and after time periods and or control intersections. The crash rates are expressed as a combined before and after crash rate based on the total number of evaluated quarters with the associated DEV count for each year and quarter as reported by the Iowa DOT between 2001 through 2006. As illustrated in TABLE 58, the camera enforced intersections showed a decrease in crash rates for each of the four subgroups leading to the conclusion that there is a slight decreasing trend in crashes at these intersections based on the calculated crash rates.

Additionally, the camera enforced intersections saw an average crash rate reduction of 20.78%. The intersection of Broadway and 21st Street experienced a slight increase in "Other RLR Crashes". An important item to note is some of the crash subgroups showed very high reductions or increases (e.g. 100%, 149.24%, etc.). These large numbers are due to the fact that not many crashes occurred at the intersection in general; thus when a slight change occurs to the resulting percent change is quite high.

TABLE 58 Council Bluffs Change in Crash Rate per Studied Intersection

Intersection	Total Recorded Crashes			Rear-End RLR Crash			Other RLR Crash			Not a RLR Crash		
	Before	After	% Change	Before	After	% Change	Before	After	% Change	Before	After	% Change
RLR Camera Enforced Intersections												
Broadway & 16th Street	1.09	0.86	**-21.38%**	0.19	0.17	**-8.80%**	0.21	0.11	**-44.73%**	0.70	0.54	**-21.94%**
Willow Avenue & 7th Street	1.49	0.49	**-67.31%**	0.21	0.12	**-42.79%**	0.53	0.00	**-100.00%**	0.75	0.37	**-50.96%**
Broadway & 35th Street	1.10	0.90	**-17.77%**	0.21	0.34	**61.89%**	0.31	0.11	**-64.02%**	0.57	0.45	**-21.51%**
Broadway & 21st Street	0.68	0.60	**-11.68%**	0.25	0.23	**-10.58%**	0.18	0.19	**6.46%**	0.25	0.19	**-25.48%**
Kanesville Boulevard & 8th Street	1.07	0.90	**-15.61%**	0.23	0.24	**5.12%**	0.11	0.02	**-80.89%**	0.72	0.64	**-11.82%**
Control Intersection												
24th Street & 27th Street	1.84	2.27	**23.91%**	0.10	0.08	**-25.23%**	0.16	0.39	**149.24%**	1.57	1.80	**14.65%**
35th Street & Nebraska Avenue	0.95	0.76	**-19.23%**	0.15	0.15	**2.31%**	0.10	0.15	**53.46%**	0.70	0.46	**-34.23%**
Broadway & Kanesville Blvd.	0.63	0.43	**-30.95%**	0.13	0.00	**-100.00%**	0.18	0.24	**34.51%**	0.33	0.20	**-39.64%**
Broadway & 1st Street	1.30	1.14	**-12.46%**	0.00	0.00	**0.00%**	0.20	0.12	**-41.15%**	0.48	0.67	**40.41%**

TABLE 58 also lists the change in crash rates (MEV) for the control intersections selected. The control intersection also saw a decrease in crash rates, but there are no evident trends that show a reduction in RLR type crashes at these intersections. Using the results shown in TABLE 58, all of the intersection crash data were combined to find the system crash rates for camera enforced and control intersections; results can be found in TABLE 59.

TABLE 59 Council Bluffs Combined Change in Crash Rates at Camera and Control Intersections

Descriptive Statistics	Total Recorded Crashes	Rear-End RLR Crash	Other RLR Crash	Not RLR Associated Crash
RLR Camera Enforced Intersections				
Before Installation Total Entering Vehicles	201,459,013	201,459,013	201,459,013	201,459,013
Before Installation Avg. Entering Vehicles per Quarter	14,389,929	14,389,929	14,389,929	14,389,929
Before Installation Total Crashes	206	44	42	120
Before Installation Average Crashes per Quarter	15	3	3	9
Before Installation Crash Rate (MEV)	1.02	0.22	0.21	0.60
After Installation Total Entering Vehicles	141,965,381	141,965,381	141,965,381	141,965,381
After Installation Avg. Entering Vehicles per Quarter	15,773,931	15,773,931	15,773,931	15,773,931
After Installation Total Crashes	115	33	13	68
After Installation Average Crashes per Quarter	13	4	1	8
After Installation Crash Rate (MEV)	0.81	0.23	0.09	0.48
PERCENT CHANGE IN CRASH RATE	**-20.78%**	**6.43%**	**-56.08%**	**-19.59%**
Non-Camera Enforced Intersections				
Before Installation Total Entering Vehicles	99,903,238	99,903,238	99,903,238	99,903,238
Before Installation Avg. Entering Vehicles per Quarter	7,135,946	7,135,946	7,135,946	7,135,946
Before Installation Total Crashes	106	10	20	76
Before Installation Average Crashes per Quarter	7.57	0.71	1.43	5.43
Before Installation Crash Rate (MEV)	1.06	0.10	0.20	0.76
After Installation Total Entering Vehicles	68,898,769	68,898,769	68,898,769	68,898,769
After Installation Avg. Entering Vehicles per Quarter	7,655,419	7,655,419	7,655,419	7,655,419
After Installation Total Crashes	70	3	16	51
After Installation Average Crashes per Quarter	7.78	0.33	1.78	5.67
After Installation Crash Rate (MEV)	1.02	0.04	0.23	0.74
PERCENT CHANGE IN CRASH RATE	**-4.25%**	**-56.50%**	**16.00%**	**-2.70%**

As shown in TABLE 59, the descriptive statistics performed on a system wide levels using the studied intersections estimated RLR cameras have a much greater impact on reducing crash rates for 3 of the 4 crash type subgroups, including Total Recorded Crashes, Other RLR Crashes, and Non RLR Associated Crashes. Of particular interest is the "Other RLR Crash" subgroup which experienced a 56.08% decrease in crash rates at camera enforced intersections. Similar to other RLR effectiveness studies performed, a slight increase of 6.46% in the "Rear-End RLR Crash" subgroup was found at camera enforced intersections. Although the average percent change in total crashes at the control intersection presented in TABLE 59 show reduction of 4.25%, this value may not be significant based on the available data. To test the significance of these results, it was determined by the researchers that a statistical model was needed. It was determined that a Bayesian model could possible show significance using the before and after crash data extrapolated from the Iowa DOT's database.

6.5 COUNCIL BLUFFS HIERARCHICAL BAYESIAN MODEL

Similar to the statistical model created to evaluate the violations found in Clive in Section 3.9.2, the following explanatory variables were available for consideration.

- *Camera:* Presence or absence of camera at each approach
- *Posted Speed Limit:* 30, 35, 40, 45, 50 or 55 mph (was not considered in the model)
- *Movement:* Right, left, or through movements (was not considered in the model)
- *Time:* 7:00- 9:00 AM, 11:00 AM – 1:00 PM, and 4:00 – 6:00 PM (was not considered in the model)
- *Before Crash Data:* The number of crashes recorded before camera installation
- *After Crash Data:* The number of crashes recorded after camera installation
- *Volume:* Traffic volume per movement per peak hour

For this statistical model, individual approach sites could not be created similar to the statistical model used in the Clive violation study because crash data were considered within a certain radius of the intersection, thus each camera enforced or control intersection was treated as a single "site". Using the explanatory variables "before crash data" and "after crash data" a hierarchical Bayesian model was created to evaluate the statistical significance in change between the before and after periods accounting for the possibility of regression to the mean bias'. Similar to the Poisson regression model used in the Clive violation study, before and after crash observations were considered discrete variables (0,1,2,3,…,n), thus a response variable was defined using the following equation.

$$y_{ij} = \text{number of crashes in site i, time j.}$$

Where:

The number of before or after crashes at a given site is going to follow a Poisson distribution with the parameter μ_{ij} , where this parameter represents both the mean and the variance of the distribution at each site.

Since the AADT differs at the camera enforced and control intersections, it was anticipated that the mean at every approach would be different by a factor of the AADT. The mean of the distribution was adjusted by taking the AADT multiplied by a certain parameter λ_{ij} , where log-lambda represented the linear combination of the explanatory variables (camera presence, traffic volume, crashes, etc.). Therefore, a way to express the crash average at each site and time as a linear function was found. The first level of the Bayesian hierarchy was written in the statistical way as follows.

$$y_{ij} \sim Poisson(\mu)$$
$$\mu_{ij} = \lambda_{ij} * aadt \big/ 1000$$
$$\log(\lambda_{ij}) = \beta_1 + \beta_2 * X_{1ij} + \beta_3 * t_{ij} + \beta_4 * X_{1ij} * t_{ij} + *\beta_5 * X_{1ij} * (t_{ij} - t_{0i}) * I(t_{ij} > t_{0i}) +$$
$$\beta_6 * X_{2ij} + \beta_7 * X_{3ij} + \beta_8 * X_{4ij} + site_i$$

[6-3]

Where:

$$X_{1ij} = \begin{cases} 1 & \text{if there was a treatment in that site at any time} \\ 0 & \text{o.w.} \end{cases}$$

t_{0i} = first quarter where camera was used

$$I(t_{ij} > t_{0i}) = \begin{cases} 1 & \text{if condition is met } (t_{ij} > t_{0i}) \\ 0 & \text{o.w.} \end{cases}$$

$X_{2ij}, X_{3ij}, X_{3ij}$ are functions to express seasonality

$$X_{2ij} = \cos(2 * \pi/4 * s_{ij}), \qquad s_{ij} = 1,2,3,4$$
$$X_{3ij} = \cos(2 * 2\pi/4 * s_{ij}), \qquad s_{ij} = 1,2,3,4$$
$$X_{4ij} = \sin(2 * \pi/4 * s_{ij}), \qquad s_{ij} = 1,2,3,4$$

Finally, the covariate "site" was considered a random factor that took into account the correlation that was going to exist among the observations made at the same site.

Each site was defined as $N(0, \sigma^2_{site})$ **[6-4]**

Where:

$$\sigma^2_{site} \sim IGamma\ (100, 100)$$

The second level of the Bayesian hierarchy was specified by giving the distribution of the hyper parameters β_k where k = 1,…,8. Thus,

$$\beta_k \sim N(0,1000) \qquad k = 1,...,8$$ **[6-5]**

6.5.1 Model Results

Once the sites were defined and the statistical model was developed, the data from each crash subgroup were analyzed. The results of the analysis are shown in TABLE 60 through TABLE 71. The mean and its 95% credible sets (2.5% and 97.5% quantiles) are given for each intersection that was studied. A 95% credible set indicates that there is a 95% probability that the mean found is between the lower and upper limits of the given set. Illustrated in TABLE 60 are the results of the Bayesian model for the crash subgroup "total crashes" as defined in Section 6.1.

TABLE 60 Total Crash Expected Frequency per Camera Enforced Site During "Before" and "After" Periods

Site	Before			After		
	Mean	2.5% quan	97.5% quan	Mean	2.5% quan	97.5% quan
Broadway & 16th St.	4.291	3.129	5.665	3.088	1.832	4.779
Willow & 7th St.	0.739	0.409	1.208	0.707	0.355	1.201
Broadway & 53th St.	3.146	2.217	4.318	2.391	1.444	3.793
Broadway & 21st St.	2.221	1.517	3.062	1.605	0.907	2.565
Kanesville & 8th St.	4.897	2.872	8.126	4.023	2.430	6.182

Shown in TABLE 60 are the adjusted expected crash frequencies for the crash subgroup "Total Crashes" per 1,000 entering vehicles. Similar to the Descriptive Statistics, Kanesville and 8th Street had the highest expected total crash frequency while Willow Avenue and 7th Street had the lowest. As shown, the expect crash frequency and credible sets have decreased slightly from number of crashes per 1,000 entering vehicles between the two periods suggesting that crashes at camera enforced intersections have decreased. Shown below in TABLE 61 are the expected crash frequencies per control site.

TABLE 61 Expected Total Crash Frequency per Control Site

Site	Mean	2.5% quan	97.5% quan
24th St. & 27th St.	2.568	1.691	3.792
35th St. & Nebraska Ave.	1.315	0.800	2.009
Broadway & Kanesville	1.767	1.070	2.609
Broadway & 1st St.	1.992	1.338	2.823

The expected crash frequency and quantiles were inputted into the statistical model for the years included in this study (2001-2006). TABLE 62 presents the results for expected crash frequency for the before and after study.

TABLE 62 Posterior Mean and 95% Credible Set of the Expected Total Crash Frequency, Averaged Over Control Sites, Before Installation, and After Installation

Periods	Mean	2.5% quan	97.5% quan
Before	3.058805	2.667549	3.428702
After	2.362816	2.022583	2.847496
Control	1.910439	1.670678	2.18088

As illustrated in TABLE 62, the results for the before and after periods, the camera enforced intersections saw a 0.69 in 1,000 entering vehicle improvement in crashes. However, as shown by the control intersections, the City of Council Bluffs selected the right intersections to enforce with RLR cameras because the posterior mean is lower than the before and after posterior mean. Tables for the Bayesian Model can be found in Appendix E. Shown in TABLE 63 through TABLE 66 are the statistical model results for rear-end crashes.

Illustrated in TABLE 63 are the expected rear-end crash frequencies for the before and after study periods. As shown, Broadway and 16th Street had the highest number of expected crashes per 1,000 entering vehicles while Willow Avenue and 7th Street had the lowest. Similar to the total crash study, the 2.5% and 97.% quantiles decreased between periods. Illustrated in TABLE 64 are the results of the control intersections.

TABLE 63 Rear-End Crash Expected Frequency per Camera Enforced Site During "Before" and "After" Periods

Site	Before			After		
	Mean	2.5% quan	97.5% quan	Mean	2.5% quan	97.5% quan
Broadway & 16th St.	0.814	0.369	1.480	0.312	0.053	0.787
Willow & 7th St.	0.181	0.073	0.420	0.093	0.014	0.284
Broadway & 53th St.	0.693	0.326	1.245	0.283	0.048	0.723
Broadway & 21st St.	0.586	0.254	1.118	0.227	0.036	0.591
Kanesville & 8th St.	0.642	0.233	1.356	0.284	0.046	0.722

TABLE 64 Expected Rear-End Crash Frequency per Control Site

Site	Mean	2.5% quan	97.5% quan
24th St. & 27th St.	0.317	0.132	0.660
35th St. & Nebraska Ave.	0.243	0.089	0.481
Broadway & Kanesville	0.569	0.242	1.115
Broadway & 1st St.	0.393	0.165	0.771

As shown in TABLE 64, Broadway and Kanesville Boulevard had the highest expected rear-end crash frequency while 35th Street and Nebraska had the lowest. TABLE 65 presents the posterior means for the before, after, and control studies.

TABLE 65 Posterior Mean and 95% Credible Set of the Expected Rear-End Crash Frequency, Averaged Over Control Sites, Before Installation, and After Installation

Periods	Mean	2.5% quan	97.5% quan
Before	0.583439	0.4357736	0.7577809
After	0.23982	0.142261	0.3633249
Control	0.980738	0.263568	0.5315207

As illustrated in TABLE 65 between the before and after periods, the RLR camera enforced intersections saw an average decrease in rear-end crashes by 0.343 crashes per 1,000 entering vehicles. Also comparing the RLR camera enforced intersection to control intersections, if RLR cameras were not present the expected number of rear-end crashes would increase by 0.39 crashes per 1,000 entering vehicles. TABLE 66 through TABLE 69 present the results for other RLR type crashes.

TABLE 66 Other RLR Type Expected Crash Frequency per Camera Enforced Site During "Before" and "After" Periods

Site	Before			After		
	Mean	2.5% quan	97.5% quan	Mean	2.5% quan	97.5% quan
Broadway & 16th St.	0.807	0.353	1.448	0.758	0.329	1.450
Willow & 7th St.	0.155	0.058	0.335	0.191	0.072	0.375
Broadway & 53th St.	0.707	0.325	1.280	0.704	0.300	1.365
Broadway & 21st St.	0.746	0.318	1.369	0.704	0.302	1.372
Kanesville & 8th St.	1.076	0.366	2.299	1.119	0.499	2.110

As shown in TABLE 66, the expected crash frequency for other RLR type crashes was highest at Kanesville Boulevard and 8th Street and lowest at Willow Avenue and 7th Street. However, as shown in the after period, both of these intersections saw an increase in expected crash frequencies while the other enforced intersections saw a decrease. TABLE 67 presents the expected other RLR type crash frequency for the selected control intersections.

TABLE 67 Expected Other RLR type Crash Frequency per Control Site

Site	Mean	2.5% quan	97.5% quan
24th St. & 27th St.	0.114	0.027	0.282
35th St. & Nebraska Ave.	0.142	0.034	0.369
Broadway & Kanesville	0.228	0.053	0.564
Broadway & 1st St.	0.109	0.015	0.269

As illustrated in TABLE 67, the control intersections had a much lower expected crash frequency than the camera enforced intersections once the traffic volumes were adjusted. TABLE 68 presents the posterior means of the before, after, and control intersections.

TABLE 68 Posterior Mean and 95% Credible Set of the Expected Other RLR Crash Frequency, Averaged Over Control Sites, Before Installation, and After Installation

Periods	Mean	2.5% quan	97.5% quan
Before	0.698087	0.5232724	0.9061383
After	0.695236	0.4926080	0.9053004
Control	0.148285	0.0862236	0.22853798

As shown in TABLE 68, once the traffic volumes were adjusted, the RLR camera intersections only showed a slight improvement while the control intersections had a much lower posterior mean. Unfortunately, these figures show the RLR cameras had little affect on other RLR type crashes when the before and after expected crash frequencies are compared to each other and the control intersections. TABLE 69 through TABLE 71 present the results of the statistical analysis for non-RLR type crashes.

TABLE 69 Non-RLR Type Expected Crash Frequency per Camera Enforced Site During "Before" and "After" Periods

	Before			After		
Site	Mean	2.5% quan	97.5% quan	Mean	2.5% quan	97.5% quan
Broadway & 16th St.	2.662	1.679	4.018	1.978	1.155	3.112
Willow & 7th St.	0.435	0.207	0.811	0.432	0.202	0.783
Broadway & 53th St.	1.606	0.990	2.394	1.264	0.706	1.926
Broadway & 21st St.	0.812	0.434	1.299	0.608	0.314	1.047
Kanesville & 8th St.	3.309	1.948	5.550	2.847	1.738	4.311

Illustrated in TABLE 69 are the expected crash frequencies at the camera enforced intersections for the before and after study periods. As shown, Kanesville and 8th Street had the highest expected crash frequency while Willow and 7th Street had the lowest. Also shown, all of the sites had improvement in expected crash frequencies in the after study period. Presented in TABLE 70 are the results from the selected control intersections.

TABLE 70 Expected Non-RLR Type Crash Frequency per Control Site

Site	Mean	2.5% quan	97.5% quan
24th St. & 27th St.	2.204	1.403	3.264
35th St. & Nebraska Ave.	0.880	0.517	1.395
Broadway & Kanesville	0.913	0.484	1.472
Broadway & 1st St.	1.520	0.946	2.295

TABLE 70 illustrates the expected crash frequency for the control intersections. Similar to the camera enforced intersections, the expected crash frequency values were similar. TABLE 71 presents the results of the posterior means for the before, after and control intersections.

TABLE 71 Posterior Mean and 95% Credible Set of the Expected Non-RLR Type Crash Frequency, Averaged Over Control Sites, Before Installation, and After Installation

Periods	Mean	2.5% quan	97.5% quan
Before	1.764922	1.488224	2.060102
After	1.425956	1.1316860	1.752029
Control	1.379335	1.1711190	1.592289

Illustrated in TABLE 71 are the posterior means for the before, after, and control intersections. As shown, the before and after periods showed a minimal improvement, while the control intersections showed a much lower posterior mean than the before and after results for the camera enforced intersections.

6.6 COUNCIL BLUFFS INITIAL RESULTS

A Poisson regression using a Bayesian model was created to evaluate extracted crash data from the Iowa DOT's crash database that was categorized into four crash subgroups. Using the crash data in each crash subgroup, the model evaluated crash data and provided a crash rate per 1,000 entering vehicles for before, after, and control crash data. Overall, the initial results concluded that there was not a statistically significant decrease in crashes, although the descriptive statistics showing a reduction. When the data were analyzed for the before and after periods, the resulting decrease or increase did not fall below the control intersection's mean and crash expectancy. This resulted in the researchers questioning the validity of the model based on the available sample size and the total number of before and after crashes. The descriptive statistics results were much different in that the crash rate for the intersection and combined intersections was based on fluctuating daily entering vehicles which differed from intersection to intersection, thus giving different results. The main difference between the two statistical methods used was descriptive statistical, although power are weaker values that those that come from a model. When you perform statistics using only average crashes and weighted daily entering vehicles, it can not be determined if values or correlated. Another factor that influenced the overall results for both types of statistics performed was the sample size. The sample size was limited to only one to two years of valid after data, sometimes with only one or zero crashes.

6.7 COUNCIL BLUFFS SUMMARY OF FINDINGS

Automated enforcement in Council Bluffs began August 4, 2005 at 4 intersections to help improve safety on one of the city's highest traffic volume corridors; a fifth camera was located in a residential area near a school and two churches. The city of Council Bluffs entered into a 5-year contract with the RLR camera manufacture Redflex after Chapter 9.16 of the Council Bluffs Municipal Code was passed by a 3 to 1 vote. Similar to Clive, Redflex took 8 to 12 hour video of possible candidate intersections for RLR cameras. Upon the signing of the terms of agreement in May 2005, the camera system was installed by Redflex and the city agreed on a 15 day warning period for drivers once the cameras were activated. Unlike Clive, the City of Council Bluffs payment structure is based on a tiered system where the fee collected by Redlfex is based on the daily citations issued at each approach, and the city typically receives an average of $16 per ticket. Currently, Council

Bluff's RLR program is the only operating program in Iowa, and no pending lawsuits to put the cameras on hiatus are known about at this time.

A study performed by the Center for Transportation Research and Education at Iowa State University was performed as an Iowa DOT project to evaluate the effectiveness of Iowa's three RLR programs. A crash study was performed using quarterly crashes extracted from the DOT database and categorized into crash subgroups which included: total crashes, rear-end crashes, other RLR crashes, and non-RLR crashes. Using the crash rate equation listed in the 5th Edition of the ITE Traffic Engineering Handbook, the crash rate was found using the number of crashes per crash subgroup divided by the exposure rate which was the daily entering vehicles. The DEV was found using the Iowa DOT database for each year of the crash study. To find the change in crash rates, descriptive statistics were used and a hierarchical Bayesian model was also created using field and crash data to find the expected crash frequency of each crash subgroup for both the camera enforced and control intersections. Based on the two statistical methods used, the descriptive statistics suggest an improvement in RLR type crash rates and an increase in rear-end type crash rates. The statistical model resulted in showing the difference in crash data for both the camera enforced and control intersection crashes to be statistically insignificant thus concluding that the RLR cameras are not effective in reducing RLR related crashes. It was also concluded that a small sample size may have influenced both the descriptive statistics and the statistical model results leading the researchers to believe that more data and a larger sample size is needed.

6.8 DAVENPORT DESCRIPTIVE STATISTICS RESULTS

Using the same analysis method as described Section 6.3, the results for Davenport are shown in TABLE 72. As mentioned in Section 5.2, Davenport's RLR cameras were installed in different quarters, and one camera system was moved to the intersection of Lincoln Avenue and Locust Street during the second quarter of 2006 following an effectiveness study and change of contract. This resulted in minimal after data for the intersection of Lincoln Avenue and Locust Street.

TABLE 72 Davenport Change in Crash Rates per Studied Intersection

Intersection	Total Recorded Crashes			Rear-End RLR Crash			Other RLR Crash			Not a RLR Crash		
	Before	After	% Change	Before	After	% Change	Before	After	% Change	Before	After	% Change
RLR Camera Enforced Intersections												
Kimberly Road & Welcome Way	1.42	1.34	**-5.20%**	0.27	0.32	**18.20%**	0.61	0.39	**-36.30%**	0.54	0.64	**18.20%**
Kimberly Road & Brady Street	1.21	1.93	**59.10%**	0.28	0.73	**156.80%**	0.23	0.36	**60.50%**	0.70	0.83	**19.00%**
Harrison Street & 35th Street	1.11	1.05	**-5.70%**	0.11	0.06	**-42.70%**	0.36	0.00	**-100.00%**	0.64	0.98	**54.00%**
Lincoln Avenue & Locust Street	1.51			0.16			0.49			0.86		
Kimberly Road & Elmore Avenue	0.52	2.22	**329.80%**	0.12	0.98	**753.20%**	0.17	0.46	**165.40%**	0.23	0.78	**241.30%**
Control Intersections												
Elmore Avenue & 53rd Street	2.63	2.13	**-18.70%**	1.21	1.02	**-15.00%**	0.25	0.22	**-9.70%**	1.18	0.89	**-24.20%**
Locust Street & Brady Street	0.89	2.10	**135.40%**	0.17	0.66	**297.30%**	0.23	0.59	**155.40%**	0.49	0.85	**72.20%**
Locust St. & Hickory Grove Rd.	1.21	1.16	**-4.40%**	0.31	0.34	**10.60%**	0.21	0.17	**-17.10%**	0.70	0.65	**-7.30%**
N. Division St. & Central Park Ave.	0.75	1.52	**103.00%**	0.11	0.51	**346.70%**	0.32	0.51	**59.50%**	0.32	0.51	**59.50%**
Pine Street & Kimberly Road	1.19	2.42	**103.60%**	0.15	0.40	**163.00%**	0.50	0.91	**82.10%**	0.54	1.11	**106.70%**

As shown in TABLE 72, the RLR camera system had the greatest impact on the intersection of Harrison Street and 35th Street which showed a reduction in crash rates for all four subgroups. The intersection of Kimberly Road and Welcome way also showed a decrease in before and after crash rates in the crash subgroup other RLR crash and Total recorded crashes. Two control intersections also saw a decrease in crash rates. As stated earlier in this report, it was hypothesized by Cunningham and Hummer that driver behavior would be affected by at intersections located less than 1 mile away from a camera enforced intersection. The intersection of Locust Street and Hickory Grove is located less than 1 mile away from the camera enforced intersection of Lincoln Avenue and Locust Street which could have had an effect in the reduction of RLR crashes at the control intersection. Also illustrated in TABLE 72 are numerous camera enforced and control intersections with substantial increase in crash rates. This phenomenon may be explained by the intersection having very few crashes to begin with and a small change (e.g. 1 crash to 2 crashes) yielding significant percent increases, or, alternatively, the RLR cameras are not helping the intersection and other engineering countermeasures should be explored. To confirm these conclusions, a statistical model could not be created in time for this thesis, and future research is underway to compare these results against a similar statistical model that was created for Council Bluffs.

6.9 DAVENPORT SUMMARY OF FINDINGS

The automated RLR enforcement program in Davenport began on January 21, 2004 when the city alderman signed a beta test agreement with Transol USA which later turned into a 5 year contract. The city traffic engineering office provided the Davenport Police Department and Transol with a list of intersections showing the highest number of average crashes from 2001 through 2003 that would be excellent candidates for the new system. Automated RLR enforced started August 25th, 2004 when the cameras at 4th Street and Division Street along with the intersection of 35th Street and Harrison Street went online. Over the next two months, three more intersections came online including cameras at Brady Street and Kimberly Way, Welcome Way and Kimberly Way, and Elmore Avenue and Kimberly Way.

Davenport's City Council set the civil fine of running a red light to be at $65 utilizing a sliding scale payment method to pay Transol for their services instead of renting the cameras at each approach. This payment method enabled the City of Davenport to generate over $260,000 to go towards new police programs and possibly hiring new police officers. The City of Davenport expanded its automated enforcement capabilities in 2005 with the addition automated speed enforcement cameras to captured drivers exceeding the speed limit at certain intersections and at mid-block locations around the city. The automated speed enforcement program contract was signed with two other companies which were Redflex and Nestor. On September 13, 2005 the City of Davenport signed a memorandum of understanding with Nestor to take over the RLR camera program after Transol went out of business. During this time, an effectiveness study was performed by the city and Nestor and the camera at 4th Street and Division Street was moved to Locust Street and Lincoln Street. This system was brought online in January, 2006. Currently, the automated RLR and speed enforcement programs are on Hiatus due to two separate lawsuits filed citing the city violated Chapter 321 and 364.22 (2) of the Iowa Code (2006). Currently, the City of Davenport has a pending class action lawsuit against the legality of the automated enforcement systems and the ACLU of Iowa has asked the Iowa Supreme Court to here and appeal from a 2006 case where a Scott County Magistrate upheld the legality of the system. Davenport plans to appeal all of the court rulings in front of the Iowa Supreme Court in 2008.

A study performed by the Center for Transportation Research and Education at Iowa State University was performed as and Iowa DOT project to evaluate the effectiveness of Iowa’s three RLR programs. For the City of Davenport, a crash study was preformed using quarterly crashes extracted from the DOT database and categorized into crash subgroups which included: total crashes, rear-end crashes, other RLR crashes, and non-RLR crashes. Using the crash rate equation listed in the 5th Edition of the ITE Traffic Engineering Handbook a before and after crash rates were found for 4 of the 5 camera enforced intersections and all 5 of the selected control intersections. Due to time constraints attached to this thesis, a statistical model could not be created thus descriptive statistics were performed with the given data. Due to the camera moving to Lincoln Avenue and Locust Street, an after study could not be performed.

The results of the descriptive statistics showed that half all of the intersections studied showed an decrease in crash rates and RLR type crash rates. It was concluded by the researchers that because the crash rates were so low to begin with that any change in a low crash rate to another slightly higher low crash rate will result in large percent change which could be misleading when performing an effectiveness study. Additionally, it was concluded with the amount of data that was available, the RLR camera at 35th Street and Harrison and Kimberly Road and Welcome Way were the most effective based on descriptive statistics which showed a decrease in crash rates for most of the crash subgroups. Based only of descriptive statistics, it cannot be concluded that the cameras in Davenport are effective or not at reducing crashes. It is recommended that a statistical model be created to further look into the effectiveness by adjusting some of the explanatory variables such as traffic volume, before and after crashes, and camera presence as mentioned in the methodology in Section 6.5. Officials with the City of Davenport have high hopes for automated enforcement, and they believe that the cameras in the city are saving lives, more importantly the citizens of Davenport and the Quad Cities are more aware of how important it is to stop if the traffic signal light is red.

CHAPTER 7: CONCLUSIONS, AND FUTURE RESEARCH

7.1 CONCLUSIONS

This thesis examined the effectiveness of Iowa' automated red light running programs in three communities using two different study methods including a cross-sectional violation study and two before and after crash studies using control intersections. Similar to other RLR effectiveness studies, this thesis took into account possible errors including regression to the mean, spillover effects, and calculating the average or averages before the statistical models were created for the cross-sectional violations study and before and after crash studies. Along with investigating the effectiveness of reducing crashes and violation, this thesis investigated how each of Iowa's RLR programs started, the possible payment methods, and intersection characteristics and geometry. By examining and reporting these factors in this document, other communities in Iowa can learn from their mistakes and the successes each community had with automated enforcement and decide if it is an appropriate countermeasure for a dangerous intersection.

The City of Clive, which began automated enforcement in July of 2006, was studied based on video recorded field data collection and data collected from the Clive Police Department. It was concluded based on this data collected in the field and a Poisson statistical model that the use of RLR cameras on Hickman Road resulted in a statistically significant reduction of violations. However, crash data relating to the RLR camera enforced intersections were not studied because there were not enough crash data to perform a valid before and after study. Based on the violation study and statistical model, the RLR cameras in Clive are effective in reducing the number of violations, but have come at a cost to the city.

Crash studies were performed in Council Bluffs and Davenport using crash data obtained and verified from the Iowa DOT. Descriptive statistics and a Bayesian model were created to evaluate the significance of the data collected. Descriptive statistics were performed for Council Bluffs which resulted in describing the change in crash rates based on average quarterly daily entering vehicles and recorded crashes. The initial results showed a reduction in RLR type crashes and an increase in rear-end type crashes. These conclusions follow many RLR effectiveness studies performed by other researchers. To model the crash data a Poisson regression was needed and a hierarchical Bayesian model were created to evaluate the before and after crash data. The crash data were analyzed by adjusting the distribution means for both the camera enforced and control intersection and adjusting the traffic volume by a certain parameter. To verify the descriptive statistic's results, the statistical model concluded that the initial results found by descriptive statistics were not statistically significant, thus questioning the effectiveness of RLR cameras in reducing crashes. It was also believed by the researchers that the sample size and the total number of before and after crashes were so low that descriptive statistical and Bayesian model results may have been skewed. Further studies are recommended with more "after" data to determine if this last result is confirmed.

Descriptive statistics were performed for the City Davenport using the available crash data from the Iowa DOT database. Time constraints attached to this thesis limited the creation of statistical model to evaluate the effectiveness of RLR cameras. Based on the descriptive statistics, it is somewhat inconclusive if the RLR cameras are effective in reducing RLR type crashes or rear-end crashes. It is believed that a similar phenomenon found in Council Bluffs is occurring in Davenport where the sample size and number of before and after crashes are skewing the results of descriptive statistics and could skew the future initial statistical model. Similar to the conclusions made of Council Bluffs, it is recommended that a Bayesian hierarchical statistical model be created for the Davenport crash data, and follow up studies be conducted to measure effectiveness when more data is available. Based on the violation data received by both cities and the type of payment plan selected by each city, both Council Bluffs and Davenport are generating a revenue that is being put towards city operations and protecting it's citizens with new police officers, equipment, and safety programs. In some eyes, capturing RLR violators and collecting a fine can be viewed as effective. Above all of the effectiveness statistical models, the one thing can be concluded with the RLR camera systems in Clive, Council Bluffs, and Davenport is, that the general public is more aware that cities are taking strong measures to save lives on public streets. If drivers know there is a chance of receiving a violation via a camera, maybe he or she will modify their driving behavior to not run the red light and possible save a life.

7.2 FUTURE RESEARCH

This study analyzed the effectiveness of three red light running programs in the State of Iowa over three different time period based on the installation of the camera system. Two future studies are recommended for Iowa's RLR programs including a comprehensive violation study for Council Bluffs and Davenport, and a crash study for Clive. Future research in the area of automated enforcement in Iowa will depend on the State Legislature and Iowa Supreme Court if a ruling or state law limits or bans the use of automated enforcement. Although this report is the second of two Iowa DOT reports that is focused on automated RLR camera systems in Iowa, there is still much to be learned that many other research institutions and city jurisdictions have researched including the following.

- Performing a spillover study at RLR camera enforced intersections and adjacent corridors
- Determine the characteristics of RLR for different seasons and weather conditions
- Research the type of traffic signal and intersection geometry that might influence a driver to run a red light
- Research and develop guidance on RLR and traffic signal coordination
- Evaluating the process of implanting a RLR camera system and provide guidance on how to determine high risk intersections and how to work with camera vendors
- Developing guidelines on how to implement and gain public support for RLR camera systems
- Develop community groups with adjacent cities or communities on how to create system wide awareness of RLR (e.g. the City of Clive works with the City of Urbandale and West Des Moines)
- Establish guidelines for city or state jurisdictions to extract and analyze valid violation and crash data relating to RLR

- Investigate if distracted drivers a prone to running a red light than a non-distracted driver

Although there are many research publications focused on RLR and their effectiveness nationwide, there is still future research to be done not only at a national level, but at a statewide level. To fully understand the effectiveness of automated RLR cameras, research must continue to investigate crash and violation data constantly studied and compared.

APPENDIX A: COUNCIL BLUFFS CRASH DESCRIPTIVE STATISTICS

Broadway & 16th St.					
Year - Quarter		Total Recorded Crashes	Rear-End RLR Crash	Other RLR Crash	Not RLR Associated Crash
Daily Entering Vehicles = 41500					
2001-01		0	0	0	0
	Crash Rate	0.00	0.00	0.00	0.00
2001-02		4	0	0	4
	Crash Rate	1.06	0.00	0.00	1.06
2001-03		8	1	1	6
	Crash Rate	2.11	0.26	0.26	1.58
2001-04		2	1	1	0
	Crash Rate	0.53	0.26	0.26	0.00
2001 Total Crashes		14	2	2	10
2001 Avg. Crash Rate		0.92	0.13	0.13	0.66
Daily Entering Vehicles = 41500					
2002-01		5	1	2	2
	Crash Rate	1.32	0.26	0.53	0.53
2002-02		10	3	3	4
	Crash Rate	2.64	0.79	0.79	1.06
2002-03		6	0	2	4
	Crash Rate	1.58	0.00	0.53	1.06
2002-04		3	0	0	3
	Crash Rate	0.79	0.00	0.00	0.79
2002 Total Crashes		24	4	7	13
2002 Avg. Crash Rate		1.58	0.26	0.46	0.86
Daily Entering Vehicles = 41250					
2003-01		2	0	0	2
	Crash Rate	0.53	0.00	0.00	0.53
2003-02		3	0	0	3
	Crash Rate	0.80	0.00	0.00	0.80
2003-03		3	1	0	2
	Crash Rate	0.80	0.27	0.00	0.53
2003-04		1	0	0	1
	Crash Rate	0.27	0.00	0.00	0.27
2003 Total Crashes		9	1	0	8
2003 Avg. Crash Rate		0.60	0.07	0.00	0.53
Daily Entering Vehicles = 42550					
2004-01		7	2	1	4
	Crash Rate	1.80	0.52	0.26	1.03
2004-02		4	1	1	2
	Crash Rate	1.03	0.26	0.26	0.52
2004-03		Quarter of Camera Installation (not included)			
2004 Total Crashes		11	3	2	6
2004 Avg. Crash Rate		1.42	0.39	0.26	0.77
2004-04		5	1	1	3
	Crash Rate	1.29	0.26	0.26	0.77
2004 Total Crashes		5	1	1	3
2004 Avg. Crash Rate		1.29	0.26	0.26	0.77
Daily Entering Vehicles = 42550					
2005-01		4	1	2	0
	Crash Rate	1.03	0.26	0.52	0.00
2005-02		4	2	0	2
	Crash Rate	1.03	0.52	0.00	0.52
2005-03		3	0	0	3
	Crash Rate	0.77	0.00	0.00	0.77
2005-04		6	0	1	5
	Crash Rate	1.55	0.00	0.26	1.29
2005 Total Crashes		17	3	3	10
2005 Avg. Crash Rate		1.09	0.19	0.19	0.64
Daily Entering Vehicles = 42550					
2006-01		1	0	0	1
	Crash Rate	0.26	0.00	0.00	0.26
2006-02		2	0	0	2
	Crash Rate	0.52	0.00	0.00	0.52
2006-03		3	1	0	2
	Crash Rate	0.77	0.26	0.00	0.52
2006-04		2	1	0	1
	Crash Rate	0.52	0.26	0.00	0.26
2006 Total Crashes		8	2	0	6
2006 Avg. Crash Rate		0.52	0.13	0.00	0.39
Crashes per Quarter Before		4.14	0.71	0.79	2.64
DEV per Quarter Before		3,794,045	3,794,045	3,794,045	3,794,045
Crashes per Quarter After		3.33	0.67	0.44	2.11
DEV per Quarter After		3,882,688	3,882,688	3,882,688	3,882,688
Before Crash Rate		1.09	0.19	0.21	0.70
After Crash Rate		0.86	0.17	0.11	0.54
% Change in Crash Rate		**-21.38%**	**-8.80%**	**-44.73%**	**-21.94%**

Willow Avenue & 7th St.					
Year - Quarter		Total Recorded Crashes	Rear-End RLR Crash	Other RLR Crash	Not RLR Associated Crash
Daily Entering Vehicles = 6905					
2001-01		1	0	1	0
	Crash Rate	1.59	0.00	1.59	0.00
2001-02		1	0	0	1
	Crash Rate	1.59	0.00	0.00	1.59
2001-03		1	1	0	0
	Crash Rate	1.59	1.59	0.00	0.00
2001-04		2	1	1	0
	Crash Rate	3.17	1.59	1.59	0.00
2001 Total Crashes		5	2	2	1
2001 Avg. Crash Rate		1.98	0.79	0.79	0.40
Daily Entering Vehicles = 6905					
2002-01		1	0	0	1
	Crash Rate	1.59	0.00	0.00	1.59
2002-02		0	0	0	0
	Crash Rate	0.00	0.00	0.00	0.00
2002-03		2	0	1	1
	Crash Rate	3.17	0.00	1.59	1.59
2002-04		2	0	0	2
	Crash Rate	3.17	0.00	0.00	3.17
2002 Total Crashes		5	0	1	4
2002 Avg. Crash Rate		1.98	0.00	0.40	1.59
Daily Entering Vehicles = 6905					
2003-01		0	0	0	0
	Crash Rate	0.00	0.00	0.00	0.00
2003-02		1	0	0	1
	Crash Rate	1.59	0.00	0.00	1.59
2003-03		0	0	0	0
	Crash Rate	0.00	0.00	0.00	0.00
2003-04		3	0	2	1
	Crash Rate	4.76	0.00	3.17	1.59
2003 Total Crashes		4	0	2	2
2003 Avg. Crash Rate		1.59	0.00	0.79	0.79
Daily Entering Vehicles = 9985					
2004-01		0	0	0	0
	Crash Rate	0.00	0.00	0.00	0.00
2004-02		0	0	0	0
	Crash Rate	0.00	0.00	0.00	0.00
2004-03		Quarter of Camera Installation (not included)			
2004 Total Crashes		0	0	0	0
2004 Avg. Crash Rate		0.00	0.00	0.00	0.00
2004-04		1	1	0	0
	Crash Rate	1.10	1.10	0.00	0.00
2004 Total Crashes		1	1	0	0
2004 Avg. Crash Rate		1.10	1.10	0.00	0.00
Daily Entering Vehicles = 9985					
2005-01		0	0	0	0
	Crash Rate	0.00	0.00	0.00	0.00
2005-02		1	0	0	1
	Crash Rate	1.10	0.00	0.00	1.10
2005-03		0	0	0	0
	Crash Rate	0.00	0.00	0.00	0.00
2005-04		0	0	0	0
	Crash Rate	0.00	0.00	0.00	0.00
2005 Total Crashes		1	0	0	1
2005 Avg. Crash Rate		0.27	0.00	0.00	0.27
Daily Entering Vehicles = 9985					
2006-01		2	0	0	2
	Crash Rate	2.20	0.00	0.00	2.20
2006-02		0	0	0	0
	Crash Rate	0.00	0.00	0.00	0.00
2006-03		0	0	0	0
	Crash Rate	0.00	0.00	0.00	0.00
2006-04		0	0	0	0
	Crash Rate	0.00	0.00	0.00	0.00
2006 Total Crashes		2	0	0	2
2006 Avg. Crash Rate		0.13	0.00	0.00	0.13
Crashes per Quarter Before		1.00	0.14	0.36	0.50
DEV per Quarter Before		670,231	670,231	670,231	670,231
Crashes per Quarter After		0.44	0.11	0.00	0.33
DEV per Quarter After		911,131	911,131	911,131	911,131
Before Crash Rate		1.49	0.21	0.53	0.75
After Crash Rate		0.49	0.12	0.00	0.37
% Change in Crash Rate		**-67.31%**	**-42.79%**	**-100.00%**	**-50.96%**

Broadway & 35th St.				
Year - Quarter	Total Recorded Crashes	Rear-End RLR Crash	Other RLR Crash	Not RLR Associated Crash
Daily Entering Vehicles = 29680				
2001-01	3	0	1	2
Crash Rate	1.11	0.00	0.37	0.74
2001-02	3	1	2	0
Crash Rate	1.11	0.37	0.74	0.00
2001-03	3	0	0	3
Crash Rate	1.11	0.00	0.00	1.11
2001-04	2	0	0	2
Crash Rate	0.74	0.00	0.00	0.74
2001 Total Crashes	11	1	3	7
2001 Avg. Crash Rate	1.02	0.09	0.28	0.65
Daily Entering Vehicles = 29680				
2002-01	3	1	1	1
Crash Rate	1.11	0.37	0.37	0.37
2002-02	2	1	0	1
Crash Rate	0.74	0.37	0.00	0.37
2002-03	5	1	2	2
Crash Rate	1.85	0.37	0.74	0.74
2002-04	3	0	0	3
Crash Rate	1.11	0.00	0.00	1.11
2002 Total Crashes	13	3	3	7
2002 Avg. Crash Rate	1.20	0.28	0.28	0.65
Daily Entering Vehicles = 29480				
2003-01	0	0	0	0
Crash Rate	0.00	0.00	0.00	0.00
2003-02	3	1	2	0
Crash Rate	1.12	0.37	0.74	0.00
2003-03	4	1	1	2
Crash Rate	1.49	0.37	0.37	0.74
2003-04	4	0	1	3
Crash Rate	1.49	0.00	0.37	1.12
2003 Total Crashes	11	2	4	5
2003 Avg. Crash Rate	1.02	0.19	0.37	0.46
Daily Entering Vehicles = 32450				
2004-01	5	1	1	3
Crash Rate	1.69	0.34	0.34	1.01
2004-02	2	1	1	0
Crash Rate	0.68	0.34	0.34	0.00
2004-03	Quarter of Camera Installation (not included)			
2004 Total Crashes	7	2	2	3
2004 Avg. Crash Rate	1.18	0.34	0.34	0.51
2004-04	5	2	1	2
Crash Rate	1.69	0.68	0.34	0.68
2004 Total Crashes	5	2	1	2
2004 Avg. Crash Rate	1.69	0.68	0.34	0.68
Daily Entering Vehicles = 32450				
2005-01	1	0	0	1
Crash Rate	0.34	0.00	0.00	0.34
2005-02	1	1	0	0
Crash Rate	0.34	0.34	0.00	0.00
2005-03	4	1	1	2
Crash Rate	1.35	0.34	0.34	0.68
2005-04	3	1	0	2
Crash Rate	1.01	0.34	0.00	0.68
2005 Total Crashes	9	3	1	5
2005 Avg. Crash Rate	0.76	0.25	0.08	0.42
Daily Entering Vehicles = 32450				
2006-01	3	1	0	2
Crash Rate	1.01	0.34	0.00	0.68
2006-02	3	1	1	1
Crash Rate	1.01	0.34	0.34	0.34
2006-03	4	2	0	2
Crash Rate	1.35	0.68	0.00	0.68
2006-04	0	0	0	0
Crash Rate	0.00	0.00	0.00	0.00
2006 Total Crashes	10	4	1	5
2006 Avg. Crash Rate	0.64	0.26	0.06	0.32
Crashes per Quarter Before	3.00	0.57	0.86	1.57
DEV per Quarter Before	2,739,195	2,739,195	2,739,195	2,739,195
Crashes per Quarter After	2.67	1.00	0.33	1.33
DEV per Quarter After	2,961,063	2,961,063	2,961,063	2,961,063
Before Crash Rate	1.10	0.21	0.31	0.57
After Crash Rate	0.90	0.34	0.11	0.45
% Change in Crash Rate	**-17.77%**	**61.89%**	**-64.02%**	**-21.51%**

Broadway & 21st St.					
Year - Quarter		**Total Recorded Crashes**	**Rear-End RLR Crash**	**Other RLR Crash**	**Not RLR Associated Crash**
Daily Entering Vehicles = 30840					
2001-01		2	0	1	1
	Crash Rate	0.71	0.00	0.36	0.36
2001-02		0	0	0	0
	Crash Rate	0.00	0.00	0.00	0.00
2001-03		2	0	0	2
	Crash Rate	0.71	0.00	0.00	0.71
2001-04		1	0	1	0
	Crash Rate	0.36	0.00	0.36	0.00
2001 Total Crashes		5	0	2	3
2001 Avg. Crash Rate		0.44	0.00	0.18	0.27
Daily Entering Vehicles = 30840					
2002-01		1	1	0	0
	Crash Rate	0.36	0.36	0.00	0.00
2002-02		6	3	0	3
	Crash Rate	2.13	1.07	0.00	1.07
2002-03		1	0	0	1
	Crash Rate	0.36	0.00	0.00	0.36
2002-04		3	1	1	1
	Crash Rate	1.07	0.36	0.36	0.36
2002 Total Crashes		11	5	1	5
2002 Avg. Crash Rate		0.98	0.44	0.09	0.44
Daily Entering Vehicles = 30640					
2003-01		3	0	2	1
	Crash Rate	1.07	0.00	0.72	0.36
2003-02		1	1	0	0
	Crash Rate	0.36	0.36	0.00	0.00
2003-03		1	1	0	0
	Crash Rate	0.36	0.36	0.00	0.00
2003-04		1	1	0	0
	Crash Rate	0.36	0.36	0.00	0.00
2003 Total Crashes		6	3	2	1
2003 Avg. Crash Rate		0.54	0.27	0.18	0.09
Daily Entering Vehicles = 32355					
2004-01		2	1	1	0
	Crash Rate	0.68	0.34	0.34	0.00
2004-02		3	1	1	1
	Crash Rate	1.02	0.34	0.34	0.34
2004-03		Quarter of Camera Installation (not included)			
2004 Total Crashes		5	2	2	1
2004 Avg. Crash Rate		0.85	0.34	0.34	0.17
2004-04		5	2	1	2
	Crash Rate	1.69	0.68	0.34	0.68
2004 Total Crashes		5	2	1	2
2004 Avg. Crash Rate		1.69	0.68	0.34	0.68
Daily Entering Vehicles = 32355					
2005-01		1	0	1	0
	Crash Rate	0.34	0.00	0.34	0.00
2005-02		1	0	1	0
	Crash Rate	0.34	0.00	0.34	0.00
2005-03		1	0	1	0
	Crash Rate	0.34	0.00	0.34	0.00
2005-04		5	3	1	1
	Crash Rate	1.69	1.02	0.34	0.34
2005 Total Crashes		8	3	4	1
2005 Avg. Crash Rate		0.68	0.25	0.34	0.08
Daily Entering Vehicles = 32355					
2006-01		0	0	0	0
	Crash Rate	0.00	0.00	0.00	0.00
2006-02		2	1	0	1
	Crash Rate	0.68	0.34	0.00	0.34
2006-03		1	0	0	1
	Crash Rate	0.34	0.00	0.00	0.34
2006-04		0	0	0	0
	Crash Rate	0.00	0.00	0.00	0.00
2006 Total Crashes		3	1	0	2
2006 Avg. Crash Rate		0.19	0.06	0.00	0.13
Crashes per Quarter Before		1.93	0.71	0.50	0.71
DEV per Quarter Before		2,828,685	2,828,685	2,828,685	2,828,685
Crashes per Quarter After		1.78	0.67	0.56	0.56
DEV per Quarter After		2,952,394	2,952,394	2,952,394	2,952,394
Before Crash Rate		0.68	0.25	0.18	0.25
After Crash Rate		0.60	0.23	0.19	0.19
% Change in Crash Rate		**-11.68%**	**-10.58%**	**6.46%**	**-25.48%**

Kanesville Blvd. & 8th St.					
Year - Quarter		Total Recorded Crashes	Rear-End RLR Crash	Other RLR Crash	Not RLR Associated Crash
Daily Entering Vehicles = 36270					
2001-01		5	0	0	5
	Crash Rate	1.51	0.00	0.00	1.51
2001-02		5	1	0	4
	Crash Rate	1.51	0.30	0.00	1.21
2001-03		4	1	1	2
	Crash Rate	1.21	0.30	0.30	0.60
2001-04		7	2	0	5
	Crash Rate	2.12	0.60	0.00	1.51
2001 Total Crashes		21	4	1	16
2001 Avg. Crash Rate		1.59	0.30	0.08	1.21
Daily Entering Vehicles = 36270					
2002-01		4	1	2	1
	Crash Rate	1.21	0.30	0.60	0.30
2002-02		3	0	1	2
	Crash Rate	0.91	0.00	0.30	0.60
2002-03		6	2	1	3
	Crash Rate	1.81	0.60	0.30	0.91
2002-04		4	2	0	2
	Crash Rate	1.21	0.60	0.00	0.60
2002 Total Crashes		17	5	4	8
2002 Avg. Crash Rate		1.28	0.38	0.30	0.60
Daily Entering Vehicles = 66845					
2003-01		7	0	2	5
	Crash Rate	1.15	0.00	0.33	0.82
2003-02		4	1	0	3
	Crash Rate	0.66	0.16	0.00	0.49
2003-03		5	2	0	3
	Crash Rate	0.82	0.33	0.00	0.49
2003-04		1	0	0	1
	Crash Rate	0.16	0.00	0.00	0.16
2003 Total Crashes		17	3	2	12
2003 Avg. Crash Rate		0.70	0.12	0.08	0.49
Daily Entering Vehicles = 55525					
2004-01		2	0	0	2
	Crash Rate	0.39	0.00	0.00	0.39
2004-02		8	2	0	6
	Crash Rate	1.58	0.39	0.00	1.18
2004-03		Quarter of Camera Installation (not included)			
2004 Total Crashes		10	2	0	8
2004 Avg. Crash Rate		0.99	0.20	0.00	0.79
2004-04		8	1	0	7
	Crash Rate	1.58	0.20	0.00	1.38
2004 Total Crashes		8	1	0	7
2004 Avg. Crash Rate		1.58	0.20	0.00	1.38
Daily Entering Vehicles = 55525					
2005-01		6	3	0	3
	Crash Rate	1.18	0.59	0.00	0.59
2005-02		4	1	0	3
	Crash Rate	0.79	0.20	0.00	0.59
2005-03		5	1	0	4
	Crash Rate	0.99	0.20	0.00	0.79
2005-04		8	1	1	6
	Crash Rate	1.58	0.20	0.20	1.18
2005 Total Crashes		23	6	1	16
2005 Avg. Crash Rate		1.13	0.30	0.05	0.79
Daily Entering Vehicles = 55525					
2006-01		1	1	0	0
	Crash Rate	0.20	0.20	0.00	0.00
2006-02		5	2	0	3
	Crash Rate	0.99	0.39	0.00	0.59
2006-03		2	0	0	2
	Crash Rate	0.39	0.00	0.00	0.39
2006-04		2	1	0	1
	Crash Rate	0.39	0.20	0.00	0.20
2006 Total Crashes		10	4	0	6
2006 Avg. Crash Rate		0.64	0.26	0.00	0.39
Crashes per Quarter Before		4.64	1.00	0.50	3.14
DEV per Quarter Before		4,357,774	4,357,774	4,357,774	4,357,774
Crashes per Quarter After		4.56	1.22	0.11	3.22
DEV per Quarter After		5,066,656	5,066,656	5,066,656	5,066,656
Before Crash Rate		1.07	0.23	0.11	0.72
After Crash Rate		0.90	0.24	0.02	0.64
% Change in Crash Rate		**-15.61%**	**5.12%**	**-80.89%**	**-11.82%**

24th St. & 27th St.					
Year - Quarter		Total Recorded Crashes	Rear-End RLR Crash	Other RLR Crash	Not RLR Associated Crash
Daily Entering Vehicles = 14830					
2001-01		2	0	1	1
	Crash Rate	1.48	0.00	0.74	0.74
2001-02		4	0	0	4
	Crash Rate	2.96	0.00	0.00	2.96
2001-03		1	0	0	1
	Crash Rate	0.74	0.00	0.00	0.74
2001-04		3	0	0	3
	Crash Rate	2.22	0.00	0.00	2.22
2001 Total Crashes		10	0	1	9
2001 Avg. Crash Rate		1.85	0.00	0.18	1.66
Daily Entering Vehicles = 14830					
2002-01		7	0	1	6
	Crash Rate	5.17	0.00	0.74	4.43
2002-02		2	0	0	2
	Crash Rate	1.48	0.00	0.00	1.48
2002-03		0	0	0	0
	Crash Rate	0.00	0.00	0.00	0.00
2002-04		4	0	0	4
	Crash Rate	2.96	0.00	0.00	2.96
2002 Total Crashes		13	0	1	12
2002 Avg. Crash Rate		2.40	0.00	0.18	2.22
Daily Entering Vehicles = 14830					
2003-01		2	0	1	1
	Crash Rate	1.48	0.00	0.74	0.74
2003-02		2	0	0	2
	Crash Rate	1.48	0.00	0.00	1.48
2003-03		3	0	0	3
	Crash Rate	2.22	0.00	0.00	2.22
2003-04		0	0	0	0
	Crash Rate	0.00	0.00	0.00	0.00
2003 Total Crashes		7	0	1	6
2003 Avg. Crash Rate		1.29	0.00	0.18	1.11
Daily Entering Vehicles = 15530					
2004-01		3	1	0	2
	Crash Rate	2.12	0.71	0.00	1.41
2004-02		2	1	0	1
	Crash Rate	1.41	0.71	0.00	0.71
2004-03	Quarter of Camera Installation (not included)				
2004 Total Crashes		5	2	0	3
2004 Avg. Crash Rate		1.76	0.71	0.00	1.06
2004-04		1	0	1	0
	Crash Rate	0.71	0.00	0.71	0.00
2004 Total Crashes		1	0	1	0
2004 Avg. Crash Rate		0.71	0.00	0.71	0.00
Daily Entering Vehicles = 15530					
2005-01		4	0	1	3
	Crash Rate	2.82	0.00	0.71	2.12
2005-02		3	0	0	3
	Crash Rate	2.12	0.00	0.00	2.12
2005-03		3	0	1	2
	Crash Rate	2.12	0.00	0.71	1.41
2005-04		6	0	1	5
	Crash Rate	4.23	0.00	0.71	3.53
2005 Total Crashes		16	0	3	13
2005 Avg. Crash Rate		2.82	0.00	0.53	2.29
Daily Entering Vehicles = 15530					
2006-01		2	0	0	2
	Crash Rate	1.41	0.00	0.00	1.41
2006-02		4	0	0	4
	Crash Rate	2.82	0.00	0.00	2.82
2006-03		2	0	1	1
	Crash Rate	1.41	0.00	0.71	0.71
2006-04		4	1	0	3
	Crash Rate	2.82	0.71	0.00	2.12
2006 Total Crashes		12	1	1	10
2006 Avg. Crash Rate		2.12	0.18	0.18	1.76
Crashes per Quarter Before		2.50	0.14	0.21	2.14
DEV per Quarter Before		1,362,363	1,362,363	1,362,363	1,362,363
Crashes per Quarter After		3.22	0.11	0.56	2.56
DEV per Quarter After		1,417,113	1,417,113	1,417,113	1,417,113
Before Crash Rate		1.84	0.10	0.16	1.57
After Crash Rate		2.27	0.08	0.39	1.80
% Change in Crash Rate		**23.91%**	**-25.23%**	**149.24%**	**14.65%**

35th St. & Nebraska Ave.					
Year - Quarter		Total Recorded Crashes	Rear-End RLR Crash	Other RLR Crash	Not RLR Associated Crash
Daily Entering Vehicles = 15675					
2001-01		4	2	0	2
	Crash Rate	2.80	1.40	0.00	1.40
2001-02		2	0	1	1
	Crash Rate	1.40	0.00	0.70	0.70
2001-03		0	0	0	0
	Crash Rate	0.00	0.00	0.00	0.00
2001-04		3	0	0	3
	Crash Rate	2.10	0.00	0.00	2.10
2001 Total Crashes		9	2	1	6
2001 Avg. Crash Rate		1.57	0.35	0.17	1.05
Daily Entering Vehicles = 15675					
2002-01		1	0	0	1
	Crash Rate	0.70	0.00	0.00	0.70
2002-02		1	0	0	1
	Crash Rate	0.70	0.00	0.00	0.70
2002-03		0	0	0	0
	Crash Rate	0.00	0.00	0.00	0.00
2002-04		0	0	0	0
	Crash Rate	0.00	0.00	0.00	0.00
2002 Total Crashes		2	0	0	2
2002 Avg. Crash Rate		0.35	0.00	0.00	0.35
Daily Entering Vehicles = 15675					
2003-01		5	1	0	4
	Crash Rate	3.50	0.70	0.00	2.80
2003-02		1	0	0	1
	Crash Rate	0.70	0.00	0.00	0.70
2003-03		1	0	0	1
	Crash Rate	0.70	0.00	0.00	0.70
2003-04		1	0	1	0
	Crash Rate	0.70	0.00	0.70	0.00
2003 Total Crashes		8	1	1	6
2003 Avg. Crash Rate		1.40	0.17	0.17	1.05
Daily Entering Vehicles = 15925					
2004-01		0	0	0	0
	Crash Rate	0.00	0.00	0.00	#DIV/0!
2004-02		0	0	0	0
	Crash Rate	0.00	0.00	0.00	0.00
2004-03		Quarter of Camera Installation (not included)			
2004 Total Crashes		0	0	0	0
2004 Avg. Crash Rate		0.00	0.00	0.00	0.00
2004-04		1	0	0	1
	Crash Rate	0.69	0.00	0.00	0.69
2004 Total Crashes		1	0	0	1
2004 Avg. Crash Rate		0.69	0.00	0.00	0.69
Daily Entering Vehicles = 15925					
2005-01		3	0	1	2
	Crash Rate	2.06	0.00	0.69	1.38
2005-02		0	0	0	0
	Crash Rate	0.00	0.00	0.00	0.00
2005-03		0	0	0	0
	Crash Rate	0.00	0.00	0.00	0.00
2005-04		2	0	0	2
	Crash Rate	1.38	0.00	0.00	1.38
2005 Total Crashes		5	0	1	4
2005 Avg. Crash Rate		0.86	0.00	0.17	0.69
Daily Entering Vehicles = 15925					
2006-01		0	0	0	0
	Crash Rate	0.00	0.00	0.00	0.00
2006-02		1	1	0	0
	Crash Rate	0.69	0.69	0.00	0.00
2006-03		1	0	1	0
	Crash Rate	0.69	0.00	0.69	0.00
2006-04		2	1	0	1
	Crash Rate	1.38	0.69	0.00	0.69
2006 Total Crashes		4	2	1	1
2006 Avg. Crash Rate		0.69	0.34	0.17	0.17
Crashes per Quarter Before		1.36	0.21	0.14	1.00
DEV per Quarter Before		1,433,603	1,433,603	1,433,603	1,433,603
Crashes per Quarter After		1.11	0.22	0.22	0.67
DEV per Quarter After		1,453,156	1,453,156	1,453,156	1,453,156
Before Crash Rate		0.95	0.15	0.10	0.70
After Crash Rate		0.76	0.15	0.15	0.46
% Change in Crash Rate		**-19.23%**	**2.31%**	**53.46%**	**-34.23%**

Broadway & Kanesville Blvd.					
Year - Quarter		Total Recorded Crashes	Rear-End RLR Crash	Other RLR Crash	Not RLR Associated Crash
Daily Entering Vehicles = 28855					
2001-01		2	0	1	1
	Crash Rate	0.76	0.00	0.38	0.38
2001-02		1	0	0	1
	Crash Rate	0.38	0.00	0.00	0.38
2001-03		1	1	0	0
	Crash Rate	0.38	0.38	0.00	0.00
2001-04		8	1	3	4
	Crash Rate	3.04	0.38	1.14	1.52
2001 Total Crashes		12	2	4	6
2001 Avg. Crash Rate		1.14	0.19	0.38	0.57
Daily Entering Vehicles = 32600					
2002-01		1	0	1	0
	Crash Rate	0.34	0.00	0.34	0.00
2002-02		2	0	1	1
	Crash Rate	0.67	0.00	0.34	0.34
2002-03		1	0	0	1
	Crash Rate	0.34	0.00	0.00	0.34
2002-04		3	1	1	1
	Crash Rate	1.01	0.34	0.34	0.34
2002 Total Crashes		7	1	3	3
2002 Avg. Crash Rate		0.59	0.08	0.25	0.25
Daily Entering Vehicles = 32500					
2003-01		4	2	0	2
	Crash Rate	1.35	0.67	0.00	0.67
2003-02		1	0	0	1
	Crash Rate	0.34	0.00	0.00	0.34
2003-03		0	0	0	0
	Crash Rate	0.00	0.00	0.00	0.00
2003-04		0	0	0	0
	Crash Rate	0.00	0.00	0.00	0.00
2003 Total Crashes		5	2	0	3
2003 Avg. Crash Rate		0.42	0.17	0.00	0.25
Daily Entering Vehicles = 31000					
2004-01		0	0	0	0
	Crash Rate	0.00	0.00	0.00	0.00
2004-02		1	0	0	1
	Crash Rate	0.35	0.00	0.00	0.35
2004-03		Quarter of Camera Installation (not included)			
2004 Total Crashes		1	0	0	1
2004 Avg. Crash Rate		0.18	0.00	0.00	0.18
2004-04		0	0	0	0
	Crash Rate	0.00	0.00	0.00	0.00
2004 Total Crashes		0	0	0	0
2004 Avg. Crash Rate		0.00	0.00	0.00	0.00
Daily Entering Vehicles = 31000					
2005-01		2	0	1	1
	Crash Rate	0.71	0.00	0.35	0.35
2005-02		3	0	2	1
	Crash Rate	1.06	0.00	0.71	0.35
2005-03		3	0	1	2
	Crash Rate	1.06	0.00	0.35	0.71
2005-04		0	0	0	0
	Crash Rate	0.00	0.00	0.00	0.00
2005 Total Crashes		8	0	4	4
2005 Avg. Crash Rate		0.71	0.00	0.35	0.35
Daily Entering Vehicles = 31000					
2006-01		0	0	0	0
	Crash Rate	0.00	0.00	0.00	0.00
2006-02		0	0	0	0
	Crash Rate	0.00	0.00	0.00	0.00
2006-03		2	0	2	0
	Crash Rate	0.71	0.00	0.71	0.00
2006-04		1	0	0	1
	Crash Rate	0.35	0.00	0.00	0.35
2006 Total Crashes		3	0	2	1
2006 Avg. Crash Rate		0.27	0.00	0.18	0.09
Crashes per Quarter Before		1.79	0.36	0.50	0.93
DEV per Quarter Before		2,853,648	2,853,648	2,853,648	2,853,648
Crashes per Quarter After		1.22	0.00	0.67	0.56
DEV per Quarter After		2,828,750	2,828,750	2,828,750	2,828,750
Before Crash Rate		0.63	0.13	0.18	0.33
After Crash Rate		0.43	0.00	0.24	0.20
% Change in Crash Rate		**-30.95%**	**-100.00%**	**34.51%**	**-39.64%**

Broadway & 1st St.					
Year - Quarter		Total Recorded Crashes	Rear-End RLR Crash	Other RLR Crash	Not RLR Associated Crash
Daily Entering Vehicles = 15430					
2001-01		3	0	1	2
	Crash Rate	2.13	0.00	0.71	1.42
2001-02		1	0	0	1
	Crash Rate	0.71	0.00	0.00	0.71
2001-03		0	0	0	0
	Crash Rate	0.00	0.00	0.00	0.00
2001-04		4	0	2	2
	Crash Rate	2.84	0.00	1.42	1.42
2001 Total Crashes		8	0	3	5
2001 Avg. Crash Rate		1.42	0.00	0.53	0.89
Daily Entering Vehicles = 15430					
2002-01		1	0	0	1
	Crash Rate	0.71	0.00	0.00	0.71
2002-02		1	0	0	1
	Crash Rate	0.71	0.00	0.00	0.71
2002-03		2	0	0	2
	Crash Rate	1.42	0.00	0.00	1.42
2002-04		2	0	1	1
	Crash Rate	1.42	0.00	0.71	0.71
2002 Total Crashes		6	0	1	5
2002 Avg. Crash Rate		1.07	0.00	0.18	0.89
Daily Entering Vehicles = 15430					
2003-01		4	0	1	3
	Crash Rate	2.84	0.00	0.71	2.13
2003-02		2	0	1	1
	Crash Rate	1.42	0.00	0.71	0.71
2003-03		1	0	1	0
	Crash Rate	0.71	0.00	0.71	0.00
2003-04		1	0	0	1
	Crash Rate	0.71	0.00	0.00	0.71
2003 Total Crashes		8	0	3	5
2003 Avg. Crash Rate		1.42	0.00	0.53	0.89
Daily Entering Vehicles = 21440					
2004-01		0	0	0	0
	Crash Rate	0.00	0.00	0.00	0.00
2004-02		5	0	1	4
	Crash Rate	2.56	0.00	0.51	2.04
2004-03		Quarter of Camera Installation (not included)			
2004 Total Crashes		5	0	1	4
2004 Avg. Crash Rate		1.28	0.00	0.26	1.02
2004-04		3	0	0	3
	Crash Rate	1.53	0.00	0.00	1.53
2004 Total Crashes		3	0	0	3
2004 Avg. Crash Rate		1.53	0.00	0.00	1.53
Daily Entering Vehicles = 21440					
2005-01		4	0	1	3
	Crash Rate	2.04	0.00	0.51	1.53
2005-02		2	0	0	2
	Crash Rate	1.02	0.00	0.00	1.02
2005-03		3	0	0	3
	Crash Rate	1.53	0.00	0.00	1.53
2005-04		2	0	1	1
	Crash Rate	1.02	0.00	0.51	0.51
2005 Total Crashes		11	0	2	9
2005 Avg. Crash Rate		1.41	0.00	0.26	1.15
Daily Entering Vehicles = 21440					
2006-01		2	0	0	2
	Crash Rate	1.02	0.00	0.00	1.02
2006-02		1	0	0	1
	Crash Rate	0.51	0.00	0.00	0.51
2006-03		0	0	0	0
	Crash Rate	0.00	0.00	0.00	0.00
2006-04		3	0	1	2
	Crash Rate	1.53	0.00	0.51	1.02
2006 Total Crashes		6	0	1	5
2006 Avg. Crash Rate		0.77	0.00	0.13	0.64
Crashes per Quarter Before		1.93	0.00	0.57	1.36
DEV per Quarter Before		1,486,332	2,853,648	2,853,648	2,853,648
Crashes per Quarter After		2.22	0.00	0.33	1.89
DEV per Quarter After		1,956,400	2,828,750	2,828,750	2,828,750
Before Crash Rate		1.30	0.00	0.20	0.48
After Crash Rate		1.14	0.00	0.12	0.67
% Change in Crash Rate		**-12.46%**	**0.00%**	**-41.15%**	**40.41%**

APPENDIX B: DAVENPORT CRASH DESCRIPTIVE STATISTICS

Kimberly Road & Welcome Way					
Year - Quarter		Total Recorded Crashes	Rear-End RLR Crash	Other RLR Crash	Not RLR Associated Crash
Daily Entering Vehicles = 45350					
2001-01		10	1	4	5
	Crash Rate	2.42	0.24	0.97	1.21
2001-02		4	1	2	1
	Crash Rate	0.97	0.24	0.48	0.24
2001-03		2	0	0	2
	Crash Rate	0.48	0.00	0.00	0.48
2001-04		7	2	1	4
	Crash Rate	1.69	0.48	0.24	0.97
2001 Total Crashes		23	4	7	12
2001 Avg. Crash Rate		1.39	0.24	0.42	0.72
Daily Entering Vehicles = 47600					
2002-01		8	1	4	3
	Crash Rate	1.84	0.23	0.92	0.69
2002-02		9	3	4	2
	Crash Rate	2.07	0.69	0.92	0.46
2002-03		2	0	2	0
	Crash Rate	0.46	0.00	0.46	0.00
2002-04		7	1	3	3
	Crash Rate	1.61	0.23	0.69	0.69
2002 Total Crashes		26	5	13	8
2002 Avg. Crash Rate		1.50	0.29	0.75	0.46
Daily Entering Vehicles = 34100					
2003-01		5	1	1	3
	Crash Rate	1.61	0.32	0.32	0.96
2003-02		5	0	3	2
	Crash Rate	1.61	0.00	0.96	0.64
2003-03		5	1	2	2
	Crash Rate	1.61	0.32	0.64	0.64
2003-04		7	1	4	2
	Crash Rate	2.25	0.32	1.29	0.64
2003 Total Crashes		22	3	10	9
2003 Avg. Crash Rate		1.77	0.24	0.80	0.72
Daily Entering Vehicles = 34500					
2004-01		7	2	4	1
	Crash Rate	2.22	0.64	1.27	0.32
2004-02		1	1	0	0
	Crash Rate	0.32	0.32	0.00	0.00
2004-03		Quarter of Camera Installation (not included)			
2004 Total Crashes		8	3	4	1
2004 Avg. Crash Rate		1.27	0.47	0.63	0.15
2004-04		7	0	4	3
	Crash Rate	2.22	0.00	1.27	0.95
2004 Total Crashes		7	0	4	3
2004 Avg. Crash Rate		2.22	0.00	1.27	0.95
Daily Entering Vehicles = 34500					
2005-01		5	1	1	3
	Crash Rate	1.59	0.32	0.32	0.95
2005-02		6	2	2	2
	Crash Rate	1.91	0.64	0.64	0.64
2005-03		6	2	1	3
	Crash Rate	1.91	0.64	0.32	0.95
2005-04		4	1	1	2
	Crash Rate	1.27	0.32	0.32	0.95
2005 Total Crashes		21	6	5	10
2005 Avg. Crash Rate		2.22	0.64	0.53	1.06
Daily Entering Vehicles = 34500					
2006-01		5	1	1	3
	Crash Rate	1.59	0.32	0.32	0.95
2006-02		1	0	0	1
	Crash Rate	0.32	0.00	0.00	0.32
2006-03		1	0	0	1
	Crash Rate	0.32	0.00	0.00	0.32
2006-04		3	2	1	0
	Crash Rate	0.95	0.64	0.32	0.00
2006 Total Crashes		10	3	2	5
2006 Avg. Crash Rate		0.79	0.24	0.16	0.40
Crashes per Quarter Before		5.64	1.07	2.43	2.14
DEV per Quarter Before		3,986,973	3,986,973	3,986,973	3,986,973
Crashes per Quarter After		4.22	1.00	1.22	2.00
DEV per Quarter After		3,148,125	3,148,125	3,148,125	3,148,125
Before Crash Rate		1.42	0.27	0.61	0.54
After Crash Rate		1.34	0.32	0.39	0.64
% Change in Crash Rate		**-5.24%**	**18.20%**	**-36.26%**	**18.20%**

Kimberly Road & Brady Street					
Year - Quarter		**Total Recorded Crashes**	**Rear-End RLR Crash**	**Other RLR Crash**	**Not RLR Associated Crash**
Daily Entering Vehicles = 50250					
2001-01		5	1	1	3
	Crash Rate	1.09	0.22	0.22	0.65
2001-02		4	0	1	3
	Crash Rate	0.87	0.00	0.22	0.65
2001-03		4	1	0	3
	Crash Rate	0.87	0.22	0.00	0.65
2001-04		4	2	0	2
	Crash Rate	0.87	0.44	0.00	0.44
2001 Total Crashes		17	4	2	11
2001 Avg. Crash Rate		0.93	0.22	0.11	0.60
Daily Entering Vehicles = 53950					
2002-01		3	0	0	3
	Crash Rate	0.61	0.00	0.00	0.61
2002-02		12	4	2	6
	Crash Rate	2.44	0.81	0.41	1.22
2002-03		1	0	0	1
	Crash Rate	0.20	0.00	0.00	0.20
2002-04		6	2	1	3
	Crash Rate	1.22	0.41	0.20	0.61
2002 Total Crashes		22	6	3	13
2002 Avg. Crash Rate		1.12	0.30	0.15	0.66
Daily Entering Vehicles = 23100					
2003-01		4	0	1	3
	Crash Rate	1.90	0.00	0.47	1.42
2003-02		7	1	2	4
	Crash Rate	3.32	0.47	0.95	1.90
2003-03		1	1	0	0
	Crash Rate	0.47	0.47	0.00	0.00
2003-04		5	0	1	4
	Crash Rate	2.37	0.00	0.47	1.90
2003 Total Crashes		17	2	4	11
2003 Avg. Crash Rate		2.02	0.24	0.47	1.30
Daily Entering Vehicles = 23400					
2004-01		1	1	0	0
	Crash Rate	0.47	0.47	0.00	0.00
2004-02		7	2	3	2
	Crash Rate	3.28	0.94	1.40	0.94
2004-03		Quarter of Camera Installation (not included)			
2004 Total Crashes		8	3	3	2
2004 Avg. Crash Rate		1.87	0.70	0.70	0.46
2004-04		5	2	0	3
	Crash Rate	2.34	0.94	0.00	1.40
2004 Total Crashes		5	2	0	3
2004 Avg. Crash Rate		2.34	0.93	0.00	1.40
Daily Entering Vehicles = 23400					
2005-01		3	2	0	1
	Crash Rate	1.40	0.94	0.00	0.47
2005-02		6	3	1	2
	Crash Rate	2.81	1.40	0.47	0.94
2005-03		4	0	2	2
	Crash Rate	1.87	0.00	0.94	0.94
2005-04		4	2	1	1
	Crash Rate	1.87	0.94	0.47	0.47
2005 Total Crashes		17	7	4	6
2005 Avg. Crash Rate		1.99	0.81	0.46	0.70
Daily Entering Vehicles = 23400					
2006-01		4	1	1	2
	Crash Rate	1.87	0.47	0.47	0.94
2006-02		5	2	2	1
	Crash Rate	2.34	0.94	0.94	0.47
2006-03		3	1	0	2
	Crash Rate	1.40	0.47	0.00	0.94
2006-04		3	1	0	2
	Crash Rate	1.40	0.47	0.00	0.94
2006 Total Crashes		15	5	3	7
2006 Avg. Crash Rate		1.76	0.59	0.35	0.82
Crashes per Quarter Before		4.57	1.07	0.86	2.64
DEV per Quarter Before		3,776,446	3,776,446	3,776,446	3,776,446
Crashes per Quarter After		4.11	1.56	0.78	1.78
DEV per Quarter After		2,135,250	2,135,250	2,135,250	2,135,250
Before Crash Rate		1.21	0.28	0.23	0.70
After Crash Rate		1.93	0.73	0.36	0.83
% Change in Crash Rate		**59.05%**	**156.78%**	**60.49%**	**18.97%**

Harrison & 35th Street					
Year - Quarter		Total Recorded Crashes	Rear-End RLR Crash	Other RLR Crash	Not RLR Associated Crash
Daily Entering Vehicles = 26200					
2001-01		2	0	2	0
	Crash Rate	0.84	0.00	0.84	0.00
2001-02		3	0	1	2
	Crash Rate	1.25	0.00	0.42	0.84
2001-03		7	3	0	4
	Crash Rate	2.93	1.25	0.00	1.67
2001-04		3	0	2	1
	Crash Rate	1.25	0.00	0.84	0.42
2001 Total Crashes		15	3	5	7
2001 Avg. Crash Rate		1.57	0.31	0.52	0.73
Daily Entering Vehicles = 26320					
2002-01		6	0	1	5
	Crash Rate	2.50	0.00	0.42	2.08
2002-02		3	0	2	1
	Crash Rate	1.25	0.00	0.83	0.42
2002-03		0	0	0	0
	Crash Rate	0.00	0.00	0.00	0.00
2002-04		3	0	0	3
	Crash Rate	1.25	0.00	0.00	1.25
2002 Total Crashes		12	0	3	9
2002 Avg. Crash Rate		1.25	0.00	0.31	0.94
Daily Entering Vehicles = 26220					
2003-01		5	1	1	3
	Crash Rate	2.09	0.42	0.42	1.25
2003-02		1	0	0	1
	Crash Rate	0.42	0.00	0.00	0.42
2003-03		1	0	1	0
	Crash Rate	0.42	0.00	0.42	0.00
2003-04		4	0	3	1
	Crash Rate	1.67	0.00	1.25	0.42
2003 Total Crashes		11	1	5	5
2003 Avg. Crash Rate		1.15	0.10	0.52	0.52
Daily Entering Vehicles = 26520					
2004-01		2	0	0	2
	Crash Rate	0.83	0.00	0.00	0.83
2004-02		0	0	0	0
	Crash Rate	0.00	0.00	0.00	0.00
2004-03		Quarter of Camera Installation (not included)			
2004 Total Crashes		2	0	0	2
2004 Avg. Crash Rate		0.41	0.00	0.00	0.41
2004-04		4	1	0	3
	Crash Rate	1.65	0.41	0.00	1.24
2004 Total Crashes		4	1	0	3
2004 Avg. Crash Rate		1.65	0.41	0.00	1.24
Daily Entering Vehicles = 36400					
2005-01		2	0	0	2
	Crash Rate	0.60	0.00	0.00	0.60
2005-02		1	0	0	1
	Crash Rate	0.30	0.00	0.00	0.30
2005-03		4	0	0	7
	Crash Rate	1.20	0.00	0.00	2.10
2005-04		2	0	0	2
	Crash Rate	0.60	0.00	0.00	0.60
2005 Total Crashes		9	0	0	12
2005 Avg. Crash Rate		0.67	0.00	0.00	0.90
Daily Entering Vehicles = 36400					
2006-01		0	0	0	0
	Crash Rate	0.00	0.00	0.00	0.00
2006-02		1	0	0	1
	Crash Rate	0.30	0.00	0.00	0.30
2006-03		2	0	0	2
	Crash Rate	0.60	0.00	0.00	0.60
2006-04		2	0	0	2
	Crash Rate	0.60	0.00	0.00	0.60
2006 Total Crashes		5	0	0	5
2006 Avg. Crash Rate		0.38	0.00	0.00	0.38
Crashes per Quarter Before		2.86	0.29	0.93	1.64
DEV per Quarter Before		2,571,425	2,571,425	2,571,425	2,571,425
Crashes per Quarter After		1.83	0.11	0.00	1.72
DEV per Quarter After		1,745,106	1,745,106	1,745,106	1,745,106
Before Crash Rate		1.11	0.11	0.36	0.64
After Crash Rate		1.05	0.06	0.00	0.98
% Change in Crash Rate		**-5.73%**	**-42.70%**	**-100.00%**	**53.99%**

Lincoln Avenue & Locust Street					
Year - Quarter		Total Recorded Crashes	Rear-End RLR Crash	Other RLR Crash	Not RLR Associated Crash
Daily Entering Vehicles = 20310					
2001-01		0	0	0	0
	Crash Rate	0.00	0.00	0.00	0.00
2001-02		1	0	1	0
	Crash Rate	0.54	0.00	0.54	0.00
2001-03		4	1	1	2
	Crash Rate	2.16	0.54	0.54	1.08
2001-04		5	1	1	3
	Crash Rate	2.70	0.54	0.54	1.62
2001 Total Crashes		10	2	3	5
2001 Avg. Crash Rate		1.35	0.27	0.40	0.67
Daily Entering Vehicles = 21350					
2002-01		1	1	0	0
	Crash Rate	0.51	0.51	0.00	0.00
2002-02		2	0	0	2
	Crash Rate	1.03	0.00	0.00	1.03
2002-03		2	0	0	2
	Crash Rate	1.03	0.00	0.00	1.03
2002-04		2	0	2	0
	Crash Rate	1.03	0.00	1.03	0.00
2002 Total Crashes		7	1	2	4
2002 Avg. Crash Rate		0.90	0.13	0.26	0.51
Daily Entering Vehicles = 21350					
2003-01		3	0	2	1
	Crash Rate	1.54	0.00	1.03	0.51
2003-02		2	0	1	1
	Crash Rate	1.03	0.00	0.51	0.51
2003-03		4	0	2	2
	Crash Rate	2.05	0.00	1.03	1.03
2003-04		2	0	2	0
	Crash Rate	1.03	0.00	1.03	0.00
2003 Total Crashes		11	0	7	4
2003 Avg. Crash Rate		1.41	0.00	0.90	0.51
Daily Entering Vehicles = 21350					
2004-01		3	0	2	1
	Crash Rate	1.54	0.00	1.03	0.51
2004-02		1	0	0	1
	Crash Rate	0.51	0.00	0.00	0.51
2004-03		7	1	1	5
	Crash Rate	3.59	0.51	0.51	2.57
2004-04		0	0	0	0
	Crash Rate	0.00	0.00	0.00	0.00
2004 Total Crashes		11	1	3	7
2004 Avg. Crash Rate		0.87	0.08	0.24	0.56
Daily Entering Vehicles = 17200					
2005-01		1	0	0	1
	Crash Rate	0.64	0.00	0.00	0.64
2005-02		2	0	0	2
	Crash Rate	1.27	0.00	0.00	1.27
2005-03		6	0	1	5
	Crash Rate	3.82	0.00	0.64	3.19
2005-04		5	1	1	3
	Crash Rate	3.19	0.64	0.64	1.91
2005 Total Crashes		14	1	2	11
2005 Avg. Crash Rate		2.23	0.16	0.32	1.75
Daily Entering Vehicles = 17200					
2006-01		3	1	1	1
	Crash Rate	1.91	0.64	0.64	0.64
2006-02		Quarter of Camera Installation (not included)			
2006 Total Crashes		3	1	1	1
2006 Avg. Crash Rate		1.91	0.64	0.64	0.64
2006-03		0	0	0	0
	Crash Rate	0.00	0.00	0.00	0.00
2006-04		1	0	0	1
	Crash Rate	0.64	0.00	0.00	0.64
2006 Total Crashes		1	0	0	1
2006 Avg. Crash Rate		0.32	0.00	0.00	0.32
Crashes per Quarter Before		2.67	0.29	0.86	1.52
DEV per Quarter Before		1,765,214	1,765,214	1,765,214	1,765,214
Crashes per Quarter After					
DEV per Quarter After					
Before Crash Rate		1.51	0.16	0.49	0.86
After Crash Rate					
% Change in Crash Rate					

Kimberly Road & Elmore Avenue					
Year - Quarter		Total Recorded Crashes	Rear-End RLR Crash	Other RLR Crash	Not RLR Associated Crash
Daily Entering Vehicles = 42700					
2001-01		4	1	0	3
	Crash Rate	1.03	0.26	0.00	0.77
2001-02		1	0	0	1
	Crash Rate	0.26	0.00	0.00	0.26
2001-03		5	4	0	1
	Crash Rate	1.28	1.03	0.00	0.26
2001-04		1	0	0	1
	Crash Rate	0.26	0.00	0.00	0.26
2001 Total Crashes		11	5	0	6
2001 Avg. Crash Rate		0.71	0.32	0.00	0.38
Daily Entering Vehicles = 53900					
2002-01		0	0	0	0
	Crash Rate	0.00	0.00	0.00	0.00
2002-02		3	0	2	1
	Crash Rate	0.61	0.00	0.41	0.20
2002-03		3	0	1	2
	Crash Rate	0.61	0.00	0.20	0.41
2002-04		4	1	1	2
	Crash Rate	0.81	0.20	0.20	0.41
2002 Total Crashes		10	1	4	5
2002 Avg. Crash Rate		0.51	0.05	0.20	0.25
Daily Entering Vehicles = 53600					
2003-01		1	0	0	1
	Crash Rate	0.20	0.00	0.00	0.20
2003-02		2	0	2	0
	Crash Rate	0.41	0.00	0.41	0.00
2003-03		2	0	2	0
	Crash Rate	0.41	0.00	0.41	0.00
2003-04		3	2	1	0
	Crash Rate	0.61	0.41	0.20	0.00
2003 Total Crashes		8	2	5	1
2003 Avg. Crash Rate		0.41	0.10	0.26	0.05
Daily Entering Vehicles = 54100					
2004-01		2	0	1	1
	Crash Rate	0.41	0.00	0.20	0.20
2004-02		5	0	2	3
	Crash Rate	1.01	0.00	0.41	0.61
2004-03		Quarter of Camera Installation (not included)			
2004 Total Crashes		7	0	3	4
2004 Avg. Crash Rate		0.70	0.00	0.30	0.40
2004-04		3	2	1	0
	Crash Rate	0.60	0.40	0.20	0.00
2004 Total Crashes		3	2	1	0
2004 Avg. Crash Rate		0.60	0.40	0.20	0.00
Daily Entering Vehicles = 14200					
2005-01		3	3	0	0
	Crash Rate	2.32	2.32	0.00	0.00
2005-02		8	3	2	3
	Crash Rate	6.17	2.32	1.54	2.32
2005-03		3	0	1	2
	Crash Rate	2.32	0.00	0.77	1.54
2005-04		2	1	0	1
	Crash Rate	1.54	0.77	0.00	0.77
2005 Total Crashes		16	7	3	6
2005 Avg. Crash Rate		3.08	1.35	0.57	1.15
Daily Entering Vehicles = 14200					
2006-01		4	3	0	1
	Crash Rate	3.09	2.32	0.00	0.77
2006-02		2	0	2	0
	Crash Rate	1.54	0.00	1.54	0.00
2006-03		4.00	2.00	0.00	2.00
	Crash Rate	3	2	0	2
2006-04		5.00	1.00	1.00	3.00
	Crash Rate	4	1	1	2
2006 Total Crashes		15.00	6.00	3.00	6.00
2006 Avg. Crash Rate		2.89	1.16	0.58	1.16
Crashes per Quarter Before		3.00	0.95	0.89	1.16
DEV per Quarter Before		4,129,303	4,129,303	4,129,303	4,129,303
Crashes per Quarter After		5.80	2.40	1.20	2.20
DEV per Quarter After		1,295,750	1,295,750	1,295,750	1,295,750
Before Crash Rate		0.73	0.23	0.22	0.28
After Crash Rate		4.48	1.85	0.93	1.70
% Change in Crash Rate		**516.12%**	**707.32%**	**327.41%**	**505.49%**

Elmore Avenue & 53rd Street					
Year - Quarter		Total Recorded Crashes	Rear-End RLR Crash	Other RLR Crash	Not RLR Associated Crash
Daily Entering Vehicles = 8734					
2001-01		6	4	0	2
	Crash Rate	7.53	5.02	0.00	2.51
2001-02		4	2	1	1
	Crash Rate	5.02	2.51	1.25	1.25
2001-03		5	1	1	3
	Crash Rate	6.27	1.25	1.25	3.76
2001-04		11	2	1	8
	Crash Rate	13.80	2.51	1.25	10.04
2001 Total Crashes		26	9	3	14
2001 Avg. Crash Rate		8.16	2.82	0.94	4.39
Daily Entering Vehicles = 33150					
2002-01		3	1	1	1
	Crash Rate	0.99	0.33	0.33	0.33
2002-02		6	3	0	3
	Crash Rate	1.98	0.99	0.00	0.99
2002-03		4	0	1	3
	Crash Rate	1.32	0.00	0.33	0.99
2002-04		8	2	1	5
	Crash Rate	2.64	0.66	0.33	1.65
2002 Total Crashes		21	6	3	12
2002 Avg. Crash Rate		1.74	0.50	0.25	0.99
Daily Entering Vehicles = 33150					
2003-01		10	8	0	2
	Crash Rate	3.31	2.64	0.00	0.66
2003-02		9	4	0	5
	Crash Rate	2.98	1.32	0.00	1.65
2003-03		1	0	1	0
	Crash Rate	0.33	0.00	0.33	0.00
2003-04		2	0	1	1
	Crash Rate	0.66	0.00	0.33	0.33
2003 Total Crashes		22	12	2	8
2003 Avg. Crash Rate		1.82	0.99	0.17	0.66
Daily Entering Vehicles = 33288					
2004-01		2	2	0	0
	Crash Rate	0.66	0.66	0.00	0.00
2004-02		5	3	0	2
	Crash Rate	1.65	0.99	0.00	0.66
2004-03	Quarter of Camera Installation (not included)				
2004 Total Crashes		7	5	0	2
2004 Avg. Crash Rate		1.15	0.82	0.00	0.32
2004-04		6	3	1	2
	Crash Rate	1.97	0.98	0.32	0.65
2004 Total Crashes		6	3	1	2
2004 Avg. Crash Rate		1.97	0.98	0.32	0.65
Daily Entering Vehicles = 26600					
2005-01		6	4	0	2
	Crash Rate	2.47	1.65	0.00	0.82
2005-02		6	3	0	3
	Crash Rate	2.47	1.24	0.00	1.24
2005-03		6	4	1	1
	Crash Rate	2.47	1.65	0.41	0.41
2005-04		6	1	0	5
	Crash Rate	2.47	0.41	0.00	2.05
2005 Total Crashes		24	12	1	11
2005 Avg. Crash Rate		2.47	1.23	0.10	1.13
Daily Entering Vehicles = 26600					
2006-01		6	3	1	2
	Crash Rate	2.47	1.24	0.41	0.82
2006-02		2	0	0	2
	Crash Rate	0.82	0.00	0.00	0.82
2006-03		4	2	1	1
	Crash Rate	1.65	0.82	0.41	0.41
2006-04		6	3	1	2
	Crash Rate	2.47	1.24	0.41	0.82
2006 Total Crashes		18	8	3	7
2006 Avg. Crash Rate		1.85	0.82	0.31	0.72
Crashes per Quarter Before		6.86	3.14	0.64	3.07
DEV per Quarter Before		2,607,143	2,607,143	2,607,143	2,607,143
Crashes per Quarter After		5.33	2.56	0.56	2.22
DEV per Quarter After		2,495,059	2,495,059	2,495,059	2,495,059
Before Crash Rate		2.63	1.21	0.25	1.18
After Crash Rate		2.14	1.02	0.22	0.89
% Change in Crash Rate		**-18.73%**	**-15.03%**	**-9.70%**	**-24.40%**

Locust Street & Brady Street				
Year - Quarter	Total Recorded Crashes	Rear-End RLR Crash	Other RLR Crash	Not RLR Associated Crash
Daily Entering Vehicles = 39000				
2001-01	6	1	2	3
Crash Rate	1.69	0.28	0.56	0.84
2001-02	3	0	1	2
Crash Rate	0.84	0.00	0.28	0.56
2001-03	5	0	2	3
Crash Rate	1.40	0.00	0.56	0.84
2001-04	1	0	1	0
Crash Rate	0.28	0.00	0.28	0.00
2001 Total Crashes	15	1	6	8
2001 Avg. Crash Rate	1.05	0.07	0.42	0.56
Daily Entering Vehicles = 41700				
2002-01	3	0	0	3
Crash Rate	0.79	0.00	0.00	0.79
2002-02	4	0	0	4
Crash Rate	1.05	0.00	0.00	1.05
2002-03	10	2	3	5
Crash Rate	2.63	0.53	0.79	1.31
2002-04	1	1	0	0
Crash Rate	0.26	0.26	0.00	0.00
2002 Total Crashes	18	3	3	12
2002 Avg. Crash Rate	1.18	0.20	0.20	0.79
Daily Entering Vehicles = 54221				
2003-01	1	0	0	1
Crash Rate	0.20	0.00	0.00	0.20
2003-02	1	0	0	1
Crash Rate	0.20	0.00	0.00	0.20
2003-03	3	1	1	1
Crash Rate	0.61	0.20	0.20	0.20
2003-04	3	2	1	0
Crash Rate	0.61	0.40	0.20	0.00
2003 Total Crashes	8	3	2	3
2003 Avg. Crash Rate	0.40	0.15	0.10	0.15
Daily Entering Vehicles = 41800				
2004-01	5	2	1	2
Crash Rate	1.31	0.52	0.26	0.52
2004-02	3	0	1	2
Crash Rate	0.79	0.00	0.26	0.52
2004-03	Quarter of Camera Installation (not included)			
2004 Total Crashes	8	2	2	4
2004 Avg. Crash Rate	1.04	0.26	0.26	0.52
2004-04	3	0	1	2
Crash Rate	0.78	0.00	0.26	0.52
2004 Total Crashes	3	0	1	2
2004 Avg. Crash Rate	0.78	0.00	0.26	0.52
Daily Entering Vehicles = 15700				
2005-01	4	1	0	3
Crash Rate	2.79	0.70	0.00	2.09
2005-02	6	2	1	3
Crash Rate	4.19	1.40	0.70	2.09
2005-03	2	1	1	0
Crash Rate	1.40	0.70	0.70	0.00
2005-04	1	1	0	0
Crash Rate	0.69	0.69	0.00	0.00
2005 Total Crashes	13	5	2	6
2005 Avg. Crash Rate	2.26	0.87	0.47	1.40
Daily Entering Vehicles = 15700				
2006-01	2	1	1	0
Crash Rate	1.40	0.70	0.70	0.00
2006-02	3	0	1	2
Crash Rate	2.09	0.00	0.70	1.40
2006-03	7	2	3	2
Crash Rate	4.89	1.40	2.09	1.40
2006-04	4	2	1	1
Crash Rate	2.79	1.40	0.70	0.70
2006 Total Crashes	16	5	6	5
2006 Avg. Crash Rate	2.79	0.87	1.05	0.87
Crashes per Quarter Before	3.86	0.71	1.00	2.14
DEV per Quarter Before	4,334,923	4,334,923	4,334,923	4,334,923
Crashes per Quarter After	3.56	1.11	1.00	1.44
DEV per Quarter After	1,697,250	1,697,250	1,697,250	1,697,250
Before Crash Rate	0.89	0.16	0.23	0.49
After Crash Rate	2.09	0.65	0.59	0.85
% Change in Crash Rate	**135.44%**	**297.30%**	**155.41%**	**72.16%**

Locust Street & Hickory Grove Road				
Year - Quarter	**Total Recorded Crashes**	**Rear-End RLR Crash**	**Other RLR Crash**	**Not RLR Associated Crash**
Daily Entering Vehicles = 35150				
2001-01	1	0	0	1
Crash Rate	0.31	0.00	0.00	0.31
2001-02	4	2	1	1
Crash Rate	1.25	0.62	0.31	0.31
2001-03	2	0	0	2
Crash Rate	0.62	0.00	0.00	0.62
2001-04	1	1	0	0
Crash Rate	0.31	0.31	0.00	0.00
2001 Total Crashes	8	3	1	4
2001 Avg. Crash Rate	0.62	0.23	0.08	0.31
Daily Entering Vehicles = 35800				
2002-01	1	1	0	0
Crash Rate	0.31	0.31	0.00	0.00
2002-02	1	0	0	1
Crash Rate	0.31	0.00	0.00	0.31
2002-03	5	1	1	3
Crash Rate	1.53	0.31	0.31	0.92
2002-04	4	0	3	1
Crash Rate	1.22	0.00	0.92	0.31
2002 Total Crashes	11	2	4	5
2002 Avg. Crash Rate	0.84	0.15	0.31	0.38
Daily Entering Vehicles = 35800				
2003-01	6	3	2	1
Crash Rate	1.84	0.92	0.61	0.31
2003-02	3	1	0	2
Crash Rate	0.92	0.31	0.00	0.61
2003-03	6	0	0	6
Crash Rate	1.84	0.00	0.00	1.84
2003-04	5	1	1	3
Crash Rate	1.53	0.31	0.31	0.92
2003 Total Crashes	20	5	3	12
2003 Avg. Crash Rate	1.53	0.38	0.23	0.92
Daily Entering Vehicles = 35800				
2004-01	3	1	0	2
Crash Rate	0.92	0.31	0.00	0.61
2004-02	2	0	0	2
Crash Rate	0.61	0.00	0.00	0.61
2004-03	Quarter of Camera Installation (not included)			
2004 Total Crashes	5	1	0	4
2004 Avg. Crash Rate	0.76	0.15	0.00	0.61
2004-04	6	0	1	5
Crash Rate	1.83	0.00	0.30	1.53
2004 Total Crashes	6	0	1	5
2004 Avg. Crash Rate	1.83	0.00	0.30	1.53
Daily Entering Vehicles = 35800				
2005-01	2	1	0	1
Crash Rate	0.61	0.31	0.00	0.31
2005-02	2	0	1	1
Crash Rate	0.61	0.00	0.31	0.31
2005-03	6	2	0	4
Crash Rate	1.84	0.61	0.00	1.22
2005-04	3	0	1	2
Crash Rate	0.92	0.00	0.30	0.61
2005 Total Crashes	13	3	2	8
2005 Avg. Crash Rate	1.00	0.31	0.15	0.61
Daily Entering Vehicles = 35800				
2006-01	2	0	1	1
Crash Rate	0.61	0.00	0.31	0.31
2006-02	6	4	0	2
Crash Rate	1.84	1.22	0.00	0.61
2006-03	3	1	0	2
Crash Rate	0.92	0.31	0.00	0.61
2006-04	4	2	1	1
Crash Rate	1.22	0.61	0.31	0.31
2006 Total Crashes	15	7	2	6
2006 Avg. Crash Rate	1.15	0.54	0.15	0.46
Crashes per Quarter Before	4.21	1.07	0.71	2.43
DEV per Quarter Before	3,483,143	3,483,143	3,483,143	3,483,143
Crashes per Quarter After	3.78	1.11	0.56	2.11
DEV per Quarter After	3,266,750	3,266,750	3,266,750	3,266,750
Before Crash Rate	1.21	0.31	0.21	0.70
After Crash Rate	1.16	0.34	0.17	0.65
% Change in Crash Rate	**-4.42%**	**10.57%**	**-17.07%**	**-7.31%**

North Division Street & Central Park Avenue				
Year - Quarter	**Total Recorded Crashes**	**Rear-End RLR Crash**	**Other RLR Crash**	**Not RLR Associated Crash**
Daily Entering Vehicles = 28400				
2001-01	1	0	0	1
Crash Rate	0.39	0.00	0.00	0.39
2001-02	1	0	1	0
Crash Rate	0.39	0.00	0.39	0.00
2001-03	3	0	0	3
Crash Rate	1.16	0.00	0.00	1.16
2001-04	2	1	0	1
Crash Rate	0.77	0.39	0.00	0.39
2001 Total Crashes	7	1	1	5
2001 Avg. Crash Rate	0.68	0.10	0.10	0.48
Daily Entering Vehicles = 33500				
2002-01	1	1	0	0
Crash Rate	0.33	0.33	0.00	0.00
2002-02	1	0	1	0
Crash Rate	0.33	0.00	0.33	0.00
2002-03	1	0	1	0
Crash Rate	0.33	0.00	0.33	0.00
2002-04	2	0	0	2
Crash Rate	0.65	0.00	0.00	0.65
2002 Total Crashes	5	1	2	2
2002 Avg. Crash Rate	0.41	0.08	0.16	0.16
Daily Entering Vehicles = 33500				
2003-01	3	0	2	1
Crash Rate	0.98	0.00	0.65	0.33
2003-02	2	0	2	0
Crash Rate	0.65	0.00	0.65	0.00
2003-03	2	1	0	1
Crash Rate	0.65	0.33	0.00	0.33
2003-04	1	0	1	0
Crash Rate	0.33	0.00	0.33	0.00
2003 Total Crashes	8	1	5	2
2003 Avg. Crash Rate	0.65	0.08	0.41	0.16
Daily Entering Vehicles = 33500				
2004-01	4	1	2	1
Crash Rate	1.31	0.33	0.65	0.33
2004-02	2	0	0	2
Crash Rate	0.65	0.00	0.00	0.65
2004-03	Quarter of Camera Installation (not included)			
2004 Total Crashes	6	1	2	3
2004 Avg. Crash Rate	0.98	0.16	0.32	0.49
2004-04	0	0	0	0
Crash Rate	0.00	0.00	0.00	0.00
2004 Total Crashes	0	0	0	0
2004 Avg. Crash Rate	0.00	0.00	0.00	0.00
Daily Entering Vehicles = 14700				
2005-01	4	0	1	3
Crash Rate	2.98	0.00	0.75	2.24
2005-02	6	2	3	1
Crash Rate	4.47	1.49	2.24	0.75
2005-03	0	0	0	0
Crash Rate	0.00	0.00	0.00	0.00
2005-04	1	0	0	1
Crash Rate	0.74	0.00	0.00	0.74
2005 Total Crashes	11	2	4	5
2005 Avg. Crash Rate	2.05	0.37	0.74	0.93
Daily Entering Vehicles = 14700				
2006-01	2	1	1	0
Crash Rate	1.49	0.75	0.75	0.00
2006-02	1	1	0	0
Crash Rate	0.75	0.75	0.00	0.00
2006-03	4	2	0	2
Crash Rate	2.98	1.49	0.00	1.49
2006-04	3	1	2	0
Crash Rate	2.24	0.75	1.49	0.00
2006 Total Crashes	10	5	3	2
2006 Avg. Crash Rate	1.86	0.93	0.56	0.37
Crashes per Quarter Before	2.36	0.36	1.00	1.00
DEV per Quarter Before	3,142,259	3,142,259	3,142,259	3,142,259
Crashes per Quarter After	2.33	0.78	0.78	0.78
DEV per Quarter After	1,531,986	1,531,986	1,531,986	1,531,986
Before Crash Rate	0.75	0.11	0.32	0.32
After Crash Rate	1.52	0.51	0.51	0.51
% Change in Crash Rate	**103.04%**	**346.68%**	**59.53%**	**59.53%**

Pine Street & Kimberly Road				
Year - Quarter	Total Recorded Crashes	Rear-End RLR Crash	Other RLR Crash	Not RLR Associated Crash
Daily Entering Vehicles = 26315				
2001-01	10	1	4	5
Crash Rate	2.42	0.24	0.97	1.21
2001-02	4	1	2	1
Crash Rate	0.97	0.24	0.48	0.24
2001-03	2	0	0	2
Crash Rate	0.48	0.00	0.00	0.48
2001-04	7	2	1	4
Crash Rate	1.69	0.48	0.24	0.97
2001 Total Crashes	23	4	7	12
2001 Avg. Crash Rate	1.39	0.24	0.42	0.72
Daily Entering Vehicles = 24115				
2002-01	8	1	4	3
Crash Rate	1.84	0.23	0.92	0.69
2002-02	9	3	4	2
Crash Rate	2.07	0.69	0.92	0.46
2002-03	2	0	2	0
Crash Rate	0.46	0.00	0.46	0.00
2002-04	7	1	3	3
Crash Rate	1.61	0.23	0.69	0.69
2002 Total Crashes	26	5	13	8
2002 Avg. Crash Rate	1.50	0.29	0.75	0.46
Daily Entering Vehicles = 12100				
2003-01	5	1	1	3
Crash Rate	1.61	0.32	0.32	0.96
2003-02	5	0	3	2
Crash Rate	1.61	0.00	0.96	0.64
2003-03	5	1	2	2
Crash Rate	1.61	0.32	0.64	0.64
2003-04	7	1	4	2
Crash Rate	2.25	0.32	1.29	0.64
2003 Total Crashes	22	3	10	9
2003 Avg. Crash Rate	1.77	0.24	0.80	0.72
Daily Entering Vehicles = 12100				
2004-01	7	2	4	1
Crash Rate	2.22	0.64	1.27	0.32
2004-02	1	1	0	0
Crash Rate	0.32	0.32	0.00	0.00
2004-03	Quarter of Camera Installation (not included)			
2004 Total Crashes	8	3	4	1
2004 Avg. Crash Rate	3.62	1.35	1.81	0.45
2004-04	7	0	4	3
Crash Rate	6.33	0.00	3.62	2.71
2004 Total Crashes	7	0	4	5
2004 Avg. Crash Rate	6.33	0.00	3.62	0.32
Daily Entering Vehicles = 12100				
2005-01	5	1	1	3
Crash Rate	1.59	0.32	0.32	0.95
2005-02	6	2	2	2
Crash Rate	1.91	0.64	0.64	0.64
2005-03	6	2	1	3
Crash Rate	1.91	0.64	0.32	0.95
2005-04	6	0	0	6
Crash Rate	5.43	0.0	0.0	5.43
2005 Total Crashes	23	5	4	14
2005 Avg. Crash Rate	5.20	0.53	0.42	3.16
Daily Entering Vehicles = 12100				
2006-01	5	1	1	3
Crash Rate	1.59	0.32	0.32	0.95
2006-02	1	0	0	1
Crash Rate	0.32	0.00	0.00	0.32
2006-03	1	0	0	1
Crash Rate	0.32	0.00	0.00	0.32
2006-04	3	2	1	0
Crash Rate	0.95	0.64	0.32	0.00
2006 Total Crashes	10	3	2	5
2006 Avg. Crash Rate	0.79	0.24	0.16	0.40
Crashes per Quarter Before	2.21	0.29	0.93	1.00
DEV per Quarter Before	1,866,845	1,866,845	1,866,845	1,866,845
Crashes per Quarter After	2.67	0.44	1.00	1.22
DEV per Quarter After	1,104,125	1,104,125	1,104,125	1,104,125
Before Crash Rate	1.19	0.15	0.50	0.54
After Crash Rate	2.42	0.40	0.91	1.11
% Change in Crash Rate	**103.62%**	**163.01%**	**82.09%**	**106.65%**

APPENDIX C: CLIVE VIOLATION STATISTICAL MODEL RESULTS

The GLIMMIX Procedure

Type III Tests of Fixed Effects

Effect	Num DF	Den DF	F Value	Pr > F
Camera	1	166	78.40	<.0001
Movement	2	166	412.35	<.0001

Figure C-1: Test of fixed effects.

Camera Least Squares Means

Camera	Estimate	Standard Error	DF	t Value	Pr > |t|	Alpha	Lower	Upper
0	-4.2417	0.1433	166	-29.59	<.0001	0.05	-4.5247	-3.9587
1	-7.4639	0.3354	166	-22.25	<.0001	0.05	-8.1261	-6.8018

Figure C-2: Estimation of parameter values for camera presence.

Differences of Camera Least Squares Means

Camera	Camera	Estimate	Standard Error	DF	t Value	Pr > |t|	Adj P
0	1	3.2223	0.3639	166	8.85	<.0001	<.0001

Figure C-3: Comparison of level for camera.

Movement Least Squares Means

Movement	Estimate	Standard Error	DF	t Value	Pr > |t|	Alpha	Lower	Upper
1	-5.7698	0.1919	166	-30.06	<.0001	0.05	-6.1488	-5.3909
2	-7.1128	0.1943	166	-36.61	<.0001	0.05	-7.4963	-6.7292
3	-4.6758	0.1839	166	-25.42	<.0001	0.05	-5.0389	-4.3127

Figure C-4: Estimation of parameter values for movements.

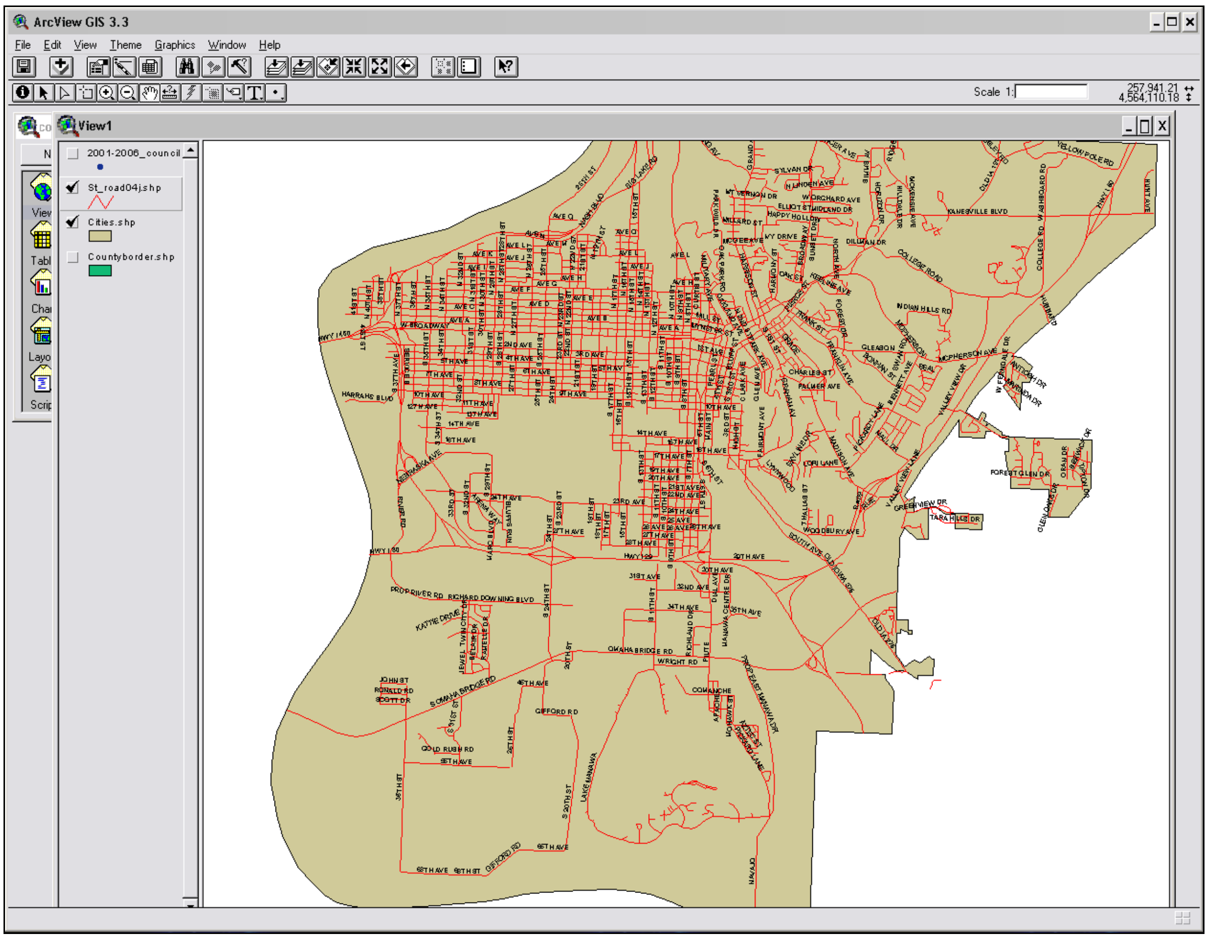
Differences of Movement Least Squares Means

Movement	Movement	Estimate	Standard Error	DF	t Value	Pr > |t|	Adj P	Alpha
1	2	1.3429	0.1029	166	13.06	<.0001	<.0001	0.05
1	3	-1.0940	0.07948	166	-13.76	<.0001	<.0001	0.05

Figure C-5: Pairwise comparison of movement levels.

APPENDIX D: COUNCIL BLUFFS AND DAVENPORT STEPS TO DETERMINE DEV USING GIS

To determine the exposure rate used for the crash rate equation, the daily entering vehicle count was needed. With the aid of ArcView and the Iowa DOT's state road, intersection, and city databases, a GIS project for Council Bluffs and Davenport was created. As illustrated in Figure D-1, a GIS map of Council Bluffs was created that shows the street network (red lines) and labels (black lettering) within the city limits (tan area).



FigureD-1. ArcView GIS image of Council Bluffs.

With a general map created and the rest of the state road network and city data removed through the quarry builder in ArcView, an analysis for Council Bluffs and Davenport could be performed within the respective city limits for 2001 through 2005.

A statewide intersection database was developed for Iowa based on the 1999 GIMS snapshot linework from the Iowa DOT. This database represents the intersection of any location where 3 or more approaches join and is shown in Figure D-2. Intersection databases were matched with 2001 through 2005 road network shape files and each year was treated as a separate analysis.

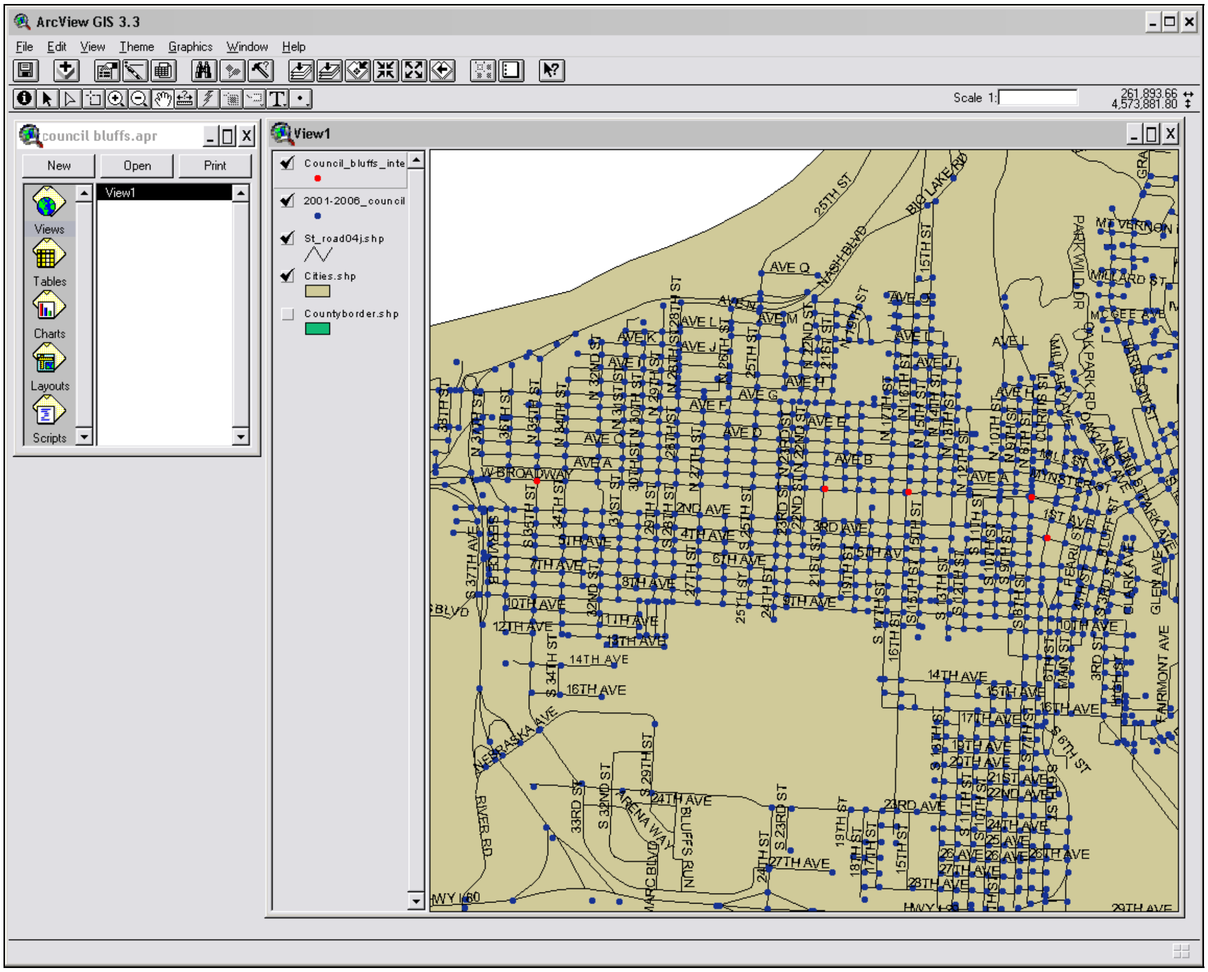


Figure D-2. Camera and control intersection point overlay.

As shown in Figure D-2, the blue dots represent an intersection where three or more line segments meet. The red dots shown represent the signalized intersections in Council Bluffs where RLR cameras are currently located.

To find the change in DEV for the specified camera enforced and control intersections, it was determined to ultimately combine the data for the four years into one or two shape files. The first step was to determine if the road network shape files for 2001 through 2005 lined up with each other. The results are illustrated in Figure D-3.

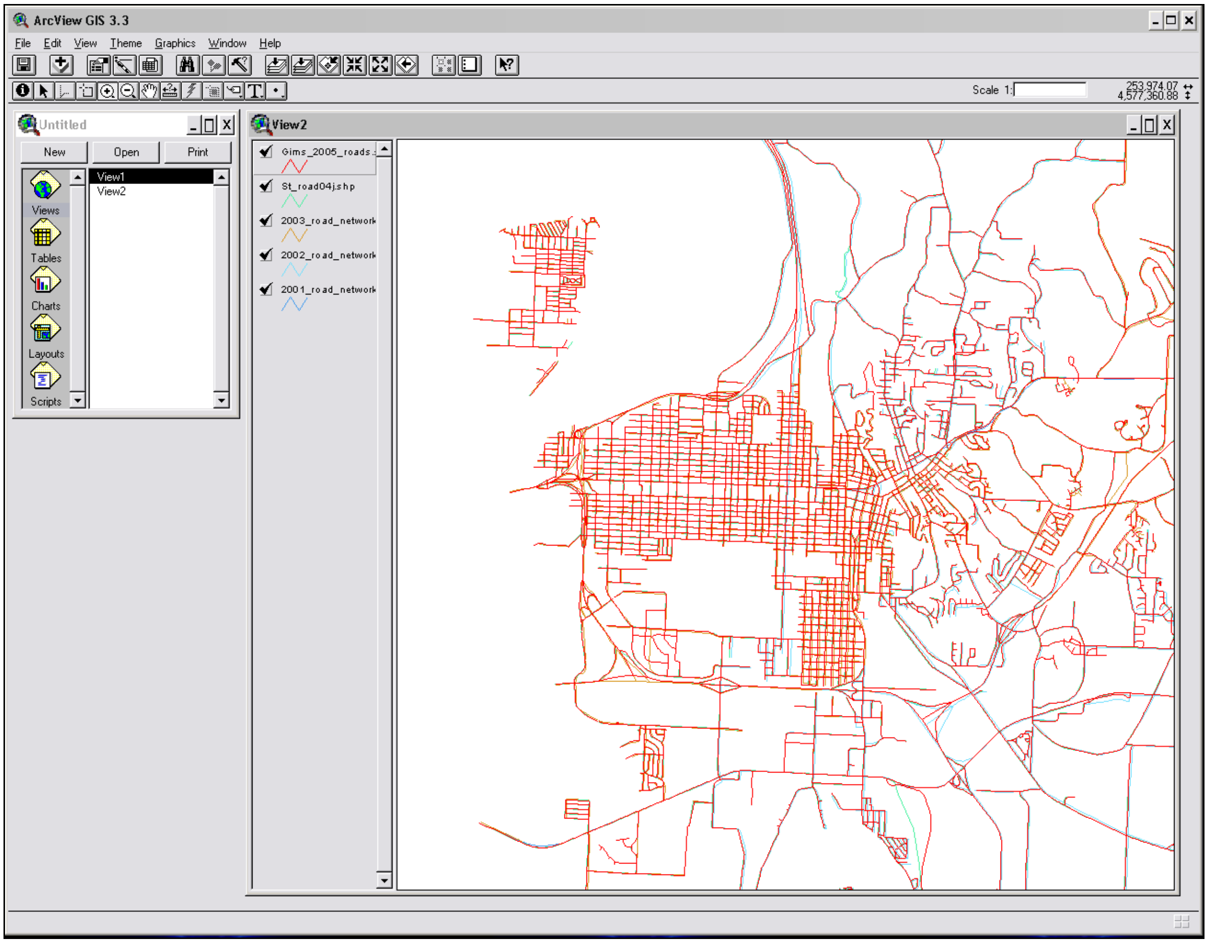
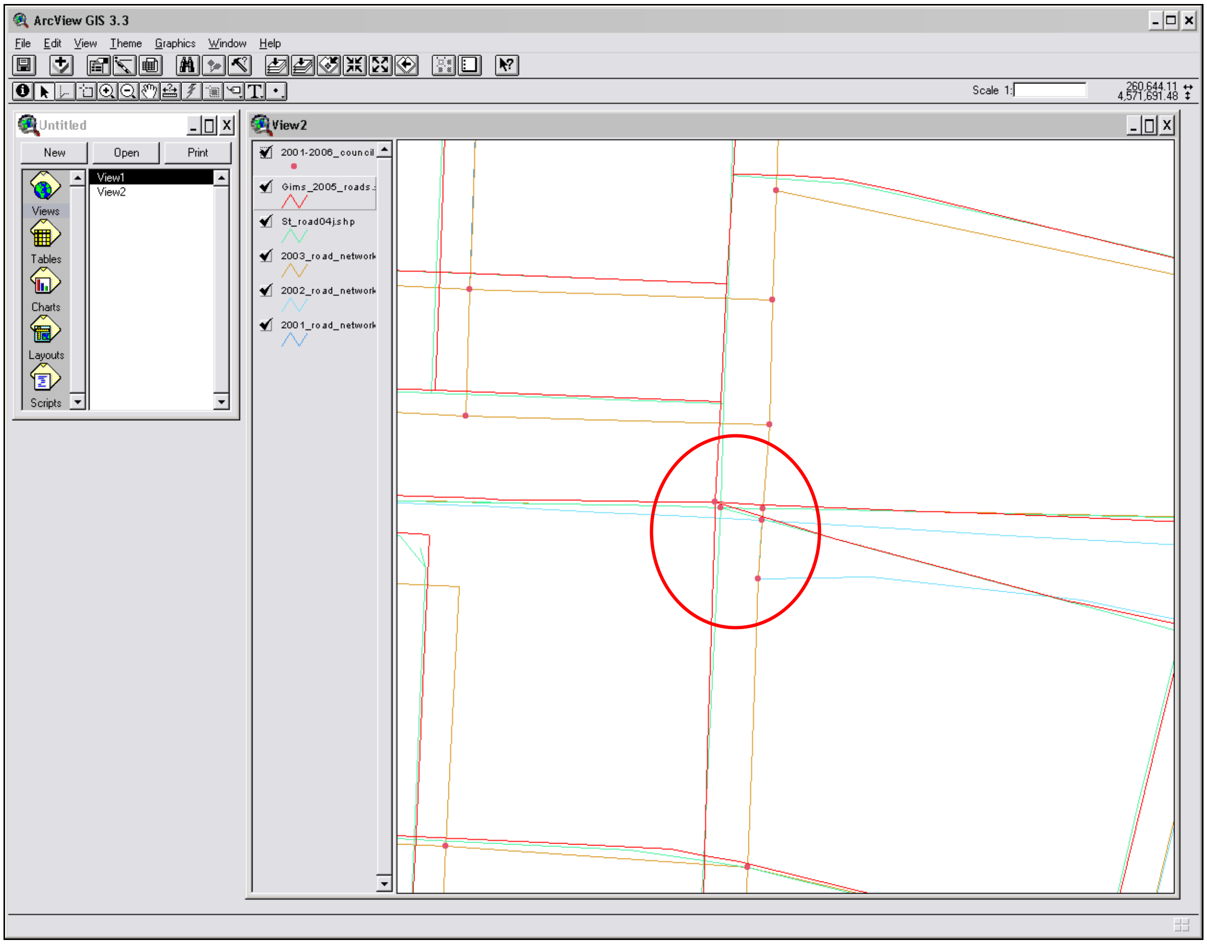


Figure D-3. Combined 2001 - 2005 state road networks.

As shown, each road network theme listed under the title "View2" has a corresponding color, and all of the themes are turned on. The resulting image illustrated in Figure D-3 indicates that many of the roads were close to matching, while other roads were hundreds of feet to miles off due to road reconstruction and known system changes or errors year to year. To determine how far the road network and intersection points were off, the road network and intersection point shape files were all loaded and turned on. The results can be seen in Figure D-4.



FigureD-4. Combined 2001 - 2005 road network and intersection mismatched points and segments.

As illustrated in Figure D-4, most of the intersection points and corresponding road networks were not exact. Within the red circle, in these 5 red dots represent the intersection points for each of the years from 2001 through 2005. It was determined by the research team that the script to find the yearly DEV for each of the points within the red circle would be run separately. The script entitled "get AADT" created by Dr. Shauna Hallmark in 2003 was loaded into ArcView and is shown in Figure D-5.

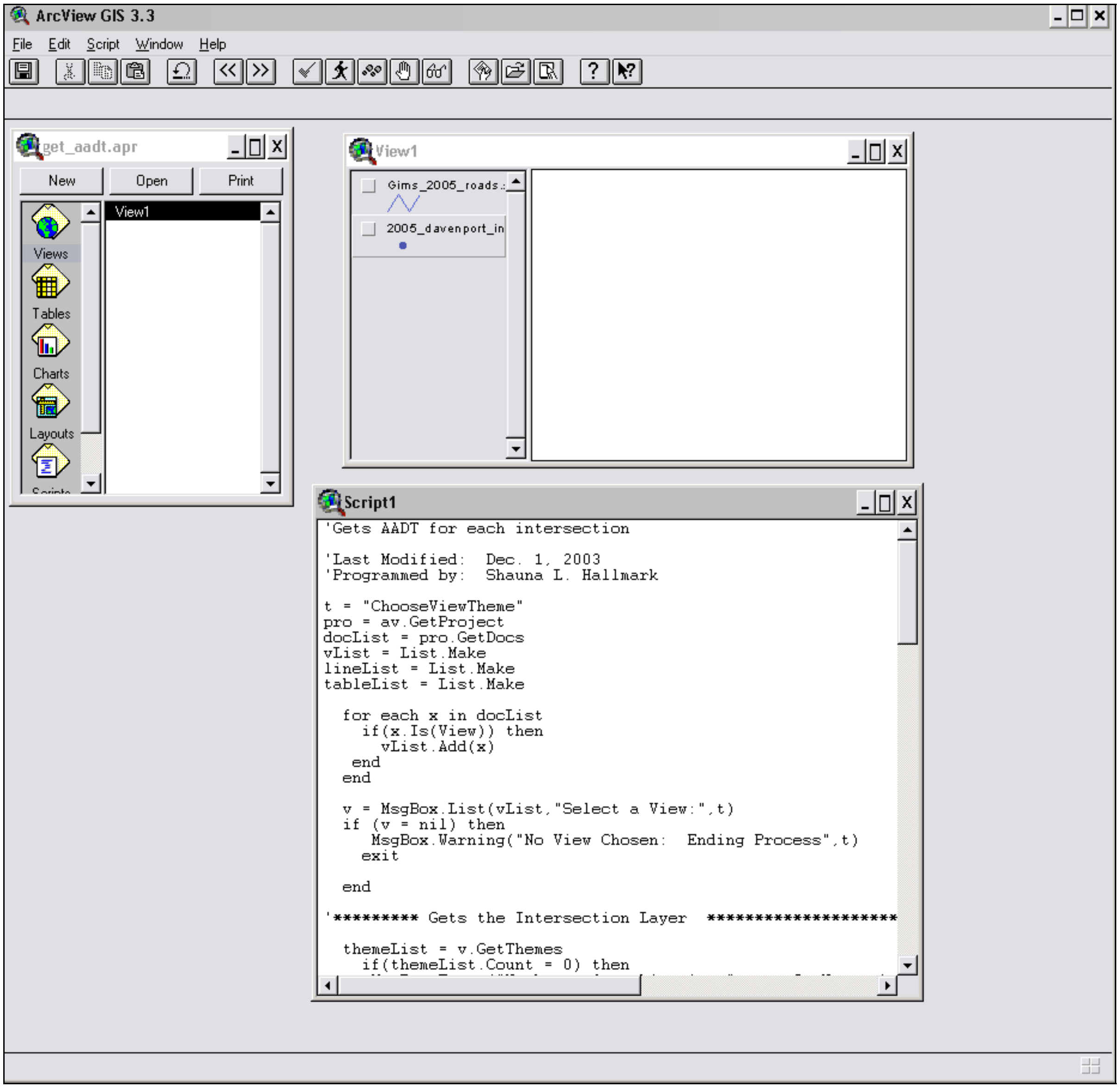


Figure D-5. Running the "get AADT" script for 2005 road network and intersection points.

As illustrated in Figure D-5, the script used was specifically programmed for ArcView and the Iowa DOT's database of road network and intersection shape files. The script is written to find the DEV for an intersection point by gathering the data of segments that are within a 5 meter radius of the intersection point. After running the script for each year, it was found that many of the intersections in Council Bluffs and Davenport resulted in 0 daily entering vehicles when the research team knew that vehicles were entering the intersection. Upon further investigation, it was found that not only did the 2001 through 2005 road network shape files not line up (as shown in D-4), but the intersection points did not lie within 5 meters of the road segments as shown in D-6.

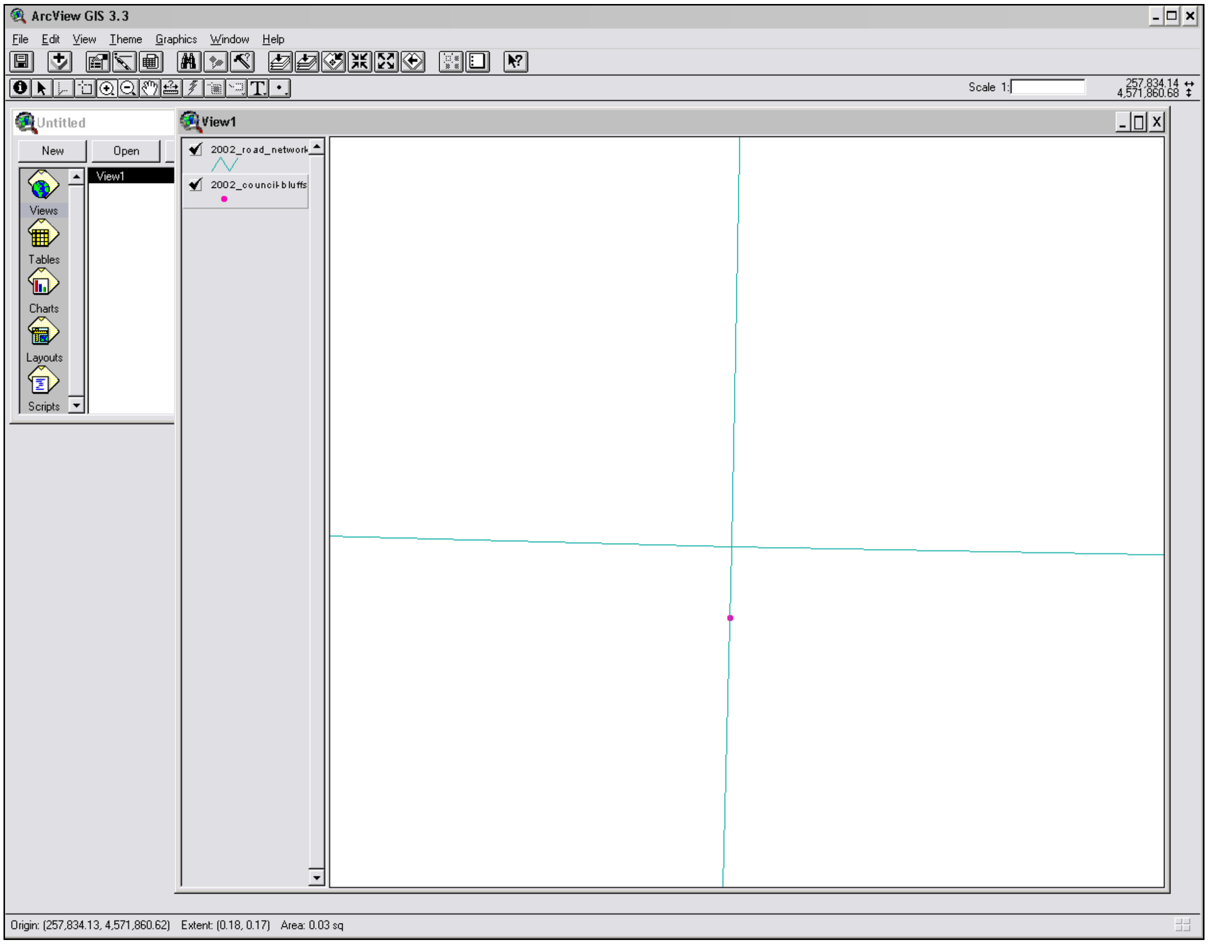


Figure D-6. 2002 intersection point mismatch with the 2002 road network shape file.

As illustrated in Figure D-6, the pink dot represents the intersection point of Broadway and 21st Street in Council Bluffs. It was found that because the pink dot was not within 5 meters of the actual intersection (the intersection of the blue lines), the script would not be able to find the segment's AADT and would report a 0 for DEV. To fix this problem, the editing feature in ArcView was used to move the intersection point. To move the intersection point within 5 meters of the road segments, the view was zoomed in as close as possible and intersection was moved to the point where the road segments crossed. The script was then performed again for each year, resulting in a DEV for the specified intersections. Once this task was completed, the shape files with the yearly DEV were combined as shown in Figure D-7.

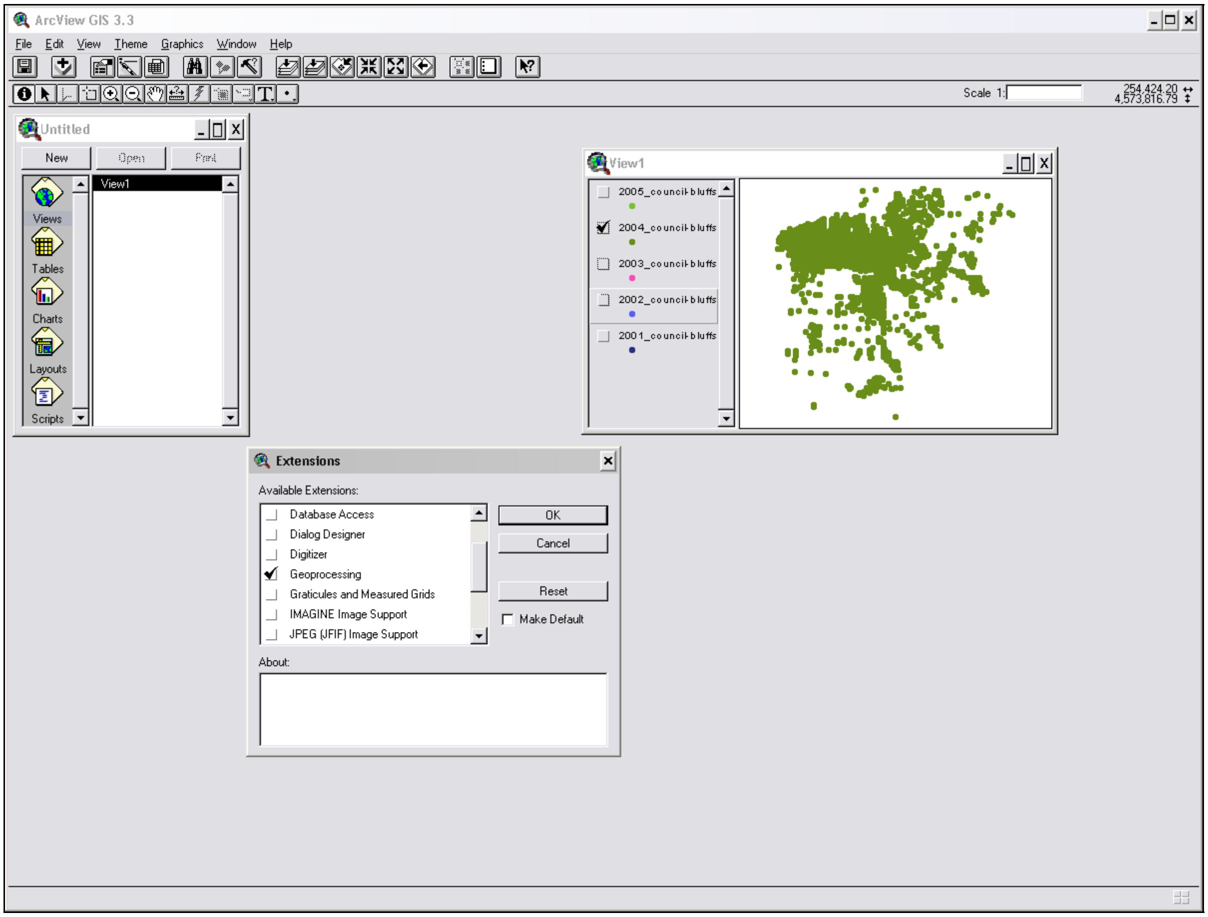
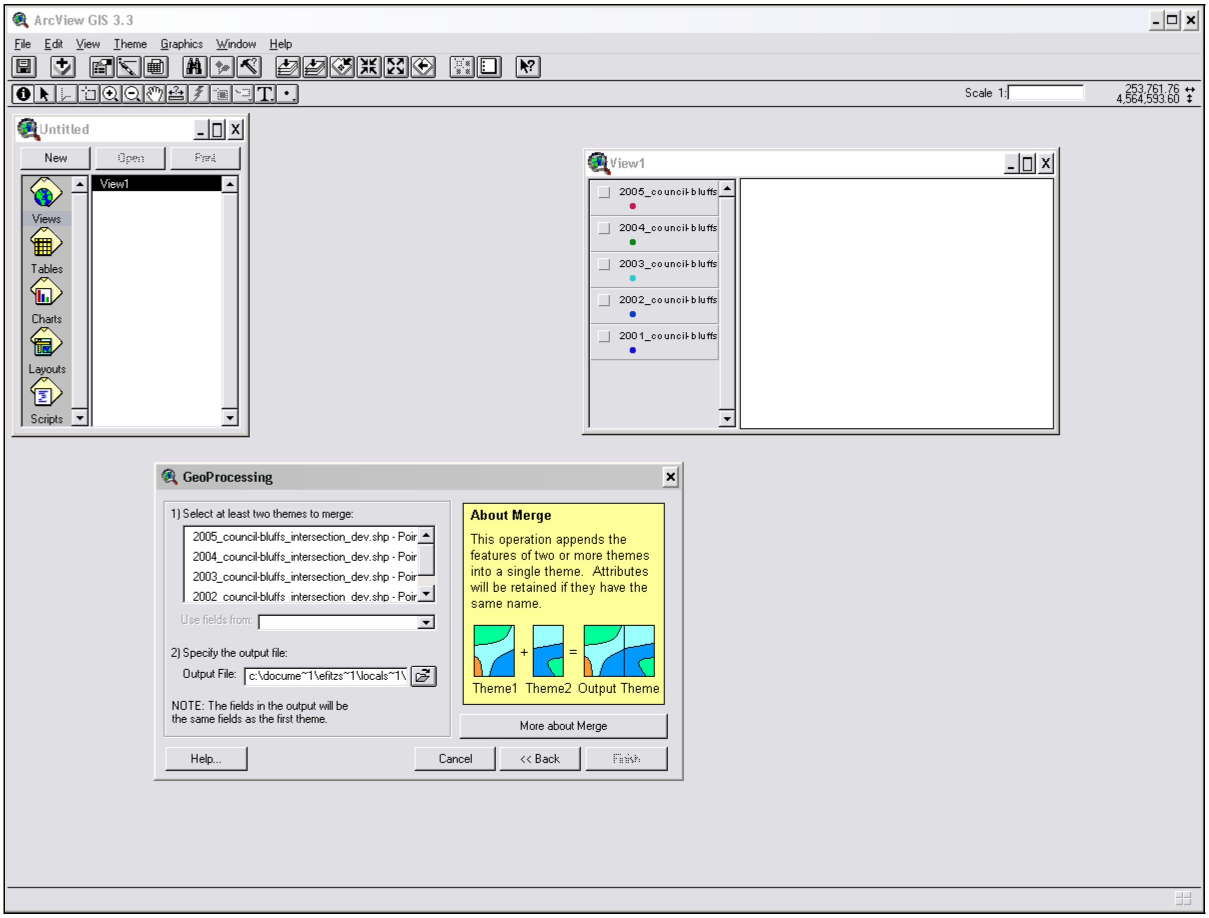


Figure D-7. Changing each post-script intersection shape file's extension to "Geoprocessing"

As illustrated in Figure D-7, each yearly intersection shape file's extension needed to be changed to Geoprocessing which enabled the feature to merge all of the intersection data together. Once the shape file extensions were changed, the merge feature under the Geoprocessing option was performed and is shown in Figure D-8.



FigureD-8. Merging the post-script intersection shapefiles to one theme.

As shown in Figure D-8, the merge feature allows one shape file to be created out of the five separate themes which included the DEV for each year. By creating a shape file with all of the combined themes and data, this file would be able to give the DEV for each year with one click as shown in Figure D-9.

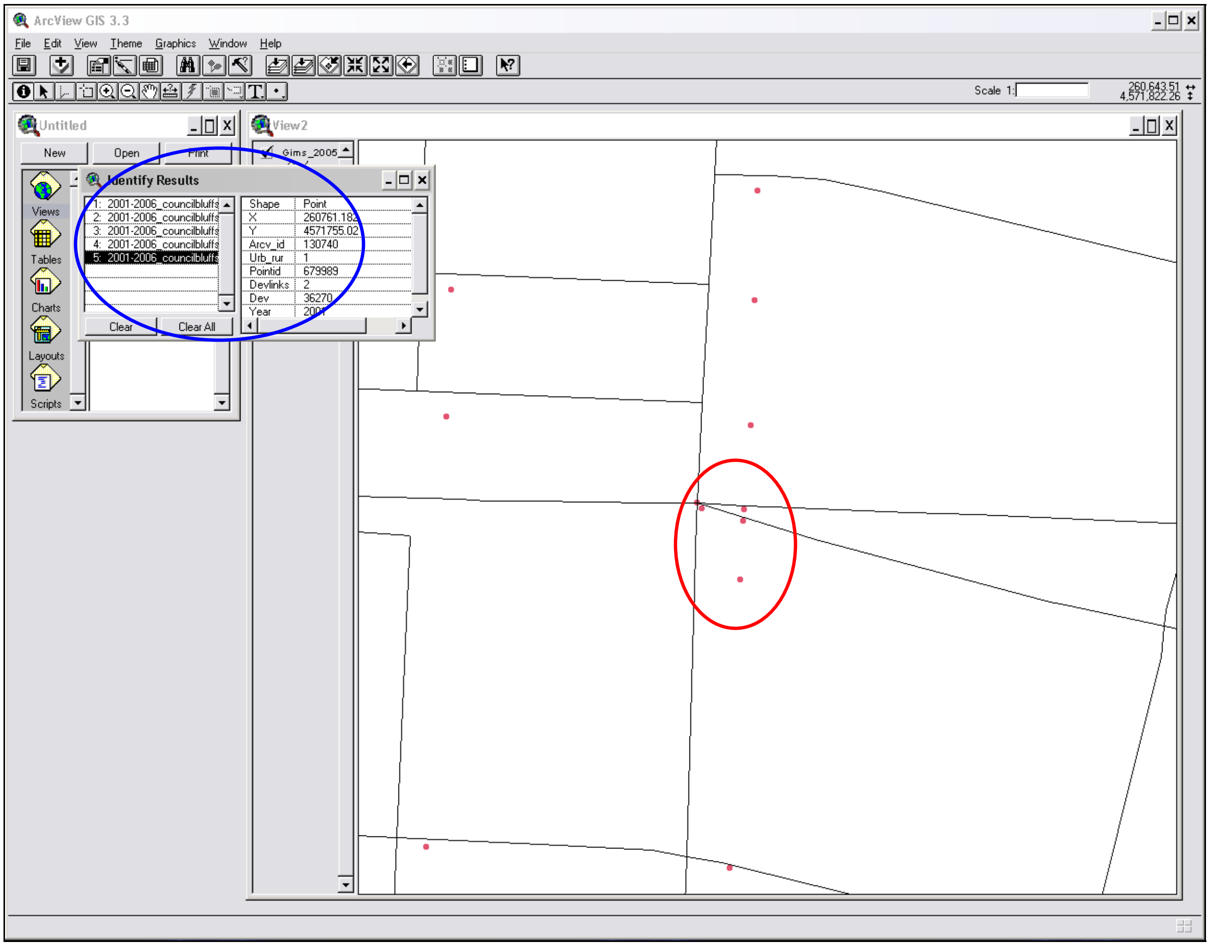
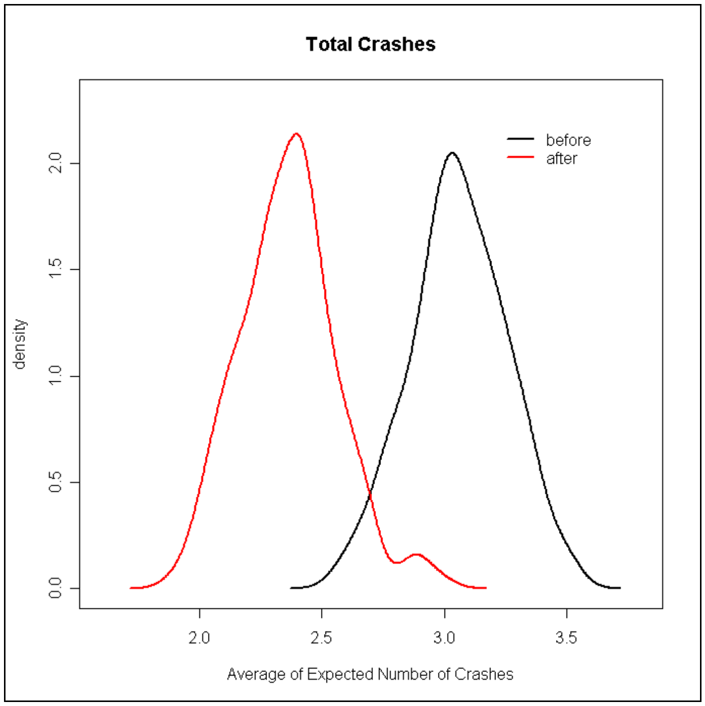
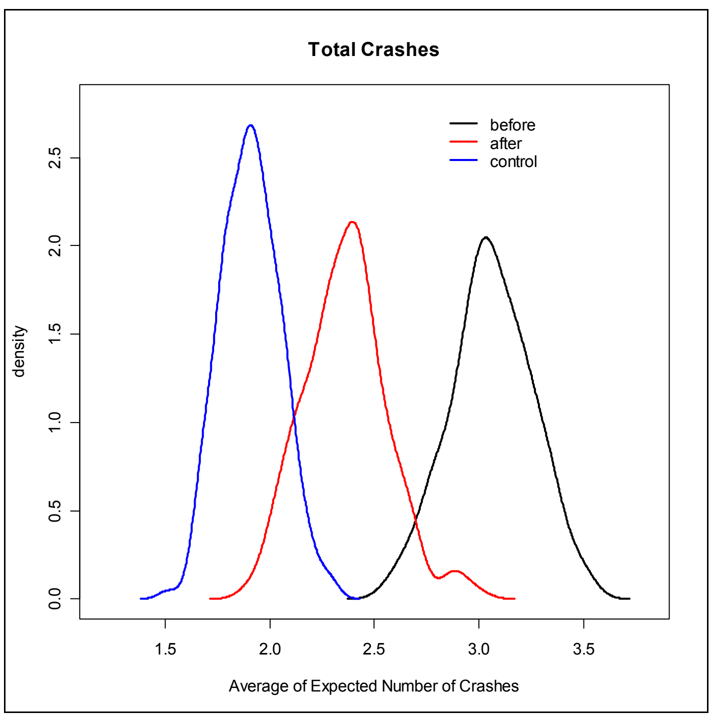


Figure D-9. Post-merge intersection theme and 2005 road network.

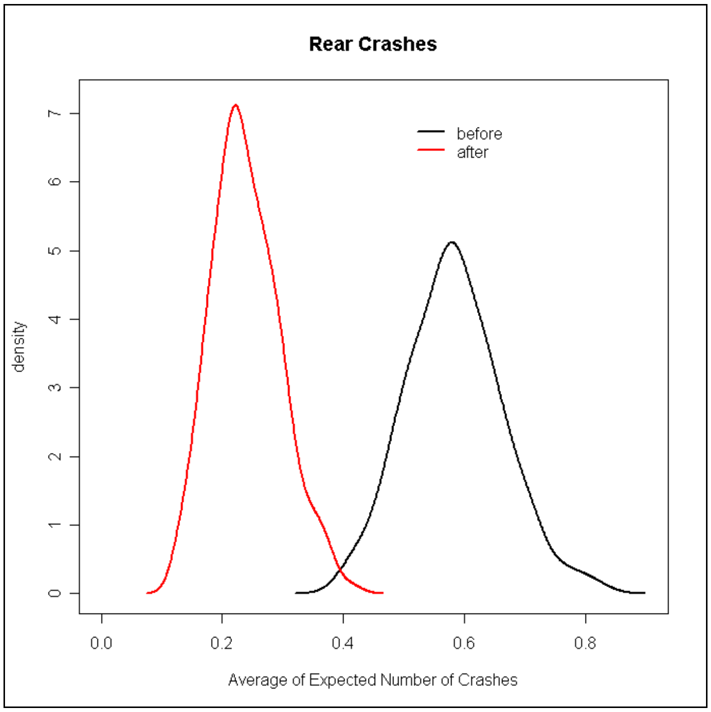
As illustrated in Figure D-9, the intersection points for 2001 through 2005 are shown as red dots. The red circle represents all of the intersection points for 2001 through 2005 for the intersection of Kanesville Boulevard and 8th Street. For reference purposes the 2005 road network shape file was loaded to find the intersection. Using the ArcView identity tool, the intersection point closest to where the road segments join was selected. Once the intersection point was selected, the "Identify Results" box appeared which had the 5 years listed on the left side and the DEV for the year selected on the right side as shown within the blue circle. Depending on what road network shape file was loaded, any point within the red circle could have been selected to get the same identity results.

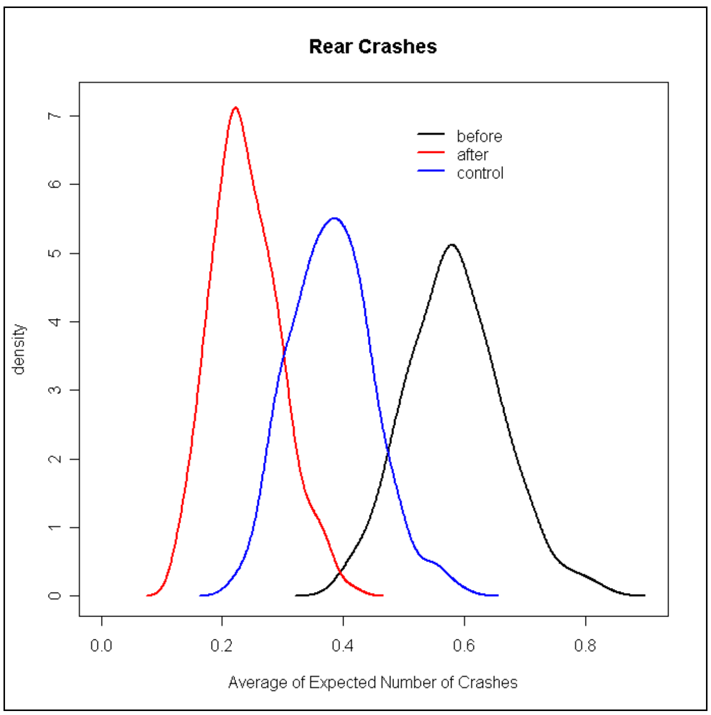
APPENDIX E: COUNCIL BLUFFS BAYESIAN MODEL CHARTS FOR EACH CRASH SUBGROUP



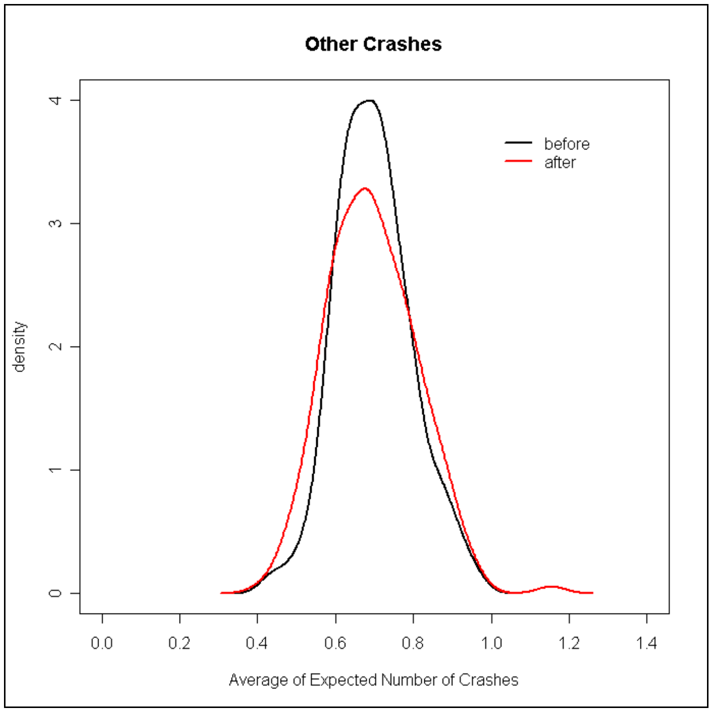


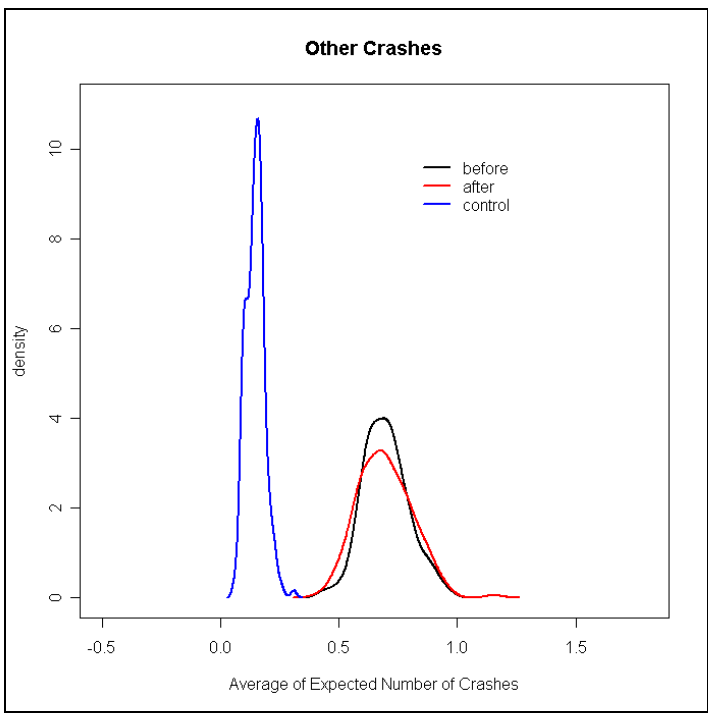
Figures E-1 & E-2. Posterior distributions of the average total crashes over sites expected crash frequencies for control, treatment before and treatment after.



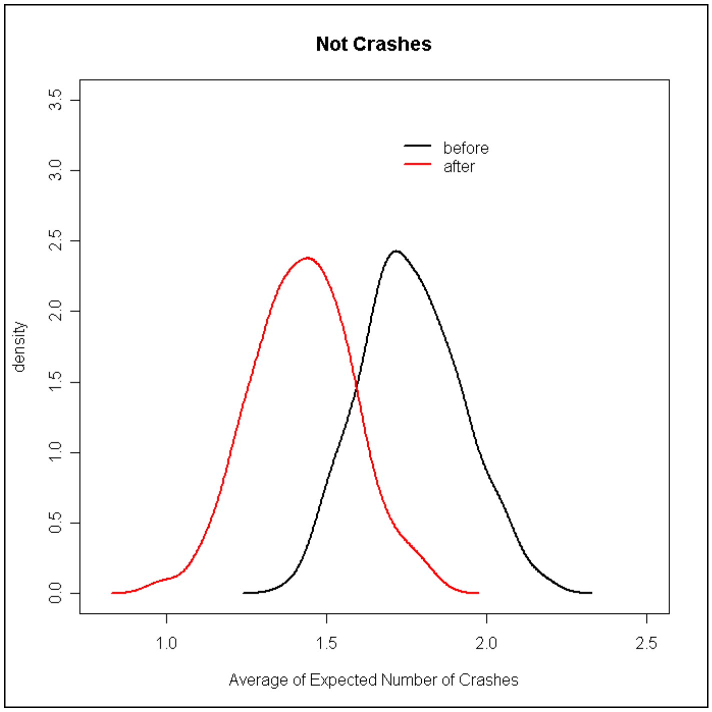


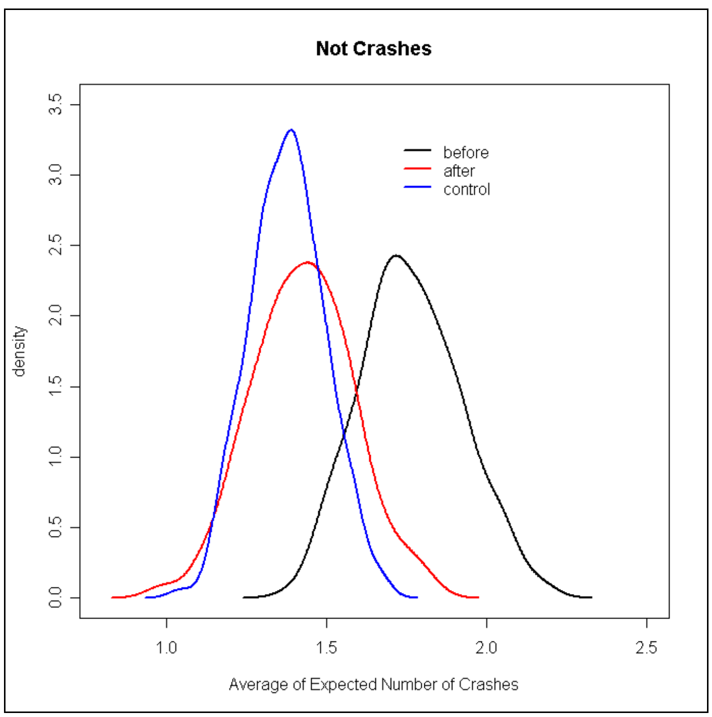
Figures E-3 & E-4. Posterior distributions of the average rear-end crashes over sites expected crash frequencies for control, treatment before and treatment after.





Figures E-4 & E-5. Posterior distributions of the average other RLR type crashes over sites expected crash frequencies for control, treatment before and treatment after.





Figures E-6 & E-7. Posterior distributions of the average non-RLR type crashes over sites expected crash frequencies for control, treatment before and treatment after.

REFERENCES

1. Federal Highway Administration. Stop Red Light Running Facts and Statistics, U.S. Department of Transportation. FHWA Safety. August 3, 2006. http://safety.fhwa.dot.gov/intersections/redl_facts.htm. Accessed Oct. 2, 2006.

2. Bonneson, J., and K. Zimmerman. *Red-Light-Running Handbook: An Engineer's Guide to Reducing Red-Light-Related Crashes.* Texas Transportation Institute, Texas A&M University, College Station, 2004.

3. Federal Highway Administration Technical Advisory T7570.2.2. *Motor Vehicle Accident Cost.* Washington D.C., 1989, pp.21-27.

4. Institute of Highway Safety, Highway Loss Data Institute, Communities with Red Light Cameras. Nov. 2006. http://www.iihs.org/research/topics/rlc_cities.html. Accessed October 10, 2006.

5. The Michie Company. *Uniform Vehicle Code and Model Traffic Ordinances*. National Committee on Uniform Traffic Laws and Ordinances. Charlottesville, Virginia, 1968.

6. Institute of Transportation Engineers. *Determining Vehicle Signal Change and Clearance Intervals*. ITE Technical Council Task Force 4TF-1. Washington, D.C., 1985.

7. Yang, C.Y., and W. Najm. *Analysis of Red Light Violation Data Collected from Intersections Equipped with Red Light Photo Enforcement Cameras*. Report DOT HS 810 580. FHWA, U.S. Department of Transportation Research and Innovative Technology Administration, 2006.

7a. Kraus, E. and C. Quiroga. Red Light Running Trends in Texas. In *Preprint CD-ROM of the 83rd Annual Meeting of the Transportation Research Board* (CD-ROM), TRB, National Research Council, Washington, D.C., 2004.

7b. Porter, B.E., and T.D. Berry. A Nationwide Survey of Self-Reported Red Light Running: Measuring Prevalence, Predictors, and Perceived Consequences. *Accident Analysis and Prevention*, Vol. 33, 2001, pp. 735-741.

7c. Retting, R.A., R.G Ulmer, and A.F. Williams. Prevalence and Characteristics of Red Light Running Crashes in the United States. *Accident Analysis and Prevention*, Vol. 31, 1999, pp. 687-694.

7d. Retting, R.A., and A.F. Williams. Characteristics of Red Light Violators: Results of Field Investigation. *Journal of Safety Research*, Vol. 27, No. 1, 1996, pp. 9-15.

7e. Bonneson J., K. Zimmerman, and M.A. Brewer. Engineering Countermeasures to Red-Light-Running. In *Proceedings of the ITE 2002 Spring Conference and Exhibit* (CD-ROM). Institute of Transportation Engineers, Washington D.C., 2002.

7f. Eccles, P.L., and H.W. McGee. *A History of the Yellow and All-Red Intervals for Traffic Signals*. Washington D.C: Institute of Transportation Engineers, 2001.

7g. Chang, M.S., C.J. Messer, and A.J. Santiago. Timing Traffic Signal Change Intervals Based on Driver Behavior. In *Transportation Research Record 1027*, TRB, National Research Council, Washington, D.C., 1985, pp. 20-30.

7h. Porter B.E., and K.J. England. Predicting Red-Light Running Behavior: A Traffic Safety Study in Three Urban Settings. *Journal of Safety Research*, Vol. 31, No. 1, pp. 1-8.

7i. Kamyab, A., T. McDonald, and J.J. Stribiak. The Scope and Impact of Red Light Running in Iowa. In *Preprint CD-ROM of the 81rd Annual Meeting of the Transportation Research Board* (CD-ROM), TRB, National Research Council, Washington, D.C., 2002.

7j. Kamyab, A., T. McDonald, and J.J. Stribiak. *Red Light Running in Iowa: The Scope, Impact, and Possible Implications*. Center for Transportation Research and Education, Iowa State University, Ames, 2000.

7k. Retting, R.A., A.F Williams, and M.A. Greene. Red-Light Running and Sensible Countermeasures: Summary of Research Findings. In *Transportation Research Record 1640*, TRB, National Research Council, Washington, D.C., 1998, pp. 23-26.

8. American Association of State Highway and Transportation Officials. *A policy on Geometric Design of Highways and Streets*. AASHTO, Washington D.C., 2001.

9. Institute of Transportation Engineers. *Determining Vehicle Signal Change and Clearance Intervals*. ITE Technical Council Task Force 4TF-1. Washington, D.C., 1994.

10. Federal Highway Administration. *Red Light Camera Systems Operational* Guidelines. National Highway Traffic Safety Administration, U.S. Department of Transportation, Washington D.C., 2005.

11. Federal Highway Administration. *Guidance for Using Red Light Cameras*. National Highway Traffic Safety Administration, U.S. Department of Transportation, Washington D.C., 2003.

12. Federal Highway Administration. *Manual on Uniform Traffic Control Devices (MUTCD) 2003*. U.S. Department of Transportation, Washington D.C., 2002.

13. Porter, B.E., and T.D. Berry. *A Nationwide Survey of Red Light Running: Measuring Driver Behaviors for the "Stop Red Light Running Program*. Behavioral Community Psychology for the DaimlerChrysler Corporation, The American Trauma Society, and Federal Highway Administration, Old Dominion University, Norfolk, 1999.

14. Evans, L., and R.W. Rothery. Influence of Vehicle Size and Performance on Intersection Saturation Flow. *Proceedings of the Eighth International Symposium on Transportation and Traffic Theory*. University of Toronto Press, Toronto, 1983.

15. Results of unpublished research conducted by BMI for the Federal Highway Administration as quoted by *Making Intersections Safer: a Toolbox of Engineering Countermeasures to Reduce Red Light Running*. Institute of Transportation Engineers, 2003.

16. McGee, H.W. et al. *Making Intersections Safer: A Toolbox of Engineering Countermeasures to Reduce Red Light Running, An Informational Report*. Report IR-115. Institute of Transportation Engineers, Federal Highway Administration, U.S. Department of Transportation, 2003.

17. Bonneson, J., K. Zimmerman, and M.A. Brewer. *Engineering Countermeasures to Reduce Red-Light Running*. Federal Highway Administration Report FHWA/TX-03/4027-2, College Station, Texas, 2003.

18. Retting, R.A., and M.A. Greene. Influence of Traffic Signal Timing on Red Light Running and Potential Vehicle Conflicts at Urban Intersections. *Transportation Research Record 1595*, TRB, National Research Council, Washington D.C., 1997, pp. 1-7.

19. Van der Horst, R., and A. Wilmink. Driver's Decision-Making at Signalized Intersections: An Optimization of Yellow Timing. *Traffic Engineering & Control*. Crowthorne, England, 1996, pp. 615-622.

20. Zegeer, C.V., and R.C. Deen. Green-Extension Systems at High-Speed Intersections. *ITE Journal*, 1978, pp. 19-24.

21. Polanis, S. Improving Safety Through Design and Operations. *Compendium of Papers for the ITE Springs Conference.* Institute of Transportation Engineers, Washington D.C., 2002.

22. Marshall, B. How Stuff Works-Question 1789. May, 2002. http://www.howstuffworks.com. Accessed October 18, 2006.

23. Miska, E., P. de Leur, and T. Sayed. *Road Safety Performance Associated with Improved Traffic Signal Design and Increased Signal Conspicuity*. Institute of Transportation Engineers, 1998.

24. "Visibility of Traffic Signal Displays for Aging and Colour Deficient Drivers-Final Report." Final report: National Committee on Uniform Control, September 2001.

25. Salek, M.E. Colorado Highway Photo Gallery: Signals From Around the State. July 9, 2006. http://www.mesalek.com/colo/picts/pgsignal.html. Accessed November 1, 2006.

26. Bonneson, J., C. Quiroga, E. Kraud, and I.V. Schalkwyk. *Red Light Running – A Policy Review.* Texas Transportation Institute, Texas A&M University, College Station, 2003.

27. Federal Highway Administration. *Red Light Camera Systems Operational Guidelines*. Report FHWA-SA-05-002. FHWA, U.S. Department of Transportation, 2005.

28. Capka, J.R. *2005 National Roadway Safety Awards.* Roadway Safety Foundation, Federal Highway Administration, U.S. Department of Transportation. http://safety.fhwa.dot.gov/awards.pdf Accessed March 2, 2007.

29. Lynn, C., and W. Ferguson. *Automated Speed Enforcement Pilot Project for the Capital Beltway: Feasibility of Photo Radar*. Virginia Transportation Research Council, November 1992.

30. Obituary: Maurice Gatsonides. *The London Independent*, Dec. 22, 2001.

31. Gatso meter BV, Company overview and History. http://www.gatsometer.com. Accessed September 29, 2006.

32. St. Vincent College, Speed. http://www.stivincent.ac.uk/Resources/Physics/Speed/speedcam2.html. Accessed September 29, 2006.

33. Erikson, G. Digital Traffic Cameras for Violators Enforcement. *Traffic Technology International*. Annual 1996, pp. 332-336.

34. Passetti, K.A., and T.H. Hicks. *Use of Automated Enforcement for Red Light Violations*. Department of Civil Engineering, Texas A&M University, College Station, 1997.

35. Retting, R.A. Automated Enforcement of Traffic Laws. *TR News*, Vol. 29, No. 201, 1999, PP. 15-18.

36. MacCubbin, R.P., Staples B.L., and A.E. Salwin. Automated Enforcement of Traffic Signals: A Literature Review. Federal Highway Administration, U.S. Department of Transportation. http://www.itsdocs.fhwa.dot.gov/jpodocs/repts_te//13603.html. Accessed Nov. 1, 2006.

37. Automated Photo Speed and Red Light Photo Enforcement Systems. Traffipax vendor information, Columbia, Maryland, 2006.

38. Battle Lines Drawn in California Legislature over Red Light Running Cameras. *Urban Transportation Monitor*, 1998, pp. 3-4.

39. Red Light Camera Enforcement, National Campaign to Stop Red Light Running, Communities with Red Light Camera Programs. http://www.stopredlightrunning.com/html/rlc_cities.htm. Accessed October 17, 2006.

40. Popolizio, R.E. New York City's Red Light Camera Demonstration Program. Institute of Transportation Engineers Compendium of Technical Papers, 1995.

41. McFadden, J., and H.W. McGee. *Synthesis and Evaluation of Red Light Running Automated Enforcement Programs in the United States*. Report FHWA-IF-00-004. FHWA, U.S. Department of Transportation, 1999.

42. New York City Government, New York City Department of Transportation, DOT to Add Red Light Camera Warning Signs. Oct. 2, 2003. http://www.nyc.gov/html/dot/html/about/pr2003/pr03_109.html. Accessed October 3, 2006.

43. Cameras Reduced Red Light Running by 20-30%. *Urban Transportation Monitor*, Vol. 11, No.2, 1997, pp. 1-3.

44. Fleck, J.L., and B. Smith. *Can We Make Red Light Runners Stop?* San Francisco Department of Parking and Traffic, 1999.

45. California Senate Bill 833. Approved October 14, 1995.

46. San Francisco Government, Department of Parking and Traffic, Red Light Photo Enforcement Program. http://www.sfgov.org/site/livablestreets_index.asp?id=14440. Accessed October 15, 2006.

47. *Automated Enforcement for Red Light Running: Issues, Models, and Implementation.* Portland Bureau of Traffic Management, 1998.

48. Burchfield, R.M. *Red Light Running Camera Program Biennial Report*. City of Portland, 2005.

49. McGee, H.W., and K.A. Eccles. *NCHRP Synthesis of Highway Practice 310: Impact of Red Light Camera Enforcement on Crash Experience*. TRB, National Research Council, Washington D.C., 2003.

50. Retting, R.A. Establishing a Uniform Definition of Red-Light Running Crashes. *ITE Journal*, Vol. 76, No. 3, 2006, pp. 20-22.

51. Council, F.M., B. Persaud, K. Eccles, C. Lyon, and M.S. Griffith. *Safety Evaluation of Red-Light Cameras*. Report FHWA-HRT-05-048. FHWA, U.S. Department of Transportation, 2005.

51a. Hiller, W., J. Ronczka, and F. Schnerring. *An Evaluation of Red Light Cameras in Sydney*. Report Number 1/93. Road Traffic Authority NSW: Road Safety Bureau. Rosebery, Australia, 1993.

51b. South D., W. Harrison, I. Portans, and M. King. *Evaluation of Red Light Camera Programs and Owner Onus Legislation.* Victoria Transport: Road Traffic Authority. Hawthorn, Victoria, 1988.

51c. Andersen, D. *A Long Term Study of Red Light Cameras and Accidents.* Research Report #261. Australian Road Research Board, Victoria, Australia, 1995.

51d. Kent, S., B. Corben, B. Fildes, and D. Dyte. *Red Light Running Behavior at Red Light Camera and Control Intersections.* Report #73. Monash University: Accident Research Centre. Clayton, Australia, 1995.

51e. Mann, T., S. Brown, and C. Coxon. *Evaluation of the Effectiveness of Installing Red Light Running Cameras at Selected Adelide Intersections.* Report 7/94. South Australian Department of Transport, Office of Road Safety, Walkerville, Australia 1994.

51f. London Accident Analysis Unit. *West London Speed Camera Demonstration Project: An Analysis of Accidents and Casualty Data 36 Months "After" Implementation and Comparison with the 36 Months "Before" Data.* London Research Centre: Environmental and Transport Studies. London, England, 1997.

51g. Hooke, A., J. Knox, and D. Portas. *Cost Benefit Analysis of Traffic and Speed Cameras.* Police Research Series Paper 20. Police Research Group, Home Office. London, England, 1996.

51h. Ng, C.H., Y.D. Wong, and K.M. Lum. The Impact of Red Light Surveillance Cameras on Road Safety in Singapore. In *Transportation Research Record Vol 6, No. 2*, TRB National Research Council, Washington D.C., 1997, pp. 72-80.

51i. Retting, R.A., and S. Kyrychenko. *Crash Reductions Associated with Red Light Enforcement in Oxnard, California*. Insurance Institute for Highway Safety, 2001.

51j. *Safe*Light. The Charlotte Department of Transportation. http://www.ci.charlotte.nc.us/citransportation/programs/safelight.htm. Accessed October 4, 2006.

51k. Maryland House of Delegates Commerce and Government Matter Committee. *Automated Enforcement Review – Red-Light Running Detection Camera Systems*. Howard County Maryland, 2001.

51l. Fleck, J.L., and B.B. Smith. Can we Make Red Light Runners Stop? Red Light Photo Enforcement in San Francisco, California. In *Transportation Research Record 1693*, TRB, National Research Council, Washington, D.C., 2001.

51m. Vinzant, J.C., and B.J. Tatro. *Evaluation of Effects of Photo Radar Speed and Red Light Camera Technology on Motor Vehicle Crash Rates*. City of Mesa Police Department, 1999. http://www.ci.meswa.az.us/police/traffic/march_1999_report.htm. Accessed October, 24, 2006.

51n. Fox, H. *Accidents at Signal Controlled Junctions in Glasgow*. Research Findings No. 23. The Scottish Office: Central Research Unit, Development Department Research Programme, 1996. http://www.scotland.gov.uk/cru/resfind/drf23-00.htm. Accessed October, 24, 2006.

51o. Winn, R. *Running the Red and Evaluations of Strathclyde Police's Red Light Camera Initiative*. The Scottish Central Research Unit: Glasgow, Scotland, 1995. http://www.scotland.gov.uk/cru/resfinds/drf7-00.htm. Accessed October, 24, 2006.

52. Retting, R.A., and S.Y. Kyrychenko. Reductions in Red Light Camera Enforcement in Oxnard, California. *American Journal of Public Health,* Vol. 92, No.11, 2002, pp.1822-1825.

53. Cunningham, C.M., and J.S. Hummer. *Evaluating the Use of Red Light Running Photographic Enforcement Using Collisions and Red Light Running Violation*. Institute for Transportation Research and Education, North Carolina State University, Raleigh, 2004.

54. Burkey, M.L., and K. Obeng. *A Detailed Investigation of Crash Risk Reduction Resulting From Red Light Cameras in Small Urban Areas*. Urban Transit Institute, North Carolina Agricultural & Technical State University, Greensboro, 2004.

55. Michalopoulos, P.G. *Machine Vision: The Way Ahead, The Emerging Technology for Advance Traffic Surveillance Management and Control*. ITS International, 1996.

56. Retting, R.A., S.A. Ferguson, and C.M. Farmer. *Reducing Red Light Running Through Longer Yellow Signal Timing and Red Light Camera Enforcement: Results of a Field Investigation*. Insurance Institute for Highway Safety, 2007.

57. Tarko, A.P., and N. Lakshmi Kanth Reddy. *Evaluation of Safety Enforcement on Changing Driver Behavior – Runs on Red*. School of Civil Engineering, Purdue University, West Lafayette, 2003.

58. Washburn, S.S., and K.G. Courage. *Investigation of Red Light Running Factors – Final Report*. Department of Civil and Coastal Engineering, University of Florida, Gainesville, 2004.

59. Maisey, G.E. *The Effect of a Mechanical Surveillance Device on Urban Signalized Intersection Accidents*. Research and Statistics Report No. 17, Road Traffic Authority, Perth, Western Australia, 1981.

60. Gains, A, M. Nordstrom, B. Heydecker, and J. Shrewsbury. *The National Safety Camera Programme, Four-year Evaluation Report.* PA Consulting Group and UCL, 2005.

61. Kendall, S. *Is Automated Enforcement Constitutional?* Insurance Institute for Highway Safety, 2004.

62. Blackburn, R.R., and D.T. Gilbert. *NCHRP Synthesis of Highway Practice 219: Photographic Enforcement of Traffic Laws*. TRB, National Research Council, Washington D.C., May 1995.

63. DC Watch, Privacy vs. Security Issues, Automated Traffic Enforcement System (ATES). April, 2003. http://www.dcwatch.com/issues/privacy15.htm. Accessed October 22, 2006.

64. McCormick, C. *McCormick on Evidence*, 3rd Ed., Sec. 214, at 671, 1984.

65. Goger, T.J. *Proof, by Radar or Other Mechanical or Electronic Devices, or Violation of Speed Regulations*. 47 American Law Reports. Ed 822, 1973.

66. Photo Blocker, http://www.photoblocker.com. Accessed November 2, 2006.

67. Clive Historical Society. Clive History. http://www.clivehistoricalsociety.com/clive_history.htm. Accessed April 20, 2006.

68. Council Bluffs Historic Preservation Alliance. Ann 1887 Introduction about Council Bluffs. http://www.cbhpa.com/1887CBwriteup.htm. Accessed April 21, 2007.

69. Quad-Cities Convention & Visitors Bureau. Quad City History. http://www.visitquadcities.com/for_the_media/nr_history.html. Accessed April 22, 2007.

70. John Deere. Company Information. http://www.deere.com/en_US/compinfo/histoyr/index.html. Accessed April 22, 2007.

71. Pline, J.L., *Traffic engineering handbook.* [Washington, D.C.]: Institute of Transportation Engineers, 1999.

72. Bonneson, J.A., and K. Zimmerman. Identifying Intersections with Potential for Red Light-Related Safety Improvements. In *Transportation Research Record 1953*, TRB, National Research Council, Washington D.C., 2006, pp. 128-136.