

A Detailed Investigation of Crash Risk Reduction Resulting From Red Light Cameras in Small Urban Areas (Preliminary)

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Phase I

A Detailed Investigation of Crash Risk Reduction Resulting from Red Light Cameras In Small Urban Areas



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16. Abstract <p>This progress report describes the activities undertaken in this partially funded project. The goals of this project are to review previous studies on Red Light Cameras (RLCs) and intersection safety, collect detailed data about the intersections, accidents, and red light cameras in Greensboro, North Carolina, and to determine the impact of various intersection features on accident rates using geospatial and statistical analysis.</p> <p>The most significant information contained in this report is the literature review on RLCs and intersection safety, background information about the location of the study, and data collection procedures. Because the data are still in need of processing and analysis, the authors do not present any final results or conclusions.</p>			
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Executive Summary

Small urban areas currently rely on automobile traffic as the primary means of transportation. As such, these areas are faced with the struggle of keeping traffic flowing as quickly and smoothly as possible, while also attempting to keep costs low and safety high. Recently, many small urban areas have been hiring outside contractors to install automated red-light enforcement cameras at some intersections. The two stated goals of many municipalities are to 1) decrease the incidence of red light running, and 2) to decrease the number of accidents due to red light violations. While many studies have documented decreases in red light running there is only sparse evidence that these cameras reduce accident rates. The goal of this research is to perform a holistic analysis of the factors that influence accident rates at intersections. As part of this analysis, we will determine the characteristics of intersections that can reap the largest benefits in terms of accident reductions from the installation of red-light enforcement cameras. In addition, various types of accidents (and accident reductions) will be examined to quantify the costs and benefits of a red-light camera program compared with other corrective actions.

This proposal was partially funded for the period January 2001 – July 2001. We will seek continued funding for January 2002-July 2002 in order to complete the organization and analysis of the data, and prepare final reports. This document details the progress of the proposal, and includes the literature survey and background information about the proposal.

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I. Introduction

1. Introduction

Nearly half of all accidents in the U.S. occur at or near intersections (USDOT, 1999 p.50). Many specific studies have been conducted that investigate various aspects of intersections related to safety and accident rates. Automated enforcement of traffic signals using cameras is a major new initiative used by many small urban areas with the goals of reducing red light running and improving safety. The use of these cameras to improve safety is justified by only a few studies that suggest that red-light cameras (RLCs) may reduce some kinds of accidents. The USDOT published a “Synthesis and Evaluation of Red Light Running Automated Enforcement Programs in the United States (McFadden and McGee 1999), concluding that while reductions in violations, cost savings, and public acceptance of the program were all benefits, “Additional crash data are needed to validate and quantify the RLR automated enforcement program’s implication on crashes.” (p. 27) No existing studies carefully examine the properties of intersections, drivers, weather, and accidents together to determine the role of RLCs in a comprehensive intersection safety program.

In the last funding-cycle of UTI our proposal to study intersection accidents and RLCs was partially funded at a level that did not allow the project to be completed. Specifically, the funding was not enough to complete the data collection. Nevertheless, the researchers working with the traffic-engineering department of the City of Greensboro collected some data on the characteristics of intersections with stoplights. Data on traffic counts (average daily volume), signal timing, number of lanes and other characteristics were collected. From the North Carolina department of Transportation (NCDOT) accident rates and types (e.g., rear-end collisions, front to side impacts), types of vehicles involved, and when the accidents occurred were collected. Other information collected are, when RLCs were placed at each intersection and the characteristics of these RLCs. Additionally, the researchers conducted and reviewed extensive literature on red light cameras and intersections and submitted a preliminary report to UTI. A major finding uncovered by our preliminary data collection and by analyzing NCDOT guidelines for RLC installation has already resulted in policy changes in Greensboro and High Point in terms of retiming some of the red lights at intersections with RLCs. It was discovered that the North Carolina statute enabling municipalities to install RLCs required certain minimum amber times, depending on speed limits. Several of the RLCs we collected data for did not meet these requirements, and Greensboro has since made appropriate changes.

2. Objective

The primary objective of this research is to analyze the impact of RLCs on red light violations and accidents in a holistic framework. Because single policy changes do not occur in a vacuum, and because the characteristics of intersections vary widely, policy makers and transportation engineers must be able to choose the most appropriate locations for RLCs. Simultaneously, this study identifies other safety-enhancing recommendations for intersections, which may differ by location, traffic flows, and other characteristics. The design of this proposal allows the detection of some types of intersections that may experience increases in accident rates after the introduction of RLCs, though such a program may reduce accident rates overall. The results also suggest other less costly safety recommendations such as changing yellow light timing.

This proposal draws upon the expertise of the research team in transportation, Geographic Information Systems, economics, and statistical analysis. The research team brings together transportation, engineering, geographical, statistical, and economic approaches into a comprehensive examination of intersection safety.

3. Research Approach and Tasks Performed

This project collected data from Greensboro, North Carolina, which began implementing a Red Light Camera (RLC) program in February 2001 under a contract with Peek Traffic. The first step was to hold meetings with local officials to inform them of the project, find contacts for various data, arrange for data acquisition, and hire graduate students in civil engineering to assist in the data collection. With the cooperation of the Greensboro Department of Transportation (GDOT) the investigators collected data on the characteristics of intersections with stop lights in the area. Data on traffic counts (average daily volume), signal timing, number of lanes, and other data were collected. From the North Carolina Department of Transportation (NCDOT), accident rates and types (e.g., rear-end collisions, front to side impact), types of vehicles involved, and when accidents occur were collected.

We also obtained information regarding when RLCs were placed at each intersection. To help small urban areas maximize the use of their resources in improving the performance of roadway transportation, the investigators will use the data to determine the most desirable placement of RLCs. The placements should be at intersections that have the most favorable outcomes, such as large reductions in red light running and accident rates. More information regarding the data collection is provided in Section III.

An extensive collection and review of the relevant literature on red light cameras and intersection safety was performed, and is reported in Section II. At present, the data collection is almost complete, but there is still a great deal of work to be done, involving the combination of data files from various sources into one comprehensive file, and matching data on accidents with data on intersection characteristics. Additionally, once

these data files are prepared, an analysis must be conducted to determine the characteristics of intersections that are associated with accidents, and the role of RLC's in accident reduction. These additional tasks for the next phase of this project are described in Section IV, along with budgetary requirements.

4. Information about Greensboro, NC

Greensboro, North Carolina is located in Guilford County, located roughly 80 miles WNW of the capital Raleigh, NC. Interstates 85 and 40 pass through the southern part of the city. According to the 2000 Census 223,891 of the county's 421,048 people live in Greensboro. In the county there were 333,534 vehicles registered to 298,732 licensed drivers in 1999 (Wiliszowski et al, 2001). The area has experienced a large amount of growth, with the city, county and state seeing population increases of 21-22% over the last decade. There are 648.8 persons per square mile in the county, compared with 165.2 persons per square mile in the state as a whole. Greensboro is part of the Greensboro-Winston Salem-High Point, NC Metropolitan Statistical Area.

The primary means of transportation in Greensboro is owner occupied vehicles, with 79.1% of the transportation mode share involving driving alone, and 12.5% carpooling (Greensboro City Data Book, 2001). The Greensboro Department of Transportation (GDOT) maintains 876 miles of roadway, while the North Carolina Department of Transportation (NCDOT) maintains another 236 miles, including the interstates, US-routes, and major state highway routes.

During the period of time considered in this report, there were 413 intersections controlled by traffic signals. According to the Greensboro Police Department, 498 accidents were classified as being caused by red light running in 1999.

Greensboro and the neighboring city of High Point contracted with Peek Traffic to install and operate their RLCs. The contracts are for three years, and specify a \$50 civil fine for violations. Of this \$50, the city is paid \$15, with the remaining \$35 retained by Peek Traffic. The first two cameras in Greensboro began operation on February 7, 2001 and citations were mailed out for offenders beginning on February 15, 2001. As of May, 2002 there were 18 cameras operating, with plans for several more. Over the first year of the RLC program, the average number of tickets issued per camera, per day was 6.8, issuing more than \$1.2 million in fines.

Table 1 presents the monthly citation count for December, 2001 at each of the camera locations. The high variability in these numbers, ranging from 9 to 345 at two intersections on Cone Boulevard suggests that intersections are extremely heterogeneous when it comes to red light running behavior. While one might think that traffic volume accounts for most of these differences, the ADV of the lowest ticket and highest ticket locations are 38,750 and 55,325 respectively. Thus, as much information as possible should be collected about these intersections, to fully understand red light running behavior and accidents.

Street 1	Street 2	December, 2001 Tickets Issued
Holden Road	Spring Garden Road	150
Wendover Avenue	English Street	69
Battleground Avenue	Brassfield Road	90
High Point Road	Pinecroft Road	312
Wendover Avenue	Church Street	138
Holden Road	Wendover Avenue	109
Randleman Road	Florida Street	12
Randleman Road	Creekridge Road	145
Battleground Avenue	Pisgah Church Road	232
Holden Road	McCuisition	72
High Point Road	Merritt Road	23
Church Street	Cone Blvd	9
Battleground Avenue	Cone Blvd	345
Wendover Avenue	Big Tree	86
Freeman Mill Road	Colisuem	34
Spring Street	Friendly Avenue	56
Wendover Avenue	Hill Street	228
Wendover Avenue	Bridford Parkway	39

A concern of all safety advocates is that new safety programs such as red light cameras should be implemented in the most efficient manner possible. There have been some critics in Greensboro that worry that the locations of some cameras may not be chosen to maximize safety, but rather to maximize citations. Their evidence is of two types. First, it is generally not the city engineers that choose the placement of the RLCs. In High Point, the city "...developed a list of about 30 potential intersections, and PEEK Traffic officials will narrow that list to about 10 where the cameras will be installed..."(Garber, 2000). Because Peek's contract specifies payment of \$35 per citation, and no compensation for accident reduction, the final decision regarding locations is not done with the proper incentives.

As possible evidence of the inefficient location of RLCs, another newspaper article noted that "Of the 23 Greensboro intersections with the most accidents caused by red light violators, only four have cameras..." (Reese, 2002). While all such intersections may not be appropriate for Red Light Cameras, one wonders why more of these intersections were not targeted. A part of our research program will be to predict intersections where RLCs might produce the greatest safety benefits.

II. Review of Relevant Literature

This research project determines the role of RLC's in reducing accidents at intersections. Because of the nature of RLC's, the focus of the research will be on signalized intersections. In order to properly determine the causes of accidents at these intersections, it is necessary to review the literature on factors that influence intersection safety in general, review previous studies of red light running, and also review previous studies about the impact that RLC's have on red light running and safety. Thus, the literature review is broken down into three sections as follows:

- A. Research on Intersection Safety
- B. Red Light Running
- C. Red Light Cameras

A. *Research on Intersection Safety*

Of 6,394,000 crashes in the year 2000 in the U.S., (44%) occurred at intersections, or were classified as "intersection-related". Of these, 47% occurred at intersections with traffic signals. (NHTSA, Traffic Safety Facts 2000). The nature of intersections poses a special set of dangers for vehicles, pedestrians and bicyclists. For vehicles, intersections are likely to involve dangerous "angle" crashes where little protection is given to drivers and occupants, and rear-end collisions where whiplash injuries are common. Approximately 22% of fatalities and 46% of injuries to pedestrians occur at intersections.

The Advocates for Highway Safety (2001) identified nine main ways to improve intersection safety:

- 1) changes to or installation of appropriate static traffic control devices
- 2) installing traffic signals
- 3) proper timing of traffic signals
- 4) installing dedicated turning lanes
- 5) removing sight distance restrictions
- 6) use of roundabouts
- 7) use of Intelligent Transportation Systems (ITS)
- 8) automated enforcement of red light running
- 9) better signing such as larger, brighter stop, yield, and speed limit information

Within these nine suggestions are components that deal with structural changes, law enforcement, and conveying information to drivers. The standard protocol of most modern safety campaigns focuses on the "Three E's": Engineering, Enforcement, and Education.

Tarawneh et al (2001) found that an education campaign significantly increased drivers' understanding of traffic laws associated with red light running. However, the Insurance Institute for Highway Safety (IIHS) (2001) is critical of the role of education in increasing safety, and believes that engineering and enforcement efforts are much more important.

Many times enforcement efforts are done on a high intensity, but unsustained program (often called a "blitz" approach). These efforts can significantly affect safety, but are too costly to be used continuously. However, a low level of targeted enforcement can have large benefits. In Australia, several areas have been using Random Road Watch programs. These programs randomly monitor areas of roadway for two hour periods of time, using marked patrol cars. The intensity of the effort is chosen at a level that can be sustained over the long run, and has been found to reduce accidents significantly, particularly fatal crashes (down 31%) (Newstead et al, 2001).

When analyzing strategies for safety improvements on roadways, one must first establish that a given strategy will produce the desired results. Occasionally, the goals of a safety program are measured in terms of compliance with the law. This is often the case with seatbelt programs, speed reduction programs, and child safety seat programs. However, the underlying goal should never be ignored, which is to reduce crashes, and the resulting fatalities, injuries, and property damage.

Once a strategy is known to increase safety, good estimates of the extent of these benefits should be made for various types of applications of the strategy. The main purpose of quantifying the benefits is so that reasonably accurate studies of efficiency can be made. A strategy with known benefits is of no practical value if its costs exceed the benefits gained, or if a strategy with similar benefits can be implemented with lower costs. The most obvious benefits to a safety program are reductions in fatalities, injuries, and property damage. There are two ways that injuries and damages are assessed in accident records. The most common, the KABCO method, categorizes accidents and injuries as:

K: Killed

A: Incapacitating or Disabling Injury

B: Not Incapacitating, but Evident, Injury

C: Possible Injury,

O: No Injury, Property Damage Only (PDO)

Another accident severity scale used is the MAIS, or Maximum Abbreviated Injury Score. It classifies accidents as follows:

Fatal

Critical (MAIS 5)

Severe (MAIS 4)

Serious (MAIS 3)

Moderate (MAIS 2)

Minor (MAIS 1)

No Injury (MAIS 0)

Under both systems, classification is somewhat subjective, and normally determined by a police officer on the scene. In the present study, we use the KABCO system as reported in our accident data. To compare severity between different types of accidents, it is convenient to attach a dollar value to each type of accident or injury. In October, 1994 the FHWA issued a list of “Comprehensive Cost Estimates”, listed in Table 2. These values were updated to 2002 dollars by the investigators of this project.¹

Also listed in Table 2 are “Standardized Crash Cost Estimates for North Carolina,” issued in December 2001 by the North Carolina Department of Transportation (Troy, 2001). The values determined in this report are also termed “comprehensive”, in that they include estimates of medical, work loss, employer costs, traffic delay, property damage, and changes in quality of life. Though these cost estimates were issued in 2001, they are measured in terms of year 2000 dollars.

Severity	Description	FHWA (1994)	FHWA (2002)	NCDOT 2001
K	Fatal	2,600,000	2,979,600	3,300,000
A	Incapacitating	180,000	206,280	200,000
B	Evident	36,000	41,256	57,000
C	Possible	19,000	21,774	27,000
PDO	Property Damage Only	2,000	2,292	3,900

In addition to accident reductions, other possible benefits or costs of implementing safety programs are changes in delays at intersections, resulting in effective increases or reductions in road capacity. These changes affect travel times for roadway users, and should be counted properly in benefit/cost ratios. While reducing speed limits may increase safety but reduce capacity, there are some safety efforts that have also been shown to increase capacity. For example, efficiently programming traffic control devices in a network can yield benefits in reduction of delays, reduced fuel use, as well as increased safety (Skabardonis, 2001).

Another important consideration is that very few safety improvement projects are undertaken randomly, as would be required for an unbiased estimate of the effects. Most often, safety efforts are directed toward intersections or roadways that have the highest accident rates in a given time period. *Ceteris paribus*, an intersection with an unusually high accident rate in one period is likely to have a lower (more average) rate in the next. This phenomenon is sometimes called the “regression to the mean effect”. Thus, the effects of a safety program targeted in this way may be overstated. Kulmala (1994) found that accidents declined approximately 20% due to regression to the mean effects, independent of any safety measures implemented. If ignored, regression to the mean

¹ Updated using GDP Implicit Price Deflator from Q1, 2002.

effects can easily mislead researchers to inappropriately attribute crash reductions to an ineffective safety program.

In addition, the quality of the data used in safety studies must be ascertained. One often overlooked aspect of accident data is censoring. One must realize that not all accidents are reported, and state laws differ on reporting requirements. In North Carolina, the crash reporting threshold is currently \$1000. That is, if a police officer is called to the scene of an accident, the officer is not required to make a report of the details of the accident unless he/she is certain that the damage is in excess of \$1000. Therefore, many accidents are never entered into a crash database, and may affect the results of accident studies if ignored. The research related to this subject has been sparse. Zegeer et al.(1998) studied the differences in various types of accidents that would be reported under three different types of reporting thresholds: traditional (value), towaway, and injury. They found that using higher thresholds (towaway versus traditional, for example) tends to seriously underreport certain types of crashes. One would expect that the traditional threshold causes similar types of bias in accident reporting.

B. Red Light Running

While installing red lights at intersections can often improve safety and improve traffic flow, such intersections are often studied because they are the scene of many devastating crashes. Retting et al (1995) found that running traffic control devices were the primary cause of 22% of all crashes, and 27% of injury crashes. They also found that crashes involving red light running are more likely to involve an injury, occurring in 45% of these crashes.

Given the danger associated with running red lights, a question one asks is, “Why would an individual would do this?” Wissinger et al (2000) discovered that the main reason people purposely run red lights is to minimize delay because they are in a hurry. In addition, Wissinger found that many people do not properly understand the law regarding red light running, which varies by state. In North Carolina, the law states that

“Vehicles facing a red light controlling traffic passing straight through an intersection from a steady or strobe beam stoplight shall not enter the intersection while the steady or strobe beam stoplight is emitting a red light controlling traffic passing straight through an intersection...” (NCGS 20-158 (b) (2))

Because many intersections contain “stop bars”, many motorists believe that their vehicle must pass the stop bar before the light turns red. However, as the law above states, it is the intersection, i.e. the curb, that is important for making a legal maneuver. Thus, vehicles may inadvertently violate the letter of the law by stopping on a stop bar that extends beyond a curb.

In addition, some drivers may run a red light because of poor signal timing. At some intersections, it has been found that so-called “dilemma zones” exist. A dilemma zone

exists when a reasonable and prudent driver can neither stop the vehicle in time, nor enter the intersection before the onset of a red light. Dilemma zones are caused by setting the amber time too low based on the speed, visibility, and grade of the intersection. For example, a vehicle 250 feet from an intersection may require 300 feet to stop, and 4.5 seconds to reach the intersection. If the amber time is less than 4.5 seconds (plus some increment for reaction time), the driver has no ability to stop, and will run the red light. In these cases, a simple solution is to increase the amber time to improve intersection safety.

However, when we want to increase safety at intersections with red lights, it is important to understand the various types of drivers, circumstances, and causes of red light running. Milazzo, Hummer, and Prothe (2001) carefully classified red light running in several ways. First, they characterized drivers into four types:

- 1) Reasonable/Prudent: an attentive, cautious driver
- 2) Inattentive: may be distracted by children in the car, cell phone, or other reasons
- 3) Reckless: does not show proper regard for their own or others' safety
- 4) Mistaken (Judgment Error)

They then characterized the reasons why someone may or may not stop:

- 1) Enforcement measures: risk receiving a ticket
- 2) Risk of Crash
- 3) Time savings

Finally, for drivers who enter an intersection, Milazzo et al (2001) classify each driver by answering the following questions about the maneuver:

- 1) Is it *safe*?
- 2) Is it *legal*?
- 3) Is it *intentional*?

The answers to these questions determine the type of behavior exhibited by the driver, and one can understand why a maneuver is performed, and what can be done to increase safety. Breaking down drivers in this way creates reasonable pictures of different types of drivers, and this information can be used to predict the effect of safety improvements on them. For example, an inattentive driver may not avoid running a red light because of increased enforcement measures, but may respond to more visible signage.

Porter and Berry (1999) used surveys to form a profile of those drivers who run red lights, identifying a red light runner as a younger person who is driving alone, and often in a hurry. While this profile is at first appealing, it is certainly not wholly inclusive of the 56% of respondents to the survey who admitted to running red lights, and one in five who admitted running at least one out of the last 10 red lights encountered prior to the survey. When asked why drivers stop for a red light, 69.3% responded because it is safer, compared to only 15.4% who stop because it is illegal.

While drivers are undoubtedly important, the characteristics of the intersections themselves can significantly impact red light running and the resulting crashes. Stimpson, Zador, and Tarnoff (1980) and others have found that simply re-timing stop lights can significantly increase safety. They found that increasing the amber time by approximately 30% can reduce the number of vehicles that enter an intersection in conflict² by 90%. Because signal timing changes are very inexpensive, and have the potential for large safety benefits, it could be argued that it should be the first issue addressed concerning red light running. Retting, Chapline, and Williams (2002) found that 40 out of 51 sites examined in New York State required timing adjustments. They found that doing so reduced crashes at these intersections by approximately 5%.

Other physical characteristics of intersections with red lights that may affect accidents were investigated by Mohamedshah, Chen, and Council (2000). They determined that traffic volume, number of lanes of traffic, and the use of fully actuated signals were all associated with higher number of accidents. The authors speculated that fully actuated signals may seem to increase accidents because they are often located in suburban, non-networked, high speed locations.

Thus, many studies have investigated differing aspects of who runs red lights and why, the associated danger, and possible intersection characteristics that can affect the magnitude of the danger. However, there is a lot of work still to be done in the evaluation of myriad options for continuing improvement of intersection safety. Proper timing of signals, or removal of unwarranted signals (Retting, Williams, and Greene, 1998) can be considered a low cost approach. Increasing fines and other sanctions against drivers who run red lights can be effective. Increased enforcement coupled with education campaigns may also help to mitigate the danger. However, traditional law enforcement methods can actually cause accidents at intersections.

If an officer observes a vehicle running a red light, issuing a citation often requires the officer to follow the offender through the light, creating additional danger to motorists. One solution to this problem is to mount a so-called “rat box” on the back side of traffic signals. These rat boxes contain light emitting diodes that activate when the signal turns red. This type of system allows an officer stationed downstream from the signal to more safely observe and cite offenders.

Recently, interest has been increasing in many municipalities in automated enforcement mechanisms, particularly for red light enforcement. We will describe this technology and the existing research in the next section.

C. Red Light Cameras³ and Previous Studies

² Vehicles that spent a minimum of 0.2 seconds in an intersection after the onset of red.

³ A good overview of RLC technology and implementation in North Carolina is found in Milazzo, Hummer, and Prothe(2001). For the sake of brevity, we only outline the major ideas here.

A red light camera (RLC) system typically employs electromagnetic loops and a pole mounted camera (either 35mm or digital) that are tied into the timing system for a traffic signal. Because the camera's position is fixed, only one direction of traffic flow is monitored at an intersection. Once the signal changes to red, the system is generally programmed with a small "enforcement tolerance" of 0.1 to 0.3 seconds, after which any vehicle crossing the loops will trigger the camera unit to take two photographs. To establish evidence of a violation, the first photograph captures the vehicle as it enters the intersection, and the second captures the vehicle's progress into the intersection. The photographs must be of sufficient resolution to allow identification of the license plate of the vehicle.

Typically these photographs are reviewed by a police official to screen out photographs taken of funeral processions, emergency vehicles, and the like. In Greensboro, NC only 40.3% of the "events" captured by RLCs during the first year of operation resulted in tickets being issued.

RLCs are an attractive option for municipalities for several reasons. Normally, municipalities are approached by an outside contractor who offers to install and operate the system with no up-front cost to the local government. These contractors earn a commission on each ticket issued, with the remainder going to the municipality. In addition to being a revenue source, the municipalities see increased safety as a benefit of RLCs.

Thus far, the safety benefits of RLC programs have not been shown convincingly. Although several studies have shown that RLCs usually reduce the rate of violations (Retting et al 1999(1), Retting et al 1999(2)), very little evidence exists that confirms that RLCs reduce accident rates. Many studies and reports⁴ have consistently demonstrated that in short periods of time after RLC programs are implemented, violation rates drop dramatically. Various programs have seen reductions in violations of between 20% and 83% as drivers become accustomed to the presence of the cameras, and are educated by the signs and public information campaigns that usually accompany RLC programs. The few known studies that find reductions in accident rates in the U.S. were conducted using data from Oxnard CA (Retting and Kyrychenko, 2001), Fairfax, VA (Retting et al 1999(1)), and Charlotte, NC (Milazzo et al 2001). Most of these studies compare crash totals for a period before and after the introduction of RLCs. While the number of crashes at intersections with RLCs declined, results varied drastically based on the type of crash. Overall, crashes went down 7% in Oxnard, and 8% in Charlotte. However, front into side crashes reportedly went down by 32% in Oxnard. This fact highlights the importance of a detailed investigation of possible crash reductions by type and severity.

A long-term study done in Australia (Andreassen, 1995) was for a ten-year period, five years both before and after the introduction of RLCs. This study found no overall decrease in accidents resulting from RLCs. This study found evidence of the regression to the mean effect, with low accident sites experiencing more accidents, and higher accident sites seeing a decrease. When compared to intersections without RLCs, a small reduction

⁴ See Maccubbin, Staples and Salwin 2001 for an extensive list.

in pedestrian accidents was observed after RLCs were introduced. Offsetting this reduction in accidents was a significant increase in rear-end collisions (approximately doubling) and front into side crashes.

It has been suggested that reductions in violations translate into increased safety. As introduced previously, Milazzo et al (2001) point out that there are many different types of red light runners and red light running. To simplify, we can think of two broad categories of red light running, low risk and high risk. Milazzo et al reviewed 34 photographs of crashes captured by red light cameras, and found that all of the crashes caused by red light running involved vehicles entering the intersection more than 1.0 second after the onset of red, and the large majority entered the intersection more than 3.0 seconds after the onset of red. Thus, it appears that drivers who run red lights soon after the onset of red, and before conflicting traffic has entered the intersection, pose little risk of causing an accident. Though this type of red light running is clearly illegal, one may argue that a reasonable, prudent, and attentive driver may occasionally risk entering an intersection in this short time window. Those drivers who enter an intersection more than one second after the onset of red can broadly be labeled as reckless, inattentive, or mistaken.

Winn (1995) found that approximately 70% of RLC violations occur between 0 and 1 second after the onset of red, and approximately 29% between 1 and 5 seconds. After the RLC program went into effect, the number of violations occurring between 0 and 5 seconds dropped by nearly 2/3. The most dangerous violations, those occurring more than 5 seconds into the red phase, did not drop in the three year period after the program began issuing tickets. Thus we see the potential problem in the connection between RLCs and safety. The reckless or inattentive (and most dangerous) red light runners also seem to respond least to an RLC program.

However, there are many anecdotal reports, and several formal studies that demonstrate decreases in accidents after RLC programs are implemented. However, the estimates of crash reductions range from 0% to 70% for angle crashes, and changes in rear end collisions ranging from a decrease of 22% to an increase of 50%.⁵ The large range of values seen in these reports raises several questions about the results:

- 1) Are these numbers controlling for other safety improvements, programs, and policy changes that are made along with RLC programs?
- 2) Are there some intersection characteristics that may influence the effectiveness of RLCs in increasing safety?
- 3) Are these changes biased because of regression to the mean effects?
- 4) Are the effects of the cameras limited to monitored intersections, or is there any spillover of benefits?

Previous reviews of the literature on RLCs and safety have been done. McFadden and McGee (1999) performed a “Synthesis and Evaluation of Red Light

⁵ See Maccubbin, Staples, and Salwin (2001) for an extensive summary of these estimates.

Running Enforcement Programs in the United States”. While they concluded that RLCs probably decrease violations between 20 and 60 percent, they suggested that “additional crash data are needed to validate and quantify the RLR automated enforcement programs implication on crashes.” (p. 27) Part of their concern was that “simple comparisons are not statistically rigorous to conclude that the RLR program will result in crash reduction immediately or in the long run.” (p. 27)

More recently, Maccubbin, Staples, and Salwin (2001) performed an extensive review of the current evidence. They write:

Each of the existing independent analysis 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 systems remains unclear.

Though it is impossible to perform a perfect evaluation of the impact of RLCs, the existing research is lacking in many fundamental ways. Zaidel (2002) uses meta-analysis of several studies to suggest a “best estimate” of the effects of RLCs of an 11% reduction in accidents. However, he suggests that most of these studies fail to control for changes in design standards, biased selection of sites, and other safety improvements. Studies that do attempt to control for these types of changes (Andreassen, 1995, Kent et al 1995) have found that RLCs provide no significant safety improvement. Flannery and Maccubbin (2002) also point to a lack of high-quality studies performed in the U.S., finding only two studies that used data on individual intersections, with usable crash data and traffic count data.

One of the most frequently cited papers that finds a decrease in crashes associated with an RLC program is by Retting and Kyrychenko (2001). This study uses 29 months of data before and after the implementation of 11 red light cameras in Oxnard, California. The study claims to use 16 observations and 12 dummy explanatory variables. Because only 16 observations were used, the authors provided a list of the data in the paper. This is reproduced in Table 3 below. The table of results from Retting and Kyrychenko’s paper is reproduced in Table 4.

Table 3: Total Crashes Before and After Enforcement

City	Type of Intersection	Before	After	% Change
Bakersfield	Nonsignalized	760	753	-0.9
Bakersfield	Signalized	771	739	-4.2
San Bernardino	Nonsignalized	1220	1283	5.2
San Bernardino	Signalized	1,324	1400	5.7

Santa Barbara	Nonsignalized	712	622	-12.6
Santa Barbara	Signalized	488	438	-10.2
Oxnard	Nonsignalized	994	1,011	1.7
Oxnard	Signalized	1,322	1,250	-5.4

Table 4: Estimated Effects on Total Crashes

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

There are several serious problems with this analysis. Firstly, the fact that only aggregate data are used for four towns, ignoring such important variables as traffic counts and the numbers of the various types of intersections involved is troubling. Secondly, if the analysis is performed as described (see appendix), 16 observations and 12 dummy variables leaves 3 error degrees of freedom. After replicating the analysis reportedly done, one should end up with the following:

Table 5 Estimated Effects on Total Crashes: CORRECTED

Effect	Degrees of Freedom	Mean Square	F-value	p-value	Estimate	Percent Reduction
Camera	1	0.0013308	8.59	0.0610	-0.07296	7
Error	3	0.00015493				

It is striking how the Estimate and Mean Square are identical to those reported by Retting and Kyrychenko, however the degrees of freedom and p-value have changed.⁶

Third, the analysis performed does not do what the authors claim. The authors believed that they were using the three cities in California other than Oxnard as controls in an analysis of variance. Using the 12 dummy variables in the manner they described reduces the estimate to a trivial calculation. First, the crash counts in Table 2 were converted to natural logarithms. As shown in the appendix, the “generalized linear regression” estimate of -.07296 is simply calculated as follows:

$$\text{Estimate} = [\ln(\text{Oxn. S Aft.}) - \ln(\text{Oxn. S Bef.})] + [\ln(\text{Oxn. NS Bef.}) - \ln(\text{Oxn. NS Aft.})]$$

$$= [7.13090 \quad - \quad 7.18690 \quad] + [6.90174 \quad - \quad 6.91870 \quad]$$

⁶ After sending emails to both Retting and Kyrychenko about this matter, we were told that they didn’t remember why there were 4 error degrees of freedom, but that they probably left out one of the dummy variables. Running 12 regressions, leaving one dummy variable out each time did not suggest that this is the case. Kyrychenko (August 9, 2002 email) said that he would “try to remember” what was actually done.

$$= -0.05600 + -0.01696 = \mathbf{-0.07296}$$

Recalling that taking the difference between two natural logarithms is equivalent to calculating the percentage difference between two numbers, all that is being done is to subtract the 1.7% from the -5.4% in Table 3. The numbers used are slightly different because instead of using the starting number as that base for the percentage difference, the natural logarithm method uses the midpoint as the base.

The overall implication is that the effect attributed to the Red Light Cameras by Retting and Kyrychenko is only a comparison of the accident growth rate between signalized and nonsignalized intersections in Oxnard, CA. The other data actually does not control for anything, nor add any information to this model. This lack of control is especially critical for this study done in California, because several important policy changes were implemented in the state during the time period of the study. Most importantly, the fine for red light violations was increased from \$104 to \$270. In addition, the graduated licensing program for minors was expanded, limiting the minor's driving privileges significantly. Because of the way this model was constructed, the p-value calculated has no statistical meaning, and the estimate cannot be described as an effect of red light cameras.

III. Data Collection

To successfully analyze how RLCs interact with other roadway characteristics to impact safety, three different types of data are needed. First, information about the physical properties of each intersection in Greensboro would be needed. For this study, we limited the scope of the data collection to intersections with a stop light. In early 2001, the investigators contacted the Director of the Greensboro Department of Transportation (GDOT). We described the nature of the project, and the Director agreed to cooperate with the data collection by assigning the Division Manager of Engineering to assist us in finding information. We were surprised to learn that the GDOT had no formal data set describing the characteristics of intersections. Thus, a graduate student was employed to collect as much data as possible from technical drawings of these intersections, working from a list of signalized intersections provided by the Engineering Department. We were disappointed to discover that many intersections had no drawings, and many drawings were incomplete.

In an attempt to obtain some of the missing information, we contacted the Traffic Signal Supervisor for the City of Greensboro. Being responsible for the maintenance of traffic signals in Greensboro, the Supervisor provided us with a list of signalized intersections that had many inconsistencies with the list from the Engineering Division. Thus, a large amount of time and effort on this project was devoted to data collection, reconciliation, and cleaning. This effort is ongoing, and will be completed by December 2002.

The second type of information needed for this project involves the RLCs themselves. We obtained the locations of Greensboro's RLCs, dates of operation, and the number of tickets issued in each month for each camera. It is important to remember the difference between number of "events" at a RLC and the number of tickets issued. Many events trigger the camera to take a snapshot, but not all events result in a ticket being issued. In many of these cases a person reviewing the snapshot determines that a violation did not occur. Other times a violation may have occurred, but a ticket cannot be issued because the license plate of the vehicle is obscured or cannot be traced. As previously mentioned, this has resulted in a 40.3% issuance rate in Greensboro. The investigators are currently attempting to obtain a more detailed breakdown of why the other 59.7% of events do not result in tickets issued. The appeals process is also of interest. In Greensboro, 5 lawyers take turns hearing appeals from ticketed drivers, and are compensated \$37.50 per appeal, regardless of the outcome. This compensation comes out of the city's \$15 share of the \$50 ticket. In the first 16 months of the RLC program, 1,244 tickets were appealed, and approximately 24% of drivers' appeals were successful (Fuchs, 2002). We will also attempt to obtain a breakdown of the justification given for these successful appeals.

Finally, it was critical to obtain data on accidents at signalized intersections. Because the GDOT does not keep any organized data on this, we turned to the HSIS, or Highway Safety Information System. The Principal Investigator at HSIS explained that HSIS only includes data on state and federal routes. Therefore, the majority of signalized

intersections under consideration would not be included in this database. We then contacted the Traffic Safety Engineer with the Safety Information Management & Support Section of the NCDOT. This section of the NCDOT is responsible for acquiring the data from police reports⁷, and entering this data into computerized databases. This so-called “Traffic Engineering Accident Analysis System” (TEAAS), is a truly modern database created in 1999 using Java for web accessibility, Oracle for database functions, and CORBA to allow many different platforms to access the data. This data is collected from accident reports filled out by police officers, required for accidents estimated to have involved more than \$1000 in damage, or an injury (See attachment 1, North Carolina Accident Report). The data is primarily contained in two types of files:

- 1) Event level data contains one record for each accident, including location, number of vehicles involved, numbers of injuries, and other data.
- 2) Unit level data contains one record for each vehicle involved in each accident. Each record details the type of vehicle, damage estimates, injury levels, indications of use of alcohol or seatbelts, and many other variables.

The investigators performed a query of this database, pulling all records that met the following conditions:

- 1) Accident occurred between 01/01/99 and 03/31/02. This will give the researchers at least 24 months of “before” data, and at least 12 months of “after” data. If necessary, additional data will be queried as it becomes available. There is approximately a three month lag time before monthly data records are available.
- 2) Accident occurred within 150 feet of the center of an intersection. This range may be tightened in the future if the 150 foot boundary includes many non-intersection related accidents.
- 3) Accident occurred in Greensboro, North Carolina.

This query produced approximately 20,000 events, with approximately 40,000 vehicles involved.

IV. Remaining Tasks

The tasks remaining are:

- 1) Completion of data organization, filling in missing values, and error correction.

⁷ A North Carolina Police Report Form is attached to this report.

- 2) Matching records in the accident database to corresponding intersections.
 - 3) Geocoding of intersections for spatial analysis.
 - 4) Statistical analysis of data.
 - 5) Formal report preparation.
-
- 1) During the fall 2001 the investigators are working to ensure that the data collected so far is complete and accurate. Because the records of the GDOT have often been incomplete, this has frequently required on site visits to various intersections.
 - 2) After the data is checked for completeness and accuracy, the database of intersections must be matched to the corresponding records in the accident database. This will be time consuming given the volume of data under consideration, and the fact that many intersections are referred to differently in the two datasets.
 - 3) Referencing the intersections by their spatial relationships will be used to investigate the so-called “spillover effects” of RLCs. Therefore, obtaining longitude and latitude of each intersection will be required. This will be done using the geocoding tools of either Mapinfo or ArcInfo.
 - 4) Because data on tickets and accidents are available monthly, the primary statistical technique will be time series analysis. This method will allow the researchers to control for long-term trends in crash rates and seasonality, and timing of camera placements at different intersections, and other properties of intersections. Because some intersections may have low counts of accidents (particularly of certain types of accidents) monthly, the research team anticipates the possibility of using monthly, bimonthly or quarterly observations if required. The data will also be put into a GIS system, to explore spatial relationships between accident rates and red light cameras. The use of spatial correlation analysis will be used to test the hypothesis that red light camera enforcement causes a “spillover effect” in increased safety at intersections that do not have red light cameras.
 - 5) The results of the analysis will be documented and a final report will be generated. We hope that this final report will be of use to transportation officials when considering intersection safety programs in general, and red-light camera enforcement in particular.

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Appendix: Analysis of Retting and Kyrychenko

As described in Retting and Kyrychenko (2001):

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

(Page 5)

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

(Page 5)

On the next page in Table 6 is the data as given in the Retting and Kyrychenko (2001) paper, along with dummy variables as described above. In addition, I have given each of the 16 observations a symbol (a through p) to simplify the equations which are to follow.

Using the 12 dummy variables, along with a column of ones to represent the regression constant, as the independent variable matrix, “X”, and the natural logarithm of the crash counts (represented by letters a-p) as the independent variable vector, I derived the formulas for the coefficient estimates (Betas) in terms of the independent variables by using the least squares formula:

$$B = (X'X)^{-1} X'Y$$

Symbol			Count	Nlog	Cam?	Bakers	Sbern	Sbarb	Sig?	Bef.	BakBef	SBernBef	BakSig	SBernSig	SBarbSig	SBardBef
a	before	ns	Bakers	760	6.63332	0	1	0	0	0	1	1	0	0	0	0
b			S	771	6.64769	0	1	0	0	1	1	1	0	1	0	0
c		ns	Sbern	1220	7.10661	0	0	1	0	0	1	0	1	0	0	0
d		s		1324	7.18841	0	0	1	0	1	1	0	1	0	1	0
e		ns	Sbarb	712	6.56808	0	0	0	1	0	1	0	0	0	0	1
f		s		488	6.19032	0	0	0	1	1	1	0	0	0	1	1
g		ns	Oxnard	994	6.90174	0	0	0	0	0	1	0	0	0	0	0
h		s		1322	7.1869	0	0	0	0	1	1	0	0	0	0	0
i	After	ns	Bakers	753	6.62407	0	1	0	0	0	0	0	0	0	0	0
j		s		739	6.6053	0	1	0	0	1	0	0	1	0	0	0
k		ns	Sbern	1283	7.15696	0	0	1	0	0	0	0	0	0	0	0
l		s		1400	7.24423	0	0	1	0	1	0	0	0	1	0	0
m		ns	Sbarb	622	6.43294	0	0	0	1	0	0	0	0	0	0	0
n		s		438	6.08222	0	0	0	1	1	0	0	0	0	1	0
o		ns	Oxnard	1011	6.9187	0	0	0	0	0	0	0	0	0	0	0
p		s		1250	7.1309	1	0	0	0	1	0	0	0	0	0	0

Table 6: Data used in replicating Retting and Kyrychenko (2001)

The formulas for the regression coefficients are in Table 7. Representing them in this way allows one to see how the various data used does (or does not) interact in calculating the coefficients. As can be clearly seen, the other three cities' data has no impact on the coefficient for the presence of the red light camera (denoted by CAMERA? In the table).

Table 7: Regression Coefficients as functions of the dependent variables, i.e. natural logarithms of crash counts

Camera?	$g - o + p - h$
Bakersfield	$\frac{1}{4}a + \frac{3}{4}i - \frac{1}{4}b + \frac{1}{4}j - o$
SanBernadino	$-\frac{1}{4}d - o + \frac{1}{4}l + \frac{3}{4}k + \frac{1}{4}c$
SantaBarbara	$-\frac{1}{4}f - o + \frac{1}{4}e + \frac{1}{4}n + \frac{3}{4}m$
Signalized?	$-g + h$
Before	$g - o$
Bak*Bef	$-g + \frac{1}{2}a - \frac{1}{2}i + \frac{1}{2}b - \frac{1}{2}j + o$
SBern*Bef	$-g + \frac{1}{2}d + o - \frac{1}{2}l - \frac{1}{2}k + \frac{1}{2}c$
Bak*Sig	$-\frac{1}{2}a + \frac{1}{2}b + g - h - \frac{1}{2}i + \frac{1}{2}j$
SBern*Sig	$-\frac{1}{2}c + \frac{1}{2}d + g - h - \frac{1}{2}k + \frac{1}{2}l$
SBarb*Sig	$-\frac{1}{2}e + \frac{1}{2}f + g - h - \frac{1}{2}m + \frac{1}{2}n$
SBard*Bef	$\frac{1}{2}f - g + o + \frac{1}{2}e - \frac{1}{2}n - \frac{1}{2}m$
Constant	o