Synthesis of Information on Red-light Camera Programs and Effects

Submitted to NCDOT

by the UNC Highway Safety Research Center

Daniel Carter

Stephanie Harrell

Christine Gomola Mullin

April 15, 2019

EXECUTIVE SUMMARY

As more cities are seeking to implement red-light camera (RLC) programs and the issues continue to be debated in the public sphere, the North Carolina Department of Transportation (NCDOT) requested this synthesis of information on RLC programs and effects.

The first part of the synthesis consisted of a review of past research on the safety effects of RLC programs. The review showed that RLC programs generally caused a decrease in angle crashes and injury crashes but increased rear-end crashes. These effects are very similar to the effects of installing a traffic signal.

The second part of the synthesis focused on information about cities that operate their own RLC program with no involvement of a contractor. The research team was unable to identify any city in North America that operates an RLC program without some aspect of contractor involvement. Larger cities (New York, Philadelphia, Chicago, and Toronto) provided oversight of the RLC program and handled certain aspects such as reviewing citations, issuing fines, and selecting locations for the cameras, but the materials and manpower for the infrastructure aspect of the red-light camera program were provided by a contractor.

The third part of the synthesis focused on the effects of officer-issued citations for red-light running. If a city does not operate an RLC program, drivers who run red-lights risk being issued a citation by a police officer. The North Carolina Court system specifies the following fines and court costs associated with running a red-light:

- Fine: $50
- Court costs: $183 (standard district court cost plus a surcharge for a Chapter 20 traffic offense)

If a driver is convicted of an officer-issued RLR violation, his or her insurance premiums will generally increase, with the effects lasting anywhere from 6 months to 3 years (see table below).

Company	Insurance points	Effect of RLR citation on premium
Geico	None indicated	Around $140 increase per month (depends on many factors), for 6 months; if license suspended, extra $20 per month
Allstate	1 point	20-30 % rate increase for 3 years
Progressive	2 points	$33 to $50 increase per month for 3 years from date of conviction

TABLE OF CONTENTS

INTRODUCTION

Red-light running (RLR) continues to be an area of concern for road safety in North Carolina, as evidenced by the red-light camera (RLC) programs operated by cities throughout the state. As more cities are seeking to implement RLC programs and the issue continues to be debated in the public sphere, the North Carolina Department of Transportation (NCDOT) requested this synthesis of information on RLC programs and effects.

This synthesis focuses on three topics:

1. Findings of past research on red-light camera program effects.
2. Costs that a city may incur to operate its own RLC program (independent of any contractor).
3. Costs that a driver would incur if issued an RLR citation by an officer.

1. SUMMARY OF PAST RESEARCH ON RED-LIGHT CAMERA PROGRAM EFFECTS

HSRC conducted a search of past research on red-light cameras and their effects on safety, focusing on studies that were more recent or based on data from North Carolina. The results are presented below in Table 1, followed by short summaries of each study. In general, studies found that RLC programs caused a decrease in angle crashes and injury crashes but increased rear-end crashes.

TABLE 1. SUMMARY OF PAST RESEARCH ON RLC PROGRAMS

Study	Location	Findings on RLC Effect
Pulugurtha and Otturu, 2014	Charlotte, NC	Decrease in general crashes; Increase in sideswipes and rear-ends
Burkey and Obeng, 2004	Greensboro, NC	General increases in total crashes, rear-end, sideswipe same direction, possible injury; Decreases in left turn opposite direction crashes
Moon and Hummer, 2010	Charlotte, NC	15-18% decrease in total crashes for *automated speed enforcement*
Council et al., 2005	Cities across the U.S.	26.4% reduction in angle crashes; 14.9% increase in rear-end crashes
Lee et al., 2014	Chicago, IL	22% reduction in the number of fatalities; 7% increase in property damage only crashes
McCartt and Hu, 2014	Arlington, VA	Decrease in RLR violations
Wong, 2014	Los Angeles, CA	24% increase in right angle crashes; 34% increase in rear-end crashes; 22% increase in injury crashes; 12% reduction in red-light running crashes
Llau et al., 2015	Miami Dade County, FL	19% decrease in injury crashes; 24% decrease in red-light running crashes; (First year only - effects were lessened in second year)
Schattler et al., 2017	Illinois	34% decrease in total crashes;

		67% decrease in angle red-light running crashes; 18% decrease in injury crashes; No change in rear-end crashes
IIHS, 2017	Chicago, IL	10% decrease in injury crashes; 19% decrease in angle injury crashes; 14% increase in rear-end injury crashes
Hu et al., 2011	Large U.S. cities	24% decrease in fatal crash rate at RLC-equipped intersections; 17% decrease in fatal crash rate at all signalized intersections in city
Hu et al., 2017	Large U.S. cities	21% decrease in fatal crash rate at RLC-equipped intersections; 14% decrease in fatal crash rate at all signalized intersections in city
Ko et al., 2017	Houston, TX	37% decrease in red-light running crashes; 47% decrease in right angle crashes; (crash increases seen after RLC program was stopped)
Park et al., 2018	Maryland	Decrease in side-impact crashes (24 out of 27 intersections) Increase in rear-end crashes (10 out of 27 intersections)
Decina et al., 2007	Worldwide	General decreases in angle crashes and increases in rear-end crashes

STUDIES FROM NORTH CAROLINA

Pulugurtha and Otturu (2014) examined the effects of red-light cameras in Charlotte, NC, using data from 80 signalized intersections, 32 of them with red-light cameras. The authors compared the time periods of "before the installation" and "after the installation" and "before the installation" and "after the termination" to determine if there were safety benefits. They found that the results were mixed. Although there were reductions in crashes for both periods overall, there was an increase in sideswipe and rear-end crashes for those intersections with red-light cameras, even after the period when the cameras were no longer working.[1]

Burkey and Obeng (2004) studied the effect of the RLC program in Greensboro, North Carolina. They analyzed data from 18 intersections that were equipped with RLCs and 285 signalized intersections that were not equipped with RLCs. They conducted a before-after study using 26 months before and 26 months after the RLC installations. They generally concluded that RLCs are associated with higher levels of many types of crashes, including total crashes, rear-end, sideswipe same direction, possible injury, and property damage only. They found a decreasing effect on left turn opposite direction crashes.

Although this synthesis focuses on RLC programs, it must be noted that North Carolina also has experience with automated speed enforcement. In a 2010 article on automated speed enforcement in

[1] The authors suggest that the downturn in the economy may explain why there was a reduction in crashes even after the red-light program was terminated.

Charlotte, North Carolina, Moon and Hummer examined 14 high-crash roadways with speed cameras throughout the metropolitan area (total of 57.6 miles). Looking at two categories of collisions (injury, including fatal, and property damage only) as a marker of effectiveness. What they found was that there was a drop in total collisions (15% to 18%) during the implementation period and that continued to last after the program was stopped.

STUDIES FROM OTHER LOCATIONS

In a 2005 evaluation of automated red-light enforcement, Council et al. looked at the safety effects and economic impacts of using red-light cameras across the country. They looked at the before and after effects of the treatment at 132 sites and found that while there was a 26.4% reduction of angle crashes at these intersections, there was a 14.9 % rise in the number of rear-end crashes. However, despite the increase in rear-end crashes, the researchers calculated that there was a $39,000 to $50,000 benefit for each intersection equipped with a red-light camera, depending on the severity of the injuries used in the analysis.

Yongdoo Lee et al., (2014) examined 1000 signalized intersections, including 190 red-light camera equipped intersections over a six-year period in Chicago, Illinois. Taking into consideration traffic volume and roadway characteristics, they found different results depending on the number of vehicles passing through the intersection and the character of the roadway (e.g. single versus multilane approaches). However, in general, the researchers found that in all red-light running crashes, there was a 22% reduction in the number of fatalities and an increase of 7% in property damage only crashes.

In a 2014 publication, McCartt and Hu conducted a study of red-light violations in 8 locations in Arlington County, Virginia. Four of the intersections were equipped with red-light cameras with an additional 2 locations that were non-camera spillover intersections. Additionally, 2 other locations were non-corridor, non-camera spillover intersections. In an adjacent county 4 non-red-light camera intersections were used as controls. In total, 12 intersections were observed. The researchers videotaped the intersections at three time periods: the “warning period” defined as one month before the cameras were installed, one month after the cameras were installed, and then a year after the red-light enforcement program began. Researchers then coded the video for red-light violations looking at time intervals of 0.5, 1, and 1.5 seconds after the light turned red. McCartt and Hu found that for each interval, the odds of a violation went down for intersections that had red-light cameras; however, results were mixed for the spillover intersections.

Examining the effect of red-light cameras on collisions in Los Angeles, Timothy Wong’s 2014 analysis for the time period 2006 to 2010 showed an increase of 17% in crashes overall, including a 24% increase in right-angle collisions and a 34% increase in rear-end collisions. Additionally, Wong found that injury crashes increased overall by 22%. In contrast, there was a 12% reduction in red-light collisions. It is worth noting that the camera program had been active and then discontinued in Los Angeles several years prior to the restart of the program. Wong evaluated the restart of the program, and it is unknown whether the prior program may have affected Wong’s results.

Llau et al. in a 2015 paper used a before and after evaluation to determine the impact on injury crashes at 20 red-light camera intersections in Miami Dade County. The red-light camera intersections were compared to 40 similar (by geometric layout and other characteristics) signalized intersections. They

found that the RLC-equipped intersections experienced a slightly greater decline in all injury categories (19%) and red-light running injuries (24%) as compared to the comparison sites after the first year of implementation. After the second year of implementation, the researchers found that the decreases were not as significant from what would be expected with only a 17% decline in red-light run related injury crashes and a non-statistically significant 12% decline in all injury crashes.

In an evaluation done for the Illinois Department of Transportation, Shattler et al. (2017) examined 41 red-light camera equipped intersections with 60 approaches looking at the effects on rear-end and angle crashes for a three-year period before treatment and a three-year period after treatment. Using crash database files from the Illinois Department of Transportation, they found that total intersection crashes were reduced by 34% and angle red-light run intersection crashes were reduced by 67%. They also found that all injury crashes at the target intersections were reduced by 18%, but rear-end crashes showed no statistically significant change.

In an IIHS Status Report (2017) the Insurance Institute reported on a Chicago study done by researchers at Northwestern University. Using before and after analysis for 340 intersections equipped with cameras compared to 236 untreated intersections, they found that injury crashes were reduced by 10% and more specifically, angle injury crashes were reduced by 19%. However, they also found that rear-end injury crashes increased by 14%.

In two papers, one published in 2011 and the second in 2017, Hu et al. examined the effect of red-light camera enforcement on fatalities in large U.S. cities (defined by having a population of 200,000 or more.) In their first paper, they found that the rate of fatal crashes at intersections with a red-light camera was 24% less than what would be expected if there were no camera at the intersection. There was a 17% reduction in the rate of fatalities at all signalized intersections from the expected rate if there were no red-light cameras in the city.

Subsequently, in Hu et al.'s 2017 paper, researchers found that there was a 21.3% reduction in the rate of fatal crashes when a camera was installed at an intersection and a 14.2% lower rate of fatal crashes at all signalized intersections when there were red-light cameras in the city. Additionally, in the 2017 paper, the authors examined what the effect of stopping a red-light enforcement program had on fatalities. Here they found that there was a 30.1% higher rate of fatalities than what would be expected if the program had not been stopped and a 16.1% higher rate of fatal crashes at all signalized intersections than what would be expected in a city that had stopped using red-light cameras.

A 2017 paper by Ko et al. also examined the effect of red-light camera deactivation on safety as well as the effect of the deactivation of the program on adjacent intersections. Using a three-phase (before, during, and after) approach, 48 red-light camera equipped intersections in Houston, Texas were examined. Overall they found a 37% decrease in red-light run crashes, with a 47% reduction of right-angle crashes after the activation of the program. When the cameras were deactivated, there was a 20% increase for all red-light run crashes and a 23% increase in right-angle crashes at those intersections where there was formerly a red-light camera. Looking at spillover effect after the cessation of the red-light camera program, they found that the level of severity of all red-light run crashes increased at nearby non-treated intersections.

In a multipart study conducted for the Maryland Department of Transportation, Park et al., (2018) utilized crash data from 27 red-light camera locations in Maryland to assess the effectiveness of the

cameras on safety. The researchers found that the impact of red-light cameras was mixed depending on the intersection, crash type, and timeframe they analyzed. For example, while there was an overall decrease in side-impact crashes for 24 out of the 27 red-light camera intersections after the treatment was implemented, there were some intersections that showed an increase in the after period for these crashes depending on the before and after time frame analyzed. Rear-end crashes increased for 10 out of the 27 treatment sites. In addition to looking at safety effects, they conducted behavioral observations to see if red-light cameras changed the way drivers behaved in response to a yellow light. The results were mixed. The authors hypothesize that the mixed results may be explained by the characteristics (i.e. some drivers are more aggressive) of the driving population in a particular area.

The research papers above remain consistent with the conclusions of Decina et al.'s *Automated Enforcement: A Compendium of Worldwide Evaluations of Results* (2007). Decina et al. found that the research on red-light cameras was generally positive, showing reductions in some crash types (angle) while not in others (rear-end). However, they argue that it is hard to come to a definitive conclusion because of both the various methodologies used in the studies and the complex nature of studying red-light camera's effects on safety.

CRASH REDUCTION COMPARISON WITH TRAFFIC SIGNALS

The effect of an RLC program has been recognized as very similar to the effect of installing a traffic signal. Table 2 shows a comparison of the safety effects based on crash reduction factors.

TABLE 2. COMPARISON OF CMFS BETWEEN TRAFFIC SIGNALS AND RLC PROGRAMS

Crash Type	Effect Due to Traffic Signal Installation*	Effect Due to Red-light Camera Installation**
Right angle	52% decrease	19% to 67% decrease (median decrease 26%)
Fatal or Injury	32% decrease	10% to 21% decrease (median decrease 18.5%) One study showed 22% increase
Rear end	58% increase	0% to 34% increase (median increase 14.5%)

* Source: FHWA CMF Clearinghouse. CMFs under countermeasure name of "Install a traffic signal" and having a quality rating of 3 or higher. Average value presented.
** Source: Studies reviewed in this synthesis

2. COST OF CITY-OPERATED RLC PROGRAMS

NCDOT requested information on cities that operate their own RLC program with no involvement of a contractor. Specifically, this part of the synthesis was tasked with learning what the cost to the city would be for such an operation.

PROCESS TO IDENTIFY AND CONTACT CITIES

Given that there is no comprehensive database or resource to identify cities with RLC programs, HSRC staff conducted a multifaceted search for information. These efforts consisted of:

- Identifying potential cities through online searches. HSRC staff conducted an online search for news articles and governmental contact information for those cities. Initial Google searches used key words that comprised the city's name, and key phrases such as "red light cameras," or "automated red light enforcement." Generally, the results consisted mostly of news articles about the programs. Various links to these articles were scanned to glean any information relevant to the project such as contact information and operational details of the program.
- Identifying potential cities through an IIHS list. HSRC staff worked from a list of cities provided by the Insurance Institute for Highway Safety.[2] A smaller list of cities was compiled from the IIHS list based on size, with larger municipalities chosen under the assumption that they would have the fiscal resources and infrastructure to run their own programs independent of a contractor. Contact information was then gathered from the local municipalities' government websites. Some time was spent on making sure they had an RLC program and that the right contact information was obtained for the program.
- Identifying potential cities through an ITE forum. HSRC staff made a post on the ITE forum requesting information on municipalities that run and maintain their own RLC program. Many engineers and public works agencies responded. Some respondents identified international cities that run their own RLC program, but none could identify cities in the U.S. that run their own program. Some provided leads that HSRC staff followed.

When HSRC identified a city that either had an RLC program and/or potentially operated their own RLC program, the team contacted the city with an initial email or exploratory phone call. If the city responded, HSRC asked further follow-up questions via phone call (see questions in Appendix A). A total of thirty United States-based municipalities were contacted (Table 3). As per a suggestion from the posting on the ITE Forum, HSRC also contacted one international city, Toronto, Ontario (Canada).

TABLE 3. CITIES CONTACTED BY HSRC WITH INITIAL EMAIL OR PHONE CALL

State	City
Alabama	**Montgomery***
Arizona	Mesa
Arizona	Tempe
California	Culver City
California	Sacramento County
California	San Francisco
California	**West Hollywood***
Delaware	Sussex County
District of Columbia	District of Columbia
Florida	Miami
Florida	**Orlando***
Florida	Sarasota

[2] https://www.iihs.org/iihs/topics/laws/automated_enforcement?topicName=red-light-running

Georgia	Atlanta
Georgia	Savannah
Illinois	Aurora
Illinois	**Chicago***
Iowa	Cedar Rapids
Iowa	**Des Moines***
Iowa	**Sioux City***
Louisiana	Baton Rouge
Louisiana	New Orleans
Maryland	Montgomery County
Maryland	University Park
New York	**New York City***
Ohio	Toledo
Pennsylvania	**Philadelphia***
Rhode Island	**Providence***
Texas	**Austin***
Texas	Dallas
Ontario	**Toronto***
Washington	Seattle

* Indicates a city that responded and provided feedback through further calls or emails.

FINDINGS FROM CITIES

Eleven U.S. and international cities responded to inquiries and provided feedback through a follow-up phone call or email. Cities that responded are marked with an asterisk and bold font in Table 3.

All cities reported that they use a contractor for some or all of their program. We were unable to identify any city in North America that operates an RLC program without some aspect of contractor involvement. The larger cities (New York, Philadelphia, Chicago, and Toronto) provided oversight and handled certain aspects, such as reviewing citations, issuing fines, and selecting locations for the cameras, but the materials and manpower for the infrastructure aspect of the red-light camera program were provided by a contractor (a detailed example from Toronto of this combined city/contractor operation is provided in the call out box below). Based on feedback from the ITE Forum post, it appears that cities in New Zealand may operate their own RLC program, but HSRC did not follow up with these cities.

We pursued each city that operated some aspect of the RLC program to learn what kind of costs were borne by the city to run the program, but we were unable to obtain specific cost numbers from the cities. As mentioned in the example below, Toronto indicated that they employ 13 part-time officers to review citation images, but we did not ascertain how many person-hours per week were required for this part of the program.

Toronto: An example of an RLC program conducted through a combination of city staff and contractor

Since all of the municipalities we contacted contracted out either all or part of their red-light camera programs, it became clear that we needed to look at why and how they chose this method of red-light automated enforcement. Toronto, Ontario, afforded us an interesting case study. Initially they began their program by purchasing their own equipment but found that this was too costly. They now lease the hardware from a contractor who also provides the manpower to install, maintain, and download the images. According to Jeffery Catlin, Supervisor for Red-light Camera Operations in Ontario, the leasing decision was made due to the ability of the contractor to maintain the resiliency of the program in a cost-effective manner. However, the more sensitive processing of images and issuing of citations is overseen by Mr. Catlin's department. The contractor is paid a flat fee, which is not dependent on the number of citations issued; thus, the contractor has no vested financial interest in the enforcement aspect of the program.

To illustrate, Mr. Catlin used an example of someone hitting one of the "poles" that the camera is mounted on as a reason for contracting out the hardware piece. If the municipality owned the equipment it would cost $10,000 for the replacement, and it might take a month or longer to enact the repair because the city would have to order the hardware and then install it. By contrast, a contractor would likely have poles ready to deploy and could replace the damaged equipment within a week. Mr. Catlin stated that the advantage of having a contractor in Toronto is that they are contractually required to report and repair a problem within 24 hours and to do maintenance and sensor checks weekly for each site.

However, it is important to note that even though the infrastructure manpower and equipment are provided by the contractor, the enforcement and oversight are run by Mr. Catlin's department. The contractor downloads the images and the drive is placed in a lock box, which the contractor cannot open once the drive is inside. The box is delivered to a stand-alone building with controlled access; the images are downloaded by the employees to computers, which are not linked to any other system and are not stored in the cloud. This is all done to maintain the integrity of the program and ensure the privacy of individuals. In Toronto there are 13 part-time officers, generally former police officers, who review the images and according to Mr. Catlin, process about 450 charges for Toronto and Ontario province every 3 days.

3. COSTS TO THE DRIVER FOR OFFICER-ISSUED RED-LIGHT RUNNING CITATIONS

If a city does not operate an RLC program, drivers who run red-lights risk being issued a citation by a police officer. When an officer gives a driver a citation for running a red-light, the driver incurs several types of costs, including a fine, court costs, and an increase to his or her insurance premium.

FINE AND COURT COSTS

The North Carolina Court system specifies the fines and court costs associated with running a red-light. The costs are as follows:

- Fine: $50[3]
- Court costs: $183[4] (standard district court cost plus a surcharge for a Chapter 20 traffic offense)

Additionally, a driver who runs a red-light will also incur 3 points on his/her license.[5]

INCREASE IN INSURANCE PREMIUM

To determine the costs for an individual convicted of running a red-light, HSRC contacted insurance companies that represented at least 5% or more of the market share of auto coverage in the United States in 2015. Three insurance companies provided some feedback on the effect that a red-light citation would have on a driver's premium (Table 4).

TABLE 4. INSURANCE COSTS FOR RED-LIGHT RUNNING CONVICTIONS

Company	% Market Share in 2015	Insurance points	Effect of RLR citation on premium
Geico	11.4%	None indicated	Around $140 increase per month (depends on many factors), for 6 months; If license suspended, extra $20 per month
Allstate	10.0%	1 point	20-30 % rate increase for 3 years
Progressive	8.8%	2 points	$33 to $50 increase per month for 3 years from date of conviction

NOTE: USAA and Farmers could not provide information. State Farm and Liberty Mutual did not reply to correspondence.

[3] NC Courts, TRAFFIC OFFENSES FOR WHICH COURT APPEARANCE MAY BE WAIVED (on execution of written waiver of appearance and trial, and plea of guilty/responsible) (Adopted by the Conference of Chief District Court Judges, October 3, 2018, pursuant to G.S. 7A-148). Accessed March 2019 at https://www.nccourts.gov/assets/documents/publications/traffic-waiver.pdf?Jc3LL4DLCIXSKRz.vj4pR1pziB.CcVPE

[4] NC Courts, 2018 Criminal Court Costs. Accessed March 2019 at https://www.nccourts.gov/documents/publications/current-court-costs

[5] NC Department of Motor Vehicles Handbook, Accessed March 2019 at https://www.ncdot.gov/dmv/license-id/driver-licenses/new-drivers/Documents/driver-handbook.pdf

The insurance agents contacted for this synthesis were, in large part, reluctant to give quotes or percent increases based on hypotheticals. The representative for Geico said that, generally, information needed to calculate insurance rates included things such as age, gender, and credit score, educational attainment, how long the individual had been a carrier of that company's insurance, and their history of payments. Two companies (USAA and Farmers) said they could not give any reasonable estimate because the information required was based on an individual's specific profile with the company. Even when presented with a hypothetical individual, they still said they could not provide information. Two companies (State Farm and Liberty Mutual) did not return the researcher's calls.

Three companies did offer either clear or hypothetical insurance quotes for an individual who was convicted of running a red-light. The representative from Geico stated that the average insurance cost increases based on her own demographics (the representative's) would be $142 a month for six months. However, if the individual had their license suspended that would add an extra $20 to the amount for the six-month period.

The representative from Allstate, without any demographic constraints, said that a red-light conviction would result in a one-point fine with a 20-30% increase for three years based on an individual's initial policy. In contrast, Progressive based their increase specifically on assigned insurance points. In the case of Progressive, a conviction for running a red-light would result in a two-point fine with each point costing $100- $150; therefore, an increase of $200-$300 to the 6-month premium ($33-$50 per month). This increase would stay in effect for three years.

BIBLIOGRAPHY

Burkey, M. & Obeng, K. (2004). A Detailed Investigation of Crash Risk Reduction Resulting From Red-light Cameras in Small Urban Areas. Urban Transit Institute, North Carolina Agricultural and Technical State University, Greensboro, NC.

Council, F. M., Persaud, B., Eccles, K., Lyon, C., & Griffith, M. S. (2005). *Safety evaluation of red-light cameras* (Final No. FHWA-HRT-05-048) (p. 98). McLean, VA: Federal Highway Administration.

Decina, L. E., Thomas, L. J., Srinivasan, R., & Staplin, L. (2007). *Automated enforcement: A compendium of worldwide evaluations of results* (Final Report No. DOT HS 810 763) (p. 136). Washington, D.C.: National Highway Traffic Safety Administration.

Llau, A. F., Ahmed, N. U., Khan, H. M. R. U., Cevallos, F. G., & Pekovic, V. (2015). The impact of red-light cameras on crashes within Miami-Dade County, Florida. *Traffic Injury Prevention*, *16*(8), 773–780. doi:10.1080/15389588.2015.1023896

Hu, W., & Cicchino, J. B. (2017). Effects of turning on and off red-light cameras on fatal crashes in large U.S. cities. *Journal of Safety Research*, *61*, 141–148. doi:10.1016/j.jsr.2017.02.019

Hu, W., McCartt, A. T., & Teoh, E. R. (2011). Effects of red-light camera enforcement on fatal crashes in large U.S. cities. *Journal of Safety Research*, *42*(4), 277–282. doi:10.1016/j.jsr.2011.06.002

IIHS. (2017). Red-light cameras reduce injury crashes in Chicago. *Status Report*, 7.

Ko, M., Geedipally, S. R., Walden, T. D., & Wunderlich, R. C. (2017). Effects of red-light running camera systems installation and then deactivation on intersection safety. *Journal of Safety Research*, *62*, 117–126. doi:10.1016/j.jsr.2017.06.010

Lee, Y., Li, Z., Zhang, S., Roshandeh, A. M., Patel, H., & Liu, Y. (2014). Safety impacts of red-light running photo enforcement at urban signalized intersections. *Journal of Traffic and Transportation Engineering (English Edition)*, *1*(5), 309–324. doi:10.1016/S2095-7564(15)30278-6

McCartt, A. T., & Hu, W. (2014). Effects of red-light camera enforcement on red-light violations in Arlington County, Virginia. *Journal of Safety Research*, *48*, 57–62. doi:10.1016/j.jsr.2013.12.001

Moon, J.-P., & Hummer, J. E. (2010). Speed enforcement cameras in Charlotte, North Carolina. *Transportation Research Record: The Journal of the Transportation Research Board*, *2182*(1), 31–39. doi:10.3141/2182-05

Park, S. Y., Lan, C.-L., & Chang, G.-L. (2018). *Evaluating the impacts of red-light camera deployment on intersection traffic safety* (Final Report No. MD-18-SHA/UM/4-37) (p. 49). Baltimore, MD: Maryland Department of Transportation, State Highway Administration.

Pulugurtha, S. S., & Otturu, R. (2014). Effectiveness of red-light running camera enforcement program in reducing crashes: Evaluation using “before the installation”, “after the installation”, and “after the termination” data. *Accident Analysis & Prevention*, *64*, 9–17. doi:10.1016/j.aap.2013.10.035

Schattler, K. L., Vadlamudi, N., & Riemann, A. (2017). *Safety evaluation of red-light running camera intersections in Illinois* (Technical Report No. FHWA-ICT-17-005) (p. 68). Washington, DC: Federal Highway Administration.

Wong, T. (2014). Lights, camera, legal action! The effectiveness of red-light cameras on collisions in Los Angeles. *Transportation Research Part A: Policy and Practice*, *69*, 165–182. doi:10.1016/j.tra.2014.08.023

APPENDIX A. QUESTIONS FOR CITIES

The following script was used during phone calls with cities to determine how they operated their RLC program.

Introduction:

Hello, my name is _____ and I'm a Research Assistant at the UNC Highway Safety Research Center. We are working with the North Carolina Department of Transportation on a project investigating red-light camera programs across the country.

Thank you very much for taking the time to speak with me.

I just want to confirm that you have an automated red-light enforcement program or otherwise known as red-light cameras. **[Confirm by e-mail first, if possible.]**

I pulled the name of your [city/town/county] from a list of red-light camera programs compiled by IIHS.

Questionnaire

1. I have two separate lines of questions the first is about the physical infrastructure of the program and the second is about reviewing and issuing citations.
2. How many cameras do you have in the city/town/county?

For municipalities who do their own work:

3. Do you contract out the installation and maintenance of the physical infrastructure or does the city/town/county run the program?

    If run by [city/town/county]:

    a. Per-approach or per-intersection
        i. [Do you know where I could find the information: online budget line item? Do you know I could speak to who might know?]
    b. Materials – camera costs (poles) – general idea
    c. How many people are involved in the installation, maintenance, & care/up-keep of the program?
    d. Any other infrastructure issues we may not be thinking of?

For the people who use a contractor:

4. How do you work with the contractor?
    a. Is it a flat fee or do they get a part of the revenue generated from the tickets?
    b. What happens if a camera goes out?
        i. How long does the contractor have to fix it?
        ii. If the camera needs to be replaced who pays to replace it? i.e. do you lease the equipment or buy it for the vendor to take care of?
    c. How are the images downloaded and transferred to your system?

The processing of the images

a. How many people review the images would you say?
b. How do you train the people who review the images?
c. How are the images stored? In the cloud, server, or on a stand-alone computer?
d. Who handles the payments?

If I or NCDOT have more questions would you be open to follow up questions?

Thank you for your time.